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MARINE BIODIVERSITY RESEARCH

Prediction and Management of Australia's Marine Biodiversity

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Jervis Bay Post-Survey Report, February 2009

R. Przeslawski, L. Radke, & M. Hughes

Record

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APPLYING GEOSCIENCE TO AUSTRALIA'S MOST IMPORTANT CHALLENGES

GEOSCIENCE AUSTRALIA SURVEY KIMBLA0109

Temporal and fine-scale variation in the biogeochemistry of Jervis Bay

Jervis Bay Post-Survey Report

FEBRUARY 2009

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By

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

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EXECUTIVE SUMMARY

The identification of suitable abiotic surrogates for biological diversity requires the collection of both physical and biological data. However, there are often constraints that preclude experimental designs that incorporate spatial and temporal replication, and the investigation of appropriate surrogates therefore involves a trade-off between overall spatial coverage and replication. We have completed a survey in Jervis Bay in which environmental and infaunal data were collected contemporaneously in order to be combined with similar data from a previous winter survey (survey number GA309) to investigate variation across seasons. Because there will be a certain error in sampling at the exact location as the previous survey, the survey design also required that replicate samples be taken at a set number of stations in order to investigate fine-scale variability (at the scale of metres).

We used grabs to collect paired geochemical and biological samples from thirty-two stations in a defined grid near Darling Road; at eight of these stations we deployed three pairs of grabs to investigate fine-scale variability. Due to good weather and extra ship time available, we also deployed a conductivity, temperature, and depth metre (CTD) to investigate vertical temperature and salinity profiles at each station in the Darling Road grid, as well as at stations throughout the entire bay. Samples are expected to be processed and analysed by late 2009, but preliminary results indicate that most physical variables and infaunal assemblages varied between seasons. In addition, variation among infaunal assemblages seems greater among stations (hundreds of metres) than within replicates at stations (metres).

1. INTRODUCTION

1.1. AIMS

The identification of suitable abiotic surrogates for biological diversity requires the collection of both physical and biological data. However, constraints often preclude effective experimental designs that incorporate spatial and temporal replication. For example, samples are often only collected from one point at a given GPS location. Moreover, the time of sample taking is rarely considered, with samples either being collected only once or pooled across different months without sufficient knowledge of temporal patterns. Despite the recent surge of interest in surrogates of marine biodiversity, the effects of spatial and temporal variation on the identification and utility of surrogates remain unknown. We have completed a survey in Jervis Bay in which environmental and infaunal data were collected contemporaneously in order to be combined with similar data from a previous winter survey (GA309) to investigate variation across seasons at a network of sites in the Darling Road grid (across hundreds of metres). Because there will be a certain error in sampling at the exact location as the previous survey, the survey design required that replicate samples be taken at a set number of stations in order to investigate fine-scale variability (at the scale of metres). This study addresses a crucial gap in current surrogacy research by examining the role of temporal and spatial replication in field sampling design and the interpretation of surrogacy relationships.

Data collected from this survey will be used to meet the following aims:

1) Examine the effects of temporal and spatial replication on the detection of surrogacy relationships.

2) Determine which abiotic and biotic factors significantly vary between winter and summer.

3) Investigate the differences in abiotic and biotic factors between locations separated by meters and hundreds of meters.

4) Further characterise the infauna and geochemistry of Jervis Bay

Due to good weather and extra ship time available, we also deployed a CTD to investigate vertical temperature and salinity profiles at each Darling Road station, as well as at stations throughout the entire bay.

1.2. SURROGACY

Australian waters represent one of the largest Exclusive Economic Zones in the world and hold some of the world's most diverse and endemic marine life. Although improved technology and protocols have facilitated marine biological sampling, the only feasible approach to enable sustainable management of this large and diverse environment is to map patterns of biodiversity through the use of physical surrogates, whereby environmental variables are used to predict patterns of marine biodiversity.

Field surveys are currently being undertaken in the Surrogates Program of the CERF Marine Biodiversity Hub to provide data that will enable a range of physical factors to be tested as useful proxies for marine benthic biodiversity. In the context of this program, Jervis Bay has been selected to test surrogates for the distribution of soft-sediment benthic species and communities. The main datasets being collected are multibeam sonar bathymetry, sediment samples, oceanographic measurements, infauna samples and towed underwater video (Anderson *et al*. 2009).

Environmental variables can affect invertebrate abundance and species richness (Radke et al. 2003), although the strength of such effects will be species-specific and vary across feeding modes and habitat requirements. Compared to epibenthic invertebrates and demersal fish, infaunal invertebrates are most likely to be strongly related to benthic factors such as sediment grain size and organic content, because they are directly exposed to these factors via burrowing and feeding.

Surveys designed to investigate appropriate surrogates normally make a trade-off in their sampling plan between overall spatial coverage and replication. Larger spatial coverage often means less replication or fine-scale sampling. Fine-scale sampling may be particularly important in heterogeneous habitats and communities, where a single sample is unable to encompass the variation at that station and is therefore not representative (Archambault & Bourget 1996, Wahl 2001). Soft sediment habitats are often considered homogenous habitats because they appear this way using common sampling methods that only focus on the seabed surface (e.g. video, multibeam, epibenthic sleds). However, soft-sediment habitats can also be heterogeneous, with organic enrichment, oxygenation, and grain size sometimes varying across meters or less (Kelaher & Levinton 2003, Wodarska-Kowaczuk & Weslawski 2008). Indeed, a study of infaunal assemblages in Jervis Bay showed high levels of heterogeneity at fine scales, with assemblages varying greatly among replicates (Hutchings & Jacoby 1994). It is unknown if all soft sediment habitats in Jervis Bay show this level of heterogeneity or if abiotic factors similarly vary across fine spatial scales. Nonetheless, it is generally accepted that variation is greater across larger spatial scales (hundreds of meters) than finer spatial scales (tens of meters), likely due to differences in habitat types.

The physical data upon which surrogacy research relies is often pooled from multiple times, sometimes spanning several seasons. Abiotic factors such as temperature, organic loads, and light attenuation vary across seasons (Holloway 1995, Przeslawski & Davis 2007); and identification of these factors as potential surrogates may therefore be hindered if sampling times are pooled across weeks, months, or seasons.

Although spatial and temporal variation have been well-studied in seagrass and fish communities of Jervis Bay (Hutchings & Jacoby 1994, Jacoby et al. 1995a), there have been comparatively few similar studies on invertebrate assemblages in deeper waters (Hutchings & Jacoby 1994) and none on spatio-temporal variation of seafloor geochemistry and biogeochemistry.

1.3 JERVIS BAY

Jervis Bay is a temperate marine environment on the south coast of NSW (35°08'S, 150°45'E), valued both economically and ecologically (Figure 1). The region is used for a unique combination of recreational, commercial, and military purposes, and the ecosystem is therefore important to a broad range of people and groups. Jervis Bay contains several types of habitats, including seagrass, sand, mud, and rocky bottoms (Figure 1); and it receives little freshwater input, in contrast to other embayments in the region (Ward 1995). The southern waters of Jervis Bay are part of the National Booderee Park, and the remaining waters encompass the Jervis Bay Marine Park, including Habitat Protection and Sanctuary Zones. In the rest of this section, we briefly review information related to variation of biogeochemical factors in Jervis Bay, specifically what is known about the biology and geochemistry of Jervis Bay, as well as spatial and temporal variation among biological and physical factors in this region.

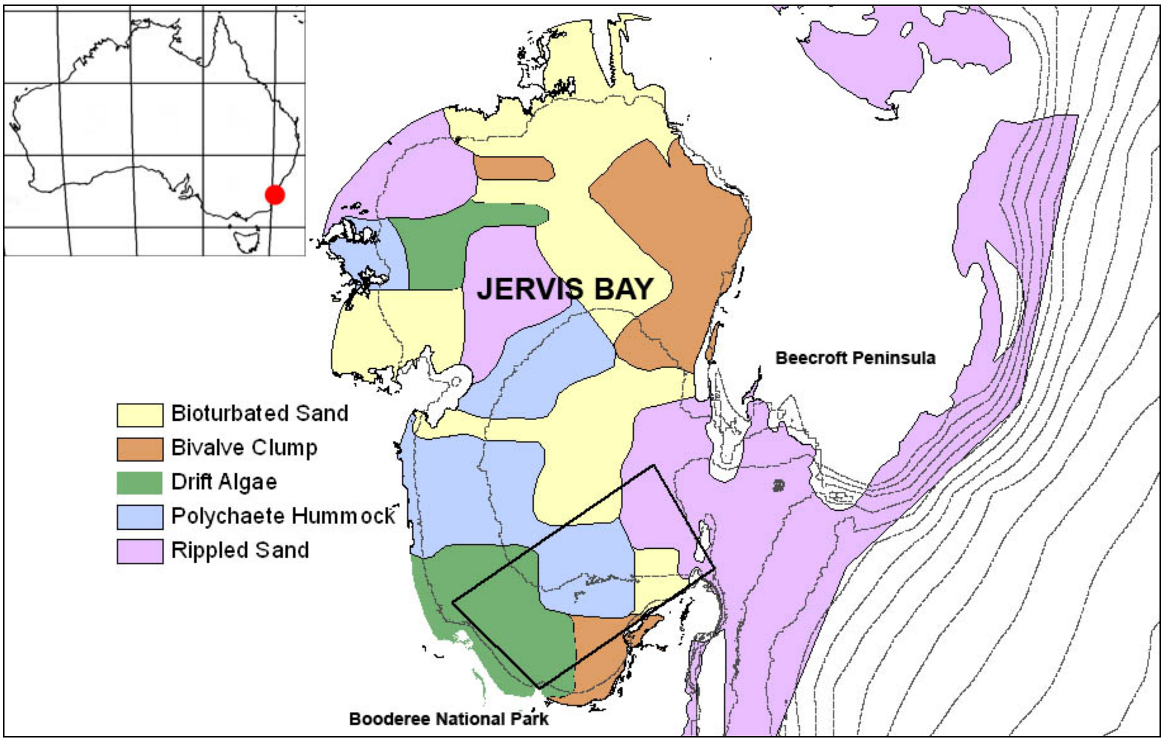

Figure 1: *Map of Jervis Bay showing Darling Road Grid outlined in black. Colours denote benthic habitats taken from Jervis Bay National Parks classifications based on historical data from mid-1980s.*

1.3.1. Benthic Biology of Jervis Bay

Jervis Bay is home to a mix of temperate and tropical species (Millar 1995), including nearly half of the total number of marine algae species in New South Wales, making it one of the richest sites in eastern Australia for marine algae (Millar 1995). Four main biological assemblages are described in (Dames & Moore 1985) based on dominant species: 'heart urchin community' with high densities of *Echinocardium cordatum,* the 'impoverished macrobenthic community' with no obvious sessile organisms, the 'polychaete hummock community' with chaetopterid worms and their mounds, and the 'mud oyster / mussel community' with clusters of bivalves. This preliminary and coarse classification scheme was expanded in the 1980s when the Department of Defence (DoD) funded a 3-year multidisciplinary project to establish baseline data for the Jervis Bay ecosystem, including the quantification of spatial and temporal variations in infaunal communities. This study revealed over 630 infaunal species including 248 crustaceans, 197 molluscs, 171 polychaetes, 15 echinoderms, and several nemerteans, sipunculans, phoronids, turbellarids, and coelenterates (Hutchings & Jacoby 1994). The DoD project also included quantification of large and conspicuous plants and animals using video transects in which 22 animals and plants could be reliably identified (Jacoby et al. 1995b). These include sea pens, kelp, drift-weed (*Gracilaria edulis* or *Acrosorium venulosum*), polychaetes (chaeopterid hummocks and eunicid trees). Bivalve clumps were also identified on video and contained up to 51 taxa (Jacoby et al. 1995b). Based on multivariate analyses, assemblages were classed into one of five groups: bivalve clumps, drift algae, polychaete hummock, bioturbated sand, and rippled sand (Jacoby et al. 1995b).

Geoscience Australia ran several short surveys to Jervis Bay in 2007-2008, some of which involved characterising benthic assemblages and geochemistry at defined stations. Samples are still being processed, but preliminary results indicate that Jervis Bay sediments contain a high abundance and richness of infauna that varies across hundreds of meters (Anderson et al. 2009).

1.3.2. Geochemistry of Jervis Bay

Very little literature has been published about the geochemistry of Jervis Bay, particularly regarding spatial and temporal variation, with the exception of (Anderson et al. 2009). Major ecological studies of Jervis Bay focus on benthic assemblages, but they do not measure sediment or geochemical factors (Ward & Jacoby 1992, CSIRO 1994, Hutchings & Jacoby 1994), which presumably affect associated benthic assemblages.

The seafloor at Jervis Bay consists largely of fine-grained sand and slopes gently and evenly towards the entrance where sands are coarser (Albani et al. 1973, Taylor et al. 1995). Invertebrate remains comprise 5-20% of the sediments (Albani et al. 1973, Taylor et al. 1995), although carbonate content in coarse sediments of the entrance may be as high as 80% (Albani et al. 1973).

Water quality and circulation may also affect benthic communities. Current speeds within the bay are quite low, often less than 0.05 ms^{-1}, although deeper currents are stronger and more directionally-consistent than surface currents (Holloway 1995). Calculations reveal that flushing times in the bay vary between 6-20 days (Holloway 1995) thus providing a coarse measurement of how long larvae, freshwater, and pollutants may remain in the bay.

1.3.3. Spatial variation at Jervis Bay

Spatial and temporal variation has been well-studied in seagrass and fish communities of Jervis Bay (Ferrell & Bell 1991, Bell et al. 1992, Ferrell et al. 1993, Jacoby et al. 1995a, Kirkman et al. 1995, Worthington et al. 1995), but there have been comparatively few studies on invertebrate assemblages in deeper waters (Hutchings & Jacoby 1994, Jacoby et al. 1995b, Anderson et al. 2009) and even less on geochemical and other environmental factors on the seafloor.

Infaunal communities vary between seagrass and sand/mud, but this may reflect differences in sampling methods used (Hutchings & Jacoby 1994). Infaunal assemblages varied between 12 and 20m depth in muddy/sand sediments (Hutchings & Jacoby 1994).

Surveys of fish and mobile macroinvertebrates revealed that assemblages were less similar among habitats than within a habitat (Jacoby et al. 1995a and references therein). Similarly, a study of infauna from tidal flats around Jervis Bay confirmed that assemblages were different at a spatial scale of hundreds of meters but were more homogenous at the 20 meter scale (Winberg et al. 2007). In contrast, a study of infaunal assemblages in Jervis Bay showed high levels of heterogeneity at fine scales, with assemblages varying greatly among replicates for both hand-operated coring (four replicates within a 2m x 2m plot) and Smith Macintyre grab sampling (five replicates within an unspecified area) (Hutchings & Jacoby 1994). These studies suggest that biological heterogeneity exists within soft sediments of and may be affected by the sampling methods, taxa of interest, and spatial scale. Heterogeneity affects marine protected area planning and management, with habitats and assemblages that vary across fine spatial scales (e.g. heterogeneous) requiring conservation of larger continuous areas than more homogeneous habitats and assemblages (Winberg et al. 2007).

Differences in polychaete/mollusc/echinoderm species composition were most pronounced among sites, following pooling of replicates (Hutchings & Jacoby 1994). Many species were abundant at all sites, and differences in species composition were due to a few rare species in which more than 25% of species recorded were represented by <10 individuals (Hutchings & Jacoby 1994).

1.3.4. Temporal variation at Jervis Bay

Surprisingly, infaunal polychaetes show little seasonality, with species composition remaining relatively stable across 2-5 month intervals over 28 months (Hutchings & Jacoby 1994). Interannual variation in benthic assemblages may be stronger than seasonal changes (Stephenson et al. 1974, Stephenson et al. 1977). Species composition of benthic communities can be highly unpredictable (Stephenson et al. 1977); however, communities in Jervis Bay may be more stable due to limited freshwater input, and core species will likely remain relatively stable (Hutchings & Jacoby 1994).

Salinity and temperature have strong seasonal contrasts, with warmer summer months associated with distinct isotherms and slight salinity gradients and winter months associated with more homogenous temperatures and salinities (Holloway 1995).

Large amounts of driftweed were recorded in Darling Road location during the Oct-Nov 1988 navy survey, and it was suggested this may be a seasonal phenomenon (DoD, 1989). Fish and decapods have been associated with the driftweed *Gracilaria verrucosa* in Jervis Bay, but these communities were a sub-set of those found in nearby *Posidonia australis* beds (Langtry & Jacoby 1996).

2. METHODS

2.1. SURVEY AREA & OVERVIEW

Samples were taken from the Darling Road study area, called the Darling Road grid, in the south end of Jervis Bay (Figure 2; Anderson et al., 2009). This area encompasses a range of soft-sediment habitats in both Commonwealth and State waters, including drift algae, polychaete hummocks and unconsolidated sand (Anderson et al. 2009) (Figure 1). 32 stations in the Darling Road Grid were chosen based on sampling success from the Jervis Bay survey in August 2008 (survey number GA309). For the current survey, we revisited stations from which both biological and geochemical samples were easily obtained on the previous survey in August (Figure 2).

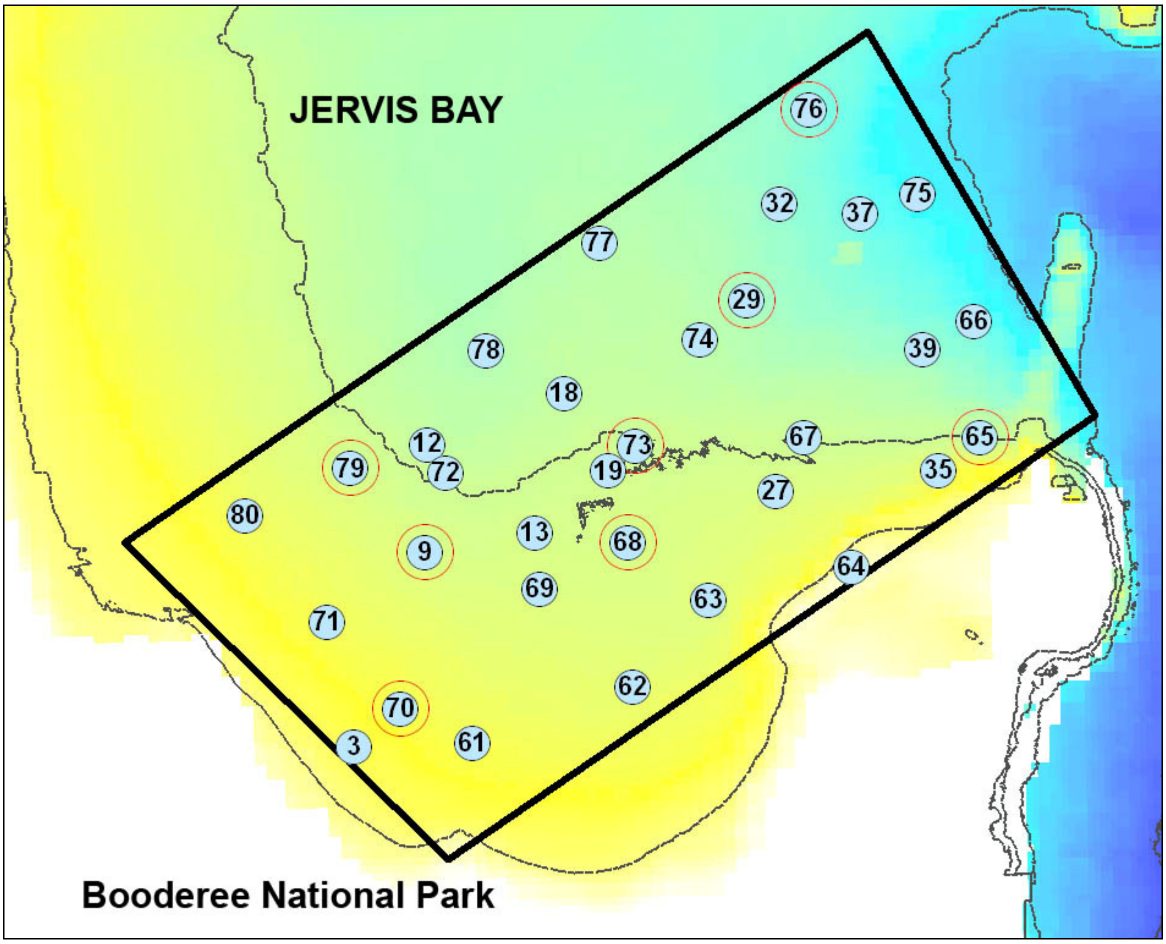

Figure 2: *Stations in the Darling Road Grid sampled to investigate temporal variation in biology and geochemistry. Numbers represent station names based on survey GA309. The stations outlined in red were also chosen to investigate fine-scale variation in biology and geochemistry. Each of these stations was therefore sampled with at least 6 grabs each (3 x biology, 3 x geochemistry).*

At the end of the survey, we had time left and undertook CTD profiling at all 32 Darling

Road stations previously sampled, as well as 12 additional stations across the entire bay (Figure 3).

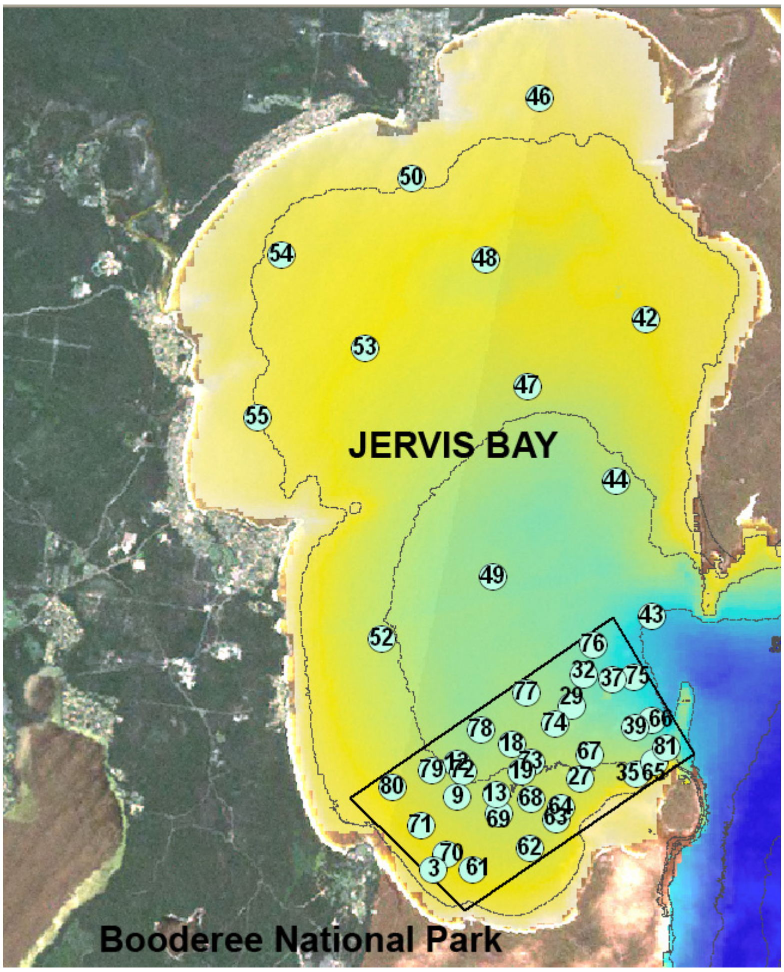

Figure 3: *Location of stations from which CTD readings were taken. Numbers represent station names based on surveys GA312 & GA 309.*

The survey team included six staff from Geoscience Australia (Table 1) and was conducted on the *R.V. Kimbla,* an 18-metre research vessel (Figure 4).

Table 1: Survey participants for the biogeochemical survey in Jervis Bay, 9-13th February 2009 (KIMBLA0109). All staff are from Geoscience Australia.

NAME	ROLE
Dr. Rachel Przeslawski*	Biologist
Dr. Lynda Radke	Geochemist
Dr. Peter Harris	Sedimentologist
Dr. Michael Hughes	Oceanographer
Anna Potter	GIS / Researcher

John Jaycock	Field Technician

* Survey leader

Figure 4: *The R.V. Kimbla, an 18-metre research vessel on which the current survey was conducted.*

2.2 GRAB SAMPLING

For each station, a 2-liter Van Veen grab and 250 ml Shipek grab were deployed at the same time. The Van Veen grab was used to collect biological samples as it usually returned a larger amount of sediment than the Shipek, and the Shipek grab was used to sample geochemistry as it minimised disturbance to the sample. The Shipek uses a spring-loaded scoop triggered by the release of a sliding weight on the top of the sampler as it makes contact with the seabed. This device can collect an intact sample of sediment up to 5 cm by 12 cm in area and 5 cm thick. Upon triggering, the grab immediately covers the sample, which prevents disturbance during retrieval to the surface. Grain size samples were taken from Van Veen grabs, unless the sample size was deemed too small, in which case it was taken from the Shipek grab.

2.3 BIOLOGICAL SAMPLES

The sample from the Van Veen grab was immediately transferred to a Nally bin. Sediment height was measured at four corners and averaged in order to provide a direct comparison of sample size with the biological samples collected from GA309 (Anderson et al. 2009). We also weighed the sample by decanting excess water through a 500-µm sieve and weighing the remaining sediment and animals.

All sediment was then washed through a 500-µm sieve such that all animals and particles larger than 500 µm were retained. Macrofauna were photographed, and worms, zoanthids, and other similar soft-bodied animals were removed for preservation in 4% buffered formalin. The remaining animals and associated sieved material were preserved in 70% ethanol for later identification in the laboratory.

2.4 GEOCHEMISTRY SAMPLES

Immediately after the Shipek grab sampler was back aboard, the sample was removed from the grab. The top 2 cm of the sediment (wet) was then sub-sampled into six separate containers to separately measure: (i) grain size; (ii) porosity and bulk density (10 cc volumetric bottles); (iii) potentially bio-available trace elements (10 cc volumetric bottles which were acid washed prior to use); (iv) chlorophyll *a* concentrations (10 cc volumetric bottles wrapped in aluminium foil); and (v-vi) two 58 ml falcon vials for the measurement of TCO_2 pools and production rates (on the pore waters) and major element oxide composition, fine sediment surface area, carbon and nutrient contents and carbon and nitrogen isotopic composition (on the solid phase).

The porosity and chlorophyll a samples were frozen immediately after collection. The falcon vials were wrapped in aluminium foil and placed in a container in which seawater was held at near in situ water temperatures. No later than 5 hours after collection, the pore waters of one of the two falcon vials (labelled time = zero) were extracted by centrifugation (8890 rpm; 5 minutes) and placed in 3 ml exetainers that had been pre-charged with 0.025 ml of mercuric chloride (to poison the samples). Approximately 24 hours later, the second of the two falcon vials from each site (labelled time = 1) were sampled by the same methods. These extracts were then stored in the refrigerator prior to analysis for dissolved inorganic carbon (DIC).

2.5 WATER COLUMN MEASUREMENTS

Conductivity, temperature, depth and calculated salinity were logged using a Seabird Electronics SBE 37-SMP MicroCAT recorder. The manufacturer-quoted accuracy of the thermister and conductivity cell are 0.002°C and 0.003 mS cm^{-1}, respectively. Profiles were collected by logging continuously (i.e. sampling every 5 s) and lowering the instrument through the full water depth at an approximate rate of 0.10–0.15 m s^{-1}. This yielded a reading every 0.50–0.75 m water depth.

In addition, a Li-Cor LI 250A Light Meter with a LI-192SA Underwater Quantum Sensor was deployed at each station to record photosynthetically active radiation (PAR) within surface waters (i.e. the top half metre of the water column) and within a half metre of the seabed. Water temperature, conductivity, salinity, dissolved oxygen, and dissolved oxygen saturation were also measured at these two depths at each station using a YSI 650 Multiparameter Display System with YSI 600XLM-M Sonde.

3. Preliminary Results

3.1 BIOLOGY

Sieved material varied across station and included samples dominated by chaetopterid worms, seagrass, drift algae, coarse sand, and miscellanous biogenic fragments (Figure 5). Initial observations suggest that variation among infaunal assemblages is greater among stations (hundreds of meters) than within replicates at stations (meters).

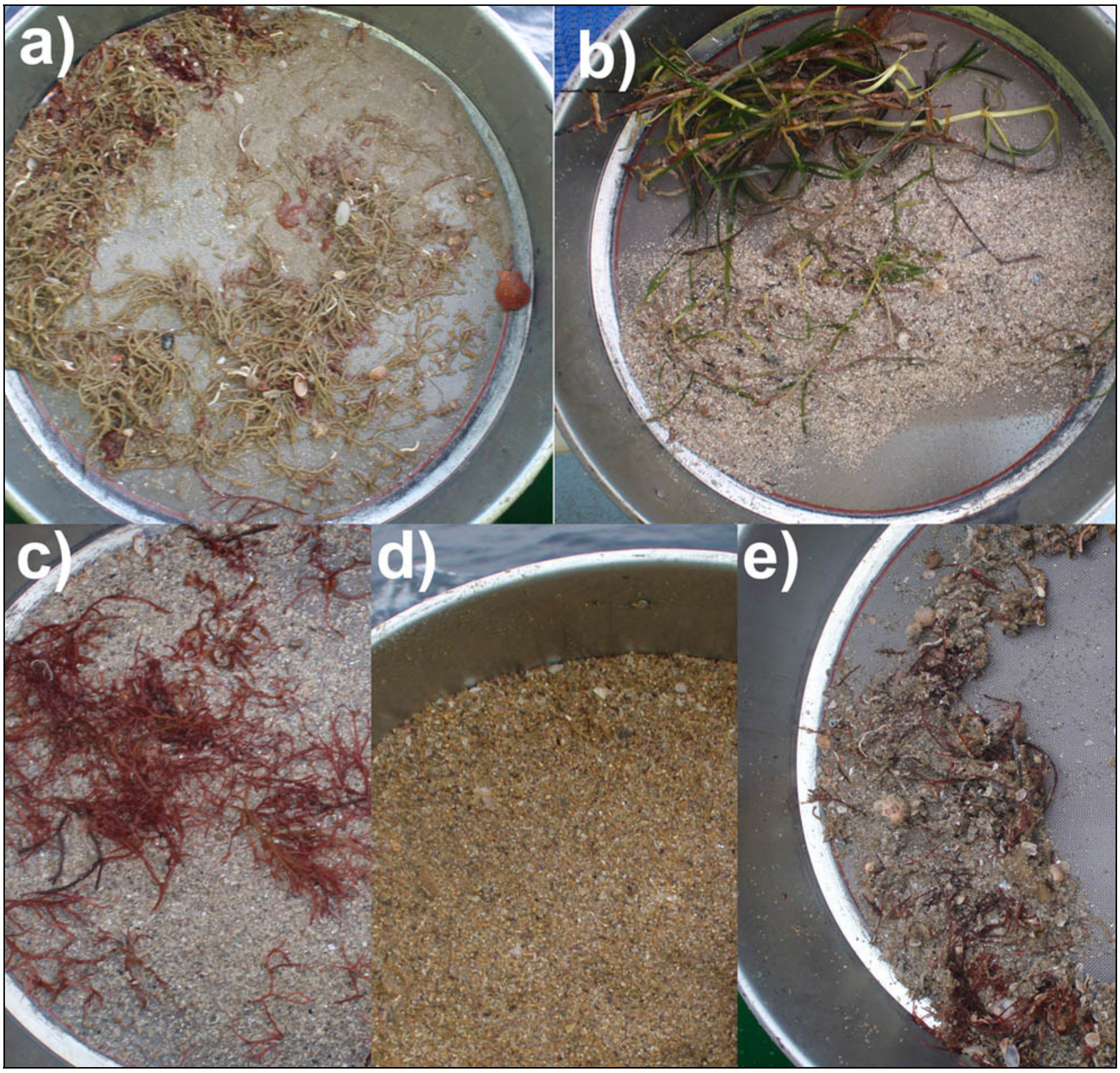

Figure 5: *Material retained on a 500 µm sieve from Van Veen grab samples, representing a range of biological assemblages including those dominated by a) chaetopterid worms, likely Mesochaetopterus minutes (Station 73), b) seagrass (Station 64), c) drift algae (Station 62), d) coarse sand (Station 66), and e) shell grit and miscellaneous biogenic fragments (Station 78). Photos by R. Przeslawski.*

Similar animals were collected across winter (GA309) and summer (KIMBLA0109) surveys, including amphipods, chaetopterid worms, scallops, heart urchins, crinoids, and brittlestars (Figure 6). In addition, we sampled several macrofauna during summer that were not collected on the winter survey (Figure 7), although these often occurred once or at a single station.

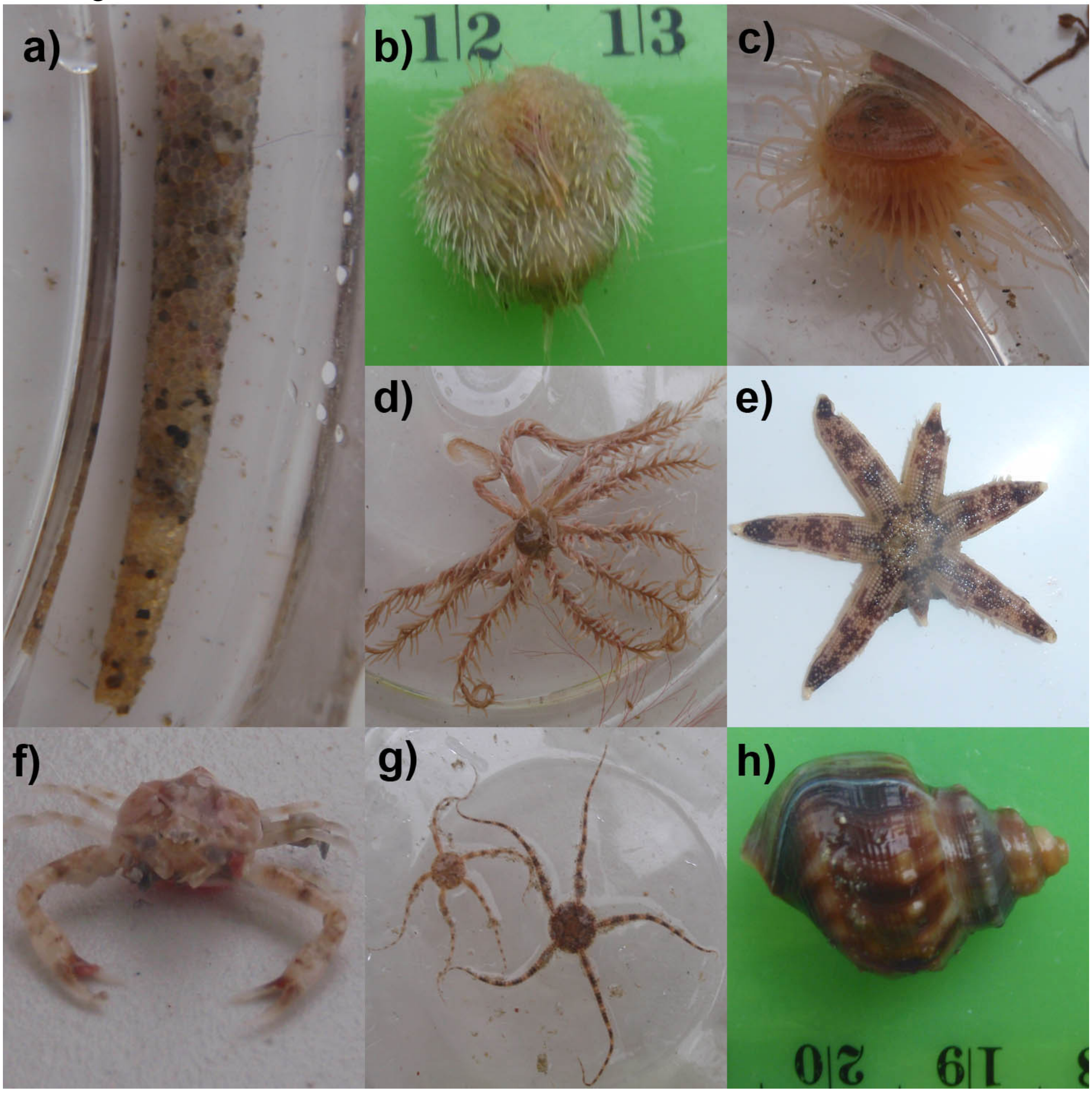

Figure 6: *Taxa collected on both the winter (GA309) and summer (KIMBLA0109) surveys: a) Pectinidae (mason worm), b)* Echinocardium *sp. (heart urchin), c) Limidae bivalve, d) crinoid, e) asteroid (seastar), f) crab, g) ophiuroid (brittlestar), and h) neogastropod. Photos by R. Przeslawski.*

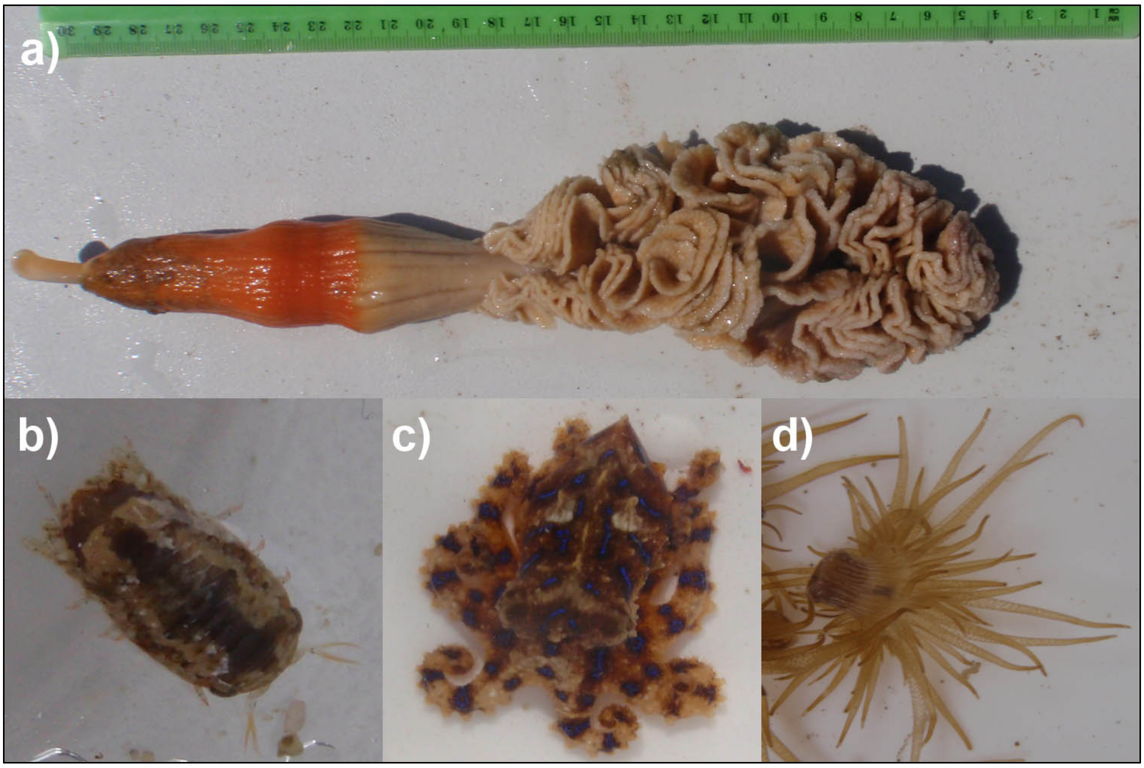

Figure 7: *Macrofauna collected on only the summer (KIMBLA0109) survey:* a) *Pennatulacean (sea pen), b) isopod, c)* Hapalochlaena maculosa (*blue-ringed octopus), and d) zoanthid. Photos by R. Przeslawski.*

3.2 WATER COLUMN MEASUREMENTS

Individual profiles of temperature and salinity for each site from the CTD are shown in Appendices 7.3 and 7.4. The temperature profiles at the deepest sites (Site 29, 32, 37, 39, 65–66, 73–76) show 2 water masses with relatively uniform temperature in the vertical and a thermocline below each (Appendix 7.3). Shallower sites show a single surface water mass of uniform temperature with an underlying thermocline. The shallowest sites show a well mixed water column with respect to temperature. The salinity profiles were generally uniform with depth, except the deeper sites tended to have marginally more saline water near the bed (Appendix 7.4).

The surface and bottom temperature data from the CTD are summarised as contour plots in Figures 8 and 9. Surface temperatures generally ranged between 20 and 20.8°C, and the warmest water was at the northeast end of the grid; closest to the bay entrance. Bottom temperatures generally ranged between 17 and 20°C, with the warmest temperatures along the southwest and southeast margins of the grid; in the shallower water depths.

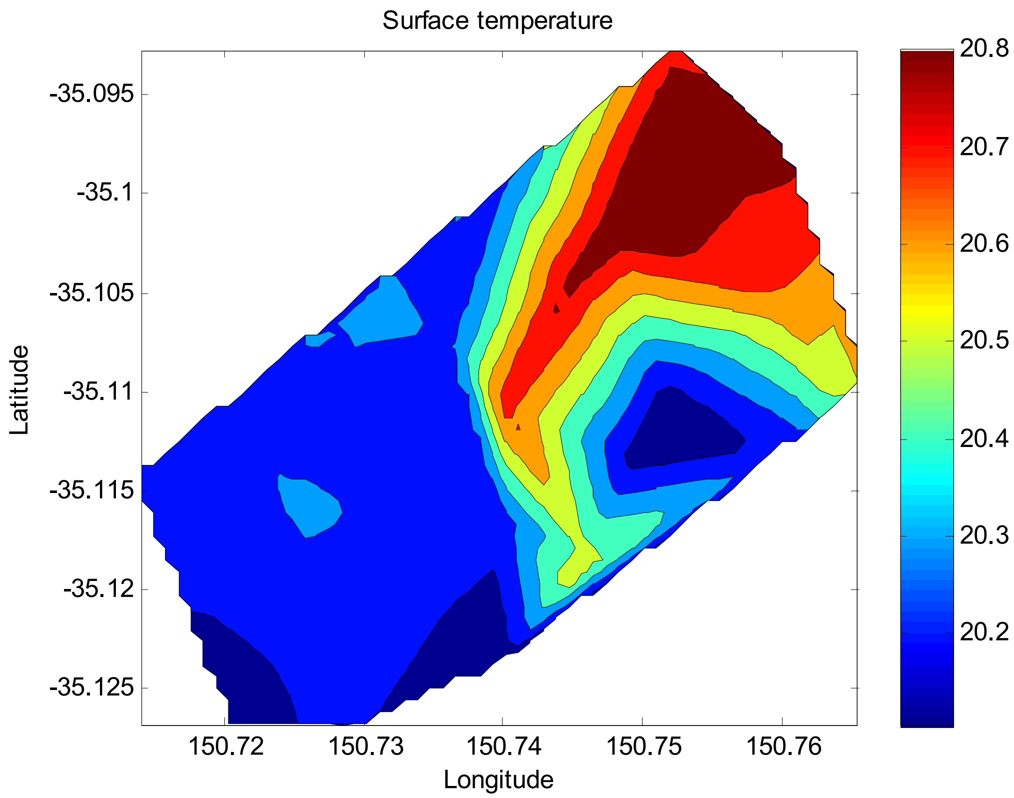

Figure 8: *Contour plot of surface temperature measured on 12 and 13 February, 2009.*

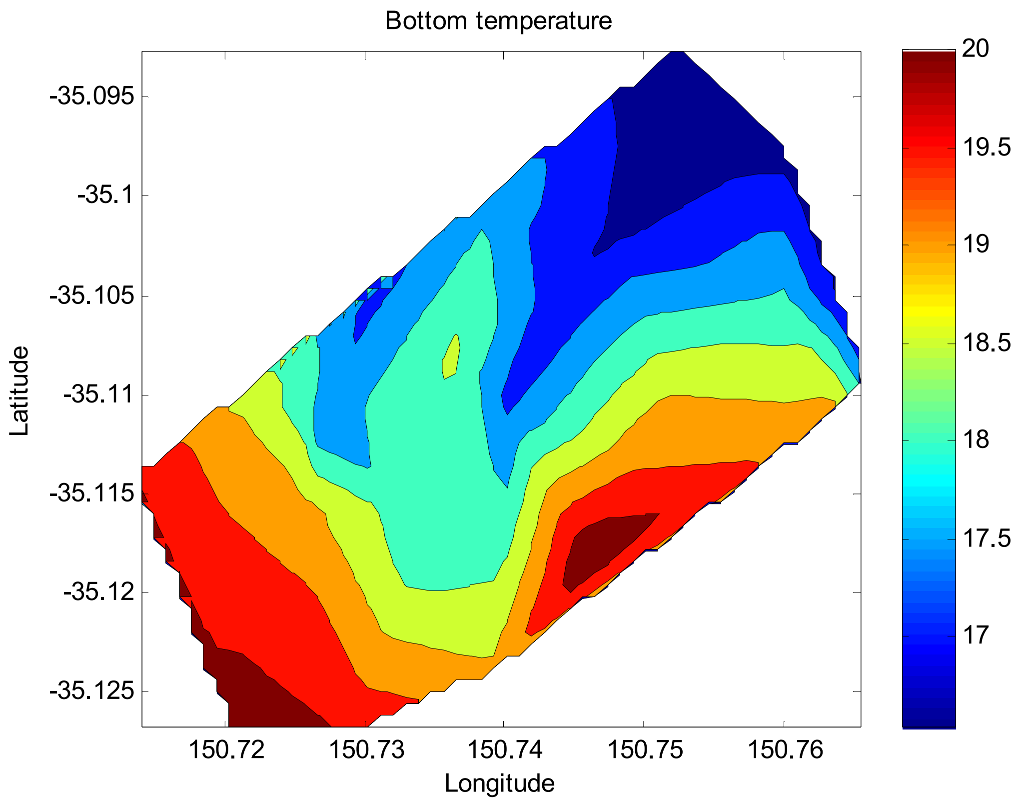

Figure 9: *Contour plot of bottom temperature measured on 12 and 13 February, 2009.*

The surface and bottom salinity data are summarised as contour plots in Figures 10 and 11. Surface salinities generally ranged between 34.6 and 35.5, with a patch of lower salinity water two-thirds of the way along the grid. Bottom salinities were more restricted and generally ranged between 35.5 and 35.8, with a patch of higher salinity water about one-third of the way along the grid.

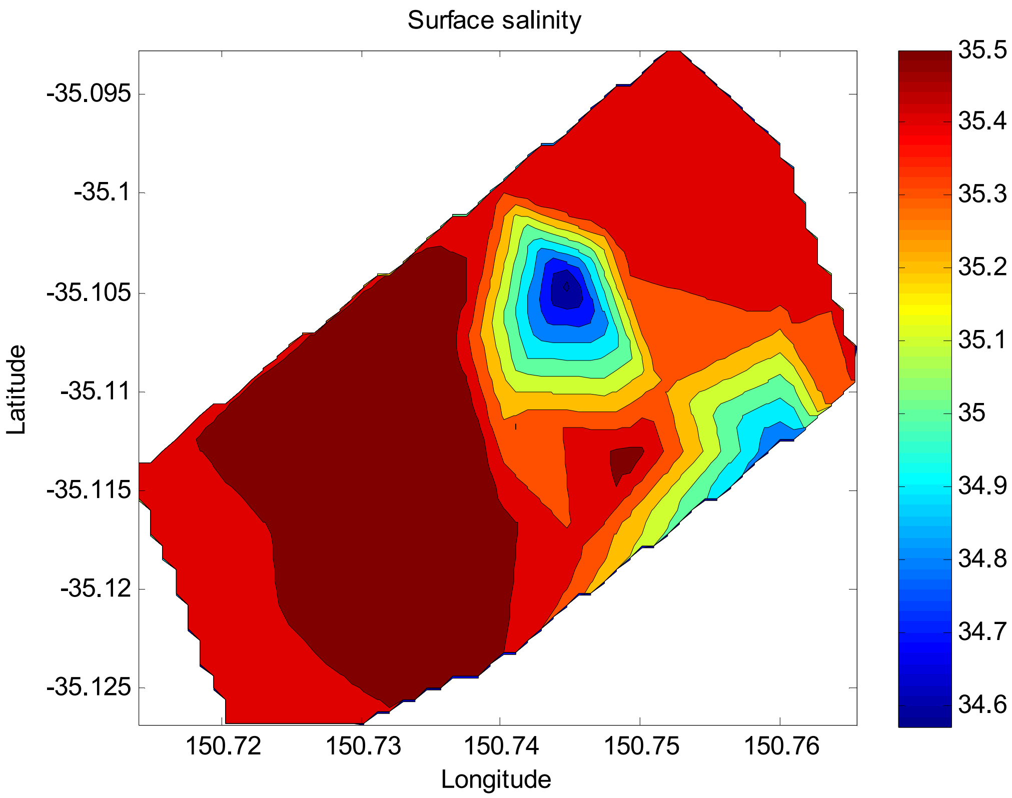

***Figure 10**: Contour plot of surface salinity measured on 12 and 13 February, 2009.*

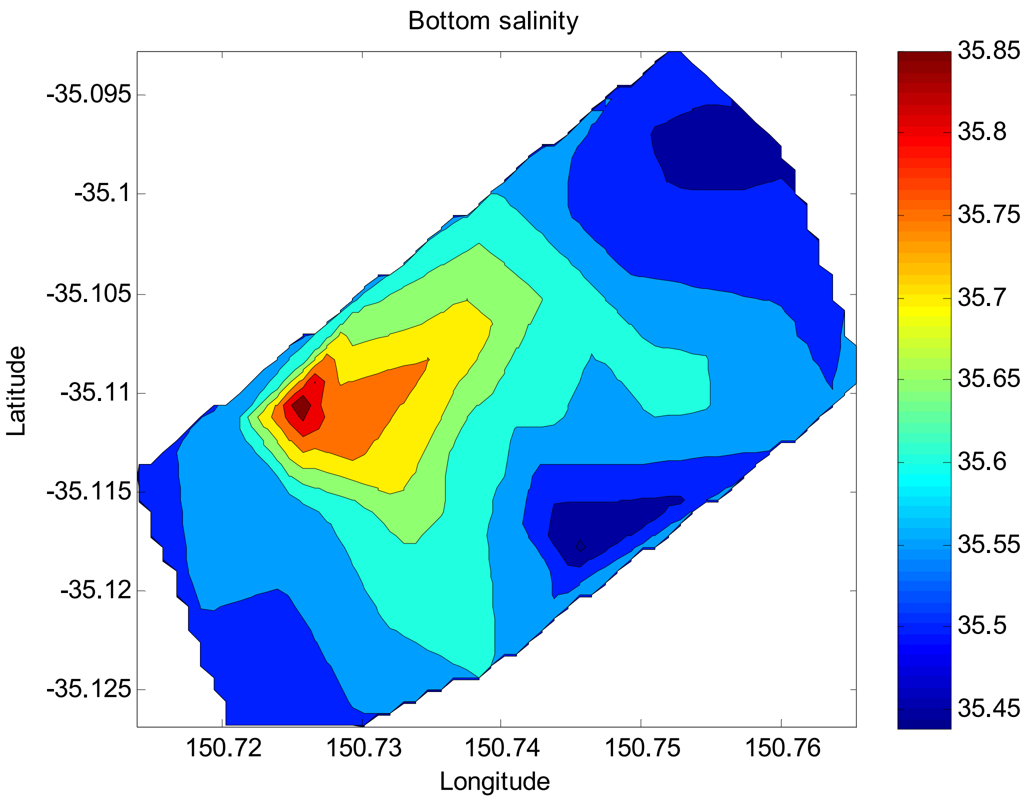

Figure 11: *Contour plot of bottom salinity measured on 12 and 13 February, 2009.*

Vertical diffuse attenuation coefficients (Kd), an estimate of the amount of light attenuated by water per metre depth of water, were calculated from the surface and bottom water PAR measurements (Kd (m^{-1}) = ln(Io/Iz)/z)) and are presented in Figure 12 and 13. The pattern of measurements observed in February appeared to be more random than that observed in August. This is potentially due to variable cloud cover between surface and bottom readings, because of the generally overcast conditions experienced in February. However, Kd values were generally lower in February (0.11 ± 0.03) than in August (0.14 ± 0.03) indicating that more visible light was reaching the benthos in the summer months, as expected.

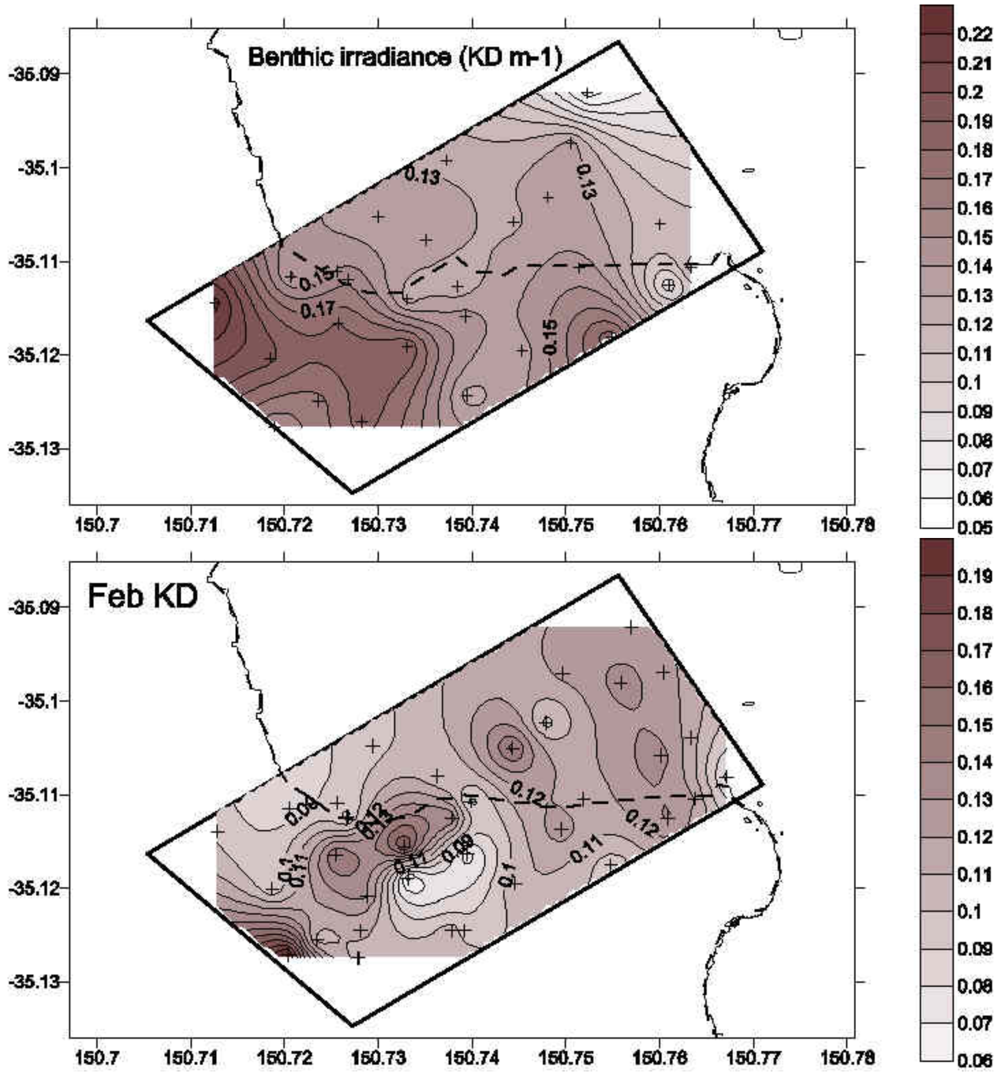

Figure 12: *Comparison of benthic irradiance (Kd) based measurements taken in August 2008 (top panel) and February 2009 (bottom panel). The 20 m depth contour comprises the hashed line through the diagram.*

The dissolved oxygen data (concentrations and percent saturation) are provided in the format of contour plots in Figure 13 together with similar plots from August 2008. The ranges of dissolved oxygen concentrations were lower in February 2009 (6.4 - 8.4 mg L^{-1}) than in August 2008 (8.1- 9.1 mg L^{-1}). These differences are due in part to the effect of higher water temperatures in February (16.3 ± 1.4°C compared to 14.2 ± 0.2°C) in lowering the solubility of dissolved oxygen in seawater. However, the percent saturation values of dissolved oxygen were also lower in February (95.5 ± 7%) than in August (106 ± 2.7%) (Figure 13) indicating that benthic respiration rates were probably also higher due to the enhanced organic matter production expected in the summer months. The saturation values of dissolved oxygen are a measurement that is independent of water temperature and salinity. The vial incubation experiments, which measure CO_2 production over a set time interval, should be able to resolve this supposition.

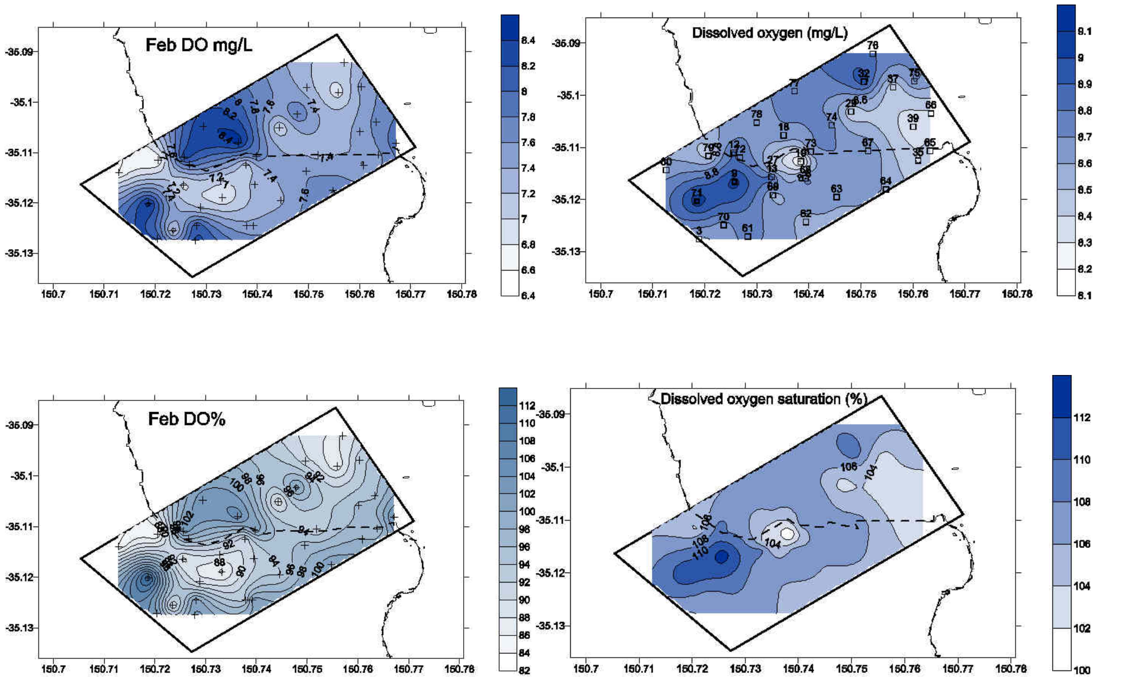

Figure 13. *A comparison between dissolved oxygen concentrations (DO mg L^{-1}) and percent saturation (DO %) from measurements taken in bottom waters in August 2008 (right hand side) and February 2009 (left hand side). The 20 m depth contour comprises the hashed line through the diagram.*

4. Timeline & Outputs

Biological and geochemical processing began the week after the survey was finished but will take some time to complete. Job requests for physical samples were made on February 18/09 for the full suite of analyses indicated in Section 2.3, and it is anticipated that all analyses will be turned around by the end of April 09 with the exception of samples designated for XRF which may be delayed due to technical issues with the laboratory.

We expect to have full biological species matrices for both GA 309 and the current survey within the year (Table 2). We will first conduct exploratory multivariate analyses to characterise stations based on their biological assemblages and environmental characteristics (multi-dimensional scaling plots and principal component analyses, respectively), particularly differences between winter and summer samples. Following this, we will use the BIO-ENV procedure (Primer v.6) to investigate the relationships between abiotic and biotic variables. This test will reveal the primary abiotic factors that relate to biodiversity, and we can then use these factors to perform correlations across seasons and across replicate numbers to investigate the stability of surrogacy relationships across different spatial and temporal scales. Other statisticians and modellers in the CERF Hub may also use this data to derive and test seascapes in the region, develop interpolated maps, and conduct spatial analyses.

Table 2: Timeline for sample processing and data analyses.

TASK	DATES	NAMES
Sort & identify Jervis Bay infauna	Feb – Aug 09	McArthur/Przeslawski
Process grain size samples	May 09	Radke
Process geochemical samples[1]	May 09	Radke
Exploratory analyses	September 09	Przeslawski/Radke
BIO-ENV, correlations, etc	Oct 09-Nov 09	Przeslawski
Spatial analyses, modelling, seascapes	Aug 09 onwards	Huang/Li/etc.

[1] Excluding XRF samples

Results from this survey will be communicated through a range of outlets, encompassing both scientific and public audiences:

- *Post-survey report.* The current report details survey design, sampling map, details of samples collected, and the estimated time frame for data acquisition and analyses.

- *Jervis Bay Benthic Species Guide*. Any new infauna not recorded from previous surveys will be photographed and added to the planned Jervis Bay Benthic Species Guide.

- *Newsletters*. If there is interest, we will write a brief summary of our survey and/or results for the CERF Marine Hub Newsletter and/or AusGeo News.

- *Conference*s & *workshops*. Results will be presented at national conferences (e.g. AMSA) and CERF workshops.

- *CERF datasets*. Results from this survey will contribute to the overall Jervis Bay data holdings and can be used in other surrogacy research projects by CERF Hub researchers.

- *Peer-reviewed publications.* We anticipate publishing two papers that directly address the aims stated above: 1) Seasonal and fine-scale spatial variation of geochemistry and infauna of Jervis Bay, and 2) Does the identification of abiotic marine surrogates depend on temporal and spatial scales?. In addition, our datasets may contribute to peer-reviewed publications produced by other members of the CERF Marine Hub (e.g. corroboration of regional seascapes).

5. Significance

This research will complement previously planned research in the CERF program, in which the inter-annual variation among surrogacy relationships will be compared across several temperate rocky reefs (temporal: annual, spatial: kilometres). The current study aims to investigate finer scales (temporal: seasonal, spatial: metres) and will allow us to determine whether or not the relationships between abiotic and biotic variables change over time and spatial scale. Such information will be crucial to optimise the likelihood of identifying suitable surrogates for marine biodiversity in soft-sediment environments. To our knowledge, this is the first study to examine how the relationships between environmental factors and marine macro-infaunal diversity may vary over time and space.

This research will contribute to our knowledge of Jervis Bay by providing co-located records of environmental factors and infauna. When combined with data from previous CERF Jervis Bay surveys (e.g. GA309 and GA312), this information will provide detailed maps of a soft sediment habitat and a robust dataset of the infaunal diversity of the southern part of the bay in relation to sedimentological, geochemical and biogeochemical variables.

Results from this study will also reveal fine-scale complexity of soft-sediment habitats in Jervis Bay. Heterogeneity affects marine protected area planning and management, with habitats and assemblages that vary across fine spatial scales (i.e. heterogeneous) requiring conservation of larger continuous areas than more homogeneous habitats and assemblages.

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7. Appendix

7.1. DAILY LOG

Monday Feb 9
We arrived at HMAS Creswell at midday and loaded the boat. Grab sampling commenced at 14:30 and ended at 17:30.

Tuesday Feb 10
Grab sampling from 09:00 – 17:00. Sporadic rain all day, but seas calm. Took Lynda ashore at 14:00 to undertake geochemical processing.

Wednesday Feb 11
Grab sampling continued from 08:30 – 16:30. Mike joined the survey at midday when we dropped off Lynda.

Thursday Feb 12
Grab sampling completed at midday, but two stations that had already been sampled had been incorrectly entered into the ship's navigation system (station 71 and 62). We sampled at the correct stations and renamed previous stations 83 and 82 respectively. Commenced CTD measurements in Darling Rd Grid until 16:00.

Friday Feb 13
Peter, Lynda, Anna collected mangrove and beach samples and left for Canberra. Rachel, Mike and John went out on the boat to deploy CTD. Large swell. We finished Darling Rd Grid stations and took CTD readings at most of the baywide stations from previous surveys (GA 309 and GA 312).

~ R. Przeslawski

7.2 LOCATIONS OF ALL STATION OPERATIONS

The key for the table is: Shipek = Shipek Grab; Van Veen = Van Veen Grab; gs =grain-size sample collected; gc = geochemistry samples collected; bio = biology sample collected; Wca/b = surface/bottom water column records.

Sample N	Sample ID	Latitude	Longitude	Date/Time (local)	Water depth (m)	Sample type	Sampled For:
1982587	KIMBLA0208_F03_WCB	-35.127135	150.72041	9/02/2009 14:38	12.8	Water column	bottom water observations
1982586	KIMBLA0208_F03_WCA	-35.127135	150.72041	9/02/2009 14:38	12.8	Water column	surface water observations
1982585	KIMBLA0109_F03_GRA_1	-35.127575	150.72025	9/02/2009 14:48	12.6	Grab Shipek	grain size
	KIMBLA0109_F03_GRB_1	-35.12748	150.7203	9/02/2009 14:51	12.6	Grab Van Veen	biology
1982584	KIMBLA0109_F03_GRA_1B	-35.127001	150.72052	9/02/2009 14:53	12.7	Grab Shipek	geochemistry
1982605	KIMBLA0208_F61_WCB	-35.127473	150.72789	9/02/2009 15:14	14.6	Water column	bottom water observations
1982604	KIMBLA0208_F61_WCA	-35.127473	150.72789	9/02/2009 15:14	14.6	Water column	surface water observations
1982602	KIMBLA0109_F61_GRA_1	-35.126668	150.7272	9/02/2009 15:16	14.6	Grab Shipek	geochemistry
1982603	KIMBLA0109_F61_GRB_1	-35.126668	150.7272	9/02/2009 15:16	14.6	Grab Van Veen	grain size
1982601	KIMBLA0109_F61_GRB_1B	-35.126137	150.727	9/02/2009 15:18	14.6	Grab Van Veen	biology
1982610	KIMBLA0208_F82_WCB	-35.124583	150.72809	9/02/2009 15:28	15.5	Water column	bottom water observations
1982609	KIMBLA0208_F82_WCA	-35.124583	150.72809	9/02/2009 15:28	15.5	Water column	surface water observations
1982607	KIMBLA0109_F82_GRA_1	-35.12412	150.7277	9/02/2009 15:31	15.5	Grab Shipek	geochemistry
1982608	KIMBLA0109_F82_GRB_1	-35.12377	150.72749	9/02/2009 15:34	15.5	Grab Van Veen	biology/grain size
1982606	KIMBLA0109_F82_GRA_1B	-35.124653	150.72863	9/02/2009 15:54	15.5	Grab Shipek	geochemistry
1982596	KIMBLA0208_F18_WCB	-35.108008	150.73632	9/02/2009 16:05	19.5	Water column	bottom water observations
1982595	KIMBLA0208_F18_WCA	-35.108008	150.73632	9/02/2009 16:05	19.5	Water column	surface water observations
1982594	KIMBLA0109_F18_GRB_1	-35.10783	150.73645	9/02/2009 16:08	20	Grab Van Veen	biology/grain size
1982593	KIMBLA0109_F18_GRA_1	-35.10783	150.73645	9/02/2009 16:08	20	Grab Shipek	geochemistry
1982600	KIMBLA0208_F78_WCB	-35.10482	150.72939	9/02/2009 16:22	21.5	Water column	bottom water observations
1982599	KIMBLA0208_F78_WCA	-35.10482	150.72939	9/02/2009 16:22	21.5	Water column	surface water observations
1982598	KIMBLA0109_F78_GRB_1	-35.104533	150.72949	9/02/2009 16:26	21.5	Grab Van Veen	biology/grain size
1982597	KIMBLA0109_F78_GRA_1	-35.104533	150.72949	9/02/2009 16:26	21.5	Grab Shipek	geochemistry
1982592	KIMBLA0208_F12_WCB	-35.110895	150.72565	9/02/2009 16:50	20	Water column	bottom water observations
1982591	KIMBLA0208_F12_WCA	-35.110895	150.72565	9/02/2009 16:50	20	Water column	surface water observations
1982590	KIMBLA0109_F12_GRB_1	-35.109792	150.72577	9/02/2009 16:52	20.2	Grab Van Veen	grain size

1982588	KIMBLA0109_F12_GRB_1B	-35.10898	150.72555	9/02/2009 16:56	20.4	Grab Van Veen	biology
1982589	KIMBLA0109_F12_GRA_1	-35.10898	150.72555	9/02/2009 16:56	20.4	Grab Shipek	geochemistry
1982632	KIMBLA0208_F77_WCB	-35.124583	150.73787	10/02/2009 9:16	23	Water column	bottom water observations
1982631	KIMBLA0208_F77_WCA	-35.124583	150.73787	10/02/2009 9:16	23	Water column	surface water observations
1982630	KIMBLA0109_F77_GRB_1	-35.099205	150.73842	10/02/2009 9:27	23	Grab Van Veen	biology
1982629	KIMBLA0109_F77_GRA_1	-35.099205	150.73842	10/02/2009 9:27	23	Grab Shipek	geochemistry/grain size
1982636	KIMBLA0208_F32_WCB	-35.097063	150.74967	10/02/2009 9:53	25.7	Water column	bottom water observations
1982635	KIMBLA0208_F32_WCA	-35.097063	150.74967	10/02/2009 9:53	25.7	Water column	surface water observations
1982634	KIMBLA0109_F32_GRB_1	-35.097293	150.75008	10/02/2009 9:57	25.7	Grab Van Veen	biology/grain size
1982633	KIMBLA0109_F32_GRA_1	-35.096805	150.75071	10/02/2009 10:01	25.9	Grab Shipek	geochemistry
1982628	KIMBLA0208_F75_WCB	-35.096945	150.76037	10/02/2009 10:20	29.5	Water column	bottom water observations
1982627	KIMBLA0208_F75_WCA	-35.096945	150.76037	10/02/2009 10:20	29.5	Water column	surface water observations
1982626	KIMBLA0109_F75_GRB_1	-35.096998	150.76062	10/02/2009 10:23	29.9	Grab Van Veen	biology/grain size
1982625	KIMBLA0109_F75_GRA_1	-35.096998	150.76062	10/02/2009 10:23	29.9	Grab Shipek	geochemistry
1982620	KIMBLA0208_F66_WCB	-35.10395	150.76331	10/02/2009 10:40	29	Water column	bottom water observations
1982619	KIMBLA0208_F66_WCA	-35.10395	150.76331	10/02/2009 10:40	29	Water column	surface water observations
1982617	KIMBLA0109_F66_GRA_1	-35.103697	150.76391	10/02/2009 10:44	28.8	Grab Shipek	geochemistry
1982618	KIMBLA0109_F66_GRB_1	-35.103477	150.76434	10/02/2009 10:46	28.8	Grab Van Veen	biology/grain size
1982624	KIMBLA0208_F67_WCB	-35.110497	150.75189	10/02/2009 11:03	20	Water column	bottom water observations
1982623	KIMBLA0208_F67_WCA	-35.110497	150.75189	10/02/2009 11:03	20	Water column	surface water observations
1982622	KIMBLA0109_F67_GRB_1	-35.110672	150.75215	10/02/2009 11:07	20.9	Grab Van Veen	biology/grain size
1982621	KIMBLA0109_F67_GRA_1	-35.110672	150.75215	10/02/2009 11:07	20.9	Grab Shipek	geochemistry
1982616	KIMBLA0208_F64_WCB	-35.117563	150.75481	10/02/2009 11:20	6.5	Water column	bottom water observations
1982615	KIMBLA0208_F64_WCA	-35.117563	150.75481	10/02/2009 11:20	6.5	Water column	surface water observations
1982613	KIMBLA0109_F64_GRA_1	-35.11688	150.75574	10/02/2009 11:24	7.5	Grab Shipek	geochemistry/grain size
1982612	KIMBLA0109_F64_GRA_PLA	-35.11688	150.75574	10/02/2009 11:24	7.5	Grab Shipek	plant sample
1982614	KIMBLA0109_F64_GRB_1	-35.11802	150.75439	10/02/2009 11:29	5.5	Grab Van Veen	biology
1982611	KIMBLA0109_F64_GRB_PLA	-35.11802	150.75439	10/02/2009 11:29	5.5	Grab Van Veen	plant sample
1982737	KIMBLA0109_F76_GRB_R1	-35.092627	150.75261	10/02/2009 12:23	25.5	Grab Van Veen	biology/grain size
1982736	KIMBLA0109_F76_GRA_R1	-35.092627	150.75261	10/02/2009 12:23	25.5	Grab Shipek	geochemistry
1982725	KIMBLA0208_F65_WCB	-35.110447	150.76377	10/02/2009 12:26	20.5	Water column	bottom water observations
1982724	KIMBLA0208_F65_WCA	-35.110447	150.76377	10/02/2009 12:26	20.5	Water column	surface water observations
1982719	KIMBLA0109_F65_GRB_R1	-35.110985	150.76387	10/02/2009 12:29	20	Grab Van Veen	biology/grain size
1982718	KIMBLA0109_F65_GRA_R1	-35.110985	150.76387	10/02/2009 12:29	20	Grab Shipek	geochemistry

1982721	KIMBLA0109_F65_GRB_R2	-35.110805	150.76337	10/02/2009 12:44	19.5	Grab Van Veen	biology/grain size
1982720	KIMBLA0109_F65_GRA_R2	-35.110805	150.76337	10/02/2009 12:44	19.5	Grab Shipek	geochemistry
1982723	KIMBLA0109_F65_GRB_R3	-35.110795	150.76369	10/02/2009 12:58	21	Grab Van Veen	biology/grain size
1982722	KIMBLA0109_F65_GRA_R3	-35.110795	150.76369	10/02/2009 12:58	21	Grab Shipek	geochemistry
1982743	KIMBLA0208_F76_WCB	-35.0921	150.757	10/02/2009 13:20	25	Water column	bottom water observations
1982742	KIMBLA0208_F76_WCA	-35.0921	150.757	10/02/2009 13:20	25	Water column	surface water observations
1982739	KIMBLA0109_F76_GRB_R2	-35.092112	150.7524	10/02/2009 13:45	24.9	Grab Van Veen	biology/grain size
1982738	KIMBLA0109_F76_GRA_R2	-35.092112	150.7524	10/02/2009 13:45	24.9	Grab Shipek	geochemistry
1982741	KIMBLA0109_F76_GRB_R3	-35.092185	150.7524	10/02/2009 14:02	25	Grab Van Veen	biology/grain size
1982740	KIMBLA0109_F76_GRA_R3	-35.092185	150.7524	10/02/2009 14:02	25	Grab Shipek	geochemistry
1982641	KIMBLA0208_F80_WCB	-35.11396	150.71289	10/02/2009 14:49	15.5	Water column	bottom water observations
1982640	KIMBLA0208_F80_WCA	-35.11396	150.71289	10/02/2009 14:49	15.5	Water column	surface water observations
1982639	KIMBLA0109_F80_GRB_1	-35.114337	150.71306	10/02/2009 14:53	15.3	Grab Van Veen	biology/grain size
1982638	KIMBLA0109_F80_GRA_1B	-35.114463	150.7132	10/02/2009 14:53	15.3	Grab Shipek	grain size
1982637	KIMBLA0109_F80_GRA_1	-35.114365	150.71283	10/02/2009 15:09	15.5	Grab Shipek	geochemistry
1982752	KIMBLA0208_F79_WCB	-35.111495	150.72055	10/02/2009 15:18	18.2	Water column	bottom water observations
1982751	KIMBLA0208_F79_WCA	-35.111495	150.72055	10/02/2009 15:18	18.2	Water column	surface water observations
1982745	KIMBLA0109_F79_GRB_R1	-35.111538	150.72062	10/02/2009 15:24	18.5	Grab Van Veen	biology/grain size
1982744	KIMBLA0109_F79_GRA_R1	-35.111538	150.72062	10/02/2009 15:24	18.5	Grab Shipek	geochemistry
1982747	KIMBLA0109_F79_GRB_R2	-35.111905	150.72027	10/02/2009 15:38	17.9	Grab Van Veen	biology/grain size
1982746	KIMBLA0109_F79_GRA_R2	-35.111905	150.72027	10/02/2009 15:38	17.9	Grab Shipek	geochemistry
1982750	KIMBLA0109_F79_GRB_R3	-35.112287	150.7205	10/02/2009 15:54	18	Grab Van Veen	biology
1982749	KIMBLA0109_F79_GRA_R3	-35.112287	150.7205	10/02/2009 15:54	18	Grab Shipek	geochemistry
1982748	KIMBLA0109_F79_GRA_R3B	-35.112287	150.72003	10/02/2009 15:58	18	Grab Shipek	grain size
1982709	KIMBLA0208_F09_WCB	-35.116435	150.7255	10/02/2009 16:08	18	Water column	bottom water observations
1982708	KIMBLA0208_F09_WCA	-35.116435	150.7255	10/02/2009 16:08	18	Water column	surface water observations
1982703	KIMBLA0109_F09_GRB_R1	-35.116544	150.72522	10/02/2009 16:12	18	Grab Van Veen	biology/grain size
1982702	KIMBLA0109_F09_GRA_R1	-35.116325	150.72537	10/02/2009 16:12	18	Grab Shipek	geochemistry
1982705	KIMBLA0109_F09_GRB_R2	-35.117018	150.72438	10/02/2009 16:25	18	Grab Van Veen	biology/grain size
1982704	KIMBLA0109_F09_GRA_R2	-35.117018	150.72438	10/02/2009 16:25	18	Grab Shipek	geochemistry
1982706	KIMBLA0109_F09_GRA_R3	-35.11645	150.72518	10/02/2009 16:42	18	Grab Shipek	geochemistry
1982707	KIMBLA0109_F09_GRB_R3	-35.11675	150.72519	10/02/2009 16:45	18	Grab Van Veen	biology/grain size
1982646	KIMBLA0208_F83_WCB	-35.120865	150.72883	11/02/2009 9:15	18.8	Water column	bottom water observations
1982645	KIMBLA0208_F83_WCA	-35.120865	150.72883	11/02/2009 9:15	18.8	Water column	surface water observations

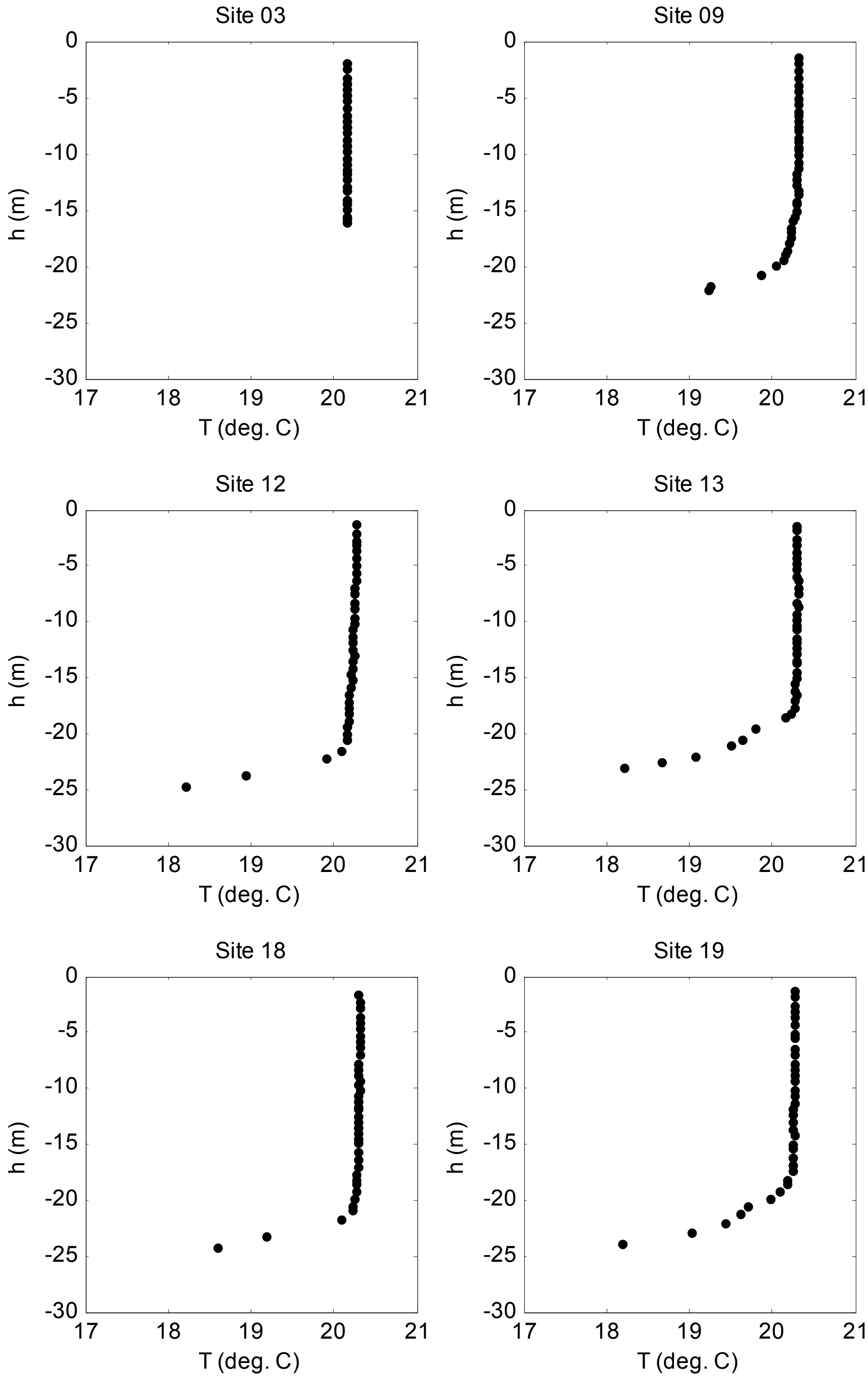
1982644	*KIMBLA0109_F83_GRB_1*	*-35.119963*	*150.72989*	*11/02/2009 9:18*	*18.9*	*Grab Van Veen*	*biology*
1982642	*KIMBLA0109_F83_GRA_1B*	*-35.119963*	*150.72989*	*11/02/2009 9:18*	*18.9*	*Grab Shipek*	*grain size*
1982643	*KIMBLA0109_F83_GRA_1*	*-35.120713*	*150.72958*	*11/02/2009 9:29*	*18.6*	*Grab Shipek*	*geochemistry*
1982764	*KIMBLA0208_F70_WCB*	*-35.12559*	*150.72353*	*11/02/2009 9:46*	*16*	*Water column*	*bottom water observations*
1982763	*KIMBLA0208_F70_WCA*	*-35.12559*	*150.72353*	*11/02/2009 9:46*	*16*	*Water column*	*surface water observations*
1982755	*KIMBLA0109_F70_GRB_1*	*-35.125412*	*150.72381*	*11/02/2009 9:48*	*16*	*Grab Van Veen*	*biology*
1982754	*KIMBLA0109_F70_GRA_1B*	*-35.125412*	*150.72381*	*11/02/2009 9:48*	*16*	*Grab Shipek*	*grain size*
1982753	*KIMBLA0109_F70_GRA_1*	*-35.125472*	*150.72381*	*11/02/2009 10:00*	*16*	*Grab Shipek*	*geochemistry*
1982650	*KIMBLA0208_F69_WCB*	*-35.118933*	*150.73317*	*11/02/2009 10:27*	*19*	*Water column*	*bottom water observations*
1982649	*KIMBLA0208_F69_WCA*	*-35.118933*	*150.73317*	*11/02/2009 10:27*	*19*	*Water column*	*surface water observations*
1982648	*KIMBLA0109_F69_GRB_1*	*-35.119095*	*150.73346*	*11/02/2009 10:30*	*19*	*Grab Van Veen*	*biology/grain size*
1982647	*KIMBLA0109_F69_GRA_1*	*-35.119095*	*150.73346*	*11/02/2009 10:30*	*19*	*Grab Shipek*	*geochemistry*
1982775	*KIMBLA0208_F68_WCB*	*-35.116413*	*150.73947*	*11/02/2009 10:43*	*20*	*Water column*	*bottom water observations*
1982774	*KIMBLA0208_F68_WCA*	*-35.116413*	*150.73947*	*11/02/2009 10:43*	*20*	*Water column*	*surface water observations*
1982766	*KIMBLA0109_F68_GRA_R1*	*-35.11658*	*150.73982*	*11/02/2009 10:45*	*20*	*Grab Shipek*	*geochemistry*
1982767	*KIMBLA0109_F68_GRB_R1B*	*-35.116558*	*150.74022*	*11/02/2009 10:48*	*20*	*Grab Van Veen*	*grain size*
1982765	*KIMBLA0109_F68_GRB_R1*	*-35.116455*	*150.73956*	*11/02/2009 10:52*	*20*	*Grab Van Veen*	*biology*
1982770	*KIMBLA0168_F68_GRB_R2*	*-35.116505*	*150.73936*	*11/02/2009 10:59*	*20*	*Grab Van Veen*	*biology/grain size*
1982769	*KIMBLA0168_F68_GRA_R2*	*-35.11655*	*150.73953*	*11/02/2009 11:02*	*20*	*Grab Shipek*	*geochemistry*
1982768	*KIMBLA0168_F68_GRA_R2_PLA*	*-35.11655*	*150.73953*	*11/02/2009 11:02*	*20*	*Grab Shipek*	*plant sample*
1982772	*KIMBLA0168_F68_GRA_R3*	*-35.116562*	*150.73959*	*11/02/2009 11:14*	*20*	*Grab Shipek*	*geochemistry*
1982771	*KIMBLA0168_F68_GRA_R3_PLA*	*-35.116562*	*150.73959*	*11/02/2009 11:14*	*20*	*Grab Shipek*	*plant sample*
1982773	*KIMBLA0168_F68_GRB_R3*	*-35.116436*	*150.73991*	*11/02/2009 11:19*	*20*	*Grab Van Veen*	*biology/grain size*
1982758	*KIMBLA0109_F70_GRB_R2*	*-35.125602*	*150.72335*	*11/02/2009 11:45*	*15.9*	*Grab Van Veen*	*biology*
1982757	*KIMBLA0109_F70_GRA_R2*	*-35.125548*	*150.72339*	*11/02/2009 11:45*	*15.9*	*Grab Shipek*	*geochemistry*
1982756	*KIMBLA0109_F70_GRA_R2B*	*-35.12556*	*150.72339*	*11/02/2009 11:47*	*15.9*	*Grab Shipek*	*grain size*
1982762	*KIMBLA0109_F70_GRB_R3*	*-35.125577*	*150.72325*	*11/02/2009 11:58*	*15.6*	*Grab Van Veen*	*biology*
1982761	*KIMBLA0109_F70_GRA_R3*	*-35.1255*	*150.72338*	*11/02/2009 12:00*	*15.6*	*Grab Shipek*	*geochemistry*
1982760	*KIMBLA0109_F70_GRA_R3B*	*-35.125567*	*150.72361*	*11/02/2009 12:02*	*15.9*	*Grab Shipek*	*geochemistry*
1982759	*KIMBLA0109_F70_GRA_R3C*	*-35.125567*	*150.72361*	*11/02/2009 12:12*	*15.9*	*Grab Shipek*	*grain size*
1982654	*KIMBLA0208_F27_WCB*	*-35.113765*	*150.74953*	*11/02/2009 13:15*	*18.8*	*Water column*	*bottom water observations*
1982653	*KIMBLA0208_F27_WCA*	*-35.113765*	*150.74953*	*11/02/2009 13:15*	*18.8*	*Water column*	*surface water observations*
1982652	*KIMBLA0109_F27_GRB_1*	*-35.11376*	*150.75022*	*11/02/2009 13:20*	*18.9*	*Grab Van Veen*	*biology/grain size*
1982651	*KIMBLA0109_F27_GRA_1*	*-35.113672*	*150.74947*	*11/02/2009 13:24*	*18.9*	*Grab Shipek*	*geochemistry*

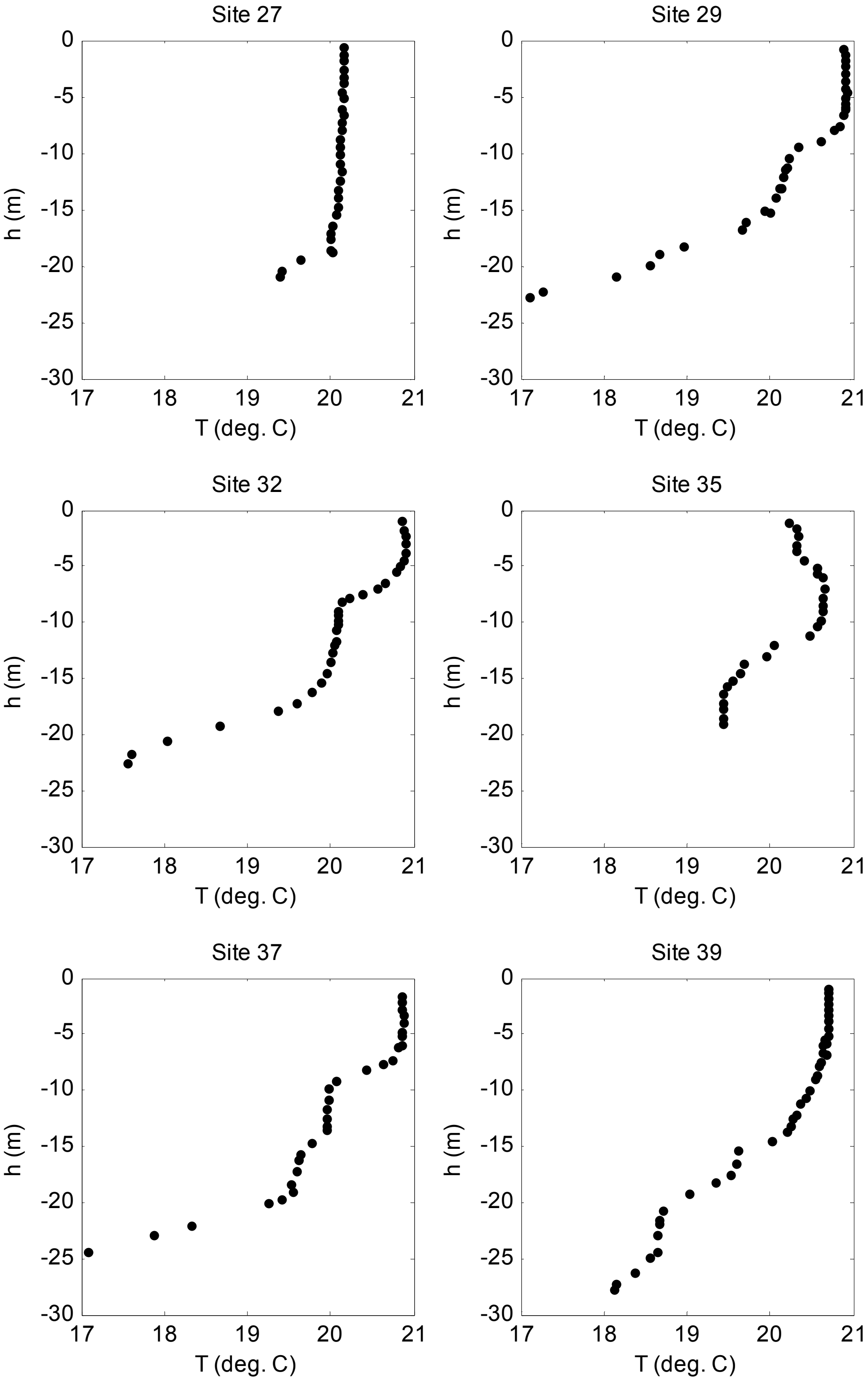
1982658	*KIMBLA0208_F39_WCB*	*-35.105822*	*150.7601*	*11/02/2009 13:37*	*25*	*Water column*	*bottom water observations*
1982657	*KIMBLA0208_F39_WCA*	*-35.105822*	*150.7601*	*11/02/2009 13:37*	*25*	*Water column*	*surface water observations*
1982655	*KIMBLA0109_F39_GRA_1*	*-35.106163*	*150.76013*	*11/02/2009 13:42*	*24.9*	*Grab Shipek*	*geochemistry*
1982656	*KIMBLA0109_F39_GRB_1*	*-35.106047*	*150.76033*	*11/02/2009 13:46*	*24.6*	*Grab Van Veen*	*biology/grain size*
1982663	*KIMBLA0208_F35_WCB*	*-35.112539*	*150.76083*	*11/02/2009 14:11*	*17*	*Water column*	*bottom water observations*
1982662	*KIMBLA0208_F35_WCA*	*-35.112539*	*150.76083*	*11/02/2009 14:11*	*17*	*Water column*	*surface water observations*
1982660	*KIMBLA0109_F35_GRA_1*	*-35.112497*	*150.76096*	*11/02/2009 14:15*	*17*	*Grab Shipek*	*geochemistry*
1982661	*KIMBLA0109_F35_GRB_1*	*-35.11212*	*150.76127*	*11/02/2009 14:17*	*17*	*Grab Van Veen*	*biology/grain size*
1982659	*KIMBLA0109_F35_GRA_1B*	*-35.112077*	*150.76135*	*11/02/2009 14:24*	*17*	*Grab Shipek*	*geochemistry*
1982668	*KIMBLA0208_F63_WCB*	*-35.119508*	*150.74455*	*11/02/2009 14:35*	*19*	*Water column*	*bottom water observations*
1982667	*KIMBLA0208_F63_WCA*	*-35.119508*	*150.74455*	*11/02/2009 14:35*	*19*	*Water column*	*surface water observations*
1982666	*KIMBLA0109_F63_GRB_1*	*-35.119705*	*150.74457*	*11/02/2009 14:38*	*19*	*Grab Van Veen*	*biology*
1982665	*KIMBLA0109_F63_GRA_1*	*-35.119705*	*150.74457*	*11/02/2009 14:38*	*19*	*Grab Shipek*	*geochemistry*
1982664	*KIMBLA0109_F63_GRA_1B*	*-35.119645*	*150.74468*	*11/02/2009 14:41*	*19*	*Grab Shipek*	*grain size*
1982672	*KIMBLA0208_F74_WCB*	*-35.10505*	*150.74432*	*11/02/2009 14:58*	*21*	*Water column*	*bottom water observations*
1982671	*KIMBLA0208_F74_WCA*	*-35.10505*	*150.74432*	*11/02/2009 14:58*	*21*	*Water column*	*surface water observations*
1982670	*KIMBLA0109_F74_GRB_1*	*-35.105142*	*150.74429*	*11/02/2009 15:01*	*21*	*Grab Van Veen*	*biology*
1982669	*KIMBLA0109_F74_GRA_1*	*-35.105142*	*150.74429*	*11/02/2009 15:01*	*21*	*Grab Shipek*	*geochemistry/grain size*
1982676	*KIMBLA0208_F37_WCB*	*-35.098053*	*150.75588*	*11/02/2009 15:15*	*26*	*Water column*	*bottom water observations*
1982675	*KIMBLA0208_F37_WCA*	*-35.098053*	*150.75588*	*11/02/2009 15:15*	*26*	*Water column*	*surface water observations*
1982673	*KIMBLA0109_F37_GRA_1*	*-35.098095*	*150.75585*	*11/02/2009 15:18*	*26*	*Grab Shipek*	*geochemistry/grain size*
1982674	*KIMBLA0109_F37_GRB_1*	*-35.09826*	*150.7562*	*11/02/2009 15:24*	*26*	*Grab Van Veen*	biology
1982680	*KIMBLA0208_F19_WCB*	*-35.112488*	*150.7378*	*11/02/2009 15:44*	*19*	*Water column*	*bottom water observations*
1982679	*KIMBLA0208_F19_WCA*	*-35.112488*	*150.7378*	*11/02/2009 15:44*	*19*	*Water column*	*surface water observations*
1982677	*KIMBLA0109_F19_GRA_1*	*-35.112567*	*150.73747*	*11/02/2009 15:46*	*19*	*Grab Shipek*	*geochemistry*
1982678	*KIMBLA0109_F19_GRB_1*	*-35.1127*	*150.7374*	*11/02/2009 15:48*	*19*	*Grab Van Veen*	*biology*
1982684	*KIMBLA0208_F13_WCB*	*-35.11563*	*150.73283*	*11/02/2009 16:08*	*19*	*Water column*	*bottom water observations*
1982683	*KIMBLA0208_F13_WCA*	*-35.11563*	*150.73283*	*11/02/2009 16:08*	*19*	*Water column*	*surface water observations*
1982682	*KIMBLA0109_F13_GRB_1*	*-35.115677*	*150.73264*	*11/02/2009 16:11*	*19*	*Grab Van Veen*	*biology/grain size*
1982681	*KIMBLA0109_F13_GRA_1*	*-35.115635*	*150.73266*	*11/02/2009 16:14*	*19*	*Grab Shipek*	*geochemistry*
1982689	*KIMBLA0208_F72_WCB*	*-35.112428*	*150.72672*	*12/02/2009 8:47*	*20.5*	*Water column*	*bottom water observations*
1982688	*KIMBLA0208_F72_WCA*	*-35.112428*	*150.72672*	*12/02/2009 8:47*	*20.5*	*Water column*	*surface water observations*
1982686	*KIMBLA0109_F72_GRA_1*	*-35.112062*	*150.72657*	*12/02/2009 8:50*	*20*	*Grab Shipek*	*geochemistry*
1982687	*KIMBLA0109_F72_GRB_1*	*-35.111988*	*150.72649*	*12/02/2009 8:55*	*20*	*Grab Van Veen*	*biology*

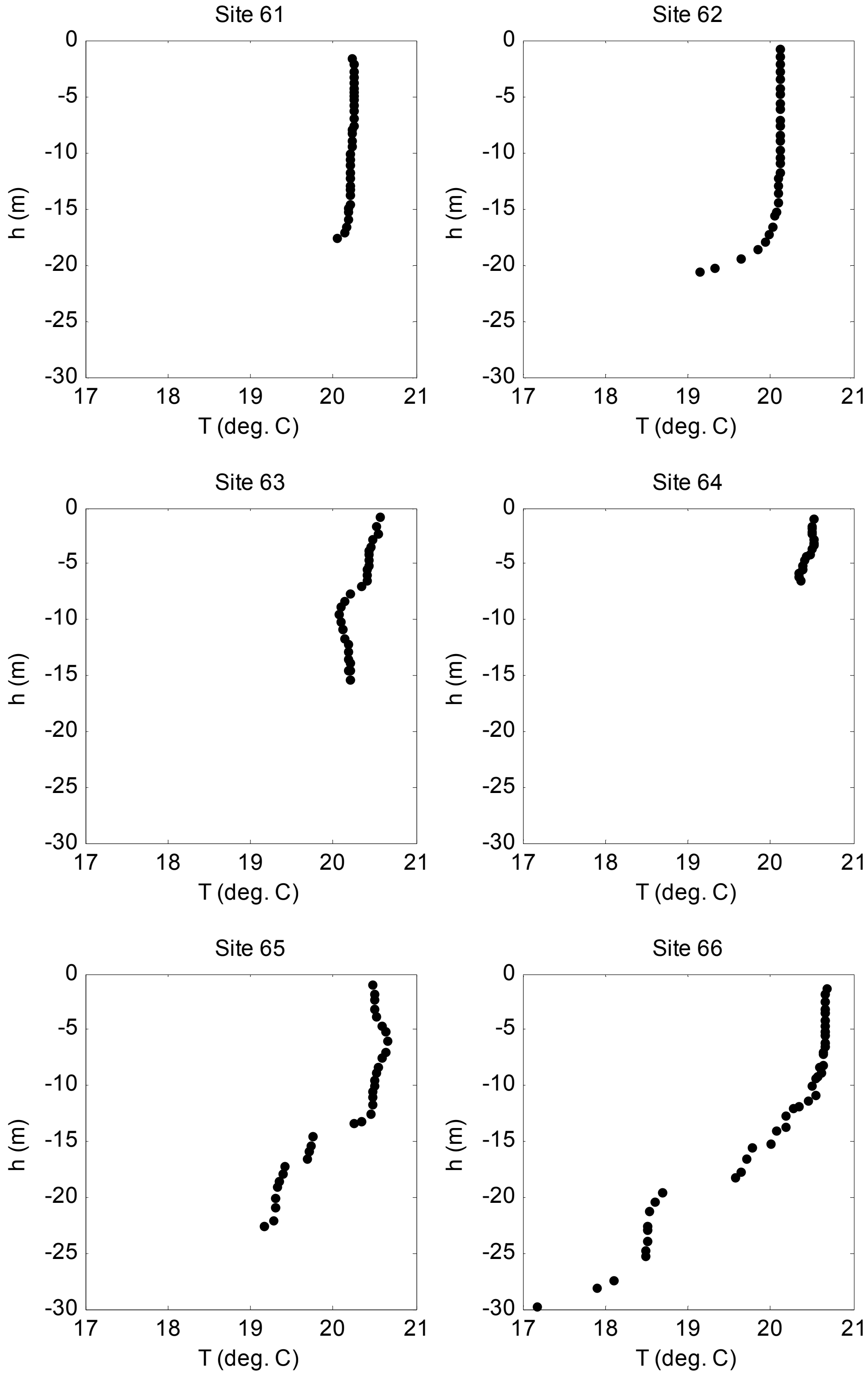
1982685	*KIMBLA0109_F72_GRA_1B*	*-35.112507*	*150.72661*	*12/02/2009 8:58*	*20*	*Grab Shipek*	*grain size*
1982735	*KIMBLA0208_F73_WCB*	*-35.110765*	*150.73985*	*12/02/2009 9:09*	*20.5*	*Water column*	*bottom water observations*
1982734	*KIMBLA0208_F73_WCA*	*-35.110765*	*150.73985*	*12/02/2009 9:09*	*20.5*	*Water column*	*surface water observations*
1982727	*KIMBLA0109_F73_GRA_R1*	*-35.110943*	*150.73986*	*12/02/2009 9:11*	*20.5*	*Grab Shipek*	*geochemistry*
1982728	*KIMBLA0109_F73_GRB_R1*	*-35.110838*	*150.73989*	*12/02/2009 9:13*	*20.5*	*Grab Van Veen*	*biology*
1982726	*KIMBLA0109_F73_GRA_R1B*	*-35.110702*	*150.74005*	*12/02/2009 9:15*	*20.5*	*Grab Shipek*	*grain size*
1982731	*KIMBLA0109_F73_GRB_R2*	*-35.110918*	*150.74015*	*12/02/2009 9:31*	*20*	*Grab Van Veen*	*biology*
1982730	*KIMBLA0109_F73_GRA_R2*	*-35.110918*	*150.74015*	*12/02/2009 9:31*	*20*	*Grab Shipek*	*geochemistry/grain size*
1982729	*KIMBLA0109_F73_GRB_R2_PLA*	*-35.110918*	*150.74015*	*12/02/2009 9:31*	*20*	*Grab Van Veen*	*plant sample*
1982733	*KIMBLA0109_F73_GRB_R3*	*-35.110947*	*150.73971*	*12/02/2009 9:52*	*20.5*	*Grab Van Veen*	*biology*
1982732	*KIMBLA0109_F73_GRA_R3*	*-35.110947*	*150.73971*	*12/02/2009 9:52*	*20.5*	*Grab Shipek*	*geochemistry/grain size*
1982717	*KIMBLA0208_F29_WCB*	*-35.102388*	*150.74783*	*12/02/2009 10:15*	*24*	*Water column*	*bottom water observations*
1982716	*KIMBLA0208_F29_WCA*	*-35.102388*	*150.74783*	*12/02/2009 10:15*	*24*	*Water column*	*surface water observations*
1982710	*KIMBLA0109_F29_GRA_R1*	*-35.102188*	*150.74765*	*12/02/2009 10:19*	*24*	*Grab Shipek*	*geochemistry/grain size*
1982711	*KIMBLA0109_F29_GRB_R1*	*-35.103197*	*150.74751*	*12/02/2009 10:24*	*24*	*Grab Van Veen*	*biology*
1982712	*KIMBLA0109_F29_GRA_R2*	*-35.103013*	*150.74756*	*12/02/2009 10:39*	*24*	*Grab Shipek*	*geochemistry/grain size*
1982713	*KIMBLA0109_F29_GRB_R2*	*-35.103045*	*150.74751*	*12/02/2009 10:41*	*24*	*Grab Van Veen*	*biology*
1982714	*KIMBLA0109_F29_GRA_R3*	*-35.102953*	*150.74756*	*12/02/2009 11:00*	*24*	*Grab Shipek*	*geochemistry/grain size*
1982715	*KIMBLA0109_F29_GRB_R3*	*-35.102783*	*150.7468*	*12/02/2009 11:12*	*24*	*Grab Van Veen*	*biology*
1982692	*KIMBLA0208_F81_WCB*	*-35.108115*	*150.76714*	*12/02/2009 11:31*	*25*	*Water column*	*bottom water observations*
1982691	*KIMBLA0208_F81_WCA*	*-35.108115*	*150.76714*	*12/02/2009 11:31*	*25*	*Water column*	*surface water observations*
1982690	*KIMBLA0109_F81_GRA_1*	*-35.108702*	*150.76627*	*12/02/2009 11:43*	*25*	*Grab Shipek*	*geochemistry/grain size*
1982697	*KIMBLA0208_F71_WCB*	*-35.120078*	*150.71871*	*12/02/2009 13:06*	*16*	*Water column*	*bottom water observations*
1982696	*KIMBLA0208_F71_WCA*	*-35.120078*	*150.71871*	*12/02/2009 13:06*	*16*	*Water column*	*surface water observations*
1982693	*KIMBLA0109_F71_GRA_1*	*-35.120182*	*150.71866*	*12/02/2009 13:14*	*16*	*Grab Shipek*	*grain size*
1982694	*KIMBLA0109_F71_GRB_1*	*-35.119181*	*150.71884*	*12/02/2009 13:17*	*16*	*Grab Van Veen*	*biology*
1982695	*KIMBLA0109_F71_GRA_2*	*-35.120317*	*150.71879*	*12/02/2009 13:17*	*16*	*Grab Shipek*	*geochemistry*
1982701	*KIMBLA0208_F62_WCB*	*-35.124562*	*150.73925*	*12/02/2009 13:40*	*17*	*Water column*	*bottom water observations*
1982700	*KIMBLA0208_F62_WCA*	*-35.124562*	*150.73925*	*12/02/2009 13:40*	*17*	*Water column*	*surface water observations*
82699	*KIMBLA0109_F62_GRB_1*	*-35.123803*	*150.73903*	*12/02/2009 13:45*	*17*	*Grab Van Veen*	*biology/grain size*
1982698	*KIMBLA0109_F62_GRA_1*	*-35.1237*	*150.73902*	*12/02/2009 13:45*	*17*	*Grab Shipek*	*geochemistry*
1982776	*KIMBLA0208_F84_PLA*	*-35.05041*	*150.67445*	*13/02/2009 9:45*	*NA*	*Vegetation*	*plant sample/geochemistry*
1982777	*KIMBLA0208_F85*	*-35.04933*	*150.67725*	*13/02/2009 9:52*	*NA*	*Solid phase*	*geochemistry/grain size*
1982778	*KIMBLA0208_F86*	*-35.04918*	*150.67731*	*13/02/2009 9:55*	*NA*	*Solid phase*	*geochemistry/grain size*

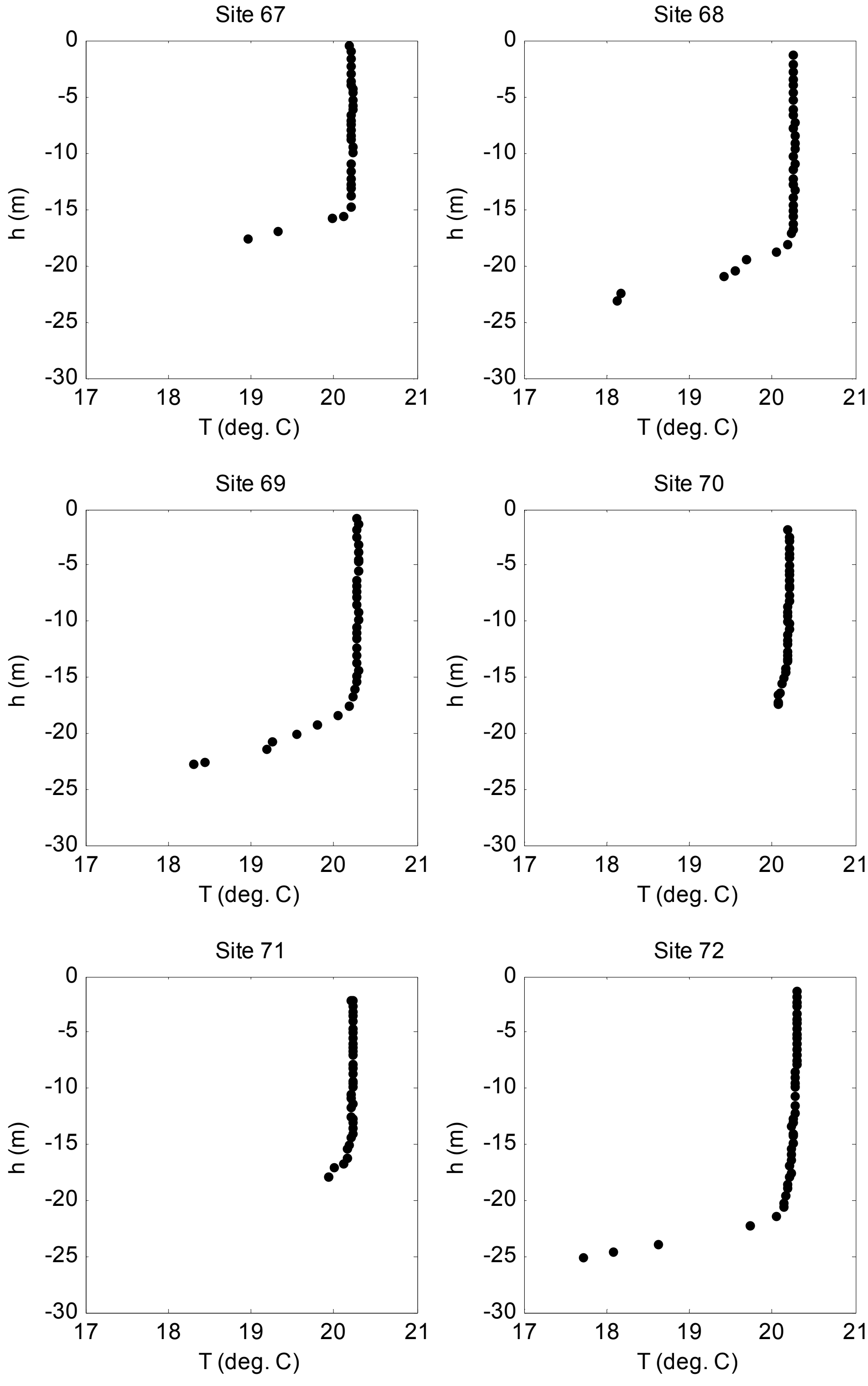
7.3 TEMPERATURE PROFILES FROM CTD

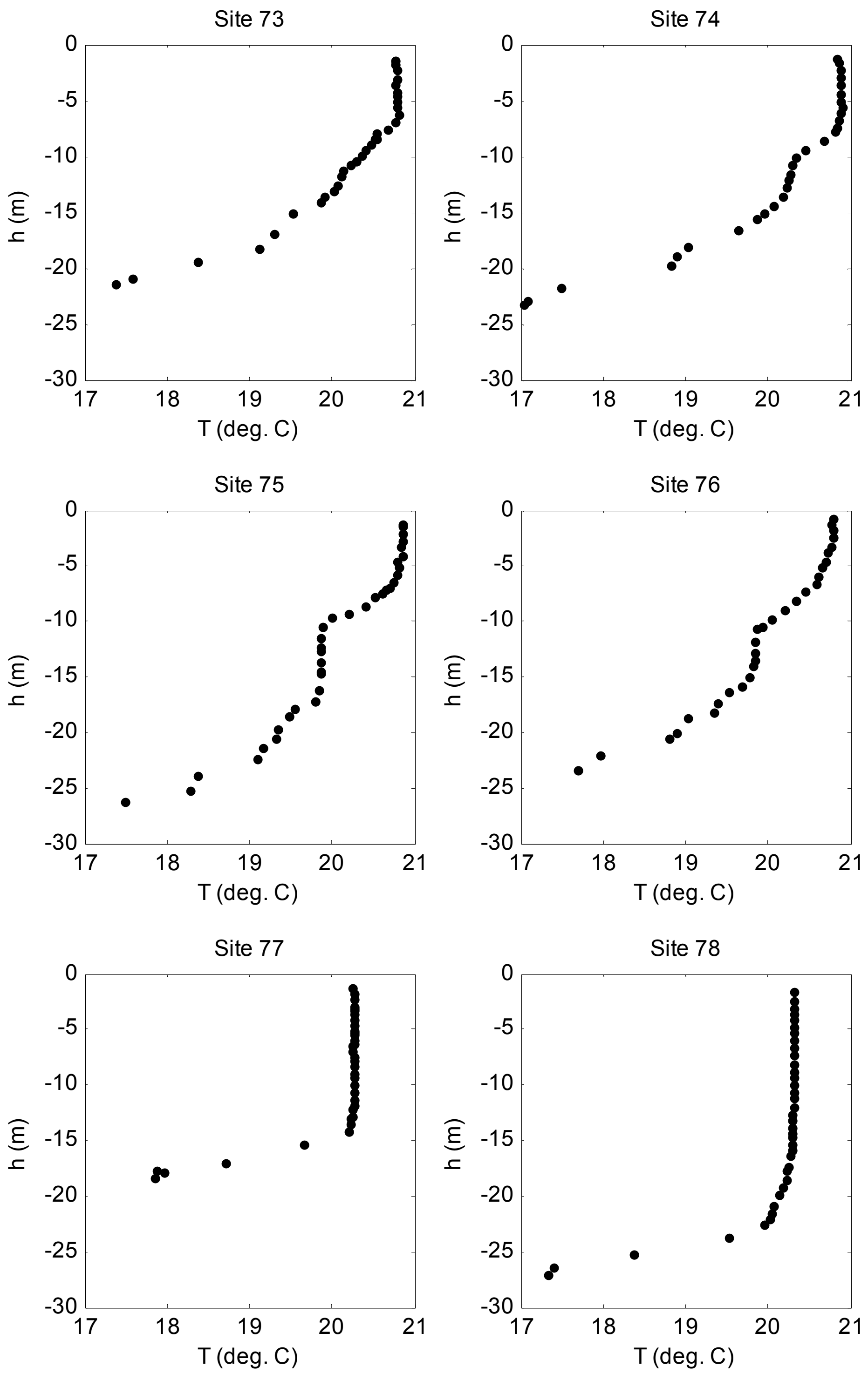
Each plot represents measurements at sites in the Darling Road grid on 12 and 13 February, 2009 (h = water depth)

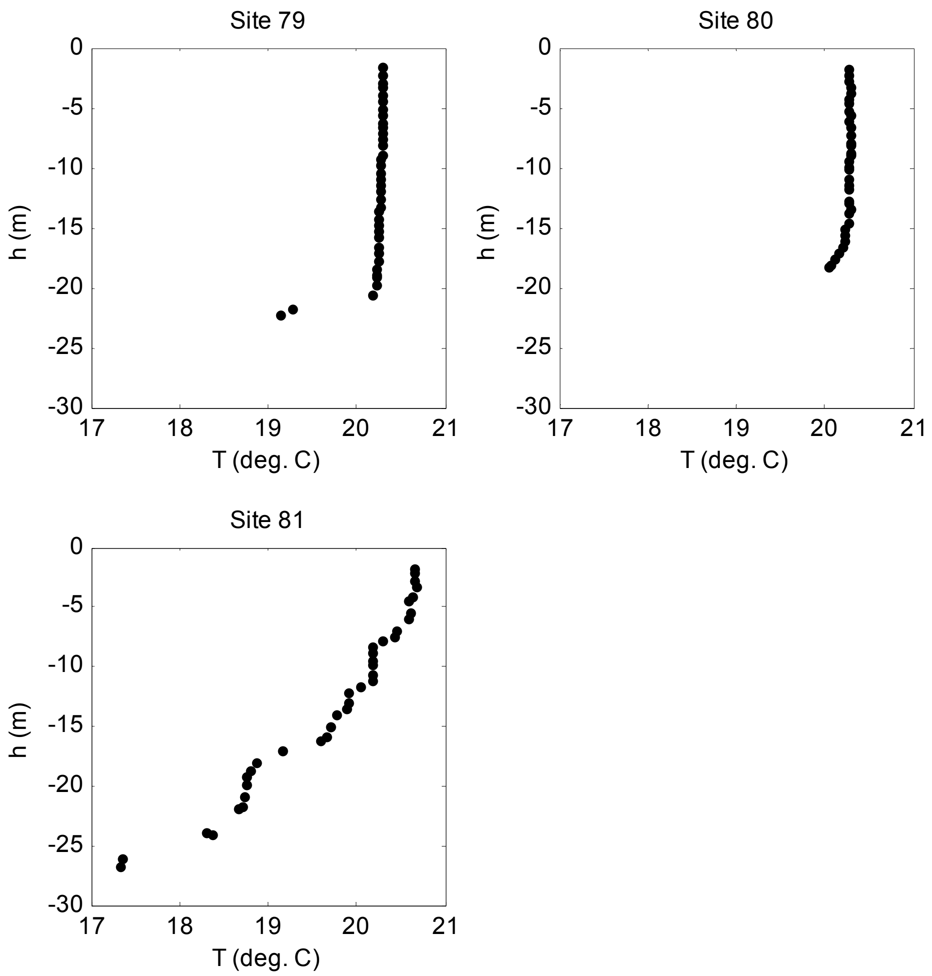



Site 27
Site 29
Site 32
Site 35
Site 37
Site 39
h (m)
T (deg. C)
0
-5
-10
-15
-20
-25
-30
17
18
19
20
21


Site 61
Site 62
Site 63
Site 64
Site 65
Site 66
h (m)
0
-5
-10
-15
-20
-25
-30
17
18
19
20
21
T (deg. C)

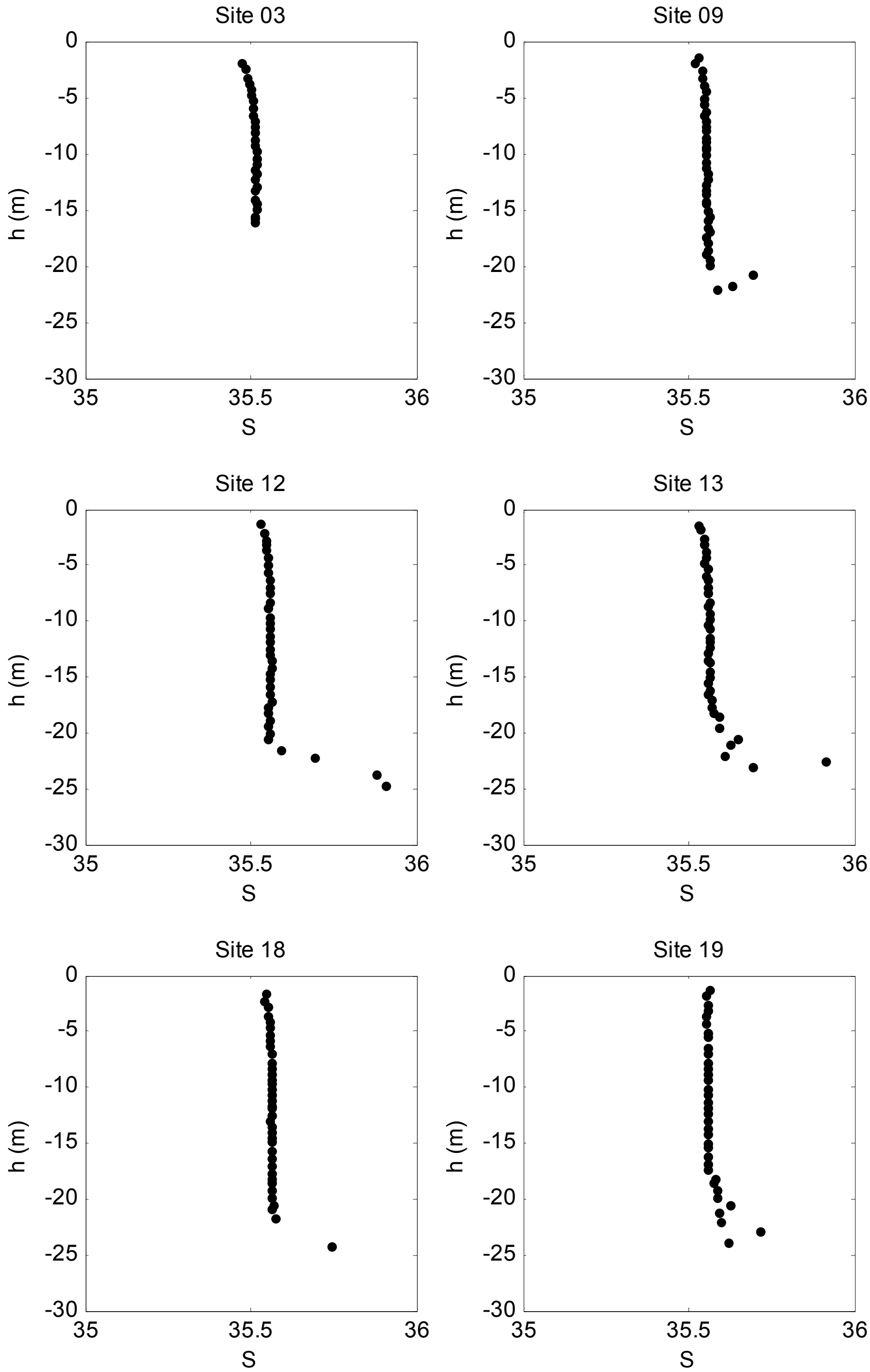

Site 67
Site 68
Site 69
Site 70
Site 71
Site 72
h (m)
T (deg. C)
0
-5
-10
-15
-20
-25
-30
17
18
19
20
21

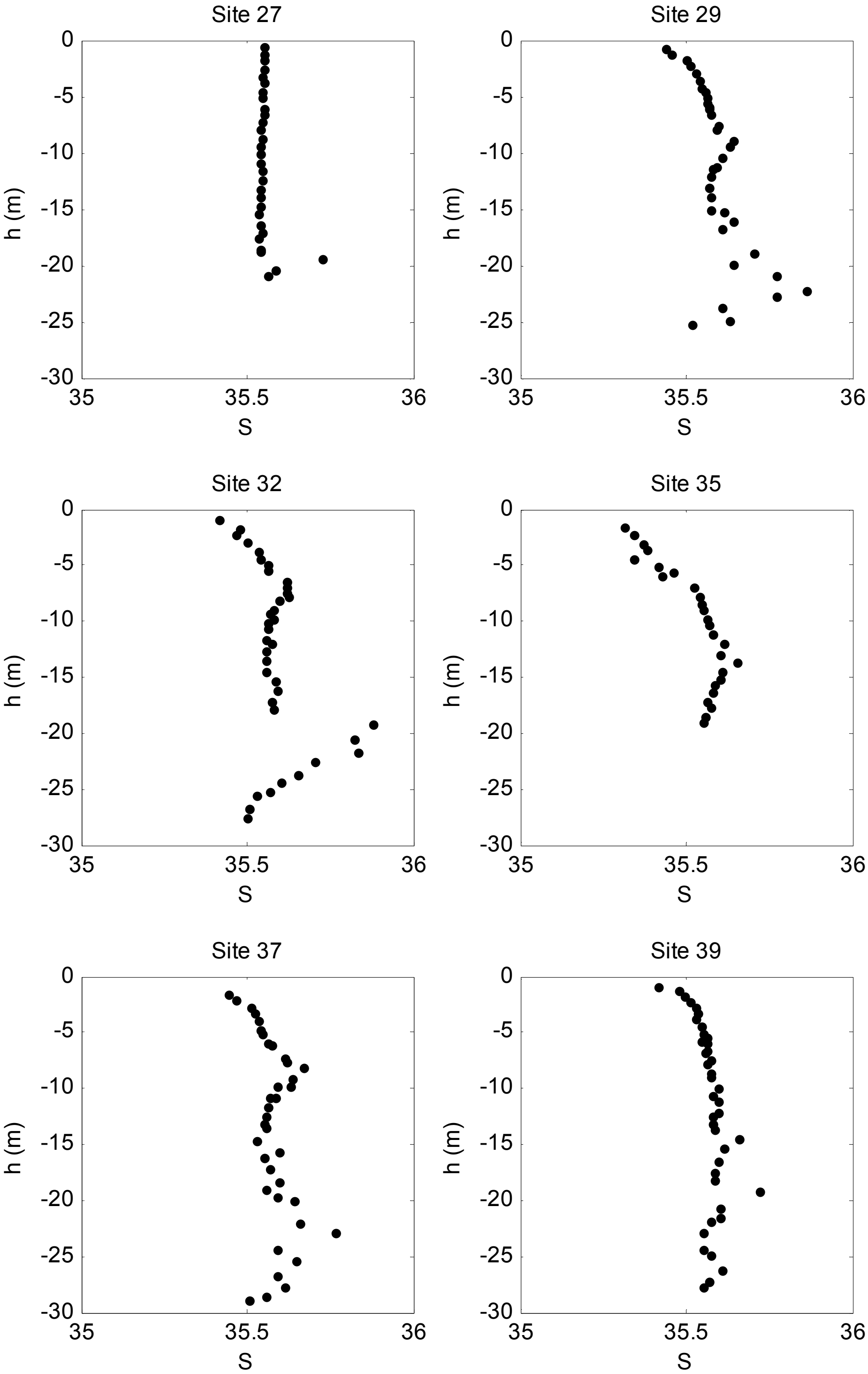

Site 73
Site 74
Site 75
Site 76
Site 77
Site 78
h (m)
T (deg. C)
0
-5
-10
-15
-20
-25
-30
17
18
19
20
21

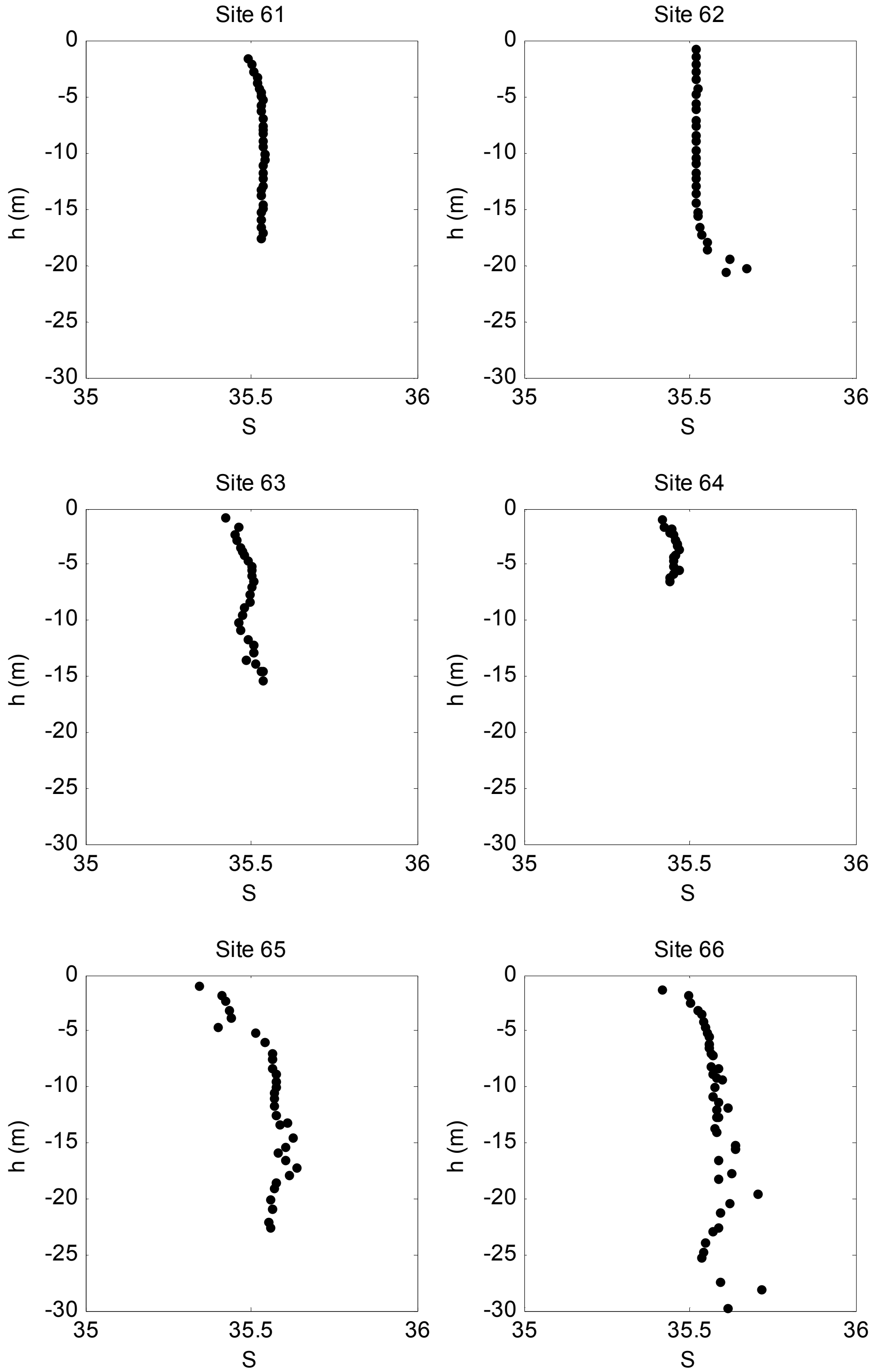

Site 79
Site 80
Site 81
h (m)
T (deg. C)
0
-5
-10
-15
-20
-25
-30
17
18
19
20
21

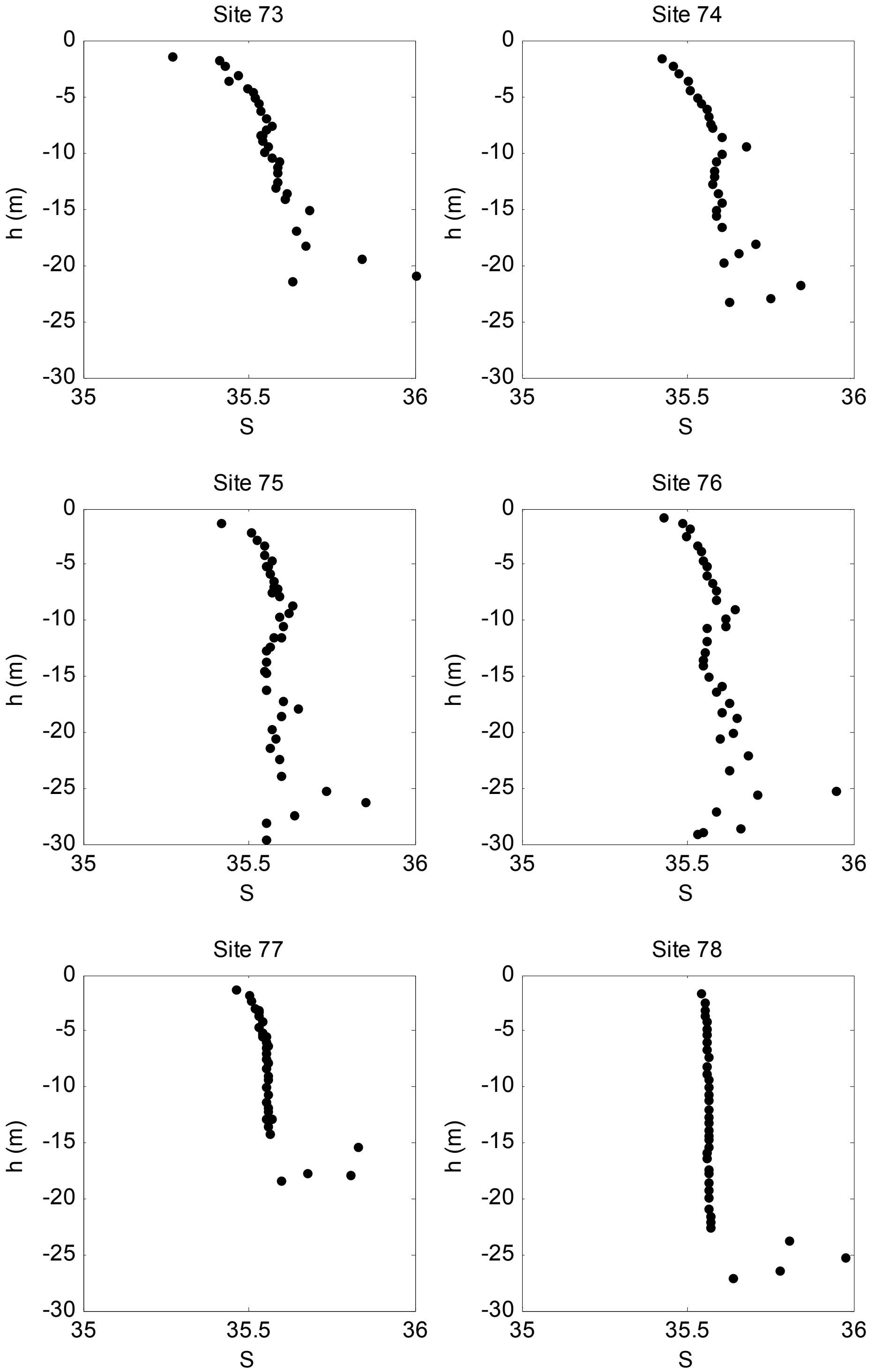
7.4 SALINITY PROFILES FROM CTD

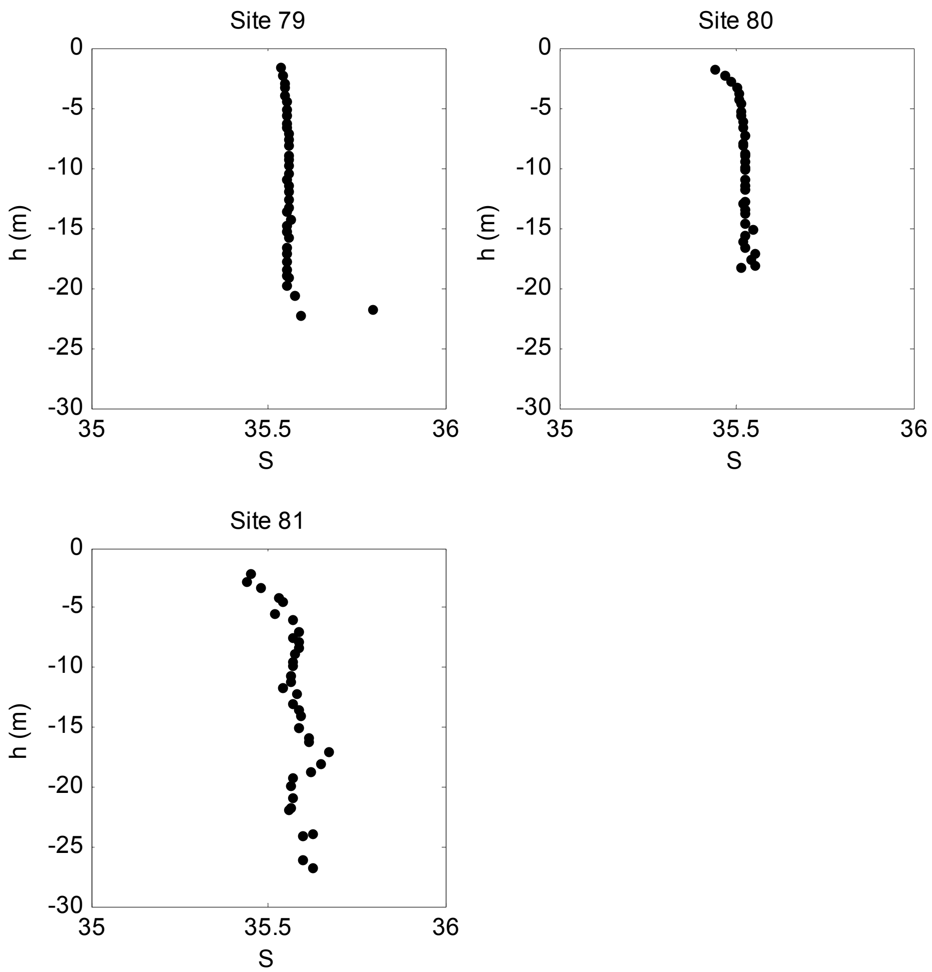
Each plot represents measurements at sites in the Darling Road grid on 12 and 13 February, 2009.




Site 27
Site 29
Site 32
Site 35
Site 37
Site 39
h (m)
0
-5
-10
-15
-20
-25
-30
35
35.5
36
S


Site 61
Site 62
Site 63
Site 64
Site 65
Site 66
h (m)
S
0
-5
-10
-15
-20
-25
-30
35
35.5
36


Site 73
Site 74
Site 75
Site 76
Site 77
Site 78
h (m)
S
0
-5
-10
-15
-20
-25
-30
35
35.5
36


Site 79
Site 80
Site 81
h (m)
S
0
-5
-10
-15
-20
-25
-30
35
35.5
36