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MARINE BIODIVERSITY RESEARCH
Prediction and Management of Australia's Marine Biodiversity

Carnarvon Shelf Survey Post-Survey Report

12 August – 15 September 2008

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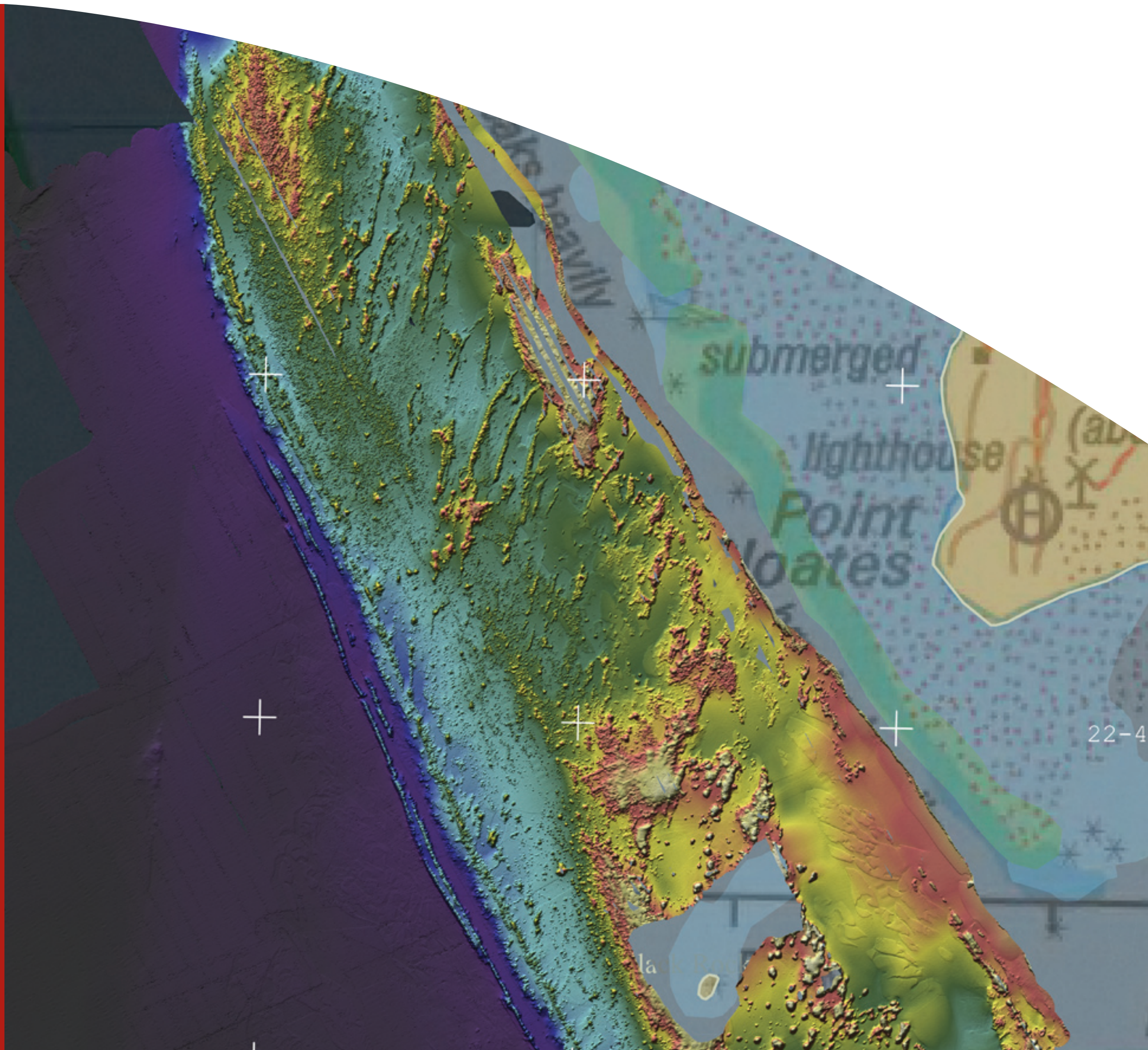

APPLYING GEOSCIENCE TO AUSTRALIA'S MOST IMPORTANT CHALLENGES

GEOSCIENCE AUSTRALIA SURVEY SOL4769

Carnarvon Shelf Survey Post-Survey Report

AUGUST 12TH – SEPTEMBER 15TH 2008

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by

Brooke, B.[1], Nichol, S. [1], Hughes, M. [1], McArthur, M. [1], Anderson, T. [1], Przeslawski, R. [1], Siwabessy, J. [1], Heyward, A. [2], Battershill, C. [3], Colquhoun, J. [2], and Doherty, P. [3]

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MARINE BIODIVERSITY RESEARCH
Prediction and Management of Australia's Marine Biodiversity

Australian Government | Australian Institute of Marine Science

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Executive Summary

This report provides a description of the CERF Marine Biodiversity Hub's survey of the Carnarvon Shelf, Western Australia, in August and September, 2008. The survey was a collaboration between the Australian Institute of Marine Science (AIMS) and Geoscience Australia (GA) aboard *RV Solander*, as part of the Hub's Surrogates Program. The purpose of field surveys in the Surrogates Program is to collect high-quality, accurately co-located data to enable the robust testing of a range of physical parameters as surrogates of patterns of benthic biodiversity in strategically selected, spatially discrete areas that are representative of much broader benthic environments.

The report describes the methods employed in the survey and the datasets collected. Additional processing of most of the physical data (wave and current measurements, multibeam sonar bathymetry and backscatter, sediment grab samples, acoustic sediment profiles) and biological data (towed underwater video and stills photography, bottom sediment samples, near-bottom plankton samples) collected is required before comparative analysis between the data sets can commence. However, a number of initial interpretations of the physical data have been made, and examples of the types of biota encountered in the towed video and stills photography and initial interpretations of the benthic communities encountered are provided. The survey was focussed on three strategically selected study areas on the southern Carnarvon Shelf at Mandu, Point Cloates and Gnaraloo. A small additional area was also examined near the Muiron Islands, in the mouth of Exmouth Gulf, at the end of the survey.

Wave and current data were collected at Point Cloates during the survey and the data show that wave conditions were highly variable, with significant wave height ranging from approximately 0.5 to 4.5 m, but arriving persistently from the west-southwest. The tide regime off Point Cloates is microtidal, mixed, mainly semi-diurnal with a mean spring and neap range of 0.98 m and 0.25 m, respectively. The tidal current floods to the south and ebbs to the north off Point Cloates, which is consistent with a clockwise rotating tidal amphidrome centred to the southwest of the region. The data collected show non-tidal, surface currents extended to a depth of at least 30 m and were directed to the northeast-northwest sectors, consistent with wind patterns during the deployment period. Non-tidal bottom currents were directed to the south to west-southwest, consistent with the regional geostrophic current. Salinity and temperature measurements suggest that the regional geostrophic current may also influence the shallow (30 m) inner shelf.

The most complex seabed habitat occurs on the inner shelf, especially at Point Cloates where ridges, mounds and raised hardground produce a highly rugose inner shelf that covers 33% of the sampling area. The inner shelf at Mandu likewise features mounds and ridges, but here these features represent 11% of the sampling area. Surface sediments at both areas range from sand to gravel, however, quantitative grain-size measurements are yet to be completed. At Gnaraloo, rugose seafloor on the inner shelf covers just 2% of the sampling area and surface sediments are mostly sand. At all sample areas the inner shelf sediments are predominantly light grey unweathered skeletal carbonate, indicative of a modern age, rather than the darker yellow and brown weathered sediment common on the middle and outer shelf. On the middle shelf of all survey areas, seabed dunes indicate transport of bottom sediments across the shelf towards the northeast. The sand-dominated middle shelf at Gnaraloo has the most extensive fields of large scale bedforms that extend to 45 m water depth. At Mandu and Point Cloates, bedform fields on the middle shelf are more localised, possibly reflecting the spatial variance in sediment type from sand to gravelly sand and gravel; although at Point Cloates bedforms occur to 100 m water depth in gravelly sediment. Low ridges extend along the shelf at Mandu and Point Cloates in 75 – 80 m water depth and appear to represent a drowned shoreline that partly survived marine transgression during the late Pleistocene.

Towed underwater video and still photography reveal mixed assemblages along the Carnarvon Shelf, including hard corals, sponge gardens, rhodolith beds, bioturbated sediments, and comparatively barren sand. All sampling areas exhibit decreasing habitat complexity with distance offshore, with seabed habitat complexity markedly higher in the central region of Point Cloates. All three locations are dominated by expansive mid-shelf sands with mobile bedforms, with more stable soft-sediment and low-relief outcrops recorded offshore.

A large range of fauna was collected from an epi-benthic sled, although specimens have yet to be identified. The amount of rhodoliths collected decreased from north to south latitudes, while the amount of sponge material collected increased in the southern latitudes. Grab samples suggest that sediment grain size may be an important factor in explaining infaunal distributions, although all samples sorted to date were characterized by low infaunal biomass compared to other CERF survey locations. Sampling of the benthos and planktobenthos was also successfully undertaken, and preliminary results indicate rich planktobenthic assemblages on Carnarvon Shelf even above relatively barren sand.

1. Introduction

This report provides a description of the research activities completed during the CERF Marine Biodiversity Hub's survey of the Carnarvon Shelf, WA, aboard *RV Solander*, as part of the Hub's Surrogates Program. The survey was a collaboration between the Australian Institute of Marine Science (AIMS) and Geoscience Australia (GA), undertaken in August and September, 2008. The purpose of field surveys in the Surrogates Program is to collect high-quality, accurately co-located data to enable the robust testing of a range of physical parameters as surrogates of patterns of benthic biodiversity. The objective is to test these relationships in strategically selected, spatially discrete areas that are representative of much broader benthic environments, and where the bio-physical data collected complement existing data for these areas.

The report describes the methods employed in the seabed mapping and sampling, and current and wave monitoring during the survey, as well as a log of the survey activities. Preliminary results are provided of the analysis of multibeam sonar, sediment samples and oceanographic data. Examples of the types of biota encountered in the towed video and stills photography, and initial interpretations of the benthic communities encountered, are also provided.

1.1. AIMS OF THE CARNARVON SHELF SURVEY

The key aim of the survey is to acquire data to enable a range of physical environmental parameters of the southern Carnarvon Shelf to be tested as surrogates of patterns of benthic biodiversity. There are two important steps in this research:

1. Collect high-resolution bio-physical data from three spatially discrete latitudinal areas that sample the entire width of the shelf, to examine potential fine-scale surrogacy relationships. These data will enable estimates of the relative importance of latitude, distance offshore, water depth, physical setting, exposure and local habitat complexity as surrogates in explaining benthic biodiversity patterns on this shelf.
2. Use the new results to extrapolate between the three study areas to model habitat and benthic biota types over a broader area of the shelf. This will be achieved using the new multibeam sonar coverage of areas outside the three sample areas and validation of the biological predictions using existing AIMS underwater video and seabed samples.

1.2. STUDY AREA

The study area is located in the southern section of the Carnarvon Shelf of central Western Australia. This area lies within and adjacent to the Ningaloo Marine Park (Figure 1.1). The park is widely recognised as an ecologically important and valuable bioregion where there is convergence between tropical and subtropical environments. The geomorphology of this section of the Carnarvon Shelf is also highly variable, especially the shelf width which increases from less than 6 km in the north near Mandu to more than 30 km in the south at Gnaraloo (Figure 1.1). Based on existing AIMS and CSIRO survey data, the areas of shelf examined appear representative of much larger areas of major types of seabed habitats that occur on the Carnarvon Shelf.

1.3. SAMPLING STRATEGY AND METHODS OVERVIEW

To examine the relative importance of bio-physical patterns over latitudinal and offshore gradients, three areas were selected for detailed acoustic mapping and sediment and biological sampling, located offshore Mandu in the north (~ 22^0 10'S), Point Cloates in the centre (~ 22^0 30'S), and Gnaraloo in the south (~ 23^0 45'S) (Figure 1.1). In each of the three survey areas, sampling stations were selected to cover the spatial extent and known seabed complexity of each area as identified from existing AIMS-towed-video seabed habitat characterisations, biological collections, and sediment sampling experience (Figure 1.2). Additional sample stations were added during the survey based on the distribution of benthic habitat types suggested in the new multibeam sonar bathymetry and backscatter. On the last two days of the survey, a small area adjacent to the Muiron Islands in the mouth of Exmouth Gulf was also mapped and sampled as an auxiliary northern-most region.

At most sample stations, 500 m towed-video, two 50 m benthic sled tows, and 2 sediment grab samples were collected. Multiple waypoints were recorded for each sampling task at each station, marking the location, time and depth for each grab, the beginning and end of each towed video transect and the beginning and end of each epibenthic sled deployment. For selected stations in Mandu (stations 1-16), 3 grabs and 3 sled tows were undertaken in order to test the effects of increased fine-scale replication on overall results.

To provide a concurrent time series of the oceanographic environment, Acoustic Doppler Current Profilers (ADCP) were deployed near Pt Cloates and collected wave and current data for the duration of the survey. These hydrographic data compliment a longer hydrographic time series collected from an AIMS oceanographic instrument permanently moored off Tantabiddi, 30 km north of Mandu. Acoustic sub-bottom profiles were collected across the shelf, using Chirp and Sparker sub-bottom profilers, within the three main survey areas to help map the geomorphology and sedimentary processes of the shelf, especially areas of sediment accumulation and hardground.

The survey was a 24 hour operation, with two twelve hour shifts. Multibeam mapping was predominantly undertaken during the night shift, apart from a few days when conditions were favourable for mapping close in to the fringing reef or when conditions were too rough for working on deck. Sub-bottom profiles of the shelf were also predominantly collected during the night. The day shift was used to undertake the seabed sampling and towed video.

1.4. TIMETABLE AND PERSONNEL

The survey was run in two legs: Leg 1, 12th to 29th of August; and Leg 2, 30th of August to 15th of September, with a crew change-over on the 30th of August when *Solander* returned to Exmouth for reprovision and maintenance (Table 1). The installation and testing of GA acoustic equipment on the vessel began during the transit from Fremantle to Exmouth (4th – 7th August) prior to the survey (Table 1). During the northern transit, GA ADCPs were deployed on the Carnarvon Shelf in around 20 and 50 m water depths, offshore Pt Cloates, to ensure the longest possible time series of wave and current data were collected during the survey. There was also a short survey (9-10th of August) to service AIMS oceanographic instruments moored off Tantabiddi immediately prior to the CERF survey during which the acoustic and video equipment were tested.

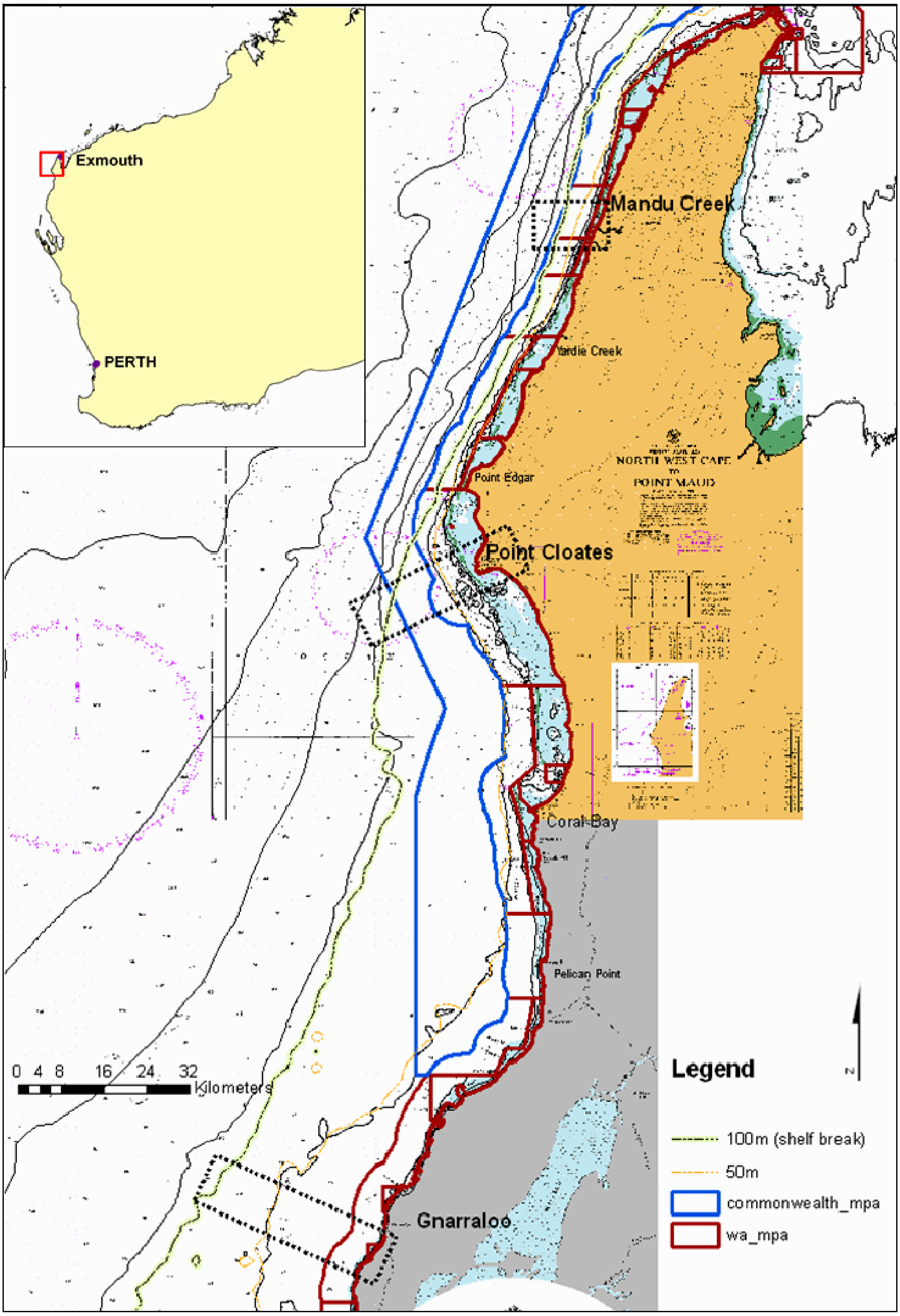

Figure 1.1: *The three sample areas (dotted line boxes) offshore from Mandu Creek, Point Cloates and Gnaraloo. Each area extends across the shelf to the shelf break at ~120m. The inset shows the location of Exmouth and the Cape Range Peninsula on the central coast of Western Australia. The underlay map comprises Hydrographic Charts AUS00745 (NW Cape to Coral Bay) and AUS00330 (Coral Bay to Gnaraloo).*

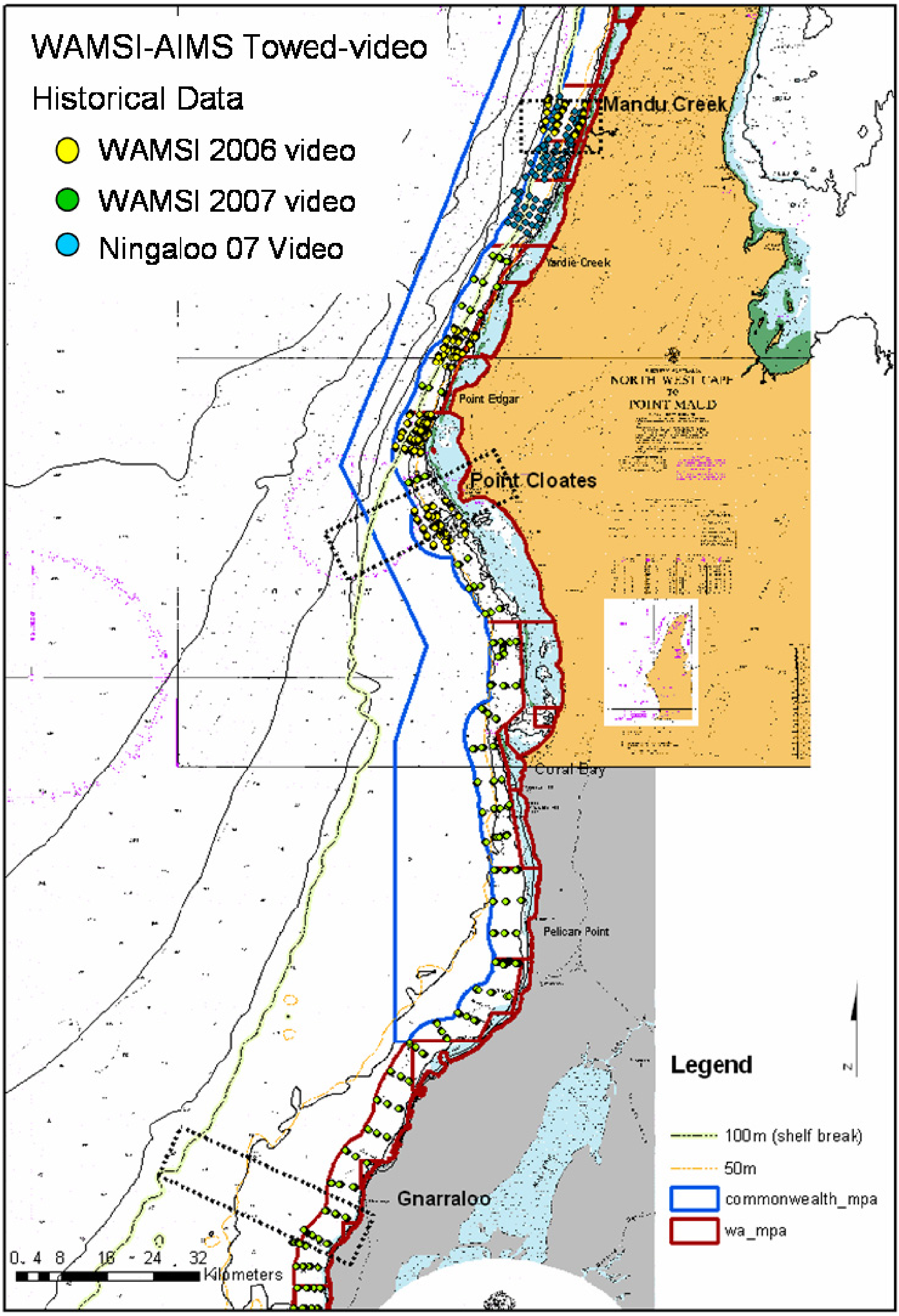

Figure 1.2: *Existing towed underwater video collection sites in relation to the Marine Biodiversity Hub's survey areas. The underlay map comprises Hydrographic Charts AUS00745 (NW Cape to Coral Bay) and AUS00330 (Coral Bay to Gnaraloo).*

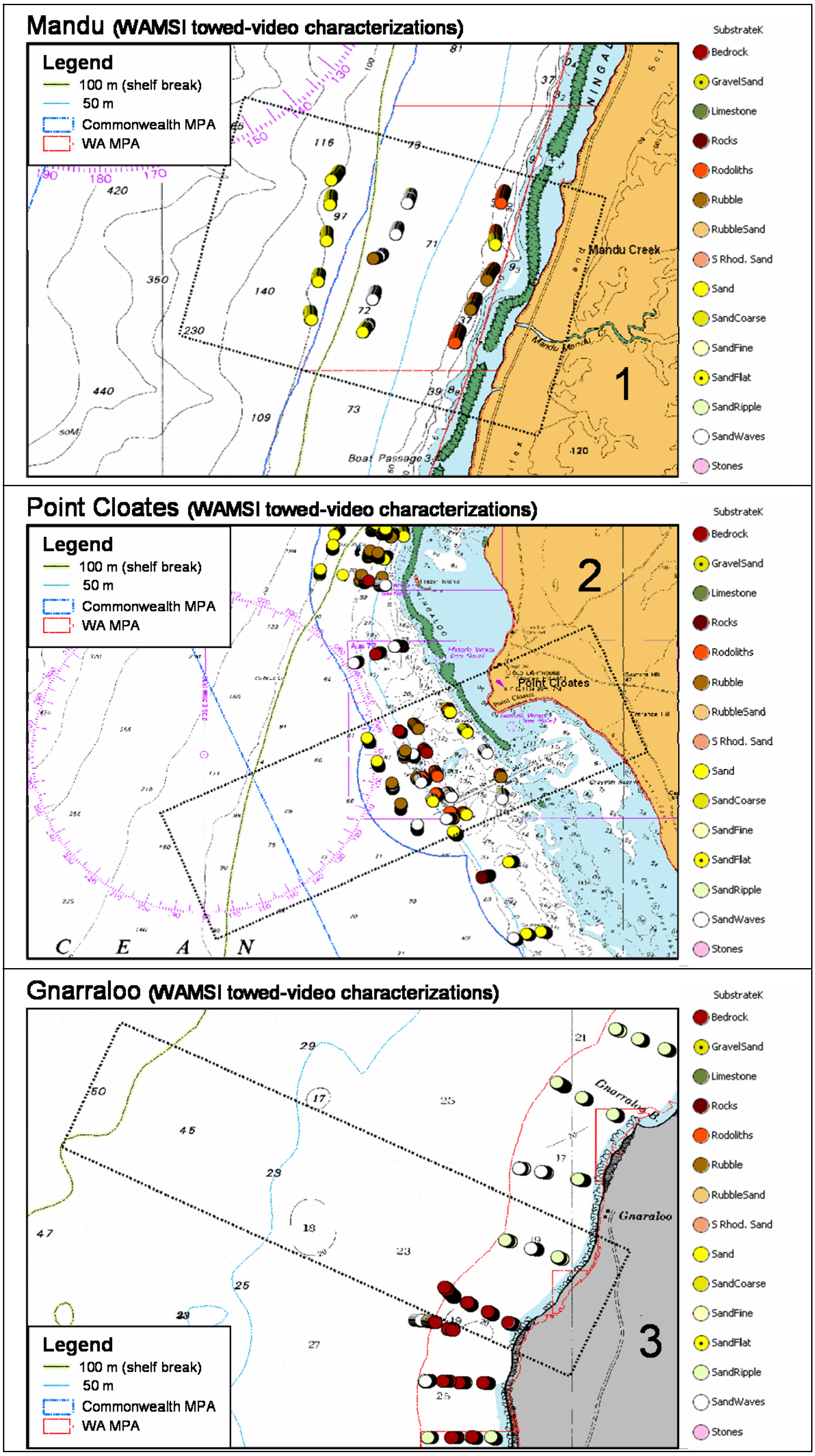

Figure 1.3: *Existing seabed habitat characterisations for the Carnarvon Shelf off Ningaloo Reef collected by AIMS under the WAMSI program. Boxes mark the survey sample areas.*

Table 1: CERF Carnarvon survey science crew and their roles on *RV Solander*.

STAFF/ORGANISATION	**ROLE**
TRANSIT, FREMANTLE-EXMOUTH, 4TH - 7TH AUGUST	
Cary McLean AIMS	Cruise leader
Michael Hughes GA	GA Team Leader/ADCPs
Cameron Buchanan GA	Multibeam Sonar (MBS)
Craig Wintle GA	Deploy ADCPs
Ian Atkinson GA	MBS/Electronics
Stephen Hodgkin GA	Electronics/ADCPs
AIMS MOORING SURVEY, 9TH - 10TH AUGUST	
Cary McLean AIMS	Cruise Leader
Ian Atkinson GA	MBS/Electronics
Cameron Buchanan GA	MBS
Craig Wintle GA	Test SBP/MBS
Stephen Hodgkin GA	Electronics/SBP
CERF SURVEY LEG 1, 12TH - 29TH AUGUST	
Chris Battershill AIMS	Cruise Leader/Ecology
Jamie Colquhoun AIMS	Ecology
Emily Twiggs AIMS	Ecology
Oliver Gomez WA Museum	Taxonomy
Brendan Brooke GA	GA Team Leader/Sediments/SBP
Cameron Buchanan GA	MBS
Justy Siwabessy GA	MBS
Ian Atkinson GA	MBS/Electronics
Stephen Hodgkin GA	Electronics/Video
Matthew McArthur GA	Ecology
Rachel Przeslawski GA	Ecology/Sediments
CERF SURVEY LEG 2, 30TH AUGUST – 15TH SEPTEMBER	
Andrew Heyward AIMS	Cruise Leader/Ecology
Emily Twiggs AIMS	Ecology
Peter Speare AIMS	Ecology
Carsten Wolff AIMS	Ecology
Scott Nichol GA	GA Team Leader/Sediments/SBP
Cameron Buchanan GA	MBS
Mike Sexton GA	MBS
Ian Atkinson GA	Sub-bottom Profilers/MBS
Stephen Hodgkin GA	Electronics/Video
Matthew McArthur GA	Ecology

2. Physical Oceanography

2.1. INTRODUCTION

Oceanographic measurements were obtained from two fixed seabed moorings deployed on a shore-normal transect on the inner shelf adjacent to Point Cloates for a period of 33 days. The first mooring was deployed in approximately 50 m water depth and the second mooring in 30 m water depth (Figure 2.1). These sites are approximately 1.8 and 11 km seaward of Point Cloates, respectively. The locations of the moorings were chosen in order to: (i) determine the relative importance of waves, tides and other currents on the inner shelf adjacent to Point Cloates, and (ii) quantify any cross-shelf gradients in these processes. The data from these moorings will also provide a useful comparison with the long-term oceanographic moorings located further to the north (off Tantabiddi) and maintained by the Australian Institute of Marine Science (AIMS).

2.2. SITE 1

2.2.1. Mooring description and sample regimes

The mooring at Site 1 was located at 22° 49.0294′S 113° 36.9100′E in 54 m water depth. It consisted of a *RD Instruments Workhorse Sentine*l 600 kHz acoustic Doppler current profiler (ADCP; Serial No. 5581) and a *van Essen* conductivity-temperature-depth (CTD) probe. The instruments were attached to a triangular frame together with an acoustic release, a 60 m ground line (sinkable rope) to a bottom weight, and a 50 m line (floatable rope) to a second bottom weight to enable grappling for the mooring if the acoustic release failed. The mooring was deployed at 02:05 hrs on 09/08/2008 (GMT) and retrieved at 00:00 hrs on 12/09/2008 (GMT).

The ADCP measures the 3-dimensional current vector from the Doppler shift of sound reflected from the water column using two pairs of orthogonal acoustic beams. The instrument was programmed to obtain profiles of current velocity extending from 4.07 m above the instrument to the water surface with measurements (sample bin elevations) spaced 3.00 m apart. A total of 60 pings were averaged over 900 s to provide current velocity time series with a sampling interval of 15 minutes for each bin elevation. The instrument functioned continuously throughout the deployment, returning 33 days of current velocity data for sample bins 1 to 15 (approximately 4.5 to 46.5 m above the bed), as well as near-bed water temperature and water depth. Current velocity data from the remaining two bins higher in the water column were adversely affected by surface reflections etc. and have been excluded from analysis. The ADCP was also programmed to measure waves for a 20 minute burst every 2 hours, however, the instrument is close to its limit of capability in 50 m water depth and the measured wave data is unreliable. Nevertheless, there is wave data available for Site 2 (see Section 2.3).

The *van Essen* CTD probe measures conductivity, temperature and pressure, and therefore salinity and depth. The instrument was setup to sample continuously at 5 minute intervals, and it returned reliable measurements for the full deployment period.

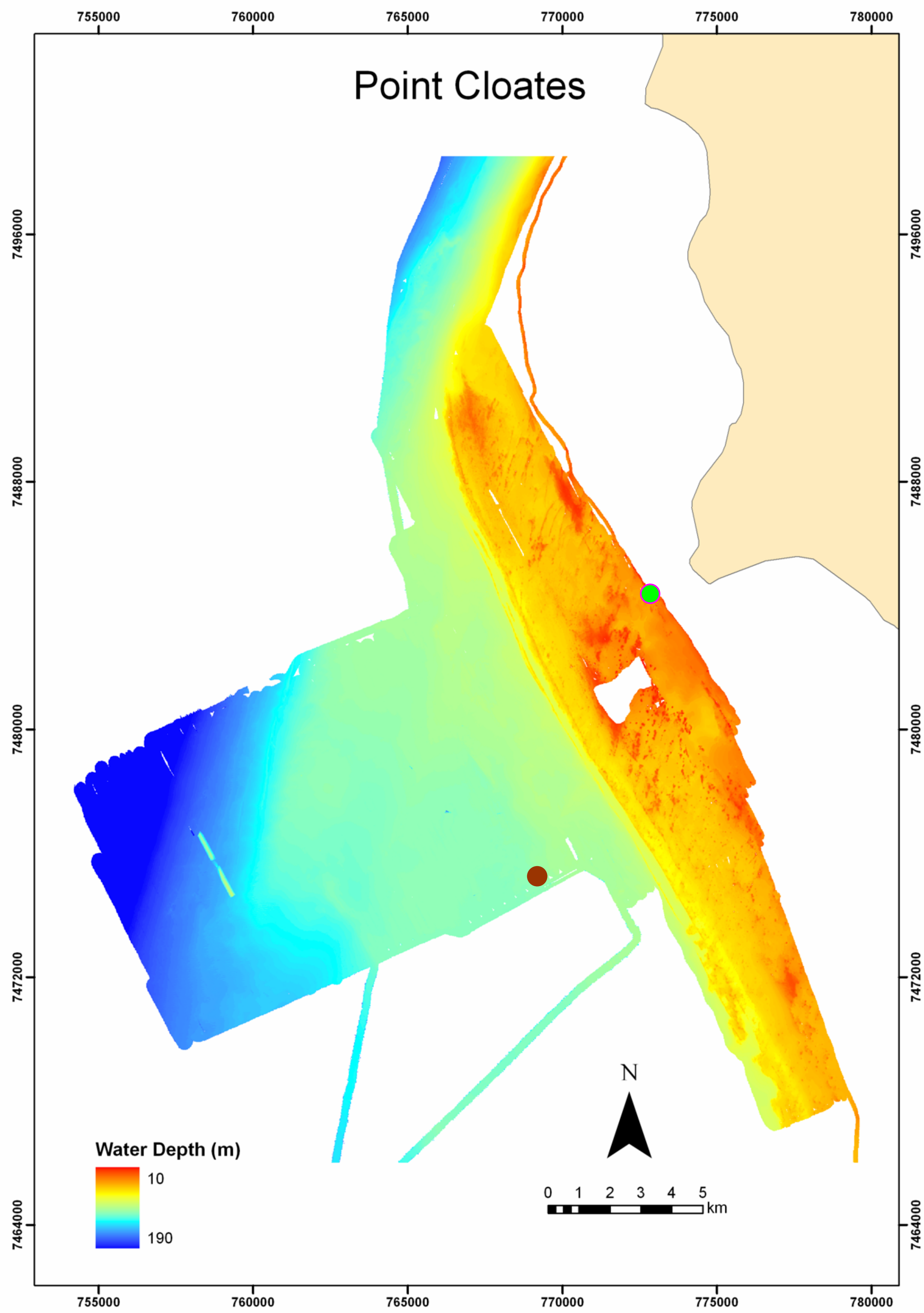

Figure 2.1: *Map of Point Cloates area showing the location of Site 1 (brown circle) in approximately 50 m water depth and Site 2 (green circle) in approximately 30 m water depth.*

2.2.2. Meteorology

Atmospheric pressure and wind speed for the deployment period, measured at the Bureau of Meteorology's Learmonth airport meteorological station (Station 005007), are shown in Figure 2.2. The measured variations in atmospheric pressure were acounted for when converting the measured bottom water pressure to water depth. The minimum and maximum atmospheric pressure recorded over the deployment period were 1012 and 1025.6 hPa, respectively. The maximum recorded average wind speed was 8.61 m s^{-1}.

2.2.3. Tidal water levels

The time series of water level relative to mean sea level obtained by the ADCP is shown in Figure 2.2. A classical harmonic analysis of this time series was performed to determine the amplitudes and phases of the tidal constituents. The method used followed Pawlowicz et al. (2002), which is based on a method initially proposed by Foreman (1977) and includes nodal corrections. Using this method a total of 45 astronomical and 101 shallow-water constituents can be resolved, depending on the record length. The 33.9 days of data available from the ADCP deployment yielded the amplitudes and phases of 35 tidal constituents, which are listed in Table 2.1 along with their 95 % confidence limits. These harmonic constituents account for 98.2% of the water level variation at the deployment site.

The tide can be classified according to the ratio of key diurnal to semi-diurnal tidal constituents. This is represented by the form factor F (e.g. Pugh, 2004)

$$F = \frac{a_{K1} + a_{O1}}{a_{M2} + a_{S2}}$$

where a is amplitude and the subscript denotes the relevant constituent. The amplitudes listed in Table 2.1 indicate a value for F of 0.5779, which is indicative of a mixed, mainly semi-diurnal tide. The mean spring tidal range was calculated to be 0.979 m and the mean neap range was 0.245 m.

2.2.4. Currents

The current magnitude and direction for sampling bins located between 4.5 and 46.5 m above the bed are shown Figure 2.3. A time-varying current speed due to the tide was frequently measured at the deployment site. The current direction did not always reverse, however, due to other non-tidal currents that were also active. The generation of near-bed shear in the current profile is clearly evident in the magnitude record, and appears to be greatest at times of largest current speed, which is expected (Figure 2.3, top panel). At other times there is also evidence for internal shear generated higher in the water column by water masses flowing in different directions (Figure 2.3, bottom panel).

Time series of the east, north, and vertical components of current velocity, as well as the current magnitude and direction, are shown in Figures 2.4 and 2.5 for two elevations, 4.5 m and 46.5 m

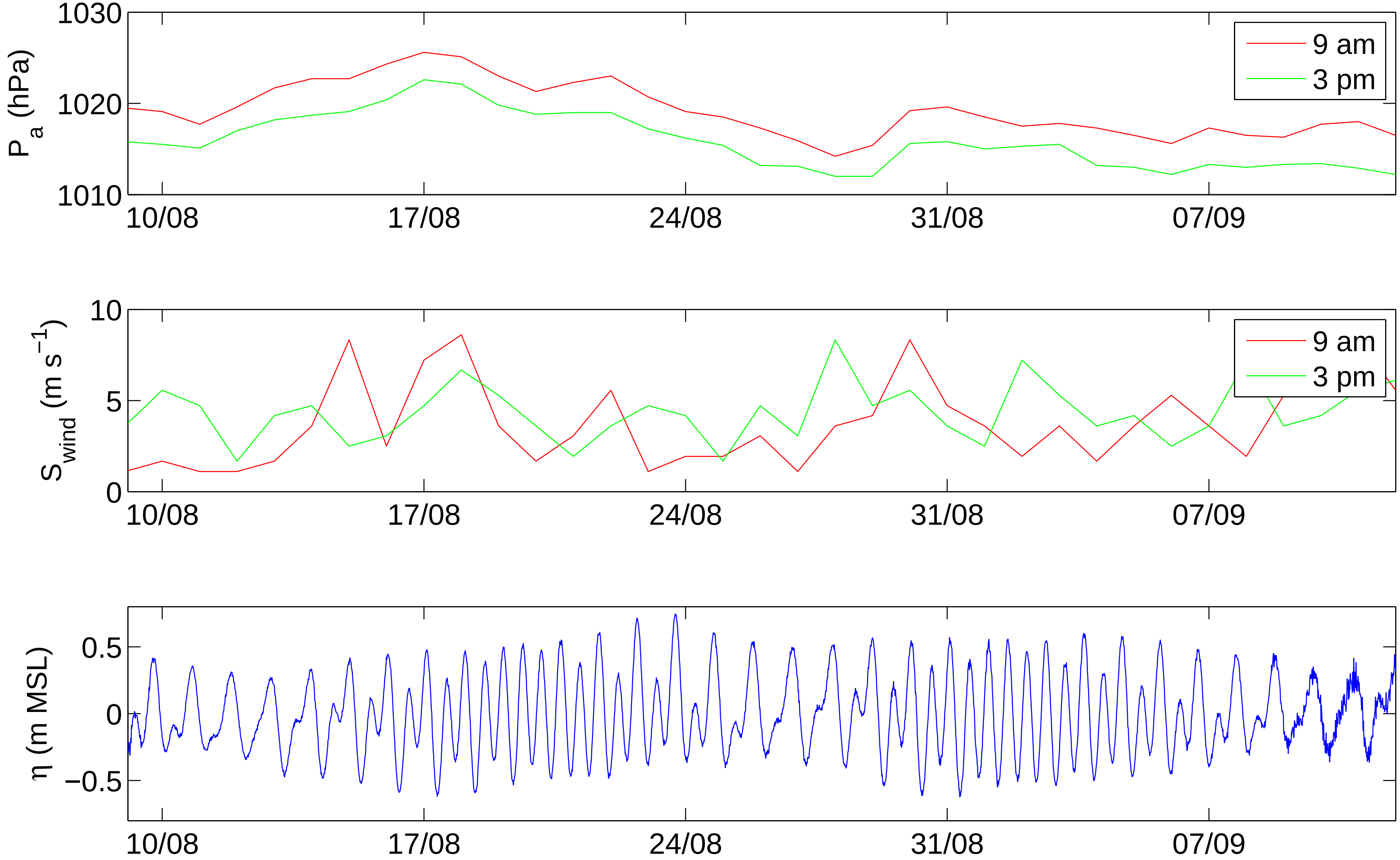

Figure 2.2: *Time series of atmospheric pressure (P_a), wind speed (S_{wind}), and sea level (η) relative to mean sea level (MSL) measured over the deployment period. P_a and S_{wind} were provided by the Commonwealth Bureau of Meteorology.*

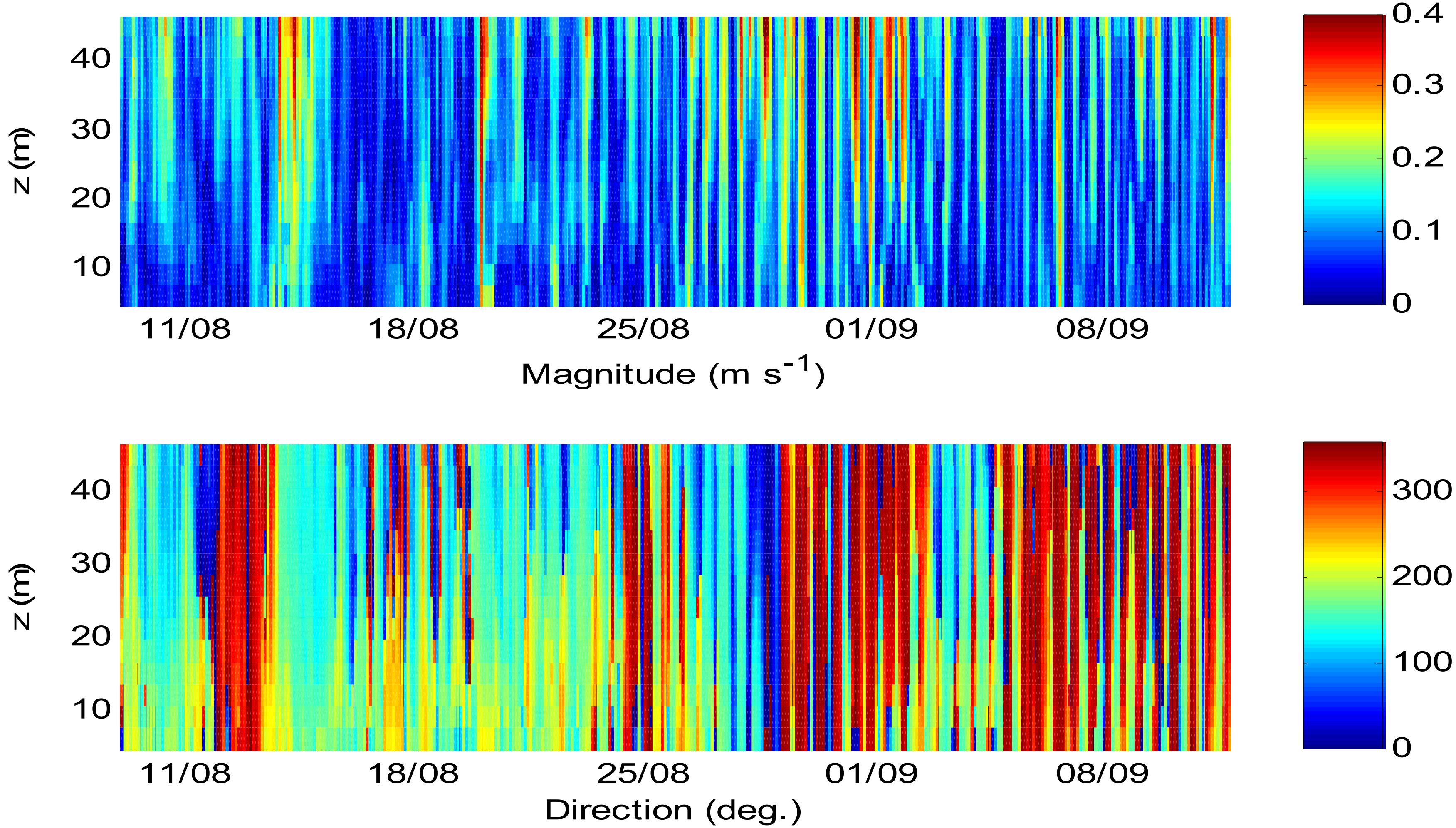

Figure 2.3: *Contour plots of current magnitude and direction between 4.5 and 46.5 m above the bed at Site 1.*

Table 2.1. Listing of the amplitudes, phases and errors of the harmonic constituents resolved from the available 33.9 day record. The errors are for a 95 % confidence interval. The Greenwich phase was computed with nodal corrections.

TIDE	FREQUENCY (CYCLES HR^{-1})	AMPLITUDE (M)	AMPLITUDE ERROR	PHASE (DEGREES)	PHASE ERROR	SIGNAL-TO-NOISE RATIO
MM	0.001512	0.0334	0.005	12.59	8.64	44
MSF	0.002822	0.0277	0.005	179.35	10.19	32
ALP1	0.034397	0.0026	0.003	167.43	78.83	0.63
2Q1	0.035706	0.0028	0.003	27.97	72.39	0.74
Q1	0.037219	0.0214	0.003	134.25	10.26	38
*O1	0.038731	0.125	0.003	153.16	1.78	1.80E+03
NO1	0.040269	0.0141	0.006	218.05	25.11	5.7
*K1	0.041781	0.1578	0.004	174.39	1.34	1.90E+03
J1	0.043293	0.0126	0.003	165.3	13.51	14
OO1	0.044831	0.0097	0.003	199.99	17.84	11
UPS1	0.046343	0.0016	0.002	188.66	89.07	0.43
EPS2	0.076177	0.0038	0.003	14.29	57.26	1.3
MU2	0.07769	0.011	0.004	78.56	20.29	9.3
*N2	0.078999	0.0561	0.004	7.85	3.69	2.30E+02
*M2	0.080511	0.3059	0.003	39.63	0.7	8.00E+03
L2	0.082024	0.0063	0.002	51.82	25.67	6.5
*S2	0.083333	0.1835	0.003	103.38	1.1	2.90E+03
ETA2	0.085074	0.0051	0.003	119.07	31.15	4.1
MO3	0.119242	0.0009	0.001	71.64	91.41	0.46
*M3	0.120767	0.0008	0.001	192.84	121.63	0.29
*MK3	0.122292	0.0005	0.001	92.77	159.67	0.18
*SK3	0.125114	0.0022	0.002	214.89	47.19	1.4
MN4	0.159511	0.0006	0.001	18.85	162.35	0.16
M4	0.161023	0.0027	0.002	126.82	36.66	2.2
SN4	0.162333	0.0015	0.002	85.67	63.34	0.82
MS4	0.163845	0.0017	0.002	171.24	59.28	0.86
S4	0.166667	0.0022	0.002	111.74	48.45	1.4
2MK5	0.202804	0.0004	0.001	356.98	140.31	0.24
2SK5	0.208447	0.0006	0.001	216.44	108.04	0.47
2MN6	0.240022	0.0004	0.001	324.81	179.89	0.12
M6	0.241534	0.0005	0.001	332.05	186.68	0.13
2MS6	0.244356	0.0024	0.002	51.6	41.47	2.3
2SM6	0.247178	0.0013	0.002	89.96	69.98	0.74
3MK7	0.283315	0.0005	0.001	304.15	157.42	0.15
M8	0.322046	0.0009	0.001	255.3	83.58	0.51

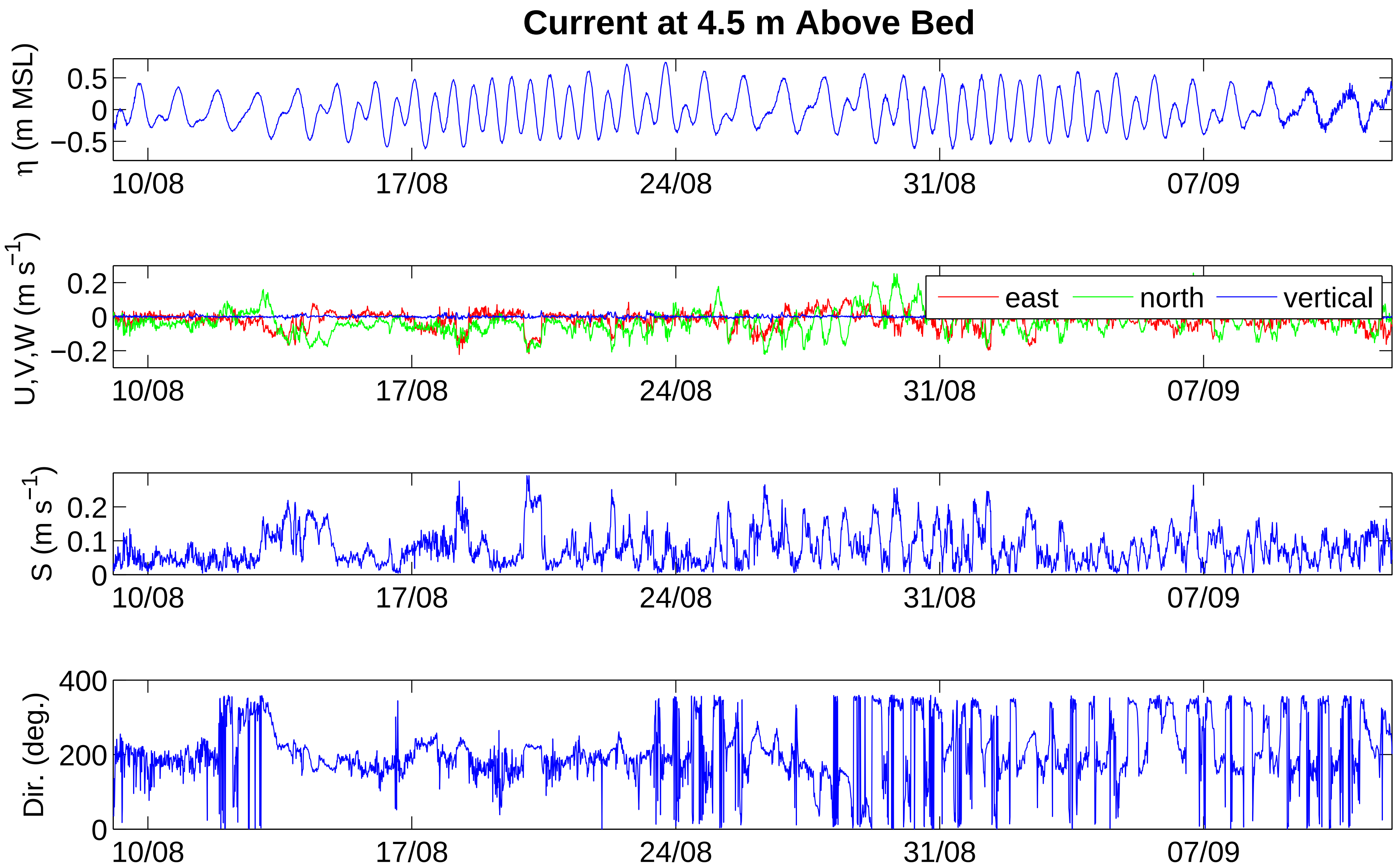

Figure 2.4: *Time series of sea level (η); east, north and vertical components of the current vector, (U, V, W); current magnitude (S) and current direction measured at 4.5 m above the bed at Site 1.*

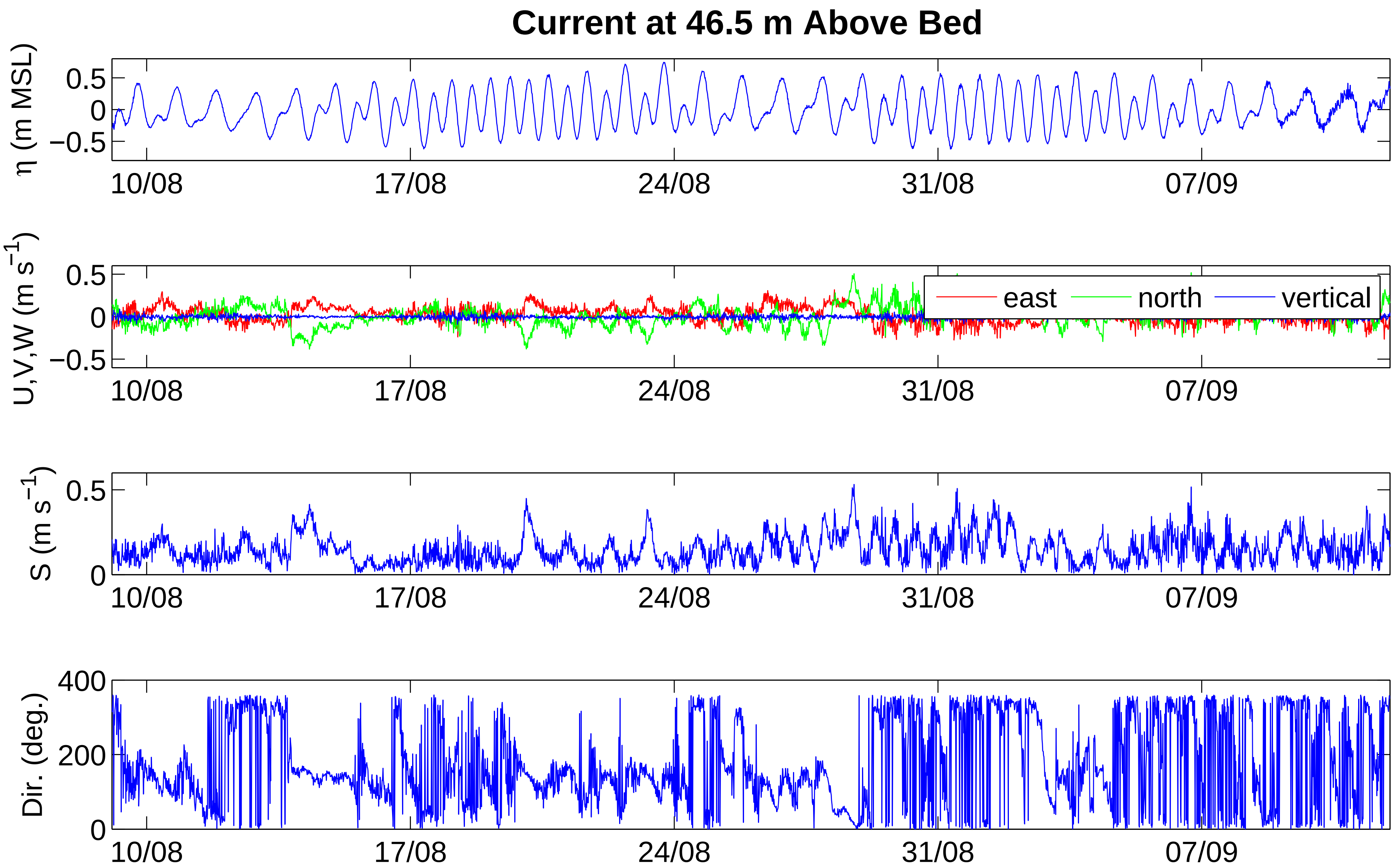

Figure 2.5*: Time series of sea level (η); east, north and vertical components of the current vector, (U, V, W); current magnitude (S) and current direction measured at 46.5 m above the bed at Site 1.*

above the bed, respectively. Mean and root-mean-square near-bed (4.5 m above the bed) current speeds were 0.08 and 0.05 m s^{-1}, respectively. With respect to extremes, the near-bed current speeds exceeded 0.16 m s^{-1} for 10 % of the time and 0.23 m s^{-1} for 1 % of the time. The maximum near-bed current speed was 0.29 m s^{-1}. The corresponding near-surface current speeds are listed in Table 2.2 and are consistently larger, as expected

Table 2.2. Current magnitude statistics for two elevations in the water column at Site 1.

STATISTIC	NEAR-BED (4.5 M)	NEAR-SURFACE (46.5 M)
MEAN	0.08 m/s	0.15 m/s
ROOT-MEAN-SQUARE	0.05 m/s	0.09 m/s
10 % EXCEEDENCE	0.16 m/s	0.27 m/s
1 % EXCEEDENCE	0.23 m/s	0.40 m/s
MAXIMUM	0.29 m/s	0.53 m/s

The flood and ebb of the tidal current is roughly directed to the south and north, respectively, in the absence of other current activity. This is consistent with the deployment site being located on the eastern limb of a clockwise-rotating amphidrome centred further to the west. A barotropic tidal model driven by TOPEX/Poseidon altimetry data for the world's oceans show a clockwise rotating M2 amphidrome centred to the southwest of the deployment site. The phase difference between water level and velocity at the deployment site varied between 0° and 40°.

Contoured histograms of the east and north components of the current vector as well as rose plots of current direction show that the measured near-bed currents were predominantly directed to the southern quadrants whereas the near-surface currents were more variable; favouring both the southeast and northwest quadrants (Figure 2.6). Progressive vector plots for the two elevations, 4.5 m and 46.5 m above the bed, show distinctly different behaviours. The net displacement for near bed waters is to the south-southeast throughout the deployment. The displacement for near-surface water, however, was initially to the southeast and then to the north-northwest, with an overall net displacement to the northeast.

The east and north components of the current velocity vector were low-pass filtered in order to remove the semi-diurnal and diurnal tidal variation and highlight non-tidal currents. A simple zero-phase, 36 hour, moving-average filter was used. The current magnitude and direction for 4.5 m and 46.5 m above the bed were then calculated from the low-pass filtered vector components and these are shown in Figure 2.7. The near-surface non-tidal currents were predominantly directed to the north-northwest to northeast sector over the deployment period, whereas the near-bed non-tidal currents were predominantly directed to the south to west-southwest sector. The former is consistent with the south-southwest to south-southeast winds that persisted during the deployment period, and the latter is consistent with the regional geostrophic current field during the deployment (Figure 2.8).

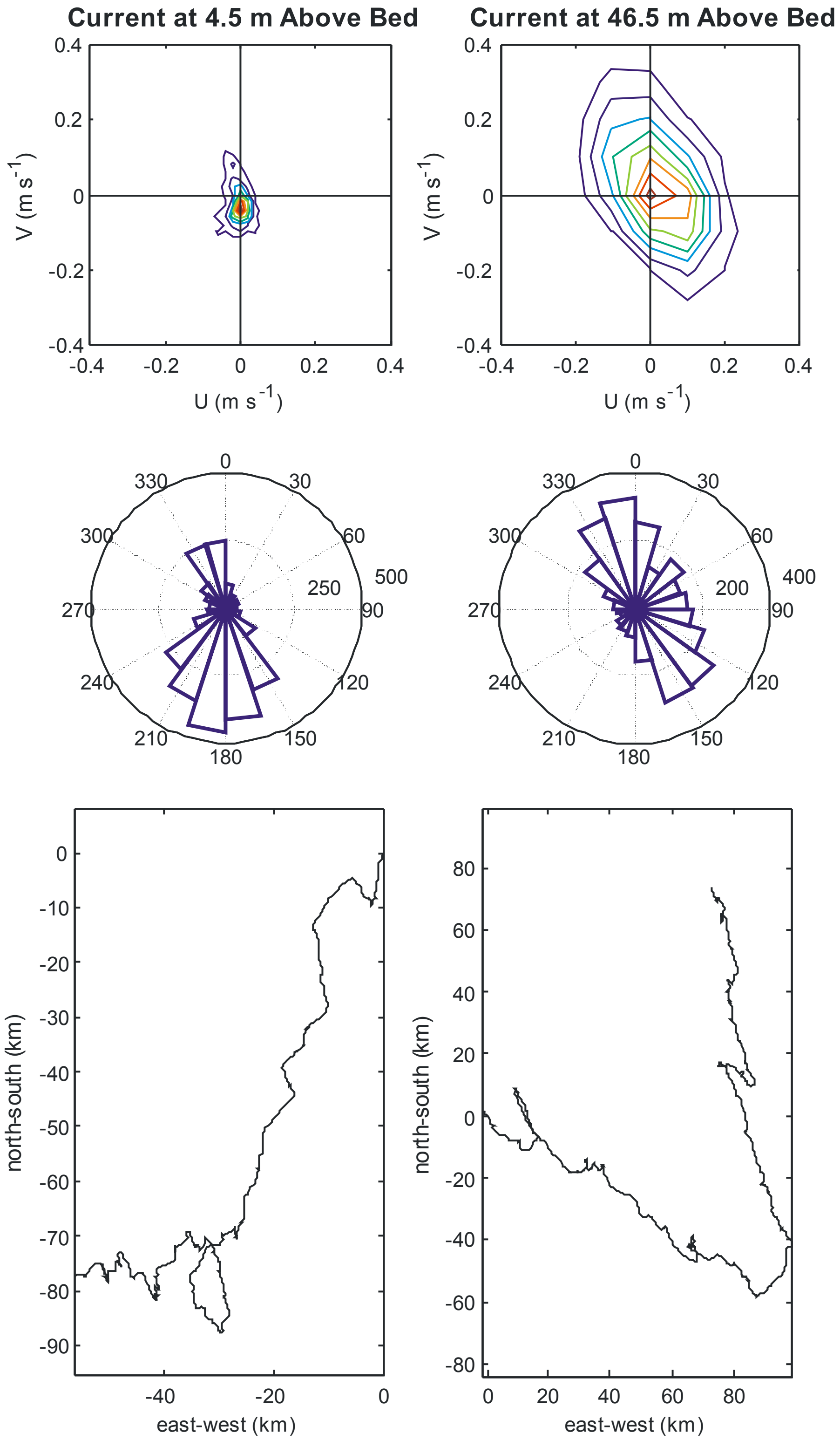

Figure 2.6: Contoured histograms of the east and north (U and V) components of the measured current vectors at 4.5 m and 46.5 m above the bed (top panels) at Site 1. Rose plots of the current direction (middle panels). Progressive vector plots (bottom panels).

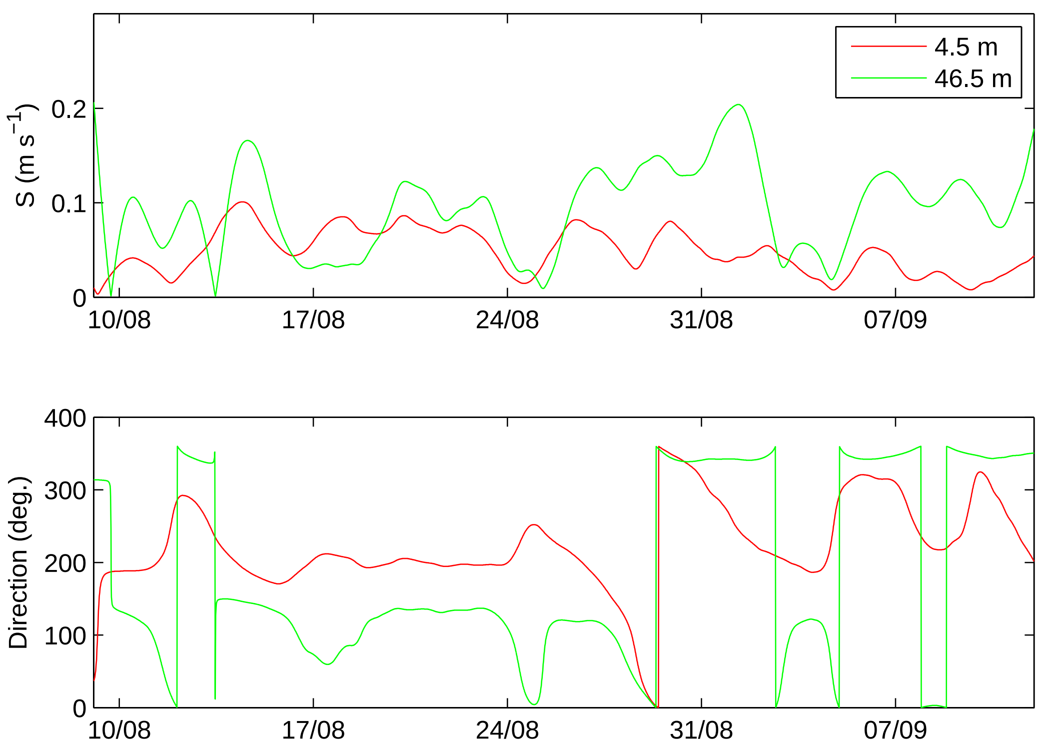

***Figure 2.7**: Time series of low-pass filtered current magnitude and direction measured at 4.5 m and 46.5 m above the bed at Site 1.*

2.2.5. Temperature and salinity

Time series of near-bed water temperature and salinity over the deployment period are shown in Figure 2.9. Temperature varied cyclically with a period of 7–11 days, and ranged between 21.90° and 23.29°. The measured temperature variations are consistent with sea surface temperature (SST) variations recorded by satellite and relate to tropical Leeuwin current water impinging onto the inner shelf (Figure 2.8). The satellite image for the 26th August 2008 corresponds with the maximum temperature recorded at Site 1 and the image for the 1st September 2008 corresponds with the minimum recorded water temperature.

2.3. SITE 2

The available meteorological data presented in relation to Site 1 is applicable to Site 2. The tidal water level data presented from Site 1 matches closely with that measured at Site 2, so no further analysis of tidal water levels at Site 2 were undertaken.

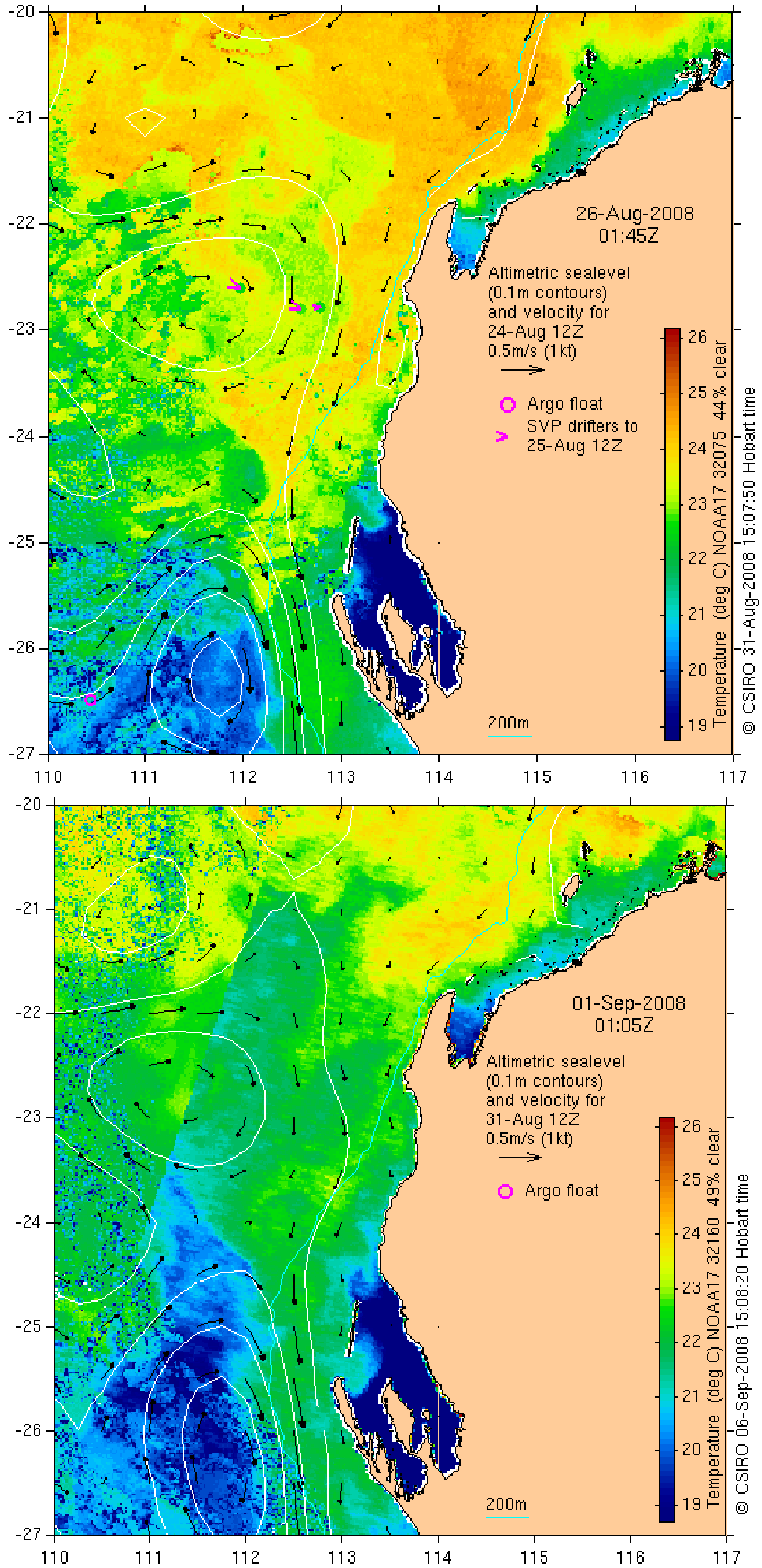

Figure 2.8: *Satellite-derived sea surface temperature images with super-imposed (inferred) geostrophic circulation. Images provided by CSIRO Marine and Atmospheric Research.*

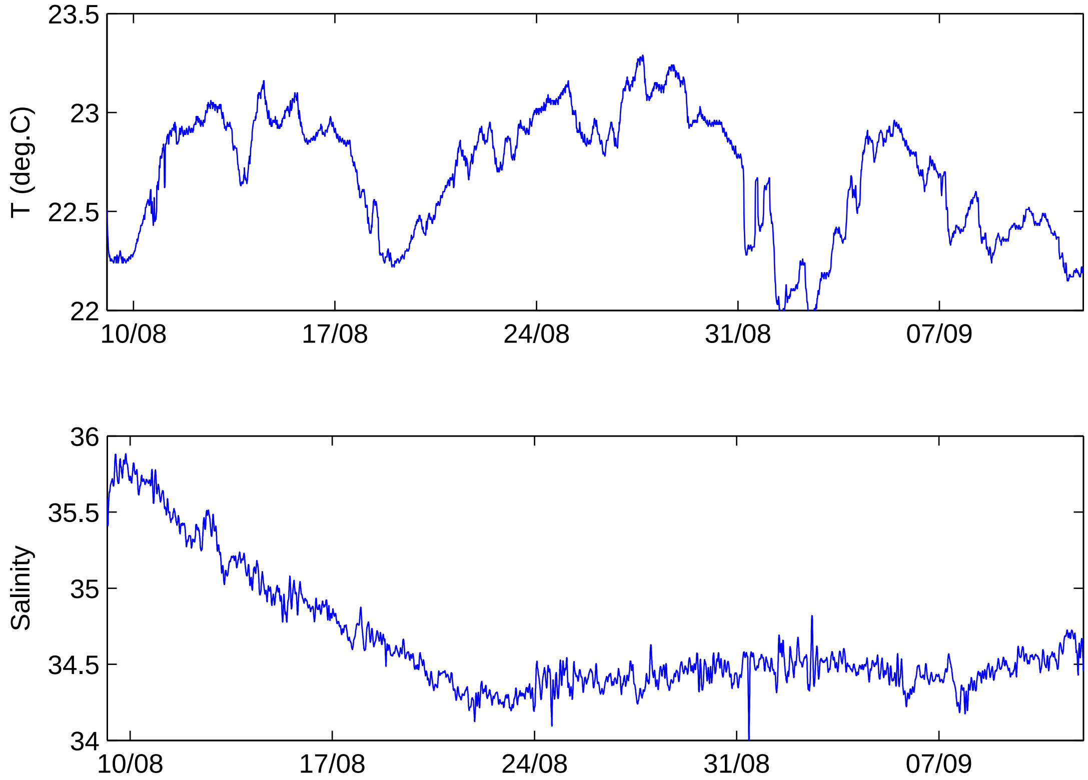

Figure 2.9: *Time series of near-bed water temperature and salinity at Site 1.*

2.3.1. Mooring description and sample regimes

The mooring at Site 2 was located at 22° 43.2789′S 113° 38.8500′E in 32 m water depth. It consisted of a Nortek Vector Acoustic Doppler Velocimeter (ADV; Serial No. N4103) and a Seabird SBE37 CTD probe. The instruments were attached to a rectangular frame, a 40 m ground line (sinkable rope) to a bottom weight and acoustic release, and a 40 m line (floatable rope) to a second bottom weight to enable grappling for the mooring if the acoustic release failed. The mooring was deployed at 02:30 hrs on 09/08/2008 (GMT) and retrieved at 23:45 hrs on 11/09/2008 (GMT).

The ADV measures the 3-dimensional current vector from the Doppler shift of sound reflected from the water column using three orthogonal acoustic beams. The instrument was programmed to obtain point measurements of current velocity at 2 Hz for 10 minute bursts every 2 hours. The sampling elevation was 1 m above the bed. The instrument functioned continuously throughout the deployment, returning 33 days of current velocity and water depth records suitable for wave, non-tidal current and limited tidal current analysis.

The Seabird SBE37 CTD probe measures conductivity, temperature and pressure, and therefore salinity and depth. The instrument was setup to sample continuously at 15 minute intervals, and it returned reliable measurements for the full deployment period.

On the 24/08/2008 this mooring became entangled during a towed video transect. As a consequence the mooring had to be recovered and redeployed. The second location was at 22° 43.0968′S 113° 38.8320′E in slightly deeper water.

2.3.2. Water level and currents

The time series of burst-averaged water depth and currents measured at 1 m above the bed at Site 2 are shown in figure 2.10. The discontinuity in the water depth record marks the time when the mooring was recovered and redeployed. Water level variations match closely between the two sites (cf. Figure 2.10 and 2.2). The burst-averaged near-bed currents at Site 2 are of similar magnitude to those at Site 1. Mean and root-mean-square current speeds were 0.04 and 0.04 m s^{-1}, respectively at Site 2. With respect to extremes, the near-bed current speeds exceeded 0.10 m s^{-1} for 10 % of the time and 0.21 m s^{-1} for 1 % of the time. The maximum near-bed current speed was 0.27 m s^{-1}. The general trend of larger currents speeds during the second half of the deployment at Site 2 is consistent with that observed at Site 1 (cf. Figure 2.4 and 2.10). The pattern of persistent, south-south-westerly directed flow for the period 13–23 August measured at Site 1 is absent at Site 2 however. With the exception of short-lived reversals of low-magnitude current speed to the south, related to the flooding tide, the current at Site 2 was overwhelmingly directed to the north-northwest (Figure 2.10).

The general pattern of north-northwest-directed current at Site 2 is clearly apparent in the contoured histogram of the east and north components of the current vector as well as the rose plot of current direction shown in Figure 2.11. The corresponding progressive vector plot shows a steady displacement of near bed waters to the north-northwest throughout the deployment. The total displacement was 85 km. There is therefore expected to be considerable horizontal shear between inshore (Site 1) and offshore (Site 2) waters off Point Cloates.

2.3.3. Temperature and salinity

Time series of near-bed water temperature and salinity over the deployment period are shown in Figure 2.12. Temperature varied cyclically between 21.31° and 23.31° and salinity varied roughly inversely with temperature, ranging between 34.86 and 35.14. The pattern is broadly similar to that measured further seaward at Site 1, suggesting tropical Leeuwin current water reached inshore as far as Site 1. Given the nearshore circulation just described, however, the water mass arrived via a countercurrent from the south.

2.3.4. Waves

In addition to the analysis of burst-averages of the data already discussed in Section 2.3.2, a further analysis was undertaken of the burst-sample records to obtain wave information. The water level record for each sample burst was corrected for dynamic pressure attenuation with depth prior to analysis for wave statistics. Standard auto-spectral analysis was performed on each

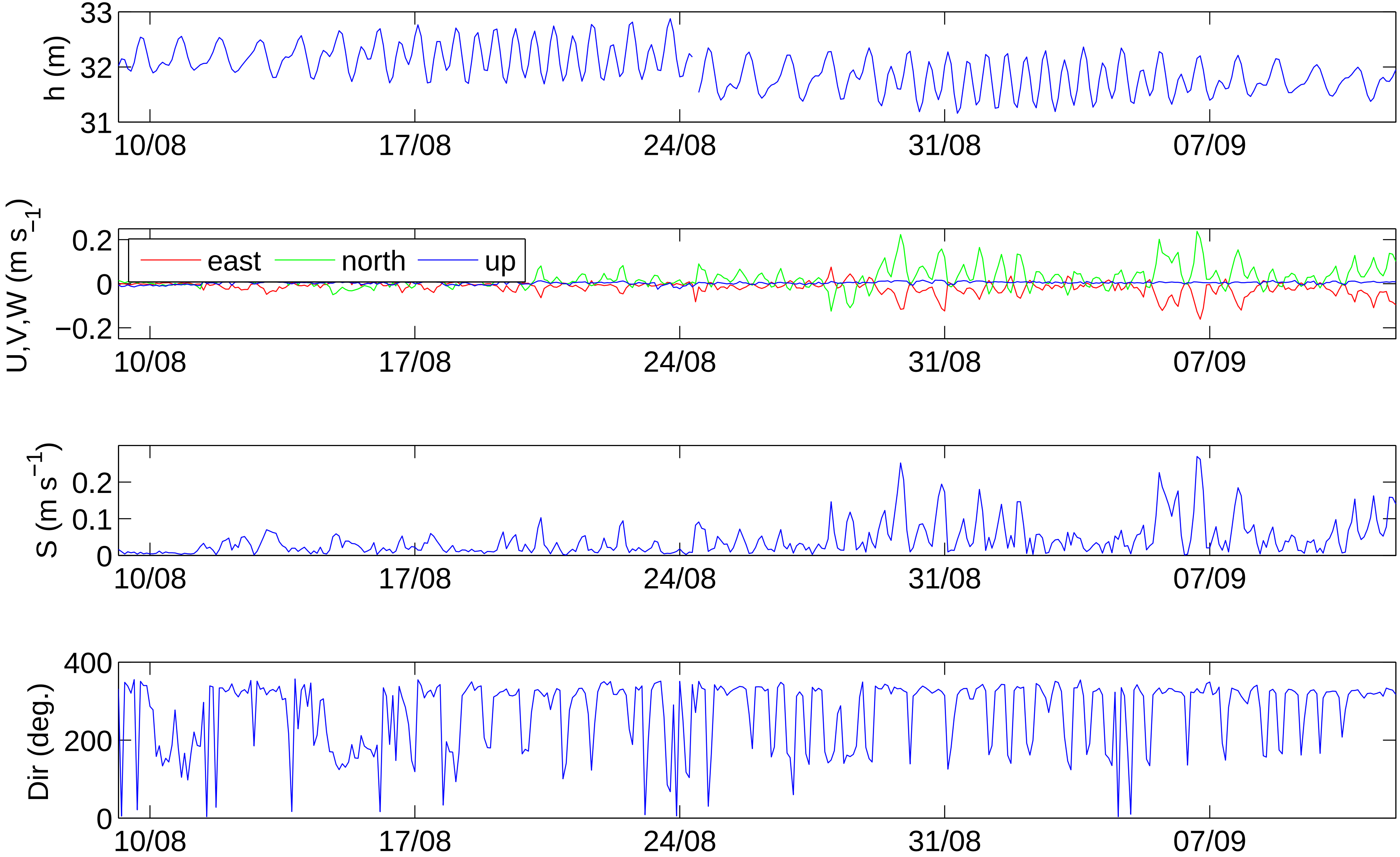

Figure 2.10: *Time series of water depth (h); east, north and vertical components of the current vector, (U, V, W); current magnitude (S) and current direction measured at 1 m above the bed at Site 2.*

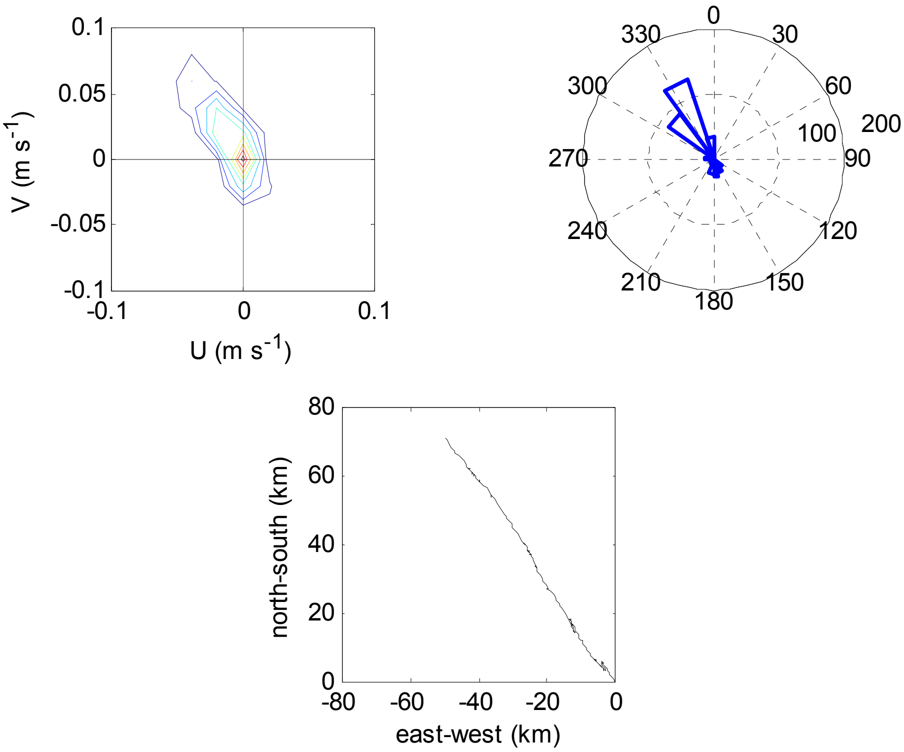

Figure 2.11*: Contoured histogram of the east and north (U and V) components of the measured current vector (left panel) at Site 2. Rose plot of the current direction (right panel). Progressive vector plot (bottom panel).*

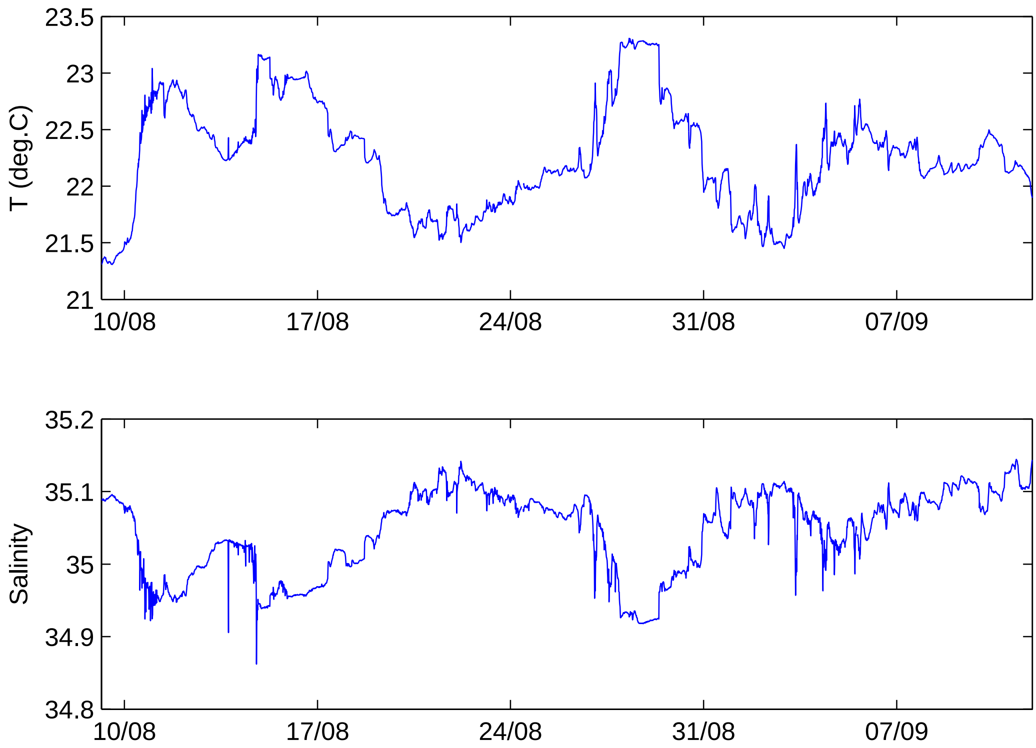

Figure 2.12*: Time series of near-bed water temperature and salinity at Site 2.*

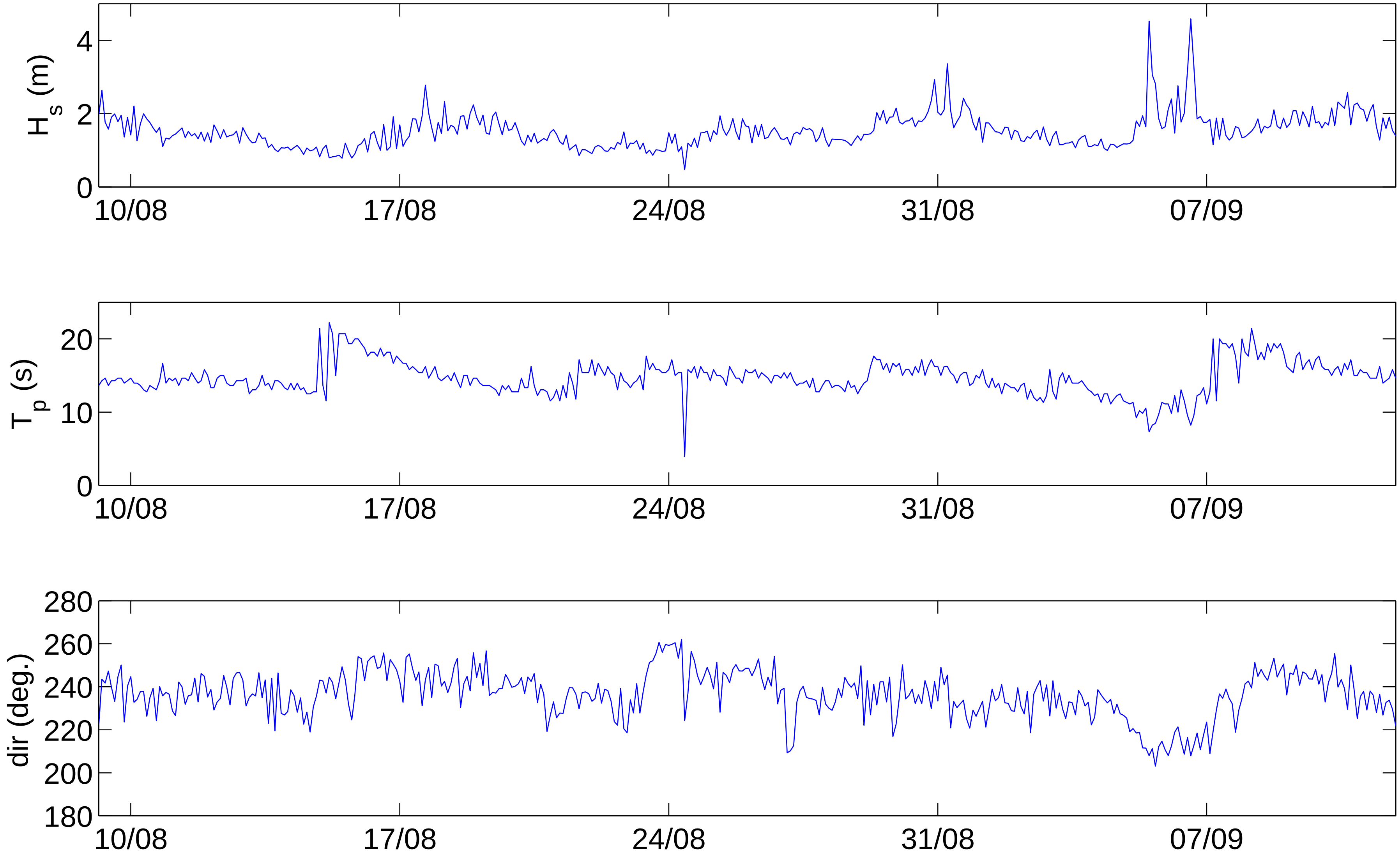

Figure 2.13: *Time series of significant wave height (H_s), peak period (T_p), and wave direction at Site 2.*

sample burst of water level data and the moments of the spectra were used to calculate significant wave height and peak period. Wave direction was calculated from the east and north components of the instantaneous current vector. The calculated time series of significant wave height, peak period and wave direction are shown in Figure 2.13. Wave heights ranged between 0.47 and 4.59 m with peak periods ranging from 7.3 to 22 s. The modal wave direction was from the west-southwest over the deployment period (Figure 2.14).

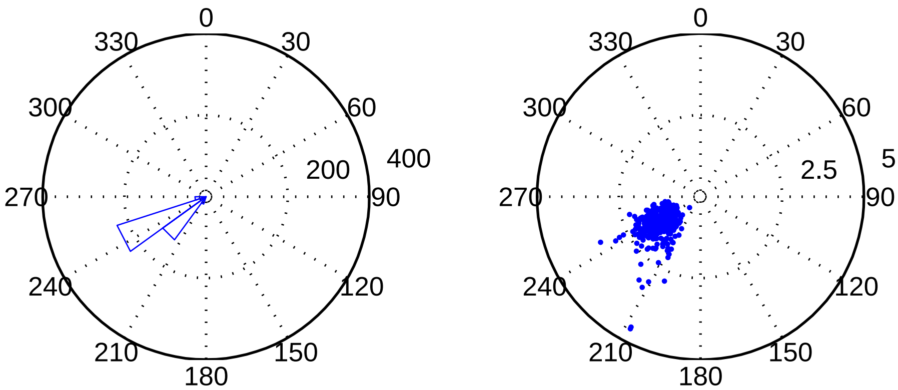

Figure 2.14: *histogram of wave directions (left panel) and compass plot of wave height and direction (right panel) at Site 2.*

2.4. SUMMARY

Two oceanographic moorings were deployed off Point Cloates in approximately 50 m and 30 m water depth. The deployment period covered 34 days during late winter and early spring. Wave conditions were highly variable during the deployment period, with significant wave height ranging from approximately 0.5 to 4.5 m, but arriving persistently from the west-southwest. These conditions are typical for the time of year. The tide regime off Point Cloates is microtidal, mixed, mainly semi-diurnal with a mean spring and neap range of 0.98 m and 0.25 m, respectively. The tide is almost diurnal during neaps. The tidal current floods to the south and ebbs to the north off Point Cloates, which is consistent with a clockwise rotating tidal amphidrome centred to the southwest of the region. Non-tidal, surface currents at the outer 50 m site were directed to the northeast-northwest sectors, consistent with wind patterns during the deployment period. Non-tidal bottom currents at the same site, however, were directed to the south to west-southwest sector, consistent with the regional geostrophic current. At the inner 30 m site, non-tidal bottom currents were directed to the north-northwest. This is consistent with the wind pattern during the deployment period driving surface currents to a depth of 30 m or so, but salinity and temperature measurements suggest that a counter-current of the regional geostrophic current further offshore may also influence the inner site.

3. Bathymetry of Carnarvon Shelf

3.1. INTRODUCTION

High resolution multibeam sonar mapping was undertaken on *RV Solander* with a *Simrad* EM3002(D) 300 kHz multibeam sonar (MBS) system and *Applanix* motion reference and positioning system coupled with a high-precision *C-Nav* GPS system. EM3002 data was acquired using Kongsberg's *Seabed Information System* (*SIS*) software. This software has the flexibility required for reconnaissance mapping and mapping relatively large areas of seabed, provides a high level of information in the helmsman display, and supports *Applanix* true heave logging that is used in post-processing the multibeam data to further reduce heave artefacts and provide higher quality bathymetry, especially in rough sea conditions. Vessel speed while acquiring data varied between 5 and 13 knots, but was mostly 8 to 12 knots, with slower speeds during rougher conditions and at inshore areas close to the fringing coral reef. Multibeam data processing was undertaken during the survey using *Caris Hips and Sip*s V6.1 software. However, final processing, especially to remove more complex artefacts (e.g. elevation errors produced by dynamic draft characteristics) was completed after the survey at GA.

Complete coverage of the seabed between the outer edge of Ningaloo reef and the outer continental shelf was achieved within the Mandu Creek, Point Cloates and Gnaraloo survey areas (Table 3.1; Figure 3.1). At Mandu Creek and Point Cloates, mapping extended to the shelf break, but not at Gnaraloo where the shelf is 48 km wide. Total mapped areas are 80 km^2 at Mandu Creek, 281 km^2 at Point Cloates and 321 km^2 at Gnaraloo. In addition, an area of 277 km^2 was mapped between the Mandu Creek and Point Cloates sampling areas, plus 79 km^2 to the north of Mandu Creek. The only major gap in mapping coverage is an area of 2 km^2 on the inner shelf at Point Cloates in the vicinity of Black Rock, where shoals are a hazard to navigation.

Table 3.1: Bathymetric zones of Mandu Creek, Point Cloates and Gnaraloo survey areas.

AREA	BATHYMETRIC ZONE	DEPTH RANGE (M)	WIDTH (KM)	AVERAGE GRADIENT (^{o})	RELIEF (M)
Mandu Creek	Inner shelf	15 - 60	1.3	2.3	0.2 - 5
	Mid shelf	60 - 80	3.5	0.3	0 - 0.5
	Outer shelf	80 - 150	2.7	1.4	0 - 1
Point Cloates	Inner shelf	10 - 60	5.0	0.4	2 - 15
	Mid shelf	60 - 75	8.5	0.08	<1
	Outer shelf	75 - 170	7.0	0.6	0 - 1.5
Gnaraloo	Inner shelf	10 - 35	>2	0.7	0.5 - 5
	Mid shelf	35 - 70	19	0.09	0.2 - 5
	Outer shelf	70 - 110+	>11	0.2	0 - 1

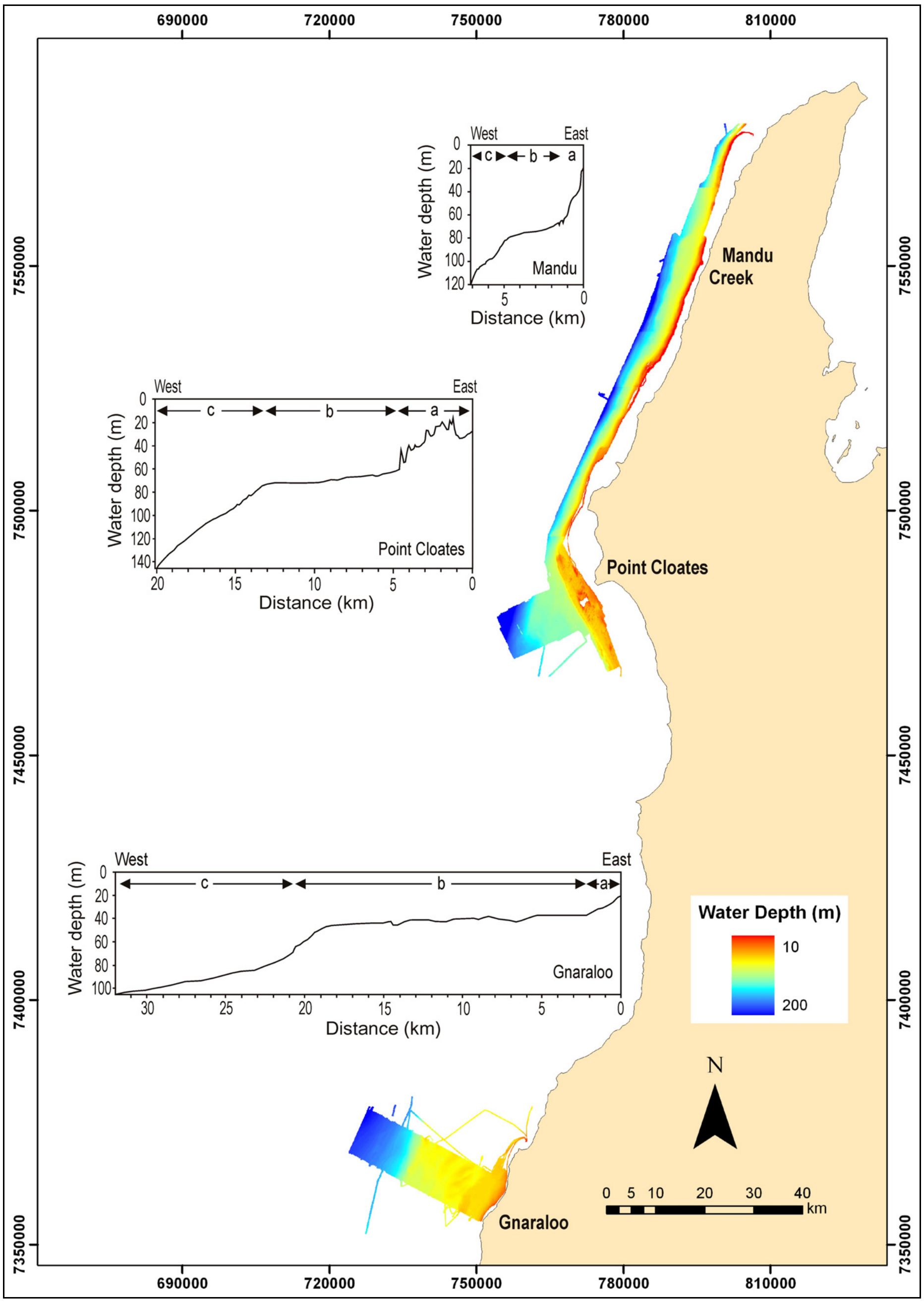

Figure 3.1: *Multibeam coverage of the Carnarvon Shelf, showing bathymetric profiles at Mandu Creek, Point Cloates and Gnaraloo with inner shelf (a), mid shelf (b) and outer shelf (c) indicated.*

3.2. MANDU CREEK

The continental shelf at Mandu Creek is approximately 7.5 km wide with an average gradient of 1^{o}, ranging in water depth from 15 m on the edge of Ningaloo reef to 150 m at the shelf break. The inner shelf, mid shelf and outer shelf have the following characteristics:

Inner Shelf: The mapped area of inner shelf at Mandu Creek is up to 1.3 km wide and extends from 15 m to 60 m water depth on an average gradient of 2.3^{o} (Figure 3.2). The profile of the inner shelf comprises two distinct segments, a narrow (~200 m wide) segment that slopes at 4^{o} – 5^{o} to 35 m water depth and incorporates part of the outer reef, and a convex segment that extends to 60 m depth on a slope of about 2^{o}. Local relief across the inner shelf is also distinctly different between these segments. Thus, the steeper part is characterised by closely spaced mounds and ridges that rise up to 5 m above the sea floor (Figure 3.3). Ridges are discontinuous, extending up to 500 m and are uniformly oriented to the north-northeast. In places, closely spaced mounds are aligned in the same direction. This morphology extends the length of the survey area, with one 200 m wide gap that forms an inlet to Ningaloo lagoon. The outer, convex segment of the inner shelf has a smooth, generally featureless sea floor. The exception to this is in the vicinity of the lagoon inlet where a local field of bedforms occurs. These bedforms are subtle features that are 20 – 50 cm high, up to 30 m wide and 200 m long.

Mid Shelf: The mid shelf at Mandu extends 3.5 km from 60 m to 80 m water depth on a gradient of 0.3^{o}. For the most part, the sea floor is smooth across the mid shelf with the exception of an area of bedforms located immediately seaward of the inner shelf in 60 – 70 m water depth. These bedforms are best developed within the northern half of the survey area, where they occur as a discontinuous field along 16 km of the shelf. Bedform shape includes linear and crescentic forms with lee faces oriented to the northeast, wavelengths of 70 – 170 m and heights of 0.2 – 0.5 m. Within the southern half of the survey area at Mandu, bedforms are mapped within one small area on the mid shelf covering 2 km alongshore by 500 m cross-shelf. In this area, bedforms are less than 0.5 m high and less well defined than the northern field. However, they do maintain a clear northeast orientation. Outside this area the remainder of the mid shelf is smooth.

Outer Shelf: The outer shelf at Mandu Creek is 2.7 km wide with an average gradient of 1.4^{o} between 80 m and 150 m water depth. Toward the south, the outer shelf widens to 3.6 km with a gradient of approximately 1^{o}. Overall, the outer shelf has a convex profile that steepens to 3-4^{o} toward the shelf break. Across this profile, the seafloor is generally smooth, with the exception of an area in 105 – 110 m water depth where local relief of 1 m occurs. This relief is associated with small mounds that are 20 – 40 m wide and follow a general north-south alignment. In places, the mounds are less than 10 m apart and form a ridge that can be traced 200 – 300 m along the shelf. In other areas the mounds are more widely spaced and form a field up to 700 m wide, but maintain a parabathic alignment that extends the length of the survey area. The only other bathymetric feature on the outer shelf is a discontinuous ridge that is 1 m high and extends along the break in slope with the mid shelf in 80 m water depth.

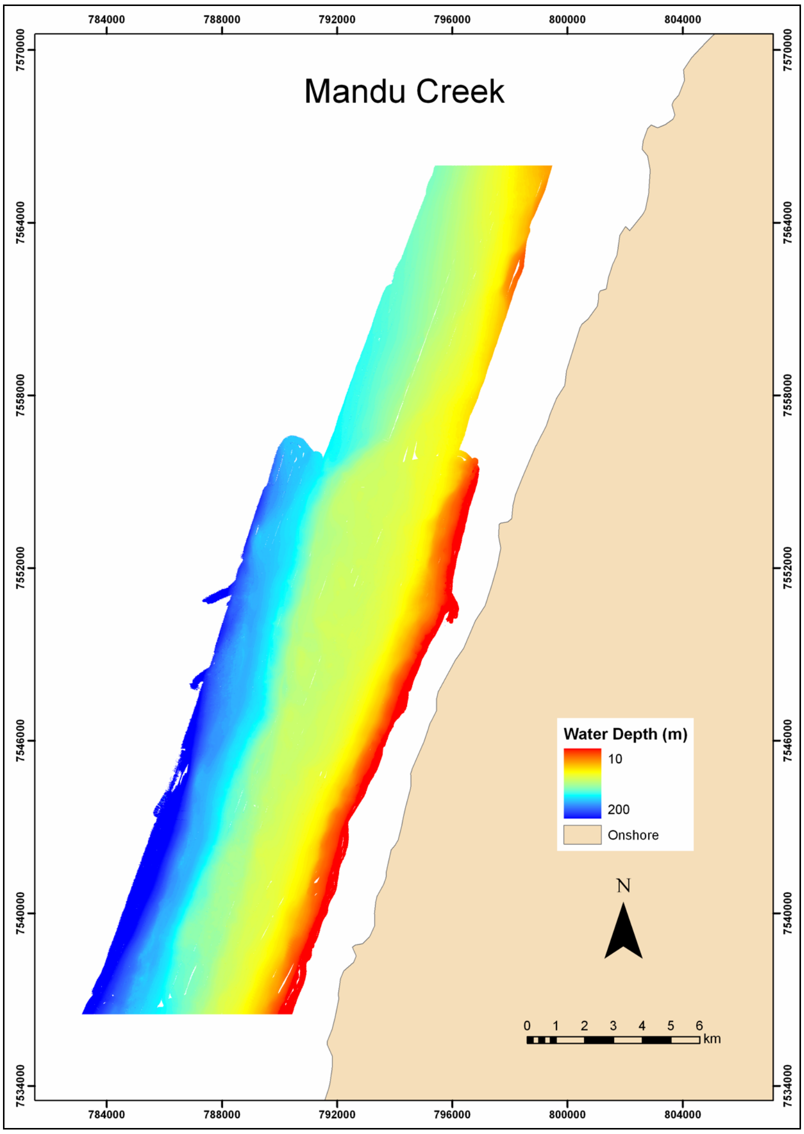

Figure 3.2: *Generalised bathymetry for the Mandu Creek area of Carnarvon shelf based on multibeam sonar data. Bathymetric zones include the inner shelf (red), mid shelf (yellow) and outer shelf (blue).*

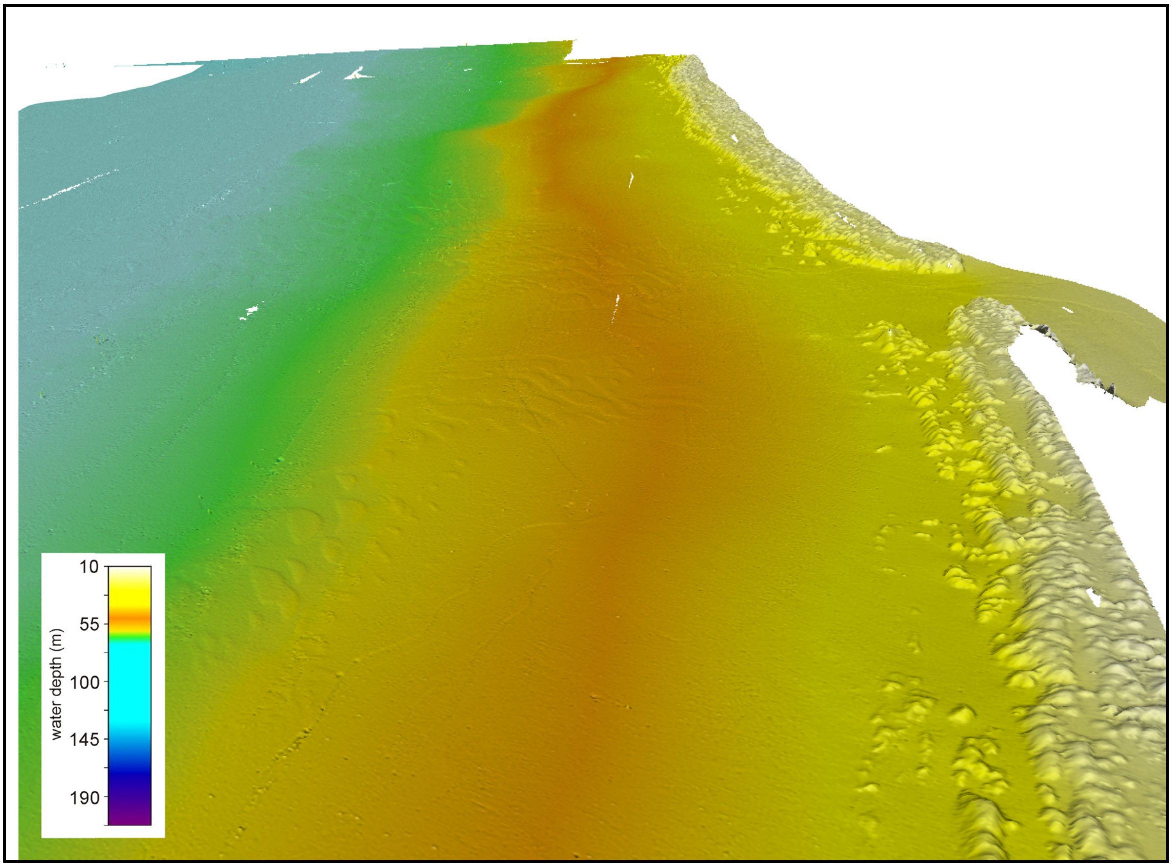

Figure 3.3: *False colour perspective view of the continental shelf at Mandu looking to the north, showing ridges and mounds (lithified beaches & dunes) on the inner shelf and bedforms on the mid shelf. The inlet to Ningaloo lagoon is also shown.(Vertical exaggeration = 3x, view angle 30^o)*

3.3. POINT CLOATES

The continental shelf at Point Cloates is approximately 20 km wide and comprises three geomorphically distinct bathymetric zones to seaward of the reef-lagoon system, as follows (Figure 3.4):

Inner Shelf: Survey coverage of the inner shelf at Point Cloates extends from 20 m to 60 m water depth for an area that extends 34 km alongshore and 5 km across the shelf (Table 3.1). The average gradient of the mapped area is 0.4^o with local relief ranging between 2 m and 15 m across a highly rugose and complex geomorphology of mounds, ridges and raised hardground. The geomorphic complexity of the inner shelf is greatly reduced at the northern and southern ends of the mapped area, where the inner shelf tapers to a width of 1 km and 2.5 km, respectively. In these areas, the sea floor is smooth with bathymetric relief of 0.5 m to 10 m across widely spaced mounds.

A prominent geomorphic feature of the inner shelf at Point Cloates is a ridge that extends 15 km in 60 m water depth and defines the transition from inner shelf to mid shelf (Figure 3.5). The ridge ranges between 6 m and 20 m in height and is broken only by two narrow gaps that are 200 – 300 m wide. At its highest point, the ridge is 200 m wide and has two crest lines separated by a shallow (3 m deep) trough, or swale. Elsewhere the ridge has a single crest and is 60 – 80 m wide. In cross-section the ridge preserve a smooth profile that is concave along the seaward face. A second ridge is located landward of the outer ridge in 50 m water depth. This ridge is up to 10 m high and can be traced for 22 km along the inner shelf, but in contrast to the outer ridge, is characterised by an irregular morphology and has numerous narrow gaps. In places the ridge lacks a clear crest line and instead comprises a series of closely spaced mounds.

To landward of the second ridge the remainder of the inner shelf is covered by a field of isolated mounds, narrow ridges and areas of raised hardground (Figure 3.5). The majority of the smaller mounds are 2 – 5 m high and densely scattered across the inner shelf with no particular orientation. However, some mounds are weakly aligned, either parallel to the larger ridges further seaward, or along a path directed to the north-northeast. To the north of Black Rock, between 35 m and 40 m water depth, the density of mounds is reduced and narrow ridges provide the main form of bathymetric relief. These ridges are uniformly aligned to the north-northeast, with lengths that range between 500 m and 1.5 km and are up to 16 m high. These ridges are poorly defined to absent in the area south of Black Rock. Here the inner shelf is characterised by mounds that are more widely scattered than in the northern area. Areas of raised hardground are up to 15 m high and are located around Black Rock and toward the reef edge where they form irregular surfaces that cover between 0.5 and 1.2 km^2.

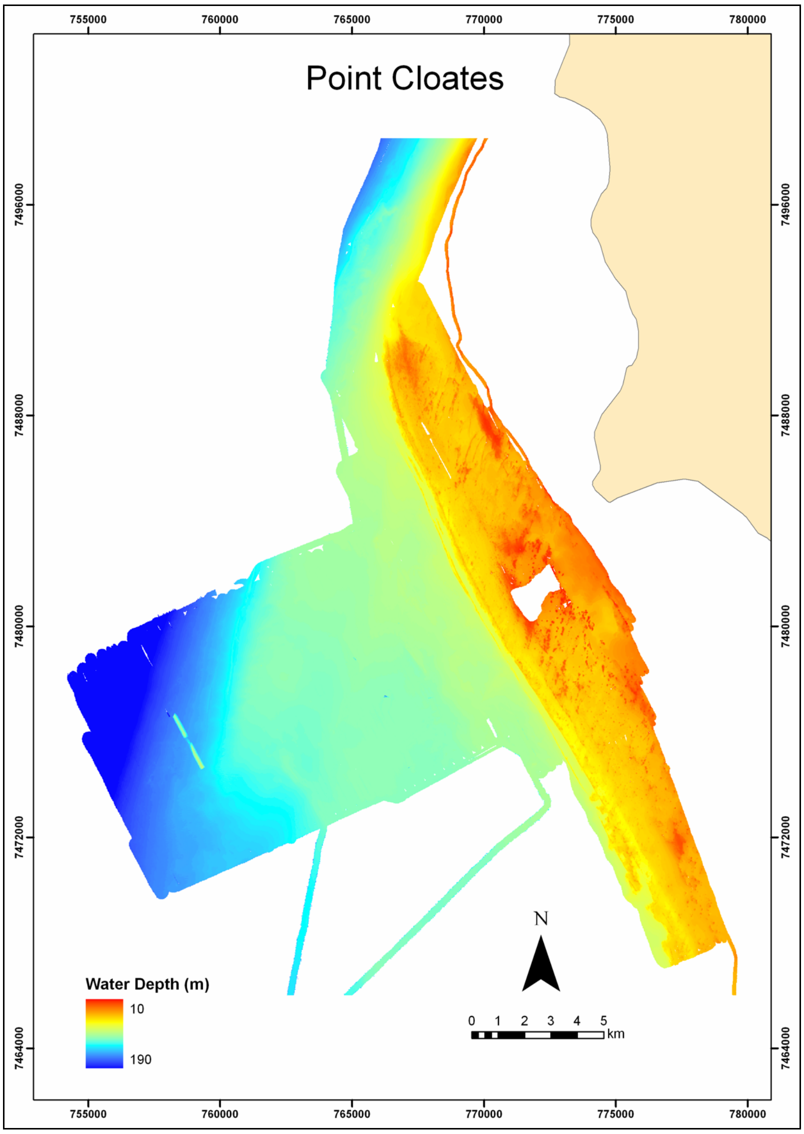

Figure 3.4: *Generalised bathymetry for the Point Cloates area of Carnarvon shelf based on multibeam sonar data. Bathymetric zones include the inner shelf (red & yellow), mid shelf (green) and outer shelf (blue).*

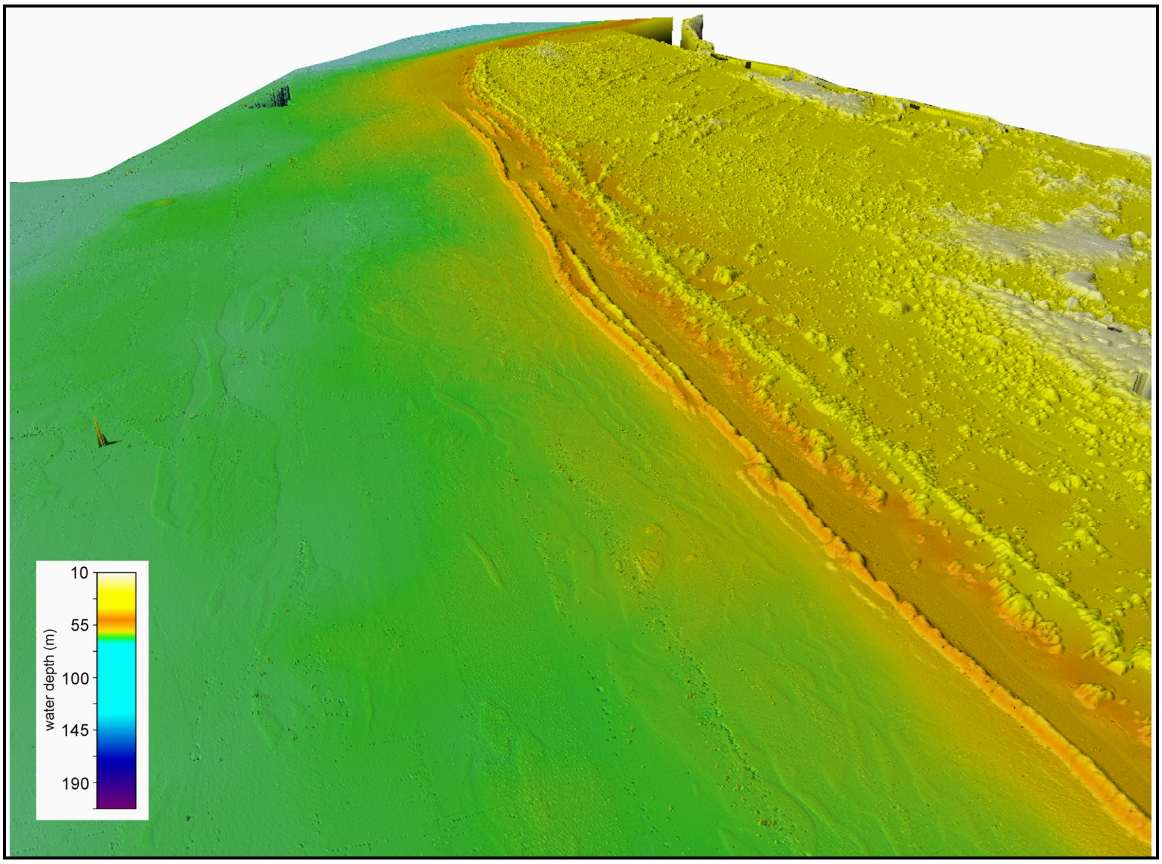

Figure 3.5: *False colour perspective view of the continental shelf at Point Cloates looking to the northeast, showing ridges and mounds (lithified beaches & dunes) and hardground on the inner shelf and bedforms on the mid shelf (Vertical exaggeration = 3x, view angle 30°)*

Evidence for bedform development on the inner shelf at Point Cloates is limited to the area between Black Rock and the reef edge. In this area, lobate bedforms 0.5 m to 1 m high with dimensions up to 200 m by 400 m have a general alignment to the northwest. Outside of this area, the seafloor between mounds and ridges and around hardground is flat.

Mid Shelf: The mid shelf zone at Point Cloates is about 8.5 km wide and gently sloping at 0.08° between the 60 m and 75 m isobaths. Relief across this surface is less than 1 m, forming a series of shore parallel ridges and runnels (Figure 3.5). The ridges are about 0.5 m high and discontinuous, ranging in length from 200 m to ~1 km. In cross-section, the larger ridges are 10s of metres wide and flat-topped. Toward the northern part of the survey area, the definition of ridges becomes less clear and the seabed is mostly featureless.

Outer Shelf: The outer shelf zone extends about 7 km from 75 m water depth to the shelf break at 170 m, located in the northwest corner of the mapped area (Figure 3.5, green to light blue). This zone displays a subtle convex profile with an average gradient of 0.6°, steepening to ~1.7° toward the shelf break. Relief across the outer shelf ranges from flat seabed to low ridges and extensive fields of bedforms. Two parallel linear ridges are located in 84 m and 92 m water depth and each extend about 4 km along a near north to south orientation. Each ridge is up to 3 m high and has a characteristic sharp asymmetric profile, with a seaward slope of 2° and landward facing slope of 10-15°.

Two bedform morphologies are recognised for the outer shelf. The first type is symmetrical in profile, up to 1.2 m high and spaced 60 m apart. These bedforms extend as a near-continuous field along the 90 - 100 m isobath interval and are oriented to the northeast. The second type of bedform occurs in the deeper waters of the outer shelf, between 150 m and 180 m water depth. Here bedforms are 4 m high, oriented to the northeast and are broadly crescent-shaped with wavelengths of approximately 140 m.

3.4. GNARALOO

The mapped area of continental shelf at Gnaraloo is 32 km wide, ranging in water depth from 10 m to 110 m. This area includes part of the inner shelf, the mid shelf and part of the outer shelf, but does not extend to the shelf break (Figure 3.6). The characteristics of these bathymetric zones are as follows:

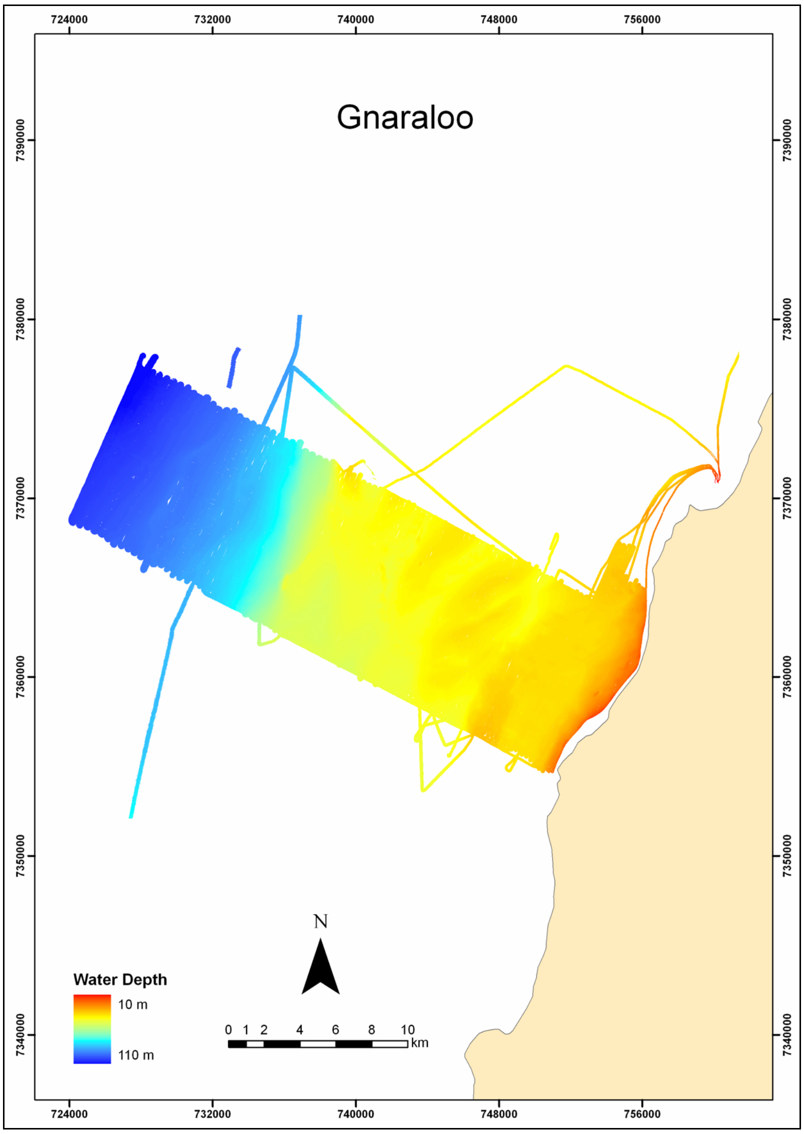

Figure 3.6: *Generalised bathymetry for the Gnaraloo area of Carnarvon shelf based on multibeam sonar data. Bathymetric zones include the inner shelf (red), mid shelf (orange & yellow) and outer shelf (blue).*

Inner Shelf: The Gnaraloo inner shelf has been mapped between 10 m and 35 m water depth. In the centre of Gnaraloo embayment this part of the inner shelf is 2 km wide with an average gradient of 0.7^o. Toward the southern end of the bay, the mapped area of the inner shelf is about 700 m wide and steeper, with a gradient of about 1^o. Local relief across the inner shelf ranges from decimetres in areas with bedforms, to 5 m across isolated ridges and mounds. Bedforms are best developed in the centre of Gnaraloo embayment where the inner shelf is widest. In this area, bedforms are linear, up to 1 km long and aligned obliquely to the shelf profile on a northwest to southeast trend. Bedforms are mostly 0.5 m high but width varies between 40 m and 80 m and spacing is up to 100 m. Cross-sectional profiles are characterised by an irregular (rippled?) stoss surface and lee sides facing northeast. Bedform development and sediment cover becomes patchy on some areas of the inner shelf, particularly toward the reef edge in less than 23 m water depth. In these areas, the seafloor appears rough, indicating hardground. At the northern end of the survey area, bedforms are more widely spaced than in the central part of the embayment and have a crescentic plan form. This area is also characterised by areas devoid of sediment cover, with areas of an irregular hardground surface that is likely to be limestone. The isolated ridges and mounds are scattered along the inner shelf in 20 – 30 m water depth, rising from the sea floor by 2 – 5 m. Ridges are linear features that are aligned parallel to the shoreline, are 40 – 140 m wide and extend up to 500 m along the shelf. Mounds are smaller than ridges, less than 2 m high and widths of 10 – 20 m.

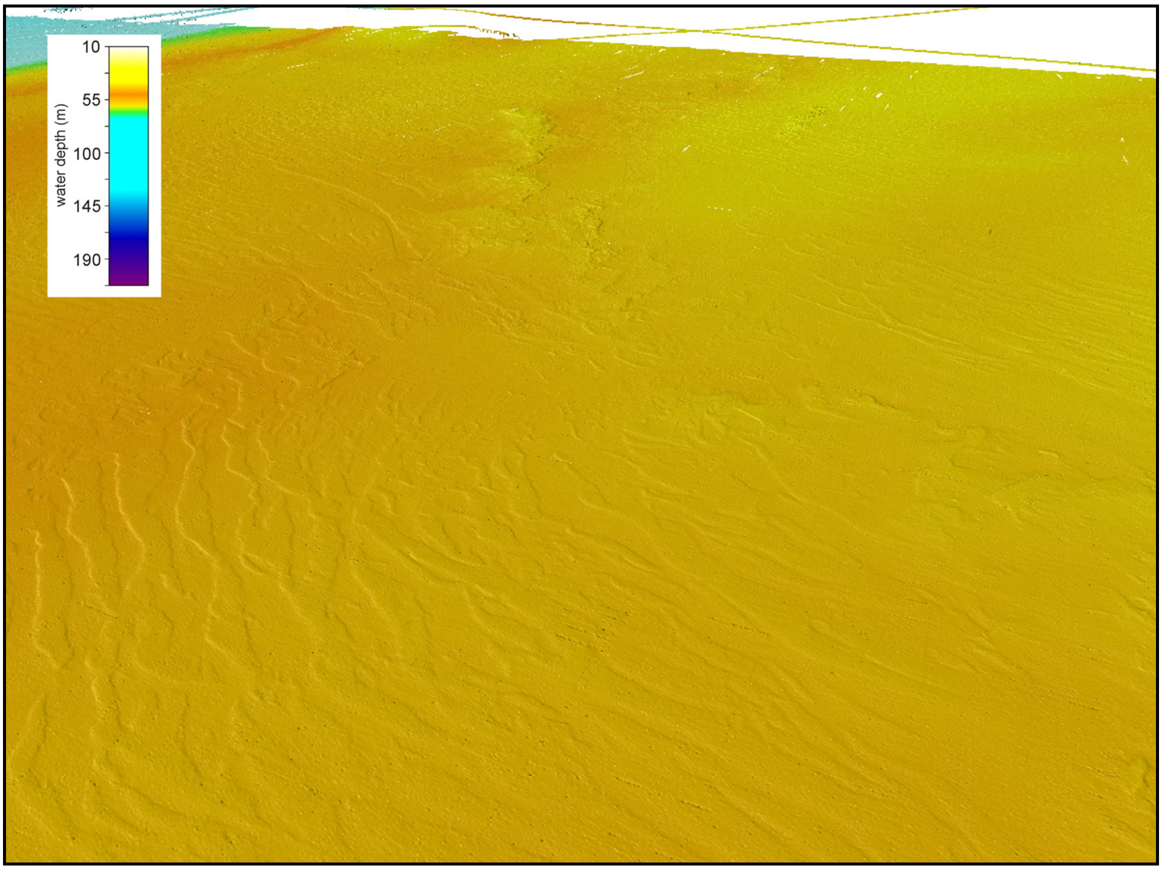

Figure 3.7: *False colour perspective view of the continental shelf at Gnaraloo looking to the north, showing extensive area of bedforms on the mid shelf (Vertical exaggeration = 3x, view angle 30^o)*

Mid Shelf: The mid shelf at Gnaraloo is approximately 19 km wide with an average gradient of 0.09^o. The bathymetric range of the mid shelf is from 35 m to 70 m, but the greater part of the zone is within a 17 km wide area between the 35 m and 50 m isobaths that slopes at 0.04^o (Figure 3.1). The outer 2 km of the mid shelf is steeper at 0.6^o and in places the break in slope coincides with a low (~1 m), discontinuous ridge at about 48 m water depth. Along the northern part of the mapped area, this steeper part of the mid shelf has a 2 m high scarp in 54 m water depth.

Between 35 m and 45 m water depth the surface of the mid shelf at Gnaraloo is characterised by isolated ridges and extensive fields of bedforms (Figure 3.7). Deeper waters of the mid shelf are generally featureless. Across the shallower part of the mid shelf, bedforms are consistently oriented with less sides facing to the northeast. The dominant morphology is a linear bedform that extends up to 2 km along the sea bed. Shorter crescent-shaped bedforms are present as isolated features along the edges of linear bedform fields. Bedform heights are 0.2 – 0.4 m, widths 20 – 50 m and spacings of 10 – 60 m. Ridges occur in 45 m water depth, rising 2 – 5 m above the seabed. The largest ridge is approximately 2 km long, aligned north-south and grades to hardground at its southern end. In places, the sides of the ridge and hardground appear to be partly buried by sediment.

Outer Shelf: The section of the outer shelf mapped by the survey is 11 km wide and extends to 110 m water depth on an average gradient of 0.2^o. The seafloor within this area is flat, with no evidence for bedform development. The only features that add relief to the seafloor are several small mounds located in 78 m water depth in the northern part of the survey area. These mounds are up to 1 m high and 20 – 100 m wide, and are likely to be outcrops of limestone.

3.5. ADDITIONAL MAPPING – MUIRON ISLANDS

An additional area of 52 km^2 was mapped to the north of the Muiron Islands in the outer Exmouth Gulf during the last two days of the survey (Figure 3.8). The mapped area encompasses a small part of the inner shelf between 24 m and 45 m water depth, a section of the mid shelf out to 80 m water depth and an area of the outer shelf to 150 m water depth. Key characteristics of these zones include: bedforms on the inner shelf with average wavelength of 250 m and height of 5 m with crests aligned north-south; ridges on the mid shelf up to 4 m high and 250 m wide that follow the broad curved planform of this part of the shelf; a steep slope of 20^o between the mid shelf and outer shelf with localised slumps, and; bedforms in 135 m water depth on the outer shelf that are up to 4 m high with average wavelengths of 180 m (Figure 3.9).

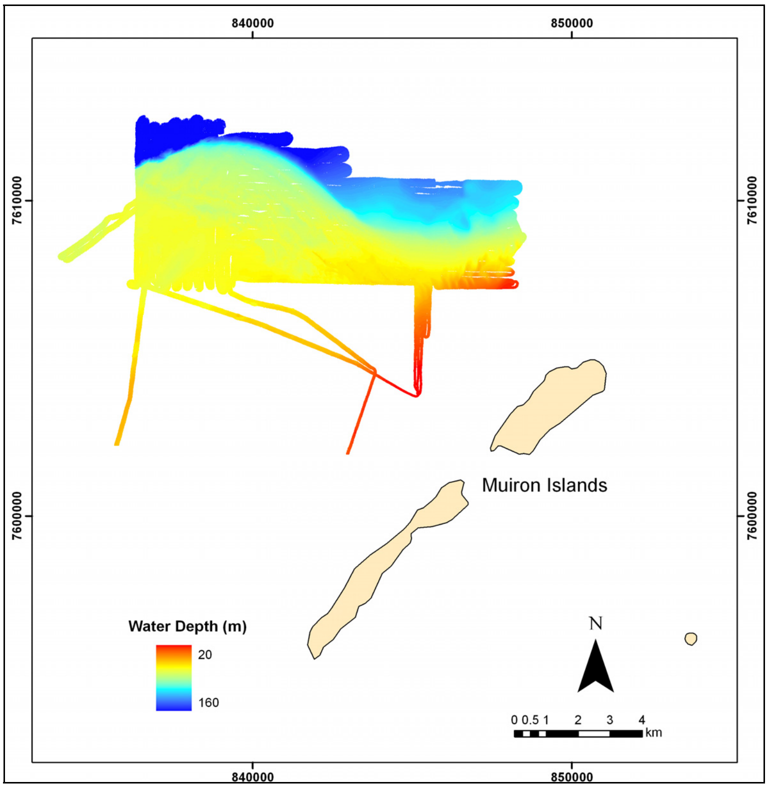

Figure 3.8: *Generalised bathymetry for the area north of Muiron Islands, outer Exmouth Gulf based on multibeam sonar data. Bathymetric zones include the inner shelf (red), mid shelf (orange & yellow) and outer shelf (blue).*

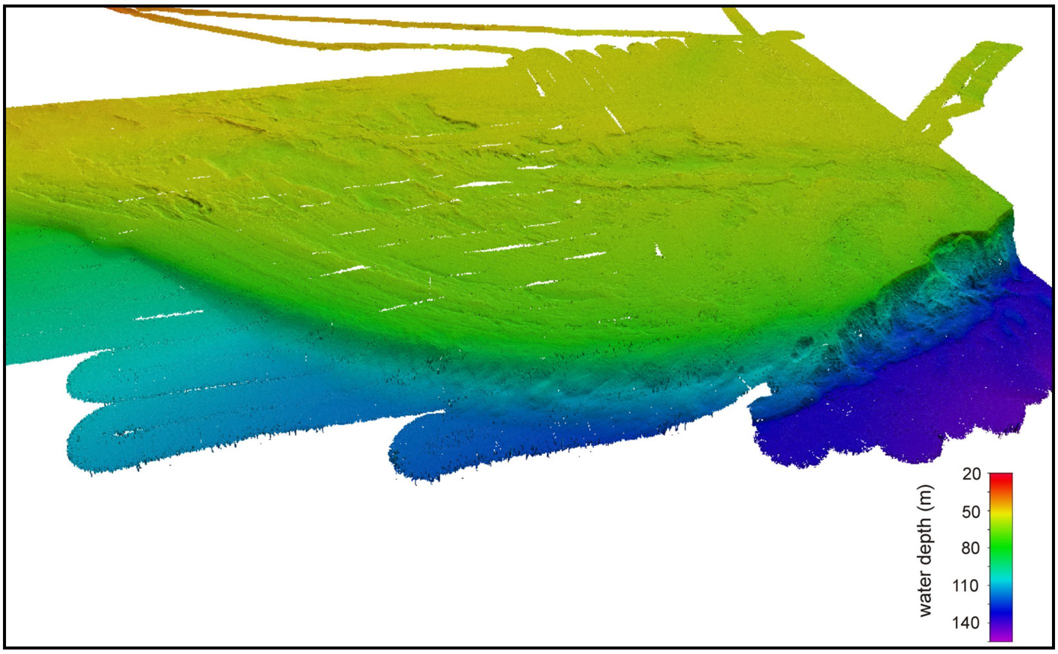

Figure 3.9: *False colour perspective view of the mid shelf and outer shelf to the north of the Muiron Islands, viewed to the south and showing ridges on the mid shelf and steep slope with slumps at the mid- to outer shelf boundary.*

3.6. MULTIBEAM BACKSCATTER DATA

The multibeam backscatter data collected with the EM3002 multibeam acoustic system on the Carnarvon survey has been completely processed using the Curtin University Centre for Marine Science and Technology (CMST) and Geoscience Australia Multibeam Toolbox (MST-GA MB Toolbox). A key component of the processing is the removal of the angular dependence of the backscatter signal strength, which was achieved using the approach developed by CMST (Gavrilov *et al.* 2005; Gavrilov, Siwabessy & Parnum 2005).

Initial Results: The fully calibrated backscatter for the three main survey areas was gridded to 5 m (Mandu, Pt Cloates, Figures 3.10 and 3.11) and 10 m (Gnaraloo, Figure 3.12) spatial resolution. Distinct zones of backscatter are evident at all sites. The next step in this work is to compare these data with morphometric parameters derived from the multibeam bathymetry, sediment data and video and stills images to determine the influence of physical and biological seabed features on the backscatter signals.

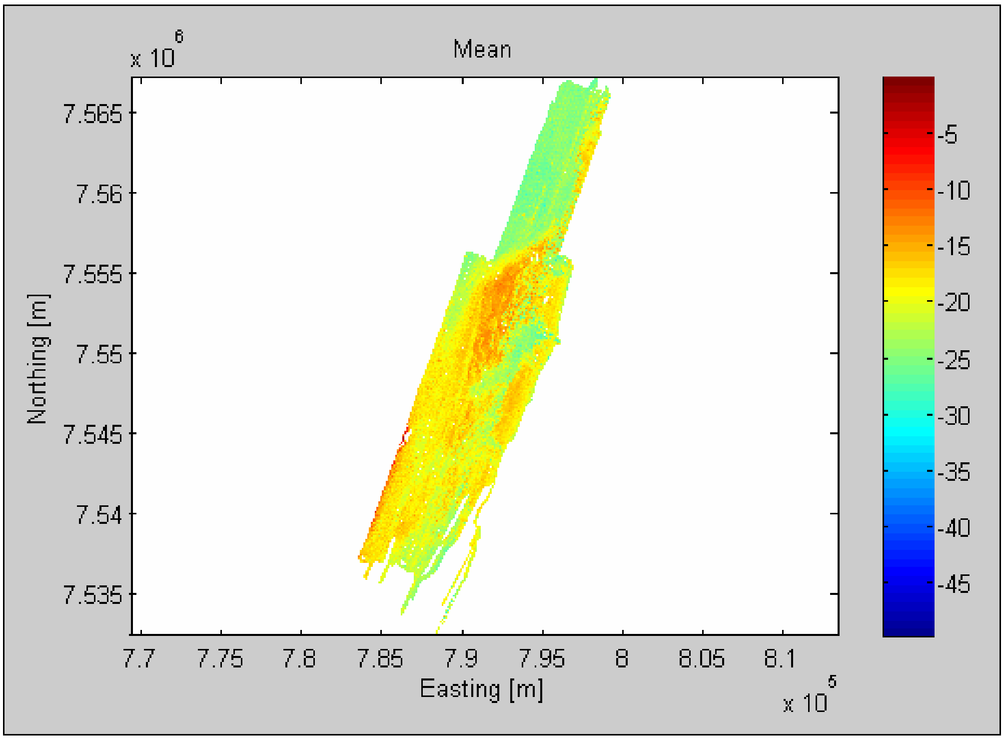

Figure 3.10: *Processed backscatter (decibels) image of the Mandu area, 5m grid.*

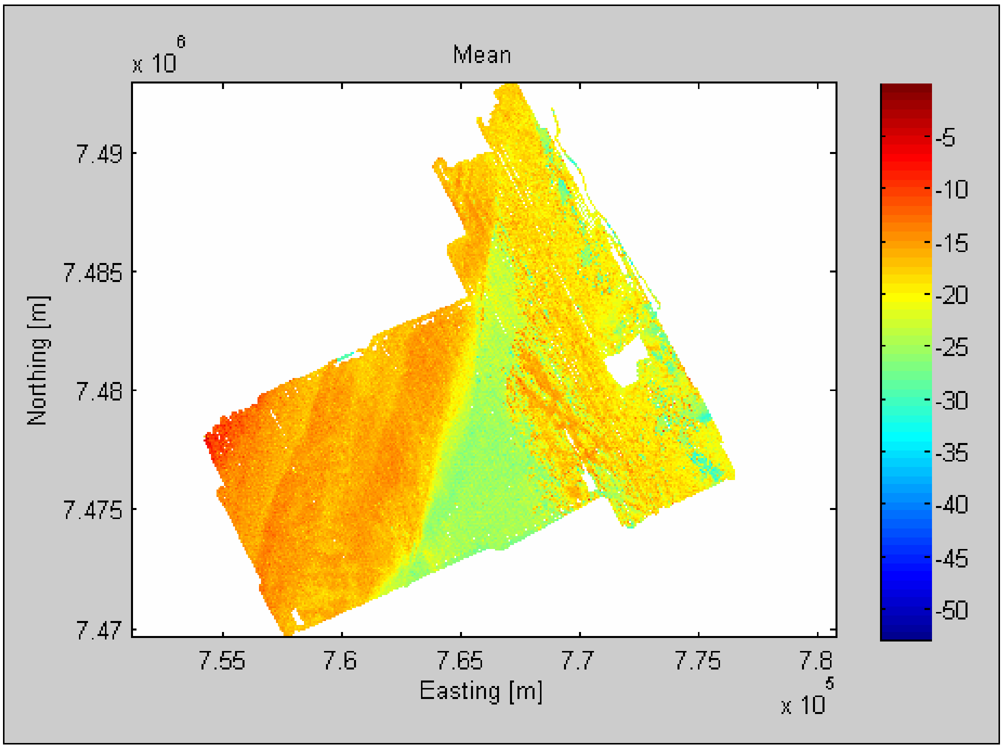

Figure 3.11: *Processed backscatter (decibels) image of the Pt Cloates area, 5m grid.*

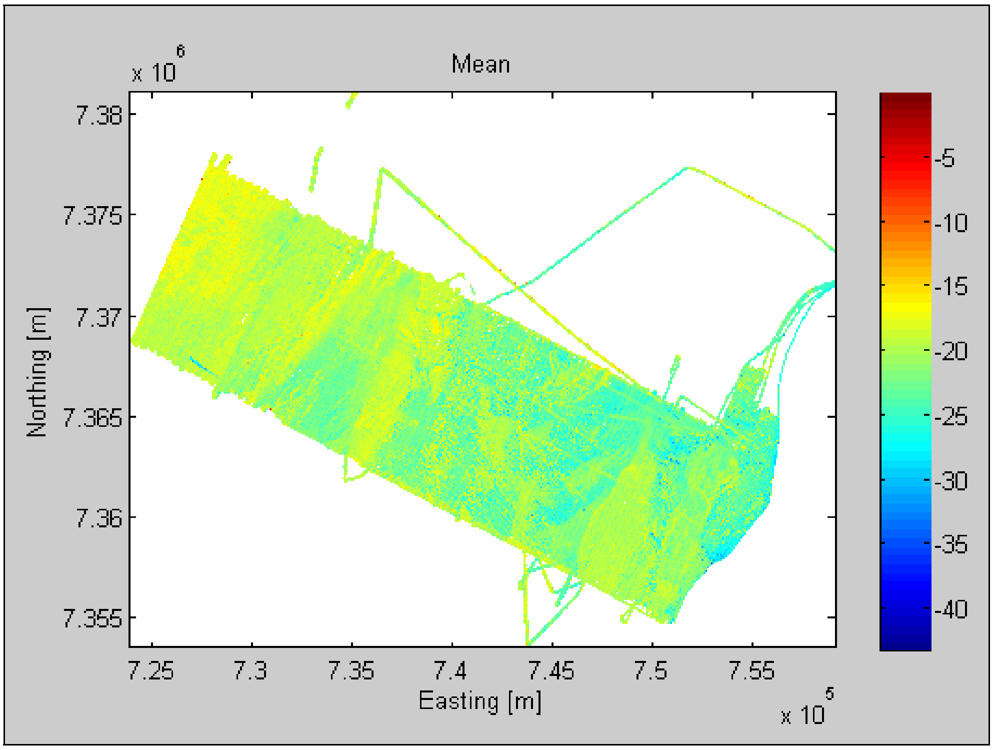

Figure 3.12: *Processed backscatter (decibels) image of the Gnaraloo area, 10m grid.*

3.7. ACOUSTIC SUB-BOTTOM PROFILES

Sub-bottom profiles of the shelf were collected in each survey area using an Edgetech 3200XS ‘Chirp’ sub-bottom profiler, comprising a swept frequency 2–12 kHz transducer mounted in a SB-216S towfish; and a Geoacoustics SE880 (0.8 – 1.5 kHz) ‘Sparker’ system. Data quality is varied, with cross-shelf profiles providing the better images of shelf stratigraphy. Additional processing of this data is required prior to further interpretation. However, raw data at Mandu Creek shows evidence for progradation of a drowned shoreline in 100 m water depth, and at Point Cloates the results show sediment has accreted around bommie mounds on the inner shelf (Fig. 3.13).

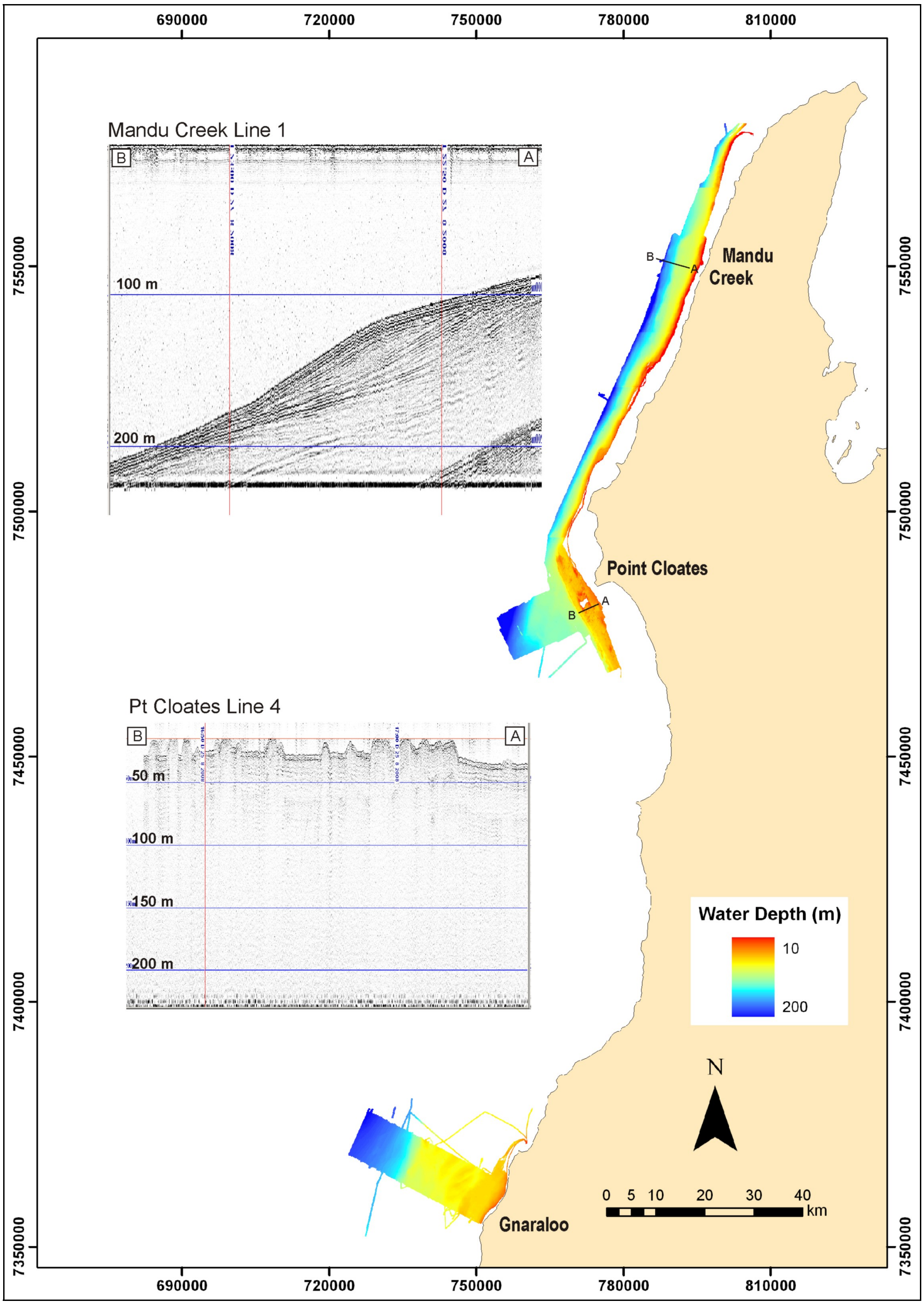

Figure 3.13: *Examples of sub-bottom profiles at Mandu Creek and Point Cloates.*

4. Surface Sediments of the Carnarvon Shelf

4.1. INTRODUCTION

A total of 266 sediment grab samples were collected from the Carnarvon shelf using a Smith McIntyre seabed grab sampler (Figure 4.1). The samples are divided approximately evenly between the Mandu Creek (n = 81 samples), Point Cloates (n = 92) and Gnaraloo (n = 93) areas. The remaining ten samples were collected from the area to the north of Muiron Islands. The full sample set represents 102 sampling stations at which two sediment grabs were collected in close proximity. Within the Mandu Creek sampling area, three grabs were collected at 19 stations and at Gnaraloo single grabs were taken at three stations. At Muiron Islands single grabs were collected at five stations (Appendix 8.2). Visual descriptions of grain size and colour for all sediment samples have been made and are summarised in Tables 4.1 & 4.2 and Figures 4.2 – 4.7. For all samples, carbonate material is the dominant constituent of surface sediments, incorporating a mix of shell and bryozoan fragments, forams and rhodoliths.

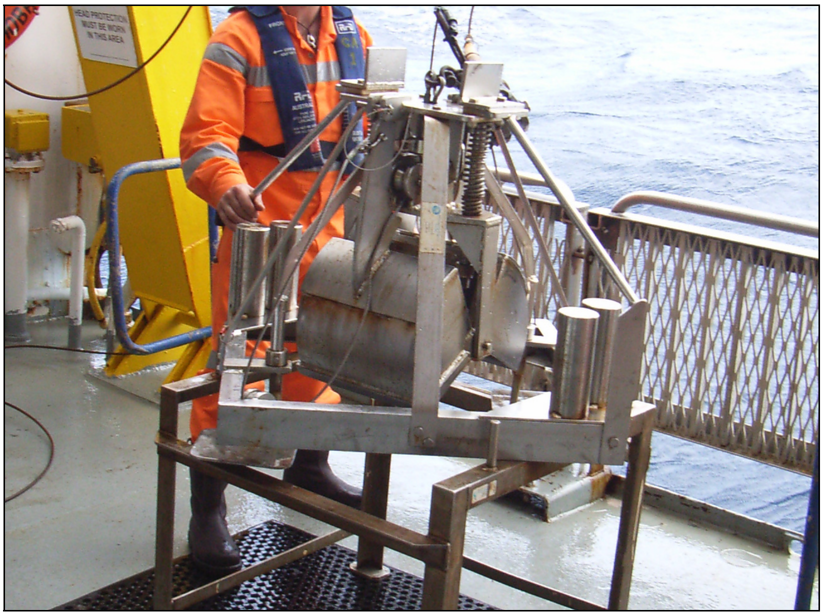

Figure 4.1: *The Smith-McIntyre bottom sediment sampler that was operated from the starboard deck of RV Solander.*

4.2. SEDIMENT GRAIN SIZE

At Mandu Creek, sediments from the inner shelf include gravelly sand (n = 9 samples), gravel (n = 6) and some sand samples (n = 5). In contrast, the mid shelf is dominated by sand samples (n = 24) with lesser amounts of gravelly sand (n = 7) and fewer muddy sand samples (n = 4). The outer shelf at Mandu yielded mostly muddy sand (n = 17) with only localised deposits of gravel (n = 5) and sand (n = 2).

Within the Point Cloates sampling area sediments on the inner shelf and mid shelf are broadly similar, with sand the most common size class (n = 18 & 19, respectively). Gravel occurs as a sub-dominant sediment type on the inner and mid shelf (n = 14 & 12, respectively), whereas mixed size grades (muddy sand, gravelly sand) are rare to absent. Samples from the outer shelf at Point Cloates are mostly gravel (n = 8), with an equal number comprising muddy sand and gravelly sand (n = 4 each). Only one sample from the Cloates outer shelf is classed as sand.

Table 4.1: Number (n) and percentage of shelf sediment samples within broad size classes for each sample area, with dominant size class highlighted in bold. Percentages not calculated for Muiron samples due to the small sample size.

SAMPLING AREA		SAND		MUDDY SAND		GRAVELLY SAND		GRAVEL		TOTAL
		n	%	n	%	n	%	n	%	n
MANDU CREEK	Inner shelf	5	24	1	5	9	43	6	28	21
	Mid shelf	24	67	4	11	7	19	1	3	36
	Outer shelf	2	8	17	71	0	0	5	21	24
POINT CLOATES	Inner shelf	18	45	0	0	8	20	14	35	40
	Mid shelf	19	54	0	0	4	11	12	34	35
	Outer shelf	1	7	4	23	4	23	8	47	17
GNARALOO	Inner shelf	9	100	0	0	0	0	0	0	9
	Mid shelf	47	77	0	0	11	18	3	5	61
	Outer shelf	14	64	0	0	8	36	0	0	22
MUIRON IS	Inner shelf	1	-	0	-	0	-	0	-	1
	Mid shelf	2	-	4	-	2	-	0	-	8
	Outer shelf	0	-	1	-	0	-	0	-	1

Gnaraloo is dominated by sand across all parts of the continental shelf, although coarser sediments do occur in deeper waters. Thus, all nine samples from the inner shelf are sand, as are 47 of the 61 mid shelf samples. Samples of gravelly sand were recovered in comparatively small numbers from the mid shelf (n = 11) and the outer shelf (n = 8). No muddy samples were recovered from any part of the shelf at Gnaraloo.

At the Muiron Islands survey area the majority of samples were from the mid shelf where muddy sand (n = 4), sand (n = 2) and gravelly sand (n = 2) occur. Single samples from the inner shelf and outer shelf are sand and muddy sand, respectively.

4.3. SEDIMENT COLOUR

At Mandu Creek, Point Cloates and Gnaraloo the majority of shelf sediments are brown to yellow brown in colour, with no clear bathymetric distribution (Table 4.2). The only sediment colour group that appears restricted by water depth are grey sediments. In each sampling area, grey sediments occur predominantly on the inner shelf and shallower parts of the mid shelf and are typically sands.

Table 4.2: Number (n) of shelf sediment samples within Munsell colour groups for each sample area, with dominant colour highlighted in bold. Percentages not calculated for Muiron samples due to the small sample size. (* note: Two inner shelf samples at Mandu & four at Pt Cloates are on hardground so no sediment colour has been assigned)

SAMPLING AREA		BROWN		GREY		OLIVE BROWN		YELLOW		YELLOW BROWN		TOTAL
		n	%	n	%	n	%	n	%	n	%	
MANDU CREEK	Inner shelf	8	*38*	5	*24*	0	*0*	2	*9*	4	*19*	21*
	Mid shelf	16	*44*	1	*3*	2	*6*	0	*0*	17	*47*	36
	Outer shelf	2	*8*	0	*0*	3	*12*	0	*0*	19	*79*	24
POINT CLOATES	Inner shelf	26	*72*	8	*22*	0	*0*	*2*	*6*	0	*0*	36*
	Mid shelf	21	*60*	8	*23*	0	*0*	2	*6*	4	*11*	35
	Outer shelf	9	*53*	0	*0*	0	*0*	0	*0*	8	*47*	17
GNARALOO	Inner shelf	3	*33*	6	*67*	0	*0*	0	*0*	0	*0*	9
	Mid shelf	45	*74*	5	*8*	0	*0*	0	*0*	11	*18*	61
	Outer shelf	4	*18*	0	*0*	8	*36*	0	*0*	10	*45*	22
MUIRON IS	Inner shelf	0	-	1	-	0	-	0	-	0	-	1
	Mid shelf	4	-	2	-	1	-	0	-	1	-	8
	Outer shelf	0	-	0	-	1	-	*0*	-	0	-	1

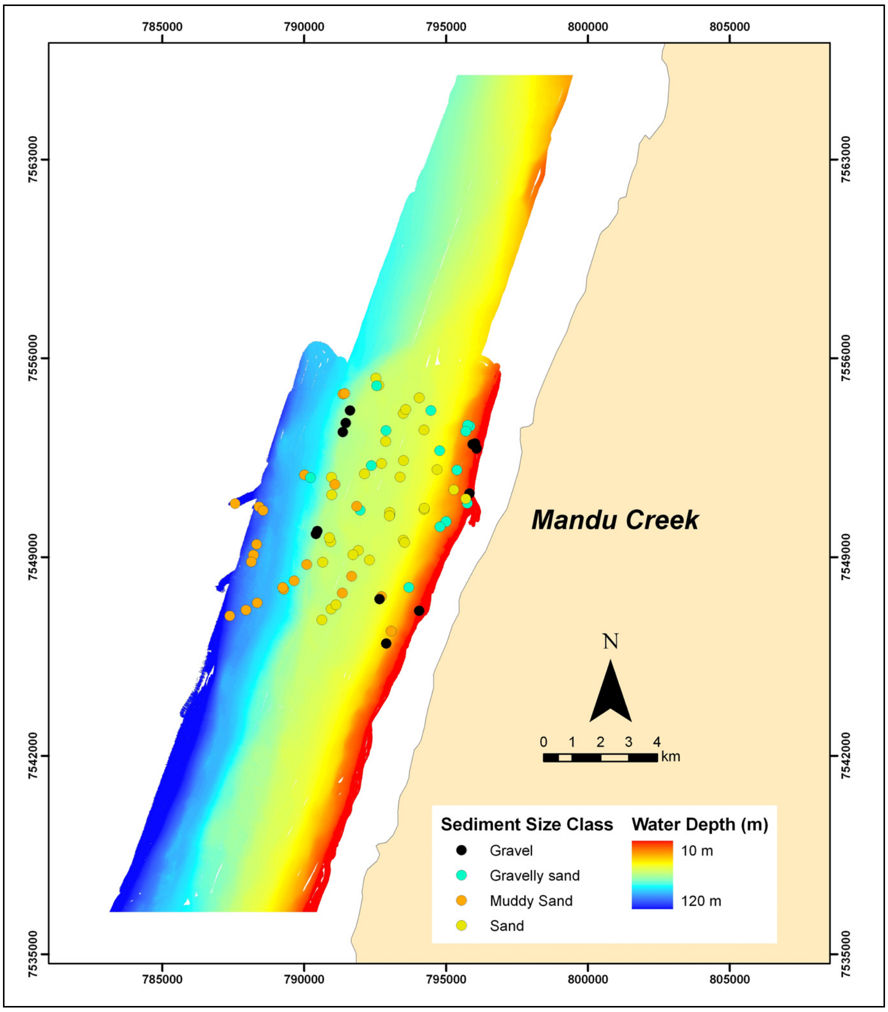

Figure 4.2: *Folk sediment size classes of surface sediments in the Mandu Creek sampling area.*

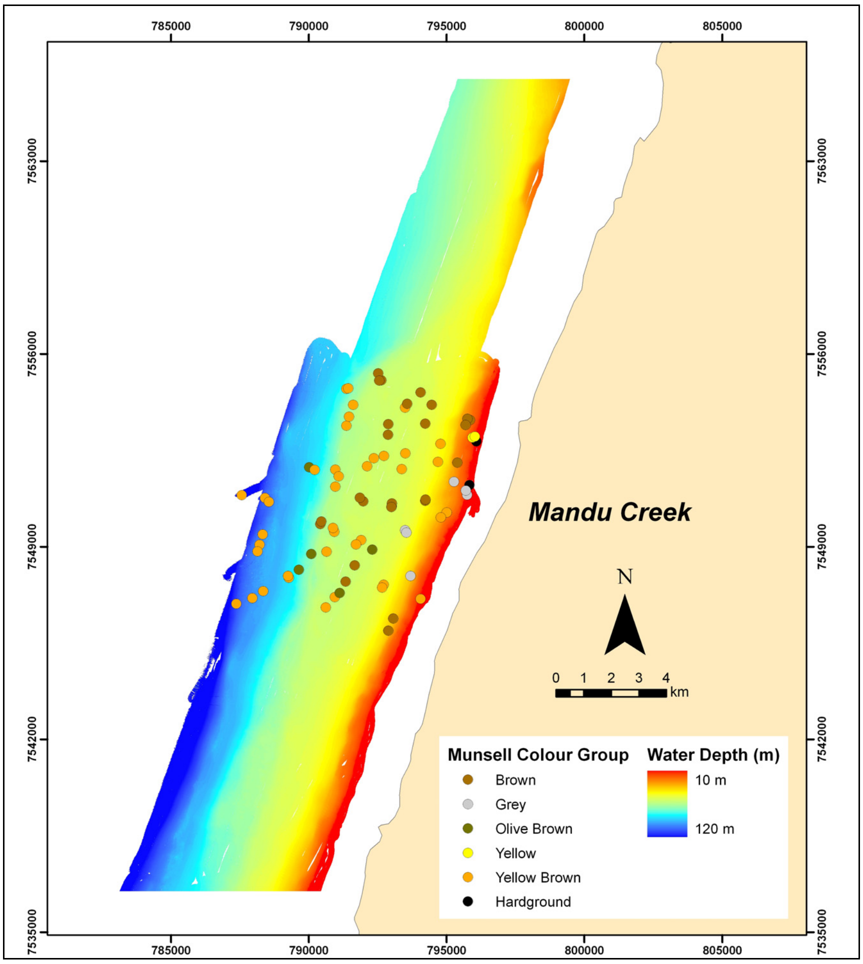

Figure 4.3: *Munsell colour of surface sediments in the Mandu Creek sampling area.*

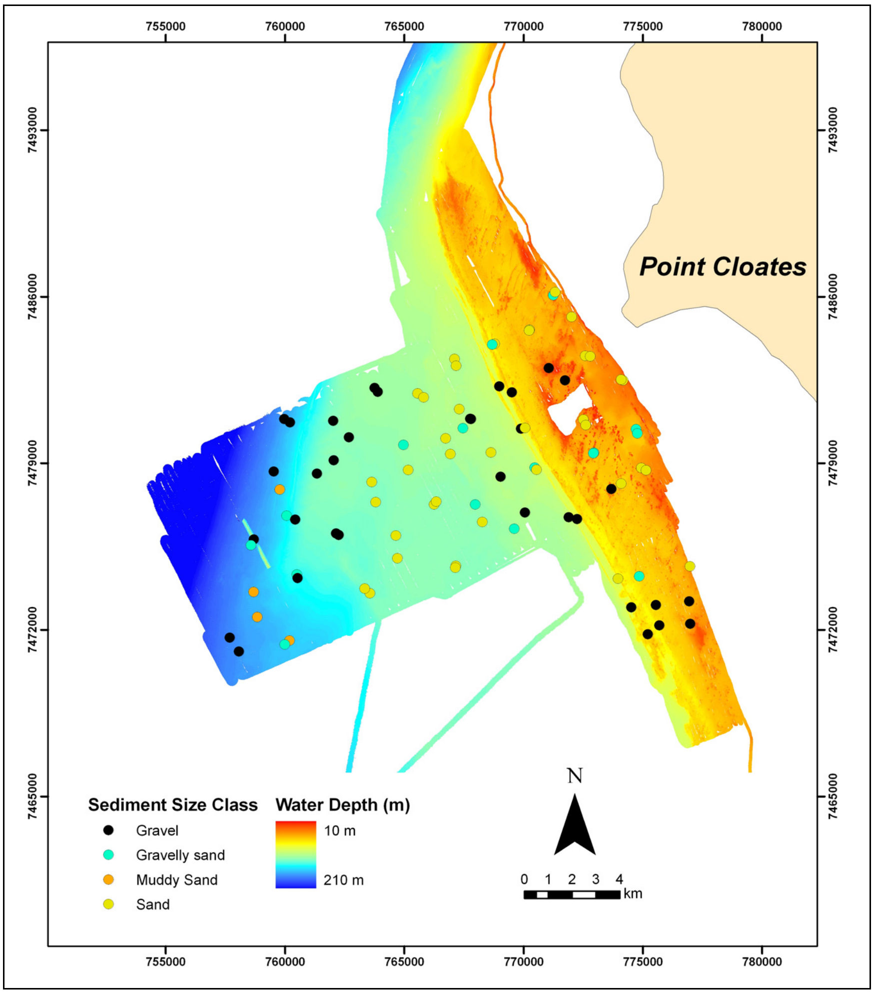

Figure 4.4: *Folk sediment size classes of surface sediments in the Point Cloates sampling area.*

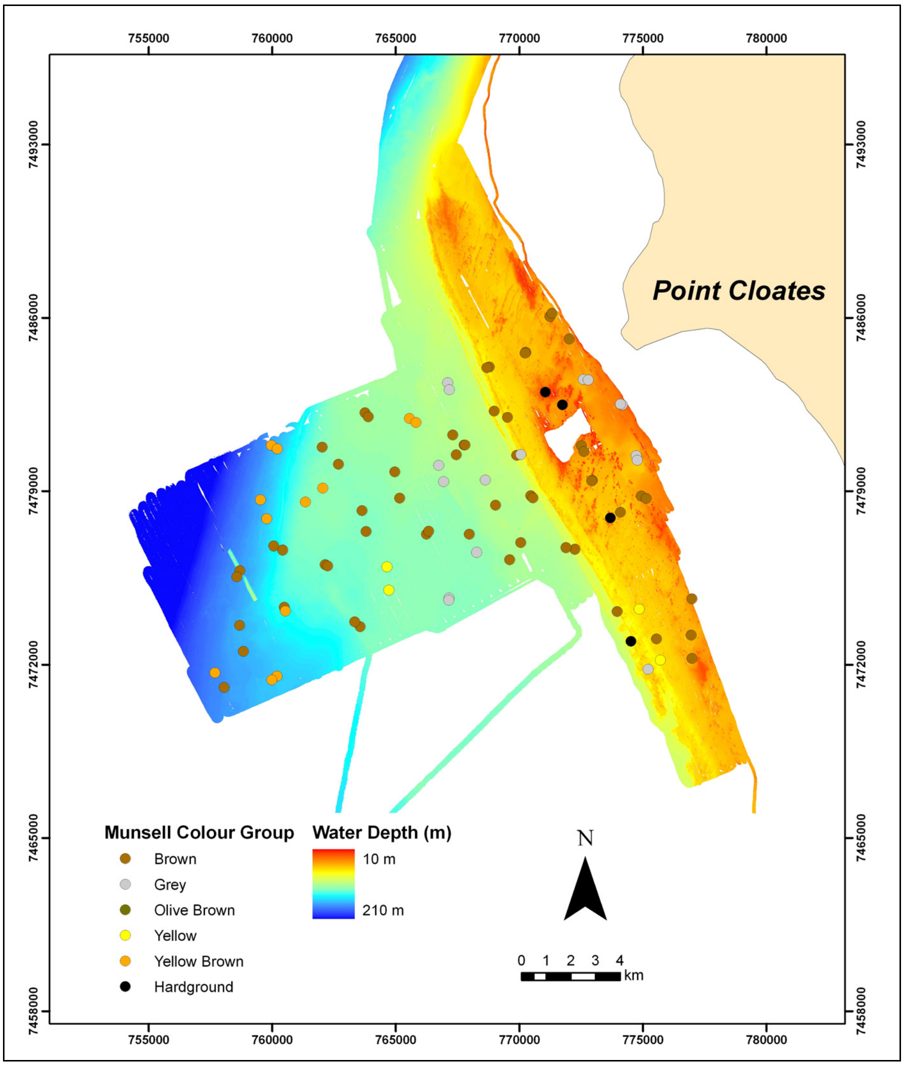

Figure 4.5: *Munsell colour of surface sediments in the Point Cloates sampling area.*

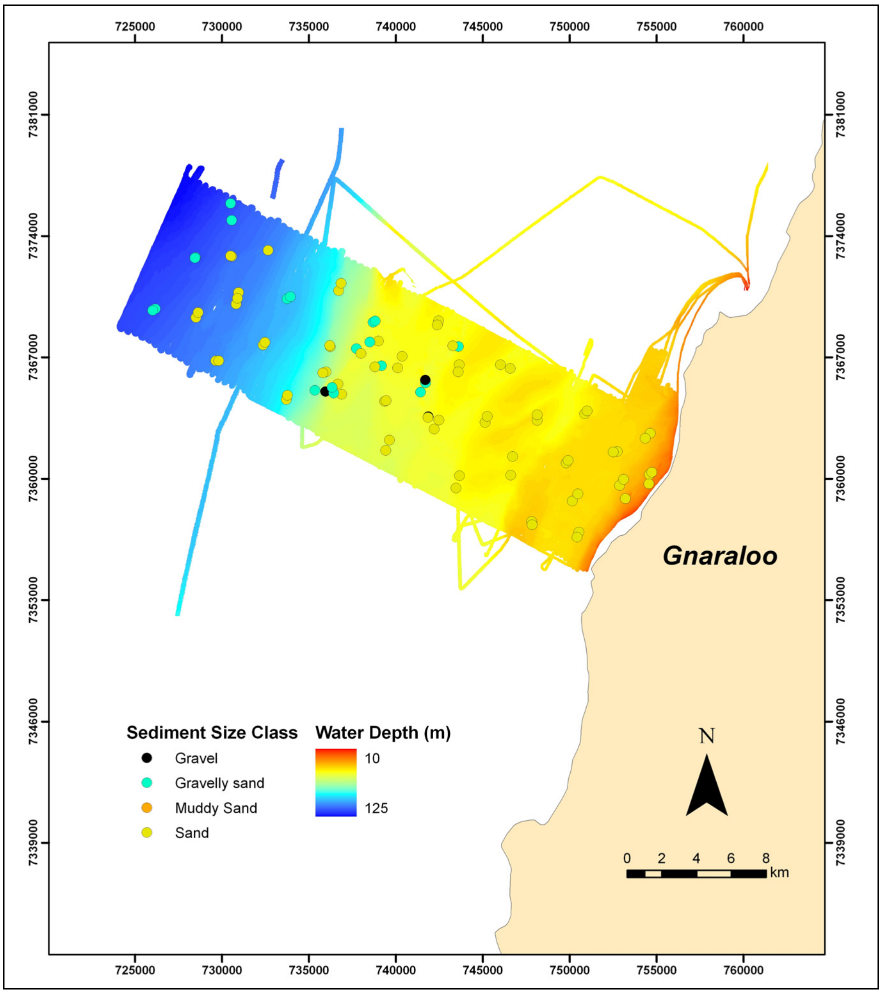

Figure 4.6: *Folk sediment size classes of surface sediments in the Gnaraloo sampling area.*

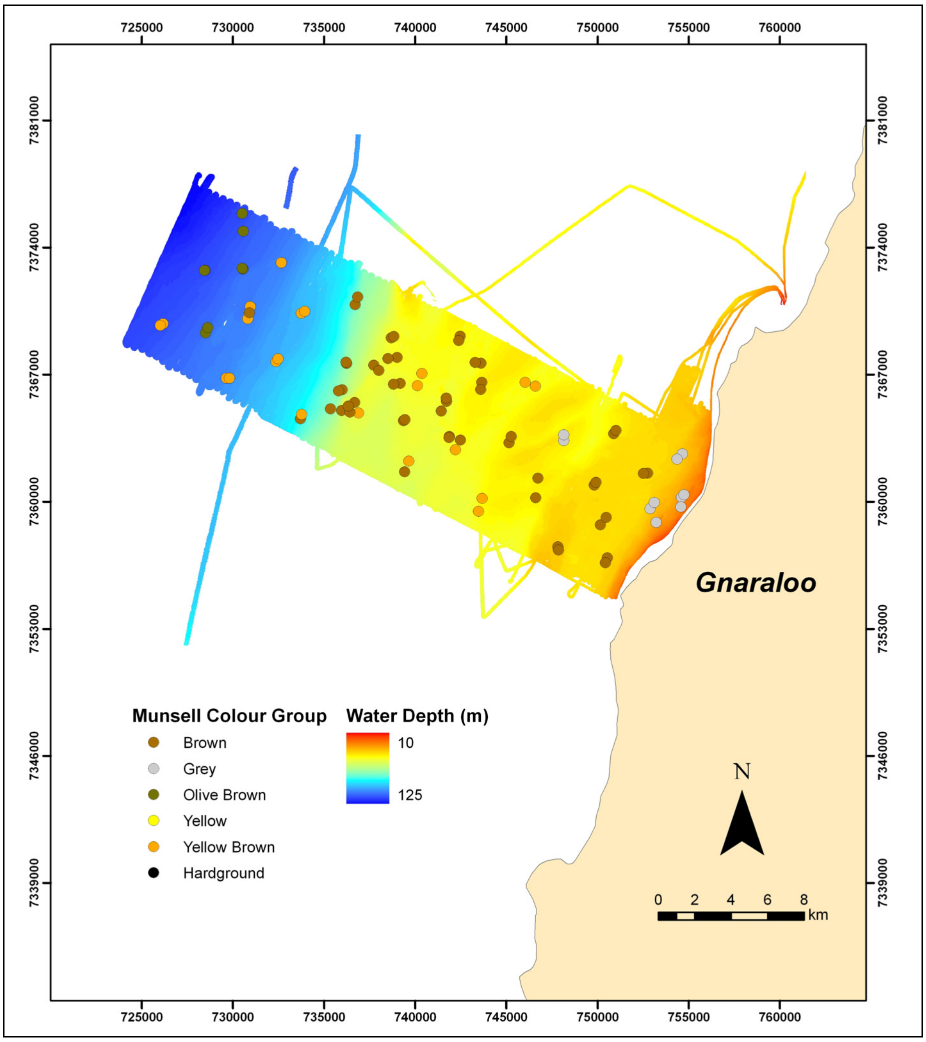

Figure 4.7: *Munsell colour of surface sediments in the Gnaraloo sampling area.*

4.4. INITIAL SYNTHESIS & INTERPRETATION - GEOMORPHOLOGY & SEDIMENTS

Within a regional trend of a continental shelf that decreases in width to the north, the sections of the Carnarvon Shelf represented by Mandu Creek, Point Cloates and Gnaraloo reveal strong contrasts in geomorphic complexity of the seafloor and in the degree of weathering and mobility of seabed sediments. In terms of geomorphic complexity, the inner shelf is the most complex part of the shelf, with Point Cloates the exemplary case. Here ridges, mounds and raised hardground produce a highly rugose sea floor across the inner shelf covering 78 km^2, or 33% of the Point Cloates sampling area. Accordingly, surface sediments in this area vary spatially between sand, gravel and mixed gravelly sand. The inner shelf at Mandu is also characterised by mounds and ridges, but here these features cover 7.5 km^2 which represents 11% of the sampling area at Mandu Creek. Again, surface sediments range from sand to gravel. At Gnaraloo, however, rugose seafloor on the inner shelf is limited to localised areas of raised hardground with a combined area of 7.3 km^2, representing 2% of the sampling area and as a result, the surface sediments are mostly sand. Of note, the inner shelf yielded the greatest number of light grey sand samples. This colour is interpreted to reflect the lack of weathering (i.e. oxidation) of the sand fraction which is consistent for a modern sediment facies. In all survey areas the rugose form of the inner shelf prevents a continuous sediment cover and limits bedform formation to localised fields of small bedforms (i.e. ripples).

Bedforms mapped on the mid shelf of all areas provide clear evidence for transport of sediments across the sea bed, although the timescales of bedform activity cannot be determined. Among the three survey areas, the sand-dominated mid shelf at Gnaraloo has the most extensive fields of large scale bedforms where they extend to 45 m water depth. At Mandu and Point Cloates bedform fields on the mid shelf are more localised, possibly reflecting the spatial variance in sediment type from sand to gravelly sand and gravel; although at Point Cloates bedforms occur to 100 m water depth in gravel sediments. For all survey areas, the lee sides of bedforms are consistently oriented toward the northeast, indicating migration in this direction under the influence of bottom currents generated by the prevailing southwest swell. In all three sampling areas, sediment colour tends to grade across the mid shelf from grey in shallower water to brown and yellow brown further seaward. This suggests a transition from modern to palimpsest and possibly relict sediments across the mid shelf. Additional evidence for relict deposits on the mid shelf is mapped at Mandu and Point Cloates in 75 – 80 m water depth, where low ridges extend along the shelf. The orientation and form of these ridges is consistent with a drowned shoreline that partly survived marine transgression during the late Pleistocene. Gravel sediments in weathered condition (i.e. oxidised yellow brown) sampled from these ridges support this interpretation.

The outer shelf is generally an area of low to negligible relief in all mapped areas. Localised areas of bedforms do exist in these deeper waters and some examples suggest relatively large scale transport, such as at Point Cloates in 150 m water depth. Overall, however, the outer shelf appears to be a comparatively stable area of the seabed. The majority of sediment samples from the outer shelf at Mandu and Point Cloates are muddy sand, with gravel and gravelly sand also present. This gravel fraction is typically yellow brown in colour, comprising stained shell fragments that are likely to be relict deposits of late Pleistocene age. At Gnaraloo sediments on the outer shelf are mostly sand with minor gravel, but sediment colour is yellow brown to olive brown which again indicates a relict sediment body in this area.

An interpretation of the origin and age of the ridges and mounds on the inner shelf at Point Cloates and Mandu Creek is relevant to an understanding of the distribution of these geomorphic features on the shelf particularly given their importance as benthic habitats. A key characteristic of the ridges is their orientation relative to the modern coastline. At Point Cloates, the long, continuous ridges in 50 – 60 m water depth follow an alignment that is sub-parallel to the present coastline and the shorter ridges in

~40 m water depth are obliquely oriented to the coast. This pattern is consistent with a relict beach-dune system whereby the shore-parallel ridges are interpreted as drowned beaches and foredunes, and the oblique ridges as the remnants of parabolic sand dunes that extended landward of the former coast. Both these geomorphic features have modern analogues on the coast today. Critically, preservation of these drowned shorelines and dunefields requires that lithification of their constituent sediments occur prior to transgression by rising sea level. Hence it is presumed that the ridges comprise cemented carbonate sands, preserved either as beachrock or aeolianite, in the case of the drowned foredunes and parabolic dunes. Preservation of former shorelines and dunes has been recorded elsewhere along the coast of southern Western Australia (e.g. Collins, 1988; Brooke et al, in press). However, the multibeam data collected during this survey provide for the most detailed case study to date.

5. Seabed Habitats and Their Biological Assemblages

5.1. INTRODUCTION

To examine the distribution and abundance of marine flora and fauna across the Carnarvon shelf and to examine the importance of seabed habitat complexity in structuring benthic assemblages, three latitudinal areas were surveyed: Mandu in the north, Point Cloates in the central region, and Gnaraloo in the south. Within each of these areas, biological and seabed habitat information was collected across the shelf using towed-video transects, epi-faunal sleds, and infaunal grabs. A 500 m towed-video transect was initially run at each station to characterise the types of seabed habitats and macro-organisms present (Figure 5.1). Next, the epi-benthic assemblage was sampled using two 50 m towed epi-benthic sleds (Figure 5.7), while the infaunal assemblage was sampled using two sediment samples collected with a Smith McIntyre grab sampler (Figure 5.9). At a sub-set of stations in Mandu (stations 1-16), three replicate grabs and sleds were deployed to investigate the effects of increased fine-scale sample effort on quantification of broad-scale biodiversity patterns. The combination of towed-video, epi-benthic sleds, and infaunal grabs enabled a broader range of species and assemblage types to be examined and as such provides a more holistic approach to understanding and predicting seabed assemblages.

5.2. TOWED-VIDEO OBSERVATIONS AND CHARACTERISATIONS

The distribution of seabed habitats and associated assemblages were visually examined using tow-video footage from the immediate nearshore to just beyond the shelf break in each survey area. At each station within the three survey areas a single towed-video transect was undertaken using the AIMS's towed-video system (Figure 5.1), deployed from the stern of the *RV Solander* and towed for a distance of approximately 500 m. An operator used a remote-controlled winch to maintaining an altitude of 0.5 - 2 m above the seabed. The towed-camera system housed a forward-facing video camera and down-facing stills camera and their associated lights. Using the forward-facing video camera, video was transmitted to the surface via coaxial cable where video footage could be watched by observers in real-time, and simultaneously recorded to digital video tapes, which were subsequently backed up to portable hard drives.

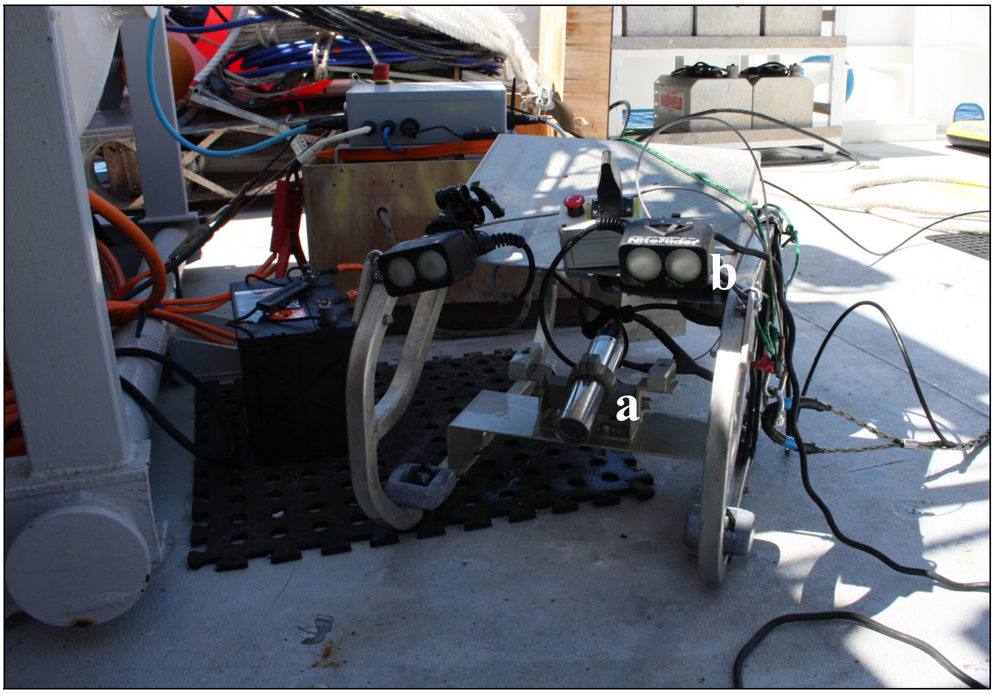

***Figure 5.1**: Front view of the AIMS towed video array showing the video camera (a) and light mountings (b).*

For each video transect, real-time characterisations of the seabed were undertaken using the AIMS habitat classification scheme (e.g. Speare et al., 2004). In this scheme, keyboard classifications of substrata (e.g. rhodoliths, sand ripples, gravel), benthos (e.g. sparse sponges, dense hard corals, fish school), and individual organisms (e.g. sea cucumber, sponge, soft coral) were recorded and linked with ships navigation (i.e. UTC date and time, depth, latitude and longitude). During each video transect, the vertically mounted stills camera took digital photographs of the benthos every two seconds. These still images will be used to identify taxa in higher resolution and calculate percentage cover estimates. All still images were backed up to hard drive, with archived tapes stored at AIMS in WA and backup DVD's stored at GA in Canberra. The methodologies required to post-process video and still images is being examined so that consistency between the CERF data and historical datasets, such as those collected by AIMS through the WASMI program, and those of the SeaBed Biodiversity Program undertaken on the GBR by a consortium of agencies lead by CSIRO and AIMS. Currently no video or still images have been post-processed.

During the survey 32 video stations were sampled at Mandu, 44 at Point Cloates, and 46 at Gnaraloo. Several broad-scale spatial patterns were identified from preliminary video observations. In particular, all three areas exhibited decreasing habitat complexity with distance offshore, although this pattern was less pronounced in the Gnaraloo region. Seabed habitat complexity was also markedly higher in the central region of Point Cloates, which was characterised by an extensive and highly rugose inshore zone. Similarly, all three locations appear dominated by expansive mid-shelf sands with mobile bedforms, while the outer shelf has more stable soft-sediment habitat and low-relief reef.

5.2.1. Mandu sampling area

Mandu was the northern-most region surveyed and was characterised by a variety of seabed habitats, from a high-relief inner shelf; mobile bedforms in the middle shelf; and more stable soft-sediment and low-relief outcrops on the outer shelf (Figure 5.4a-h). The most common habitat types were the extensive soft-sediment habitats in the form of sand ripples and bioturbated sands located in the mid-shelf region (Figure 5.4a,b). Outer shelf areas were also dominated by soft-sediments with relatively low relief and contained isolated patches of low reef and gravel habitats where small sessile organisms, such as colonial ascidians, were found attached to the substratum (Figure 5.4c). The inner shelf was the most complex, dominated either by extensive rhodolith beds (Figure 5.4e,f,h) or high-relief reefs that were densely covered in foliose corals (Figure 5.4g). The inner shelf reefs supported diverse flora and fauna, including a plethora of corals, sponges, red and green alga, urchins, starfish, and fish, but were restricted to a relatively narrow shore-parallel zone (Figure 5.2).

5.2.2. Point Cloates sampling area

Point Cloates had the most complex seabed features of all three areas surveyed. As with Mandu, the inner shelf of Point Cloates was characterised by high-relief reefs, mobile sands in the middle shelf, and more stable sediments offshore with isolated patches of low-lying reef (e.g. Figure 5.5a-h). Unlike Mandu, however, the inshore reefs off Point Cloates were more rugose and extended considerably further (100's of m's) offshore (Figure 5.2). These reefs supported a diverse flora and fauna dominated by either rhodolith beds (Figure 5.5c), exposed reef covered in filamentous red alga, or high-relief reefs that were densely covered in foliose corals, coralline algae, and bryozoans (e.g. Figure 5.5g,h). Mid-shelf habitats were characterised mostly by mobile sands (e.g. Figure 5.5a), with isolated patches of low-lying biogenic rubble (e.g. Figure 5.5d). The outer shelf, like Mandu, was characterised by soft-sediments and isolated patches of low-lying biogenic rubble or reef (Figure 5.5c). However, offshore areas at Point Cloates appeared to support more stable assemblages characterised by large-sized gorgonians and sponges (e.g. Figure 5.5f).

5.2.3. Gnaraloo sampling area

At Gnaraloo the shelf is approximately twice as wide as at Point Cloates, and four to five times wider than at Mandu. However, unlike either Mandu or Point Cloates, which were characterised by a structurally complex inner shelf, Gnaraloo had no substantial inner shelf reef. A few isolated high-relief outcrops were observed inshore (e.g. Figure 5.6f,h) but were surrounded by mobile sands (Figure 5.6b). Filamentous red alga and rhodolith beds were also recorded on the inner shelf at Gnaraloo (e.g. Figure 5.6e,h), but these habitats were considerably less common than those recorded off Mandu and Point Cloates (e.g. Figure 5.6e,h). Although hard corals were common on Gnaraloo inner shelf reefs, sponges appeared to make an equal or greater contribution to reef communities. Middle shelf and outer shelf areas were dominated by mobile sands with isolated patches of biogenic rubble and low-lying reef (Figure 5.6a,c,d). These hard substrates supported a variety of patch-reef assemblages dominated by sponges and other sessile invertebrates, such as gorgonians, bryozoans, and ascidians.

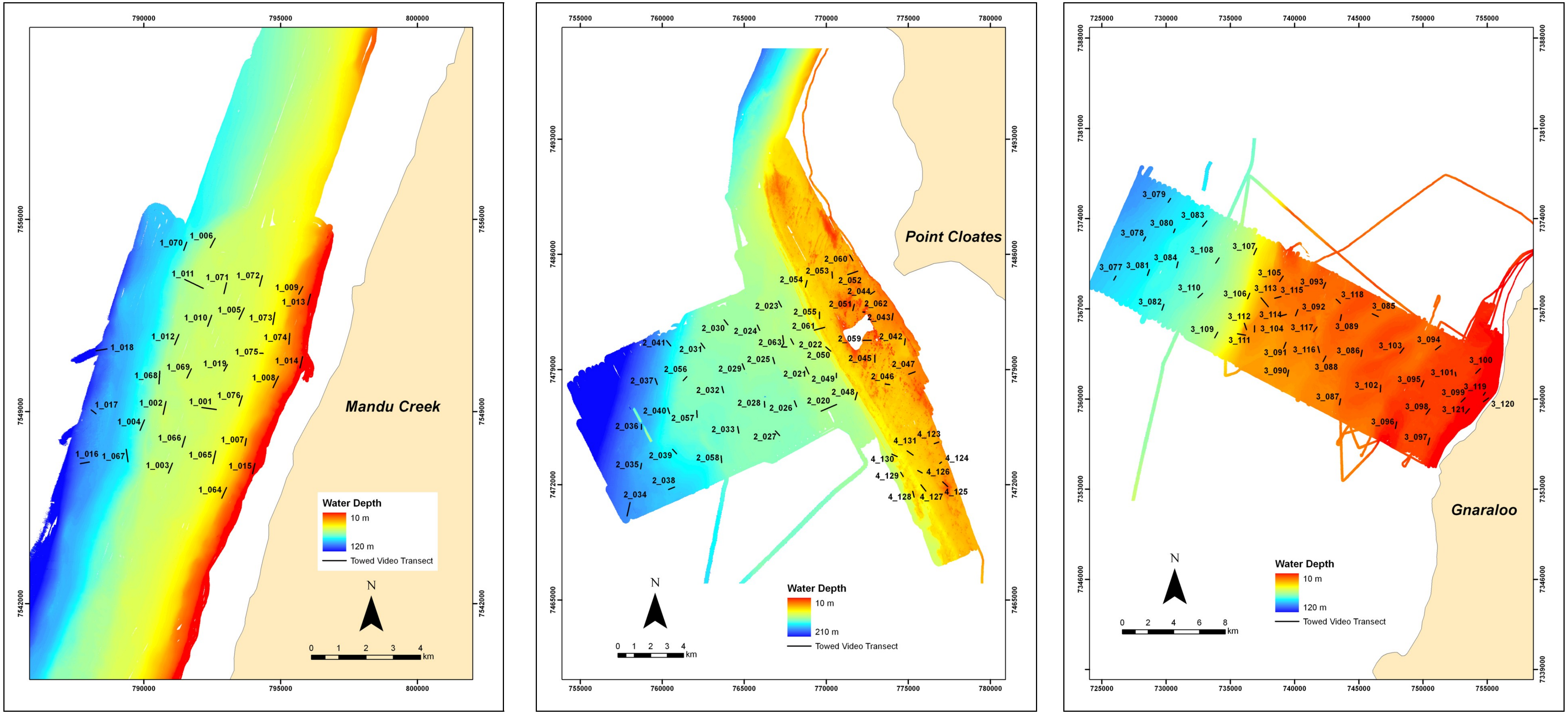

Figure 5.2: *The location of towed video transects completed in the Mandu Creek (n= 32), Point Cloates (n=44), and Gnarloo (n= 46) sampling areas.*

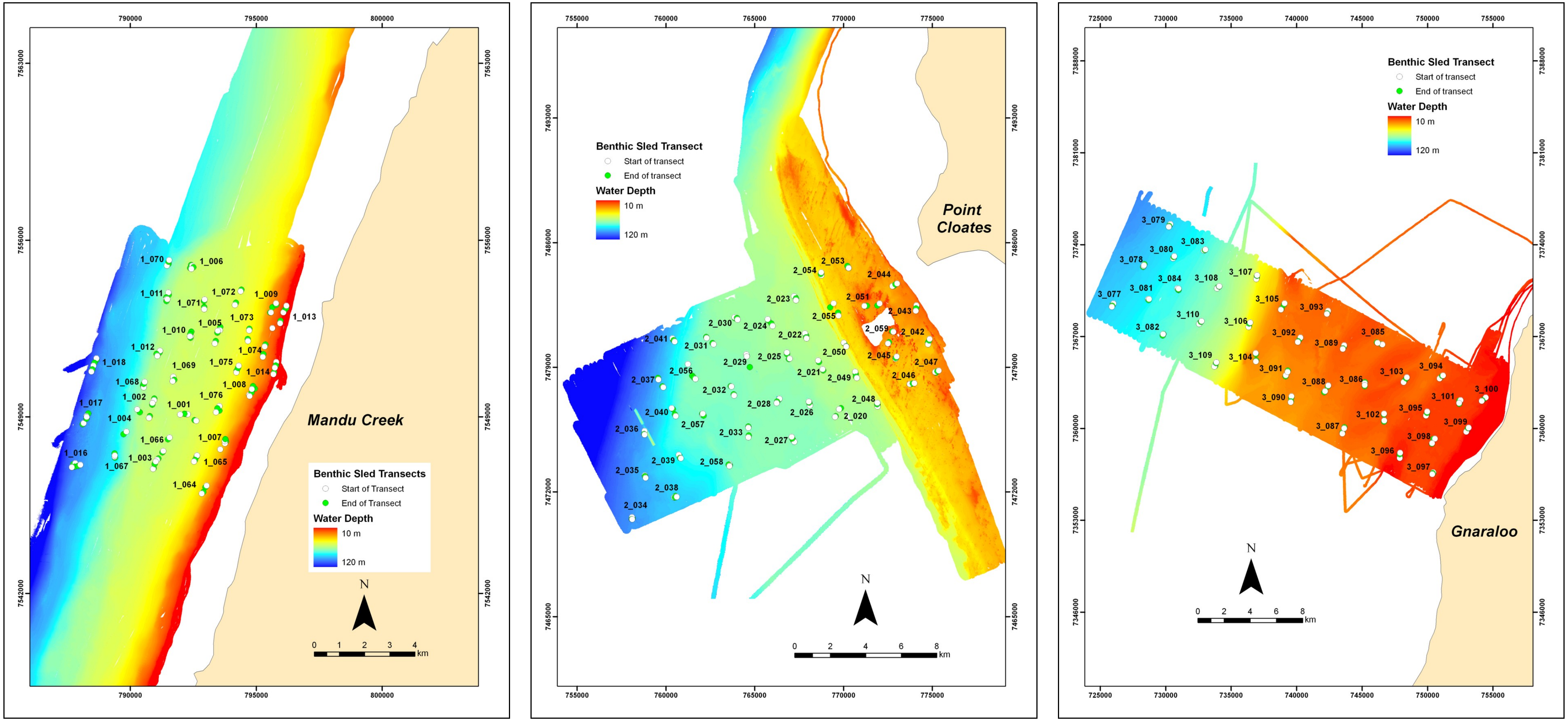

Figure 5.3: *The location of epi-benthic sleds collected in the Mandu Creek (n= 30), Point Cloates (n=38), and Gnarloo (n= 34) sampling areas.*

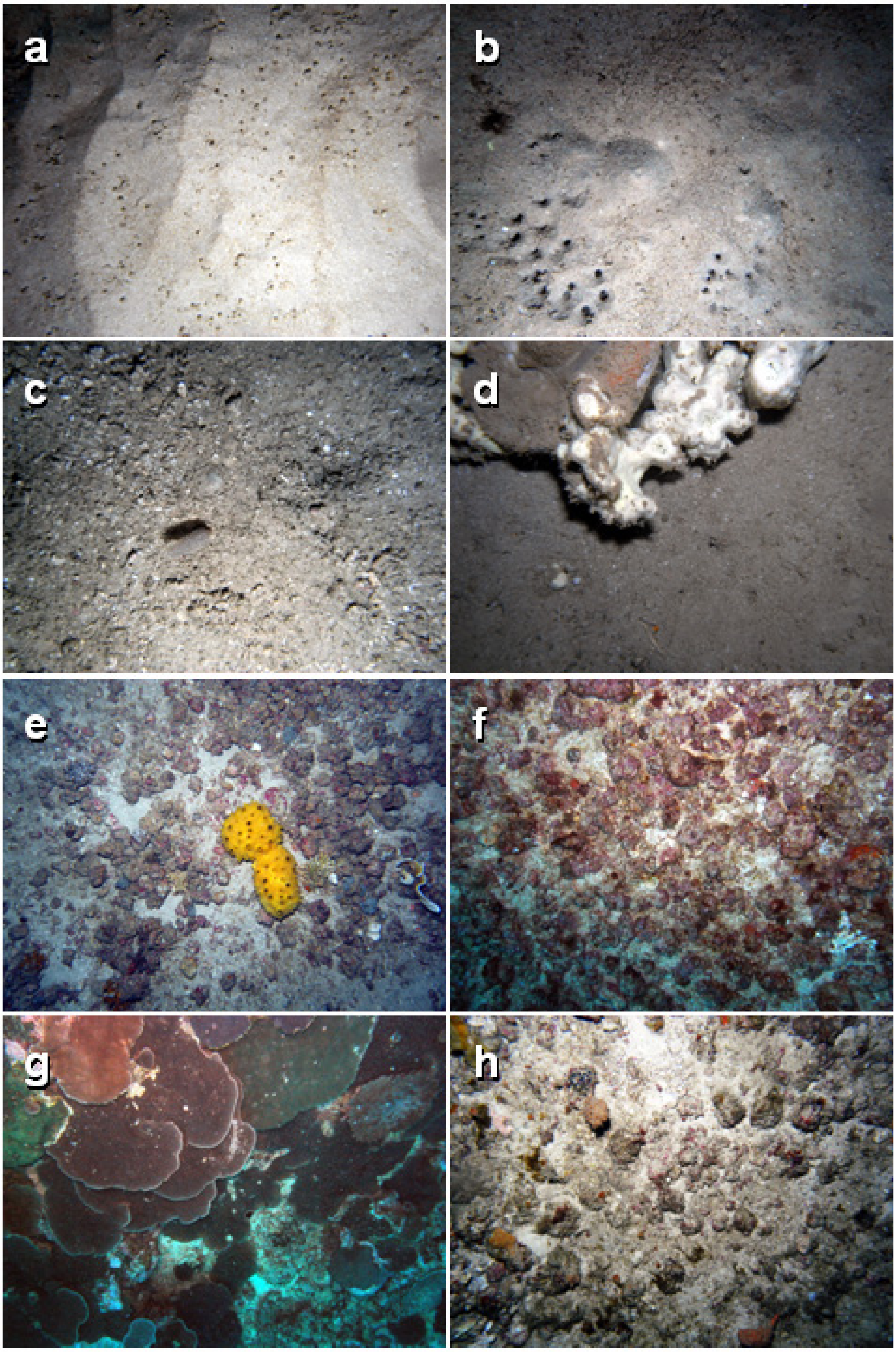

Figure 5.4: *Still photographs of habitat types recorded from within the Mandu sampling area. a) mid-shelf sand ripples at station 72; b) bioturbated sediments in the mid-shelf at station 3; c) outer shelf biogenic rubble with colonial ascidian at station 6; d) reef-edge with white sponge at inner shelf station 7; e) rhodolith bed with yellow sponge from inner shelf, station 64; f) rhodolith bed from inner shelf station 13; g) foliose corals covering an inshore reef at station 14; h) inner shelf rhodolith bed with filamentous red algae and sessile invertebrates, station 74.*

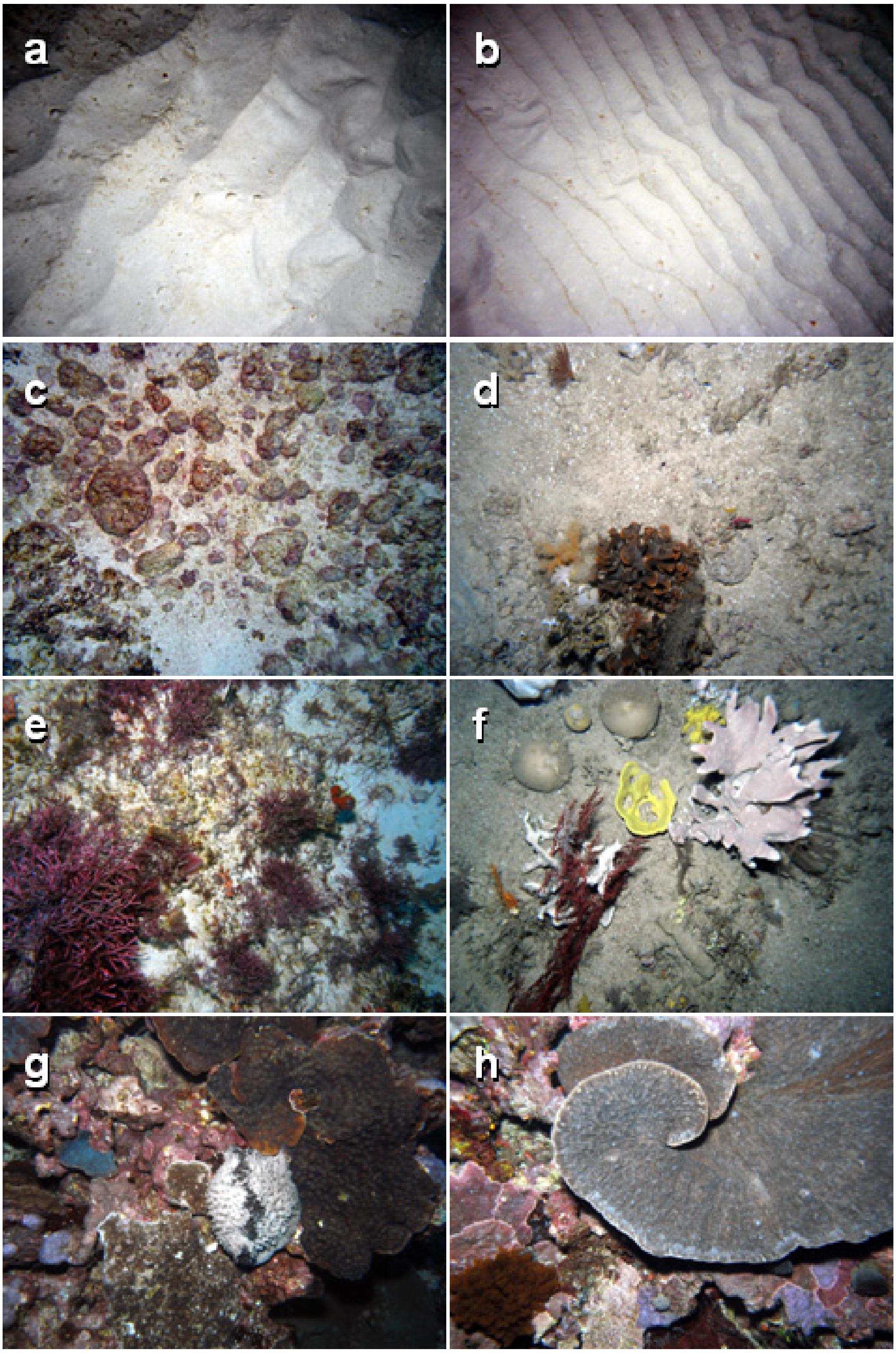

Figure 5.5: *Still photographs of habitat types recorded from within the Point Cloates sampling area. a) mid-shelf sand ripples from station 23 (e.g. 2_023); b) inner shelf sand ripples at station 47; c) inner shelf rhodolith bed over coarse sand from station 51; d) biogenic rubble from mid-shelf station 21, with a diverse assembly of sessile invertebrates including foliose coral, bryozoans, hydroids, and soft corals; e) inner shelf reef with a cover of filamentous red algae and sessile invertebrates, station 23; f) low-lying biogenic reef from outer shelf station 36, with a diverse assembly of sessile invertebrates including sponges, gorgonians, and crinoids; g) High-relief reef covered in foliose corals and sponges, inner shelf station 55; h) High-relief reef covered in foliose corals, coralline algae, and bryozoans, seaward margin of Ningaloo fringing reef, station 61.*

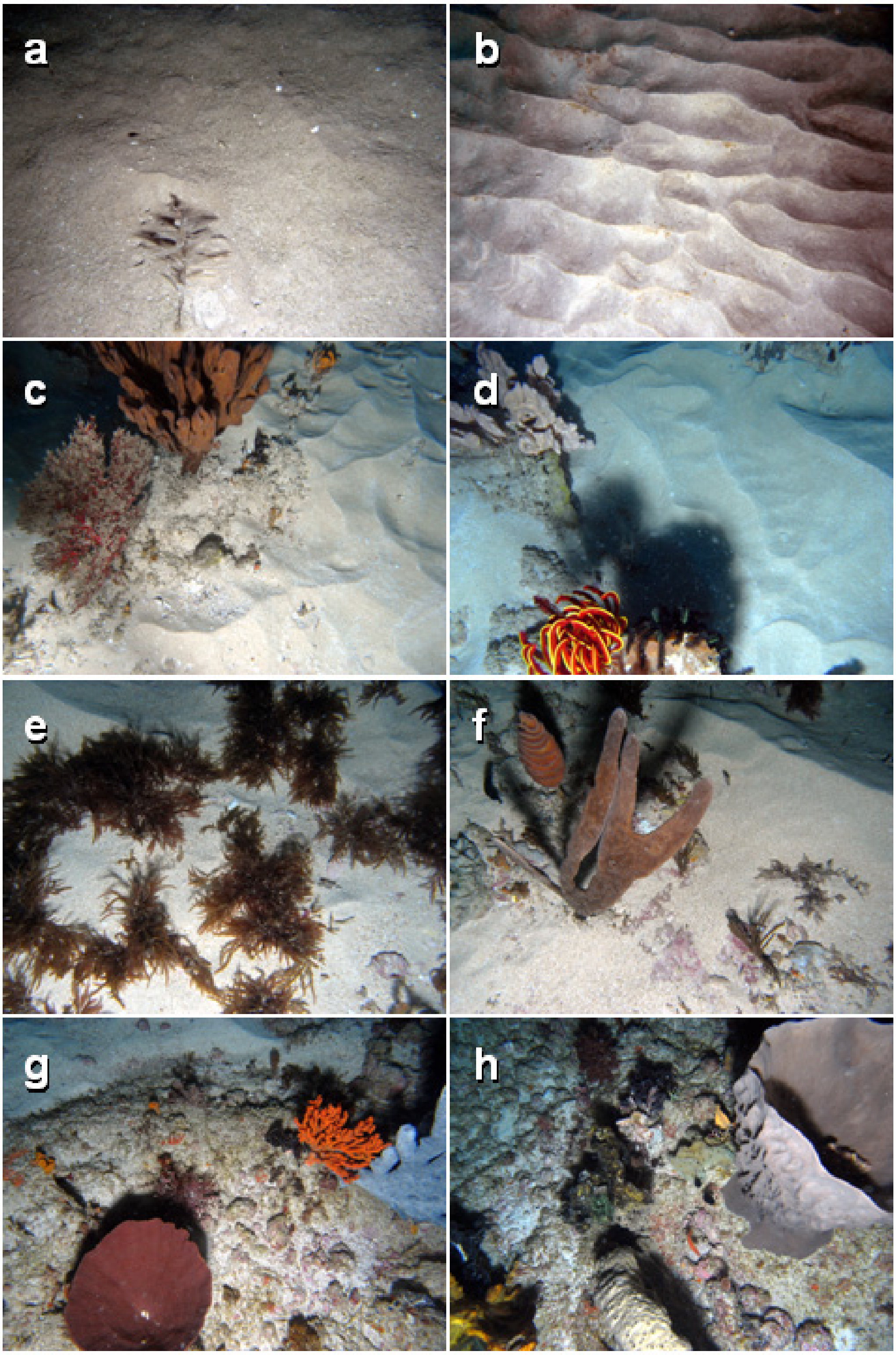

Figure 5.6: *Still photographs of habitat types recorded from within the Gnaraloo sampling area. a) outer shelf soft-sediment at station 84 with hydroid colony and fish; b) inner shelf sand ripples from station 100; c) patchy hard substratum with gorgonian and sponges mid-shelf station 85; d) patchy hard substratum with sponges and associated crinoids mid-shelf station 86; e) inner shelf sand ripples and filamentous red algae on biogenic rubble at station 97; f) sand ripples and exposed reef with sponges and filamentous red algae, inner-shelf station 97; g) Exposed biogenic reef with foliose coral, sponges, rhodoliths, and filamentous red algae, inner-shelf station 96; h) Rhodolith bed and low-lying reef, with sponges, ascidians, bryozoans, and crinoid, station 96.*

5.3. EPIFAUNAL COLLECTIONS

To examine the distribution and abundance of epifauna across the extent of the three survey areas, two 50 m epi-benthic sleds were towed over the seabed at each station. These data will be used to identify species; obtain biomass data for key taxa, such as sponges; and relate these taxa to those recorded in the video transects. As the seabed in the survey areas is in places composed of high-biomass coral and sponge dominated reefs (*unpublished AIMS/WAMSI data*), the epi-benthic sled used in this survey (Figure 5.7) was specifically designed by AIMS at WA to have a larger-than-usual mouth (sled opening) and an extended cod end to enable the successful collection of large quantities of sample material. Once the sample was retrieved, it was transferred to the weigh bucket, and weighed to record the amount of sample collected. When material exceeded 25 kg (*e.g.* rhodolith beds), the weight was estimated using the weight of a sub-sample and visual estimation of total material. Specimens were then sorted into taxa-similar groups in the ship's laboratory, with unique specimens photographed when time permitted. Specimens were then preserved in either ~90 % ethanol or isopropyl alcohol, while worms were preserved in 4% buffered formalin. To facilitate easy identification, molluscs and ascidians were relaxed in MgCl prior to preservation.

Still photographs were collected on some sleds to provide a link between in-hand taxonomic identifications and the habitat type of each biota that was sampled. Digital photographs were taken using a forward facing high-resolution camera attached to the cross bar of the sled, set to take a shot every two seconds for the tow-duration (Figure 5.1). Due to logistical issues, still images were not recorded at all stations. Still images recorded during each shot were backed up to hard drive and await examination.

Figure 5.7: *Epi-benthic sled sampling: Left – deployment of the epi-benthic sled showing the large opening of the sled and the location of the stills camera and associated lights. Right – the epi-benthic sled suspended by the capstan winch (out of frame) showing the cod end distended with sample material.*

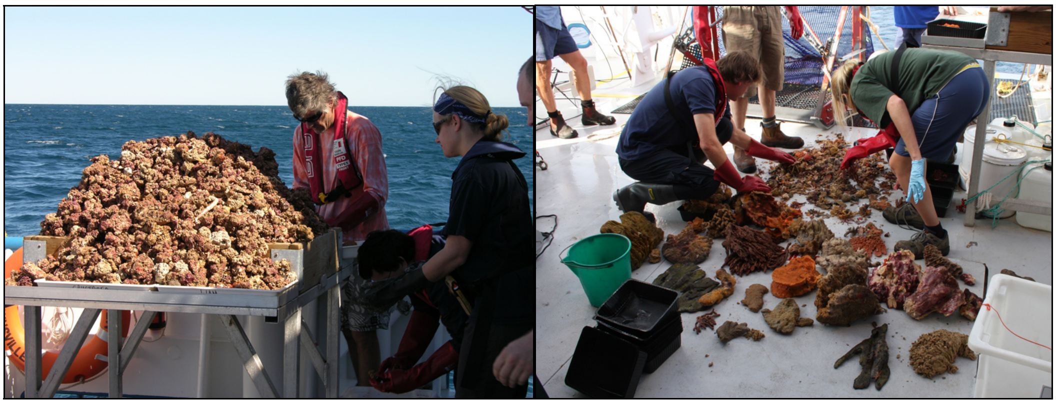

Figure 5.8: *Epi-benthic collections: Left – an example of the high volumes of rhodolith material collected from inshore at Mandu. Right – an example of the high volume of sponge-dominated material collected from Gnaraloo.*

At the completion of the survey, all epi-faunal samples were transported to the Museum of Western Australia for storage prior to further processing, taxonomic identification and enumeration by AIMS, GA, and Museum staff. While no epi-faunal samples have been processed so far, some preliminary observations were made during field collections. For example, the amount of rhodoliths collected decreased from north to south latitudes, while inversely, the amount of sponge material collected increased in the southern latitudes, with the highest sponge biomasses collected from the mid-shelf regions at Gnaraloo (Figure 5.8). The combination of acoustic images and video footage identified that habitat complexity and high-relief reefs were most common on the inner shelf at all three survey areas. Similarly, species richness also appeared to be higher inshore within these complex reefal areas - although accurate numeric measures of species richness and epifaunal assemblage patterns will need to wait for the taxonomic processing of the stored samples.

5.4. INFAUNAL COLLECTIONS

To examine the distribution and abundance of infauna across the extent of the three survey areas, two Smith McIntyre grabs were attempted at each station. As some stations lay over hard ground, not all grabs were successful. Successful grab samples were sieved through a 0.5 mm mesh and the retained material was preserved in ~ 90 % ethanol. At the completion of the survey, infaunal samples were transported to Geoscience Australia for further microscopic sorting to enable taxonomic identification and enumeration. At the time of writing this report, a random selection of samples had been sorted (n=30). From these samples it appears that sediment grain size may be an important factor in explaining infaunal distributions with coarse sediments dominated by crustacean taxa (e.g. Figure 5.9), while fine sediments were characterized by low densities of deposit feeding polychaetes (e.g. Figure 5.9). Independent of grain size, all samples sorted so date were characterised by low infaunal biomass, especially compared to other CERF locations, such as Jervis Bay (McArthur, personal observations).

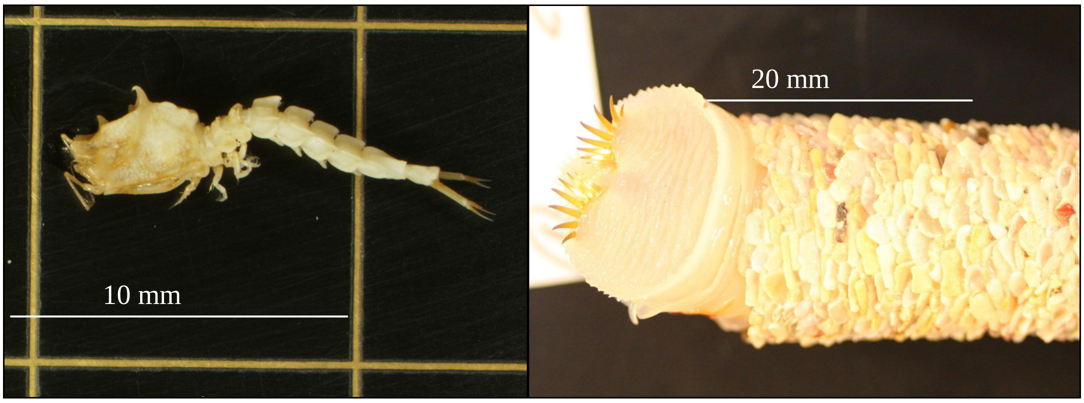

Figure 5.9: *Examples of infauna collected by the Smith McIntyre grab. Left – bodotriid cumacean from medium coarse sediment in the Mandu Creek area. Right – deposit feeding mason worm, Amphictene sp. from fine sand in the Point Cloates area.*

5.5. BENTHIC/PELAGIC COUPLING

The mounted assembly for planktobenthic sampling (MAPS) was deployed at six stations to test the efficacy of this approach for examining the coupling between infauna and hyperbenthic plankton. The equipment consists of a Woods Hole sled to sample the benthos surmounted by a pop-up frame holding a tri-layered net to sample the planktobenthos (Figure 5.10). The MAPS was designed to sample both systems concurrently and uses a bottom-sensing trigger to open and close the plankton net thereby excluding plankton from higher in the water column. A previous attempt at Lord Howe shelf resulted in sediment plume contamination of the plankton nets and poor operation of the opening-closing mechanism. Accordingly, prior to trials at Carnarvon Shelf, an adjustable spring was added to prevent the frame from swinging open during deployment, and an aluminium visor was bolted to the top of the sled to deflect any sediment plumes generated by the sled's movement along the bottom (Figure 5.10). The Carnarvon Shelf deployments represent the first time that concurrent sampling of benthos and planktobenthos has been successfully undertaken. Samples retained in the 1 mm mesh bag from the sled consisted primarily of coarse sediments, and they were therefore elutriated on collection and the retained fauna preserved in ~ 90 % ethanol. Plankton from the nested nets (1000 µm, 500 µm and 100 µm) were elutriated to remove the small amount of sediment collected in the nets, washed onto appropriate size mesh sieves and preserved in ~ 4 % buffered formalin.

Figure 5.10: *The mounted assembly for planktobenthic sampling (MAPS).*

At the time of writing, planktobenthic samples from the 1000 and 500 µm nets had been sorted and photographed, and some benthic samples from the sled had been sorted. Preliminary sorting of the planktobenthic samples indicate the MAPS was successful at retaining species from the hyperbenthos and excluding species known to occur only in the open water column. Mysids have been identified from the 1000 and 500 µm nets, and these crustaceans are known to occur primarily in the area immediately above the seafloor (Figure 5.11a). Other plankton identified in the nets can occur near the bottom as well as further up in the water column (e.g. ostracods, arrow worms). Copepods and chaetognaths (arrow worms) were the most common taxa found in the planktobenthos (Figure 5.11b,c). In addition to numerous adults, early life stages have been identified from the planktobenthos, including gastropod veligers, brooding ostracods, crustacean zoea, and chordate eggs (Figure 5.12).

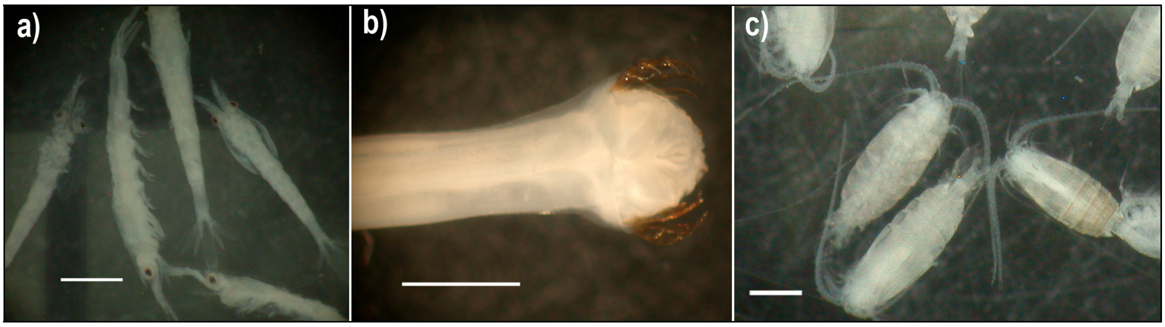

Figure 5.11: *Adults collected from the MAPS 1000 and 500 µm nets, including a) mysids, b) chaetognath, and c) copepods. Scale bars represent 100µm.*

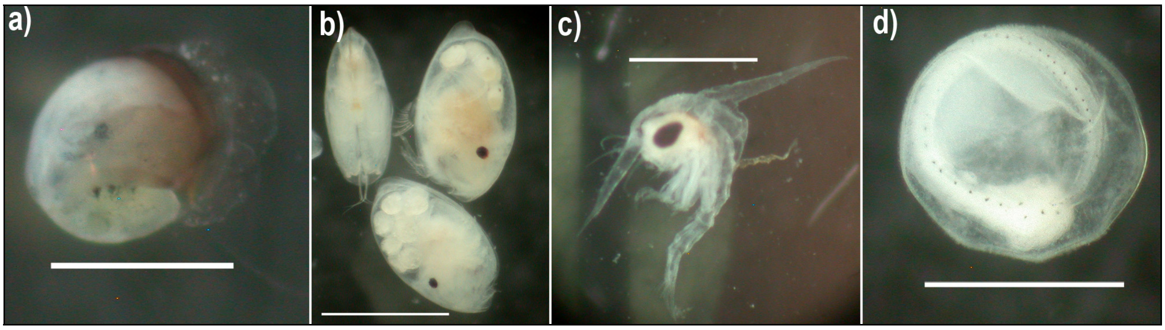

Figure 5.12: *Early life stages collected from the MAPS 1000 and 500 µm nets, including a) gastropod veliger, b) pelagic ostracods with visible brooded embryos, c) brachyuran zoea, and d) chordate egg. Scale bars represent 100µm.*

5.6. HABITATS AND BIOLOGICAL ASSEMBLAGES OF THE MUIRON ISLANDS

During the transit back to Exmouth, an additional day of mapping and sampling was undertaken at the Murion Islands, with 52 km^2 area mapped immediately north of the Muiron Islands (24 - 150 m water depth). Seven stations were sampled over the mapped area using towed-video and sediment grab sampling. The Muiron Islands are located at the entrance to the Exmouth Gulf, a large shallow estuarine embayment and as such will be influenced by a variety of different physical conditions than those areas surveyed further south along the Carnarvon Shelf. Initial observations from the towed-video collected on the outer shelf show unconsolidated muddy-sands with patches of hard substrate that support diverse filter feeding assemblages dominated by sponges and gorgonians (e.g. Figure 5.13).

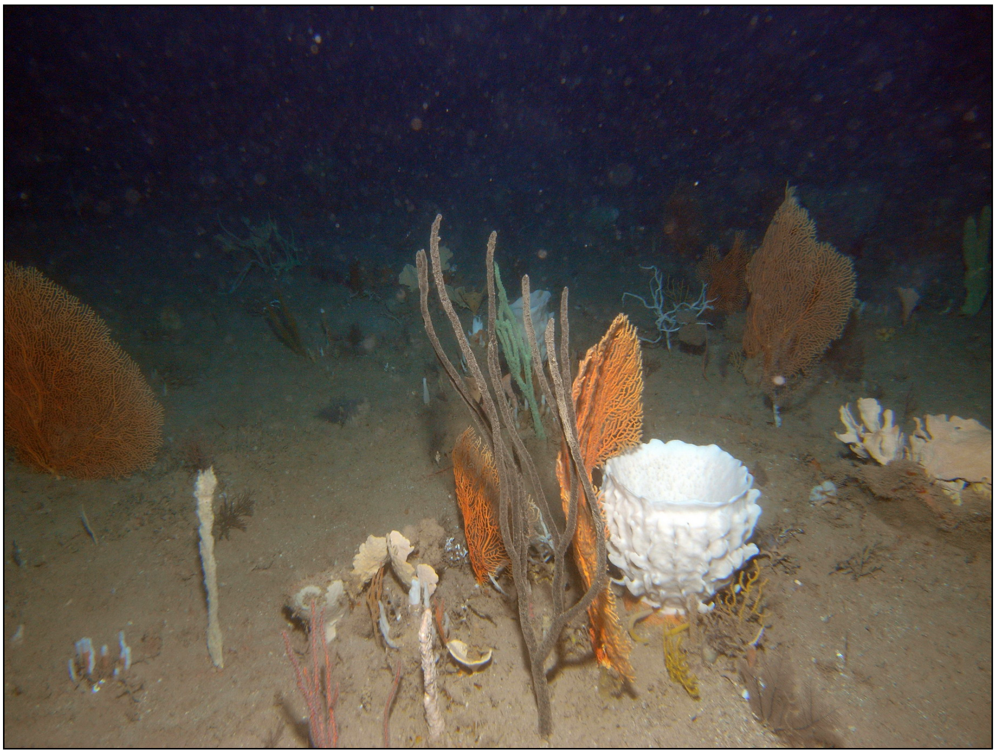

Figure 5.13: *Still photograph of a diverse assemblage of filter feeding sponges and gorgonians on the largely flat, soft sediment outer-shelf seabed near the Murion Islands.*

6. Summary

High-quality, accurately co-located multibeam sonar data, towed-video footage, stills photographs and seabed samples were collected by AIMS and GA staff aboard *RV Solander* at three strategically selected study areas on the southern Carnarvon Shelf, at Mandu, Point Cloates and Gnaraloo. A small additional area was also examined near the Muiron Islands, in the mouth of Exmouth Gulf, at the end of the survey. Over the survey period, wave and current data were collected at Point Cloates to enable estimation of the degree of exposure of the shelf to wave and current energy. The data collected will be used to determine covariance between physical parameters (seabed morphology, acoustic backscatter, sediment grain size, seabed shear stress) and measures of benthic biodiversity (species richness, community type). The expectation is that the data provide both broad-scale and fine-scale spatial patterns in seabed complexity and biodiversity.

Additional processing of most of the physical and biological data collected is required before comparative analysis between the data sets can commence. However, a number of initial observations have been made. In terms of the oceanographic data, wave conditions were highly variable during the survey, with significant wave height ranging from approximately 0.5 to 4.5 m, but arriving persistently from the west-southwest. The tide regime off Point Cloates is microtidal, mixed, mainly semi-diurnal with a mean spring and neap range of 0.98 m and 0.25 m, respectively. The tidal current floods to the south and ebbs to the north off Point Cloates, which is consistent with a clockwise rotating tidal amphidrome centred to the southwest of the region. Non-tidal, surface currents extended to a depth of at least 30 m and were directed to the northeast-northwest sectors, consistent with wind patterns during the deployment period. Non-tidal bottom currents are directed to the south to west-southwest, consistent with the regional geostrophic current. Salinity and temperature measurements suggest that the regional geostrophic current may also influence the shallow (30 m) inner shelf.

The most complex seabed habitat occurs on the inner shelf, especially at Point Cloates. Here, ridges, mounds and raised hardground produce a highly rugose inner shelf that covers 33% of the Point Cloates sampling area. The inner shelf at Mandu likewise features mounds and ridges, but here these features represent 11% of the sampling area. Surface sediments at both areas range from sand to gravel. At Gnaraloo, rugose seafloor on the inner shelf covers just 2% of the sampling area and surface sediments are mostly sand. At all sample areas the inner shelf sediments are predominantly light grey unweathered skeletal carbonate, indicative of a modern age, rather than the darker yellow and brown weathered sediment common on the middle and outer shelf. In all survey areas the rugose form of the inner shelf prevents a continuous sediment cover, with localised fields of small-scale bedforms. On the mid shelf of all survey areas, seabed dunes indicate transport of bottom sediments across the shelf towards the northeast. The sand-dominated mid shelf at Gnaraloo has the most extensive fields of large scale bedforms that extend to 45 m water depth. At Mandu and Point Cloates, bedform fields on the mid shelf are more localised, possibly reflecting the spatial variance in sediment type from sand to gravelly sand and gravel; although at Point Cloates bedforms occur to 100 m water depth in gravelly sediment. Low ridges extend along the shelf at Mandu and Point Cloates in 75 – 80 m water depth and appear to represent a drowned shoreline that partly survived marine transgression during the late Pleistocene.

Towed underwater video and still photography reveal mixed assemblages along Carnarvon Shelf, including hard corals, sponge gardens, rhodolith beds, bioturbated sediments, and comparatively barren sand. All sampling areas exhibit decreasing habitat complexity with distance offshore, with seabed habitat complexity markedly higher in the central region of Point Cloates. All three locations are dominated by expansive mid-shelf sands with mobile bedforms, with more stable soft-sediment and low-relief outcrops recorded offshore.

A large range of fauna was collected from the epi-benthic sled, although specimens have yet to be identified. The amount of rhodoliths collected decreased from north to south latitudes, while the amount of sponge material collected increased in the southern latitudes. Grab samples suggest that sediment grain size may be an important factor in explaining infaunal distributions, although all samples sorted to date were characterised by low infaunal biomass compared to other CERF locations. This survey represents the first known time an epi-benthic sled was used to concurrently sample the benthos and planktobenthos, and preliminary results indicate rich planktobenthic assemblages on the Carnarvon Shelf even above relatively barren sand.

7. References

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8. Appendix

8.1. SUMMARY LOG OF SURVEY ACTIVITIES

Leg 1, August 13th – 28th August
13/08/2008

- All personnel arrive on board. Set up ship and stow supplies/equipment.
- 1030. Called a scientific briefing, all science personnel and crew present. Discussed major aims and priorities. Science staff then discussed uniform nomenclature for labelling sites etc (for consistency across the teams present: 1_001_GR01 = Area1_Station 1_ Grab sample #1). Discussed replication requests (n=2 or 3), agreed to begin with n=3. Focus this leg to be Areas 1 & 2 (Mandu and Pt Cloates). Agreed to have daily morning and evening briefings for progress and setting plans for subsequent days. Morning briefings each morning with the Captain. Regular review of the days program pending completion of tasks and taking in to account any equipment breakdowns etc.
- 1930. Set sail. Unannounced emergency muster practice completed.
- Multibeam profiling through the night. Began with a corridor through Area 1 (Mandu), to permit better sampling strategy for Video, Grab and Sled sampling. This also permits preliminary assessment of the heterogeneity of the seafloor (can avoid highly elevated reef systems to ensure gear isn't fouled).
- Throughout the Cruise all data to be backed up on at least two systems (external hard drives). This includes multibeam, SBP (sub bottom profiling), TVA (towed video), GR (benthic grab, Smith MacIntyre), sled video camera, stills strobing camera on the TVA
- TVA tow body and SL (benthic sled). All camera/video data is to be downloaded after each dive. GPS, waypoints and tracks recorded on ships server and on two hard drives. Supplementary GPS recorded on Garmin hand held and downloaded each day. Tow video imagery is georeferenced.

14/08/2008

- Swath section (mid Mandu) completed by 0930.
- TVA, grab and sled equipment and computers/GIS systems setup and operational by 0930.
- 0930 Toolbox meeting to assign tasks and with ships crew run through operations for each task (deployment, retrieval, processing for: TVA, GR and SL).
- Examination of the multibeam images from the previous night suggested two distinct strata (running parallel to the coast) of interest. The waypoints provided in the Science plan for the cruise falling within these strata were selected to commence the program. Trial run commenced.
- Two sites completed with TVA, n=3 Sleds and n=2 grabs. TVA image poor from start, and camera unit found to be slightly flooded on retrieval. One light unit also flooded. Camera/light changed and unit flushed for maintenance on board.
- 1800 Multibeam continues.

15/08/2008

- Multibeam mapping till 0800.
- 4 stations completed with n=3 SL reps.
- Multibeam middle of the day for 2 hrs as the sea conditions permitted very close inshore operation near the reef front (completed the inner most lines).

16/08/2008

- 4 stations completed with n=3 repls SL.
- SBP/Chirper/Sparker trials 3hrs done midday to access the inner most regions of workable shallow water.
- Tested SBP and ran lines from 1800 to 0300, then multibeam.

17/08/2008

- 6 stations completed with n=3 reps SL.
- SBP tie in lines from1500 to completion over night.
- 6 additional stations requested by GA (3 inshore and 3 deeper that those waypoints provided to date). Reason, to cover off on new habitat/unusual topography from multibeam.
- 2000 Review meeting between CL and GA staff. Concern over progress (slow to date for the number of stations to be completed) and discussion about the request for n=3 replicate SL's. Also concern over the fast rate of consumption of ETOH and containers (already not enough on board). Discussion on sample size and station dispersion strategy. Agreed to continue with n=3 SL and n=3 GR for most of Mandu, but n=2 for Pt Cloates given the larger number of stations there. CL to order more ETOH/containers (also enough for Leg 2 given the time to delivery).

18/08/2008

- 5 stations completed.
- MAPS trial runs, 2 stations completed
- 4 additional GR sites completed to provide n=3 GR reps for Mandu stations so far.
- Complete SBP tie-in lines for Mandu.

19/08/2008

- 2 more GR stations for n=3rd reps.
- MAPS (epibenthic sled) run for near surface sediments and bottom plankton completed.
- Picked up ETOH supplies from Tantabiddi.
- From midday, multibeam to Pt Cloates and around Black Rock reef (need daylight).
- Swath mapping through night of mid-section of Area 2 to inform TVA/GR/SL sampling program initiation.

20/08/2008

- Begin Pt Cloates sampling (Area 2).
- 9 Stations completed mid sections (already swathed).
- Swath mapping from 1900 through night.

21/08/2008

- 9 stations completed Pt Cloates.
- Swath mapping from 1900 through night.

22/08/2008

- 7 stations completed.
- Midday for 4 hours: Swath mapping around Black Rock (v shallow and unchartered). Need high sun to see reef.

23/08/2008

- 7 stations completed and one started.
- Towed video unit caught on GA ADCP array at site 2_052. Had to cut TVA free and buoy off for retrieval by divers next day.
- Swath mapping through night.

24/08/2008

- 7 stations commenced (GR/SL, but no TVA) around Black Rock and mid-shelf.
- Retrieved tow video and redeployed ADCP array.

25/08/2008

- Completed 24th Aug stations with tow video transects (7).

- Completed a further station and two long video runs (Stations 2_061 and 2_062) to groundtruth processed backscatter data.
- Sail to Coral Bay to pick up extra Isopropynol and sample barrels from courier.
- Completed two night time TVA runs and 2 GR stations to further ground truth backscatter data.
- Completed SBP tie-in lines throughout Area 2.
- Swath through night completing Area 2.

26/08/2008

- Completed Pt Cloates swath infilling.
- Steam to Mandu @0930.
- Completed 6 stations.
- Continue extension of northern area swath mapping through night.

27/08/2008

- Completed the last 7 prescribed stations at Mandu
- Completed inshore swath mapping south of Mandu
- Completed extension mapping north of Mandu.

28/08/2008

- Continued swath mapping until mid morning.
- Complete MAPS sampling Mandu.
- Steam, back (while mapping) to Exmouth for refit of anchor chain, Tennex staff arrived at Exmouth 27/8/08.
- Post trip debrief with Master of the vessel.

Leg 2, 30th August – 15th September

30/08/08

- All GA personnel arrive in Exmouth and board *RV Solander* by early afternoon.
- Handover meeting held between GA cruise leaders (Leg 1 and 2) and science staff.
- AIMS cruise leader arrives late afternoon and meets with crew and science staff to confirm plan for the next couple of days; that being transit to the Gnaraloo survey area.
- Safety briefing from first mate plus tour of entire ship for new science staff.
- Set sail at 2200 hrs to transit south toward the Gnaraloo survey area.

31/08/08

- Arrived Gnaraloo survey area and commenced swath mapping in early hours.
- Spent day swath mapping the outer part of the Gnaraloo survey area.
- Some science crew still getting their sea legs in short 2-3 m swell from SW.

1/09/08

- Spent day swath mapping the outer part of the Gnaraloo survey area.
- Some science crew still getting their sea legs in short 2-3 m swell from SW.

2/09/08

- Mapping continued overnight. By 0800 approximately one-third of the Gnaraloo area has been covered.
- Preliminary multibeam map for the outer shelf shows gently sloping, generally featureless seabed; probably sandy bottom.
- Commenced sampling mid-morning, with towed video, benthic sled and sediment grab used as stations 3_77 to 3_78 in the morning; followed by stations 3_79 to 3_82.
- Six stations completed in good sea conditions (sea state 1). All gear working well.

3/09/08

- Swath mapping continued overnight with rate of coverage slightly less as we move into shallower water and beam coverage decreases.
- A minor problem with CARIS software required a re-survey of two lines that were shot yesterday afternoon. Problem resolved by Cameron Buchanan.
- Sampling continued all day in very good sea conditions (sea state 0-1). Sampling occurred in the morning was in ~ 90 m water depth, and in the afternoon in ~40 m.
- Seven stations completed (stations 3_83 to 3_89).

4/09/08

- Swath mapping continued overnight, with approximately 50% of the Gnaraloo area now covered.
- Sampling continued in excellent sea conditions, concentrating on the mid shelf area in 35 – 45 m water depth.
- Six stations completed (stations 3_90 to 3_096).

5/09/08

- Swath mapping continued overnight.
- Sampling on the mid shelf continued in deteriorating sea conditions. During the day the swell rose to 2 – 3 m and the sea became lumpy with wind increasing to 20 knots from SW. Sampling halted at 1600 hrs due to strain being placed on video cable by rough sea conditions.
- Five stations completed (stations 3_97 to 3_101).

6/09/08

- Swath mapping continued overnight in 30 knot wind and 3 – 4 m swell from SW.
- Sampling resumed in the morning at 38 m isobath in continued rough sea conditions.
- Sampling stopped at 1300 hrs due to safety concerns with gear deployment.
- Decision made by skipper to head closer to shore and lay anchor until sea conditions improved. Vessel rolling up to 30^{o} when beam on to the swell.
- 1600 hrs arrived at Red Bluff for the night.
- Three stations completed (stations 3-102 to 3_104).

7/09/08

- Weather and sea conditions improved, wind 20 knots and easing with 1 m swell.
- Swath mapping resumed in the morning after 0800 hrs, with aim of mapping shallower waters along the outer edge of the reef at Gnaraloo. Rapid improvement in sea conditions allowed mapping in 20 m water depth.
- Sampling resumed in the afternoon in 40 – 50 m water depth.
- Four stations completed (stations 3_105 to 3_108).

8/09/08

- Swath mapping continued overnight in excellent sea conditions; light winds and <1m swell.
- Sampling continued during the morning at deeper water sites on the outer shelf at ~80 m water depth. These sites complete the planned sampling stations for Gnaraloo.
- During the afternoon swath mapping resumed on the inner shelf area of Gnaraloo.
- Two stations completed (stations 3_109 to 3_110).

9/09/08

- Swath mapping continued overnight and morning until 1000 hrs.
- Multibeam map was used to select additional sampling sites, with a focus on low ridge features on the mid to inner shelf.

- Towed video was used at eight stations to inspect bottom type and benthic communities. Noted a strong association between ridges as hardground and sponge gardens with little coral. Areas surrounding ridges are generally sandy, with low bedforms and have very low abundance of sponges.
- Eight stations completed – video and grabs only (no benthic sled) (stations 3_111 to 3_118).
- Sparker sub-bottom profiler deployed at 2000 hrs in moderate sea conditions. Two cross shelf lines and one tie-line completed overnight.

10/09/08

- This morning we returned to Red Bluff and sent four of the ships crew ashore so that one of the crew could attend to a family emergency. Ground transportation was arranged for travel to Carnarvon from Gnaraloo Station. Opportunity used to restock on some provisions.
- After dropping off the shore party we returned to the survey area and continued with towed video inspection and grab sampling of hardground sites on the inner shelf.
- Four stations completed (stations 3_119 to 3_122).
- Also completed additional sparker lines before exiting the Gnaraloo area and transiting north to Coral bay.
- Lay anchor at Coral Bay overnight.

11/09/08

- Transited from Coral Bay to Point Cloates after 0800 hrs to resume swath mapping and extend the Cloates mapped area to the south.
- Sea conditions becoming rough on 2 m swell from SW.
- Swath mapping continued all day.

12/09/08

- Swath mapping of the Point Cloates extension continued overnight and was complete by 0700.
- Two ADCP instruments deployed at the start of the survey were then recovered. One mooring could not be recovered due to the failure of the acoustic release system.
- In the afternoon towed video and grab sampling was undertaken at nine sites in the newly mapped area at Point Cloates.
- Nine stations completed – video and grabs only (no benthic sled) (stations 4_123 to 4_131).
- Transited overnight toward Muiron Islands area to the north of Exmouth.

13/09/08

- Arrived Muiron Islands by about 0700 hrs and started swath mapping an area to the west of North Muiron Island between 25 m and 100 m isobaths.
- Swath mapping continued until mid afternoon, then deployed the MAPS plankton sampler at three stations.
- Also undertook towed video, benthic sleds and sediment grabs at three sites identified from the multibeam data as potential hardground.
- Three stations completed (5_132 to 5_134).

14/09/08

- Continued swath mapping overnight in the Muiron Island area until 1000hrs.
- Collected towed video and sediment grabs at four sites in deeper water area of the mapped area, up to 100 m.
- Four stations completed – video and grabs only (no benthic sled) (stations 5_136 to 5_139).
- 1200 hrs sampling ended.
- Transited to Exmouth, arriving at wharf by 1600 hrs.
- Gear and samples packed and partly off loaded onto wharf.

15/09/08

- Offloading of gear and samples completed by 1200 hrs.
- All science crew disembarked by 1230 hrs.

8.2. SAMPLE TYPE AND LOCATION FOR ALL STATION OPERATIONS OF SURVEY SOL4769

Key for sample codes

GR = sediment grab	Plankton = MAPS benthic plankton sample
SLs = benthic sled start location	SLf = benthic sled finish location
TVAs = towed video start location	TVAf = towed video finish location

SAMPLE_TYPE	ID	LATITUDE	LONGITUDE
GR	1_001_GR01	-22.13750000	113.82990000
GR	1_001_GR02	-22.13890000	113.82810000
GR	1_001_GR03	-22.14049500	113.83380000
SLs	1_001_SL01	-22.13870000	113.83350000
SLf	1_001_SL01	-22.13860000	113.83300000
SLs	1_001_SL02	-22.14100000	113.83690000
SLf	1_001_SL02	-22.14080000	113.83620000
SLs	1_001_SL03	-22.13880000	113.83060000
SLf	1_001_SL03	-22.13860000	113.82300000
TVAs	1_001_TVA1	-22.13890000	113.83710000
TVAf	1_001_TVA1	-22.13830000	113.83190000
GR	1_002_GR01	-22.14150000	113.81780000
GR	1_002_GR02	-22.13490000	113.82040000
GR	1_002_GR03	-22.13365900	113.81992500
SLs	1_002_SL01	-22.14030000	113.81870000
SLf	1_002_SL01	-22.13960000	113.81900000
SLs	1_002_SL02	-22.13390000	113.82050000
SLf	1_002_SL02	-22.13330000	113.82060000
SLs	1_002_SL03	-22.13490000	113.81990000
SLf	1_002_SL03	-22.13550000	113.81980000
TVAs	1_002_TVA1	-22.13650000	113.81920000
TVAf	1_002_TVA1	-22.14080000	113.81830000
GR	1_003_GR01	-22.15980000	113.81790000
GR	1_003_GR02	-22.15630000	113.82100000
GR	1_003_GR03	-22.15492300	113.82265500
Plankton	1_003_MAPS1	-22.16121300	113.81906900
Plankton	1_003_MAPS1	-22.16035100	113.81988600
SLs	1_003_SL01	-22.15850000	113.82060000
SLf	1_003_SL01	-22.15820000	113.82080000
SLs	1_003_SL02	-22.15520000	113.82210000
SLf	1_003_SL02	-22.15470000	113.82260000
SLs	1_003_SL03	-22.15580000	113.82160000
SLf	1_003_SL03	-22.15670000	113.82120000
TVAs	1_003_TVA1	-22.15670000	113.82190000

TVAf	1_003_TVA1	-22.16010000	113.82050000
GR	1_004_GR01	-22.14760000	113.80820000
GR	1_004_GR02	-22.11393000	113.81110000
GR	1_004_GR03	-22.14236300	113.81242500
SLs	1_004_SL01	-22.14530000	113.81010000
SLf	1_004_SL01	-22.14630000	113.80900000
SLs	1_004_SL02	-22.13730000	113.81410000
SLs	1_004_SL03	-22.14170000	113.81400000
TVAs	1_004_TVA1	-22.14270000	113.81170000
TVAf	1_004_TVA1	-22.14620000	113.81020000
GR	1_005_GR01	-22.11400000	113.84370000
GR	1_005_GR02	-22.05630000	113.50650000
GR	1_005_GR03	-22.10875700	113.84478000
SLs	1_005_SL01	-22.11320000	113.84340000
SLf	1_005_SL01	-22.11230000	113.84380000
SLs	1_005_SL02	-22.10846000	113.84530000
SLf	1_005_SL02	-22.10730000	113.84540000
SLs	1_005_SL03	-22.10870000	113.84450000
SLf	1_005_SL03	-22.10930000	113.84440000
TVAs	1_005_TVA1	-22.10530000	113.84630000
TVAf	1_005_TVA1	-22.05630000	113.84450000
GR	1_006_GR01	-22.08500000	113.83590000
GR	1_006_GR02	-22.08270000	113.83480000
GR	1_006_GR03	-22.08510400	113.83513400
SLs	1_006_SL01	-22.08630000	113.83390000
SLf	1_006_SL01	-22.08530000	113.83380000
SLs	1_006_SL02	-22.08560000	113.83420000
SLf	1_006_SL02	-22.08640000	113.83340000
SLs	1_006_SL03	-22.08670000	113.83390000
SLf	1_006_SL03	-22.08610000	113.83470000
TVAs	1_006_TVA1	-22.08260000	113.83550000
TVAf	1_006_TVA1	-22.08570000	113.83390000
GR	1_007_GR01	-22.09249000	113.84516667
GR	1_007_GR02	-22.08873000	113.84975000
GR	1_007_GR03	-22.14895900	113.84743800
SLs	1_007_SL01	-22.08931000	113.84806667
SLf	1_007_SL01	-22.14813333	113.84843333
SLs	1_007_SL02	-22.08880000	113.84795000
SLf	1_007_SL02	-22.14731667	113.84818333
SLs	1_007_SL03	-22.09058000	113.84631667
SLf	1_007_SL03	-22.14731667	113.84818333
TVAs	1_007_TVA1	-22.14820000	113.84790000
TVAf	1_007_TVA1	-22.15060000	113.84750000
GR	1_008_GR01	-22.11470000	113.81310000
GR	1_008_GR02	-22.12790000	113.85970000
GR	1_008_GR03	-22.12953500	113.85768500
SLs	1_008_SL01	-22.07880000	113.85701667
SLf	1_008_SL01	-22.07745000	113.85915000
SLs	1_008_SL02	-22.07909000	113.85716667
SLf	1_008_SL02	-22.07830000	113.85796667
SLs	1_008_SL03	-22.07757000	113.85798333
SLf	1_008_SL03	-22.07691000	113.85845000

TVAs	1_008_TVA1	-22.07647000	113.85886667
TVAf	1_008_TVA1	-22.13133333	113.85701667
GR	1_009_GR01	-22.09745000	113.86730000
GR	1_009_GR02	-22.09710000	113.86641000
GR	1_009_GR03	-22.09906400	113.86582700
SLs	1_009_SL01	-22.06440000	113.86543333
SLf	1_009_SL01	-22.05990000	113.86530000
SLs	1_009_SL02	-22.05904000	113.86666667
SLf	1_009_SL02	-22.05941000	113.86680000
SLs	1_009_SL03	-22.06107000	113.86483333
SLf	1_009_SL03	-22.06106000	113.86453333
TVAs	1_009_TVA1	-22.05811000	113.86678333
TVAf	1_009_TVA1	-22.05966000	113.86573333
GR	1_010_GR01	-22.11320000	113.83150000
GR	1_010_GR02	-22.10978300	113.83730000
GR	1_010_GR03	-22.11054600	113.83378200
SLs	1_010_SL01	-22.11061700	113.83390000
SLf	1_010_SL01	-22.10917000	113.83433000
SLs	1_010_SL02	-22.11070000	113.83425000
SLf	1_010_SL02	-22.11136000	113.83405000
SLs	1_010_SL03	-22.11081000	113.83380000
SLf	1_010_SL03	-22.11005000	113.83400000
TVAs	1_010_TVA1	-22.10790000	113.83480000
TVAf	1_010_TVA1	-22.11160000	113.83350000
GR	1_011_GR01	-22.09318400	113.82620000
GR	1_011_GR02	-22.10010000	113.82391600
GR	1_011_GR03	-22.09714300	113.82483600
SLs	1_011_SL01	-22.09525800	113.82525300
SLf	1_011_SL01	-22.09617600	113.82541700
SLs	1_011_SL02	-22.09779000	113.82446100
SLf	1_011_SL02	-22.09705800	113.82450500
SLs	1_011_SL03	-22.09766500	113.82489500
SLf	1_011_SL03	-22.09839200	113.82460900
TVAs	1_011_TVA1	-22.11024000	113.83164000
TVAf	1_011_TVA1	-22.09629000	113.82507000
GR	1_012_GR01	-22.12009100	113.82046900
GR	1_012_GR02	-22.11453400	113.82030000
GR	1_012_GR03	-22.11674800	113.82151300
Plankton	1_012_MAPS1	-22.11883100	113.82087600
Plankton	1_012_MAPS1	-22.11761800	113.82087900
SLs	1_012_SL01	-22.11790800	113.82147200
SLf	1_012_SL01	-22.11721700	113.82176800
SLs	1_012_SL02	-22.11610400	113.82244300
SLf	1_012_SL02	-22.11677400	113.82228200
SLs	1_012_SL03	-22.11805300	113.82141600
SLf	1_012_SL03	-22.11730000	113.82113000
TVAs	1_012_TVA1	-22.11440000	113.82334000
TVAf	1_012_TVA1	-22.11779200	113.82189500
GR	1_013_GR01	-22.10448400	113.86971400
GR	1_013_GR02	-22.10320900	113.86829300
GR	1_013_GR03	-22.10288800	113.86910000
SLs	1_013_SL01	-22.10551700	113.86843700

SLf	1_013_SL01	-22.10466700	113.86855500
SLs	1_013_SL02	-22.10168800	113.86959900
SLf	1_013_SL02	-22.10086800	113.87002800
SLs	1_013_SL03	-22.09923100	113.87071200
SLf	1_013_SL03	-22.10002700	113.87061200
TVAs	1_013_TVA1	-22.10036900	113.86966900
TVAf	1_013_TVA1	-22.10388800	113.86871400
GR	1_014_GR01	-22.11882000	113.86754400
GR	1_014_GR02	-22.12200000	113.86683400
GR	1_014_GR03	-22.12055000	113.86629200
SLs	1_014_SL01	-22.11945700	113.86722700
SLf	1_014_SL01	-22.12039800	113.86713000
SLs	1_014_SL02	-22.12380000	113.86620000
SLf	1_014_SL02	-22.12320000	113.86640000
SLs	1_014_SL03	-22.12145200	113.86671500
SLf	1_014_SL03	-22.12064300	113.86703800
TVAs	1_014_TVA1	-22.12465200	113.86646100
TVAf	1_014_TVA1	-22.12093700	113.86727700
GR	1_015_GR1	-22.15638600	113.85114000
TVAs	1_015_TVA1	-22.15638600	113.85114000
TVAf	1_015_TVA1	-22.15973100	113.85029100
GR	1_016_GR01	-22.15481800	113.79576300
GR	1_016_GR02	-22.15913000	113.78644900
GR	1_016_GR03	-22.15718900	113.79199800
SLs	1_016_SL01	-22.15693700	113.79062100
SLf	1_016_SL01	-22.15731000	113.78990100
SLs	1_016_SL02	-22.15840000	113.78939000
SLf	1_016_SL02	-22.15815900	113.79045100
SLs	1_016_SL03	-22.15749000	113.79261800
SLf	1_016_SL03	-22.15791100	113.79175400
TVAs	1_016_TVA1	-22.15747000	113.78927600
TVAf	1_016_TVA1	-22.15690600	113.79246100
GR	1_017_GR01	-22.13960000	113.79420000
GR	1_017_GR02	-22.13617900	113.79519100
GR	1_017_GR03	-22.14181300	113.79351000
SLs	1_017_SL01	-22.14260000	113.79360000
SLf	1_017_SL01	-22.14300000	113.79320000
SLs	1_017_SL02	-22.14012400	113.79464900
SLf	1_017_SL02	-22.13906600	113.79528700
SLs	1_017_SL03	-22.14032100	113.79470100
SLf	1_017_SL03	-22.14098200	113.79461800
TVAs	1_017_TVA1	-22.14099300	113.79450200
TVAf	1_017_TVA1	-22.13978600	113.79273400
GR	1_018_GR01	-22.12348200	113.78760700
GR	1_018_GR02	-22.12430000	113.79580000
GR	1_018_GR03	-22.12547500	113.79717900
SLs	1_018_SL01	-22.11929000	113.79803160
SLf	1_018_SL01	-22.11982700	113.79809500
SLs	1_018_SL02	-22.12195800	113.79696400
SLf	1_018_SL02	-22.12090500	113.79734100
SLs	1_018_SL03	-22.12412000	113.79618400
SLf	1_018_SL03	-22.12325500	113.79660300

TVAs	1_018_TVA1	-22.11963000	113.79801300
TVAf	1_018_TVA1	-22.12031100	113.79408400
GR	1_019_GR01	-22.12619100	113.84039300
GR	1_019_GR02	-22.12530500	113.84043300
GR	1_019_GR03	-22.12642700	113.84030000
Plankton	1_019_MAPS1	-22.12690000	113.83950000
Plankton	1_019_MAPS1	-22.12570000	113.83970000
Plankton	1_019_MAPS2	-22.11900000	113.84240000
Plankton	1_019_MAPS2	-22.12090000	113.84180000
TVAs	1_019_TVA1	-22.12614200	113.83955800
TVAf	1_019_TVA1	-22.12401900	113.84071700
GR	1_064_GR01	-22.16299000	113.84160000
GR	1_064_GR02	-22.16700000	113.84000000
SLs	1_064_SL01	-22.16410000	113.84130000
SLf	1_064_SL01	-22.16470000	113.84090000
SLs	1_064_SL02	-22.16700000	113.83950000
SLf	1_064_SL02	-22.16640000	113.84010000
TVAs	1_064_TVA1	-22.16800000	113.83960000
TVAf	1_064_TVA1	-22.16440000	113.84120000
GR	1_065_GR01	-22.15200000	113.83810000
GR	1_065_GR02	-22.15290000	113.83750000
SLs	1_065_SL01	-22.15340000	113.83740000
SLf	1_065_SL01	-22.15380000	113.83730000
SLs	1_065_SL02	-22.15560000	113.83630000
SLf	1_065_SL02	-22.15500000	113.83670000
TVAs	1_065_TVA1	-22.15670000	113.83620000
TVAf	1_065_TVA1	-22.15250000	113.83710000
GR	1_066_GR01	-22.14580000	113.82780000
GR	1_066_GR02	-22.15120000	113.82470000
SLs	1_066_SL01	-22.14710000	113.82670000
SLf	1_066_SL01	-22.14780000	113.82610000
SLs	1_066_SL02	-22.15200000	113.82440000
SLf	1_066_SL02	-22.15250000	113.82410000
TVAs	1_066_TVA1	-22.15140000	113.82520000
TVAf	1_066_TVA1	-22.14790000	113.82630000
GR	1_067_GR01	-22.15030000	113.80470000
GR	1_067_GR02	-22.14970000	113.80440000
SLs	1_067_SL01	-22.15433000	113.80570000
SLf	1_067_SL01	-22.15470000	113.80590000
SLs	1_067_SL02	-22.15390000	113.80580000
SLf	1_067_SL02	-22.15322000	113.80570000
TVAs	1_067_TVA1	-22.15660000	113.80610000
TVAf	1_067_TVA1	-22.15250000	113.80540000
GR	1_068_GR01	-22.13250000	113.81540000
GR	1_068_GR02	-22.13160000	113.81580000
SLs	1_068_SL01	-22.12940000	113.81640000
SLf	1_068_SL01	-22.12870000	113.81620000
SLs	1_068_SL02	-22.12740000	113.81680000
SLf	1_068_SL02	-22.12810000	113.81640000
TVAs	1_068_TVA1	-22.12660000	113.81680000
TVAf	1_068_TVA1	-22.13080000	113.81660000
GR	1_069_GR01	-22.12480000	113.83030000

GR	1_069_GR02	-22.12360000	113.82910000
SLs	1_069_SL01	-22.12540000	113.82770000
SLf	1_069_SL01	-22.12620000	113.82780000
SLs	1_069_SL02	-22.12700000	113.82750000
SLf	1_069_SL02	-22.12650000	113.82810000
TVAs	1_069_TVA1	-22.12870000	113.82650000
TVAf	1_069_TVA1	-22.12560000	113.82800000
GR	1_070_GR01	-22.08800000	113.82370000
GR	1_070_GR02	-22.08780000	113.82430000
SLs	1_070_SL01	-22.08570000	113.82450000
SLf	1_070_SL01	-22.08510000	113.82510000
SLs	1_070_SL02	-22.08366000	113.82530000
SLf	1_070_SL02	-22.08430000	113.82510000
TVAs	1_070_TVA1	-22.08400000	113.82550000
TVAf	1_070_TVA1	-22.08675000	113.82450000
GR	1_071_GR01	-22.10280000	113.83860000
GR	1_071_GR02	-22.09930000	113.83860000
SLs	1_071_SL01	-22.10100000	113.83910000
SLf	1_071_SL01	-22.10020000	113.83910000
SLs	1_071_SL02	-22.09750000	113.83920000
SLf	1_071_SL02	-22.09810000	113.83900000
TVAs	1_071_TVA1	-22.09710000	113.83990000
TVAf	1_071_TVA1	-22.10070000	113.83900000
GR	1_072_GR01	-22.09890000	113.85160000
GR	1_072_GR02	-22.09270000	113.85380000
SLs	1_072_SL01	-22.09929000	113.85090000
SLf	1_072_SL01	-22.09850000	113.85130000
SLs	1_072_SL02	-22.09440000	113.85300000
SLf	1_072_SL02	-22.09380000	113.85330000
TVAs	1_072_TVA1	-22.09460000	113.85250000
TVAf	1_072_TVA1	-22.09810000	113.85160000
GR	1_073_GR01	-22.11140000	113.85630000
GR	1_073_GR02	-22.10540000	113.85710000
SLs	1_073_SL01	-22.11210000	113.85620000
SLf	1_073_SL01	-22.11140000	113.85610000
SLs	1_073_SL02	-22.10830000	113.85660000
SLf	1_073_SL02	-22.10770000	113.85660000
TVAs	1_073_TVA1	-22.10660000	113.85720000
TVAf	1_073_TVA1	-22.11060000	113.85650000
GR	1_074_GR01	-22.11780000	113.86210000
GR	1_074_GR02	-22.11150000	113.86310000
SLs	1_074_SL01	-22.11770000	113.86200000
SLf	1_074_SL01	-22.11670000	113.86220000
SLs	1_074_SL02	-22.11400000	113.86260000
SLf	1_074_SL02	-22.11320000	113.86290000
TVAs	1_074_TVA1	-22.11340000	113.86260000
TVAf	1_074_TVA1	-22.11700000	113.86240000
GR	1_075_GR01	-22.12420000	113.85210000
GR	1_075_GR02	-22.12380000	113.85220000
SLs	1_075_SL01	-22.12340000	113.85190000
SLf	1_075_SL01	-22.12287000	113.85200000
SLs	1_075_SL02	-22.12100000	113.85280000

SLf	1_075_SL02	-22.12180000	113.85250000
TVAs	1_075_TVA1	-22.12010000	113.85330000
TVAf	1_075_TVA1	-22.12010000	113.85210000
GR	1_076_GR01	-22.13400000	113.84520000
GR	1_076_GR02	-22.13470000	113.84570000
SLs	1_076_SL01	-22.13560000	113.84570000
SLf	1_076_SL01	-22.13720000	113.84570000
SLs	1_076_SL02	-22.13780000	113.84440000
SLf	1_076_SL02	-22.13637000	113.84490000
TVAs	1_076_TVA1	-22.13420000	113.84620000
TVAf	1_076_TVA1	-22.13760000	113.84510000
GR	2_020_GR01	-22.79982800	113.62631300
GR	2_020_GR02	-22.79362800	113.63058300
SLs	2_020_SL01	-22.80015800	113.62547400
SLf	2_020_SL01	-22.79977300	113.62583500
SLs	2_020_SL02	-22.79617900	113.62764700
SLf	2_020_SL02	-22.79567100	113.62857800
TVAs	2_020_TVA1	-22.79395500	113.63606900
TVAf	2_020_TVA1	-22.79777000	113.62698200
GR	2_021_GR01	-22.77107900	113.61619500
GR	2_021_GR02	-22.78018600	113.62034900
SLs	2_021_SL01	-22.77172000	113.61563500
SLf	2_021_SL01	-22.77252100	113.61611400
SLs	2_021_SL02	-22.77610100	113.61822600
SLf	2_021_SL02	-22.77672700	113.61856500
TVAs	2_021_TVA1	-22.77755000	113.61927600
TVAf	2_021_TVA1	-22.77379100	113.61731000
GR	2_022_GR01	-22.75840500	113.60758700
GR	2_022_GR02	-22.75845100	113.60788700
SLs	2_022_SL01	-22.75809300	113.60811200
SLf	2_022_SL01	-22.75924500	113.60881500
SLs	2_022_SL02	-22.76065500	113.60912800
SLf	2_022_SL02	-22.76014000	113.60890100
TVAs	2_022_TVA1	-22.76135000	113.60987800
TVAf	2_022_TVA1	-22.75847200	113.60816000
GR	2_023_GR01	-22.73580700	113.60070000
GR	2_023_GR02	-22.73837400	113.60136100
SLs	2_023_SL01	-22.73935400	113.60174800
SLf	2_023_SL01	-22.73998600	113.60253600
SLs	2_023_SL02	-22.74145700	113.60297300
SLf	2_023_SL02	-22.74051100	113.60287300
TVAs	2_023_TVA1	-22.74105100	113.60231100
TVAf	2_023_TVA1	-22.73782000	113.60049300
GR	2_024_GR01	-22.74912800	113.58586800
GR	2_024_GR02	-22.75054000	113.58841500
SLs	2_024_SL01	-22.75126000	113.58766600
SLf	2_024_SL01	-22.75178800	113.58788000
SLs	2_024_SL02	-22.75462900	113.59034600
SLf	2_024_SL02	-22.75341400	113.58970900
TVAs	2_024_TVA1	-22.75410900	113.58968200
TVAf	2_024_TVA1	-22.75117600	113.58819600
GR	2_025_GR01	-22.76599800	113.59770100

GR	2_025_GR02	-22.77188000	113.59969300
SLs	2_025_SL01	-22.76790800	113.59836400
SLf	2_025_SL01	-22.76873900	113.59854300
SLs	2_025_SL02	-22.77104000	113.60003200
SLf	2_025_SL02	-22.77125000	113.59957200
TVAs	2_025_TVA1	-22.77224800	113.59882800
TVAf	2_025_TVA1	-22.76880300	113.59770000
GR	2_026_GR01	-22.79089200	113.61020800
GR	2_026_GR02	-22.79740000	113.61320000
SLs	2_026_SL01	-22.79464700	113.61168400
SLf	2_026_SL01	-22.79411900	113.61151000
SLs	2_026_SL02	-22.79268700	113.61095100
SLf	2_026_SL02	-22.79320300	113.61111000
TVAs	2_026_TVA1	-22.79240000	113.61100000
TVAf	2_026_TVA1	-22.79560000	113.61230000
GR	2_027_GR01	-22.81421800	113.60271900
GR	2_027_GR02	-22.81498000	113.60252900
SLs	2_027_SL01	-22.81321200	113.60336400
SLf	2_027_SL01	-22.81238600	113.60268400
TVAs	2_027_TVA1	-22.80907900	113.60009900
TVAf	2_027_TVA1	-22.81156600	113.60260000
GR	2_028_GR01	-22.79116700	113.59338000
GR	2_028_GR02	-22.79006600	113.59423200
SLs	2_028_SL01	-22.79144600	113.59488500
SLf	2_028_SL01	-22.79193200	113.59451200
SLs	2_028_SL02	-22.79364600	113.59329100
SLf	2_028_SL02	-22.79295900	113.59355000
TVAs	2_028_TVA1	-22.79606900	113.59350000
TVAf	2_028_TVA1	-22.79299000	113.59319600
GR	2_029_GR01	-22.76870000	113.58050000
GR	2_029_GR02	-22.77820000	113.58260000
SLs	2_029_SL01	-22.76920000	113.57620000
SLf	2_029_SL01	-22.77020000	113.57650000
SLs	2_029_SL02	-22.77030000	113.57650000
SLf	2_029_SL02	-22.77570000	113.57830000
TVAs	2_029_TVA1	-22.77564500	113.58106600
TVAf	2_029_TVA1	-22.77250000	113.57960000
GR	2_030_GR01	-22.74730000	113.56830000
GR	2_030_GR02	-22.74880000	113.56970000
SLs	2_030_SL01	-22.75050000	113.56940000
SLf	2_030_SL01	-22.75100000	113.56970000
SLs	2_030_SL02	-22.75170000	113.57110000
SLf	2_030_SL02	-22.75090000	113.57080000
TVAs	2_030_TVA1	-22.75140000	113.57080000
TVAf	2_030_TVA1	-22.74870000	113.56850000
GR	2_031_GR01	-22.76620000	113.55820000
GR	2_031_GR02	-22.76010000	113.55170000
SLs	2_031_SL01	-22.76450000	113.55820000
SLf	2_031_SL01	-22.76390000	113.55760000
SLs	2_031_SL02	-22.76130000	113.55440000
SLf	2_031_SL02	-22.76080000	113.55410000
TVAs	2_031_TVA1	-22.76160000	113.55490000

TVAf	2_031_TVA1	-22.76450000	113.55730000
GR	2_032_GR01	-22.79060000	113.56960000
GR	2_032_GR02	-22.78300000	113.56780000
SLs	2_032_SL01	-22.79020000	113.56990000
SLf	2_032_SL01	-22.78960000	113.56970000
SLs	2_032_SL02	-22.78570000	113.56840000
SLf	2_032_SL02	-22.78550000	113.56800000
TVAs	2_032_TVA1	-22.78520000	113.56780000
TVAf	2_032_TVA1	-22.78870000	113.56890000
GR	2_033_GR01	-22.81174800	113.57890000
GR	2_033_GR02	-22.80320000	113.57800000
SLs	2_033_SL01	-22.81130000	113.57820000
SLf	2_033_SL01	-22.81032000	113.57840000
SLs	2_033_SL02	-22.80640000	113.57810000
SLf	2_033_SL02	-22.80580000	113.57800000
TVAs	2_033_TVA1	-22.80700000	113.57750000
TVAf	2_033_TVA1	-22.81070000	113.57829100
GR	2_034_GR01	-22.84298900	113.51102000
GR	2_034_GR02	-22.84820000	113.51480000
SLs	2_034_SL01	-22.85288000	113.51510000
SLf	2_034_SL01	-22.85340000	113.51550000
SLs	2_034_SL02	-22.85390000	113.51520000
SLf	2_034_SL02	-22.85380000	113.51500000
TVAs	2_034_TVA1	-22.85711000	113.51290000
TVAf	2_034_TVA1	-22.84970000	113.51450000
GR	2_035_GR01	-22.82550000	113.52040000
GR	2_035_GR02	-22.83500000	113.52210000
SLs	2_035_SL01	-22.83150000	113.52180000
SLf	2_035_SL01	-22.83219000	113.52204000
SLs	2_035_SL02	-22.83273000	113.52220000
SLf	2_035_SL02	-22.83190000	113.52190000
TVAs	2_035_TVA1	-22.83116000	113.52040000
TVAf	2_035_TVA1	-22.82810000	113.52090000
GR	2_036_GR01	-22.80555000	113.52020000
GR	2_036_GR02	-22.80780000	113.51900000
SLs	2_036_SL01	-22.80903000	113.52127000
SLs	2_036_SL02	-22.81090000	113.52130000
SLf	2_036_SL02	-22.81055000	113.52100000
TVAs	2_036_TVA1	-22.80950000	113.52050000
TVAf	2_036_TVA1	-22.80676000	113.52060000
GR	2_037_GR01	-22.78654000	113.53040000
GR	2_037_GR02	-22.77970000	113.52780000
SLs	2_037_SL01	-22.78670000	113.53111000
SLf	2_037_SL01	-22.78620000	113.53060000
SLs	2_037_SL02	-22.78283000	113.52830000
SLf	2_037_SL02	-22.78200000	113.52810000
TVAs	2_037_TVA1	-22.78140000	113.52810000
TVAf	2_037_TVA1	-22.78470000	113.52940000
GR	2_038_GR01	-22.84374000	113.53544000
GR	2_038_GR02	-22.84521000	113.53347000
SLs	2_038_SL01	-22.84240000	113.53800000
SLf	2_038_SL01	-22.84170000	113.53880000

SLs	2_038_SL02	-22.84208000	113.53943000
SLf	2_038_SL02	-22.84240000	113.53850000
TVAs	2_038_TVA1	-22.84080000	113.54080000
TVAf	2_038_TVA1	-22.84227000	113.53720000
GR	2_039_GR01	-22.81860000	113.53790000
GR	2_039_GR02	-22.82000000	113.53830000
SLs	2_039_SL01	-22.82080000	113.54020000
SLf	2_039_SL01	-22.82130000	113.54050000
SLs	2_039_SL02	-22.82250000	113.54130000
SLf	2_039_SL02	-22.82230000	113.54090000
TVAs	2_039_TVA1	-22.82260000	113.54162000
TVAf	2_039_TVA1	-22.82020000	113.53920000
GR	2_040_GR01	-22.79640000	113.53333000
GR	2_040_GR02	-22.79780000	113.53690000
SLs	2_040_SL01	-22.79720000	113.53580000
SLf	2_040_SL01	-22.79770000	113.53650000
SLs	2_040_SL02	-22.80120000	113.53810000
SLf	2_040_SL02	-22.80040000	113.53770000
TVAs	2_040_TVA1	-22.80060000	113.53700000
TVAf	2_040_TVA1	-22.79750000	113.53590000
GR	2_041_GR01	-22.75970000	113.53170000
GR	2_041_GR02	-22.76100000	113.53410000
SLs	2_041_SL01	-22.76180000	113.53560000
SLf	2_041_SL01	-22.76240000	113.53600000
SLs	2_041_SL02	-22.76350000	113.53690000
SLf	2_041_SL02	-22.76270000	113.53630000
TVAs	2_041_TVA1	-22.76340000	113.53710000
TVAf	2_041_TVA1	-22.76060000	113.53450000
GR	2_042_GR01	-22.76120000	113.67530000
GR	2_042_GR02	-22.76280000	113.67580000
SLs	2_042_SL01	-22.76250000	113.67570000
SLf	2_042_SL01	-22.76160000	113.67570000
SLs	2_042_SL02	-22.75980000	113.67650000
SLf	2_042_SL02	-22.76060000	113.67630000
TVAs	2_042_TVA1	-22.75720000	113.67610000
TVAf	2_042_TVA1	-22.76060000	113.67570000
GR	2_043_GR01	-22.74280000	113.66950000
GR	2_043_GR02	-22.74250000	113.66880000
SLs	2_043_SL01	-22.74290000	113.66890000
SLf	2_043_SL01	-22.74363000	113.66910000
SLs	2_043_SL02	-22.74570000	113.66870000
SLf	2_043_SL02	-22.74450000	113.66880000
TVAs	2_043_TVA1	-22.74710000	113.66810000
TVAf	2_043_TVA1	-22.74350000	113.66860000
GR	2_044_GR01	-22.73370000	113.65400000
GR	2_044_GR02	-22.73390000	113.65600000
SLs	2_044_SL01	-22.73340000	113.65560000
SLf	2_044_SL01	-22.73330000	113.65630000
SLs	2_044_SL02	-22.73200000	113.65820000
SLf	2_044_SL02	-22.73250000	113.65730000
TVAs	2_044_TVA1	-22.73160000	113.65750000
TVAf	2_044_TVA1	-22.73320000	113.65500000

GR	2_045_GR01	-22.77040000	113.65820000
GR	2_045_GR02	-22.77060000	113.65800000
SLs	2_045_SL01	-22.77020000	113.65800000
SLf	2_045_SL01	-22.76970000	113.65820000
SLs	2_045_SL02	-22.76900000	113.65860000
SLf	2_045_SL02	-22.76980000	113.65810000
TVAs	2_045_TVA1	-22.76660000	113.65820000
TVAf	2_045_TVA1	-22.77040000	113.65830000
GR	2_046_GR01	-22.78190000	113.66960000
GR	2_046_GR02	-22.78410000	113.66570000
SLs	2_046_SL01	-22.78290000	113.66610000
SLf	2_046_SL01	-22.78270000	113.66680000
SLs	2_046_SL02	-22.78240000	113.66860000
SLf	2_046_SL02	-22.78250000	113.66770000
TVAs	2_046_TVA1	-22.78230000	113.66470000
TVAf	2_046_TVA1	-22.78260000	113.66740000
GR	2_047_GR01	-22.77590000	113.67770000
GR	2_047_GR02	-22.77670000	113.67960000
SLs	2_047_SL01	-22.77650000	113.67990000
SLf	2_047_SL01	-22.77680000	113.68030000
SLs	2_047_SL02	-22.77580000	113.68190000
SLf	2_047_SL02	-22.77610000	113.68110000
TVAs	2_047_TVA1	-22.77530000	113.68240000
TVAf	2_047_TVA1	-22.77660000	113.67860000
GR	2_048_GR01	-22.79570000	113.65190000
GR	2_048_GR02	-22.79510000	113.64840000
SLs	2_048_SL01	-22.79450000	113.64870000
SLf	2_048_SL01	-22.79370000	113.64860000
SLs	2_048_SL02	-22.79270000	113.64850000
SLf	2_048_SL02	-22.79340000	113.64840000
TVAs	2_048_TVA1	-22.78710000	113.64820000
TVAf	2_048_TVA1	-22.79130000	113.64710000
GR	2_049_GR01	-22.77650000	113.63420000
GR	2_049_GR02	-22.77730000	113.63500000
SLs	2_049_SL01	-22.77710000	113.63610000
SLf	2_049_SL01	-22.77830000	113.63640000
SLs	2_049_SL02	-22.78020000	113.63700000
SLf	2_049_SL02	-22.77960000	113.63650000
TVAs	2_049_TVA1	-22.77940000	113.63570000
TVAf	2_049_TVA1	-22.77680000	113.63570000
GR	2_050_GR01	-22.76180000	113.62830000
GR	2_050_GR02	-22.76150000	113.62990000
SLs	2_050_SL01	-22.76250000	113.62950000
SLf	2_050_SL01	-22.76280000	113.62980000
SLs	2_050_SL02	-22.76440000	113.63090000
SLf	2_050_SL02	-22.76420000	113.63090000
TVAs	2_050_TVA1	-22.76480000	113.63210000
TVAf	2_050_TVA1	-22.76250000	113.62910000
GR	2_051_GR01	-22.73860000	113.63920000
GR	2_051_GR02	-22.74320000	113.64599000
SLs	2_051_SL01	-22.74370000	113.64040000
SLf	2_051_SL01	-22.74360000	113.64190000

SLs	2_051_SL02	-22.74230800	113.64880000
SLf	2_051_SL02	-22.74333000	113.64760000
TVAs	2_051_TVA1	-22.73890000	113.64560000
TVAf	2_051_TVA1	-22.74237000	113.64470000
TVAs	2_052_TVA1	-22.72270000	113.64130000
GR	2_052_GR01	-22.71910000	113.64820000
GR	2_053_GR01	-22.72420000	113.63110000
GR	2_053_GR02	-22.72450000	113.63090000
SLs	2_053_SL01	-22.72440000	113.63110000
SLf	2_053_SL01	-22.72460000	113.63150000
SLs	2_053_SL02	-22.72460000	113.63150000
SLf	2_053_SL02	-22.72360000	113.63080000
TVAs	2_053_TVA1	-22.72480000	113.63230000
TVAf	2_053_TVA1	-22.72130000	113.63200000
GR	2_054_GR01	-22.72980000	113.61700000
GR	2_054_GR02	-22.73010000	113.61600000
SLs	2_054_SL01	-22.72860000	113.61660000
SLf	2_054_SL01	-22.72790000	113.61650000
SLs	2_054_SL02	-22.72704000	113.61651000
SLf	2_054_SL02	-22.72790000	113.61630000
TVAs	2_054_TVA1	-22.72990000	113.61640000
TVAf	2_054_TVA1	-22.72630000	113.61720000
GR	2_055_GR01	-22.74810000	113.62440000
GR	2_055_GR02	-22.74590000	113.61920000
SLs	2_055_SL01	-22.74259800	113.62360000
SLf	2_055_SL01	-22.74470000	113.62170000
SLs	2_055_SL02	-22.74890000	113.62640000
SLf	2_055_SL02	-22.74730000	113.62610000
TVAs	2_055_TVA1	-22.74710000	113.62510000
TVAf	2_055_TVA1	-22.74340000	113.62500000
GR	2_056_GR01	-22.77500000	113.55220000
GR	2_056_GR02	-22.78020000	113.54550000
SLs	2_056_SL01	-22.77470000	113.54430000
SLf	2_056_SL01	-22.78060000	113.54680000
SLs	2_056_SL02	-22.78220000	113.54860000
SLf	2_056_SL02	-22.78150000	113.54770000
TVAs	2_056_TVA1	-22.78019000	113.54690000
TVAf	2_056_TVA1	-22.78240000	113.54480000
GR	2_057_GR01	-22.80280000	113.55370000
GR	2_057_GR02	-22.80330000	113.55470000
SLs	2_057_SL01	-22.80040000	113.55290000
SLf	2_057_SL01	-22.79980000	113.55260000
SLs	2_057_SL02	-22.79970000	113.55300000
SLf	2_057_SL02	-22.80070000	113.55340000
TVAs	2_057_TVA1	-22.80240000	113.55350000
TVAf	2_057_TVA1	-22.79870000	113.55310000
GR	2_058_GR01	-22.82520000	113.56790000
GR	2_058_GR02	-22.82350000	113.56570000
SLs	2_058_SL01	-22.82500000	113.56790000
SLf	2_058_SL01	-22.82550000	113.56830000
SLs	2_058_SL02	-22.82600000	113.56810000
SLf	2_058_SL02	-22.82530000	113.56760000

TVAs	2_058_TVA1	-22.82700000	113.56850000
TVAf	2_058_TVA1	-22.82320000	113.56800000
GR	2_059_GR01	-22.75790000	113.65370000
GR	2_059_GR02	-22.76000000	113.65470000
SLs	2_059_SL01	-22.75650000	113.65660000
SLf	2_059_SL01	-22.75640000	113.65590000
SLs	2_059_SL02	-22.76250000	113.65370000
SLf	2_059_SL02	-22.76190000	113.65430000
TVAs	2_059_TVA1	-22.75860000	113.65110000
TVAf	2_059_TVA1	-22.75840000	113.65600000
GR	2_060_GR01	-22.71100000	113.64050000
GR	2_060_GR01	-22.71910000	113.64820000
GR	2_060_GR02	-22.70980000	113.64120000
GR	2_060_GR02	-22.70980000	113.64120000
TVAs	2_060_TVA1	-22.71490000	113.64430000
TVAf	2_060_TVA1	-22.71188000	113.64230000
TVAs	2_061_TVA1	-22.75180000	113.62830000
TVAf	2_061_TVA1	-22.75340000	113.62210000
TVAs	2_062_TVA1	-22.74300000	113.65190000
TVAf	2_062_TVA1	-22.74296000	113.65060000
GR	2_063_GR01	-22.76200000	113.60460000
GR	2_063_GR02	-22.75480000	113.60300000
TVAs	2_063_TVA1	-22.76090000	113.60400000
TVAf	2_063_TVA1	-22.75670000	113.60340000
TVAs	2_063_TVA2	-22.76294000	113.60600000
TVAf	2_063_TVA2	-22.76298000	113.60280000
SLs	2-027_SL02	-22.81074300	113.60195700
SLf	2-027_SL02	-22.81154600	113.60230000
GR	3_077_GR1	-23.76700000	113.21930000
GR	3_077_GR2	-23.76790000	113.21780000
SLf	3_077_SL1f	-23.77046667	113.21723333
SLs	3_077_SL1s	-23.76968333	113.21781667
SLf	3_077_SL2f	-23.77123333	113.21693333
SLs	3_077_SL2s	-23.77201667	113.21663333
TVAf	3_077_TVA1f	-23.76931700	113.21861700
TVAs	3_077_TVA1s	-23.77221700	113.21700000
GR	3_078_GR1	-23.74000000	113.24150000
GR	3_078_GR2	-23.74020000	113.24120000
SLf	3_078_SL1f	-23.74418333	113.23963333
SLs	3_078_SL1s	-23.74355000	113.23990000
SLf	3_078_SL2f	-23.74226667	113.24055000
SLs	3_078_SL2s	-23.74306667	113.24015000
TVAf	3_078_TVA1f	-23.74153300	113.24081700
TVAs	3_078_TVA1s	-23.74445000	113.23926700
GR	3_079_GR1	-23.72036516	113.26163849
GR	3_079_GR2	-23.71160000	113.26090000
SLf	3_079_SL1f	-23.71495000	113.25896667
SLs	3_079_SL1s	-23.71435000	113.25945000
SLf	3_079_SL2f	-23.71578333	113.25858333
SLs	3_079_SL2s	-23.71633333	113.25825000
TVAf	3_079_TVA1f	-23.71436700	113.25940000
TVAs	3_079_TVA1s	-23.73481756	113.26369121

GR	3_080_GR1	-23.73913525	113.26194350
GR	3_080_GR2	-23.73882861	113.26136337
SLf	3_080_SL1f	-23.73741667	113.26230000
SLs	3_080_SL1s	-23.73806667	113.26195000
SLf	3_080_SL2f	-23.73709768	113.26238894
SLs	3_080_SL2s	-23.73645064	113.26277665
TVAf	3_080_TVA1f	-23.73836700	113.26205000
TVAs	3_080_TVA1s	-23.73570852	113.26319521
GR	3_081_GR1	-23.77123867	113.24226023
GR	3_081_GR2	-23.76858259	113.24341717
SLf	3_081_SL1f	-23.76622780	113.24372807
SLs	3_081_SL1s	-23.76638220	113.24369112
SLf	3_081_SL2f	-23.76692398	113.24410943
SLs	3_081_SL2s	-23.76625304	113.24434867
TVAf	3_081_TVA1f	-23.76855151	113.24263995
TVAs	3_081_TVA1s	-23.76445465	113.24404456
GR	3_082_GR1	-23.79363419	113.25389102
GR	3_082_GR2	-23.79354246	113.25551946
SLf	3_082_SL1f	-23.79008981	113.25541813
SLs	3_082_SL1s	-23.79067834	113.25517942
SLf	3_082_SL2f	-23.79113460	113.25510929
SLs	3_082_SL2s	-23.79016793	113.25525925
TVAf	3_082_TVA1f	-23.79285154	113.25416046
TVAs	3_082_TVA1s	-23.78865196	113.25559524
GR	3_083_GR1	-23.73568648	113.28239018
GR	3_083_GR2	-23.75783978	113.26615733
SLf	3_083_SL1f	-23.73190592	113.28509421
SLs	3_083_SL1s	-23.73219445	113.28488353
SLf	3_083_SL2f	-23.73196775	113.28552935
SLs	3_083_SL2s	-23.73149336	113.28597167
TVAf	3_083_TVA1f	-23.73353817	113.28416562
TVAs	3_083_TVA1s	-23.72980319	113.28729794
GR	3_084_GR1	-23.76393298	113.26482084
GR	3_084_GR2	-23.76089225	113.26562959
SLf	3_084_SL1f	-23.75971612	113.26635600
SLs	3_084_SL1s	-23.75863916	113.26547705
SLf	3_084_SL2f	-23.75925103	113.26610847
SLs	3_084_SL2s	-23.75880000	113.26630000
TVAf	3_084_TVA1f	-23.76294812	113.26489084
TVAs	3_084_TVA1s	-23.75873824	113.26588706
GR	3_085_GR1	-23.79510871	113.42010301
GR	3_085_GR2	-23.79325932	113.41453645
SLf	3_085_SL1f	-23.79468257	113.41912945
SLs	3_085_SL1s	-23.79483989	113.41979439
SLf	3_085_SL2f	-23.79359819	113.41565198
SLs	3_085_SL2s	-23.79384206	113.41611320
TVAf	3_085_TVA1f	-23.79477269	113.41942948
TVAs	3_085_TVA1s	-23.79288875	113.41473830
GR	3_086_GR1	-23.82341555	113.40649791
GR	3_086_GR2	-23.82028058	113.40760756
SLf	3_086_SL1f	-23.82106795	113.40720332
SLs	3_086_SL1s	-23.82170203	113.40707746

SLf	3_086_SL2f	-23.82371459	113.40706181
SLs	3_086_SL2s	-23.82299787	113.40700203
TVAf	3_086_TVA1f	-23.82283632	113.40663182
TVAs	3_086_TVA1s	-23.81854868	113.40752920
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GR	3_087_GR2	-23.85129393	113.39243620
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SLs	3_087_SL1s	-23.85658514	113.39085872
SLf	3_087_SL2f	-23.85231762	113.39226816
SLs	3_087_SL2s	-23.85291878	113.39226362
TVAf	3_087_TVA1f	-23.85715247	113.39078006
TVAs	3_087_TVA1s	-23.85281806	113.39162634
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SLf	3_088_SL2f	-23.82843778	113.37678180
SLs	3_088_SL2s	-23.82770446	113.37734846
TVAf	3_088_TVA1f	-23.82298958	113.37991777
TVAs	3_088_TVA1s	-23.82697984	113.37773945
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GR	3_089_GR2	-23.79725124	113.39067587
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SLf	3_089_SL2f	-23.79796754	113.39033402
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TVAf	3_089_TVA1f	-23.79390217	113.39119838
TVAs	3_089_TVA1s	-23.79815308	113.39027454
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GR	3_090_GR2	-23.83340962	113.35267901
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SLs	3_090_SL2s	-23.83568549	113.35180222
TVAf	3_090_TVA1f	-23.83776652	113.35073642
TVAs	3_090_TVA1s	-23.83321636	113.35166917
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GR	3_091_GR2	-23.81281903	113.35027352
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TVAs	3_092_TVA1s	-23.79530393	113.35613040

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GR	3_093_GR2	-23.77307691	113.37845930
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SLs	3_093_SL1s	-23.77229004	113.37865794
SLf	3_093_SL2f	-23.77406314	113.37798327
SLs	3_093_SL2s	-23.77454066	113.37773645
TVAf	3_093_TVA1f	-23.77149691	113.37885131
TVAs	3_093_TVA1s	-23.77562633	113.37697466
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GR	3_094_GR2	-23.81640783	113.46381926
SLf	3_094_SL1f	-23.81713325	113.46352144
SLs	3_094_SL1s	-23.81759381	113.46301408
SLf	3_094_SL2f	-23.81575839	113.46506800
SLs	3_094_SL2s	-23.81540972	113.46565913
TVAf	3_094_TVA1f	-23.81731093	113.46347837
TVAs	3_094_TVA1s	-23.81440130	113.46734263
GR	3_095_GR1	-23.84381393	113.45264797
GR	3_095_GR2	-23.84241121	113.45361685
SLf	3_095_SL1f	-23.84260215	113.45369904
SLs	3_095_SL1s	-23.84336835	113.45327599
SLf	3_095_SL2f	-23.84136177	113.45400983
SLs	3_095_SL2s	-23.84051609	113.45419656
TVAf	3_095_TVA1f	-23.84347269	113.45302251
TVAs	3_095_TVA1s	-23.83907917	113.45492652
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GR	3_096_GR2	-23.87616781	113.43402782
SLf	3_096_SL1f	-23.87210826	113.43430115
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SLs	3_096_SL2s	-23.86907527	113.43450526
TVAf	3_096_TVA1f	-23.87304140	113.43394511
TVAs	3_096_TVA1s	-23.86834254	113.43478044
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GR	3_097_GR2	-23.88220718	113.45940766
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SLs	3_097_SL2s	-23.88346178	113.45884435
TVAf	3_097_TVA1f	-23.88406598	113.45889447
TVAs	3_097_TVA1s	-23.87923406	113.46021961
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GR	3_098_GR2	-23.85979201	113.45946667
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TVAs	3_098_TVA1s	-23.85893096	113.46000975
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GR	3_099_GR2	-23.85183775	113.48518117
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TVAs	3_099_TVA1s	-23.85061822	113.48677014
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GR	3_100_GR2	-23.83016000	113.49700000
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SLs	3_100_SL2s	-23.83259319	113.49486577
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TVAs	3_100_TVA1s	-23.83343490	113.49454237
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GR	3_101_GR2	-23.83760087	113.47904124
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SLs	3_101_SL2s	-23.83423298	113.47800477
TVAf	3_101_TVA1f	-23.83548287	113.47934150
TVAs	3_101_TVA1s	-23.83286720	113.47882573
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GR	3_102_GR2	-23.85054906	113.42133876
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SLs	3_102_SL1s	-23.84242676	113.42187533
SLf	3_102_SL2f	-23.84790863	113.42203297
SLs	3_102_SL2s	-23.84712720	113.42218927
TVAf	3_102_TVA1f	-23.84279170	113.42213207
TVAs	3_102_TVA1s	-23.84754927	113.42186374
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GR	3_103_GR2	-23.81895378	113.43577414
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SLs	3_103_SL2s	-23.81718136	113.43852309
TVAf	3_103_TVA1f	-23.82021470	113.43640644
TVAs	3_103_TVA1s	-23.81646742	113.43922912
GR	3_104_GR1	-23.80989133	113.32519015
GR	3_104_GR2	-23.80464714	113.32303999
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SLs	3_104_SL1s	-23.80797372	113.32519769
SLf	3_104_SL2f	-23.80296086	113.32515226
SLs	3_104_SL2s	-23.80227730	113.32496681
TVAf	3_104_TVA1f	-23.80708389	113.32503119
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GR	3_105_GR2	-23.77153742	113.34347086
SLf	3_105_SL1f	-23.77133266	113.34369018
SLs	3_105_SL1s	-23.77201604	113.34326280
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SLs	3_105_SL2s	-23.76760352	113.34595808
TVAf	3_105_TVA1f	-23.77135223	113.34362849
TVAs	3_105_TVA1s	-23.76744648	113.34632507

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GR	3_106_GR2	-23.78466696	113.31808668
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TVAf	3_106_TVA1f	-23.78395454	113.31925944
TVAs	3_106_TVA1s	-23.77986816	113.32094436
GR	3_107_GR1	-23.75601600	113.32255251
GR	3_107_GR2	-23.75223064	113.32381566
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SLs	3_107_SL2s	-23.74859834	113.32508583
TVAf	3_107_TVA1f	-23.75277365	113.32359415
TVAs	3_107_TVA1s	-23.74840562	113.32562381
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GR	3_108_GR2	-23.75967130	113.29532328
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TVAs	3_108_TVA1s	-23.75543063	113.29716565
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GR	3_109_GR2	-23.81094870	113.29458107
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SLs	3_109_SL1s	-23.81199637	113.29418310
SLf	3_109_SL2f	-23.80952270	113.29536648
SLs	3_109_SL2s	-23.80891922	113.29568454
TVAf	3_109_TVA1f	-23.81164747	113.29473918
TVAs	3_109_TVA1s	-23.80756261	113.29703707
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SLf	3_110_SL2f	-23.78133003	113.28346415
SLs	3_110_SL2s	-23.78074144	113.28398769
TVAf	3_110_TVA1f	-23.78366835	113.28154845
TVAs	3_110_TVA1s	-23.78064170	113.28492897
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GR	3_111_GR2	-23.80872468	113.31613170
GR	3_111_GR3	-23.80947372	113.32062957
TVAf	3_111_TVA1f	-23.80941700	113.31823300
TVAs	3_111_TVA1s	-23.80846700	113.31206700
GR	3_112_GR1	-23.79845871	113.31618798
GR	3_112_GR2	-23.79905399	113.31437137
GR	3_112_GR3	-23.80648616	113.31972623
TVAf	3_112_TVA1f	-23.80099346	113.31710926
TVAs	3_112_TVA1s	-23.80563396	113.31891324
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GR	3_113_GR2	-23.78850767	113.33575516

TVAf	3_113_TVA1f	-23.78308954	113.32961674
TVAs	3_113_TVA1s	-23.78912009	113.33524365
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GR	3_114_GR2	-23.79533357	113.34376614
TVAf	3_114_TVA1f	-23.79434810	113.34915733
TVAs	3_114_TVA1s	-23.79573996	113.34412186
GR	3_115_GR1	-23.78196089	113.34548290
GR	3_115_GR2	-23.78252617	113.34060666
TVAf	3_115_TVA1f	-23.78197658	113.34484500
TVAs	3_115_TVA1s	-23.78320681	113.34004884
GR	3_116_GR1	-23.82085379	113.37433705
GR	3_116_GR2	-23.82130370	113.37417991
TVAf	3_116_TVA1f	-23.82075846	113.37490200
TVAs	3_116_TVA1s	-23.81640039	113.37353608
GR	3_117_GR1	-23.80818932	113.36976690
GR	3_117_GR2	-23.80339727	113.37250201
GR	3_117_GR3	-23.80177446	113.37235658
TVAf	3_117_TVA1f	-23.80619976	113.37012307
TVAs	3_117_TVA1s	-23.80283372	113.37276391
GR	3_118_GR1	-23.78408950	113.39068025
GR	3_118_GR2	-23.78372103	113.38748117
TVAf	3_118_TVA1f	-23.78597753	113.39025273
TVAs	3_118_TVA1s	-23.78310959	113.38706702
GR	3_119_GR1	-23.84912017	113.49972493
GR	3_119_GR2	-23.84779654	113.50101472
TVAf	3_119_TVA1f	-23.84853706	113.50069081
TVAs	3_119_TVA1s	-23.84656165	113.50205747
GR	3_120_GR1	-23.85387296	113.49955939
TVAs	3_120_TVA1f	-23.85309462	113.50083386
TVAs	3_120_TVA1s	-23.85046661	113.50476266
GR	3_121_GR1	-23.86181477	113.48634493
TVAf	3_121_TVA1f	-23.86148086	113.48718958
TVAs	3_121_TVA1s	-23.85817020	113.49010025
GR	3_122_GR1	-23.60250848	113.60286870
TVAf	3_122_TVA1f	-23.60224304	113.60168515
TVAs	3_122_TVA1s	-23.60081325	113.59778964
GR	4_123_GR1	-22.81286009	113.69829009
TVAf	4_123TVA1f	-22.81352014	113.69719646
TVAs	4_123TVA1s	-22.81452005	113.69451986
GR	4_124_GR1	-22.82617270	113.69824976
TVAf	4_124TVA1f	-22.82533114	113.69789674
TVAs	4_124TVA1s	-22.82451958	113.69892012
GR	4_125_GR1	-22.83465862	113.69880430
TVAf	4_125TVA1f	-22.83538103	113.69989716
TVAs	4_125TVA1s	-22.83790171	113.70294505
GR	4_126_GR1	-22.82776476	113.68467935
TVAf	4_126TVA1f	-22.82944390	113.68493303
TVAs	4_126TVA1s	-22.83062463	113.68760342
GR	4_127_GR1	-22.83544666	113.68625240
TVAf	4_127TVA1f	-22.83727821	113.68701394
TVAs	4_127TVA1s	-22.84065756	113.68997545
GR	4_128_GR1	-22.83887388	113.68156255

TVAf	4_128TVA1f	-22.84084545	113.68222898
TVAs	4_128TVA1s	-22.84406805	113.68309110
GR	4_129_GR1	-22.82879816	113.67467251
TVAf	4_129TVA1f	-22.83055229	113.67484875
TVAs	4_129TVA1s	-22.83282289	113.67644754
GR	4_130_GR1	-22.81804868	113.66901106
TVAf	4_130TVA1f	-22.82063516	113.66942073
TVAs	4_130TVA1s	-22.82196189	113.67267588
GR	4_131_GR1	-22.81697784	113.67766062
TVAf	4_131TVA1f	-22.81879607	113.67838599
TVAs	4_131TVA1s	-22.82105127	113.68204439
GR	5_132_GR1	-21.59506058	114.30370206
GR	5_132_GR2	-21.59540000	114.30320000
SLf	5_132_SL1f	-21.59693699	114.30464766
SLs	5_132_SL1s	-21.59721453	114.30479476
TVAf	5_132_TVA1f	-21.59606321	114.30510277
TVAs	5_132_TVA1s	-21.59489786	114.30398991
GR	5_133_GR1	-21.59794836	114.31071070
SLf	5_133_SL1f	-21.59918816	114.31226568
SLs	5_133_SL1s	-21.59947588	114.31262881
TVAf	5_133_TVA1f	-21.60090111	114.31336724
TVAs	5_133_TVA1s	-21.59753300	114.31155000
GR	5_134_GR1	-21.60024662	114.32531948
SLf	5_134_SL1f	-21.59694136	114.32017589
SLs	5_134_SL1s	-21.59718607	114.32047049
TVAf	5_134_TVA1f	-21.59935115	114.32336308
TVAs	5_134_TVA1s	-21.59653860	114.31955627
TVAf	5_135_TVA1f	-21.58958140	114.31506699
TVAs	5_135_TVA1s	-21.59700852	114.30320152
GR	5_136_GR1	-21.60143686	114.34562692
TVAf	5_136_TVA1f	-21.60037947	114.34653133
TVAs	5_136_TVA1s	-21.60402086	114.34367135
GR	5_137_GR1	-21.59076726	114.36465855
TVAf	5_137_TVA1f	-21.59238839	114.36341111
TVAs	5_137_TVA1s	-21.59610663	114.36080365
GR	5_138_GR1	-21.57685036	114.31036227
GR	5_138_GR2	-21.58509107	114.30568154
TVAf	5_138_TVA1f	-21.57891673	114.30962810
TVAs	5_138_TVA1s	-21.58518172	114.30586177
GR	5_139_GR1	-21.56649542	114.25616186
GR	5_139_GR2	-21.57324696	114.25406328
TVAf	5_139_TVA1f	-21.56839135	114.25569265
TVAs	5_139_TVA1s	-21.57286124	114.25466278
Plankton	5_1PNf	-21.59481099	114.34285875
Plankton	5_1PNs	-21.59471386	114.34477872
Plankton	5_2PNf	-21.59281725	114.32271795
Plankton	5_2PNs	-21.59347310	114.32151421
GR	5_3_GR1	-21.59210000	114.34680000
Plankton	5_3PNf	-21.58969993	114.34930698
Plankton	5_3PNs	-21.59038319	114.34839377