THE LONG MUD

Benthos and shorebirds of the foreshore of Eighty-mile Beach, Western Australia

Report on the
'Anna Plains Benthic Invertebrate and bird Mapping 1999'
(ANNABIM-99)

Edited by
Theunis Piersma[1,2], Grant B. Pearson[3], Robert Hickey[4] & Marc Lavaleye[1]

[1]Department of Marine Ecology and Evolution,Royal Netherlands Institute for Sea Research (NIOZ), P.O. Box 59, 1790 AB Den Burg, Texel, The Netherlands, E-mail: theunis@nioz.nl

[2]Animal Ecology Group, Centre for Ecological and Evolutionary Studies, University of Groningen, P.O. Box 14, 9750 AA Haren, The Netherlands

[3]Western Australian Department of Conservation and Land Management (CALM), WA Wildlife Research Centre, P.O. Box 51, Wanneroo, WA 6065, Australia, E-mail: grantp@DCLM.wa.gov.au

[4]Department of Geography and Land Studies, Central Washington University, Ellensburg, WA 98926, U.S.A., E-mail: rhickey@cwu.edu

With contributions from
Michelle Crean (Curtin University of Technology), Petra de Goeij (NIOZ),
Pieter J.C. Honkoop (University of Sydney, NIOZ), Maria Mann (Environs Kimberley),
Danny I. Rogers (Charles Sturt University) and the *Landscope*-expeditioners

ROYAL NETHERLANDS INSTITUTE FOR SEA RESEARCH (NIOZ), TEXEL

WESTERN AUSTRALIAN DEPARTMENT OF CONSERVATION
AND LAND MANAGEMENT (CALM)

ENVIRONS KIMBERLEY, BROOME

CENTRAL WASHINGTON UNIVERSITY, ELLENSBURG, WA, USA

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SUMMARY

1. Eighty-mile Beach is a 230 km long linear sand-coast. A beach of 100-500 m width is bordered by 0.5 to 4 km wide intertidal mudflats. The intertidal zone is estimated to comprise more than 60,000 ha (600 km^2) of mud and sand that are exposed by semidiurnal tides with a range of about 6 m.

2. Eighty-mile Beach is known for its accumulations of tropical seashells (from deep water) and also as a key nonbreeding area for noerthern hemisphere shorebirds. About half a million roosting shorebirds have been counted in recent years, including 50% of the world's Great Knots *Calidris tenuirostris*. In February 2004 more than 2 million Oriental Pratincoles *Glareola maldivarum* used Eighty-maile Beach as a daytime roost.

3. Based at the Anna Plains homestead, a team comprised of 72 volunteers (including 8 Landscope expeditioners, 8 Notre Dame University students, 33 local volunteers, 7 logistical support people and 16 science volunteers) and 8 scientific co-ordinators, visited 818 intertidal sample sites on the Eighty-mile Beach foreshore between 8 and 22 October 1999. The sample stations were laid out in seven grid-sections with 200 m intersections along 80 km of the beach. The northernmost section was found 10 km north of the Anna Plains entry to the beach, the southernmost 65 km to the south of the entry. At each of the sampling stations samples were taken to determine de densities of macrozoobenthic species and grain size distributions. The 818 stations yielded almost 19,000 individual invertebrates, which were all counted, measured and identified to various taxonomic levels. In addition, shorebird counts were made along the beach at high tide, and on the different grid-sections during low tide.

4. To collect benthos, at each sampling station three cores with a diameter of 10.2 cm (1/120 m^2) were taken to a maximum depth of 30 cm (less if the corer hit a shell or rock layer and no benthos could be expected to live deeper). The sediment was sieved on the spot over a sieve with a mesh-size of 1 mm. All material retained on the sieve was quantitatively transferred into a plastic bag and brought to the laboratory for sorting and identification. Anthozoans, decapods, gastropods, bivalves, scaphopods, echinoids, holothurians and hemichordates were classified to species level, polychaetes and crustaceans to family-level and nemerteans and sipunculids only to phylum-level. At each grid point a sediment core was also taken with a diameter of 4.4 cm to a depth of 10 cm. Samples were transferred to a plastic bag, labelled and stored until grain size analysis in the laboratory.

5. We identified 112 different taxa, and for most of the taxa, length-frequency diagrams and distribution maps are presented in this report. Forty of the taxa were not previously found during the extensive macrozoobenthic surveys of Roebuck Bay. Among these were several bivalve species (an unknown *Tellina*, *Theora fragilis* and *Paphies* cf. *altenai*), the relatively large Columbellid snails (*Mitrella essingtonensis*), the tiny *Ringicula* snail and a tiny tuskshell (*Polyschides gibbosus*). Among the bristle worms (Polychaeta), the 5 cm large *Pectinaria* or gold combs were totally new, while clumps of the reef-forming Sabellariidae were frequently found near the low-water line. These tube-living *Sabellaria* are peculiar to mechanically undisturbed sedimentary shores. New to the group of Cnidaria were the sea pens (Pennatulacea) and the burrowing sea anemone with its parasitic epitonid snails. A flat sanddollar (*Arachnoides tenuilus*) and a sea cucumber (*Protankyra verrilli*) were also new.

6. Sediments were courser at the highest intertidal level and became finer towards the low water line. Benthic assemblages also differed among tidal heights, a change mainly due to echinoids and polychaetes that increased in number towards the lower tidal levels. There was an alongshore gradient in the characteristics of sediments and benthic assemblages as well. Although each section along the beach supported a unique collection of macrozoobenthic invertebrates, the distribution of sediments and the structure of benthic assemblages were quite poorly correlated. This may partly be explained by tropical cyclone Vance, which hit the coast of Western Australia only a few months before our study and may have lead to extensive reworking of the intertidal sediments.

7. Despite the superficially uniform appareance of Eighty-mile Beach, the different stretches of the coast were important for different shorebird species. On a broad scale, the distribution of shorebirds was positively related to the abundance of their presumed prey. The numbers of birds counted on Eighty-mile Beach at high tide and their species composition, corresponded fairly well with the numbers and species composition of shorebirds seen on the intertidal flats at low tide.

8. In the final chapter we review the management issues of Eighty-mile Beach, and make some recommendations based on the data accumulated in this report.

SAMENVATTING

1. Eighty-mile Beach is een 230 km langgerekt kustgebied. Het 100-500 meter brede zandstrand grenst aan een 0,5 tot 4 km breed waddengebied. De getijdezone omvat meer dan 60.000 ha (600 km^2) zand en modder, waar een getijcyclus van 12,5 uur en een getijrange van zo'n 6 m de dienst uitmaken.

2. Eighty-mile Beach is bekend vanwege zijn enorme rijkdom aan tropische schelpen (afkomstig uit dieper water) maar evenzeer als één van de belangrijkste niet-broedgebieden voor wadvogels, die op het noordelijke halfrond, in de arctis, broeden. In de afgelopen jaren zijn er zo'n half miljoen wadvogels geteld, waaronder 50% van de wereldpopulatie van de Grote Kanoet *Calidris tenuirostis*. In februari 2004 werd het strand van Eighty-mile Beach door meer dan twee miljoen Vorkstaartplevieren *Glareola maldivarum* gebruikt als tijdelijke rustplaats.

3. Vanuit de thuisbasis 'Anna Plains Station', vond van 8 tot 22 oktober 1999 een expeditie plaats op het wad van Eighty-mile Beach. Een team bestaande uit 72 vrijwilligers (inclusief 8 Landscope-expeditieleden, 8 studenten van de Notre Dame Universiteit, 33 lokale vrijwilligers, 7 logistieke krachten en 16 wetenschappers) en 8 wetenschappelijke co-ordinatoren, bemonsterde 818 monsterpunten (stations). Op zeven lokaties langs 80 km strand werd een grid-bemonstering gedaan. Ieder grid bestond uit 70-150 monsterpunten met een tussen-afstand van 200 m. Het noordelijkste grid lag 10 km ten noorden van de strandopgang van Anna Plains Station, het zuidelijkste 65 km ten zuiden van de strandopgang. Op elk monsterpunt werd een bodemfauna- en een sedimentmonster genomen, om respectievelijk de dichtheid van de macro-zoobenthische soorten en de korrelgrootte te bepalen. De 818 monsterpunten leverden bijna 19.000 individuele ongewervelde dieren (evertebraten) op, die allemaal zijn geteld, gemeten en geïdentificeerd tot op verschillende taxonomische niveaus. In aanvulling hierop werden er wadvogel-tellingen gedaan gedurende hoogwater op het strand en gedurende laagwater in de 7 verschillende gridlokaties.

4. Om de bodemfauna te verzamelen, werden op ieder monsterpunt met behulp van een steekbuis met een diameter van 10.2 cm (1/120 m^2) monsters genomen tot een maximale diepte van 30 cm (maar minder diep wanneer een schelplaag geraakt werd waaronder toch geen benthos kan leven). Het sediment werd ter plekke gezeefd over een zeef met een maaswijdte van 1 mm. Al het materiaal dat achterbleef op de zeef werd in een plastic zakje gedaan en naar het laboratorium gebracht om direct te worden gesorteerd en geidentificeerd. Zeeanemonen, garnalen, slakken, tweekleppige schelpdieren, olifantstanden, stekelhuidigen, zeekomkommers en hemichordaten werden geclassificeerd tot soort-niveau, borstelwormen en kreeftachtigen tot op familie-niveau en nemertijnen en sipunculiden alleen tot op phylum-niveau, Op ieder monsterpunt werd ook een sedimentmonster genomen met een steekbuis met een diameter van 4,4 cm en tot op een diepte van 10 cm. Deze monsters werden in een plastic zak gedaan, van een label voorzien en opgeslagen totdat de korrelgrootte analyses in het lab werden gedaan.

5. We identificeerden 112 verschillende taxa waarvan voor de meeste in dit rapport lengte-frequentie diagrammen en verspreidingskaartjes zijn gepresenteerd. Veertig van de taxa waren in voorgaande jaren niet eerder gevonden in Roebuck Bay, gedurende de extensieve macrozoobenthische bemonsteringen door hetzelfde onderzoeksteam. Tot deze taxa behoren verschillende tweekleppige schelpdieren (zoals, een onbekende *Tellina*, *Theora fragilis* en *Paphies* cf. *altenai*), de relatief grote columbellide slak (*Mitrella essingtonensis*), de kleine *Ringicula* slak en een kleine olifantstand (*Polyschides gibbosus*). Nieuw waren ook de 5 cm grote goudkammetjes *Pectinaria*. Klompjes rifvormende Sabellariidae werden vaak gevonden dichtbij de hoogwaterlijn. Deze in kokers levende borstelwormen zijn kenmerkend voor mechanisch ongestoorde wadbodems. Nieuw voor de groep van de holtedieren waren de zeepen (Pennatulacea) en de gravende zeeanemoon met zijn parasitaire epitonide slakken. Een platte zanddollar (*Arachnoides tenuilus*) en een zeekomkommer (*Protankyra verrilli*) waren ook nieuw.

6. Het sediment was grofkorreliger hoog in het getijdezone en fijner naarmate je de laagwaterlijn nadert. De benthische gemeenschappen verschilden ook tussen getijde-hoogten, een verandering die hoofdzakelijk veroorzaakt wordt door de stekelhuidigen echinoids en borstelwormen (polychaeten) die naar de laagwaterlijn toe in aantallen toenamen. Er was ook een gradient in de karakteristieken van sedimenttypes en benthische gemeenschappen langs de kustlijn. Alhoewel elke sectie langs de kustlijn een unieke collectie van macrozoobenthische evertebraten had, was er nauwelijks een correlatie tussen de verspreiding van sedimenttypen en de structuur van benthische gemeenschappen. Dit kan gedeeltelijk worden verklaard door de tropische cycloon Vance, die de kust van Australië slechts een paar maanden voor onze studie raakte hetgeen zou kunnen hebben geleid tot een intensieve omwoeling van de wadbodem.

7. Ondanks dat EMB er nogal uniform uit lijkt te zien, bleken de verschillende stukken kust duidelijk verschillende wadvogels aan te trekken. Grofweg was de verspreiding van de wadvogels positief gerelateerd aan de aantallen van hun prooien. De aantallen vogels die geteld werden op EMB gedurende hoogwater en de soortensamenstelling correspondeert behoorlijk goed met de aantallen en soortensamenstelling van de wadvogels op het wad tijdens laagwater.

8. In het laatste hoofdstuk geven we een overzicht van de management issues van EMB en doen we enkele aanbevelingen gebaseerd op de gegevens uit het rapport.

1. PROLOGUE

Grant Pearson

This planet, Earth – the biosphere in which we thrive and go about our daily business – is clearly in trouble. We are constantly informed of new threats to more of the Earth's biological diversity. Much has been written about this increasing loss of not just species and genes and memes, but of whole ecosystems and the functional processes necessary to support healthy, living communities. Less has been written on the strategic actions needed to arrest this decline and manage the biota and plans that demand us to adapt to ecologically sustainable development.

We present here a report on one of the world's richest tropical intertidal wetlands in an attempt to document, at least a part, of its biota, to capture in time a record of that biota, and to appraise the community of the remarkable wildlife values of this remote and important ecosystem. Perhaps as an outcome of this, a small part of Australia's West Kimberley can be preserved purely for its wildlife values without the need to sacrifice portions in a compromised barter system that has always been flawed and that often provided justification for eventual degradation through commercial development.

Our report highlights the need to focus on more than the essential wildlife values of the intertidal flats. It demonstrates the potential power of community interaction and, by placing the mudflats within a bioregion that is much more than a simple ecologically defined area of scientific interest, draw recognition to the true values of the whole ecosystem. There is a human identity that must be considered, along with the landscapes, that engenders a sense of place in addition to the ecological processes operating across those landscapes. These social overlays are important – for cultural and traditional reasons as well as the pragmatism that demands serious examination of values beyond scientific interest.

Nothing can be achieved towards the proper conservation of the wonders of places like Eighty-mile Beach or Roebuck Bay without supportive communal goodwill. The human communities, their willingness for social commitment, and the political economies within them will shape the level of conservation of the ecological and the biophysical features of these and many other heritage jewels. The success and extent of the conservation effort will be judged by our ability to convey the importance of these areas to the wider community. Historically, scientists are not good at communicating in terms that everyone can understand. They are, however, good at identifying the core problems and providing workable solutions. This is the challenge!

Figure 1.1. Absorbed in admiration for the shells on Eight-mile beach. Photo by Theunis Piersma

2. INTRODUCTION

Theunis Piersma & Grant Pearson

Among the wetland wonders of the northern part of Western Australia, the intertidal foreshore of Anna Plains Station, representing the northernmost 80 km of Eighty-mile Beach, stands out for its importance as a key nonbreeding area used by arctic-breeding migratory shorebirds. Along Eighty-mile Beach, about half a million roosting shorebirds have been counted in recent years (2.8 million Oriental Pratincoles more counted by AWSG in Februery 2004, 414,000 in October 1998; C.D.T. Minton et al. pers. comm.). The great majority of these birds occur at the beach along Anna Plains Station, 25 to 75 km south of Cape Missiessy. Although it is widely agreed that most species (other than Little Curlew *Numenius minutus* and Oriental Plover *Charadrius veredus*) use the intertidal foreshore as their feeding area, nobody had studied either the feeding distribution and behaviour of shorebirds or the nature of their food resources along Eighty-mile Beach.

Such knowledge is required if we are to conserve the immense and internationally shared natural values of Eighty-mile Beach. We must also find informed compromises between the increasing use of beach and foreshore by the increasing human population in the Kimberley Region and their use by beasts and birds. This is no trivial statement! A large proportion (50.1% for Eighty-mile Beach, 7.1% Roebuck Bay, D. Rogers pers comm) of the world's Great Knots (*Calidris tenuirostris*) depends on (very specific portions of) Eighty-mile Beach and Roebuck Bay for moult, survival and fuelling for migration. This is also true for, perhaps, all the Red Knots (*Calidris canutus*) and Bar-tailed Godwits (*Limosa lapponica*) of specific, reproductively isolated and morphologically and behaviourally distinct subspecies. The intertidal macrobenthic community of the Anna Plains foreshore is undescribed and is likely to contain unique species and species assemblages. Some of these species will be new to science.

Indeed, northwest Australia is truly unique for a particular biogeographic reason. It is the *only* area in the entire Indo-Pacific faunal region where intertidally foraging molluscivore shorebirds such as Red and Great Knots comprise a dominant part of the avifauna (Baker & Piersma 2000, Piersma in prep.). Everywhere else in the Indo-Pacific, the shorebird community consists predominantly of crab-eating species such as Whimbrels (*Numenius phaeopus*), Grey Plovers (*Pluvialis squatarola*), Greater and Lesser Sand Plovers (*Charadrius leschenaultii* and *C. mongo-*

Figure 2.1. Last expeditionary preparations at he WA Wildlife Research Centre, Wanneroo, Perth. Photo by Theunis Piersma.

lus),Terek Sandpipers (*Xenus cinereus*) and Grey-tailed Tattler (*Heteroscelus brevipes*) (Turpie & Hockey 1993, de Boer 2000, J.M. Diamond pers. comm.)

This project builds on the logistical methods and the techniques developed and used successfully during the co-operative intertidal benthic invertebrate mapping project in Roebuck Bay in June 1997 (ROEBIM-'97, Pepping *et al.* 1999) and the low tide shorebird counting methods developed by Danny Rogers (a PhD student of shorebird foraging at Charles Sturt University) in Roebuck Bay from October 1997 onwards. In the period 8-22 October 1999, we made a concerted attempt to map both the invertebrate macrobenthic animals (those retained by a 1 mm sieve) along the Anna Plains foreshore and the shorebirds capitalising on this resource.

Based at the Anna Plains Station homestead, our team comprised 72 volunteers (8 Landscope expeditioners, 8 Notre Dame University students, 33 local volunteers, 7 logistical support people, 16 science volunteers) and 8 scientific co-ordinators (Petra de Goeij, Marc Lavaleye and Theunis Piersma from NIOZ, Pieter Honkoop from University of Sydney, Grant Pearson from DCLM (Fig. 2.1.), Danny Rogers from Charles Sturt University, and Bob Hickey and Michelle Crean from Curtin University). We visited about 900 sample stations laid out in a grid with 200 m intersections (the stations representing about 75 km² of intertidal mudflat) at 7 intertidal 'blocks' along about 80 km of beach (see Fig. 3.1). The northernmost sector was found 10 km north of the Anna Plains entry to the beach, the southernmost 65 km to the south. In the course of digging up, sieving and sorting the mudsamples from the 900 stations, we identified (Fig. 2.2.) and measured 18,600 individual invertebrates that represented about 112 taxa at taxonomic levels ranging from species (bivalves, gastropods, brachiopods and echinoderms) and families (polychaete worms, crustaceans and sea anemones) to phyla (Phoronida, Sipuncula, Echiura, Nemertini, Hemichordata).

This report aims to bring together the science and the lore. The expeditionary exploits are described and the data collected is summarised. All the taxa that we identified during the sorting of the mud samples receive separate treatment in an account that deals with systematics and taxonomy as well as with distribution and ecology. In addition, more labour-intense, integrative, analyses are presented with respect to the GIS database that is being developed for the Anna Plains foreshore, benthic community structure in relation to sediment characteristics and the distribution of shorebirds relative to the food resources. We strive to eventually publish these analyses in the refereed literature. The success of our enterprise will ultimately depend on the positive effect it has on Australia's willingness to defend and protect Eighty-mile Beach as a benthic biodiversity hotspot rather than an area of economic reward. In the last chapter, we therefore attempt to summarize the possible implications of our findings for future attempts at ecologically sensible management form.

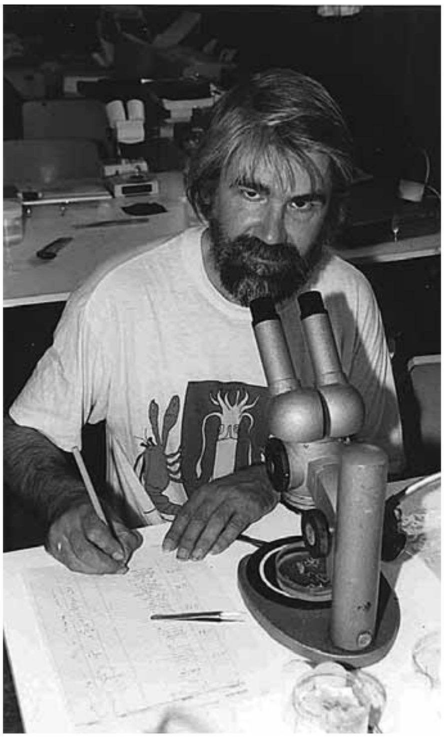


Figure 2.2. Coming to grips with biodiversity: Marc Lavaleye identifying sorted benthic samples from Eight-mile beach. Photo by Theunis Piersma.

3. METHODS, ORGANIZATION AND LOGISTICS

Grant Pearson, Maria Mann
& Theunis Piersma

3.1. METHODS

The study took place along the section of Eighty-mile Beach bordering Anna Plains Station, stretching from 10 km north of the Anna Plains entry to the beach to about 65 km south of the Anna Plains beach entry between 8 and 22 October, 1999. Along this stretch of beach, 6 full and 1 partial 'blocks' of sampling points bordered by the high tide line on the landward side and the low tide line on the seaward side were selected. The midpoints along the beach were 15 km apart. The northern-most block was found 10 km north of the Anna Plains beach entry; the southernmost block was 65 km to the south of that point. Other blocks were found 5 km, 20 km, 35 km and 50 km to the south of the beach entry, and all blocks were named accordingly (Fig. 3.1). With a spring tide on 11 October, sampling during the first week took place with spring tidal ranges, the full extent of intertidal flat being exposed. However, during the sampling of the blocks at 50 km and 65 km, the range of our sampling was severely constrained by neap tidal ranges.

Each block consisted of 10 to 14 transects 200 m apart on a grid running east-west (the '-10 km' to the '35 km' blocks) or south-north (the '50 km' and '65 km' blocks). Along each transect (numbered A to N from south to north), sample stations were defined every 200 m (assigned numbers going from 1 to 20 in east-west or south-north directions), each of the blocks covered part of a predetermined 200 m grid covering the whole length of the Eighty-mile Beach foreshore. Every sampling station received a unique position-key (POSKEY) composed of the block-ID, the transect-ID and the down-the-shore-station-ID, an example being '35K3'. Each POSKEY was linked to predetermined coordinates UTM (Universal Transverse Mercator) coordinates, using the Australian Map Grid 1966 as the horizontal datum. Navigating by GPS, teams of 2-5 peo-

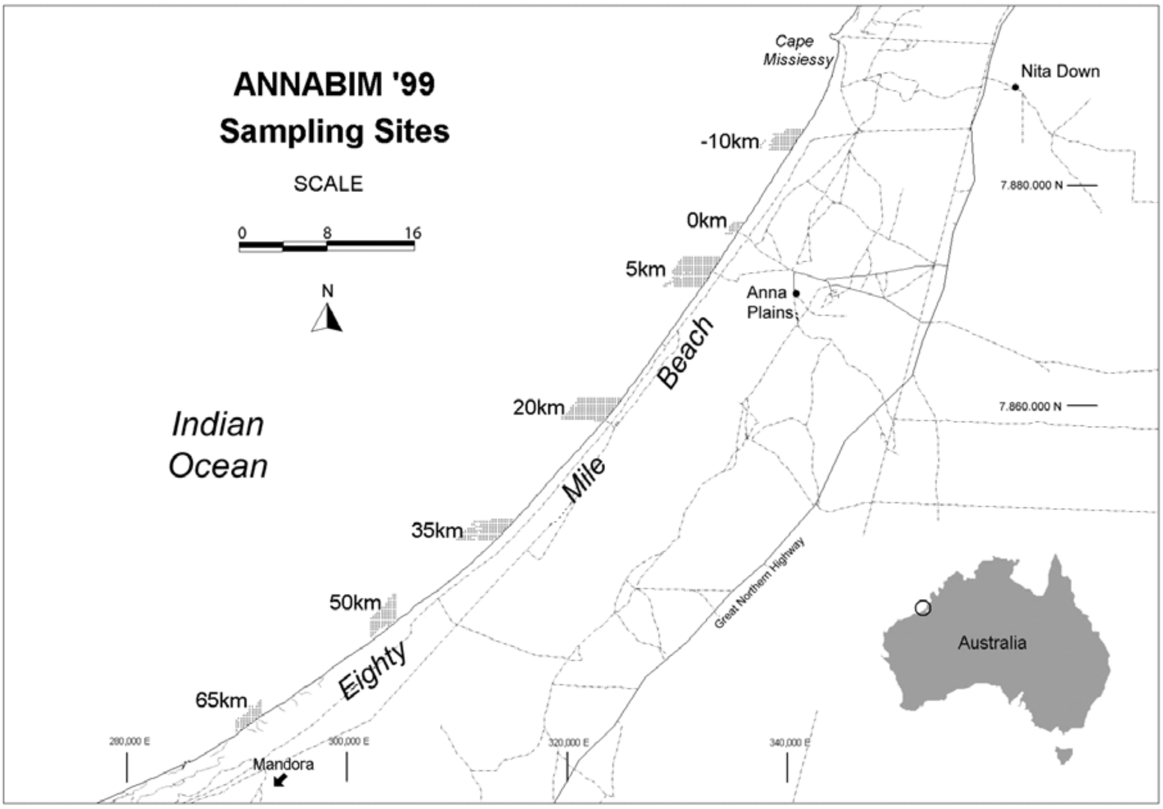


Figure 3.1. Site map with the 7 sampling blocks, Eighty-mile Beach.

ple visited each of the stations based upon preassigned UTM coordinates. It turned out to be helpful to use a hand compass to keep direction while moving about on the mudflats to help compensate for the inaccuracies of up to 100 metres inherent in current GPS technology (at the time of the fieldwork, selective availability had not yet been turned off).

At each station, a corer made of PVC-pipe was pushed down three times to a depth of 20 cm (less if the corer hit a hard shell layer below which we expect no macrobenthic animals to live), and the core samples, each covering 1/120 m², removed. The samples, with a total surface area of 1/40 m², were sieved over a 1 mm mesh and the remains retained on the sieve placed into a plastic bag, to which a waterproof label indicating the station was added. At the same time, a sediment sample was taken with a depth of 10 cm and a diameter of 4.4 cm (surface area = 1/650 m²), stored in a labelled plastic bag and kept at outside temperature for transport to the laboratory. These sediment samples were for the analyses of grain size and organic content.

In the field, records were made of the nature of the sediment, the presence or absence of shell layers and a visible oxygenated layer, the penetrability (depth of footsteps made by an average person, in cm), and the presence of visible large animals on the mud surface - the sort of animals (sand dollars, mudskippers) that are easily missed by our sampling technique. The sheets also allowed us to record which of the predetermined stations were actually visited, the names of the observers and the times of sampling.

The biological samples were taken back to camp, stored in a fridge at 4°C for a maximum of 1.5 days, and sorted in low plastic trays (Fig. 3.2).

All living animals were then kept in seawater, again at 4°C for a maximum of one day, upon which they were examined under a microscope and all invertebrates were assigned to a single taxonomic category (Fig. 3.3). At the same time, the maximum length (in the case of molluscs and worm-like organisms), or the width of the core body (in brittle stars), was measured in mm. The latter information will be used to produce predictions of the benthic biomass values using existing predictive equations. A reference collection was made of all taxa for more detailed study of the species at a later stage.

The sediment samples have been analysed for grain size and distribution. Upon completion of the analyses they have been stored for possible future reference.

Figure 3.2. Big time sorting at the Anna Plains Station basecamp.using the shade of the big trees, volunteers search the sieved samples for living animals. Photo by Theunis Piersma.

Figure 3.3. Students Lindsay Goodwin and Adam Kent from Notre Dame University examine samples under the guidance of taxonomists Marc Lavaleye (at rear), Danny Rogers (obscured), Petra de Goeij and Loisette Marsh in the mobile laboratory. Photo by Grant Pearson.

3.2. ORGANIZATION

Environs Kimberley Inc. (EK) was responsible for local publicity, recruitment from the local community, account and expenditure management, and liaison. The successful incorporation of the local community into the field program was essential. The role of the community in the monitoring of the Eighty-mile Beach intertidal mudflats was considered an important factor in facilitating community involvement in future benthic work. The continued promotion of the benthic work by EK in their regular newsletter is likely to maintain local enthusiasm for benthic research.

The Broome Bird Observatory (BBO) has traditionally provided an important link between the local community and research activities and continued to assist with the provision of the BBO mudflat monitoring equipment. BBO staff also participated in the field preparations and subsequent collection management and data analysis.

3.3. LOGISTICS

The northern extremity of Eighty-mile Beach is located about 250 km south of the town of Broome. Access to the sampling sites was gained by arrangement with Anna Plains Station. The project planned to establish a base at the edge of the beach but, on arrival, it was clear that in early 1999, Cyclone “Vance” had swept away most of the beach site. At the kind invitation of John Stoate, manager of the Anna Plains Station, an alternative campsite was located near the Station homestead.

Broome was the closest centre to the base camp for supplies of food and equipment. The logistics of feeding and caring for up to 40 participants of all ages and physical fitness required a high level of supervision and considerable resources.

More than 80 people participated in this project over the 14 days of sampling, 3 days of report writing and weeks of preparation and finalisation. Many of these played support roles that ensured the success of the project. A description of the roles is provided here, that may assist future workers with their planning.

PROJECT PLANNING

A core group representing each collaborating institution established science objectives and time scales. Members of this group were responsible for the recruitment of suitable support personnel for their respective roles.

VICTUALLING

Week 1. A cooking team was established during the planning process to enable groceries and fresh meat to be purchased in Perth. The meat was frozen for transport. Fresh vegetables and fruit were purchased on the day before departure.

Weeks 2 –3. Additional food requirements were purchased in Broome and transported to the camp by road as required.

Potable water was always available in iced containers prepared overnight in the mobile freezer.

TRANSPORT

Adequate transport was essential for the success of a project of this nature. Several four-wheel drive vehicles were required for a variety of purposes. Passenger vehicles were required to convey participants from Broome Town or Broome Bird Observatory to Anna Plains Station and 4x4 vehicles were needed to get people to and from the sample sites along Eighty-mile Beach.

The expedition provided seating for 47 people in the following off-road vehicles:

TYPE	PROVIDER	SEATS
Ford Courier Dual Cab Utility	DCLM Woodvale	5
Mitsubishi Pajero	DCLM Woodvale	5
Toyota Landcruiser Troop carrier	Curtin University School of Applied Geology	6
Toyota Landcruiser Troop carrier	Budget Hire	11
Toyota Hilux Dual Cab utility	Broome Hire	5
Toyota Hilux wagon	T Costello	5
Mitsubishi L3oo 4x4 Bus	DCLM Broome	7
Truck 4x4 10 tonne	Wallis Drilling	3

A supply of 1500 litres of diesel fuel was carried in a bulk tank on the Wallis truck plus 800 litres (4 drums) of unleaded petrol and 1600 litres (8 drums) of premium unleaded petrol for the Wallis hovercraft (Fig. 3.4). Fuel was dispersed with a drum pump and by gravity feed from the bulk supply. In addition to the carrying capacity of the Wallis truck, there were two tandem axle trailers capable of carrying up to 2 tonnes of equipment and food.

The small hovercraft and its trailer were carried on the Wallis truck.

Figure 3.4. Finn Pedersen (Environs Kimberley), Ken Hartnett (DCLM), and the mighty Wallis truck and hovercraft display the Gordon Reid banner. Photo by Grant Pearson.

AMENITIES

Drinking water was supplied direct from the Anna Plains Station bore supply.

Power could be provided by several sources, including an 8 Kva generator hired for the purpose at Port Hedland, a 5 Kva generator provided by Wallis Drilling and when possible the station power supply.

First Aid was available from trained DCLM personnel in addition to the presence on the logistic support crew of a trained nurse, Chris Nicholson.

Toilets were assembled with hessian surrounds and erected over long drops at the rear of the camp. Showers were not provided but the presence of the hot bore close to the camp ensured a hot bath was always possible. Fresh water was always available from the Station supply for washing equipment and or bodies.

Participants were accommodated in their own tents, or tents were provided where necessary.

A trailer mounted high-pressure fire unit was used to provide immediate wash down of participants and vehicles at the entrance to the beach. Water capacity of this was 1000 litres and refills were available from the Station supply. This served an important function given the tendency for the mud to cause minor irritation for some samplers if left on the skin for prolonged periods. It also prevented salt corrosion of the vehicles.

EVIRONMENTAL CONDITIONS

The climate at Eighty-mile Beach is described as semi-arid monsoon and is drier than the climate experienced at Broome. The mean annual rainfall is less than 400 mm, most falling between November and June. Cyclones may have a significant effect on rainfall, temperature and humidity. The mean monthly maximum temperatures range between 28.2°C (July) and 36.1°C (Dec) while the minima range between 11.7°C (July) and 25.5°C (Jan).

The October period can be extremely hot or (as in October 1999) relatively mild and, although it is not regarded as the beginning of the wet season, rain can occur. Daytime temperatures can range to the mid 40s with high overnight minima. Temperatures during the expedition rarely exceeded 32°C.

Mosquito borne diseases such as Ross River Virus and Australian Encephalitis can be encountered in the region. Protective measures against these include avoiding mosquito breeding sites at dusk or dawn, covering up between dusk and dawn and use of insect repellents containing the chemical DEET.

Figure 3.5. Our vehicles were able to drive on the top end of the beach where the substrate was hard. We avoided using the beach at high tide to prevent disturbance of roosting shorebirds. Photo by Theunis Piersma.

COMMUNICATIONS

Effective communication between sample teams and community support organisations was essential. Telecommunications were possible using a Nera Satellite Phone. Radio communications were available using HF radio (DCLM channels) and Royal Flying Doctor Services frequencies and VHF (DCLM) for short-range communication. Weather forecasts were available from AM radio broadcasts, HF contact with DCLM offices or by Satphone.

Regular scheduled radio calls are a duty-of-care feature of the DCLM Science Division in-field operations. When distance precludes communication with the WA Wildlife Research Centre at Woodvale alternative contact can be arranged through regional centres. In this case, contact was maintained with Broome District Office.

ACCESS TO SITES

Eighty-mile Beach is about 220 km long, extending from Cape Missiessy in the north to Cape Keraudren in the south. The area of interest for the survey extended from about 15 km south of Cape Missiessy for a distance of 80 km south towards Mandora Station (Fig. 3.1). Access to the sites was possible from the camp base along a well-defined station track to the beach. This point is referred to as site 00. To access each specific sampling block, vehicles were able to drive onto the hard pan of the beach on receding tides (Fig. 3.5). All vehicles were required to be off the beach at least two hours before high tide to avoid disturbing roosting shorebirds and impact on the higher, softer sand beach.

The transects of some of the blocks sampled held 19 sites in a line at right angles out from the shore. At 200 metres apart, the distal site was 3.8 km offshore during the period of the survey (an even greater distance could be expected at times of higher spring tidal influence). The Wallis Hovercraft (Fig. 3.6) and the small BBO hovercraft made access to these sites possible. The effort required to walk to these more distant sites through soft mud was considerable and, as described once by Danny Rogers, best attempted by superhuman lunatics or lesser men with hovercrafts!

Figure 3.6. Jamie Wallis steering his Wallis Hovercraft over the mud of Eighty-mile Beach. Photo by Theunis Piersma.

4. ACKNOWLEDGEMENTS

Grant Pearson, Petra de Goeij, Bob Hickey, Pieter Honkoop, Marc Lavaleye, Theunis Piersma & Danny Rogers

Logistically, the prospect of mapping the benthic invertebrates of Eighty-mile Beach is daunting. The large expanse of intertidal zone requires a correspondingly large number of participants (at least 80 were involved in this survey) to successfully complete such a survey. Providing for such a team can be difficult to achieve without an adequate budget. In this context, we acknowledge the personal financial contribution from the Landscope Expeditioners Richard and Susan Ahrens, Lawrence Bartlett, Fiorenzo Conforti, Fiona Joshua, Loisette Marsh, William Millar and David Seay (Fig. 4.1). The contribution from this group added significantly to the success of the expedition and has helped lay a strong foundation for on-going community involvement in benthic studies at Eighty-mile Beach, Roebuck Bay, and King Sound.

The Lotteries Commission provided a grant of $29,695 and established a solid financial base for the project. Community involvement could now be fostered and the success of this aspect has been considerable. On-going monitoring by community groups at the three sites in the Kimberley has been initiated by two local participants from this expedition and is due largely to the financial support from Lotteries Commission. There is great potential to bring to the local communities a fresh perspective of the value of intertidal habitats by future interactions with state, national, and international scientific input.

The Pearl Producers Association provided a grant of $4500 towards the costs of the expedition (including airfares for scientists from NIOZ) and is gratefully acknowledged. Our thanks to Mick Buckley and Richard McLean for their support. The DCLM Landscope Visa Conservation Fund provided $2900 towards the cost of a vehicle to and from the site. This was the first solid offer of financial support for the expedition and provided the basis upon which optimistic planners could plan.

The Western Australian Department of Main Roads very generously loaned the expedition a

Figure 4.1. An exhausted group Landscope Expeditioners and Notre Dame University students, volunteers from Broome and other expeditioners freshly back in camp at the Anna Plains station after a long early morning of field work. Photo by Grant Pearson.

Figure 4.2. Landscope Expeditioners and Notre Dame University students at the mobile laboratory loaned to the Expedition by Derby Main Roads Department

mobile facility caravan that was converted for the expedition into a laboratory (Fig. 4.2). This excellent facility provided a clean air-conditioned environment for the task of identifying the thousands of invertebrate specimens, data entry, and map generation. These activities continued well into each night, without interruption from the usual hordes of insects that can be present in October. We are indeed indebted to Main Roads and in particular Andy Jameson and Bryan Bannon for their assistance and support.

The exhaustive nature of this work is demanding on individuals and the need to collect samples quickly during spring tide periods can place additional strains on resources. Intelligent site selection is imperative to maximise gain per unit of effort in high tropical temperatures. The role of Michelle Crean in the generation of a quality GIS database from which location maps could be produced is acknowledged. The two primary foci in this survey involved the relationship of shorebird feeding sites to the nature and distribution of the

Figure 4.3. Overview of the central lawn of the ANNABIM-camp at Anna Plains Station. Expeditioners have just returned from a sampling trip to the Eighty-mile Beach foreshore. Photo by Theunis Piersma.

Figure 4.4. Jamie Wallis (right) sharing a moment with an exclusive marine invertebrate - a sea pen - and with Theunis Piersma (left). Photo by Grant Pearson.

Figure 4.5. Jamie Wallis, major logistic contributions to the expedition: the 10 tonne truck towing the 7-seat hovercraft, loaded up for the 2000 km long journey back to Perth. Photo by Theunis Piersma.

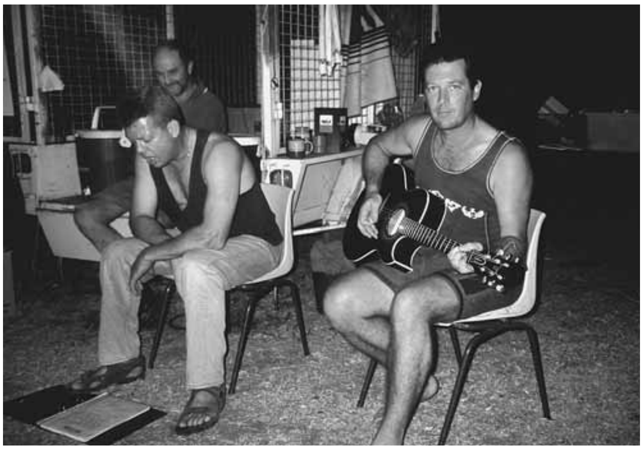


Figure 4.6. Chris Nicholson (left) and Brent Johnson (right) provided evening entertainment as well as food. Photo by Petra de Goeij.

benthic biomass and the further development of community interest in intertidal environments. The former consequently restricted the survey to the northern 100 km of Eighty-mile Beach and the latter benefited from this site selection because of the elevated biological (shorebird) components of that part of the study site.

Students from The University of Notre Dame, Fremantle Campus contributed a total of $800 towards the operating costs of the expedition and provided a very high quality of input into all aspects of the expedition operations. Their youthful exuberance and dedication to tasks were exceptional and contributed to the overall success of this project.

A total of 81 people provided some input into the expedition (Fig. 4.3). During the survey, 68 adults participated in field collections of samples and sorting, the primary science activities of the survey. It is pleasing that four children participated at various times and with a variety of activities. Their presence on site enabled parents to participate and thus contribute significantly. Another 9 people assisted by providing logistical support or advice and are listed as participants.

The results achieved after only 15 days of survey fieldwork are impressive and a credit to all those involved. We are indebted to every member of the expedition for his or her own important contribution. We are especially grateful for the following contributors to the *ANNABIM-99* survey.

Jamie Wallis, Director of Wallis Drilling (Fig. 4.4), provided an extraordinary high level of specific support with the provision of a 10 tonne truck and superb 7-seat hovercraft (Fig. 4.5). Both these items of equipment provided free, ensured flexibility of operations and a quality of support previously only dreamed about. The generosity and professionalism of Jamie and his company is gratefully acknowledged

Figure 4.7. Anna Plains Station manager John Stoate (left) is presented with his ANNABIM T-shirt by Grant Pearson. Photo by Petra de Goeij.

Figure 4.8. Aerial view of the Anna Plains Station homestead with the expedition camp on the central lawn. Eighty-mile Beach can be seen in the upper right corner. Photo from small helicopter by Pieter Honkoop.

Figure 4.9. Notre Dame University students Danielle Gabriel (left), Shawn Debono (window-hanger), Megan Driscoll (right) and others are ready for a foray to the beach in the Curtin University “troopy”. Photo by Theunis Piersma.

Ted Costello and Warren Utting kept the machinery operating throughout the project, assisted with catering and offered their special skills and support around the camp and in the field. Their attention to detail, camp knowledge and ready offer of assistance at any time of the day or night (including a midnight run by Ted and Bob Hickey to Broome hospital) was invaluable. The vehicle provided by Ted was a significant asset for an expedition that struggled at times for adequate transport as a result of the overwhelming numbers of local Broome participants.

Brent Johnson, Chris Nicholson, and Joanne Varley provided a superb cuisine and a quality of catering that defies description (Fig. 4.6). Joanne continued the standard in the second week with able assistance from Jan and Kevin Dawson, Pat and Bill Duxbury, Helen MacArthur, Marcel Ponti, and Mavis Russell. The positive attitude and camp experience of these people contributed greatly to the high spirit of the camp and science activities.

We are also especially grateful for the generosity and tolerance shown by the Manager/Director of Anna Plains Station, John Stoate (Fig. 4.7). By allowing the expedition to camp near the station homestead, he ensured that participants would have access to abundant shade and potable water, be well looked after and able to concentrate on the field and lab work without wasting valuable time and energy on maintenance of camp activities in the hot sand (Fig. 4.8). We are also grateful for the assistance and advice from the Anna Plains mechanic Bob Fleming. The provision of the Anna Plains aircraft for a low-level aerial photographic reconnaissance was of value for the possible identification of fresh water upwellings along the intertidal zone of the northern part of the beach. John also supported the concept of regular monitoring of Eighty-mile Beach benthos by a local community based group at several sites near the Anna Plains access track, and provided a protected site adjacent to the main workshop for the mobile laboratory. This proactive and supportive action is very gratefully acknowledged.

Special thanks go to Jim Lane, Keith Morris, and Neil Burrows of DCLM Science Division and Allen Grosse, Tim Willing, and Debbie Burke of DCLM West Kimberley District for their support for the project and for making DCLM staff and equipment available. We are especially grateful that Allen Grosse loaned us only one of his vehicles!

Ron Watkins provided the Curtin Troopcarrier 4x4 that was of immense value for towing and reliable transport of participants (Fig. 4.9). Our thanks also for his input into the planning of the study. Leigh Davis and Graeme Behn of DCLM Information Management Service assisted with the acquisition of Landsat and aerial photographs of the study site.

Coca Cola Bottling, through John Triplett, donated two 1000 litre potable water containers. Clive Minton is thanked for providing the results of his shorebird count of 1998 and for his ongoing valuable advice. Thanks to Nick Budge, Alan Clarke, Sandy Grose, Rod Mell and Sue Pegg, for assistance before, during and at the completion of the project. Special thanks to Ken Hartnett for his capable assistance as off-sider for Jamie Wallis and assistant in the camp.

The following people participated in one way or another in the fieldwork at Eighty-mile Beach (Fig. 4.10):

Figure 4.10. Grant Pearson (left) and Theunis Piersma (right) writing the acknowledgement-section for the preliminary report during a little-curlew-catch at Lake Eda in the days after the expedition. Photo by Petra de Goeij.

BROOME COMMUNITY: Persinne Ayensberg, Ruth Bowser, Venetia Brockman, Andrew Bussau, Jacinta Bussau, Cass Hutton, Jackie Cochrane, Liz Cochrane, Anne Marie Davies, Jan Dawson, Kevin Dawson, Bill Duxbury, Pat Duxbury, Maura Garry, Matt Gillis, Sharon Grey, Lucy Lawrence, Charlotte Matheson, Helen Macarthur, Conor McGovern, Veronica Parry (Ronnie), Harley Pedersen, Kane Pedersen, Maria Pedersen, Marcel Ponti, Jamara Ryan, Michael Slattery, Roni Star, Jacinta Thomas, Michelle Wardley, Tim Watson, Danielle Whitfield.
DCLM: Debbie Burke, Allen Grosse, Brent Johnson, Grant Pearson, Joanne Varley, Tim Willing.
DCLM VOLUNTEERS: Michelle Costello, Ted Costello, Ken Hartnett, Karen McKeogh, Caitlin McKeogh, Shapelle McNee, Chris Nicholson, Jack Robinson, Mavis Russell, Warren Utting, Jamie Wallis.
CURTIN UNIVERSITY: Michelle Crean, Bob Hickey.
ENVIRONS KIMBERLEY: Pat Lowe, Maria Mann.
LANDSCOPE EXPEDITIONS: Richard Ahrens, Susan Ahrens, Lawrie Bartlett, Fiorenzo Conferti, Fiona Joshua, Loisette Marsh, William Millar, David Seay, Kevin Kenneally, Jean Paton, Marianne Lewis.
NIOZ: Petra de Goeij, Pieter Honkoop, Marc Lavaleye, Theunis Piersma, Danny Rogers.
LOGISTIC SUPPORT: Roland Breckwoldt, Anne Breckwoldt, Finn Pedersen, John Stoate.
NOTRE DAME FREMANTLE: Shawn Debono, Megan Driscoll, Danielle Gabriel, Lindsay Goodwin, Benson Holland, Adam Kent, Marie Louise Thonell, Matt Valente.

Figure 4.11. Grant Pearson enacting Banjo Petterson and reviving expediton memories during Petra de Goeij's dissertation-party in September 2001, a time otherwise spent working on this report. Photo by Ron de Boer.

During the compilation and write-up of this report we received help in the following ways. Funding from the Netherlands Organization for Scientific Research (NWO; a PIONIER-grant to TP) covered the travel expenses when Grant Pearson travelled to The Netherlands in August-September 2001 to build the basis of this report. Kees Camphuysen once more helped us out with his skills in getting data on to maps. Central Washington University donated $500(US) toward publication costs.

Grant Pearson is especially grateful for the inspirational support and encouragement from Theunis Piersma throughout this and other memorable projects and to Petra de Goeij and Theunis for their hospitality in 2001 in Texel (Fig. 4.11). Special thanks to the core mudbashers Theunis, Petra, Marc Lavaleye, Pieter Honkoop, Bob Hickey, Danny Rogers and Jamie Wallis for their enthusiasm and genius in their fields. Thanks also to Mike Scanlon, Stuart Halse and Jim Cocking for help with graphs and analyses and to Jim Lane, Keith Morris and Neil Burrows for their continued support with our studies on the intertidal mudflats. Mavis Russell and Ted Costello continued to provide enduring support. Personal thanks also to John Stoate for his valued input and to Maria Mann (Fig. 4.12) and Pat Lowe for their contribution and patience. Allan Burbidge and Ewen Tyler are thanked for their comments on the manuscript.

The lay-out of this report was made by Nelleke Krijgsman, and the production as well as the cover-design was in the hands of Henk Hobbelink. We are grateful to Richard Woldendorp for gracefully making available his aerial photographs for the cover.

Figure 4.12. Grant Pearson (left) sharing a quiet moment with Environs Kimberley's Maria Mann (right) at the ANNABIM-campground. Photo by Theunis Piersma.

5. PERSONAL ACCOUNTS AND EXPEDITION SONGS

Fiona Elizabeth Joshua, Jack Robinson, Marc Lavaleye and others

5.1. THE DAILY DIARY – PART 1

(by Fiona Elizabeth Joshua, Fig. 5.1) {Fiona was a member of the Landscape Expedition, is from Melbourne and describes herself as a science communicator/ presenter/journalist. She has completed a PhD at Monash University and further post graduate studies in science communication and journalism and now freelances as a science journalist.}

Figure 5.1. Landscape expeditioner Fiona Joshua writing the daily log. Photo by Theunis Piersma.

Friday 8 October

The Landscape volunteers met at the Continental Hotel in Broome, that is after discovering that it was now called the Mercure Hotel. David, Richard, Sue, Fiorenzo and I all tentatively introduced ourselves. Sometime later, Grant, Ted and Joanne arrived, on behalf of DCLM, and we all relaxed as they were very welcoming. Dusty and Lawrie were also introduced as Landscape volunteers.

We picked up a few supplies, including essential alcoholic beverages, and stopped in at the DCLM centre to pick up a vehicle. While things were being organised, there was time for a look at the reptile exhibition, and here we also met another Landscape volunteer, Loisette, as well as Petra and Theunis, two of the Dutch scientists. Meeting in a snake house was purely coincidental; at least I hoped so at the time. Now people's names were just getting out of hand, but we headed out of town en mass toward the Broome Bird Observatory (BBO). Those of us unfamiliar with the area were delighted to experience the rich-red, dirt track with a backdrop of beautiful coastline.

The staff of the BBO were extremely hospitable and rustled up some lunch, apparently without warning, on our arrival. Here, we also met Danny, a PhD student, and some undergraduate students from Notre Dame University (Fremantle campus) who were undertaking field studies. Benson, Marie-Louise, Adam and Shawn are the Australian students, and these were joined by Megan, Danielle, Matt and Lindsay, exchange students from the sister Notre Dame University in Indiana, USA.

There were introductory talks from Grant, Theunis and Danny about what we trying to do and what we might expect. I was feeling quite overwhelmed since I had come from a Chemistry and Science Journalism background. All this talk which seemed to relate benthos, mapping, hovercraft, GPS, mud, beach topography and birds to each other was going over my head. I did, however, have faith in our leaders and was sure I would have it all under control in no time - not!

That afternoon, Danny and Theunis each went sampling in the mud and any really keen people also went out to try their mud legs. Theunis took a group to Dampier Creek where they found a spot as indicated by the GPS, but it was not the right spot. Good start. They did, however find the Great Knot flock they were looking for and Saw sacred Ibises foraging on the mud flats. They also found a sea-hare and a compound ascidian, as they found out later from our resident echinoderm expert, Loisette. The group collected only four sampling points and ran out of light, but it was a good start. Danny also did not get as many points as he might have liked since a group of eight does not seem to move as fast as a group of one. He did, however, have high hopes for the group as they seemed competent enough. That's a relief.

The rest of us chose to stroll along the beach. I watched the great red orb of sun set three times: twice behind the rocks and once over the water. We could then see the lights of Broome in the distance. The geology of the area was also fascinating as there were rocks of rich orange, pink and deep red colours. There was even a rock formation in the shape of a large bird of prey; how appropriate at a bird observatory.

That evening, we ate a lovely dinner in the presence of some green tree frogs, and this was followed by a slide show from the previous expedition at Roebuck Bay.

Saturday 9 October

The BBO provided such luxurious accommodation that I overslept; nevertheless, somehow I managed to be ready on time. We did, however, not leave for another half hour, which allowed more and more money to be spent at the BBO shop. Time now for a photo opportunity and we were back on the beaten track. We had not travelled five minutes before we were blessed with two sea eagles flying overhead. We had to come back to Broome to pick up the spare tyre and were greeted with a flock of Little Curlews and a pair of Black Kites. The tyre not being ready, we went off to the Saturday morning Courthouse Markets. Theunis' shopping expedition resulted in a deceased member of the team joining us - a dead Little Curlew! Theunis and Al fought over the wings and I wondered if we were at KFC. If we did not have enough carcasses in the car, Al then insisted on stopping to adopt the "beautiful" head of a Wedge-tailed Eagle.

As we cruised across Roebuck Plains, we were granted with a special treat; four magnificent Brolgas and a Straw-necked Ibis were parading on the plains. Some pyromaniac in a commodore put a stop to our delight as we observed fires being deliberately lit on this high fire danger day. But we did get the rego!

We finally arrived at our destination. The original plan was to camp behind the dunes of Eighty-mile Beach itself; however, a cyclone had destroyed the site. Instead, accommodation had become luxurious as we were now to camp on the cattle station at Anna Plains, thanks to John the part-owner. Our caterers, Brent and Chris, were introduced to us here. Chris expressed a wish to be called "Steel" while Brent, when asked what he wished to be called, replied "Dishes" as he thrust the teatowel into Chris' hand. We also met Ted's daughter, Michelle, who would be generally helping out, and Marc, another of the Dutch scientists.

This afternoon was our Dry Run, in actual fact quite wet. It was our training session where we learned to collect using a core, to sieve and to record samples, and use a global positioning system (GPS). Those in Theunis' group observed fiddler crabs as well as *Macrophthalmus* (sentinel crabs), aptly named because they do have large protruding eyes on stalks. Snails of the genus *Nassarius* were also observed. These invertebrates have been commonly labelled by those at BBO as Ingrid Eating Snails, apparently so called because ten years ago they were literally eating Ingrid! Petra informed us that she wished to demonstrate to her group how to take a "proper" sample - knee-deep in mud. Danny, on the other hand, stayed at home to "get on top of his samples". Watch your step, Danny!

Other activities from today must be mentioned. Ted and Joanne went back to Broome for still more supplies, plus Pieter, the fourth of the Dutch scientists. On the way back, would you believe, they ran out of petrol. Joanne blamed Ted but he blamed the van that they were dragging. So off Ted went back to Broome *again* while Pieter and Joanne stayed on the plains. There are reports that stress levels were high for these two. All manner of vehicles, including helicopters, tooted and scoffed at the pair. They had only one can of beer plus a bottle of cider between them, and there was mention of 100ft bullants, death adders, even a Tasmanian Tiger! Have they used that second testicle already?

Once again we enjoyed a delicious dinner, this time thanks to Brent and Chris. Rather than frogs, tonight our dinner was overseen by a family of Frogmouths. We were privileged enough to watch a parent feed its chick.

After dinner, we all said a little about ourselves to the rest of the group, which enabled us to meet John from Anna Plains, and Jamie, Ken and Warren who were to be playing a major maintenance role. Some of us then went off to the Anna Plains bore spring to have a delicious spa. There was no separating of guys and girls here; it's everyone in, wearing nothing but your undies, jocks, or nothing at all if you fancy.

Sunday 10 October

There was no sleeping in this morning as the station musters clang sounded at 5.00am. The task for most expeditioners was to *sort* the samples obtained so far, a first time for many. The Landscape contingent sorted the samples obtained at Dampier Point for Danny's research. Examples of some finds were crabs of the genera *Leucosia* and *Macrophthalmus* as well as some tusk shells. Marc assisted the Notre Dame students in sorting Saturday's samples, and they reported an abundance of Polychaetes (bristle worms). Chris became quite excited when Petra showed him a Maldanidae, a big firm pink worm. "A horse-penis worm, we call this," said Petra with a grin on her face. Others were calling it a peanut worm - it must be a Dutch thing.

Grant took Marie, Danielle and me, supposedly a light crew, down to the beach to test out the buggy. If we could get it up and running, some of the less fit people would have more opportunity to get out on the mud flats. The trip was unsuccessful as the tide was already too far in, and not only that, the buggy had a flat battery. The battery was extracted and recharged but, although Jamie, Ken and Grant tinkered with the buggy, the thing still didn't work. Perhaps the hovercraft would have more success, especially if they could get it down the narrow track. Success! Jamie was flying the hovercraft across the mud, now across the sand, now wildly across anything in his path! Is that a wheelie? A stunned Loisette, Sue and Matt emerged, and Jamie confessed that it was twelve months since he had driven the thing. It wasn't just the heat that was making him perspire!

The hovercraft crew did, nevertheless, report that they had seen three different sea-snakes, and we saw a dead one on the beach as well as many beautiful shells and sponges. Grant also began our education in bird watching in the area. He pointed out Bar-tailed Godwits, Great and Red Knots and a Curlew Sandpiper. To continue our education, he then took us off to the Brolga Damn. As we arrived, four magnificent brolgas were wading on the other side of the damn. These took flight, and suddenly appeared 14 more from behind the mound to join the first four in flight. Fantastic! We also saw a Sharp-tailed Sandpiper, Little Curlews, Hard heads, a black-winged Stilt and a Coot, which Grant called *Cootus dimentus*. You almost had me going there, mate.

Sunday afternoon was mud time again, the real thing this time. I was in Marc's group with Lindsay. Marc called himself the lazy man because he was the dry recorder who also did not carry anything while the two girls did all the manual labour. I was the lucky one who carried the bucket the whole way. This was fine until the last sample when the bucket was full and the mud was up to my thighs. But we survived.

What I did not realise was that there was a bigger drama yet to come. I was sitting on the windowsill of the 4WD when I suddenly heard the engine of the hovercraft behind me getting louder and louder. And then it was really loud, and I could feel sand stinging as it sprayed against my back. I knew this thing was really close, and so I thought the best thing to do would be to squash myself against the car. I trusted that Jamie knew what he was doing - only just. Apparently, he missed me by about 50cm! Still more dramas; the car broke down on the way home and so we walked back to camp.

That evening, we celebrated Ted's birthday with some carrot cake. Fiorenzo declared that today was "the same bloody mud", while Pieter was glad to be back on this side of Australia after two years (he has been working as a post-doc at Sydney Uni). Matt was a victim of the latest instrument of torture, the little hovercraft. He described the experience as "it sucks". He wanted to wear a full-body condom to protect himself from the mud and could not be bothered wearing the ear-plugs, thus lost some of his hearing. "It did get us out to the tide line, though, which is apparently a good thing."

Some continued sorting samples after dinner, while others took a trip to the bore to try out the new spray-cap which had been designed by Chris. Chris and Brent then entertained us with a couple of tunes, Chris singing and Brent accompanying on guitar.

Monday 11 October

There were 115 samples to be sorted, and so Theunis made an executive decision that only one team would be going sampling, the hovercraft team, while all others would sort and identify. I seemed to extract many samples of *Siliqua* in my efforts, which made Petra very happy. She explained that the soft shell of these bivalves is easy to crush and is thus the perfect food for Great Knots. I was delighted to hear that it was a "really interesting find". Danielle and Benson returned from their hovercraft expedition *over the moo*n about having seen six sharks.

At the lunchtime briefing, Theunis informed us that we had successfully sorted over 100 of the 115 samples and were therefore up to speed. Teams were assigned for the afternoon collection and this time I was mud bashing with Grant and Shawn. What a team! After waiting about an hour for the tide to go out with everyone else, we then collected 23 samples, the record for the day. Only nobody allowed us to claim the record as they said we had cheated because we didn't turn around when we were supposed to have.

Danny and David had been bird watching and had become completely stuck in the mud. They did, however, conclude that they had seen a nice variety of waders and that the area was really rich in places. There seems to be obvious differences in the benthos in the different mud types, and this was being reflected in the change in wader species in the different areas.

More breakdowns. The hovercraft had a breakdown while the DCLM vehicle also had trouble. After numerous jumpstarts, Grant managed to drive along the beach, without headlights, while holding a torch out of the window to shine on previously made tracks. The man can do anything!

Loisette had stayed in camp to sort the samples from that morning's hovercraft group and had found them to be "atrocious". They were basically just shell samples. There was a debrief after dinner, and then various meetings followed. We finished off the night with some stargazing through Danny's telescope and managed to identify the four moons of Jupiter and the Pleiadas cluster. An early night was had by all to prepare for the early morning to follow.

Tuesday 12 October

The musterers clang at 5.00 am was actually useful for the Expeditioners this morning, as we wanted to leave at 6.00 am to catch the morning tide. My turn for the hovercraft challenge with Ken, Sue and the legendary hovercraft driver, Jamie! It was not the most productive of trips as the tide was already out by the time we got out on the water, and it was coming in at a furious pace. Nevertheless, the hovercraft team were more successful than the walkers; some were frustratingly only able to gather one sample or even none. The return trip from the beach included a stop at the Brolga damn and the grave of Daniel Joseph O'Brien, a gold prospector who was speared in the near-by bush in 1935.

Danny and Marc remained at camp to identify and record data, and others stayed to sort the build up of samples. Later everyone joined in the identification and sorting processes, and Pieter was quite excited as he had found a new type of tusk shell which was pointed at each end. The work-in-progress report from Danny, Marc and Pieter is that, while the biodiversity may not be quite as high or exciting as Roebuck Bay, there is more than initially expected. They are also rather pleased to find results indicating that areas showing a high density of benthos are consistent with an abundance of birds in those areas.

Joanne, Ted and Warren made up the team who returned to town to pick up a different rental vehicle. Hopefully this one will work. A new group also arrived: Jackie, a lecturer from Notre Dame University, Broome campus, together with some of her students: Sharon and her 5 year old son Tim, another Danielle, Maria and her sons Liam and Harley (5 and 7 y.o.) and Maria's sister Ruth (Fig. 5.2). We were all really pleased that some locals from the Broome community were being included in this work, particularly as that had not been the case for the Roebuck Bay trip.

In the afternoon, two teams went sampling to catch the second tide. Marie and I were lucky enough to go mustering cattle! Trevor, a station musterer, generously offered to show us the drafting, earmarking, inoculating and castration processes. We even had a go ourselves. Unfortunately, I also witnessed the death of a young male who suffocated during transportation due to another animal sitting on its head.

The musterers came around for a drink that evening and so we felt we should entertain them before retiring to prepare for an even earlier morning than yesterday. Oh help!

Figure 5.2. Broome residents Ruth Bonser and Maria Pedersen and her children. Photo by Theunis Piersma.

Postscript: Unfortunately, one of the musterers became quite intoxicated and consequently made quite a nuisance of himself. This incident prompted Grant to make the executive decision that the camp would close at 10 pm, particularly as children were now staying in camp. This also meant that the early risers would be able to get some sleep. Of course, people who wished to work in the mud lab were free to do this late into the night, as there is always more work to be done.

Wednesday 13 October

This morning's wake up call was the ghastly hour of 4.15 am! A number of groups went out to the mud to take advantage of the morning tide, while the Landscopers sorted and identified before packing lunch to go on a high-tide bird-count with Danny.

There were two vehicles on the count. In the first, Danny impressively counted individual species, while I recorded, and David counted total numbers within a flock. Richard and Dusty, in the second vehicle, counted birds in flight that flew behind the first car to ensure that birds were not being pushed ahead and then being recounted. Danny was happy that the data recorded appeared to be consistent between the two vehicles. We covered 20.2 km of beach and, remarkably enough, counted approximately 20,000 waders. This figure almost brought a tear to Danny's eye; his whole face changes when he talks about the "vulnerable waders". Watching the flocks take flight along the vast Eighty-mile Beach was a wonderful experience for all of us, especially when the whole flock would curve around into a figure eight.

Figure 5.3. Landscape expeditioner and echinoderm specialist Loisette Marsh recovering from a hovercraft experience. Photo by Grant Pearson.

Numerous species were encountered, the waders included Grey, Oriental, Red-capped and Greater Sand Plovers, Black-tailed and the most numerous Bar-tailed Godwits, Grey-tailed Tattlers, Marsh, Terek and Curlew Sandpipers, Greenshanks, Whimbrels, Red-necked Stints, Ruddy Turnstones, the impressive Pied Oystercatchers, Red Knots and of course Great Knots. These latter birds are known to be characteristic of North Western Australia, since two thirds of the world's population of Great Knots come to roost here. In addition to the waders, various terns were observed. These included Whiskered, Caspian, Gull-billed, Crested and Lesser Crested Terns.

Following the count, it was time for Loisette's big moment (Fig. 5.3). We were going on an Echinoderm hunt. We drove 30 km down the Eighty-mile Beach to try to locate the perfect environment for these critters - not too much mud! Loisette had given us a plastic bag to collect samples for her, and thus, worried I would miss something, I kept repeating to myself: brittle stars, starfishes, sea cucumbers and sea urchins. Unfortunately, all was to no avail; my bag came back empty. Even Loisette found only two echinoderms. They were, however, different species.

Many groups took pleasure in seeing turtle tracks on the beach that day. We saw mounds at the top of the tracks where we suspect the eggs were buried. One of our new volunteers, young Tim, did not enjoy his mud experience. One step into the mud had him churning the water works, which might explain his response to the alternative water works. On seeing the bore, he proclaimed: "boring". Our other young volunteers seemed to have a better day; Michelle was very impressed with the sorting techniques of Liam and Harley. Our not so young but young at heart boys also had a fine day. Ted, Warren, Chris and Brent found and claimed a dingy on the beach.

Joanne came back filthy from a hovercraft experience and insisted on telling us about her excitement. No, not about the hovercraft trip, but about finding a new toilet! Jo, That's the pissaphone! It is definitely NOT a chick thing. Danny, on the other hand, had found something he was not happy about. He declared his definition of a biologist to be “honest people who steal pencils and lollies”.

The time had come for Lawrie’s long awaited contribution to this diary. He feels that everyone has blended in really well and been particularly tidy. Everyone has found a way to help in their own way. “Grant is, of course, crucial to the operation because he is the one arranging everything. Most people couldn’t run a chook raffle. Ted and Warren have kept the machinery going, and Jamie’s contribution is particularly significant. In a group this size, you are bound to get frustration. I have appointed myself quartermaster and tried to move things into a logical order, so that, if something went missing, I knew where it was. I do the little things other people don’t notice, otherwise camp becomes a mess. I am happy to mix with younger people, and make sure they’re getting on O.K. as well.”

Since it was officially the last night for Landscopers, the debrief was a little different. Theunis reported that he hoped the 20 km site would be completed tomorrow and that results of the southern side of the studied area show it to be richer than the northern side. He then presented Grant with a gift on behalf of the Dutch Scientists. The gift was a Dutch liqueur fermented with herbs and is called Juttertje - try pronouncing that! Apparently a Jutter is one who searches for little treasures along the beach. The legend goes that a Jutter was wandering along the beach when he saw a sailor, half-dead, washed up on the shore. The Jutter saved the sailor’s life and, in return, the sailor gave the Jutter the secret of this herbal brew.

Grant then said a few thank-yous and as he finished we were suddenly struck with a fabulous performance from “Lawrie the Loser”. Brent and Chris finished with a delightful song from the heart entitled Talgarno Bore Blues.

Thursday 14 October

A 4.15 morning again for those going mud bashing, and it was a tough bash. The problem is that the tide just insists on coming in. It caught up to the samplers! Danielle (US) reported that the mud was thigh-high, while Danny noticed that he was surrounded by “a seething mass of silvery grey” (pop-eye mullet) as well as thrashing fiddler sharks. He did, however, also claim that it made the groups more productive as you knew you had to get out of there. Danielle (Broome) really appreciated the way the guys helped out the girls towards the end when they were having trouble. It gave her “a warm fuzzy feeling”.

Meanwhile, back at the ranch, literally, further sorting and identification were occurring. Loisette pointed out a live sand dollar that still had its spines intact, while Petra and Marc concluded that sea cucumbers are much more abundant on Eighty-mile Beach than in Roebuck Bay. Petra is also quite excited to have found some new bivalves. Just to make Loisette happy after yesterday’s disappointment, Danny, Richard and David brought back two lovely echinoderm samples: a sea cucumber and a crinoid.

The time had come for the Landscopers to pack up. We had a final debrief and then it was time for a major photo opportunity. O.K. BUT THE CHEF ISN’T HERE. Where else would Brent be but at the bore? So we had Mr Assistant Chef, or Camp Slut as he wished to be known, take a photo using every camera present in the place. An hour later we had another photo session so that our two chefs could be included.

The official Landscope portion of the trip had ended. I decided to stay on for a couple of days because I simply could not draw myself away from that mudbath, while other Landscopers expressed a desire to stay but were committed elsewhere. The vehicles departed after goodbyes, and we all felt it had been a most enjoyable and rewarding experience. Thank you so much Grant, Theunis and everybody else.

5.2 THE DAILY DIARY – PART 2

(by volunteer logistical support, Jack Robinson, Fig. 5.4)

Figure 5.4. Jack Robinson (left) with Petra de Goeij inspects an old Black Swan nest on the Roebuck Plains near Broome. Photo by Theunis Piersma.

Friday 15 October

0400 hr: Everyone up and breakfast underway for a mostly dazed group. Departed at 0500. Brent and Chris had begun their final packing for the trip home.

Down to the beach to drive along to 35 km but what's this at the beach access point? A gypsies' camp? A tent embassy? No - four and a half additional volunteers who had arrived in the night. They were politely told to remove their camp to Anna Plains Station while the troops continued on their way because time and tide ..... The hovercraft successfully transported people to the further sampling sites and collected them on completion of their work.

Meanwhile, back at the camp, sorting continued with the help of new arrivals. Samples from the previous day's survey yielded a burrowing sand anemone (family Edwardsiidae). This was accompanied by a parasitic snail that squirted purple ink.

Danny with a crew of two (Sharon and Jacquie) did low tide mapping at the 20 km block. It was the equal best with minus 5 km block in terms of birds. The low spring tide made it a very long and arduous return trip, almost sapping the resolve of one member.

In the evening, Grant took the small hovercraft out to cover ground that had been missed. This was quite successful; 25 samples were obtained.

Saterday 16 October

Six teams in three vehicles departed camp at 0530 to collect samples at the 35 km block, anticipating a low tide at 0730. This block had been started the previous day and the aim was to complete what had not been achieved, especially near the low tide mark.

The hovercraft started ferrying each team to its starting point. Soon after sampling began, the hovercraft developed engine trouble - the main hydraulic drive belt broke. At least one exhausted mud basher waved frantically at the hovercraft for some time in an effort to get a ride back to shore. Eventually, foot power proved to be more reliable.

At about 1130, most teams completed their sampling and returned to camp by vehicle after a long walk to the beach. The hovercraft slowly drifted in with the tide, with the help of its diehard crew of Jamie and Benson wielding a pole. It was put to bed in the sand at the top of the tide. The retrieval process began later. With a combination of jack, winch and muscle power and using wooden poles as rollers, the 1200 kg beast was hauled onto its trailer.

Grant's hovercrafting urges were still not satisfied so he took the small one out to get more samples. It would not co-operate this time so both hovercrafts were now out of action.

Meanwhile, back at the camp, all of the Notre Dame students except three returned home to their studies, sorting continued and the camp anticipated the arrival of a big mob of new recruits. The big mob arrived around 2130. Later that night, one of the new recruits developed engine trouble so Bob and Ted the honorary ambulance bearers took the patient to Broome, returning to camp at dawn.

Sunday 17 October

After a leisurely breakfast, the new crew were instructed in sorting technique by Mavis and Karen and the two day backlog of samples was attacked with gusto. This was completed by mid-afternoon.

Danny had taken a crew (Shapelle and Jacquie) to the 35 km block at dawn for low tide bird mapping. At high tide, his crew started a bird count along the beach, working from 35 km to 25 km. At midday, Theunis took a crew of three (Mavis, Matt and Jack) to the 10 km block for a high tide count from there to 25 km. The counting was fast and furious. Great Knots were in good supply at the northern end (5 percent of the world population in a 5 km stretch) and at the other end, Bar-tailed Godwits were plentiful.

Monday 18 October

Once again, an early start was made (0515), this time to sample the 50 km block. With no hovercraft in operation, it was all done with foot power. Fortunately the ground was mostly firm sand and neap tides restricted the length of transects to about 2 km. 120 sites were sampled on 12 transects, all finished by midday.

Sorting resumed with the fresh samples and freshly washed mudbashers. Significant finds were brachiopods, amphipods and live sand dollars. Meanwhile, the mechanics took the toy hovercraft out of the pits for a test run. It passed the engine test, but then the rudder failed.

Danny, Mavis and Petra sat on the beach and watched birds in the afternoon around high tide. They were trying to establish what was on the menu, who ate what and how much. Some good data was gathered but some questions were raised in Danny's mind e.g. how do the Great Knots find, scoff and pass food so quickly and easily when he couldn't even dig up enough bivalves for a sandwich?

Tuesday 19 October

The main planned activity was to sample a few more sites at the 0 km block. Six teams were given a transect each, some already partially done. Because of the moderate neap tides, some teams still had standing water at their first sample site. Undaunted, they did their duty, even without the aid of snorkels.

The sorting backlog from the previous day was eliminated by mid afternoon and soon after, the morning's paltry yield was quickly sorted. Danny, Shapelle and Helen completed another low tide bird survey at 50 km.

In the air-conditioned Dutch Embassy, the boffins started something they call "analysis". Progress so far: sites sampled - 820, number of invertebrates collected - 14000, cumulative total length of animals collected - 1400 m, number of different taxonomic groups - 112 (compared with 200 from Roebuck Bay), average invertebrate density - 600 per m2, number of birds counted in study area - 90 000.

A sizable storm was brewing in the south so a mad rush was made to re-peg tents, cover equipment and make the place tidy (about time). As expected, this had the desired effect of holding off the rain. Three vehicles went cruising the beach looking for egg-laying turtles. A few tracks and nests were found, possibly from the previous night.

Wednesday 20 October

The storm hit in the early hours of the morning. Plenty of lightning, wind, rain but no damage. Most of the crew took the opportunity to have a lie in.

During mid-morning, two teams collected ten sediment samples from sites that had been missed on previous days. This was restricted by the small tidal difference. The rest of the crew collected some live specimens of the common invertebrates for photography by Marc.

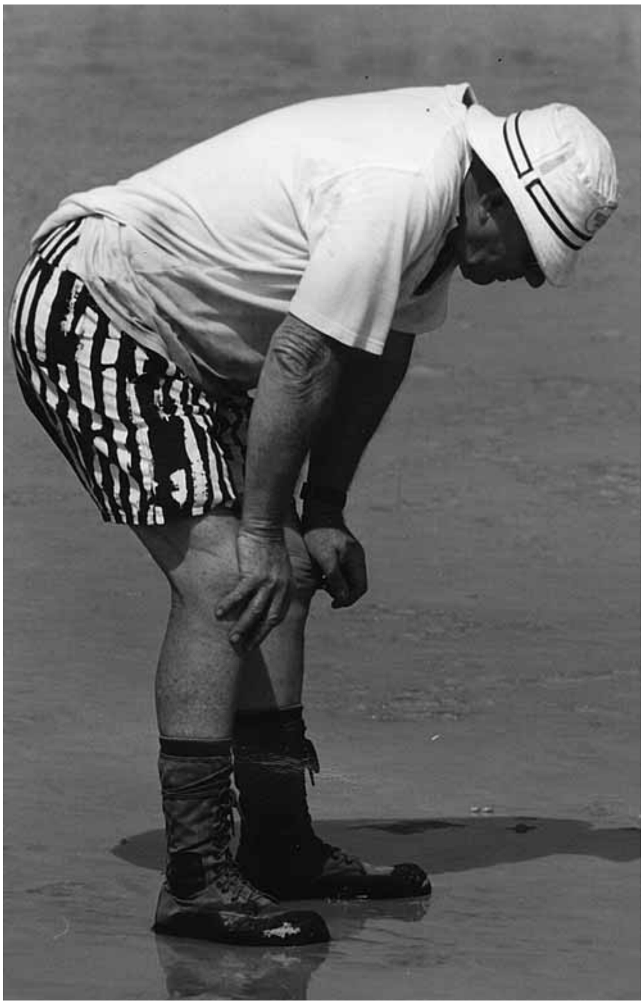
At the completion of these tasks, the whole crew was rewarded with a game of mud football. The "norms" (Grant's team) thrashed the oddballs 7 to 2. The following mud fight (Fig. 5.5) gave an opportunity to settle scores, old and new. Luckily the trailer and water tank were on the beach so everyone (almost) could wash the mud off at the end. This was followed by the usual trip to the bore for a proper wash.

Thursday 21 October

A bird surveying crew of Danny, Mavis, Petra, Theunis, Matt and Andrew left at 0800 for the 65 km block. They surveyed birds on the receding tide before the rest of the crew arrived and disturbed the site. Plenty of birds were observed in the distance but not so many were in the survey.

For the rest of the crew, a later start (0900) was possible due to the tide time (low at 1440). Seven teams including the bird surveyors sampled as many sites as possible on 12 transects. The neap tide limited access to 7 or less sites on most transects (but the group of zealots led by Grant achieved 8 sites on one transect). The ground was mostly very firm, easy walking.

About 70 samples were collected. Specimens included sea cucumbers and razor shells (*Solen*). The main task was to finish sorting and prepare to depart the next day.



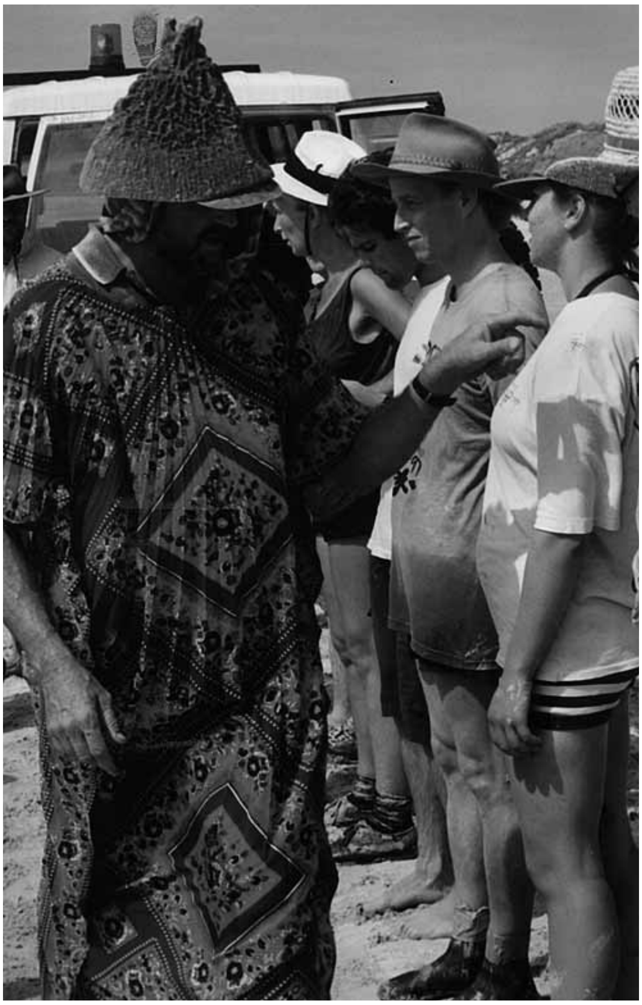


Figure 5.5. Photo documentary of the great big mud-football game during a neap tide on 20 October. Most photo's by Warren Utting.

Friday 22 October

The usual five o'clock bell and dog activities were joined by early morning helicopter noises. Anyone trying to sleep in soon gave up. Several of the crew got a quick joy ride around the Anna Plains homestead area (Fig. 5.6).

Identification of samples continued in the lab while the crew were dismantling equipment and loading vehicles. The aim was to finish the lab work by 1000 and then dismantle the lab. At 1015, a rousing cheer was heard from the lab as the last sample was completed. The lab was then cleaned and towed to its new home next to the Anna Plains workshop.

By midday, most of the loading was done. The DCLM team that had been working at Mandora dropped in for a short while. Michelle Wardley presented a painting of the beach to Grant. Some of the Broome people left during the morning.

The Wallis Drilling truck and trailer headed for Perth. At 1400, a convoy of four vehicles and two trailers headed to Broome. Bob Hickey and Michelle Crean stayed to take a flight along the beach in the Anna Plains aeroplane at low tide which was at 1530. After the flight, Bob headed for Perth taking Shapelle and Michelle was taken to Broome by Danny.

After a quick restaurant meal in Broome, Grant took a plane to Perth and left the remnants to do what they had to do at the Observatory.

Saturday 23 October

Equipment was sorted and returned to its rightful place. The Dutch scientists reacquainted themselves with the Roebuck Bay flats.

Sunday 24 October

Danny took Petra, Theunis, Marc, Mavis and Jack to Kidney Bean Pool to check for birds. Yellow chats, Turnstones, Knots, Little Curlews, Oriental Plovers, Pratincoles, Red Capped Plovers, Red necked Stints and Black Kites were seen. The pool had no standing water but the soil was moist.

Data analysis and report writing started late morning and continued until late afternoon. Grant rejoined the party in the early afternoon.

Monday 25 October

Report writing and equipment sorting continued.

Figure 5.6. Mavis Russell ready to board the small helicopter for a aerial reconnaissance of the Anna Plains station. Photo by Theunis Piersma.

5.3. A SCIENTIST'S DIARY

(by Marc Lavaleye, Fig. 5.7)

Figure 5.7. Marc Lavaleye, our chief taxonomist, in front of the "Dutch embassy", the dry laboratory. Photo by Theunis Piersma.

Sunday 3 October
After an almost 24 hour travel from Amsterdam to Perth I unfold myself from the airplane chairs that are not fitted for tall Dutchmen. Joanne Varley, librarian of CALM Woodvale, picks me up together with my heavy trunk with photographic equipment. She kindly offered to let me stay at her place. At the typical Australian one storey villa I relax in the garden at a temperature of 26°C, get a nice dinner with steak, and after some watching of rugby on TV, I have a good long sleep.

Monday 4 October
After an early breakfast Joanne drives her friend Marty to the train station, and her son Scotty to Children Care. In the rush Marty forgets his wallet and consequently doesn't go far. Joanne and I load the car with all kind of gear for the coming expedition and bring it to the CALM office. Grant Pearson, the overall organizer of the expedition, welcomes me and tells me the good news that the echinoderm specialist of the Western Australian Museum, Loisette Marsh, will join the expedition. I am surprised Grant doesn't have a long list of things for me to do, so I pay a visit to the WAM. Here I meet Jane Fromont, but she doesn't have a name yet for the strange mud-sponge that I found in 1997 and 1998 in Roebuck Bay.

Tuesday 5 October
Marty drops Joanne and me early at the CALM office. Together with Grant we are packing the trailers, and at 12:00 the 4 cars all with a trailer are ready for a group photograph for the Landscope archive. The most impressive car is the Wallis truck that carries the 1000-liter diesel container, two big water containers and an aluminium boat. The trailer carries the large hovercraft. Jamie Wallis and Ken Hartnett will drive this combination. The second car is the Mitsubishi. The trailer carries among others all our food. Brent and Chris are the drivers. Brent will be our man for the logistics of food and lodging. The third car has the trailer with our amphibious vehicle. Ted, his daughter Michele and Warren will travel in this one. Ted and Warren form our technical team. And finally the Landcruiser with the green trailer, stuffed will all kind of necessary things for the expedition, like microscopes, lights, sorting and collecting material etc. Grant, Joanne and I will drive this one. After the photograph the first 3 cars leave CALM in the direction of 80-mile beach. But they are not going far, as it is difficult to buy more than 1000 liter of diesel without the creditcard for petrol, that they have forgotten. As they haven't yet gone far, the problem is solved quickly. We leave two hours later, as Grant still had to do a lot of organizing, and continues to do so by phone as long as we are in the reach of Perth. One of the problems is that the 10m caravan that we will use as a lab is still at Broome and will not be transported to 80-mile beach. But soon it is solved, as Jamie with his truck is prepared to pick it up after he has brought his hovercraft to 80-mile beach. So finally we are all on our way. Our target for today is Meekatharra, a distance of 730 km. The landscape is green with lots of flowers. Especially the white plumes of flowers of the Smoky bush (*Ptilotus* spec.) are abundant. Further the white and purple flowers of a cudweed, Salvation Jane, and the bright blue flowers of *Lechenaultia biloba* are striking. I also see the first dead kangaroo along the road, which will prove to be a very common sight. Special things are the flocks of rose cockatoos, Galah's, that forage in meadows. Also common is another cockatoo, the Little Corella, which is white. Near Miling I see a long the road the first of many signs that says "flooded area", a bit strange as the area is rather dry with red earth from now on. Outside Wubin I see spots with salination problems caused by intense farming. Not very much further all agriculture stopped, and instead there is an open forest with grass and bushes. Slowly also the trees vanish. A fox crosses the road; they form a big threat for the indigenous marsupials and birds. Since many years the government tries with all possible means, including poison, to eradicate this introduced animal pest. At 18:30 it is dark, and we have to be careful not to hit a kangaroo or worse a bull that like the warmth of the road. At 22:30 we meet the other 3 cars at the roadhouse Meekatharra, and have warmed up pasta with bread. About 50 km further we camp along the road at "25 mile well". We are

lucky that there are no mosquito's (mozzies) as we sleep in the open air on the typical Australian swag, a combination of a piece of canvas, a thin mattress and a sleeping bag. The sky with stars is awesome. The only disturbance is the noise of an airbed going flat under some hilarity.

Wednesday 6 October

We are up at 5:15, which is not surprising as the roadtrains, typical Australian trucks with two trailers, started to pass with a lot of noise rather frequent and besides it is becoming light. Grant discovers that the airbed from yesterday actually was a tire of his car. But soon this is fixed, and we leave in convoy. The landscape is getting dryer. The vegetation of bushes is getting thinner, and most of the grass and undergrowth is vanishing so that the red earth is becoming more evident. After 100 km the first tussocks of *Spinifex* grass appear. We pass two arms of the Gascoyne River, and there is still a bit of water in them. At 9:30 we are at the Kumarina roadhouse where we have a toilet stop. I counted the roadkills so far today which are more than 30 kangaroos, 10 cows and 6 sheep. The traffic, however, is not very busy. We see about 10 cars every 100-km. After Kumarina we pass several mountain ranges, the only flowers now are the yellow ones from the Acacia bushes. After 300 km we see cone-formed hills, which seem to be grabbed from a Western movie. We tank along the road out of our own diesel container to save money. Between the *Spinifex* and termite hills I discover lots of large grasshoppers, that fly away as I disturb them. After the Tropic of Capricorn, we take the road to Port Hedland instead of the inland road. It is a beautiful mountainous area here with some clefts, and the highest point we reach is 1055m. We see trees again, and cattle and kangaroos have disappeared. After a rather quick descend through a cleft we reach a treeless plain with grass. 150 km before Port Hedland we see some strange hills build up out of gigantic boulders. Warren feels very sick and Ted will bring him into town to see a doctor, however, we have forgotten to tell him our next meeting place. We only realize this when they are out of sight, and while the other cars are going on we have a look for them. We pass the heaps of salt along the busy road and arrive at 18:20 in Port Hedland. We criss-cross the town and visit the hospital, but we can not find them, so we leave a message and go-on. In the pitch dark we arrive at our meeting point next to the De Grey River. There must be still water in it, as Jamie had a good swim to cool down. This was rather courageous as we hear during our dinner of ginger-pasta with sausages, that for a long time this place was the home of a large croc. Brent, also known as BJ, will wait here for an hour for Ted. The rest goes on to make some more kilometers in the night. After our dinner I have difficulties to keep my eyes open, but as I am driving, this is rather crucial. The others in the car are sleeping, and the music from the cassette-recorder keeps me awake and us alive. At the Sandfire Roadhouse Grant (of course) phones the roadhouse in Port Hedland, and gets the message that the car of Ted is on its way. Later we discover this was a mistake. Another 83.5 km to go to Annaplains. After 45 km we see an orange glow, but much to early for the morning sun. Closer we discover that it is a big bushfire, that is heading in an eastern direction. It crossed the road not long ago, as we pass smouldering tree stumps. It is a beautiful sight, this orange glow nearby and the towering flames in the distance. With some luck we find the turn-off for Anna Plains, and go through the gate that is not locked, and guess that it is still 20 km to the beach. It is a sandy and corrugated road, and we are all shaken thoroughly at a speed of 40 km/hour. It is a spooky drive in the pitch-dark night as often mistbanks coming from sea suddenly obscure your view completely. Wallaby's now and then are scared off by our headlights and hop away. Nobody is sure about the direction, we check a gate at the left, but decide to go straight on. At a junction we decide to stop and to just camp on the road, as left and right of the road it is covered with low thorny bushes. Without the trailer Grant drives on to check how far away the beach is and if it is not better to camp there. I grab the chance to see the beach, and join him. It is still another 7 km over a narrow track of loose dune sand, and crossing low dunes we reach 80-mile Beach. The multitude of big shells and the many tracks of land hermit crabs (*Coenobita variabilis*) at the high tide level seem to make my best expectations true. We cannot find a better place to camp here and return to the others. In the meantime BJ has arrived too, but without Ted. It is midnight and everybody is tired. Still Grant wants to have a bath first. He tells us about a borehole, that constantly spills heaps of hot water. Joanne and I are talked into it, and there we go again back on the road and criss-cross over tracks through woods. Amazingly he indeed does find it, though later the return trip seems to be much shorter. We hear the splashing water. The water of 30ºC is coming out of steel pipe of 1 meter high and 20 cm in diameter, standing in a shallow pool surrounded by trees. At 1:30 we enjoy the nice water, and Grant cheers us up by telling that another expedition did catch the highest numbers of mozzies here, and that it is further famous for the Ross River-virus. We, however, survive, and at 2:00 o'clock we are back. I roll out my swag and jump in. The sky full of stars is gorgeous. The vegetation is still wet, but the mist is gone, and luckily no mozzies at all.

Thursday 7 October
At 6:30 I am awake again. By daylight I finally can see that we camped in the middle of an extensive plain covered with low shrubs and yellow grass. There are no trees here. Everything is moist from the mist, and also the lens of my camera is dimmed. I discover a stick insect and a cockroach with a white striped front. Ted is still not here, and we are getting worried. Grant is checking our planned camping site near the beach again with BJ and Jamie. Apparently the foreseen camping place is wiped away by a recent cyclone. So they are not really thrilled about the place, and see lots of problems to get the 10 m long caravan there. At 8:10 Jamie and Ken drive to Broome to pick up the big caravan. Grant, BJ and I drive to the homestead of Anna Plains to meet the owner of this huge cattle station, which is as big as a Dutch province. The wallabies we see are not very shy. The homestead is an oasis of green grass with about 10 wooden houses around it. The houses are simple with corrugated iron roofs, and the big fancy ranch house as I expected is non-existing. The place looks deserted, and the constant noise of a generator seems to be the only live sign. We meet Bob the technician, who explains that most of the men including John Stoate are gone with all the big equipment to fight the bushfire that we saw yesterday. They already lost a million acres, but most of it is pindan forest, which is not so important for the cattle. They, however, have to take care that the fire doesn't reach the grassland. It seems that the fire is a blow for us too, as we had hoped that they could clear a place in the dunes for our campsite, which is out of the question now. We don't know what to do now, and go back to the others. There we decide to break up camp, and to all go (2 cars and 5 men) back to the homestead to wait for John Stoate. For some reason we unpack the trailers, and soon it is a big mess of all kinds of gear on the green lawn. Grant tries out his brand new toy, a satellite telephone. At 10:30 suddenly John Stoate turns up. He meets my expectations of a big rancher with his cowboy hat and spotless and fresh ironed khaki clothes. He is very friendly and knows to solve our problems at once by giving permission to camp on his nice lawn. So we set up tents and the kitchen. It is quite hot, but luckily there is some wind and the big raintree in the middle of the grass field gives us shade. Before noon Chris Hassell is coming in to bring the small hovercraft. He tells me he gave up his job as warden of the Broome Bird Observatory, and that he is now busy with a project about the Mandora marshes, 40 km south of here. This is also the reason that he is unable to join our expedition. In the afternoon we pass the time by making 5 new sieves for the benthic sampling. In the mean time finally Ted and Warren show up. Warren's health is luckily improving. At 17:00 we all go to the borehole and have a great time there in our underpants. In the evening dusk we drive back home and manage to run over a Rednecked Wallaby. Surprisingly it survives and leaps away. After dinner the long trip from Perth and the heat takes its toll, and soon everybody seeks his bed. When our own generator suddenly stops because it is out of gas, the hands of the ranch applaud, because the noise deafened the TV that they are watching.

Friday 8 October
In the morning we are seriously paid back for the noise our generator made yesterday. And it is coming back every morning! At 4:30 someone rings an old-fashioned bell to wake up the hands of the ranch. And it works. At 5:00 I have breakfast, and the sun is coming up. No mozzies now or during the night. A huge caravan of 10m long has joined our tents and trailers. It came in yesterday at 21:00. Jamie and Ted had some difficulties coupling it onto the truck as it didn't have a standard coupler to fit the towing-bracket, but obviously they managed. We will use this caravan as our identification lab and as computer room. It is rather luxurious as it has airco and some fridges. It will prove to be indispensable, especially at the end of the expedition when the heat gets intolerable. The place now starts to look if a small circus had settled, and the crowd still has to come. I am getting worried what John Stoate thinks about it, Grant realizes this too. He informs John what still can be expected, but John probably has seen worse cases, and gives us permission to stay for the whole expedition. This is really a big relief, and 6:30 Grant leaves light hearted for Broome to pick up the other Dutchies and the Landscopers. I start to fit up the caravan with tables and microscopes. BJ catches a nice Frilled necked Lizard with an expansible collar. At 9:40 four of us make a trip to the beach. The south-western wind is much stronger here, and again we are glad we can camp at the homestead. It is high tide, and I walk along the shore looking for shells. Because of the wind you don't notice the burning sun, but I have some experience and am well protected. It is a feast for a shell collector here, as it is easy to collect a whole sack of nice

shells. Striking are the big shells, especially the giant whelk (*Syrinx aruanus*) and the bailer shell (*Melo amphora*). A brown horny vase-like sponge is also abundant, and can be used as a hat. Further I discover horny corals (Gorgonaria), clumps of Bryozoans, little sharks, tracks of turtles and many other shells. From every species I collect one, and in a short time I have more than forty species of big molluscs, of which the nicest is a *Volva volva*. Most of these shells do not live on the mudflats, but come from deeper water, and are probably washed up by cyclones that are not uncommon in this part of the world. I could have walked here the whole day, but we had agreed to be back at the car at 11:30, and I hurry back. But surprisingly nobody is there anymore. I wait and enjoy watching the retreating tide. The water looks murky, and people warned us not to swim here because of stingers and sharks. Chris tried to fish here, but too much wind. Soon Ken picks me up, and explains that they moved the big hovercraft that was stalled at the beach to the camp, as they were afraid it would wash away with this wind. During lunch I see a quick small whipsnake disappearing under the tent. At the toilet I am welcomed by a green frog, a familiar sight for me, as they were so abundant in the toilets of Broome Bird Observatory. For a moment I enjoy sitting under the blossoming raintree. It smells sweet and attracts many birds that hide and sing in its crown. The rest of the day I use to identify the shells I collected.

Saturday 9 October

We are lucky that it is Saturday as the morning bell now rings at 5:30 instead of 4:30. I want to start in the lab again, but cannot open the door, as they fitted the awning wrongly. So first breakfast with toast. At 8:30 we go to the beach again. It is a 7-km drive. Halfway I see a big fruitbat, caught by the barbed wire of a fence. Chris and BJ set up a toilet near the beach, and Michelle and I stroll over the beach. I find a few more species of shells, and also discover live shells of *Donax cuneatus* that are apparently dug up by a waderbird, but were left here, as they are too big to be swallowed. Further I see many big holes of the red ghost crab (*Ocypode* spec.). Later I see in bright daylight hordes of them tip-toeing over the beach. High tide is at 11:00, but long before that the toilet is ready. It is hot again, and they long for a visit to the borehole. I show the way. In the surrounding of the borehole are lots of concrete foundations and here and there some ruins. It once was a secret military base to track rockets that were launched from the middle of Australia. Refreshed we return to the camp. I further work on the collected material, and Michelle Costello, a biology student, helps me with sorting and identification. After lunch the first two Landscopers, Lawrie and Dusty, are coming in. Later on the other landscopers arrive with a bunch of 8 American students from Philadelphia doing a training course at the Notre Dame University of Broome, and two other Dutchies, Theunis and Petra. Grant has an introduction speech and explains to the landscopers that this is not just holidays, but really participating in a scientific expedition. This means that they have too work too, but on the other hand it will not be a concentration camp. The aim of this expedition “Annabim99” will be to get an idea of the distribution of the different benthic invertebrates living on the mudflats, and how their distribution is correlated with the numbers of feeding waders. Most waders come all the way from their breeding grounds in Siberia to escape the severe winters and to feast on the abundance of invertebrates on these mudflats. I check the collecting gear they brought from BBO, and discover that they have forgotten to bring forceps and trays for sorting. A collection among the participants, however, solves this problem for this moment. At 16:00 we all go to the beach to do the first preliminary benthic sampling. We are split into four groups of 3 to 4 men, and each group sample 3 stations. Loisette Marsh and Dusty are in my group. I am glad Loisette is joining the expedition, as she is a former curator of the Western Australian Museum and has a thorough knowledge of the Australian echinoderms. When we walk to the sea the sandy beach quickly changes into soft mud, and walking gets very difficult. I decide to go first to the station furthest out, and Dusty is willing to operate the GPS and direct us to the exact coordinates. Dusty is very fit for his age and keeps up a stiff pace in the mud, and leaves me with Loisette behind. Everybody had told me 80-mile beach would be easy in comparison with Roebuck Bay, but now I suspect that none of them ventured very far onto the mudflats. For Loisette it is a big effort and I help as much as I can. When we finally arrive at the station I discover that Dusty mixed up the number eight with zero, so we walked much too far out. I don’t tell Loisette, who is pretty exhausted, and we make it a station anyway. The method of collecting the benthos is the same as used during our previous expeditions in Roebuck Bay and the King Sound. Three cores of 10 cm diameter are pushed about 20-cm deep into the sediment. The so collected material is then sieved over 1 mm. I fill in the details on the field protocol. Slowly with Loisette on my arm we head back sampling two other stations. I skip the last station, as it is almost on the beach and besides it is getting dark. We are the last to be back. At the beach entrance a kind of fire pump is installed with which we can clean ourselves and get rid of most mud. Back in the camp dinner is ready. Brent, Chris and Joanne took care of it, and will continue to do so in a satisfying way during the coming days. The last of the Dutchies, Pieter has arrived too. I have terrible headache and dive in early. The others have a meeting and discuss the sampling scheme for the following days.

Sunday 10 October

After breakfast at 6:30 the sorting of the collected samples from yesterday is started. This happens on a big table outside under the raintree. The Notre Dame students form the core of the sorters. I start with the identification of the animals. Pieter, Petra and Danny help me, and we all have our stereomicroscope installed in the big caravan. At first work is going slow, as knowledge has to be freshened up. The samples are not very interesting, and consist mostly of polychaetes. The sandy tubes of Owenidae are common, as are the red spionids and *Nephtys*. So far we don't see much difference with the mudflats of Roebuck Bay, and in fact the large numbers of Ingrid eating snails (*Nassarius dorsatus*) that we saw crawling over the mud, remembers strongly to that bay. We fail to finish the 12 samples before lunch, and after that we have no time, as the first real coring trip is scheduled directly afterwards. At 14:15 we all arrive in convoy at the beach. It is a whole organization with such a large group, and of course some things go wrong that first day. One group discovers that it forgot their sieve, and has to go back to fetch it. We are heading for block 5, which is 5 km south of the beach entrance. Pieter prepared the coordinates of the stations for each group, and guided by a GPS every group starts to walk to its first station. The mean age of my group is less than half of that from yesterday. Fiona, one of the landscopers, is a young woman with a very characteristically penetrating, though not unpleasant, voice. She is a freelance journalist and keeps up the official diary for the landscopers (see this chapter). The other member of my group is Lindsey, a student of Notre Dame. Having learned from yesterday, I keep the GPS to be sure to go to the right spots, and as a consequence the two girls have to do the dirty work. Again it is terrible mud, walking is hard, and sampling slow. Especially if we see lots of mudskippers, an indication for very soft mud, we know that it is getting tough. Still we do 7 stations towards the low water line and another 6 on our way back. As the stations are 200 m apart that's 2.5 km through deep mud. That it takes lots of time is clear, as we have to hurry to be back at the beach before dark. I somehow end up with the heavy bucket with samples in my hand. Grant picks us up with the fourwheeldrive van, that he could borrow graciously from the department of CALM in Broome. Jamie is also active with his hovercraft on the flats. He is just coming towards us, and need some power to get on the sloping beach. However, now his velocity seems to be too high to avoid a collision with our car, and panic starts in our crowded van, highlighted by the peculiar screams of Fiona. But somehow, Jamie, manage to miss us at the last moment by half a meter. Our trip back to the camp is also not flawless. The van suddenly stops, but we succeed by pushing it to get it starting again. About 500 m before the camp the wheellock indicator lights up red, and the engine dies out. We try to push it again, but we hear such strange and alarming noises, that we leave it here and walk home. The other cars have no consideration and pass us to hurry for dinner. I am surprised to see that people are scared of the wandering cattle and they all walk behind me using me as a shield. When we finally arrive, most of the dinner is already gone, but we still manage to get some white rice with a stick of saté. At 21:30 I am fully recovered and start working in the lab. We find out that all together we did 115 stations today. Sorting the biological samples from the geological ones proves to be an awful lot of work, as both bags look quite similar. Next time we will do it differently. The biological samples will then get a small vial containing the station number, while the geological samples only get a tag of water resistant paper. At 23:40 we are ready, and store all samples in the fridges. Pieter has already started to import the data from the field-forms into the computer. Danny did bird watching today, but was not impressed yet by the numbers.

Monday 11 October

At 6:00 I wake up and because the sun is burning on my tent it doesn't cost me much time to get up. I start with the last samples of 9 oct., and as the Notre Dame students try to learn something, it cost me much more time than I thought. At 9 o'clock I am finished and continue with yesterday's samples. Theunis and Petra stimulate the sorting and samples are coming in regularly. At 10 o'clock I only managed to do 5 samples, so still 100 to go. Pieter is doing the computer work. I come across a seahare (*Aplysia*) and an orange seapen (Pennatulacea). They were collected outside the quantitative sampling. Because of the tides we have an early lunch at 11:30, during which the adapted strategy concerning the labelling of the geological and biological samples is explained to everybody. Theunis arranged the sampling teams. I will be team 1, and get Lawrie, Marie and Ben today to help. The departure from camp is much more orderly than yesterday, with the result that we are much too early at the beach, and have to wait a long time before the water retreats. This is, however, far from tedious. Near the transition from the sandy beach to the mudflats I discover many small snails (Marginellidae) crawling over the mud. Today we start with block -10 (10 km north of the beach entrance). The distance from shore to the low water line is very long (about 4 km). The large distance between the low water and high water line is not only caused by the gently sloping shore but also by the enormous tide range, that can be more than 9 meters during spring tide. It is physically impossible to sample one transect completely in one day on foot. But we do our best and manage 11 stations till we meet the incoming water, and have to go back. It is a beautiful sky with some dark clouds, and we can hear and see thunder and lightning in the distance. We even get some rain. Lawrie is very enthusiast, and has a keen eye to discover small animals. With a small spade with a long handle he knows to present these animals to us. We see several mating pebble crabs (*Myrodes* cf *eudactylus*), a beautiful swimming crab (*Matuta planipes*), and a live seapen. When I touch the living tissue of the seapen it retreats into the mud, and the light yellow flexible shaft becomes visible. This is new to me as I thought that the skeleton only would become visible when the animal dies off. Marie has the most problems with the mud, but I gave her the GPS, so we have to walk on her pace. In fact this is an ideal situation as I have some time to look around for special animals. Ben is a young and quiet student and carries the bucket with samples. At a parallel transect we do another 10 stations on our back way to the beach. Time flies by, and it is dark again when we reach the comfortable sandy beach. We learn here that the hovercraft had some problems at the start. The flexible rubber skirt came loose because some plastic bolts broke off, but luckily was not torn. Of course the spare parts were still at the campsite, but in 2 hours Jamie managed to repair the damage, and finally did some sampling far out on the mudflats. In a few minutes the hovercraft can reach areas that are two hours walking for us. For the return trip I wisely avoid the van from yesterday, which again has problems reaching camp. After dinner back to the lab. This morning 100 samples were sorted, of which only 12 have been identified so far. We agreed not to work as crazy as during the Roebim'97 expedition, and so I quit for bed at 24:15.

Tuesday 12 October

Yesterday the plan came up to go very early to the beach to cover the missing stations of the -10-km block. I indeed hear them leave camp at 5:45. It is suddenly very quiet in the camp after the noise of hasty breakfast. I stayed behind to catch up with the identification. Surprisingly the 5 teams and the hovercraft are back much sooner than expected. They found that the water was already much too high to sample much. My old team didn't get a sample at all, and the best team only managed to do 2 stations. The hovercraft, however, did marvelously and came back with 9 samples. Petra and Danny now join the identification team, and Loisette helps by splitting up the samples in different animal groups. I start putting together a reference collection. At 15:45 we sigh deeply as we have finished the 115 stations of block 5. Theunis, who joined the sorting people, assures us that samples of the -10-km block are much easier as they are much poorer in animals. Of course we doubt this and suspect he only says it to motivate us. Anyway we continue identifying. Most animals stayed nicely alive in the fridges, and I see how a slim columbellid snail (*Mitrella essingtonensis*) of 1 cm can hang upside down with its foot attached to the water surface. In this way the shell can move with the receding or incoming water much quicker than by crawling. I see it later actually happening in the field too. Petra remembers to have seen it done by *Nassarius dorsatus* too in Roebuck Bay. Danny joins in to our discussion by stating that he has seen the bivalves *Nucula* and *Solema*, with their hydrophobe periostracum, floating on the surface. Further I notice that almost every sample with brittle stars (*Amphiura tenuis*) also contain one or more bright red polynoid worms. I suspect that this is a kind of symbiosis, as it is known that several other polynoids have the habit of living together with other polychaetes or echinoderms. In the afternoon two teams go sampling again and try to fill up some stations of block 5. They come back with a marine insect, a Hydrobatidae. This is one of the few insects living its whole life at sea. It skates over the water looking for prey. Further they also caught our first mantis shrimp. At dinner we notice some kids. They came from Broome today with five local women from the Notre Dame University, and also come to help. Joanne, Warren and Ted arrived at 20:00 with a new rental car from Broome. They took back the troublesome van to CALM, and luckily it just stayed alive the whole 300 km to Broome. After dinner we give some talks about the results so far. I mention the sabellarid reefs, of which we found some clumps near low tide. It is a colonial bristle worm that forms strong sandy tubes by cementing sand grains together. Further I ask if they noticed that the brown patches on the mudflats are almost gone in the morning and evening. They are made up out of diatoms, moving unicellular algae, which expose themselves to the sunlight during the day and hide in the mud during the night. At 22:00 the sorting and identifying is almost done. I found a small snail, a *Ringicula*, and when I touch it under the microscope I am surprised to see that has a reverse. It can crawl backwards, something I have never seen before. At 23:00 we call it a day. It is also the end for the Frogmouth chick, which sits in the raintree. Its parents have deserted it, and although people tried to feed it, it dies young.

Wednesday 13 October

Up at 4:30. The toilet that we were allowed to use is completely clogged up. The septic tank was not calculated for these numbers of users, so that a new improvised toilet was dug near the fence of the camp. With wire netting and blue plastic you are more or less protected from wind and spectators. However when the sun is low, the user casts a clear shadow on the plastic cloth. Very embarrassing for him, but rather hilarious for the others. On your way to it you also have to be quick to avoid the sprinklers that keep the grass green. We are up so early to try again to get some samples before the tide is coming in. In the new fourwheeldrive rental my team, now consisting of Megan, Sharon and her son Tim are brought over the beach to block 20. The sand of the short dry beach is soft and driving is difficult. The wet beach looks more smooth and easy to drive, but is even more treacherous as we found out. We get stuck, but by pushing with all hands we get out again. We see hermits and ghost crabs walking around. I count 3 tracks of turtles. At the end of the turtle tracks near the dunes two pits are dug out a few meters apart. One of it could contain eggs while the other probably is a decoy for predators. The vase-like sponges washed ashore are really abundant along the whole beach. The irregularities in their sides are caused by barnacles. We haven't walked 10 m of our transect before Tim, the boy of 7 years old, starts to cry. I thought this would be heaven for a young boy, but he certainly has a different opinion. Sharon, his mother, persuades him, and we go on. But at the first mud he starts to cry again, and utters that this is not fun. His mother tries everything, but without result. At last she sends him back to the beach. I ask if she doesn't want to stay with him, but she wants to go on and thinks it is a good lesson for Tim to stay alone there. Soon she will regret this, not so much out of consideration for her son, but because we hit the most terrible mud till now. As she is not as willowy as Megan is, it becomes an ultimate exertion for her. On top of that also one of her shoes does not survive the sucking force of the mud. Megan and I look at each other and while we go on the distant weeping of Tim, the sucking noises of the mud and the puffing of Sharon only breaks the silence. The mudskippers around watch us compassionately. But Sharon doesn't give in, and we make 11 stations towards the low water line. As I don't want us to be caught by the incoming water, we head back timely to the beach. This was a good assessment as the water hits our heels when we reach the beach. On our way back in the car, we see a small boat washed ashore. As it seems to be still in good shape, Ted picks it up later. After lunch samples to be sorted and identified wait for us. A new tellinid species, *Tellina inflata*, is found. It has the shape of *Tellina piratica*, but seems smooth. Only under the microscope I discover a nice fine sculpture on the shell surface. We also discuss the difference between mud and silt and understand that there are different interpretations. More serious is that we have three samples without labels, so these were taken in vain as they are useless to us. We also notice that we have to hurry up with the -10km samples, as they start to smell. During dinner Theunis and Grant resume the results of the previous days and thank the landscopers for their participation. Without the fee they paid this expedition would not have been possible. The Dutch honour Grant for the overall organization and offer him a bottle of Juttertje, a special alcoholic drink of the island of Texel. After that there is a small party with some musical contributions, as it is the last evening for the landscopers. Lawry does a clownish performance, and Chris and Brent perform on the guitar. However work has to go on too, and soon we are back in the lab. Jacqui, a Twiggy-like teacher of the Notre Dame University helps us in the evening with the sorting in the lab. She tells us that the university has about 80 students. A special goal of the university is to improve the education of the aboriginals. Fiona is busy with her diary, and tells us her scary adventure from yesterday night. When she wanted to go to bed she discovered one of the cowboys in her tent. He was completely intoxicated, and she couldn't get him awake even with the help of Joanne. At the end she finally went asleep on a mattress in the toilet building. Marie, a blond American student, who is not specially built for tramping in the mud, is busy outside. She has taken the task to prepare the sampling equipment for all teams, and specially important takes care that the samples and field forms reach a safe destination when the exhausted teams come back from the beach. At 23:45 we flip out the lights.

Thursday 14 October
Today one team is going to the 20-km block again, to try to finish it. The hovercraft, with Jamie on the steer and Sue as the navigator, brings them far out and that helps a lot. I only start at 7:00, and spend the whole day together with Danny, Petra and Pieter in the lab trying to catch up with the samples. The landscopers depart, and only Fiona will stay a few other days. At 17:00 we are dying for a break, and go with Danny's car to a freshwater pool, about 1-km north of the beach-homestead junction. We notice that most of the cows have a peculiar lump at the back of the neck. Further we see kangaroos, wallabies and even a donkey. The pool is indeed attractive for birds, and the most conspicuous one is the Stilt. The continuous work starts to pay its toll. Now and then people are missing for a couple of hours, to catch up on some sleep. Pieter and I keep each other awake and are the last to go to bed at 24:00. We get a nice overview of the animals living in the mud, and differences from Roebuck Bay slowly become visible. We haven't seen plastic worms (*Chaetopteridae*), nor ostracods and Lumbrineridae, all abundant in Roebuck Bay. On the other hand we found today a new bivalve and gastropod (*Sigaretus*). The colorful larvae of an insect in the samples puzzled most of us. It obviously fell out of the raintree during sorting.

Friday 15 October
For me another day of identifying animals under the microscope. Petra discovers a pink wentletrap snail (*Epitonium*) in her sample. There are also two white ones in the same sample. I ask if she also has an anemone. And indeed a big *Edwardsia* is present. I explain that the nice looking wentle traps are parasites of anemones, and with their proboscis they suck out fluids from the anemone. The pink one was probably irritated during collection, and spat some defense saliva, that turns pink when exposed. I know this from other snail families too, namely the Marginellidae and Muricidae. The famous Tyrrhian purple in Roman times was made out of crushed shells from the last family. A few other people joined the expedition, among which are Jacintha with husband from Broome, and Jack, Karen and daughter Caitlin from Perth. The last three also participated in the Derbim '98 expedition. At 17:00 it is time for a break. Pieter, I and the aborigines Ruth, Maria and son go by car to the beach. Ruth gives us a lesson of aboriginal knowledge. She shows us some large but inconspicuous green flowers in a two-meter high shrub, and demonstrates how to suck out the honey. The flowers look very much like a colibri, and that's why the shrub is called the Green Bird Flower (*Crotalaria cunninghamii*). Ruth also explains that the penetrating smell, of which we thought came from a dead cow, in fact is the smell caused by the paperbark tree. I ask if there are still dugongs here, and she confirms that these are still hunted on a small scale by the aborigines. On the beach we pick up some shells. It is amazing how quick it gets dark at this latitude. And Maria has lots of difficulties to find her rucksack that she left near the beach entrance, before we drive back.

Saturday 16 October
Pieter and Jacintha trust my biological clock and I wake them at 4:30. All 6 teams are ready at 5:30, and we leave with 3 cars for the 35-km block. We don't drive the whole 35-km over the beach but use a track just behind the dunes. Once this was the only road from Perth to Broome and especially used by hippies in the sixties. Only this part still seems reasonable ok to drive, and after 20.7 km you have to turn off to the beach. Theunis, who is driving, misses the turn off and soon we end up between some car wrecks. The problem is solved quickly and on the beach driving is better, though we have to push the car once more. The hovercraft of Jamie is still where it was left yesterday, when the teams started on this block. As the stations far out still have to be done, we made the plan to drop the teams with the hovercraft near the low waterline. And this works perfectly. My team has to do the most southerly transect and we are dropped off first. In less than 5 minutes we are several kilometers out, and enjoy seeing the mud sliding by. Karen is in my team and carries the sieve on a peculiar way on her head. We zigzag slowly back to the beach, sampling stations at two parallel transects. At first the mud is still negotiable, but soon we see mudskippers and the struggle begins. I am lucky that I don't have to care about the other team members this time (they are fit enough), as I have trouble enough on my own. It is awfully hot, because there is no wind, and for the first time I am getting short of water. Half way I reckon that we don't make it at this pace and drop the last 3 stations. In one long strenuous walk we reach the beach. At the end I pass a sandy patch with lots of dead sanddollars. It was strange to see that they were all turned around. Probably a flock of Turnstones did a good job here. We are the last ones on foot, but the hovercraft is still out there. It had an engine breakdown near low tide, and the hovercraft team that thought to have an easy day had to walk back the whole stretch too. At 12:00 we are

Figure 5.8. Annabim-expeditioners visit the Talgarno-bore for a rinse. Photo Theunis Piersma.

back at the car of Grant and drive back with him. We see about 10 tracks of turtles. One of the turtles was somehow disoriented, and made a nice full circle track, but Grant thinks he can do better and drives right through it. I now also see the reason why we do this research here, as we pass flock after flock of shorebirds. Grant is so busy avoiding soft sand patches that we miss the turnoff, but at 13:00 we are back at camp and have lunch. Refreshed, sorting and identifying starts again. It is hot in the lab, and we are sweating behind the microscopes. We are having problems with electricity, and the airco cannot be used. Even the use of the toaster and water kettle can dim the necessary lights for our microscopes. But suddenly nothing works again, and finally we find out that one of the cowboys played a trick with us by pulling the plug in the shed. The nicest find today was a frog crab (Raninidae). This species is peculiar as it has two long antennae that can form a chimney through which it can breath when it sits deep in the mud. Meanwhile most of the American students (except for Marie, Ben and Danielle) together with Fiona, Sharon and the aboriginals went back to Broome. But in return a whole new group of volunteers comes in. The camp looks much more like a hippie camp after everybody has settled. Michelle, the assistant of Bob Hickey came in today too. She claims her swag back that I happen to have, but Grant organizes in a few minutes some new bedding for me. The whole evening spend behind the microscope. Pieter and I turn out the lights at 24:00, and enjoy one of Pieters precious beers outside in an agreeable temperature. It is quiet, no mozzies and everybody sound asleep. But than we see a man staggering to the toilets, quite drunk as we think. He stops and starts moaning, complains about pain in his chest and back. Finally he screams out in pain. Grant, Bob and Ted are around in no time alarmed by the screams. We think he has heart-problems and decide that he has to go to hospital. Bob and Ted volunteer to take him those 300-km. We collect his stuff, but strange enough he hasn't any, no shoes nor sleeping bag. Later we suspect he signed in as a volunteer because of the free drinks. But as these were non-alcoholic he had to try to find an easy way back.

Sunday 17 October

No sampling today, so we have a late breakfast at 8:00. It rained rather heavily overnighty, and my tent is covered with the hairy flowers of the raintree. My clothes that I washed in the bore, and so became a bit reddish from the iron the water contained, are wet again. With Petra and Pieter, back to the caravan to our benthic animals. Danny is away with Jacqui and Shapelle to count birds at the beach. He started at the 35-km

Figure 5.9. Michael, ”the bronzed concrete worker” from Broome, sorting a sample. Photo by Theunis Piersma.

block, and will meet Theunis who started at the beach entrance. The preliminary result is that at the 35-km block lots of Bar-tailed Godwits are present, while Great knots seem to prefer the mudflats near the beach entrance, probably because the availability of bivalves here. They saw the whale bone too and also discovered a dead turtle. For me they collected some flat blue circular objects, which I recognize as *Porpita*, a floating kind of jellyfish (*Siphonophora*). In the lab it is like a sauna again. We don’t find anything exciting. The highlight is that Theunis, who is typing lots of data into the computer, suddenly looses the whole file because of a faulty plug, and has to start all over again. Michelle takes over the computer work in the afternoon. After dinner we inform the new crowd about the program, procedures and results so far. Petra explains the sampling while Jack mimics the procedure simultaneously. I talk about differences between Roebuck Bay and 80-mile Beach, and the highlight of Danny’s talk is that 90,000 waders were counted. Back in the lab we are able the finish the samples from one fridge at 22:30. Still one hundred samples to go in the other fridge. We keep these for tomorrow.

Monday 18 October

The teams leave early for the 50-km block. Between the 20 and 35 km point they count 15 turtle tracks, but the last 15 km none is seen, but it is easier driving. Danny, Petra and I struggled with the samples in the caravan, which again feels like a sauna. I do about 10 samples in an hour. At last the heat is intolerable, and in spite of electrical problems we put on the fans. The camp is very quiet with most people on the flats. Jacinta is one of the few that stayed, as she had dehydration problems yesterday. She helps us by counting the numerous brittle stars and the tubes of Owenidae. During coffee time Helen comes in, and as we could have guessed she has a big tin of homemade cookies with her. Although one car got a flat tire the sampling teams are already back at 13:00, and all planned stations were sampled. The mudflats there proved to be very sandy, and easy to walk. Pieter collected some bigger animals not seen so far. Live flat sanddollars (*Arachnoides tenuilus*), pink sea lilies (Crinoidea), big brittle stars, a few shrimps, and mussels (*Modiolus micropterus*) attached to old *Spinifex* roots. This proves that the environment there is a bit different and the submerged *Spinifex* roots show that the sea is gaining on the land. At 15:00 I have a break and go to the beach. Danny, Petra and Mavis watch the feeding behavior of the Red Knots. The Knots are very successful in finding prey, so they eat and pooh a lot. This bird shit is what Petra and Danny are after. They hurry to collect it before snails (*Nassarius dorsatus*) eat it. I stroll along the beach, as do Karen and daughter Caitlin. Again I find these *Donax cuneatus* shells dug up on the wet sandy beach by a kind of bird, but the shell is lying undamaged next to its burrow. Later I observe a turnstone here very busy with an object, but it proves to be a helmet crab (Leucosiidae). A nice view is the thousands of beautiful blue *Porpita’s* washes ashore. Karen finds a dead seasnake and a nice stone. When she drops it by accident, she discovers it is an egg, probably from an oystercatcher. Hermit crabs and ghost crabs are all hidden for the heat of the sun at this hour. At dusk we are back at the camp for dinner and more samples.

Tuesday 19 October

The identification team starts today with the samples of block 50. Soon we discover why one of the new teams was so quick in sampling yesterday. They only took one core instead of three at each station, and so the samples are useless for us. As the heat is coming in, we put on the airco for the first time. This helps a lot, and we even think that we can get rid of the backlog today. Especially as the sampling teams come back from block 0 without much success. Each team only could do 1-3 stations. Because of the neap tide most stations stayed covered by water. At 17:00 there are only 40 samples left for us, and we take a break. With some others I make a walk south of the homestead. Unfortunately the two local dogs accompany us, and so scare off the wallaby’s and kangaroos that we want to watch. We wander off the path, and have to take care of the big orb-webs, spun by large spiders between the trees. The leaves of the *Citronella* tree smell very strong. I discover a small quick brown-blue fairy-wren. Out of the direction of the sea we see groups of 4-5 Straw-Necked Ibis flying over to the forest. It is obvious that cattle farming is quite different from the Netherlands as bones and carcasses are lying around here and there. We are late for dinner, and all the rice has gone, though this time we are lucky, as there is enough vegetables and ragout. In the evening we do another 26 samples. Marie from Sweden drew some marine animals and Michelle Wardley (Ocean Artist) also starts to draw. First a shell, and than a crab. There is a difference between an artistic and a scientific drawing, and I have to be critical, but she is not scared off. We talk about these intrigueing turtle tracks, and decide that we have to see these turtles ourselves. So suddenly the plan arises to go to the beach to trail turtles. At 21:00 three cars leave for the beach. Danielle and Benson sit on our roof and have a good view, but alas we only find tracks without the turtles. Probably neap tide is not the best time to find them, as they have to make too long a walk to the beach. Striking are the many patches of small sand balls, made by the Sand Bubbler Crab (*Scopimera inflata*). On the track back we almost killed a fox, and Theunis later got a reprimand for not stepping on the gas to get rid of this pest. It is drizzling a bit, and there are indications that a storm is heading towards us. The tents are extra secured, but thunder and lightning are passing us at a distance.

Wednesday 20 October

It rained a lot overnight, and during breakfast it is pretty cool. I set up my macrophotography equipment on a table in the toiletbuilding. With two chairs I secure the table against a wall so that it cannot move anymore. Electricity for flash and light are available, so it looks perfect. But first I work through the last samples of yesterday. With help I am ready at 10:00. Tea time with biscuits from Helen. Pieter, Danielle and Ben still go out to sample some sediment samples that were not taken or were lost for some reason. I need crystal clear seawater, and ask Helen and Mavis to take care of that. I tell them that Australian toilet paper is not a good filter, as it is chlorinated, and will kill my animals. They find a way and produce 5 liters. So I start photographing. The first is a brittle star. The mess around the caravan is also cleaned up. Theunis summarizes the data in the computer, and tells us we have identified 16,000 animals at 850 station so far, and 40 species were new compared to the animals found in Roebuck Bay. Michele Wardley continues drawing her “wicked” crab. I need some more live animals for photographing, and have a look in the database to find where to locate the small seacucumbers, that are peculiar to 80-mile Beach. Most of them were found near the low tide line so it could be difficult to get a few. But we are going to try. With all available cars and people we drive to the beach to have a relaxing collecting trip. Everybody is free to do what he or she likes, and the purpose is to get some nice live animals. Everybody likes this, and also Jamie has now time to look around for small animals. He discovers a small soldier-crab, and we see how in a very peculiar way it screws itself with his legs down into the sand. I quickly find my cucumbers, catch a small anemone (*Edwardsia*), and collect a complete brittle star. These brittle stars were always a mess, broken in pieces in the sorted samples by the rough handling. Now I discover that the arms with black speckles, are not of a different species but only the distal ends of the arms. Further I collect some of these snails, *Mitrella essingtonensis*, that were fairly abundant. I am content and have the animals I wanted. Then a match in the form of a kind of Australian football is set up. Some cores define the goals. Grant and Pieter are the most fanatic, but it all ends up in a big mud fight. And even the unsuspecting spectators cannot avoid being soaped with mud. Ted Costello gets the time to put away his videocamera safely, but then he is grabbed. Roni escapes by smearing herself with mud. It all ends with a group photograph, and then to the bore to clean up (Fig. 5.8). At home I clean all animals and put them in separate vials, and take several macro-photographs before dinner. The others in the mean time have composed a long song. Every group made its contribution to write a couplet, and after dinner we all have to sing it. The melody is not quite easy and even at the last couplet it is not sung in tone very well. But we all enjoy the contents, and vote which couplet is the best. The cooks win of course, because we are afraid they would otherwise stop catering. Also Roni made a song about her experiences on the mud. I go on with my photography, and the flashes attract several people who watch what I am doing. At 00:30 I notice that there is a complete silence in the camp, and quietly I slip in to my tent.

Tuesday 21 October

Up at 6:00, the sun awakes me. I check my animals, which are all still alive. Danny with a group of birders leaves first at 8:00 to count birds at the 65-km block. The rest follows at 9:00. It is a long drive of about 2 hours. Near the 50-km block we cross some wet places on the beach, which I think is freshwater seepage. We came through without problems because we probed the area first. At the 65-km block the beach is very wide. Near the dunes is a kind of mangrove forest, but I don’t have a look there as I cannot imagine that the sea often comes that far. I think it can survive by freshwater seepage too. My team has again the most southerly transect. We still have time as tides are not far out enough. So we walk along the waterline and look for animals between the things washed ashore. So far we never saw a clear flood mark, but probably it is caused by the storm that passed us a day ago. We see lots of large grey combstars (*Luidia*), pink sea-cucumbers, regular sea-urchins, and mussels attached to old roots of *Spinifex*. I also collect a shell of *Telescopium*, an indication that once there was a real mangrove here. So the waiting is not really boring. We further build two large mounds exactly on the line we have to walk. The idea is that it is than easier to walk out in a straight line, especially as the transects are very oblique to the beach. In doing so we discover a freshly dead Red-capped Plover. The strange thing is that it is standing upright with its feet buried in the sand. It is a complete mystery to us. Finally we can sample our first station. I read the GPS, take care of labelling, and help Cinna, a hippie girl, to fill in the field protocol. Cas, an assistant warden of BBO, and Michael, a bronzed concrete worker (Fig. 5.9), take care of coring and sieving. Michael is very enthusiastic and when he sees something moving in the sand he tries to dig it up. The water slowly recedes, and we follow it. At the second and third station we find small pools with lots of tiny things actively crawling around. They prove to be amphipods that behave like hermit crabs, by hiding in a small shell. They move around with their large antennae. Low water is at 14:40. On our way there we only sample 6 stations and the last two are taken in 20 cm of water. As we are standing there around the last station in the murky water, suddenly Cinna cries. Something bumped against her ankle. Then another one of us is frightened by a similar feeling. I feel it then too. Sharks, probably Shovelnosed Sharks, looking for prey, cause the “attacks”. I have to laugh about it, but the mean mood is between fear and joy, so we head back. On our back way we find lots of seacucumbers. The big purple ones are lying on the sand, having as a holdfast a stone, wormtube or *Spinifex* root. The sandtailed cucumbers are half buried. We also come across purple sealilies (Crinoidea). It is all sand here, and we haven’t seen any patch of mud. But the Ingrid Eating Snails (*Nassarius dorsatus*) and the Sentinel Crabs (*Macrophthalmus*) don’t mind, as they are abundant here too. For the first time I see the purple form of the snail *Mitrella essingtonensis*. So far I only had seen the white form and the white one with a spiral brown band. At 16:00 we are back at the dry beach, and finally have time for lunch. It is hot again today, and our drinking bottles went empty already some time ago. We drive back with Pieter to camp, and make a stop by the dead turtle. Several barnacles are still sitting on its back. Another stop by a big dead and stinking shark, as our Irishman wants to cut out some teeth. I pick up some big irregular sea urchins (*Breynia* spec.), not seen so far. For the last time I visit the bore. At camp it is cozy under the raintree where everybody is helping with sorting. The illumination by the sorting lamps makes it a pleasant sight in the night. The identification quickly starts in the caravan, as tomorrow we will break up, and will not have time to do much. At 23:00 only Pieter and I are still working, we stop at 00:30 although still 40 samples have to be done.

Friday 22 October

After an early breakfast, we hurry to identify the animals of the last 40 samples of 80-mile Beach. It is going rather quick, but we have to, as the rest is cleaning and packing up. So the last samples I do without a chair as it was pulled away underneath to be stored in one of the trailers. Just in time we are finished, while the electricity is hooked off. Petra and Michelle take care of the reference collection and change the formalin for alcohol. Than I run to the toilet building to make my last macrophotographs of these curious amphipods that we found yesterday. Afterwards I break off my tent as one of the last and at 12:00 everybody is ready. Grant, however, has arranged with the helicopter pilot, that some of us can have a short flight over the camp. The pilot normally drives up herds of cattle, and he likes to do something different. It is my first time in a helicopter, and I manage to make some photographs of the marvelous view of the plains, the camp and the sea in the distance. We say goodbye to lots of people as ways part here. Grant gets a nice picture of 80-mile Beach painted by Michele Wardley, and we give him as a souvenir all the 1000 tags, which were used to label the samples. And then slowly one after the other is leaving the camp. Bob Hickey and Shapelle leave as one of the first for Perth. Jamie and Joanne follow them in the truck with the hovercraft. Then the van with the hippies (as I call them) leave for some unknown destination. At last we leave with 4 cars for BBO, only to leave Danny with his old car behind to do some more birding. At BBO they are busy building a new lookout for birds. Pieter and I have a quick look at the beach and discover that the mudpatch with fiddler crabs has disappeared. The eight of us go once more to Broome to have dinner in a restaurant. Grant leaves us at 19:30 to catch a plane back to Perth, as he has to see his daughter singing in a concert. He must love her very much, as he will return to Broome in a couple of days. We head back to BBO, and have a good sleep in a real bed.

Saturday 23 October
I am sleeping on the wrong side of the main barrack, and so I am burned out of my cabin by the early sun. During my breakfast I see wallaby's visiting the drinking place near the shade house. Together with Pieter I walk the Malurus trail early in the morning, and we see a lot of birds among which are Zebra Finches, friarbirds, the different kind of doves, honeyeaters and bowerbird. I miss the simple but melodious song of the butcherbird. The cause could be the large fire that almost destroyed BBO, and made the pindan much more open. The dead landcrabs are still everywhere. Soon it gets very hot. At "One tree" we enter the beach, and walk to "Little Crab Creek". And indeed this creek is completely gone, filled up with sand by a cyclone. If we walk back along the waterline, we see many mullets fleeing in a peculiar way with part of the head above the water. We also smell and find two dead green turtles. At 10:00 we are back. Then we watch with telescopes the waders on the mudflats in front of the BBO beach entrance. We see flocks of godwits (2 species), Red- and Great Knots, and Eastern Curlew. It is nice to see that these birds see the difference between an osprey and other birds of prey. If the first flies by, the birds are not disturbed at all, as they know it only eats fish, while with another bird of prey they all take into the air. Then we drive to the sewage pond of Broome to watch more birds. Danny has the key of the gate, and we see some large square ponds, separate by narrow dikes. We do not notice anything of sewage, but see Whistling-ducks, Lapwings and Royal Spoonbills. A large guanna, with yellow head and tail, roams the dikes. Then it is time to bring Pieter to the airport, and to do some shopping in Broome. In the afternoon I visit Cable Beach. On the rocks live chitons, limpets and vulcano-like barnacles (*Tetraclitella*). Further I notice that Australians are a bit more prudish than the Dutch, and changing clothes has to be done in a special building. After the sun has set into the sea we head back to BBO for diner. Again I am the last to go to bed, although it is only 22:00.

Sunday 24 October
A leisure day. We start writing up the preliminary expedition report. In the evening we have a party with barbecue at Chris and Janet's place, the former wardens of BBO.

Monday 25 October
Today we have planned a trip to Kidney Bean, and indeed early in the morning we are driving to it. The place is a shallow seasonal pond inland from One Tree lying in the middle of a large grass plain. Danny thinks it can be an important place as a high water refuge for waders. At the moment there is no water in the pond, and the muddy bottom shows cracks caused by drought. Here and there a carpet of dried waterplants covers the mud, and turnstones have turned parts of the carpet upside down looking for food. I pick up several empty shells, like *Nassarius dorsatus, Littoraria filosa, Cerithidea reidi, Elobium aurisjudae, Melosidula zonata,* and *Cassidula nucleus*. Most of them are typical habitants of the mangroves, and I suspect that they are washed by very high water caused by cyclones. In the low bushes around the pond we discover a nice yellow bird, not seen before, the Yellow Chat. Most of us are not yet recovered from the exhaustion caused by the 80-mile Beach expedition, and have a nice sleep in the grass until the sun gets too hot. At 10 o'clock we are back at BBO, and go on with the preliminary report. Michelle Crean creates the distribution maps. It will be a nice evening with a full moon. This is one of the highlights for tourist in Broome, to see the moon reflecting in the sea, which is called "staircase to the moon". With a group we decide to watch it from the beach near Dampier Creek, as we want to avoid the crowded Cable Beach. At the moment suprème, however, some clouds disturb the view, but the champagne that Jacqui brought makes a nice adventure. Then we all move to the Mangrove Hotel for the goodbye dinner on the grass terrace with live music. We have a great time, and discuss if a monitoring of some stations near Derby will be possible by local people. The view over the Roebuck Bay is stunning and we see waders flying exactly over the hotel to their resting place at the south west end of Cable Beach. After dinner we decide with a small group of die-hards to have a look there. And indeed in the dark night we see large groups of birds resting on the beach. Finally at 0:30 we are back at BBO.

Tuesday 26 October
I pack my stuff at 5:50, and after a quick breakfast I am on the road with Karen, Jack and Caitlin on our way to Perth. Could still say goodbye to Mavis and Grant who are preparing the cannon netting planned for today. At 9:00 we are at Annaplains Homestead to pick up the trailer with the Argo, the amphibious car that did not work well in the mud, and to fasten the aluminium boat on the roof of the car. At 14:30 we reach the Pardoo roadhouse just in time, as the airco, the boat on the roof and trailer have caused that we used much more petrol than we thought, and our tank is nearly empty. At 16:30 we pass Port

Hedland, and camp on the banks of the Fortescue River just before dark.

Wednesday 27 October
I walk over the pebble beach towards the river to wash my face, and a Black-fronted Dotterel is watching me. We have breakfast at the Nannutarra roadhouse, and when I tell one of the locals that this is a very nice country to live in, he is astonished and doesn't believe me. We check the tires and ropes at regular intervals, but everything seems to be ok. We more or less drive continuously, and only a few couples of Emu's stir us up. About 200 kilometers before we reach Geraldton the desert gives way to the Wheatbelt. The transition is a hilly area covered with shrubs, among which yellow flowering Proteacea. In Geraldton we camp at the caravan park, Separation Point, close to the beach. Jack leaves with the car to pick up his stuff, as he has a trip to Tanzania on his program. I phone Joanne at Woodvale Calm to expect me tomorrow between 14:00 and 15:00. She luckily has time then to take me to the airport.

Thursday 28 October
I use the last possibility to walk a beach in Australia. Lots of seagrass and seaweed has been washed ashore. I only find a few shells, among them the blue *Janthina*. After breakfast we wait for Jack. He takes his time and lets me sweat a bit, as I get worried if I will catch my plane in time. Finally at 9:20 he arrives. I realize we have to drive 350 km in 4 hours, so nothing may go wrong. I worry for nothing as we arrive exactly on time at Woodvale. Joanne brings me to the airport and without problems I depart at 17:20 for the long flight back home to the Netherlands.

APPENDIX.
During the Tracking 2000 expedition to Roebuck Bay we also made a short excursion to Anna Plains to sample some stations in the north of 80-mile Beach. Here is a short summary of our experiences.

24 March 2000
After lunch at Broome Bird Observatory we depart for a short trip to Anna Plains. We plan to sample some stations in the northern part of Eighty Mile Beach, a part that was not covered by the 1999 expedition. With seven people (Grant, Bernard Spaans, Petra, Anita Koolhaas, Anne Dekinga, Theunis and Marc) in one fourwheel drive we managed to get through the puddles in the dirt road to the highway. They were already less deep than a week ago, when you needed a map to navigate through the puddles to avoid the deeper parts, and still the water came up to the windscreen. Although we just had lunch most of us used the stop at Roebuck Road House to buy drinks and sweets. This is probably typical Australian not to leave a chance unused in this sparsely populated country. We cross the treeless plain with the grey termite hills (instead of the usual red ones). This is the old bed of the Fitzroy River, and Roebuck Bay is the old mouth of the river. The river itself now flows out into King Sound, north of Roebuck Bay. The plain is very wet, and the road is flooded in several places. The water is very clear, and we see fish and frogs fleeing from the splashing of our car. We also spot a swimming snake, lots of terns, Straw Necked Ibis, lapwings and one Australian Bustard. Just before dark we arrive at Anna Plains. We have to make a detour through the forest, as the normal road to the homestead is flooded. It is all very wet. To our amazement we discover that the dry grassland of Anna Plains is totally flooded and has turned into an enormous lake, 70 km long and 10 km wide. The water reaches the big shed and the villa of the owner, John Stoate. With some difficulty to keep our feet dry we manage to reach the laboratory caravan, where we plan to spend the night. We minimize going in and out the caravan to prevent the hordes of mosquitos from entering. After a quick meal we discuss the unexpected situation, and how we can overcome this obstacle to reach the beach. We come up with several solutions, like using a boat (not available, and besides the lake will be very shallow at places), driving around it (but probably all roads will be flooded), and using the helicopter of the station (too expensive, and it can only transport one person at the time). As all seem unrealistic we do not see a way out. We call it a day, and soon we cover the floor of the caravan and fall asleep.

25 March 2000
It is a lovely fresh morning. We now see the enormous extent of the newly formed lake. It is a strange view to see the big trucks out in the field standing in the water. The homestead is almost surrounded by the water, and we cannot leave the place without getting wet feet. The lawn where we camped a few months ago is completely soaked. There are lots of frogs in the water, but I also discover many clam shrimps (Diplostraca) and a few Notostraca (*Triops australiensis*). The last two are primitive crustaceans that are typical of temporary fresh waterbodies. Their eggs can survive long periods of drought, and animals grow very fast. I capture a large *Triops* of 3 cm length, and the next moment it has moulted al-

ready! We take some photographs, and realize that it is impossible to reach the beach, and have to abandon our sampling plan. We leave and drive to Sandfire Roadhouse to have a proper brunch. Here also the water shimmers through the open forest. As a last option to reach the sea we plan to go to Eco Beach, a resort for tourists. On the dirt track to the resort we are stopped by a puddle of 200m length and an unknown depth. This seems too much of a challenge for us, as a car from the other side shows up. From the driver we learn that it is just possible to cross. So we try. The water reaches our windscreen and starts to enter the car. So we lift our luggage and feet from the floor (except for the driver), but we manage and reach the other side. There we open the doors to get out all of the water inside the car. Via a steep detour we reach Eco Beach. It looks like a small village with nice houses that fit perfectly in the surrounding bush. From the main building that has been built on a high dune we have a nice view over the coast. The sandy beach is fairly steep and bare of shells. From here you can reach Jack Creek, eleven km north of Eco Beach. We, however, see that we cannot do much here, and head back to BBO.

In April 2000, cyclone Rosita destroyed Eco Beach, and cyclone Sam caused severe damage to Anna Plains in December 2000. Luckely there was no loss of life.

5.4. A CALM MUDDER

(by the expeditioners of ANNABIM-99 on the tune of ‘A wild rover’ Fig. 5.10)

Figure 5.10. Michelle Wardley and Lucy Lawrence playing the tunes at our final evening together at Anna Plains station. Photo by Theunis Piersma.

They came from the south, they came from the east
Some even travelled from over the seas
Lured to the mudflats by benthos and birds
They sampled and sorted and studied the turds

refrain-1:
And it’s no, nay, never, no nay never no more,
will I be a CALM mudder, no never no more

We’ve all been desk-workers for many a day
Until Grant took us outdoors on eighty miles way
It wasn’t as easy or cheap as we thought,
but great fun it was, and no scientific fraud

The mud was so sticky and deep all along
our sneakers were torn, our energies gone
the snails were a threat, the rays a menáce
but mud’******* few, and thus no disgrace

Came Bob and Michelle, they made us a grid
twentyfour thousand dots on a map, bloody shit!
We went out undaunted, made 100 a day
finished up with a thousand, to no one’s dismay

Notre Damers came also, with plenty of zest
to work in the muck, with all the world’s best
From NIOZ they all came, with great enthusiasm
Pieter, Marc, Petra, and Theunis Piersmasm

Dutchies first came to northwest in ninety-one
got stuck in the mud and had very much fun
Then Pearson met Piersma, and they fell in love
with birds and with benthos, and hoovers all above
The lab was quite sweaty and smelly all day
The Dutchies and Danny named benthos at sway

But the sorters were faster, the pots remained filled
with crabs, worms and bivalves, eventually killed

The cooks in the kitchen with no Ph D’s
Everything runs smoothly, their aim is to please
Breakfast and lunches, and dinners and teas
Coffee and Milo, and fruitcake and cheese

Jo, Jan, Shapelle, Marcel and Luc’
Kevin, Michel’, Chars, and Cinna hangs loose
Meals at odd hours and trips to the bore
Keeps the cooks clean and cooking some more

Teddie and Warren are always around
Willing and able and rarely a frown
Meateaters, veg’tarians, and vegans too
Oh shit! can’t you all just eat a stew?

Brittlestars, crabs, and worms galore
A coo-ooks delight, but not on these shores
Anna Plains Campsite, is simply the best
So hang up your mud-clothes, and have a good rest

Logistics are hard at the best of the times
Murphy’s law has no place in the slime
Good people to fix and repair all the gear
None better than Ted, Jamie, Warren were here

Anna Plains Station is paradise lost
the manager John has given us most
His lawn we have killed and his workers all fear
our raucous behaviour and spreading out gear

At Eighty Miles Beach, near Anna Plains
We all went in search of fortune and fame
We sampled, we sorted we fought with the mud
and came home each night all covered in crod

Grant told us to meet up 2 o’clock sharp
But by the time we left Broome it was well after dark
Michelle, Cin and Charlotte all in Lucy’s bus
No room in the Troopy, we’re so cool that’s no fuss

We had no idea of what to expect
But we knew that the mudpack would be put to effect
After days of mudsampling, and sorting through grit
Our minds are enriched but our complexions are shit

Packed in the Troopy, like a tin of Sardines
a sorrier sight will never be seen
Grant drove like madman, Warren was worse
but Theunis the Dutchman, drives like he’s cursed

At home I usually sleep like a rock
and usually sleep in till eleven o’clock
But here in the camp I cannot sleep in
‘cause the dogs and the triangle make a terrible din
And we tell you that Grant is a terrible man

He gets us up early, just ‘cos he can
On Monday morning he woke us at four
And then went to bed and slept some more

Those damn Ingrid Snails are a terrible curse
with them in the mud, what could be worse
They bite you, they scratch you, they crawl up your crack
I’m telling you lads, I am not coming back

The Hovercraft broke down on our very first night
We didn’t get a spin and we think that is shite
Mind you, Roni went out, and had to walk back
while Benson was rowing, all the way back

You say that to collect shells is a terrible sin
But drive over them, and they’re fit for the bin
No seriously, we have had so much fun
‘cause we’ve met the best people from under the sun

The dunnies are splendid and hessian adorned
for silhouette photos of boggers at dawn
The showers were second to Talgarno bore
the ritual bathing has soon become lore

Each evening then we must go to the bore
A girls’ car is best ‘cause we strip to the core
With knickers in hand and shampoo and soap
We return to the camp much sweeter we hope

No Theunis he said those Ingrids please count
How many per square, the exact amount
With head down, bum up, look listen and feel
The statistics he’ll tell us, after our meal

Dutchies as scientists are great in the mud
They ‘ve given their best, and sweated their blood
but give them a Troopy, they can’t drive them much
They burn out the gearbox and stuff up the clutch
Some birders were there, to help with the mud
with binocs and scopes, it sure was their blood
Spotting red caps, red necks, knees and bills
They confounded us all, with a-mazing skills

So out on the mud, went Danny and Co
“We need fifty poops”, said Petra “let’s go”
With pooppots in hand, they followed the birds
And swooped with the spoons, to pick up the turds

So Clive M. now listen, and we tell you all
‘bout the upmarket camp, on Anna Plains lawn
with electric toaster, and jugs and the plates
How did we survive, camped in the dunes mate?

We went out on mudflats, a daunting event
Fell flat on our faces, our energy spent
Got clawed at by crabs, and eaten by snails
Losing legs to the sharks would be minor details

The big muddy flats are great for the birds
It’s there they eat bivalves, cumaceans and worms
There are big sandy beaches, where birds roost a bit
And they’ve even got Ingrid’s to clean up their shit!

So thank you Theunis, Joan’, Petra and Marc
Also to Danny, Grant, Pieter, oh fark
We nearly left out Ted, Bob, Warren and Jim
Who all made a success of this year’s Annabim

They came from the south, they came from the east
Some even travelled from over the seas
Lured to the mudflats by benthos and birds
They sampled and sorted and studied the turds

refrain-2:
And it’s yes, hay, ever, yes hay ever one more
will I be the WILD mudder, for ever, for more!

6. GENERAL DESCRIPTION OF THE STUDY AREA

Grant Pearson, Robert Hickey & Pieter J.C. Honkoop

6.1. KNOWN CONSERVATION IMPORTANCE

Eighty-mile Beach is a megascale (220 km) linear sand-coast. The width of the sandy beach can vary according to cyclone impacts, but it ranges between <100m to >500m. The beach includes several muddy microscale embayments, mostly around the Mandora marsh area (Jaensch 1996). The intertidal zone is estimated to comprise more than 60,000 ha of mud and sand flats that are exposed by diurnal tides with a daily range of about 6 m. Spring tides can be over 10 m. There is a megascale (100 km long) discontinuous linear floodplain immediately east of the frontal dune system that fills intermittently to a depth of 1.5 m. It includes distinct sumplands, notably north of the Anna Plains homestead.

Eighty-mile Beach is listed as a Wetland of International Importance under the Ramsar Convention (http://www.ramsar.org/) mainly due to its well-recognised importance as a shorebird feeding ground and roost.

The Ramsar Convention on Wetlands describes 8 criterion for the nomination for wetlands for inclusion as Wetlands of International Importance. The criteria referred to in the publication “A Directory of Important Wetlands In Australia” cites Eighty-mile Beach as qualifying for Ramsar nomination on criteria 1-6. (Australian Nature Conservation Agency 1996). Our report comments later on the changes to the fish, shark, and ray populations of the intertidal zones in recent years. Further work is needed to examine the potential for these communities to satisfy Ramsar criterion 7 and/or 8.

RAMSAR CRITERIA FOR NOMINATION

Criterion 1: A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.

CRITERIA BASED ON SPECIES AND ECOLOGICAL COMMUNITIES

Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities

Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

Criterion 4: A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.

SPECIFIC CRITERIA BASED ON WATERBIRDS

Criterion 5: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.

Criterion 6: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird

SPECIFIC CRITERIA BASED ON FISH

Criterion 7: A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.

Criterion 8: A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

The foreshore and the hinterland of this remarkable wetland together form one of the most important non breeding areas in East Asia-Australasia for transequatorial migratory shorebirds (Jaensch 1996). In particular, it provides important feeding and staging areas for southward migrating shorebirds between August and November. Its role in the northward migration of shorebirds is not as well documented as the southern migration, but there is considerable evidence that the values are similar.

The site is the most important in the world for Great Knots. It also supports more than 1% of the national population of 21 species of shorebirds. The Little Tern is classified as a threatened species and is found on the beach. Of the 65 species recorded at the site, 33 are listed under international treaties designed to protect the habitat of shorebirds. These includes nine herons and allies, 31 shorebirds, and seven terns (Jaensch 1996). The beach regularly supports a few individuals of Redshank and Asian Dowitcher. *Gallinago* sp., probably Pin-tailed Snipe *Gallinago stenura*, and Long-toed Stint occur at the coastal plain swamps. Vagrants such as

Spotted Redshanks have also been recorded (Jaensch 1996).

Major arrivals of Sharp-tailed Sandpipers have been recorded on the foreshore on their southward migration. In 1984, Roger Jaensch (1996) reported 25,000 birds arriving overnight and in 1982 thousands were observed by members of the Australasian Wader Study Group (AWSG) (Jaensch 1996) resting on the beach recovering from their exhausting flights.

The foreshore between Cape Missiessy and Mandora Marshes is used as a high tide roost. Concentrated flocks of 10,000 are common along this stretch of beach. Shorebird counts undertaken by AWSG have produced figures of greater than 470,000 individuals. These counts represent the highest numbers of shorebirds for any site in Australia and amongst the highest counts for the East Asian-Australasian Flyway.

When flooded by cyclonic rains, the Mandora Marshes become the breeding site of tens of thousands of terns and waterbirds. Halse and Pearson (2000) recorded large colonies (>3,000) of Australian Pelicans and counts of 250,000 waterbirds recorded for the flooded marsh post cyclone. Jaensch (1996) also reports counts of 75,000 waterbirds on the swamps of the plain east of the frontal dunes. This included up to 10,000 Hardhead and 45,000 shorebirds (mainly Sharp-tailed Sandpiper and Little Curlew).

The most abundant species at the beach are Great Knot (>160,000), Red Knot (80,700), Curlew Sandpiper (60,000), Red-necked Stint (60,000), Bar-tailed Godwit (34,300), Large Sand Plover (304,000), and Oriental Plover (184,000). Sharp-tailed Sandpipers are found at both the beach and swamp; Little Curlew (12,000) at the plain. The site is ranked 1 or 2 in Australia for

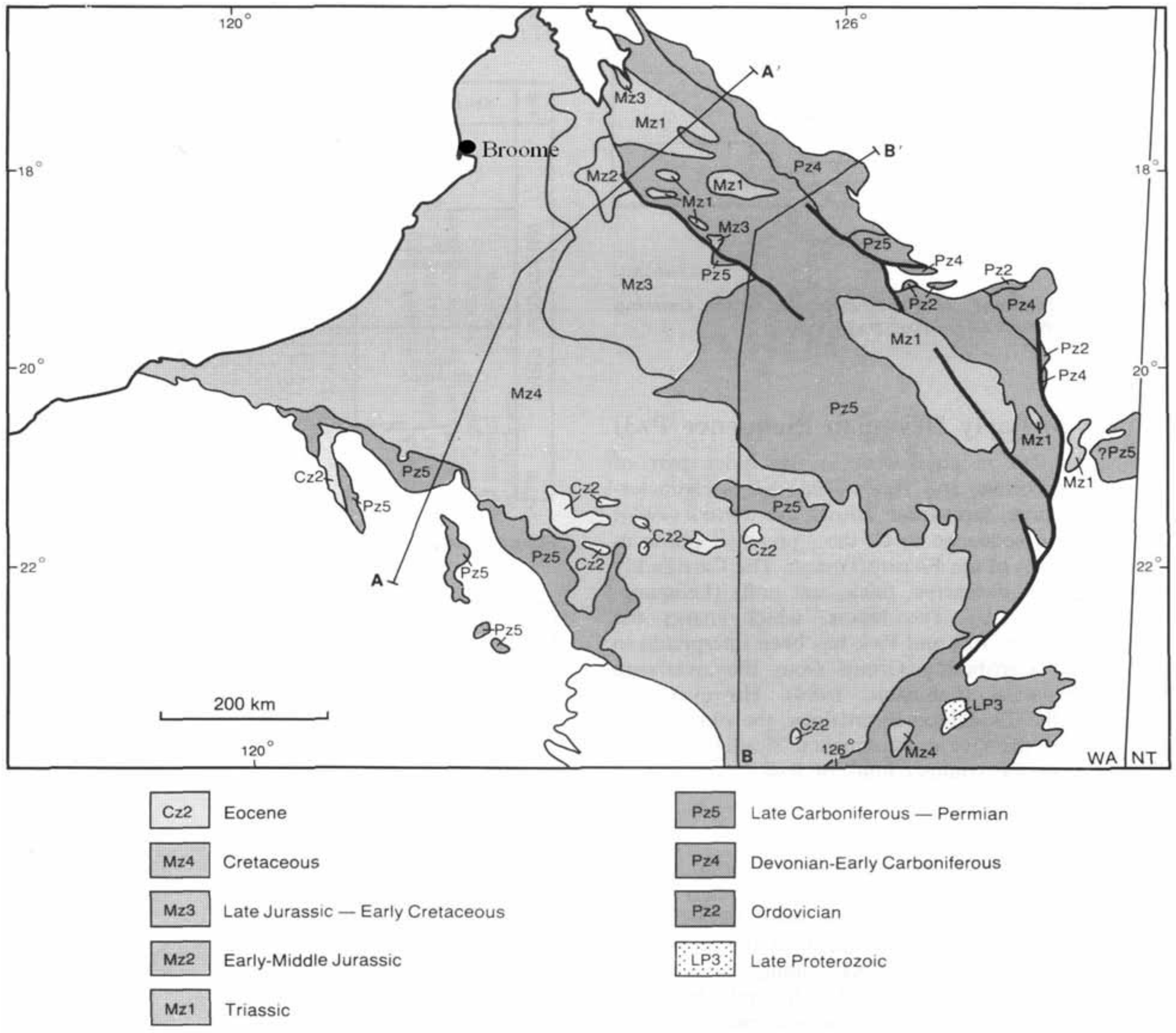


Figure 6.1. Map of Eighty-mile Beach Showing the Onshore Canning Basin (Bureau of Mineral Resources, Geology and Geophysics).

each of these species except Little Curlew (national rank 3). It supports at least 1% of the national population of the nine above mentioned abundant species and the following: Grey Plover, Grey-tailed Tattler, Terek Sandpiper, Greenshank, and Red-capped Plover (national rank 1 for each of these species). In addition, the following species are mentioned: Pacific Golden Plover, Black-winged Stilt, Ruddy Turnstone, Marsh Sandpiper, Eastern Curlew, Whimbrel, and Sanderling (Jaensch 1996).

6.2. GEOMORPHOLOGY

Cape Missiessy defines the northern tip of Eighty-mile Beach and is located about 200 km south of Broome. The beach extends for about 220 km (138 miles) south to Cape Keraudren and belies the reference “Eighty Mile” Beach given to the vast expanse of white sandy beach and intertidal mudflat.

Eighty-mile Beach lies within the Canning Basin at the western edge of the Great Sandy Desert (Fig. 6.1). The largest sedimentary basin in Western Australia, the Canning Basin is also the second largest in Australia after the Great Artesian Basin. It covers about 415,000 km² onshore and about 115,000 km² offshore. The underlying basement consists of Precambrian sedimentary rocks that were intruded by igneous rocks. Intensive metamorphism took place. These rocks were eroded until the early Ordovician when a shallow sea transgressed the area. Sediments are of continental, marine, and paralic origin depending on the relative sea level during the different geological ages, although marine facies make up most of the sequence. The onshore Canning Basin consists of predominantly Paleozoic sedimentary rocks with a thin Mesozoic and tertiary sequence (Pepping *et al.* 1999).

There is a marked contrast between the steep rocky coastline with deep inlets and numerous islands in the Kimberley terrain to the north and the almost uniformly low lying and monotonous coastal topography of the Canning Basin to the south. This area is characterised by long stretches of coast backed by extensive tidal flats relieved by low sand dunes (Fig. 6.2). Dissection of resistant coastal sediments produces low rocky cliffs as at Cape Keraudren. The south flowing ocean current carries carbonate rich sediments to the shoreline where the loss of current velocity causes the sediments to settle out. Storm surges and cyclonic events result in a high level of perturbation that can have a dramatic effect on the width and extent of the raised calcareous beaches (Pepping *et al.* 1999).

About 60 km south of site 00 there is a mangal community (*Avicenia marina*) (Fig. 6.3) that leads eastwards into the paleodrainage channel of the Mandora saltmarsh.This saltmarsh is established

Figure 6.2. Linear dunes and sandflats of Eighty-mile Beach. Photo by Grant Pearson.

over a salt flat that extends more than 50 km. Salt flats are nearly planar, salt encrusted, high tidal, hyper saline surfaces devoid of burrowing benthos. They typically occur along arid coasts where there is insufficient rainfall or seawater recharge to break down the extreme hyper salinity that forms in response to high evaporation (Pepping *et al.* 1999).

Salt flats are underlain by a variety of materials since the critical factor in their formation is not substrate type but salinity of groundwater. Most of the salt flats of the Mandora marshes have developed on muddy tidal flats now above the tidal range. At levels of MHW, they are underlain by groundwater whose salinity is super-haline to brine (100- 200 psu). Consequently, the salt surface is encrusted with fine halite crystals and locally crystals of gypsum in the subsurface. If not covered by sand dunes and sand sheets, they normally fringe the mangals where groundwater salinity increases to values that exceed the tolerance of the mangroves (80 -90 psu at maximum). Supratidal flats normally follow salt flats further inland when salinity decreases to values that enable the growth of samphire vegetation and other salt tolerant plants. This may be complicated at Mandora by surface inflow of salt water from Salt Creek about 40 km inland. However, there remains a vast area of greyish silt of fluvial and estuarine origins as opposed to the Aeolian sands that cover much of the region. These areas contain a large proportion of the fine grasses prized by the cattle producers of the region. Historically, the Mandora marshes appear to be an arid delta of an ancient river system (about 15 million years) called the Wallal Paleoriver (Graham 1999) with watercourses that can be dry for much of the year. About 10,000 years ago, the Eighty-mile Beach coastal flats extended over the Mandora marshland.

The Pindan woodland forms the last part of the morphological sequence and follows the tidal flats southwards. A steep rise in terrain explains the often well-defined boundary between the supratidal flats and dense Pindan woodland such that saline groundwater doesn't reach the roots of the shrubs and trees. The underlying material is red pindan soils of Aeolian origin (Pepping *et al.* 1999).

Most exposed coastlines such as that at Eighty-mile Beach are subjected to sand deposition due to the ability of the fast wave action to support the transfer of large sand grains to edge of the tide. The presence of the coarse beach material high on the beach profile gives the impression of the availability of large quantities of siliceous sand. Closer examination of the particles reveals the almost complete absence of silica and the dominance of calcareous particles – probably the remains of dead shells that abound offshore in deeper water. Four samples of sand from the primary dunes were submitted to The Western Australian Chemistry Centre for mineralogical analysis to determine the relative contribution of inorganic and organic materials. Representative portions were examined using a stereoscopic light microscope and found to be almost exclusively shell sand with only bare traces of fine quartz. There were skeletal remains of many types of organisms including molluscs, sea urchins, and foraminifera (Clarke 2002). Differences in particle size were considered to be related to differences in age or sedimentological history.

The dominant mineral constituents of the shells are expected to be calcite, magnesian calcite, aragonite and possibly dolomite. Confirmation of this by X-ray diffraction analysis was not carried out. The sediments that occur offshore beyond the tidal flats are possibly silica poor and shell biota rich. Thus, the composition of the material carried by the combined affect of wave and tidal action is predominantly fine-grained mud (<63 μm, P. Honkoop, pers comm.)

The presence of the soft sediment intertidal flats may have a significant impact on the effect of the wave action on the beach. At the northern reaches of Eighty-mile Beach, wave energy is dissipated by the low gradients of the mudflats and the damping effect of the soft muddy flats. Waves crossing these substrates are easily damped, with a proportion of the energy being dissipated within the sediment rich water column and the soft bed. Energy dissipation over muddy bottoms can be an order of magnitude higher than over sandy bottoms (Pepping *et al.* 1999). Thus, the combined affects of shallow gradients, sediment rich waters and muddy substrates in places combine to make the northern parts of Eighty-mile Beach a low energy environment. Exceptions include the cyclonic events causing storm-surges and extremely high waves that can drastically alter coastal morphology.

The upper intertidal areas of Eighty-mile Beach are characterised by mobile mud substrates. In places, there is a landward mangrove fringe. Shore-normal size grading may occur, resulting in totally suspended sediment accumulating onshore (Reise 1995). Tidal asymmetry with higher flood than ebb velocities may reinforce this pattern. A complementary process may be the preferential offshore movement of the more easily entrained sand-fraction (especially the fine sand) leaving the mud as an intertidal lag deposit. The southern parts of Eighty-mile Beach may possess harder sandy substrates that create a more vigorous wave action with less damping and consequently lower silt deposits.

6.3. VEGETATION

Open tussock grassland occurs in latiform arrangement behind the dune system and is dominated by Saltwater Couch *Sporobolus virginicus* and Buffle Grass *Cenchrus ciliaris*. Open scrub occurring in periform arrangement at the swamps is dominated by the paperbark *Melaleuca* spp. Beach dunes are predominantly the Green Bird Flower *Crotalaria* and spinifex *Triodia spp*; low open woodland of the shrubs *Acacia* and *Bauhinia spp*. occurs on the pindan (Jaensch 1995).

At the entrance to the Mandora Marsh area there is a mangrove community comprising *Avicenia marina* that occurs in periform arrangement (Fig. 6.3). The flood plain at this point extends east into a very extensive and biologically productive area of samphire marsh. Normally dry, this ancient remnant paleodrainage channel floods intermittently with cyclonic rain events and provides important feeding and breeding habitat for tens of thousands of waterbirds. A small calcareous dune provides a bar that occurs across the mouth of the exit of the samphire marsh preventing ingress of seawater.

The mangal communities around the Mandora Marsh delta are predominantly *Avicenia marina* and may be an indication of the specie's capacity to tolerate soil types quite different to the soils common in Roebuck Bay. The southern parts of Eighty-mile Beach possess harder sandy substrates that create a more vigorous wave action with less damping and consequently lower silt deposits. Although *A. marina* is a relatively low,

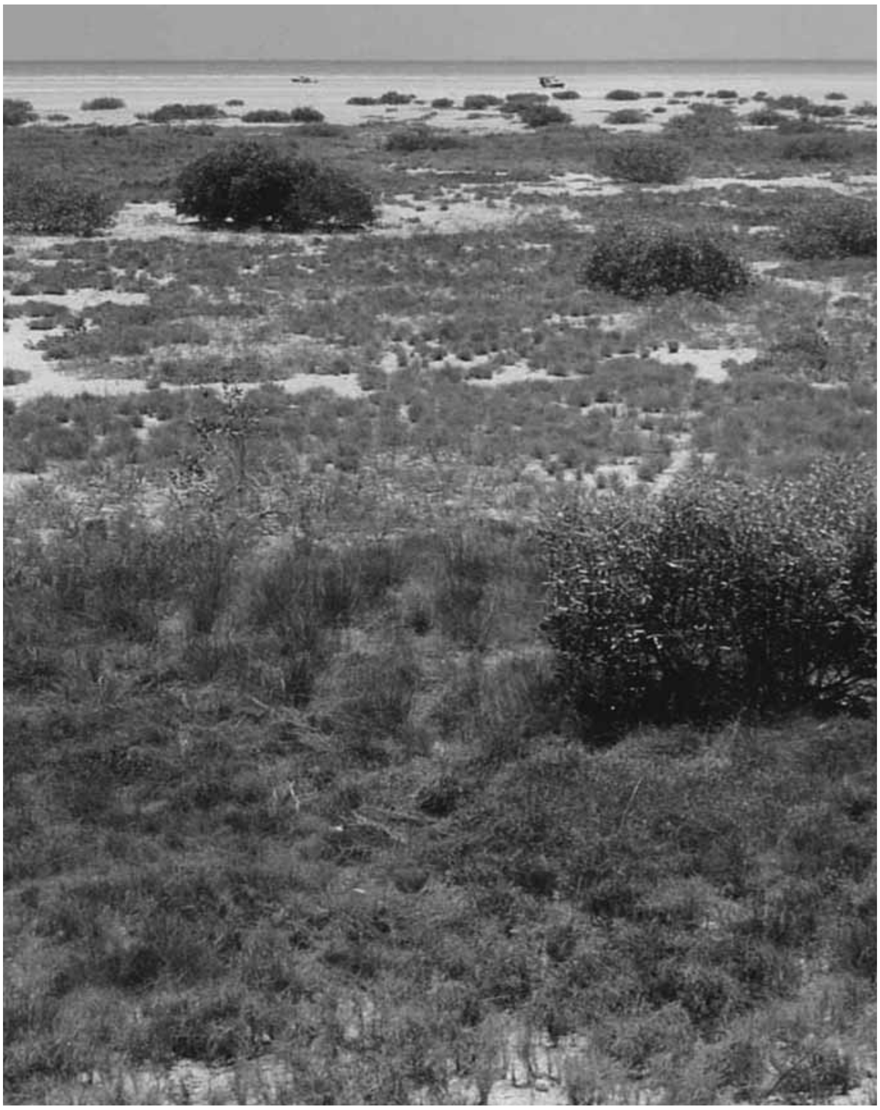


Figure 6.3. Open mangroves near the Mandora Marsh entrance at Eighty-mile Beach. Photo by Grant Pearson.

stunted form of mangrove, the comparatively harder, coarse-sand surface soils at Mandora may further limit its height and size.

The Mandora marshlands have been shown to contain important highly localised and unusual vegetation communities. A survey carried out in October 1999 by DCLMs Regional Ecologist, Gordon Graham examined the ecology of the marshlands and raised management issues. The occurrence of mound springs and ephemeral lakes near the marshland confers additional conservation value on the landscape and requires special management consideration.

Cyclonic events threaten to alter the presence of these communities and their ability to change the soil structure by steady accumulation of fine sediments. The potential for the mangroves to expand beyond the present boundaries may be limited by these influences.

6.4. CLIMATE

Eighty-mile Beach is subjected to a tropical monsoon climate typical of the Kimberley region. Between May and October, the normal situation is an anti-cyclonic belt that typically rests over the southern half of Western Australia. These extensive anti-cyclones can have an east-west diameter of 3000-4000 km and travel at speeds of 600 –700 km/day across southern and central Australia (Pepping *et al.* 1999). The Kimberley Region lies at the northern edge of the anti-cyclones. Here, the airflow is deflected by surface friction into a south-easterly trade wind that brings dry air from the interior to the northern and north-western coast.

Towards the end of the dry season, a low-pressure system develops over the Kimberley and extends southward, while a ridge of high pressure extends from the semi-permanent anticyclone in the Indian Ocean parallel to the northwest coast. Under these conditions, surface winds are westerly in the coastal districts. As the low-pressure system extends in inland areas during November, this situation occurs more frequently.

Westerly winds bring increased humidity and scattered thunderstorms as the wet season approaches. These westerly winds are not permanent, being displaced from time to time by easterlies as anticyclones over the southern region intensify and extend northward.

During the wet season (November to March), a low-pressure area is generally situated over northern Australia, and a trough extends from the Northern Territory towards the Onslow/Carnarvon area. The prevailing winds are westerly, bringing moist air from the Indian Ocean. Compared with the preceding four months, there is a marked increase in humidity, cloud cover and rainfall. Much of the rain comes from thunderstorms, but the most widespread heavy falls occur as a result of cyclonic disturbances.

Cyclones frequently originate in the Timor Sea, but can develop in the Arafura Sea or further eastward (Fig. 6.4). They generally bring extremely strong winds and torrential rainfall. As the

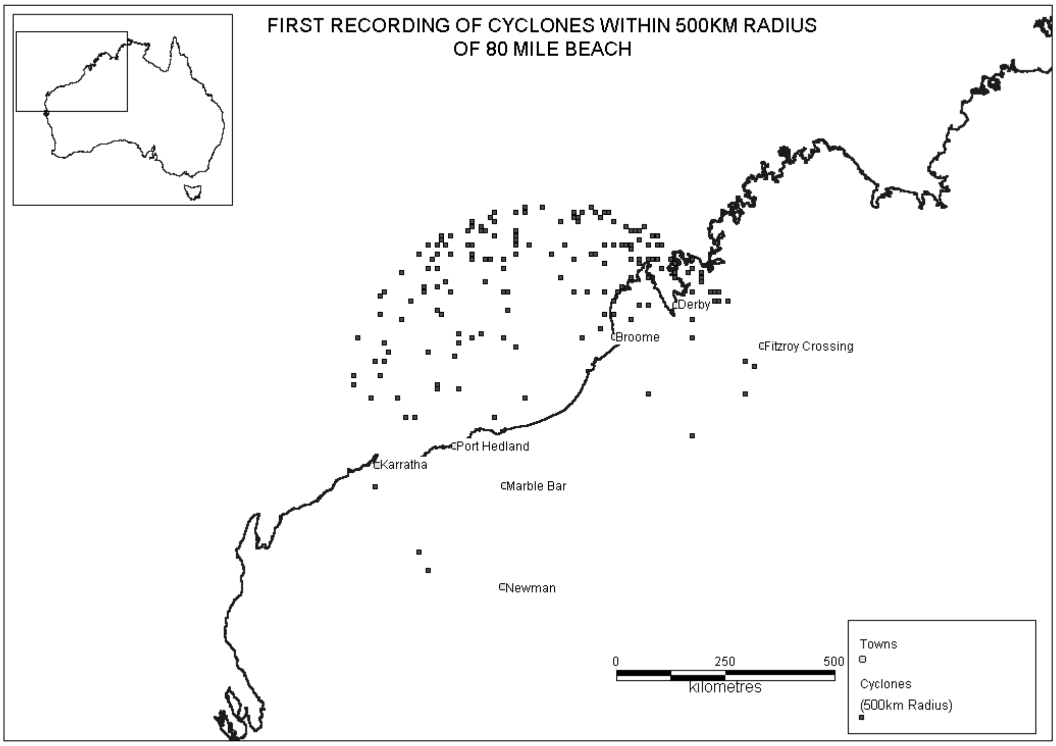


Figure 6.4. First recordings of cyclones within a 500 km radius of Eighty-mile Beach. Map: Michael Scan?????

Figure 6.5. Vegetation prior to cyclone Vance at the Anna Plains entrance (looking south). Photo by Grant Pearson.

Figure 6.6. Vegetation post cyclone Vance at the Anna Plains entrance showing wind burnt foliage and heavy siltation (looking north)

cyclonic centres move across land, their strength diminishes and wind speeds abate. However, very heavy rainfall may continue for several days and, eventually, the cyclone weakens to a rain bearing depression as it sweeps south east to the southern parts of the continent. Some cyclones have reformed in the Southern Ocean and continue progress eastwards. Cyclonic disturbances in the Kimberley are likely throughout the wet season, only rarely do they occur before December or after April (Pepping et al. 1999). Graham (1999) reports that over a period of 40 years 21 cyclones crossed the coast between Broome and the mouth of the DeGrey River. Between 1980 and 1985, six cyclones crossed the coast at Eighty-mile Beach or passed in very close proximity. From 1995 to 2000, cyclones continued to pass close or over Eighty-mile Beach with varying levels of impact. Of particular interest was cyclone Vance; its impact resulted in the loss of the narrow beach at the edge of the dunes (Fig. 6.5 and 6.6).

The extent of the influence that cyclones have on the intertidal mudflats at Eighty-mile Beach is variable and dependant on a number of factors including the distance of the eye of the cyclone from the coast, the length of time the cyclone remains off-shore adjacent to Eighty-mile Beach, the speed at which it travels as it passes Eighty-mile Beach, and especcially the location where it crosses the coast.

There are many tales of great cyclones that have created havoc and despair for locals as the cyclones swept past the Eighty-mile Beach. Anna Plains Station, located at the northern end of the beach, displays the scars of many encounters with cyclones. The main machinery shed assumed an unlikely profile after a severe cyclone in the early nineties and was eventually flattened by Cyclone Rosita in 2000 (Fig. 6.7). Events such as these are common in northern latitudes in the so-called cyclone belt. The impact of Cyclone Tracy on the city of Darwin is well recorded.

Figure 6.8 the number of cyclones recorded around Eighty-mile Beach by the Bureau of Meteorology are shown. The maps demonstrate the extent of the influence that cyclones have on coastal systems in North-west Australia. The development and maintenance of intertidal mudflats along exposed coastlines such as the Eighty-mile Beach is more curious in this context.

The impact of the cyclones on the intertidal infauna can be considerable, and yet the delicate balance of biotic intertidal systems has been maintained through the millennia and the impact of countless cyclonic events.

Intertidal ecosystems have evolved with a capacity to withstand these natural phenomena.

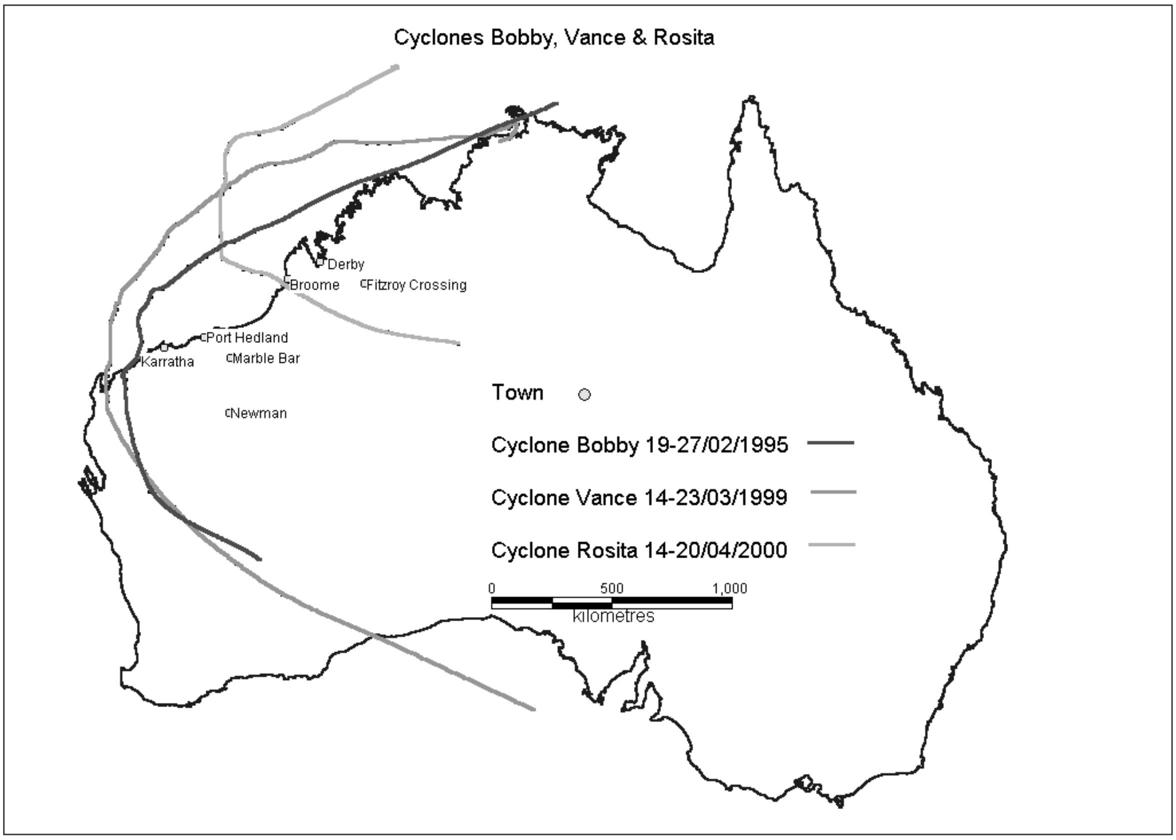


Figure 6.7. Tracks of cyclones Bobby, Vance, and Rosita.

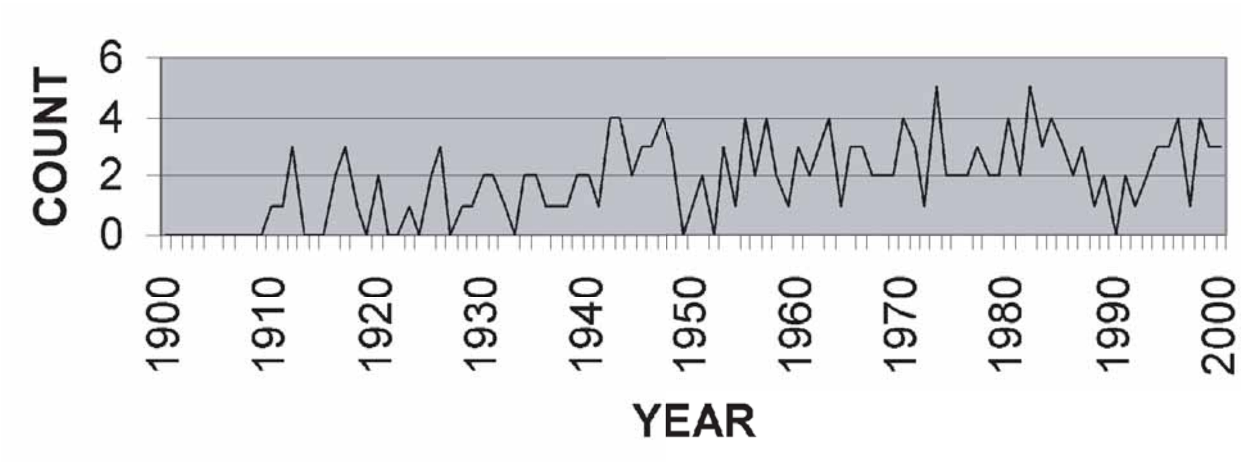


Figure 6.8. Annual number of Cyclones that have passed within 500 km of Eighty-mile Beach from 1910-2000.

Chapter 12 deals with the human impact and the potential for rapid changes to biota and the environment that exceed the impact of natural events such as cyclones. The frequency and extent of high wind events such as cyclones along the Eighty-mile Beach foreshore confront land managers with the need to protect the fragile dunes from disturbances that can cause the loss of natural vegetation. The blow-outs in the dunes near Wallal are an example of the damage that can occur from a combination of cyclones and uncontrolled human use of the foreshore.

6.5. HYDROGRAPHY

The major ocean currents of marine influence along the West Coast of Australia are the Leeuwin Current and the South Equatorial Current. Carrying warm water from the equator, they converge between the North-west Shelf and Eighty-mile Beach and drift down the west coast to the southern ocean. Rates of flow of the Leeuwin Current vary according to proximity to shore and many other factors but have been reported around 0.5 m per minute. The impact of the currents on Eighty-mile Beach is probably lower than their influence on more southern shores south of North West Cape.

6.6. MUDFLAT WIDTHS

Eighty-mile Beach is about 220 km long and the width of the intertidal zone varies between 1.5 km and >4 km wide at spring low tide. The extent of this intertidal zone is widest between the -10 km and 50 km sample sites. Data collected in October 1999 from 4 locations (-10 km, 5 km, 20 km, 35 km,) at spring low tide shows the mudflat width to be between 2600 and 3800 m. These data were collected when the heights of the Broome low tide were recorded as between –0.02 and 0.13 m.

It is evident from the tide charts that the tide can fall as low as –0.56 m. Thus, the maximum tidal amplitude (difference between the spring low and the spring high) could be calculated as about 9.93 m (-0.56 + 9.37 October 27 and 28, 1999) at Eighty-mile Beach. Taking the –0.02 to 0.13 low tide ranges for the periods that sampling took place at the 4 sites on the Eighty-mile Beach in October 1999 and averaging the results produces a figure of 0.075 as a mean low for the sampling period. The tide could have receded a further 0.485 m vertical (0.56 – 0.075) or 4.9% of the tidal range (0.485 divided by 9.93x100). This conservative figure (the mudflats are not horizontal or level) of 4.9% can be applied to mudflat widths collected in October 99 for sites –10 km, 5 km, 20 km, and 35 km, providing an estimate of mudflat width of between 2727 m and 3986 m (average = 3356.5 m). Using this mean as an indication of mudflat width would produce a mudflat area of (220 x 3356.5) more than 720 km^2

A higher multiplication figure could be used if it is accepted that about 30% of the tidal amplitude is steeply inclined sandy beach (found near the high tide line). Therefore, it could be interpreted that the 0.485 m of additional exposure relates more to the 70% of low incline mudflat or 6.551 m of tidal amplitude. This would result in a multiplication factor of 7.45% (2790; 4080) (755 km^2)

The remaining sites of the Annabim99 survey were not visited during a spring tide low and require different treatment to calculate the width of available mudflat that includes information from Landsat images and extrapolation from current available knowledge.

Examination of the Landsat image (Fig. 6.9) shows the mudflat width to be generally narrower south of the Mandora Marsh creek outlet to Cape

Keraudren. The average width (at 7 points from the Landsat image) is 770 m. The average width (6 points) for the beach north of the creek is 1650 m. Using the multiplication factor from the previous workings (7.45%), a width of mudflat south of Mandora Marsh of between 712 m and 1527 m is obtained. The mean intertidal zone is calculated at 2.6 km for the length of the beach. This equates to nearly 600 km^2 (60,000 ha.) of intertidal zone that could be exposed at spring low tides. This figure is used as a reasonable assessment of mudflat width for Eighty-mile Beach.

6.7. SURFACE SEDIMENT DISTRIBUTION

Most observers during the survey noticed the variable degree of difficulty walking over the intertidal flats. This large variation in effort (probably to a great extent reflecting the degree of muddiness or presence of small grain sizes) is reflected in the map of penetrability (Fig. 6.10). There was a general decrease in penetrability (i.e. increased 'sandiness') the more one moved southwards along Eighty-mile Beach. There was also a great degree of patchiness in recorded penetrability at each of the blocks. Often, the areas of intertidal flat with soft mud (high penetrability) were eroding mudbanks. Even though there appeared to be a tendency for midshore areas to be the muddiest, we think that the geography of mudbanks and the patterns of sediment-penetrability will be continuously dynamic. Mudbanks would build up at particular sites in periods of relatively calm wind and wave conditions and erode away when the forces of nature change in character. The loss of large amounts of the sandy beaches during Cyclone Vance illustrates the potential for weather systems to change the geography of the intertidal zones.

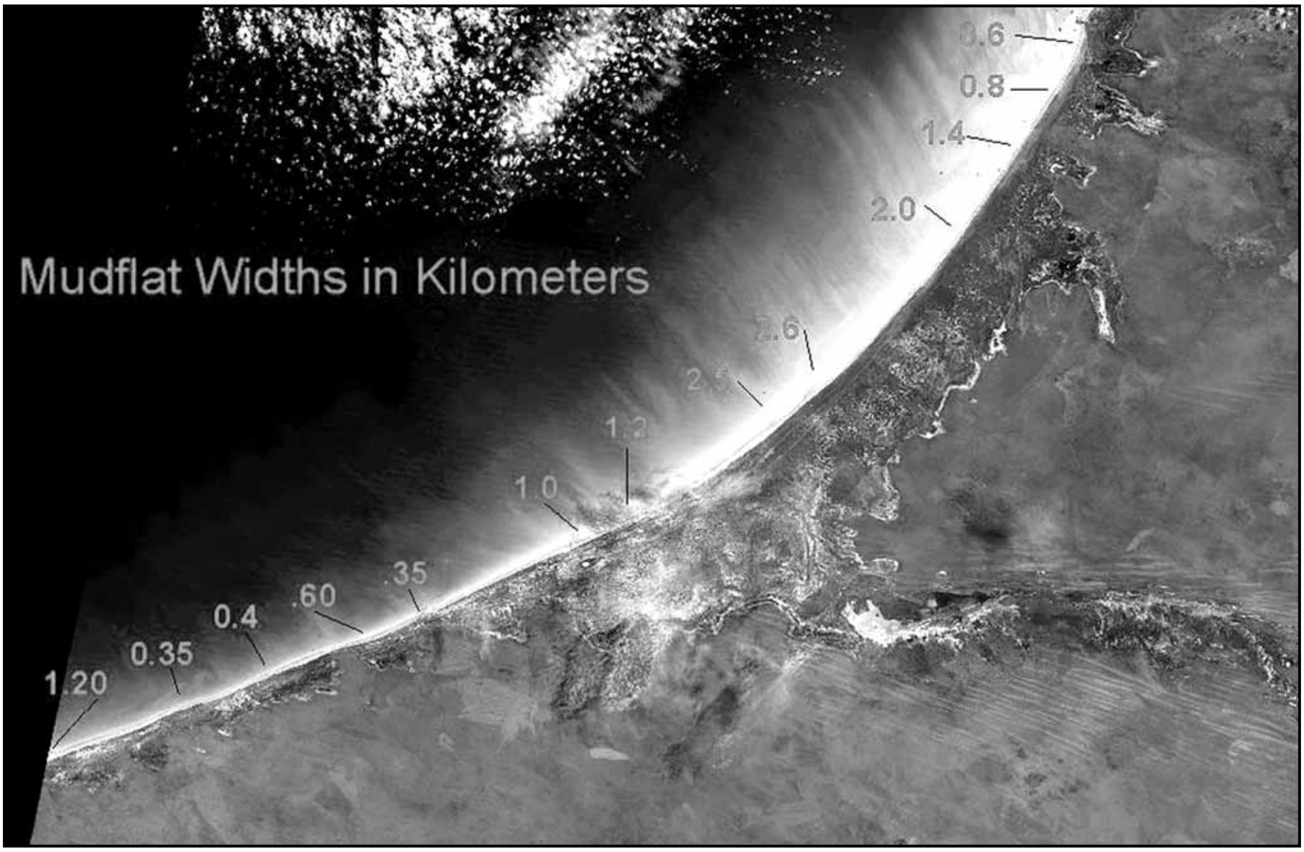


Figure 6.9. Landsat image (false color rendered in greyscale) of the Eighty-mile Beach area: mudflat widths as measured from satellite imagery.

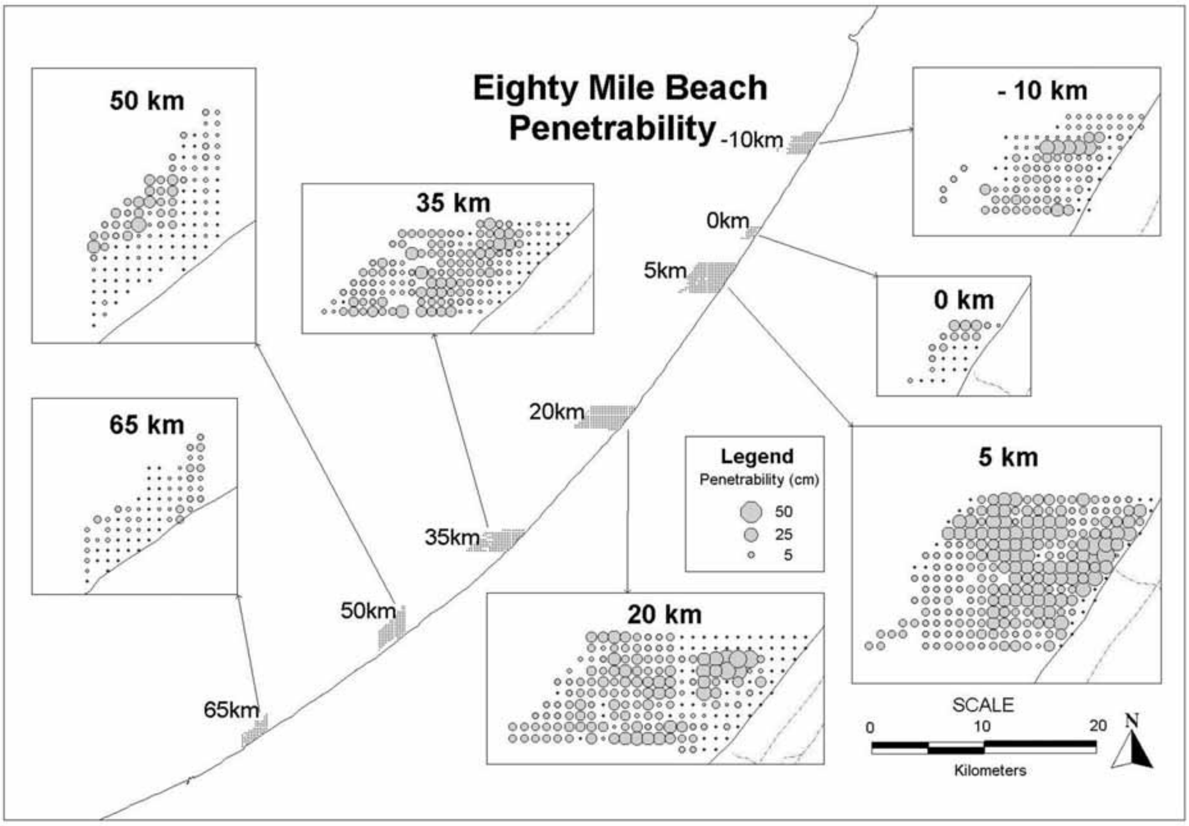


Figure 6.10. Map of penetrability of the Eight-mile Beach intertidal foreshore as measured by the benthic samplers during Annabim-99. Penetrability is deffined as the depth to which the average observer sank in the sand or mud..

7. SPATIAL ANALYSIS AT EIGHTY-MILE BEACH

Robert Hickey, Michelle Crean & Susanne Wade

7.1. INTRODUCTION

Once more into the breach – spatial technologies were required to support ecological research on the extensive mudflats of northern Western Australia. It was to be our third field season/expedition; Geographic Information Systems (GIS), remote sensing, cartography, and Global Positioning System (GPS) were all required for success.

This chapter details the mapping efforts at Eighty-mile Beach since 1999. What a place: Eighty miles (128 km) of featureless beach and mudflats. In reality, it's 142 miles (230 km) long. The monotony is only broken by tens of thousands of wading birds and a number of pretty shells. Once again, the team from Australia and the Netherlands assembled to do research into the sediments, benthic invertebrates, and birds that frequent the region. This time, nothing was done by halves. It was one of the best organised, equipped, and run research expeditions ever.

The initial base and field mapping was completed by Michelle Crean as part of her honours thesis (Crean, 2001). The remote sensing research is underway at CWU as part of Suzanne Wade's MS thesis in Resource Management (to be completed in 2003). Dr. Bob Hickey supervised both students and participated in all phases of the research. For more information about activities at Eighty-mile Beach, Roebuck Bay and King Sound, visit the project's website at http://www.cwu.edu/~rhickey/birds.html or read any of the following publications: Pepping et al, 1999; Carew and Hickey (2000), Hickey et al. (2000), or Piersma et al. (1998).

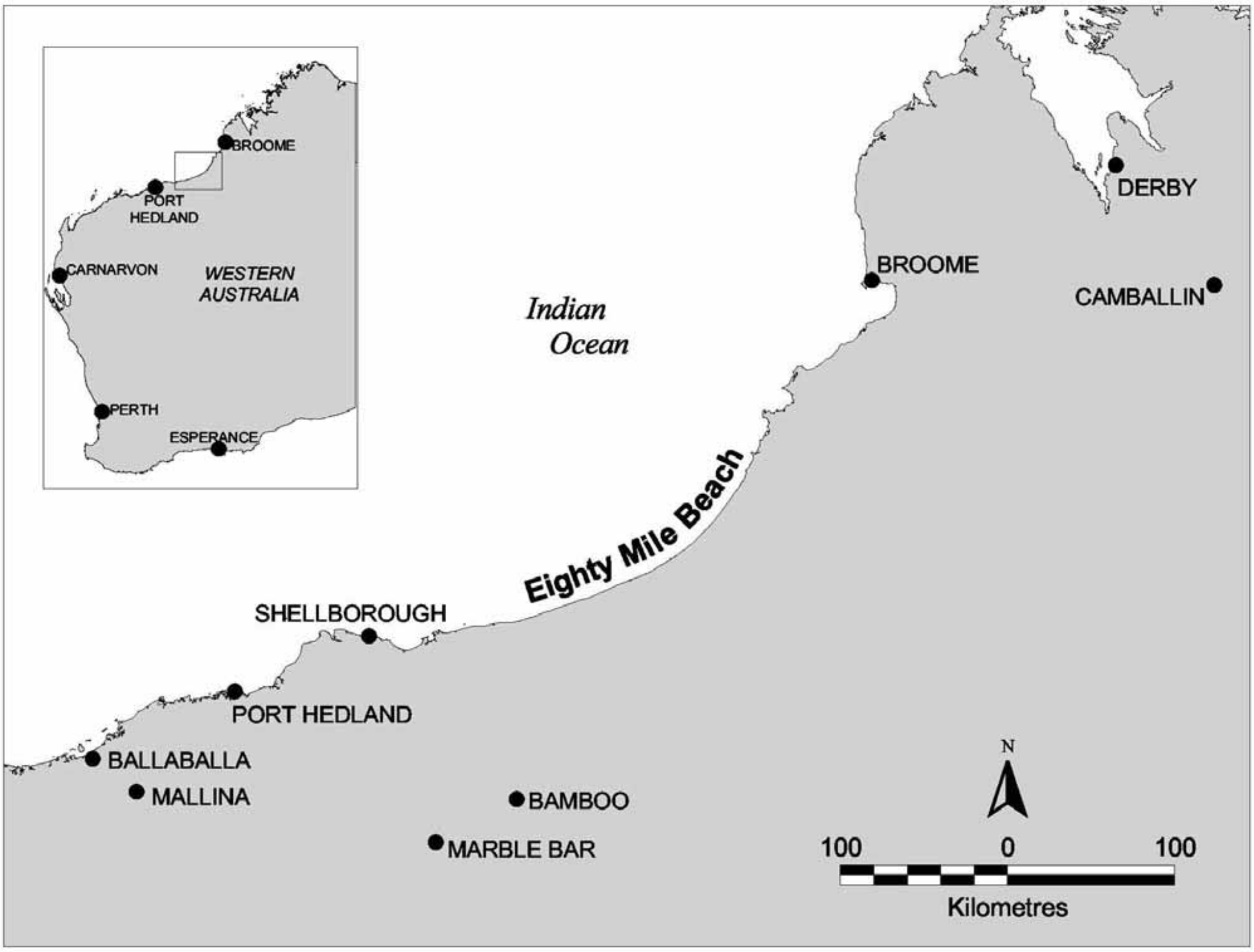


Figure 7.1. Site location within Australia.

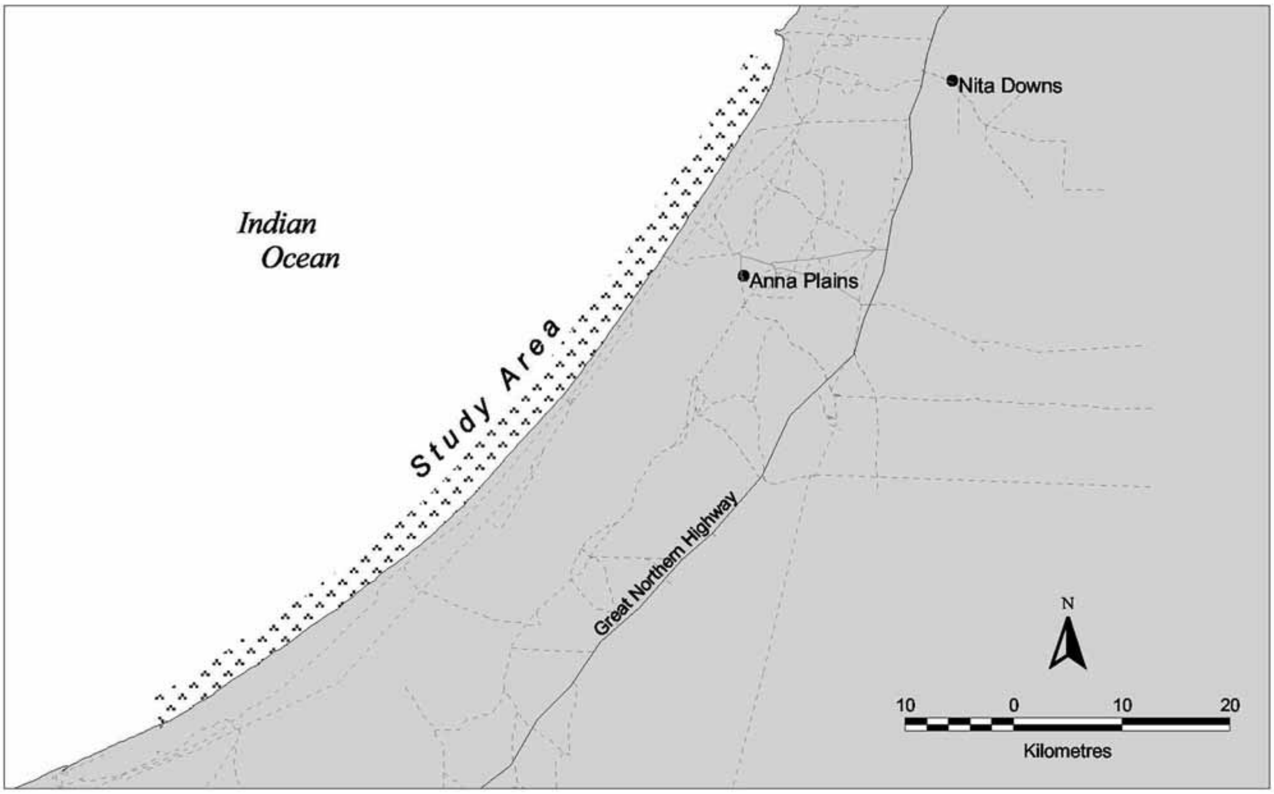


Figure 7.2. General location of the study area.

7.2. SITE LOCATION

Eighty-mile Beach is located in the north-west of Western Australia, 130 kilometres east north-east of Port Hedland and 142 kilometres south south-west of Broome (Fig. 7.1). The beach is 230 km long and about 100 metres wide. It is characterised as a sand coast which includes several muddy embayments. The adjoining mudflats are about 0.5 to 4 km wide (as observed on the field trip). The area of Eighty-mile Beach of particular interest for the field work ranges from 10 km north to 60 km south of the Anna Plains Station beach entry (Fig. 7.2). This area is where the concentrations of shorebirds are greatest (Usback & James 1992, Piersma et al. 1999) and is also manageable, in terms of travelling time, for field sampling teams that were based at the Anna Plains Station.

The section of beach studied is one of the most important migration stop-over areas for arctic-breeding shorebirds in the Asia-Pacific flyway system (Piersma et al. 1999, Usback & James 1992). In particular, it is of significance as one of the most important areas in the world for the migration of Great Knots. Almost half a million birds make Eighty-mile Beach their home in the non-breeding season from August to April. In October of 1998, 414,000 roosting shorebirds were counted along the shores of Eighty-mile Beach, with the great majority occurring at the beach near Anna Plains Station, 25 to 75 km south of Cape Missiessy (Piersma et al. 1999).

7.3. BASE MAPPING

The standards set during ROEBIM ‘97 (Pepping et al. 1999) formed the basis for the procedures used for sampling and mapping the mudflats of Eighty-mile Beach. The preparation for the field trip to Eighty-mile Beach included the creation of base maps and the design of a field methodology.

The first stage in preparing for the field work was organising the base data necessary for the sampling operation. Because of the remoteness of the beach, there was little in the way of current or large scale surveys of the area. Base data were collected by digitising 1:100,000 scale topographic maps of the area. The digitising was done in a MicroStation (Bentley Systems Incorporated 1995) environment, with the coastline, roads, tracks, and towns being captured. The MicroStation Design file was converted to a DXF (drawing interchange file), allowing direct import into the GIS software package MapInfo (MapInfo Corporation 1999). Although the maps

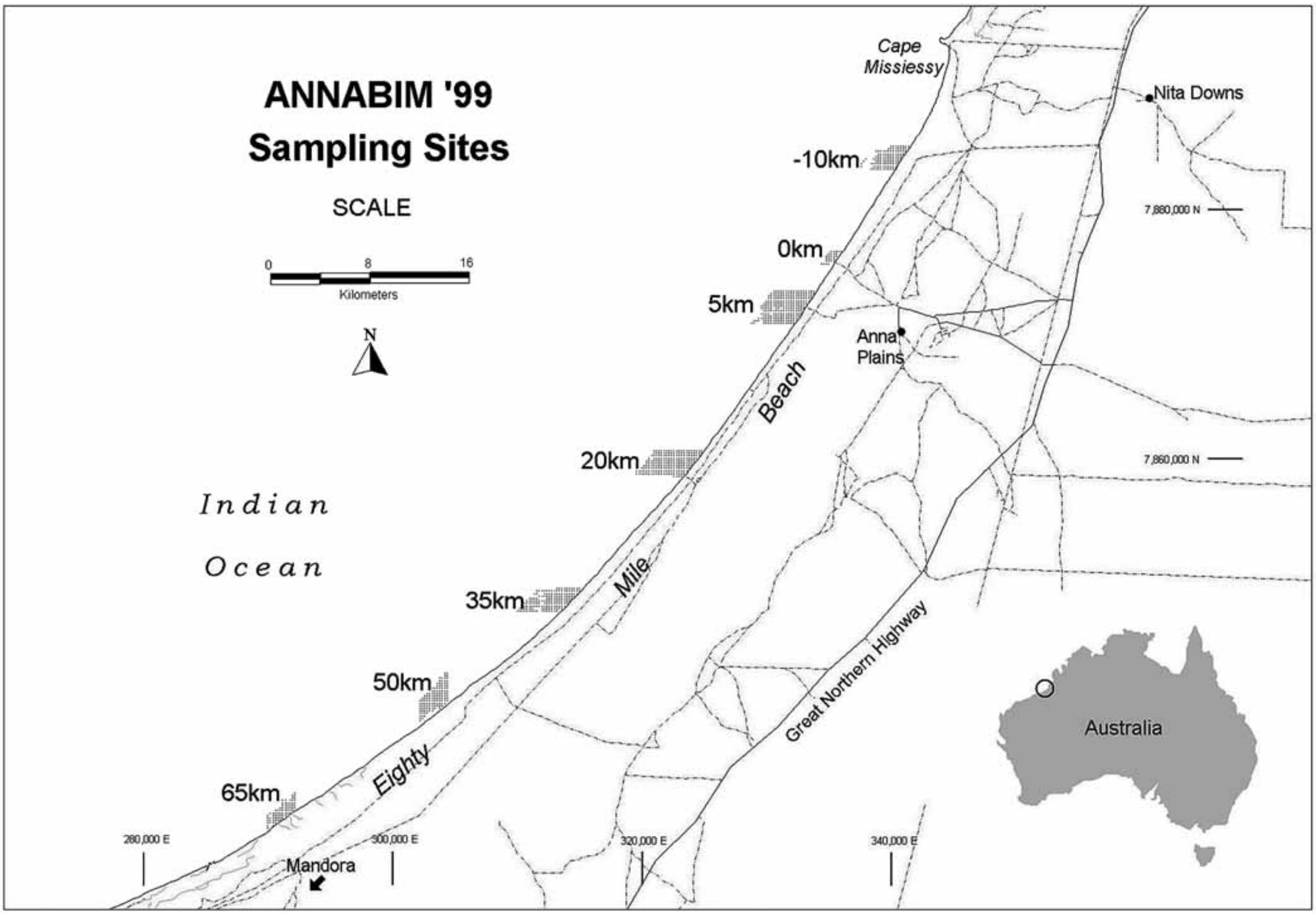


Figure 7.3. Sampling locations along Eighty-mile Beach.

used were small scale and quite old, they fit the reality surprisingly well (as observed in the field).

MapInfo is the desktop GIS package that was used for the initial storage of data because it was readily available and familiar to the researchers. Incorporating the GIS at this early stage allowed for the easy integration of field data at the later stages.

The second GIS task was requested by the biologists: to generate a map of regularly spaced points, 200 m apart, over the entire area of Eighty-mile Beach. This was initially attempted using a macro in Microsoft Excel, however, there were too many points created for the software to handle. Instead, a small Java program was written which produced a text file of Eastings, Northings, and an identifier for point locations across the mudflats. The points were generated using two SW/NE trending lines, thereby creating points that followed the general shape of the coastline. The points were imported into MS Access, converted to a Dbase 4 file, and imported into the GIS. Those points falling outside the study area were then manually selected (in a map view) and deleted. In the end, about 19,000 points were retained and provided to the biologists. This map was used as the base for selecting areas that would be sampled as part of the field work. Seven areas were later chosen and labelled according to their position relative to the Anna Plains beach entry. These sites were named: -10km, 0km, 5km, 20km, 35km, 50km and 65km (Fig. 7.3). Of those 19,000 points, approximately 900 were sampled during the two-week field season. At this point, the base maps were ready and it was time to head into the field.

7.4. GPS

The fieldwork involved extensive use of GPS (Global Positioning System) receivers. It is thus pertinent to give a brief discussion of GPS and its advantages and limitations for this sort of investigation.

GPS is based on a constellation of satellites which generate signals that can be used to obtain highly accurate geographic locational data (Kevany 1994). Generally, the receiver locates and locks onto a number of satellites (usually 4 to 6) and records the signal from each. The receiver then converts the signals into geographical coordinates that can be read by the user (Kevany 1994).

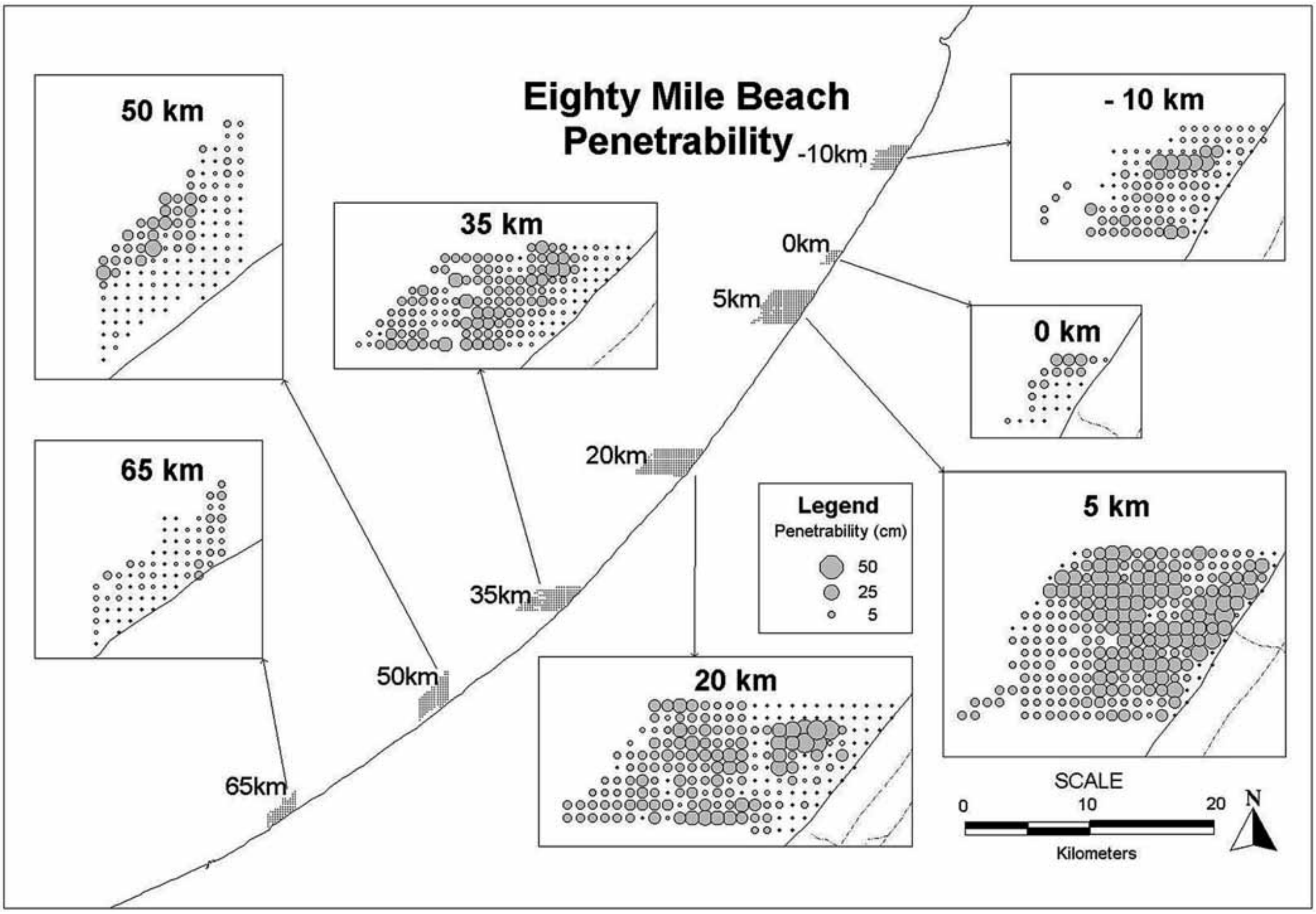


Figure 7.4. Distribution of the gastropod *Nassarius dorsatus* along Eighty-mile Beach.

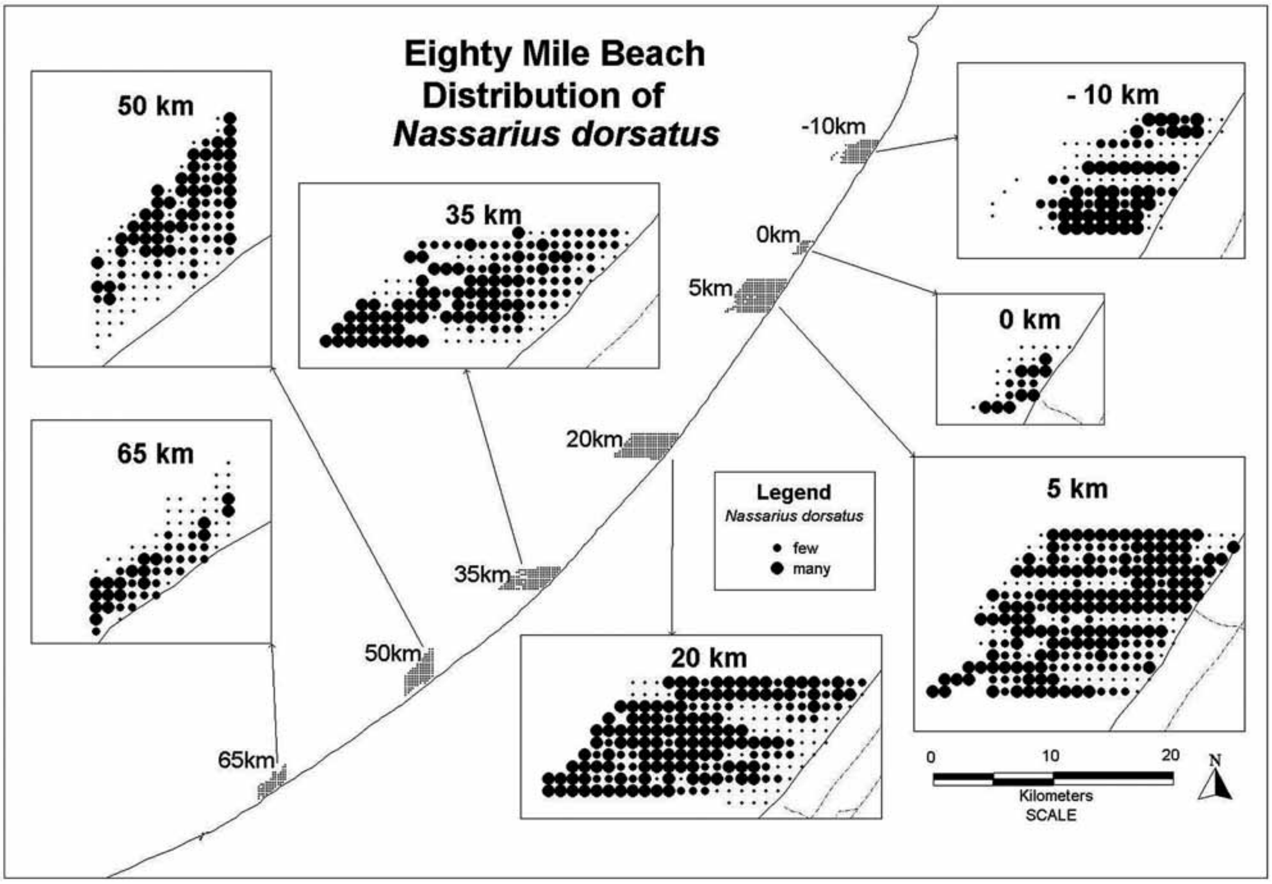


Figure 7.5. Distribution of Great Knots.

Figure 7.6. Landsat image of the Eighty-mile Beach area.

Numerous types of receivers with varying degrees of accuracy are currently available. Many have the ability for the user to record other data observed at the location and later upload to a PC. This can be especially useful for field based ecological studies such as this one. A basic GPS receiver can cost as little as (AU)$200, making using GPS viable even for studies with limited funds. There are, however, issues regarding the accuracy of the locations that are derived from GPS. Until recently (May 2000), the US Military encrypted GPS signals, degrading the accuracy for defense reasons. This was known as selective availability. Civilian users of GPS could, therefore, expect basic GPS receivers to have accuracies ranging from 30 – 100 m. Since selective availability was turned off, these same receivers generally have accuracies of 5 – 10 m (Kevany 1994, Belcher 2000).

GPS offers great potential for integrating field observations with GIS. In the case of this project, defined point locations (those generated in the earlier base mapping stage) were found using GPS receivers and sampled. For this investigation, it would be nearly impossible for data collectors to orient themselves due to a total lack of distinct topographic features. Thus, GPS allowed samplers to find pre-defined locations with ease – a task that otherwise would have been nearly impossible.

One unexpected problem that arose in the field was the perception of the accuracy of GPS. Many volunteers assumed that the GPS coordinates were “hard” (exact) locations, not “soft” (i.e., plus or minus 100 m). As such, considerable field time was wasted while volunteers attempted to find the exact location of the sample sites. In fact, one volunteer, while carefully staring at his GPS receiver, actually walked in a complete circle. Thus, we learned that a thorough explanation of GPS accuracy and use would be necessary for future fieldwork.

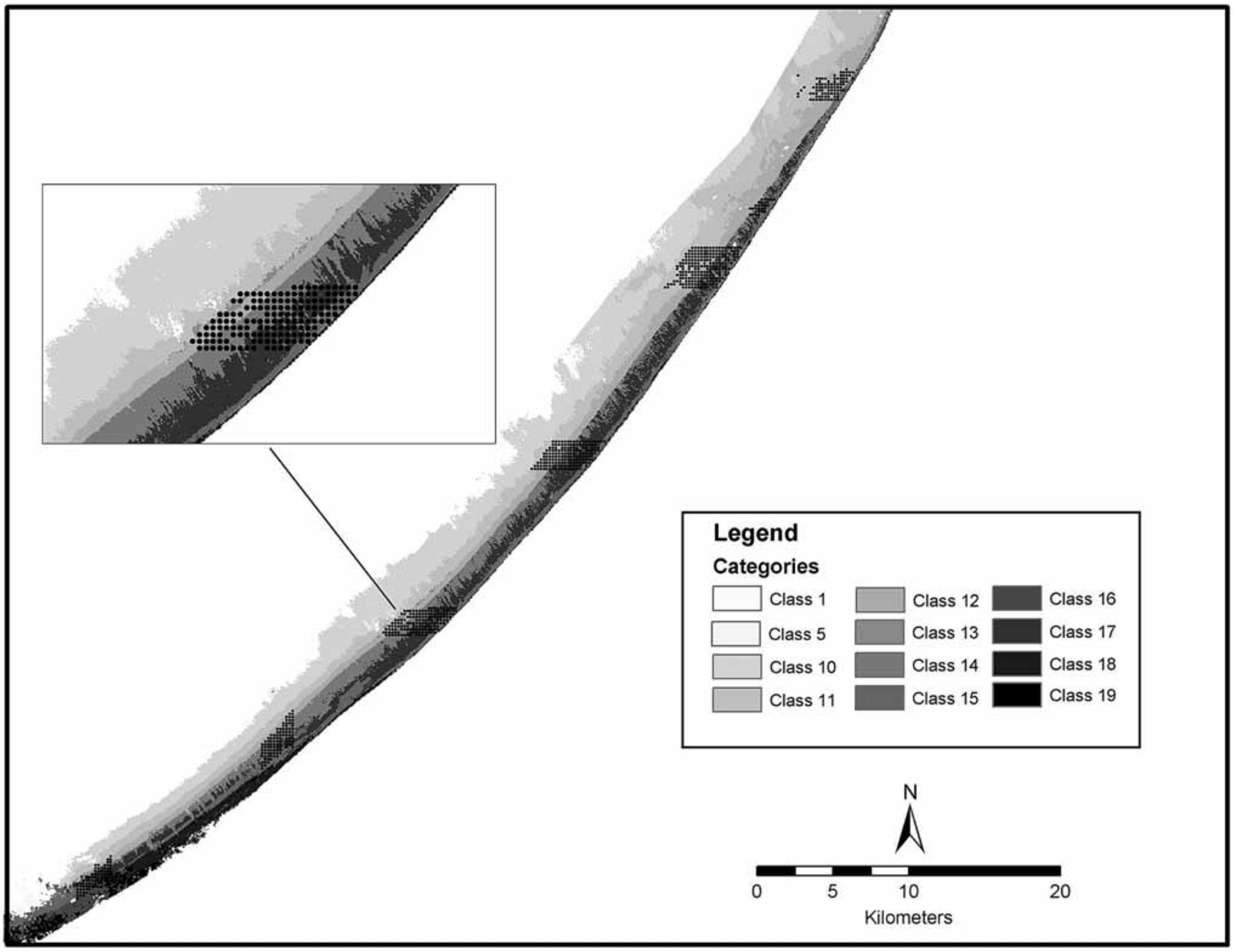


Figure 7.7. Spectral categories of Eighty-mile Beach.

7.5. DATA COLLATION

A number of laptop computers were available at the campsite. These were used to store the results of each day's fieldwork, including the results of the field questionnaires and the exact number/name of species at each sampling site. The species information was entered into a Lotus spreadsheet by the biologists; the results of the field questionnaire were entered by a number of volunteers into a Microsoft Excel 97 spreadsheet.

Unfortunately, the two datasets listed above were not directly compatible. A long evening was spent by three of us (using three different computers) – eventually we got everything into Microsoft Access and linked together into a single, large table. This was then exported in dBase 4 format and imported into MapInfo.

7.6. MAP PRODUCTION

In the two days following the fieldwork, Michelle Crean produced a series of species distribution maps that reflected the results of the sampling. They were created in MapInfo and included a map showing the sites sampled, a penetrability map (see Fig. 6.10), and 16 distribution maps for selected species of particular interest to the biologists. One example of these species maps is shown here: Ingrid eating snails – *Nassarius dorsatus* (Fig. 7.4). These maps were included in the preliminary research report (Piersma et al., 1999) and used to help the biologists explain the distribution of the various animals found at Eighty-mile Beach.

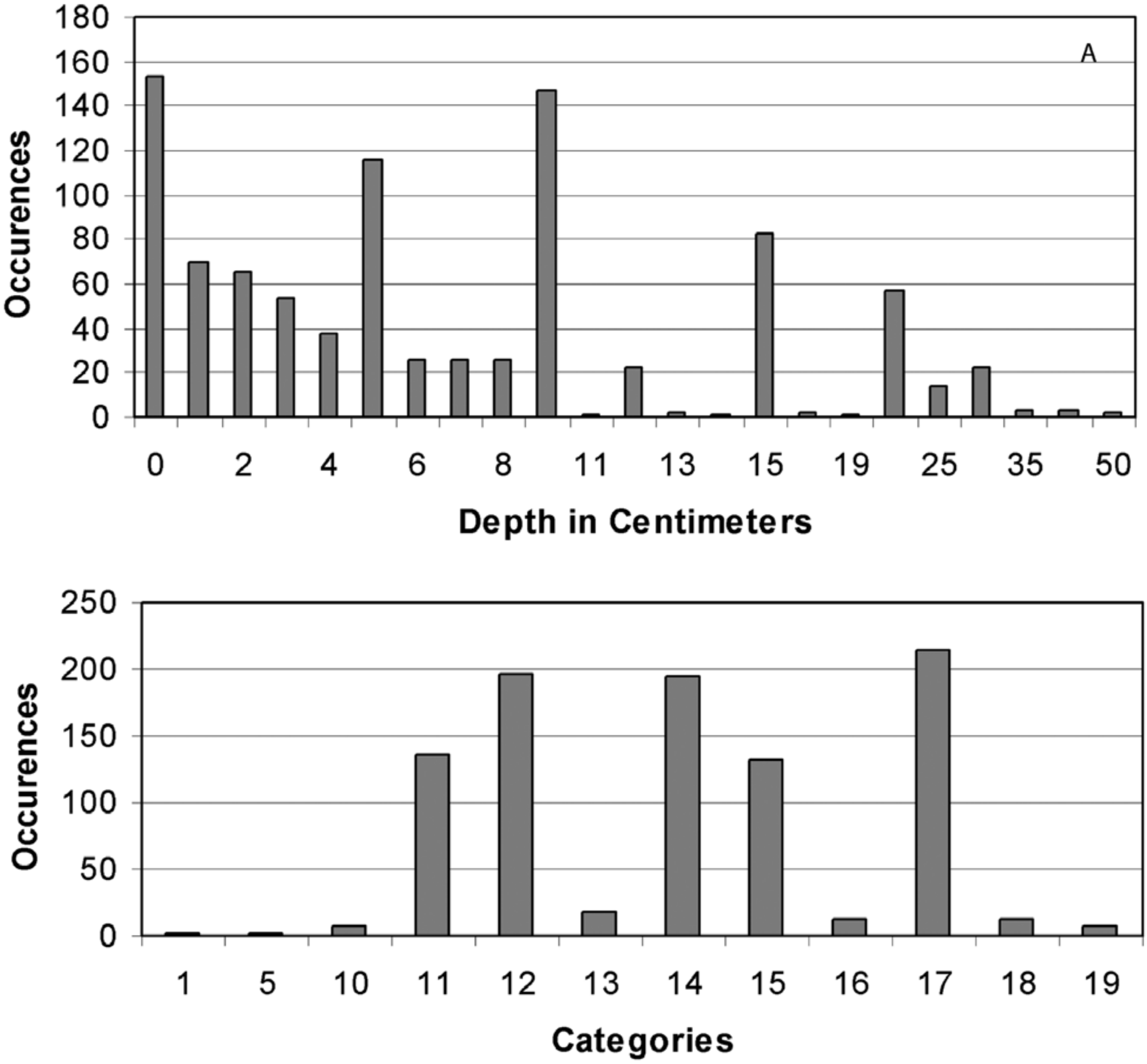


Figure 7.8. Frequency distributions of penetrability (a) and SPOT values (b).

More recently, two series of maps were produced using ArcGIS 8.1 by Bob Hickey. The first was simple bird denisities; the second a combination of bird and prey densities. Figure 7.5 is one example (Great Knots).

7.7. REMOTE SENSING APPLICATIONS

Remotely sensed data has great potential for the analysis of landscape patterns, habitat fragmentation and changes in characteristics over time (Matson 1991). The goal of this part of the project was to determine whether or not field data, when combined with remotely sensed data, could be used to extend the knowledge gained in the field over the entire mudflats. In particular, spectral reflectance patterns were compared to penetrability (a surrogate for grain size) and the distribution of various benthic species. Since the hypothesis has been formulated that penetrability is directly related to the distribution of benthic organisms, and the birds depend on the organisms for survival, it was possible to map the entire mudflat habitat by using remotely sensed imagery for likely migratory bird feeding areas.

The data used consisted of a 25m resolution, March 1994 Landsat TM image (Fig. 7.6). The instantaneous field of view is 27.5 x 27.5m (interpolated to 25m x 25m) for bands 1 to 5 and 7, and 120 x 120 metres for band 6 (Lillesand & Keifer 1994). The measurement of soil (mud) moisture is the most useful application for this study, although TM imagery is also very useful in determining vegetation health and type, geological features, landscape composition, and the differentiation of clouds, snow, and ice.

The first step in this analysis was to bring the Landsat TM image into ERDAS Imagine and define an Area Of Interest (AOI) – effectively the area between the frontal dune and the ocean. This cuts down on the processing time required for future calculations and eliminates the unneeded complexity of both the ocean and inland areas.

Next, an unsupervised classification was performed. Unsupervised classifications find meaningful patterns in the data by grouping areas with similar spectral reflectance properties. Statistics are derived from the spectral characteristics of the pixels in the image and sorted based on mathematical criteria. Unsupervised classifications are completely dependent on the data itself for the definition of classes – no other information (ie – field data) are used in this sort of classification. Thus, the results generated by the computer may or may not be what the analyst seeks. This method is usually used when less is known about the data before classification. Various numbers of classes were used to get the best mix, but it was decided after looking at a number of classifications that 25 classes seemed the best choice. A 12 class definition didn't provide unique enough spectral signatures, while 30 did not appear to improve things. Twelve iterations were used during the classification process. After classifying the AOI, the image was exported into an ESRI grid format that could be read by ArcGIS (Figure 7.7).

The classification categories mapped in Fig. 7.8 show only the spectral categories that related to the field observation sites. Classes 1 and 5 were distinct either clouds or cloud shadows, and therefore, they were eliminated from future analyses.

To compare the classified image with the field data, the two datasets needed to be merged within ArcGIS. The classified image was in raster format; the field data as a series of points with an extensive associated attribute table. The LATTICESPOT command was used to extract the spectral category directly below each field sampling point – adding that value to a new field in the point data attribute table. This attribute was named 'SPOT.' Since the point sometimes fell under two classes, approximately 50 of the 933 points were rounded into one classification category. Each rounding was easily accomplished since the number to the right of the decimal point was either a 0 or 9 (i.e. a value of 3.9 was rounded to 4).

Now that all the data was in a single attribute table, analyses could be run comparing the SPOT values with penetrability and species concentrations. At the time of this writing, the only analysis that is complete is the penetrability analysis.

Figure 7.8 illustrates the frequency distribution of penetrability and the SPOT classes. Penetrability was measured in centimeters (0-50cm) and later grouped into 5 classes in order to complete statistical testing.

Statistical measures were employed to determine if there was a relationship between spectral classification and penetrability. Bands needed to contain at least 15 samples of the total number of cases in order to be included in the testing. This was deemed a significant enough number for analysis, almost 2 percent of the total sampled. A simple chi-square test was used since the spectral category data was nominal. This test was used to determine if there is statistical significance in the relationship of the data which would justify further testing. The SPOT data (spectral characteristics under each field sampling) variable was measured against penetrability data and will be measured against benthic organism distribution.

To test the strength of the relationship between spectral values and penetrability, a Cramer's V test was conducted. Cramer's V is useful to determine if the statistical significance is the result of a large sample size, instead of any substantive relationship between variables. This equation takes chi-squared multiplied by the number of samples, multiplied either by the rows minus 1 or columns minus 1 (whichever is smaller). The coefficient ranges for 0 (no association) to 1 (perfect association). The Cramer's V number was 0.27. Since a Cramer's V of 0.10 provides a good minimum threshold for suggesting there a substantive relationship between the variables, the 0.27 is enough to show a moderate association (Research Methods 2001). In theory, analyzing imagery that fits the same reflectance categories should show similar penetrability characteristics.

Further testing indicated that category 11 showed the most significance. Each individual cell in the category showed a relationship. Category 15 also showed significance in nearly every depth measurement. The other important aspect of this testing showed that in the 0-1 cm column, the relationships between spectral reflectance and penetrability were much stronger that in the deeper measurements.

The correlation between each species of organism as well as penetrability data will need to be computed based on a discriminate analysis statistical technique. This analysis needs to be performed in order to examine the adequacy of the classification scheme. This multivariate technique will establish the way in which the classification groups differ on various measurement variables.

As the species and penetrability are analyzed and correlated with the reflectance data, a true pattern should emerge. Once a correlation is determined, this pattern will be used to map the entire mudflat. Further research should show that the birds gather to feed where large populations of benthic organisms are present. It is also expected that this analysis will show that human interaction disturbs the birds feeding patterns by indicating that benthic organisms are present, but due to human activity, the birds are not feeding in the areas. Initial results regarding these relationships are encouraging. (Author's note: at the time of writing, these analyses are being re-run using 1999 TM data. Preliminary results are very promising.)

7.8. DISCUSSION

As was demonstrated throughout this paper, spatial analysis was an integral part of all aspects of this research project. Three general subdivisions of this work can be made: (1) Base mapping (base maps, generation of sampling locations, and GPS). (2) Data display (field maps, mudflat widths, bird density mapping) and (3) Modelling (remote sensing analysis and future inundation time calculations).

The base maps can be found as part of almost every map generated throughout this project. The field maps (etc) are vital as a tool to explain both what was done and its meaning. The modelling extends what is known over a larger area.

The results of the investigation so far identify a moderately substantial relationship between penetrability and specific Landsat reflectance classes. In particular, very strong relationships were observed in categories 11 and 15 for nearly every measurement, as well as strong relationships in the 0-1 cm depth for most categories. By using these inferential statistics, an assumption can be made that these results are statistically probable for the whole population, rather than just the sample. Further investigation dealing with the actual benthic population may lead to even more conclusive results. This information can be used as a guide for explaining why species are found where they are on the mudflats. By identifying areas of the mudflats that are of interest (those areas that have high abundances of certain animals), this information can be used prior to more intensive field surveying, which could save time and money available for on-site work, thereby enabling more efficient use of project resources.

An important aspect of any ecological study is tracking changes that occur in the communities over time. With the use of GIS, it is easy to update the database with observations from subsequent studies, and with (almost) the click of a button, produce a change map for the area. GIS also has the benefit of keeping track of cultural development in the area and modelling any of the potential impacts. Remote sensing has the advantage of easily detecting large-scale changes over the area and being able to detect changes almost immediately following high impact events. For example, if a cyclone passes through the area, satellite imagery could be obtained from before and after the event, making it possible to identify the impacts of the cyclone.

7.9. LIMITATIONS

The sampling strategy was designed by the biologists. As Ludwig & Reynolds (1998) point out, any sampling strategy adopted must be related to the aims of the study and should be designed to maximise the information obtained in return for the effort and time invested. In this study, and often in others, the remote sensing scientists know little about the ecological data being examined, and the ecologists know little about remote sensing and GIS (Roughgarden et al. 1991). This can be an obstacle to effective collection of appropriate data for input into GIS and integration with remotely sensed data. This was the case in this project. Most field scientists in this study were unaware of the potential of GIS and thus inadvertently collected data in a way that was limited in its use within the GIS. Perhaps the GIS scientists could have liased more with the ecologists, to promote understanding of some of the data collection issues that are particularly relevant to integration within GIS.

An important limitation of the study was the number of field samples that could be collected. The phenomena being mapped (mudflat animal life, and soil composition), varies continuously across the mudflats. It would be impossible for teams of people to collect field data in this way, due to limitations in numbers of volunteers and time restrictions. Thus, the sampling strategy was designed so a number of discrete regular sampling sites on a 100 m grid would be visited. This sampling strategy does not reflect the nature of what is being mapped. It is proposed that the integration of remotely sensed data (which approaches continuous sampling) will aid in mapping the continuous phenomenon with greater fidelity.

The statistical techniques used in the remote sensing section were selected based on the fact that the data was nominal. It was thought that the chi-square and the Cramer's V testing were appropriate to determine that the relationship between penetrability and SPOT reflectance were more than a coincidence. The logical validity of the chi-square test is greatest when the values of the expected frequencies (E) within the cells, are fairly large, and decreases as these values of E become smaller. (Although the statistical references do not always agree on just where to draw the line, a practical rule of thumb was applied: values of E needed to be equal to or greater than 5). Although the category data was not combined, penetrability data needed to be combined into ranges in order to meet these stipulations. Another limitation is that non-parametric tests, like chi-square and Cramer's V, are rough estimates of confidence; they accept weaker, less accurate data as input than parametric tests. This limitation can also be considered a strength; because chi-square is more 'forgiving' in the data it will accept, it can be used in a wide variety of research contexts (Connor-Linton 1998). One other limitation is the fact that the individual cell chi-square numbers for the 0-1 cm column showed so much significance, it may have skewed the entire row. It should also be noted that the statistical inferences to the Landsat data show that through the techniques chosen, the reflectance data when related to the penetrability is not random, and shows a moderate relationship, but more information needs to be extrapolated from this data.

Finally, the Landsat image was not collected at the same time as the fieldwork. Therefore, there may be some differences in data, but the reflectance based on penetrability of the mudflat should not be significantly changed due to the nearly pristine state of the beach and the fact that there has not been any great physical change within the last few years. Newer imagery is being analyzed to confirm this hypothesis.

8. ATLAS OF THE MACROZOOBENTHIC FAUNA

Marc Lavaleye, Pieter Honkoop, Loisette Marsh, Grant Pearson, Theunis Piersma &
Petra de Goeij

8.1. INTRODUCTION

In this chapter we aim to present all the information on the identity, distribution, size range and ecology of the taxa that we distinguished in accessible a form as possible. Based on the list of taxa, and the summary of their distribution, we deal with all taxa separately and will give a distribution map if it is found at 5 or more stations. A picture is added if available. We hope that this preliminary 'atlas' will be an inspiration for further endeavours in summarizing the distribution of macrozoobenthos in the Kimberly region. Also, a taxon by taxon listing makes clear how little we know about the names and the ecology of most of the species, and hence will serve as a reminder that we need further research effort there. Finally, the taxon by taxon summaries will provide the background to the chapter on community structure (Chapter 9).

The mapping of the benthic fauna of the intertidal flat of Eighty-mile Beach was organized in such a way that most animals collected during the sampling were identified within one day of collection. A lot of volunteers and Landscope participants not only helped to sample so many stations, but also did most of the sorting. The identifications were then made till late in the night by the Dutch scientists from NIOZ, by Danny Rogers and by Loisette Marsh (WAM). If the identification could not be finished the same day as sampling, the sorted samples were stored in a refrigerator for the following day. The advantage of this system was that most animals were seen alive and intact, which highly improved sorting and field identification. As data were stored in the computer every day, it was possible to publish some of the results (Piersma et al. 1999) and to draw distribution maps of species quickly after the expedition. Further we had chosen this procedure as it was foreseen that none of the participants (most of them voluntary) could spend much time on the samples after the expedition. The disadvantages were that, given the enormous amount of animals (almost 19.000), the many sampling stations (818) and the limited time (14 days, 8-22 oct. 1999), the identifications could not be as thorough as in a well equipped lab or natural history museum with taxonomic specialists, reference collections and literature at hand. In all we recognized about 200 different taxa (120 in the quantitative samples), but this figure will grow substantially if groups such as e.g. the Polychaeta are split up into species instead of families.

For logistic reasons it was not possible to keep all material collected during the expedition, nor was it possible to keep material from each station separately. However, a reference collection of all recognized species was made. Most species were preserved in formalin (4%), and later stored in alcohol. After the expedition a reference collection of the common species was left behind at BBO, while the rest was stored at NIOZ for the time necessary to complete the report. Most of the Echinodermata and some other interesting species were taken by Loisette Marsh to the WAM (Western Australian Museum) and were worked out further there by her. It is our purpose that the complete reference collection will be donated to the WAM (Perth) in time.

8.2. ANNOTATED SPECIES LIST AND ATLAS

In this systematically arranged list of species, only those species encountered during the quantitative grid sampling will be mentioned and briefly discussed. All identifications have to be taken with some reserve and any critique or additional information will be appreciated. We hope that in the near future material sent to specialists will give a more detailed view of the fauna of Eighty-mile Beach. Sometimes a made-up English name for animals was coined during the expedition, and some of these names are mentioned in this list.

Body length range, number of sampling blocks, number of stations where the species were encountered and the density range are indicated for every taxon. Maps are only shown for taxa that were found at 5 or more stations. The maps only show 6 of the 7 sampling blocks. Block 0, which was a try-out sampling block with a limited number of stations, is left out, but all data are included in the text. At each station 3 random samples, each with a surface of about 83 cm^2 and maximum depth of 30 cm were taken for the macrobenthos survey. The densities in this report are therefore based on a total sampled surface of 250 cm^2 per station (on the maps in numbers/m^2). Further the range and mean of the silt content (< 63μm) and grainsize of the sediment in which the animals were found is indicated for every species. The silt content in percentage of the total weight varied from 0.1 to 99%. The range of the grainsize over all stations was less than 63 μm to 1000μm. A few stations had a very high mean grainsize. This was caused by the high contents of coarse shell grit.

8.3. COMPARISON BETWEEN EIGHTY MILE BEACH AND ROEBUCK BAY

Although many more stations were sampled at Eighty Mile Beach than at Roebuck Bay in 1997, fewer taxa were found at Eighty Mile Beach. The difference between the locations (112 against 163 taxa) may be easily explained by the higher diversity of habitats in Roebuck Bay. Here there are mangroves, creeks, rocky shores and wave-protected areas with very soft mud, all of which are not present at Eighty Mile Beach.

Nevertheless, it would be a great mistake to conclude that the fauna of Eighty Mile Beach is 'just' an impoverished Roebuck Bay fauna. More than 40 taxa were found at the Anna Plains foreshore only. Among these are several bivalve species (e.g. *Tellina* spec.1, Theora fragilis and Paphies cf altenai), the relatively large Columbellid snails (*Mitrella essingtonensis*), the tiny *Ringicula* snail, the tiny tuskshell (*Polyschides gibbosus*). Among the bristle worms, the 5 cm large *Pectinaria* or gold combs with their peculiar tubes of sand grains, were totally new, while clumps of the reef forming Sabellariidae were frequently found near the low water line. These sabellarids are peculiar to mechanically undisturbed sedimentary shores.

New in the group of the Cnidaria (e.g. sea anemones) are the sea pens (Pennatulacea) and the burrowing sea anemone with its parasitic epitonid snails. The flat sanddollar (*Arachnoides tenuilus*) and the common sea cucumber (*Protankyra verrilli*) were also new. The tiny amphipod *Corophium*, living like a hermit crab in all sorts of shells or parts of crab legs, was very abundant at some stations and is new record for our species list. The mussel *Modiolus micropterus*, that occurred in very low numbers in Roebuck Bay buried in the sediment, was found in abundance stranded on the beach and attached to old stems of the plant Spinifex.

There are several species that were peculiar, abundant or important to the Roebuck Bay intertidal benthic fauna that are missing in the Eighty Mile Beach samples. The strange cone shaped mud sponge, of which a restricted number of individuals was found at only one spot, was not found at all on the mudflats of Eighty Mile Beach. So it seems the distribution of this species is very restricted and needs special attention. Among the bivalves several common species of Roebuck Bay (*Solemya*, *Anadara granosa*, *Cultellus*, *Tellina capsoides*, *T. piratica*, *Gari lessoni*, *Anomalocardia squamosa* and *Laternula creccina*) were entirely absent at Eighty Miles Beach, suggesting a rather restricted distribution. Among the other Mollusca the scarcity of tusk shells (Scaphopoda) was striking. Not surprisingly the snails that were only seen in the neighbourhood of the mangroves, like the small Ingrid-eating snail (*Nassarius* spec.), *Salinator burmana* and the small Stenothyridae, were absent too. The plastic worms (Chaetopteridae) that occurred in high densities in Roebuck Bay and did give the sorters a hard time in 1997 were not found at all. This is also true for another polychaete family, the Lumbrineridae. The group of Ostracoda, remarkable for leaving green or purple glowing tracks during the night, were not caught in our sieves. Another crustacean, the mantis shrimp (Squillidae), was only found a few times in the Eighty Mile Beach samples, while it was rather abundant in Roebuck Bay. Among the true crabs especially the absence of the Hymenosomatidae, a tiny spider crab abundant in the muddy parts of Roebuck Bay, was striking. Of the brittle stars we only found one species that burrows in the sediment, while in Roebuck Bay there were several species.

Figure 8.1. Mudsampling on the Eighty-mile Beach foreshore in October 1999. Photo by Theunis Piersma

Table 1. Species list of intertidal macrobenthic invertebrates found in the quantitative samples, and their occurrence at the 'blocks' along the foreshore. Open dots indicate that species have been found at a single station; stars indicate occurrence at multiple stations.

Nr	'Species'-name	Family		'Block'	along	beach		
		(or higher level)	-10 km	5 km	20 km	35 km	50 km	65 km
1007	*Galeomma* spec.	Bivalvia			o			
1008	*Mysella* spec.	Bivalvia						o
1101	*Nucula* cf. *astricta*	Nuculidae		found	at 0 km	block		
1301	*Modiolus micropterus*	Mytilidae	o	o	o	*		*
1401	*Anodontia omissa*	Lucinidae	*	*	*	*	*	
1411	*Divaricella irpex*	Lucinidae		o	*	*	*	*
1601	*Heterocardia gibbosula*	Mactridae		*	*	*	*	o
1641	*Pseudopythina macropthalmensis*	Kelliidae						o
1711	*Siliqua pulchella*	Cultellidae	*	*	*	*	o	*
1803	*Tellina inflata*	Tellinidae	*	o			o	
1804	*Tellina amboynensis*	Tellinidae	*	*	*	*	*	
1810	*Gari* spec.	Psammobiidae	o					
1813	*Tellina spec. 1(Tellina* 'donax')	Tellinidae		o				
1815	*Theora* cf *fragilis* (*clog-Tellina*)	Semelidae		*	*			
1821	*Tellina* spec. *Tellina* (‘*Exotica*’)	Tellinidae	o	*	*	*	*	*
1851	*Paphies* cf *altenai*	Mesodesmatidae	*	*	*	*	*	o
1852	*Donax cuneatus*	Donacidae			o			
1881	*Solen* spec.	Solenidae						o
2201	*Epitonium* spec.	Epitoniidae			*			
2401	*eulimid* snail	Eulimidae		found	at 0 km	block		
2515	*Polinices conicus*	Naticidae	o					
2516	*Sinum* spec.	Naticidae		o	o			
2553	*Mitrella essingtonensis*	Columbellidae	o	*	*	*	o	o
2601	*Nassarius dorsatus* (Ingrid-eating snail)	Nassariidae	*	*	*	*	*	*
2701	marginellid snail	Marginellidae			o	o		
2902	*Ringicula* spec.	Ringiculidae		o	*			
2941	Acteonidae	Acteonidae				o		
2993	*Chrysallida* spec.	Pyramidellidae			o			
2994	*Turbonilla* spec.	Pyramidellidae				o		
2995	*Syrnola* spec.	Pyramidellidae				o		
3101	*Laevidentalium* cf *lubricatum*	Dentalidae			o			
3201	*Polyschides gibbosus* (tiny tuskshell)	Cadulidae	*					*
4101	nemertean worms (ribbon worms)	Nemertini		*	*	*	*	o
4201	phoronid tubeworm	Phoronida	o	*	*	*	*	*
4502	*Sipunculus* cf. *nudus*	Sipuncula	*	*	*	o		
4601	sand worm	Echiura			o			o
4901	*Balanoglossus* (Enteropneusta)	Hemichordata					o	o
5051	orbiniid bristle worm	Orbiniidae	o		o	o	*	*
5121	red polynoid worm (symbiotic)	Polynoidae	*	*	*	*	*	*
5122	Polynoidae spec.	Polynoidae	o	o		o		
5123	green Polynoidae	Polynoidae		o	o			
5124	red-headed Polynoidae	Polynoidae						o
5151	sigalionid bristle worm	Sigalionidae	o	*	*	o	o	o
5201	fire worm	Amphinomidae				o		
5301	onuphid bristle worm	Onuphidae	*	*	*	*	*	*
5401	pilargid bristle worm	Pilargidae	o	*	*	*	*	
5411	hesionid brisle worm	Hesionidae	o	*				
5451	ragworm	Nereidae			o			
5501	phyllodocid bristle worm	Phyllodocidae			o	o	o	
5502	brown Phyllodocidae	Phyllodocidae			o		o	
5511	green Phyllodocidae	Phyllodocidae				o		
5601	catworm, *Nephthys* spec.	Nephtyidae	*	*	*	*	*	*
5701	glycerid bristle worm	Glyceridae	*	*	*	*	*	*
5801	spionid bristle worm	Spionidae	*	*	*	*	*	*
5802	Spionidae with red cirri	Spionidae				o		
6001	cirratulid worm	Cirratulidae	o	o	*	*	*	o
6301	capitellid worm	Capitellidae	*	*	*	*	*	*

Nr	'Species'-name	Family		'Block'	along	beach		
		(or higher level)	-10 km	5 km	20 km	35 km	50 km	65 km
6401	bamboo worm	Maldanidae	*	*	*	*	*	o
6402	bamboo worm with tough tube	Maldanidae			o	o		
6501	mickey mouse worm	Sternaspidae		*				
6601	oweniid tubeworm	Oweniidae	*	*	*	*	*	*
6851	reef tubeworm	Sabellariidae	*	o				
6861	*Pectinaria* spec. (goldcomb)	Pectinariidae	*	*	o	o		
7201	Oedicerotidae (sandhopper)	Amphipoda	o	*	*	*	*	
7221	Corophiidae (mudshrimp)	Amphipoda	*	o	o	*	*	*
7301	*Anthura*e	Isopoda			o	o		
7311	*Eurydice* spec.	Isopoda	*	*	o		o	
7501	comma shrimp	Cumacea	o	*	*	o	*	*
7551	mysid shrimp	Mysidacea	o		o			
7601	mantis shrimp	Squillidae			o			
7701	shrimp	Caridea	*	*	*	*	o	o
7802	*Callianassa* spec. (burrowing shrimp)	Callianassidae		o	o	o		
7901	hermit crab	Paguridae	*	*	*	*	*	*
8051	*Dorippe* spec. (shell-bearing crab)	Dorippidae					o	
8071	frog crab	Raninidae				o		
8201	*Leucosia* A = cf. *Myrodes eudactylus*	Leucosiidae			o			o
8221	*Ebalia* spec.	Leucosiidae	o	o	*	o		o
8231	*Leucosia* D	Leucosiidae	o			o		
8291	swimming crab	Portunidae		o	o	o	o	
8311	*Myctyris longicarpus* (soldier crab)	Myctyridae		o	o	o		
8501	Goneplacidae	Goneplacidae	o	*	*	o		o
8601	*Macrophthalmus* spec. (sentinel crab)	Ocypodidae	*	*	*	*	*	*
8801	Chironomid larvae (Insecta)	Chironomidae					o	
9101	*Edwardsia* spec.	Anthozoa	*	*	*			o
9102	sand-Edwardsia	Anthozoa		*	*	*		
9103	*Edwardsia* white spotted tentacles	Anthozoa		*	o			
9152	sea anemone with spotted tentacles	Anthozoa			o	o		
9161	sea pen	Pennatulacea	o	*	o			
9191	hydrozoan	Hydrozoa		o				
9301	*Lingula* spec. (little lampshell)	Brachiopoda				o		
9402	*Amphiura tenuis* (brittle star)	Amphiuridae	*	*	*	*	*	*
9552	*Arachnoides tenuilus* (flat sanddollar)	Echinoidea			o		o	
9601	*Leptopentacta grisea*	Holothuroidea				o		
9602	*Protankyra verrilli* (orange)	Holothuroidea	*	*	*	*	o	*
9603	big sea cucumber with tail	Holothuroidea		*				
9604	uncolored Synaptidae	Holothuroidea		*				
9605	green Synaptidae	Holothuroidea	o					
9606	*Paracaudina chilensis*	Holothuroidea	o		o	*		*
9607	brown speckled sea cucumber	Holothuroidea					o	
9608	purple sea cucumber	Holothuroidea						o
9609	big pink sea cucumber	Holothuroidea						o
9801	*Scartelaos histophorus*	Periophthalmidae			o	o		
9810	gobid fish	Gobiidae			*	*		
9821	sole	Cynoglossidae/Soleidae		*	*	o		o

Hydrozoa (hydroid polyp)

Species number	9191
Phylum	Cnidaria
Class	Hydrozoa
Family	not identified
Distribution	1 block (5), 1 stations, no map.
Abundance	2 specimen
Density	2
Length	10 mm

Sediment characteristics

Silt fraction	78%
Grain size	< 63 µm

Remarks: Hydrozoan colonies normally do not belong to the infauna, and these specimens were found attached to small pieces of hard substrate like a shell and a polychaete tube.

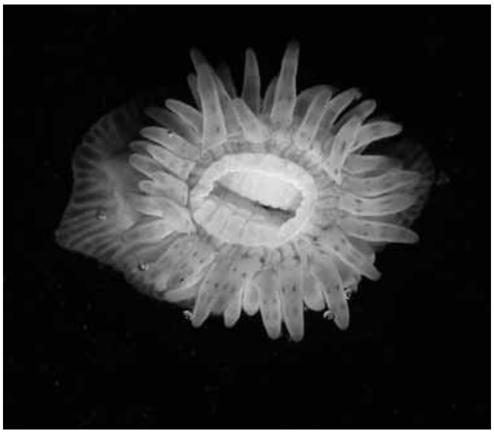
Actiniaria (Sea anemone)

Species number	9152
Phylum	Cnidaria
Class	Actiniaria
Family	not identified
Distribution	2 blocks, 4 stations, no map.
Abundance	5 specimen
Density	1-2
Length	5-12 mm

Sediment characteristics

Silt fraction	21 - 81% (mean 47%)
Grain size	< 63 - 120 µm (mean < 90 µm)

Remarks: The largest specimen had nice spots on the tentacles. Another specimen was purple colored around the mouth and divided itself into two complete individuals! Three others were sitting on a tube of an owenid polychaete.

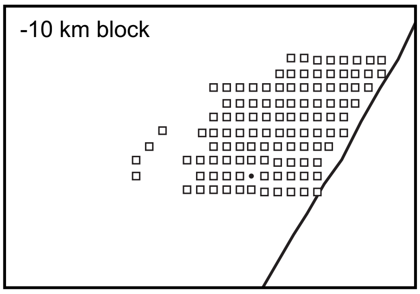


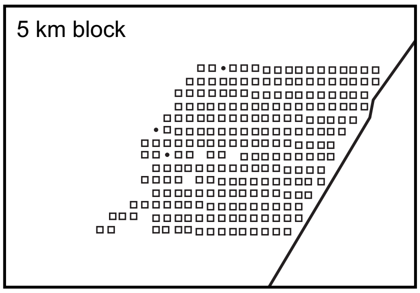
PENNATULACEA (SEA PEN)

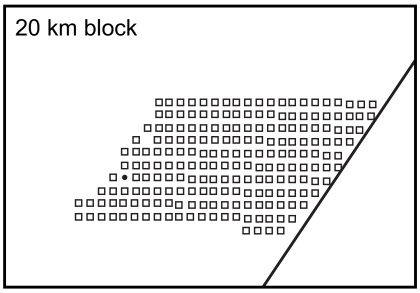
Species number	9161
Phylum	Cnidaria
Class	Anthozoa
Family	not identified
Distribution	3 blocks, 5 stations, map.
Abundance	5 specimen
Density	1
Length	15-57 mm

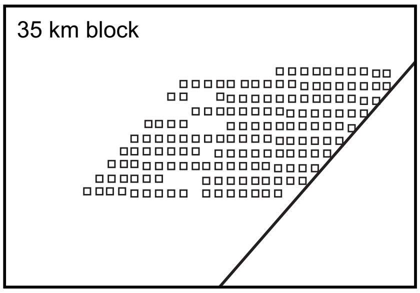
Sediment characteristics	
Silt fraction	29 - 95% (mean 63%)
Grain size	< 63 - 183 µm (mean < 87 µm)

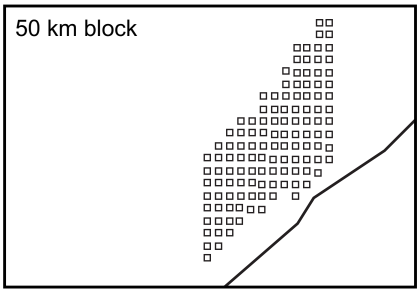
Remarks: Sea pens form a colony of polyps, often in the form of a feather. With their long fleshy foot they can bury and anchor themselves in soft sediment. The feather with polyps has an internal needle-like skeleton and is projected into the water column. It is therefore a bit surprising to find this species in the intertidal zone. This species can retract itself almost completely into the sediment, especially after disturbance. When the animal retracts itself quickly into the sediment, it is peculiar to see that the white needle-like skeleton is protruding from the top of the animal, no longer covered by any living tissue. The orange feather-like animal clearly has a back and front side, as the polyps are all directed to one side. It lives close to the low water line, only one specimen was found near the mid water line.

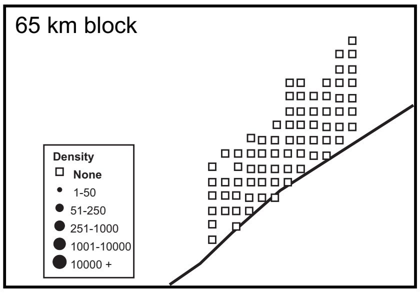












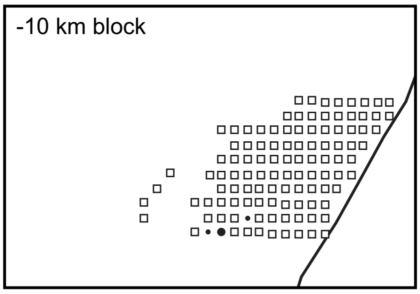
EDWARDSIA SPEC. 1

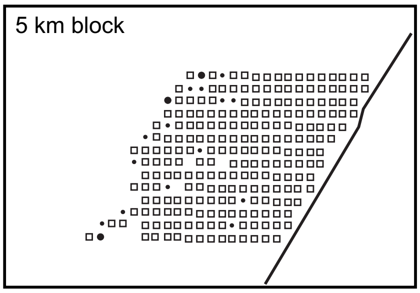
Species number	9101
Phylum	Cnidaria
Class	Actiniaria
Family	Edwardsiidae
Distribution	5 blocks, 32 stations, map.
Abundance	42 specimen
Density	1 - 3
Length	3-43 mm

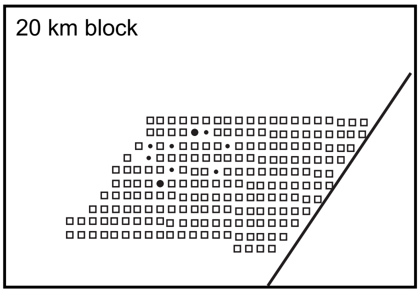
Sediment characteristics	
Silt fraction	31 - 99% (mean 77%)
Grain size	< 63 - 149 µm (mean < 73 µm)

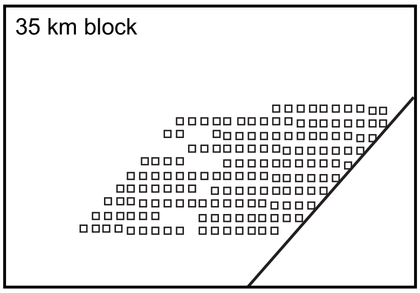
Remarks: These are relatively small and slender sea anemones that have a burrowing habit. The relatively few tentacles normally stick out of the sediment to catch prey, but can be retracted quickly on disturbance.

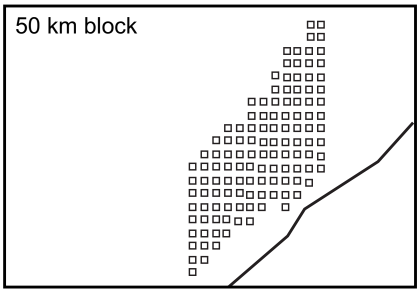
This species is very similar to Edwardsia spec.3, but it does not have the spots on the tentacles. Most specimens were found near the low water line.

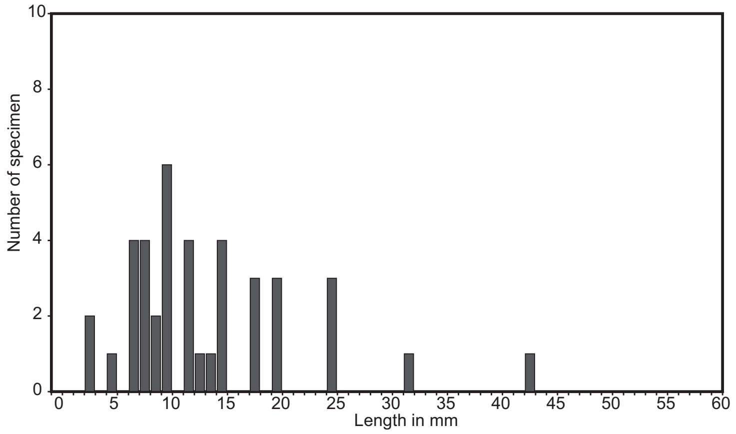


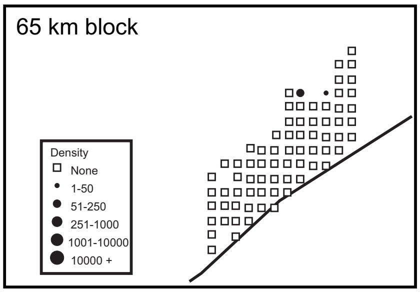












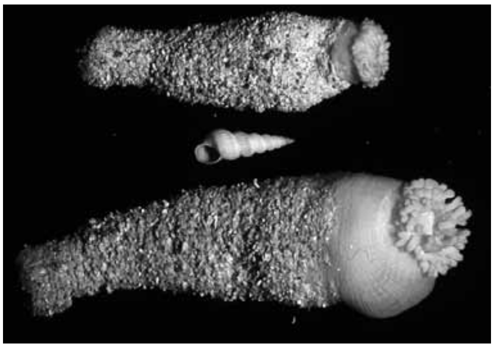
EDWARDSIA SPEC. 2 (SAND EDWARDSIA)

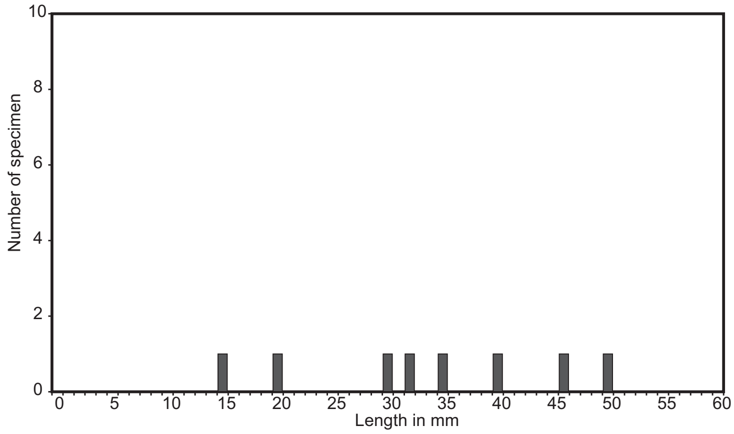
Species number	9102
Phylum	Cnidaria
Class	Actiniaria
Family	Edwardsiidae
Distribution	3 blocks, 8 stations, map.
Abundance	8 specimen
Density	1
Length	15-50 mm

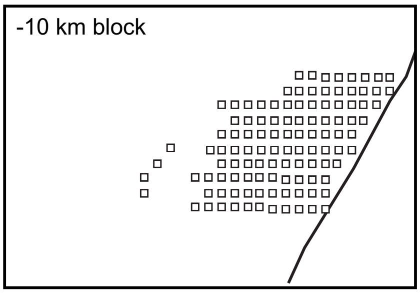
Sediment characteristics

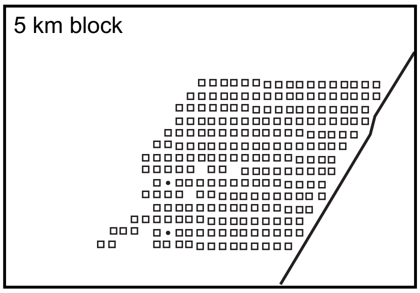
Silt fraction	16 - 88% (mean 52%)
Grain size	< 63 - 138 µm (mean < 89 µm)

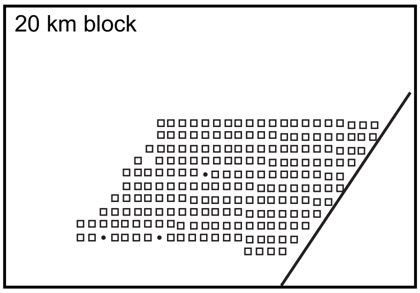
Remarks: The body of this rather large species is completely covered with sand grains, Foraminifera and small pieces of shells, except for the tentacles and mouth. On two specimens ectoparasitic snails of the genus *Epitonium* were found, in one case even 3 snails were found on one sea anemone. This species of sea anemone prefers to live at the lower half of the intertidal zone.

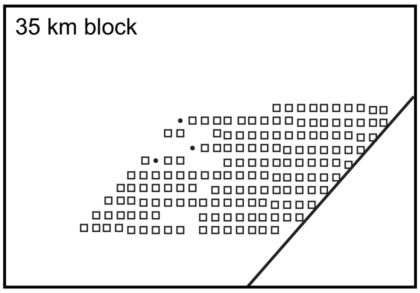


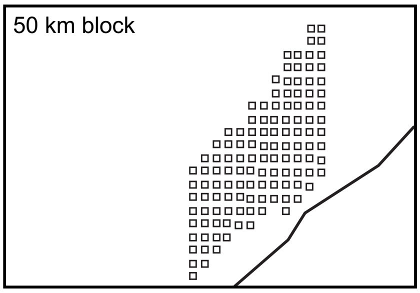


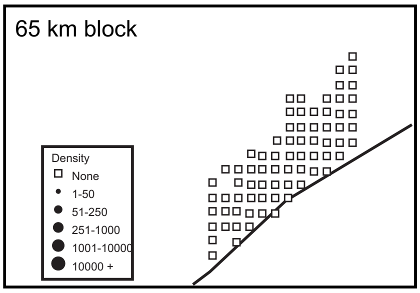












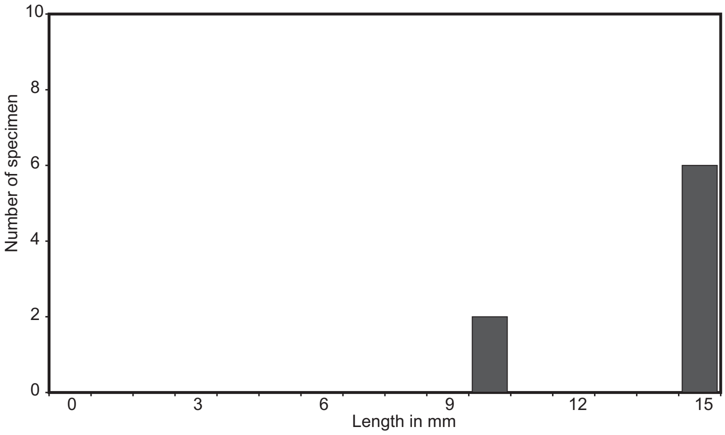
EDWARDSIA SPEC. 3
(EDWARDSIA WITH WHITE SPOTTED TENTACLES)

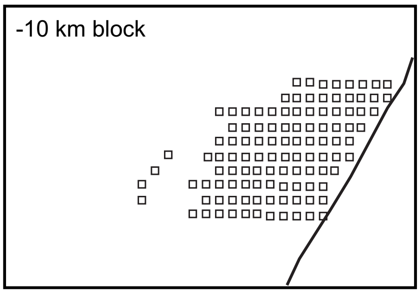
Species number	9103
Phylum	Cnidaria
Class	Actiniaria
Family	Edwardsiidae
Distribution	2 blocks, 5 stations, map.
Abundance	8 specimen
Density	1-4
Length	10-15 mm

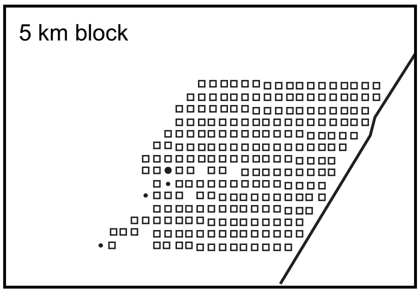
Sediment characteristics

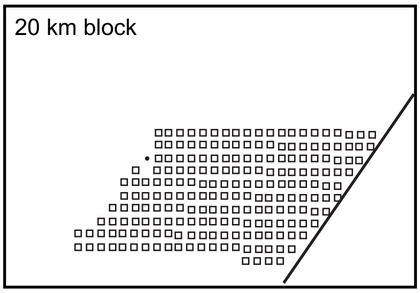
Silt fraction	54 - 91% (mean 83%)
Grain size	< 63 µm (mean < 63 µm)

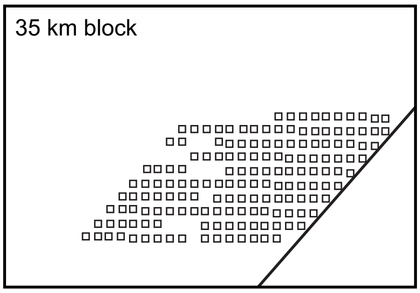
Remarks:The only difference with Edwardsia spec.1 seems to be the spotted tentacles. The skin on the body is leatherly and lightly brown colored. It lives close to the low water line.

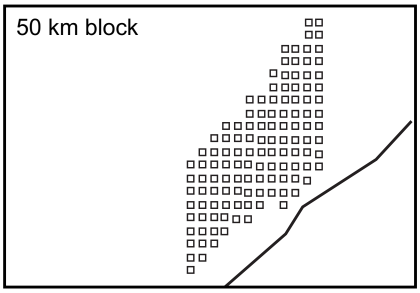


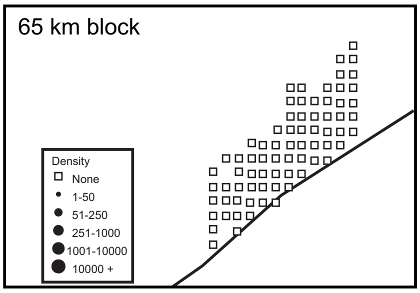










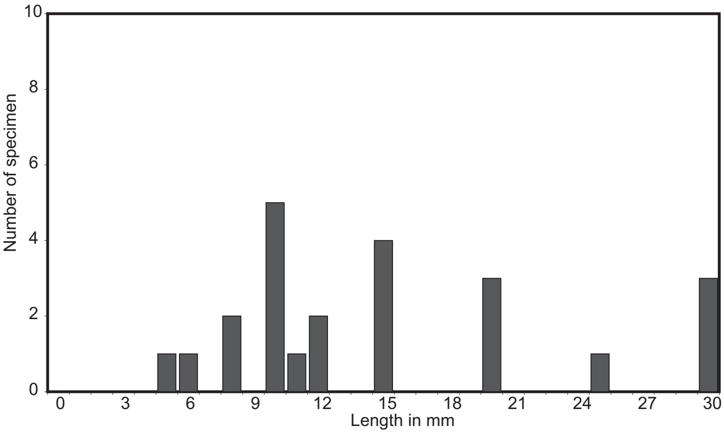


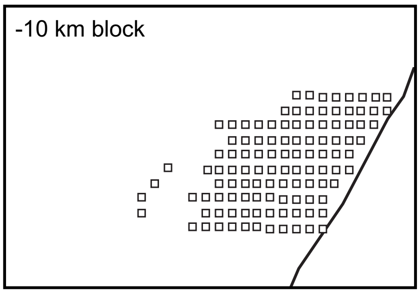
NEMERTINI (RIBBON WORM)

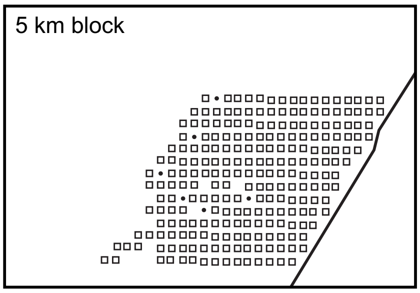
Species number	4101
Phylum	Nemertini
Class	not identified
Family	not identified
Distribution	6 blocks, 22 stations, map.
Abundance	23 specimen
Density	1-2
Length	6-30 mm

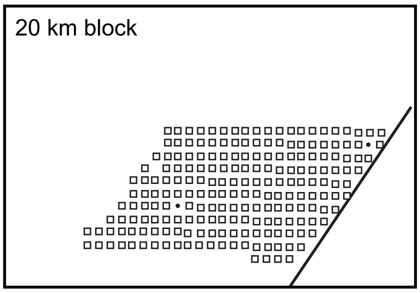
Sediment characteristics	
Silt fraction	12 - 98% (mean 57%)
Grain size	< 63 - 142 µm (mean < 81 µm)

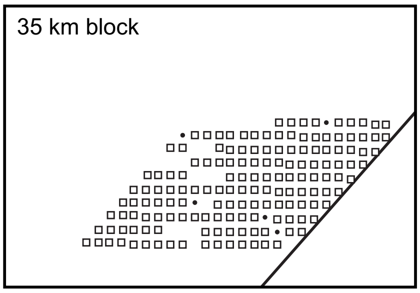
Remarks: These slimy worms break up easily during collecting or conservation. Identification to the species level is hard. These animals are predators and even can devour large bivalves. The sticky slime, which they can produce in large quantities, is a good defense against any predator. The distribution over the sampled area is rather erratic, and no obvious correlations with tidal height or sediment characteristics is apparent. This could mean that several different species are involved.

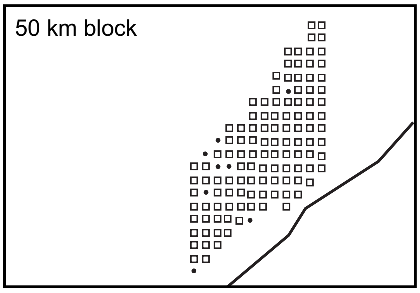


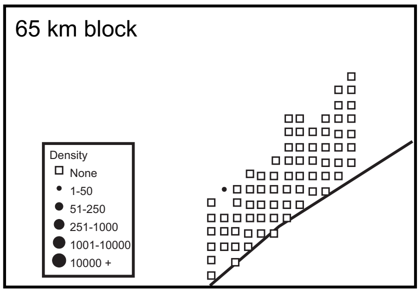












PHORONIDA

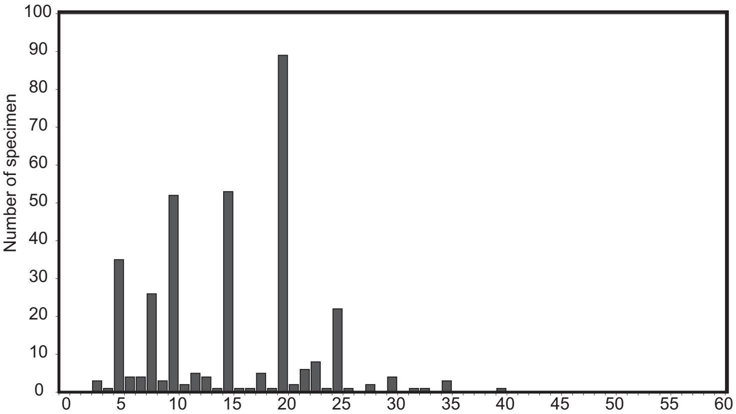
Species number	4201
Phylum	Phoronida
Class	not identified
Family	not identified
Distribution	7 blocks, 98 stations, map.
Abundance	342 specimen
Density	1-30
Length	3-40 mm

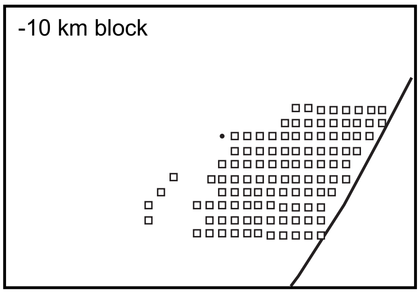
Sediment characteristics

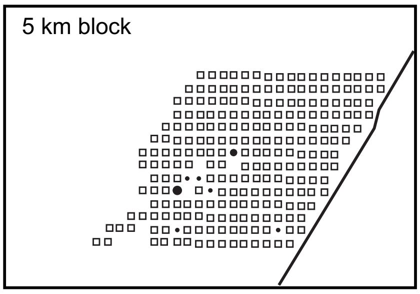
Silt fraction	1-92% (mean 50%)
Grain size	< 63 - 181 µm (mean < 86 µm)

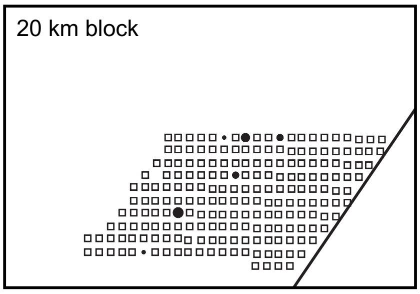
Remarks: These worm-like animals live in a sandy tube that has a resemblance to the tubes of the polychaete family Oweniidae. The animal itself is easily separated from polychaetes, because it lacks chaeta. Their tentacle crown, often lost upon collection, is also quite different from the more fleshy crown of the Oweniidae.

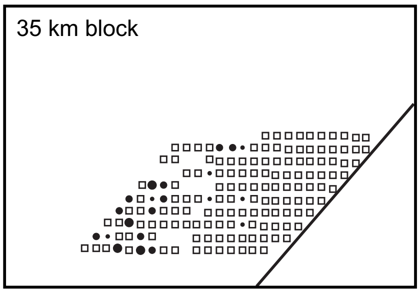
The abundance of this species increases from North to South (Block -10 to 65). In the sandy Block 65 it also lives close to the high tide level, while in the other Blocks it mostly was found in the lower half of the intertidal zone.

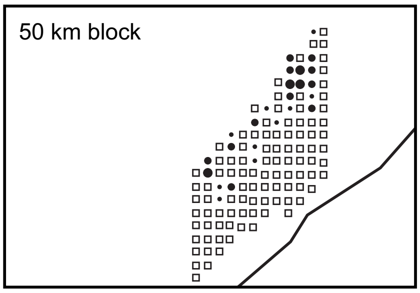


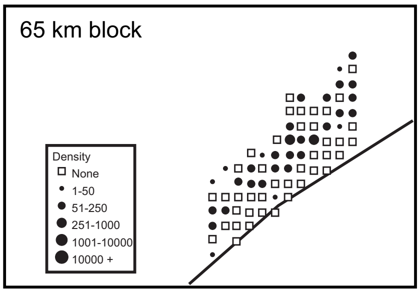












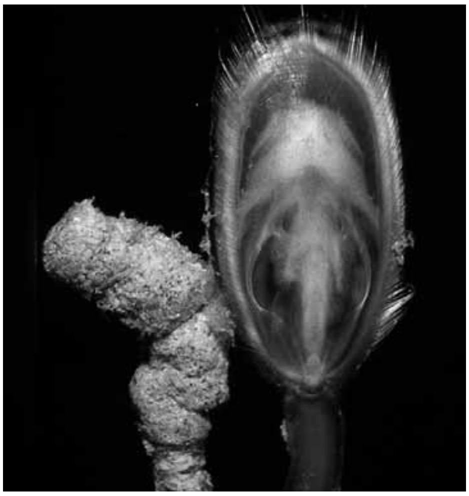
LINGULA ANATINA (BURROWING LAMPSHELL)

Species number	9301
Phylum	Brachiopoda
Class	
Family	Lingulidae
Distribution	1 block (35), 1 station, no map.
Abundance	1 specimen
Density	1
Length	8 mm

Sediment characteristics

Silt fraction	58%
Grain size	< 63 µm

Remarks: This peculiar animal looks like a bivalve, but is not related at all to mollusks. It can burrow a bit with the peduncle, which cannot be retracted into the shell. The animal sits vertically into the sediment with the peduncle directed downwards. The shell is directed upwards and the opening between the shells lies just below the surface of the sediment so that the animal is able to filter-feed.. Species very similar to our species existed more than 400 million years ago. The *Lingula* species of today are therefore called “living fossils”. Another peculiarity is that it is the only member of the phylum Brachiopoda that is eaten in Australia by man (Parker, 1982).



NUCULA CF ASTRICTA (IREDALE,1931).

Species number	1101
Phylum	Mollusca
Class	Bivalvia
Family	Nuculidae.
Distribution	Block 0, one station (B1), no map.
Abundance	1 specimen
Density	1
Length	4 mm

Sediment characteristics

Silt fraction	no data
Grain size	no data

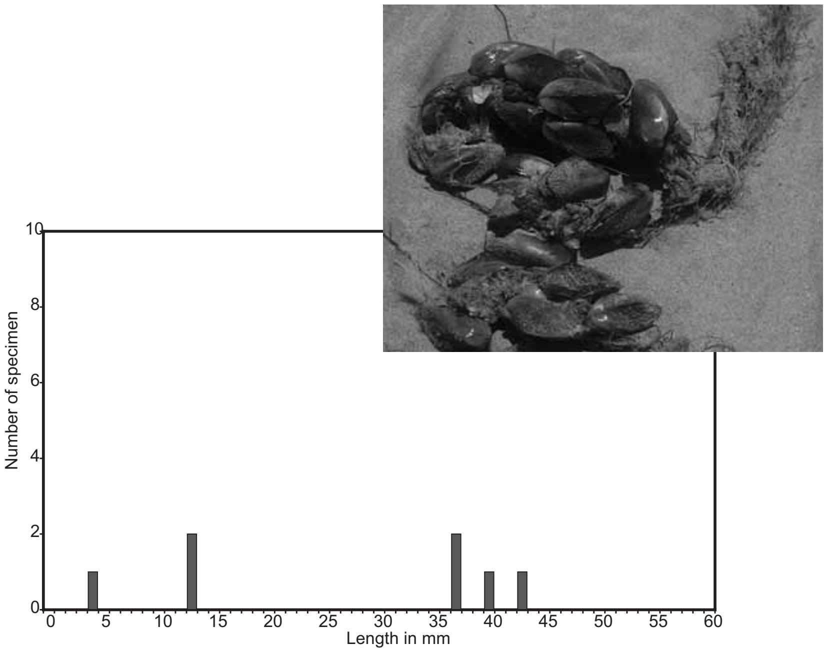
Remarks: This species looks a bit like *N. astricta*, but has a clear escutcheon that is bordered by a ridge. Also the general form of the shell is different. It is also not *N. obliqua,* as it has a light colored periostracum and a spoon like pocket for the resilium. The living shell has a yellow-green skin (periostracum). The inside of the shell is nacreous, and the hinge has many teeth (like the bloody cockle). The animal has no siphons. The rim of the foot is fringed. This species is more common in Roebuck Bay (Lavaleye et al, 1999).

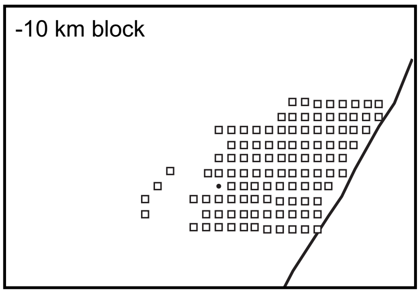
MODIOLUS MICROPTERUS DESHAYES,1836

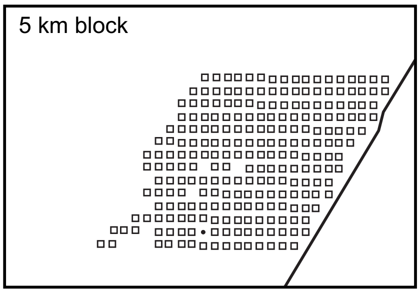
Species number	1301
Phylum	Mollusca
Class	Bivalvia
Family	Mytilidae
Distribution	5 blocks, 5 stations, map.
Abundance	7 specimen
Density	1-2
Length	4-43 mm

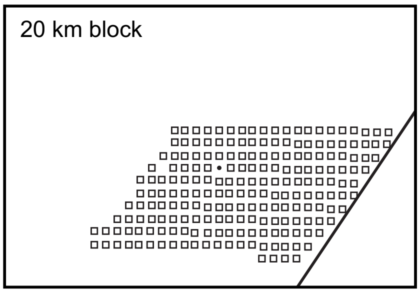
Sediment characteristics	
Silt fraction	10-78% (mean 51%)
Grain size	< 63 - 191 µm (mean < 95 µm)

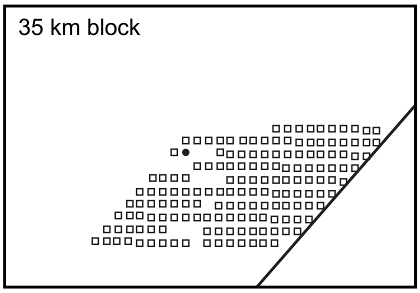
Remarks: This species was identified with Dharma (1992: pl. 18). Normally mussels sit firmly attached on rocks by their byssus threads, which they make with their foot. Unusually, this one lives buried in the fine mud, and can survive there because it constructs a kind of tube with the byssus threads towards the surface. Without this tube it could not pump water through the shell for filtering, as the animal does not have long siphons. During our expedition only a few specimens were found. However, we think that at times large spat falls can occur. Evidence for this was found in 1991 in Roebuck Bay, when fragments of these shells were often found in bird droppings (Tulp & de Goeij, 1994), constituting more than 39% of the prey intake. In Bloc 65 the animals were also found washed ashore after a storm. They were attached to the once submerged stems of Spinifex.

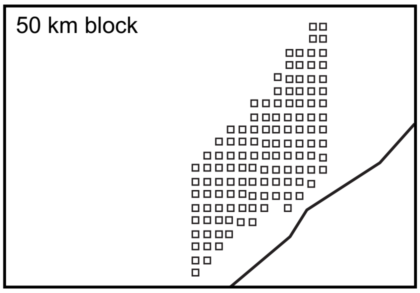


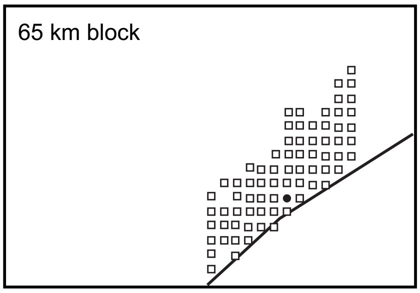

-10 km block


5 km block


20 km block


35 km block


50 km block


65 km block

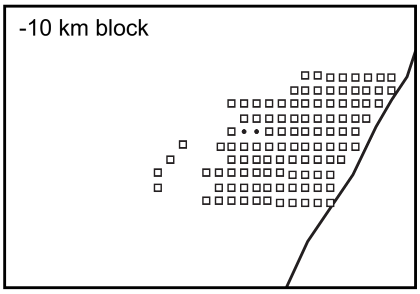
ANODONTIA OMISSA (IREDALE,1930)

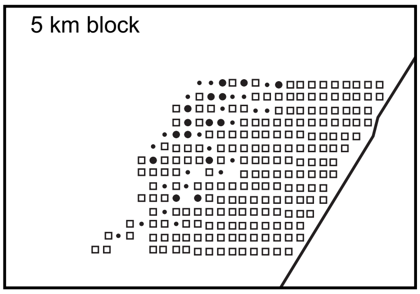
Species number	1401
Phylum	Mollusca
Class	Bivalvia
Family	Lucinidae
Distribution	6 blocks, 69 stations, map.
Abundance	123 specimen
Density	1-6
Length	2-21 mm

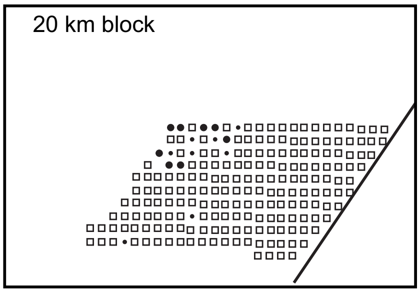
Sediment characteristics

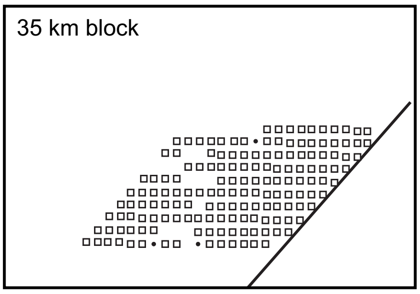
Silt fraction	16 - 99% (mean 79%)
Grain size	< 63 - 321 µm (mean < 71 µm)

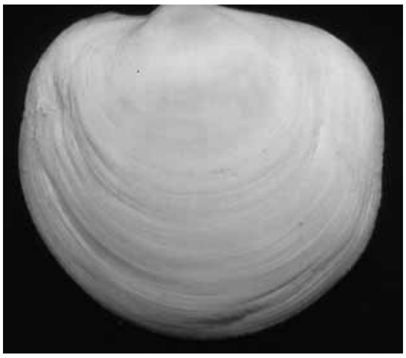
Remarks: This circular, smooth and inflated shell was identified with Lamprell & Whitehead (1992: fig. 140). This species was also reported from Roebuck Bay by Tulp & de Goeij (1994). This species prefers the lower half of the intertidal area. Although we collected more than 100 specimens there is not more than one year classes visible (see graph). This points to a life span not much longer than 1 year. This is in concordance with the conclusion of De Goeij *et al.* (2003) based on frequent sampling during six years in Roebuck Bay



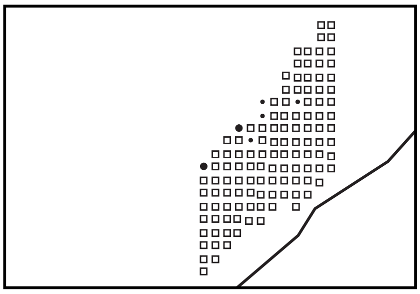


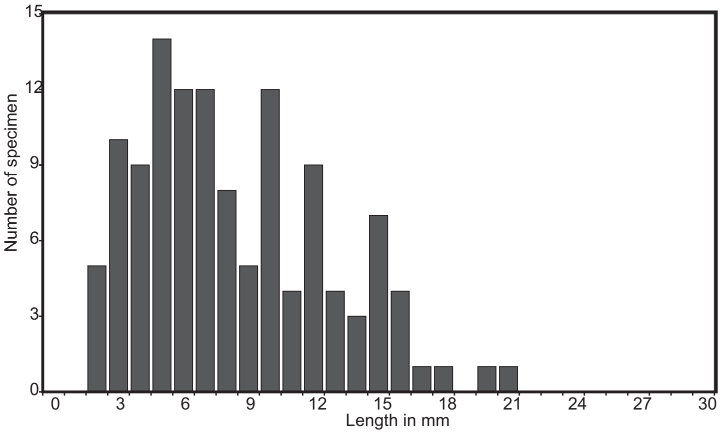


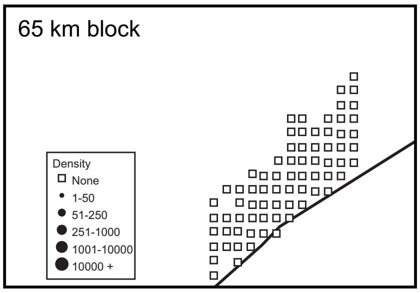




50 km block







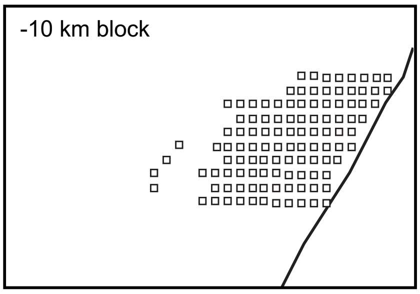
DIVARICELLA IRPEX (E.A. SMITH, 1885)

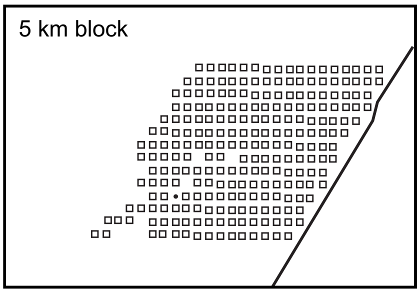
Synonym	*D. ornata* (Reeve,1850)
Species number	1411+(1413)
Phylum	Mollusca
Class	Bivalvia
Family	Lucinidae
Distribution	5 blocks, 84 stations, map.
Abundance	158 specimen
Density	1-9
Length	2-17 mm

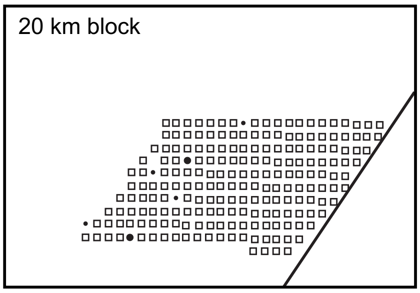
Sediment characteristics

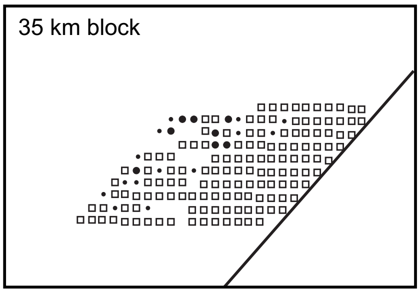
Silt fraction	2 - 92% (mean 55%)
Grain size	< 63 - 191 µm (mean < 80 µm)

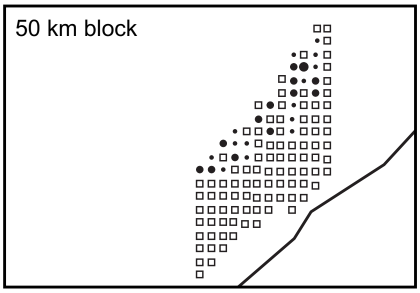
Remarks: This species with its peculiar divaricating ridges on the solid shell was identified with Dekker & Goud (1994) and Lamprell & Whitehead (1992: fig.143). This species is also common in Roebuck Bay. The other species Divaricella bardwelli that was collected in Roebuck Bay was not found on Eighty-mile Beach by us. The species perfers the lower half of the intertidal zone, and was especially common in the sandier. Blocs 35 and 50. In Bloc 65 it was probably not collected because the low water line could not be reached because of the neapy tides. From the graph it seems that there are two year classes. This is not consistent with our data from Roebuck Bay (De Goeij et al, 2003), so possible this is caused by pooling the data of different blocs where growth could be different. Identified with Dekker & Goud (1994), Lamprell & Whitehead (1992: fig. 143). This species was also reported from Roebuck Bay.

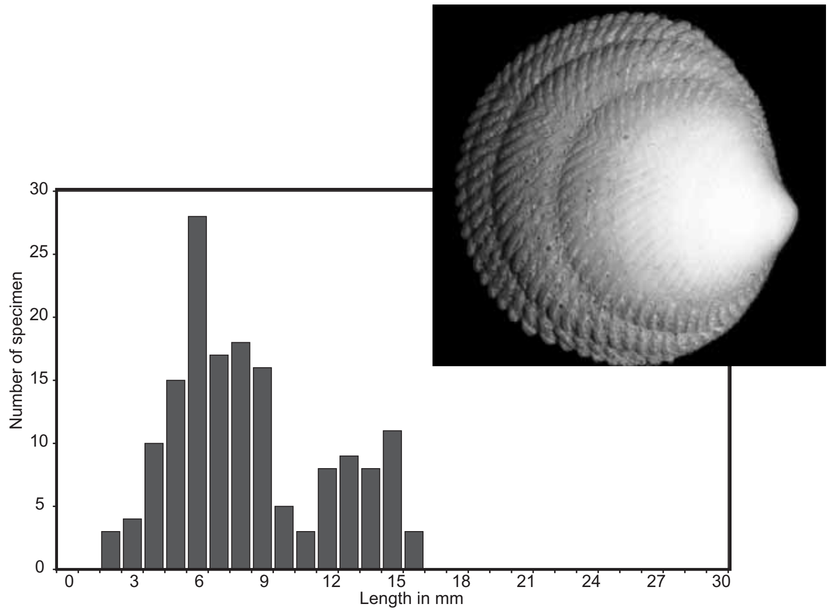


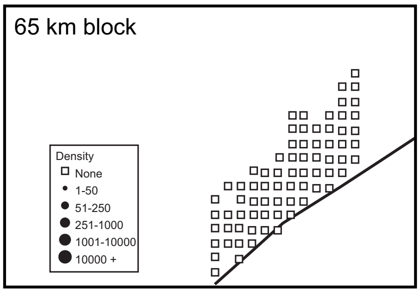












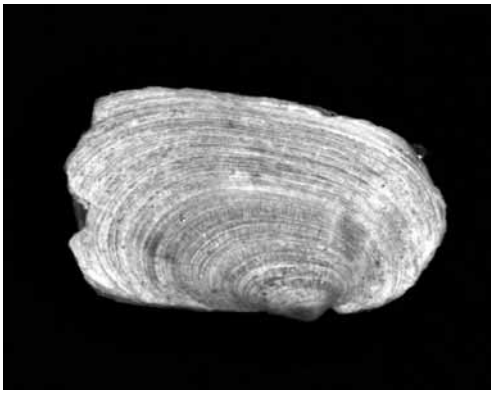
GALEOMMA SPEC.

Species number	1007
Phylum	Mollusca
Class	Bivalvia
Family	Galeommatidae
Distribution	Block 20, one station (J10), no map.
Abundance	1 specimen
Density	1
Length	3 mm

Sediment characteristics

Silt fraction	53%
Grain size	< 63 µm

Remarks: A small fragile shell gaping on both sides. In the SROEBIM-2002 expedition several of these bivalves were also found in Roebuck Bay. Always with small dimensions.



MYSELLA SPEC.

Species number	1008
Phylum	Mollusca
Class	Bivalvia
Family	Montacutidae
Distribution	Block 65, 1 station, no map.
Abundance	2 specimen
Density	2
Length	2-4 mm

Sediment characteristics

Silt fraction	57%
Grain size	< 63 µm

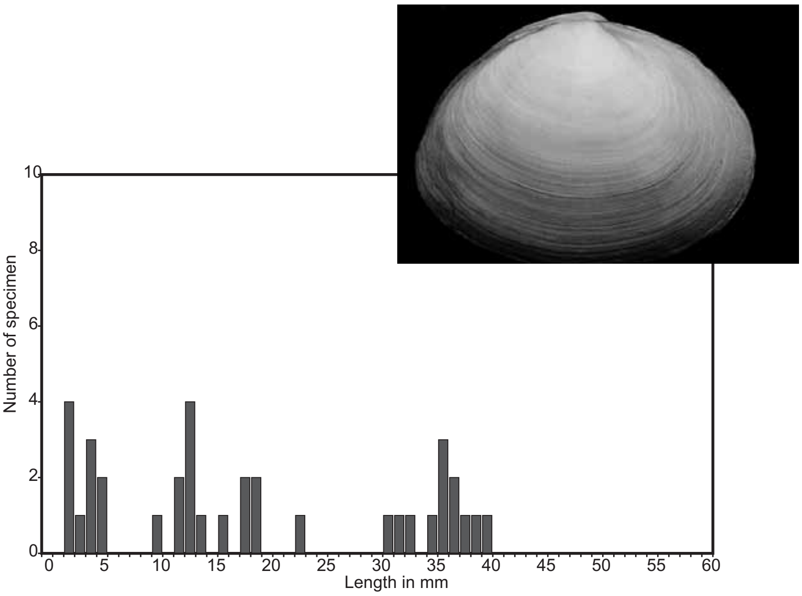
Remarks

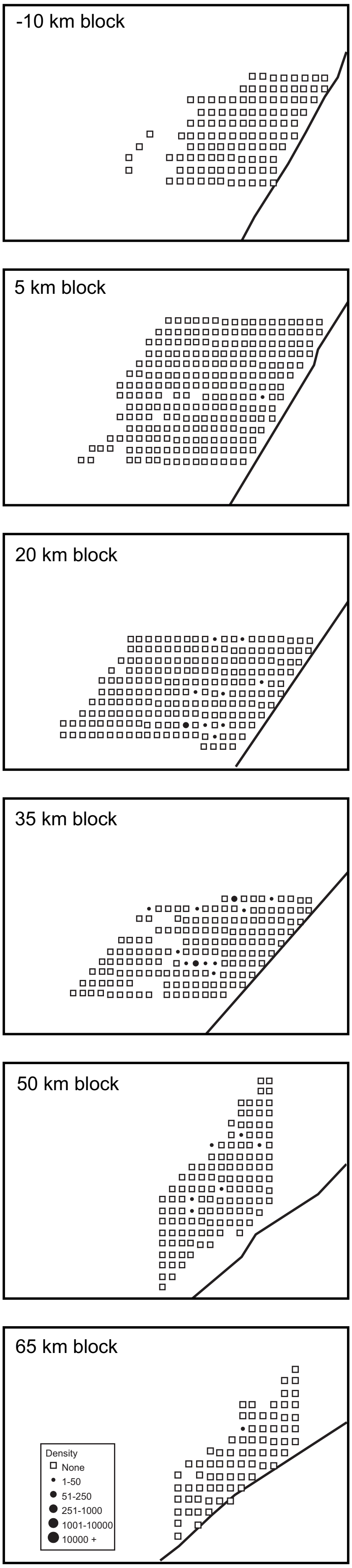
HETEROCARDIA GIBBOSULA STOLICZKA,1871

Species number	1601+(1005+1816+1817)
Phylum	Mollusca
Class	Bivalvia
Family	Mactridae
Distribution	5 blocks, 33 stations, map.
Abundance	36 specimen
Density	1-2
Length	2-40 mm

Sediment characteristics	
Silt fraction	27 - 95% (mean 64%)
Grain size	< 63 - 117 µm (mean < 77 µm)

Remarks: A brittle shell with a surface that is not shiny. Identified with Lamprell & Whitehead (1992: fig. 275). Tulp & de Goeij (1994) reported this species from Roebuck Bay under the name *Standella* cf *pellucida*.





PSEUDOPYTHINA MACROPHTHALMENSIS MORTON & SCOTT, 1989

Species number	(1641)
Phylum	Mollusca
Class	Bivalvia
Family	Kellidae
Distribution	1 blocks, 1 stations , no map.
Abundance	1 specimen
Density	1
Length	2 mm

Sediment characteristics	
Silt fraction	25%
Grain size	131 µm

Remarks: This small shell was only found alive once. Also in Roebuck Bay we only found this species a few times by core sampling. Finally it was discovered that this species lives attached to the carapace and hind legs of the sentinel crab *Macrophthalmus* spec. In the shell grit, however, the empty shells are very common in almost every sample. This shell was first described from an intertidal sandy mudflat in Hong Kong (Morton & Scott, 1989). It was found there attached to the lateral margins of the carapace and appendages of the crab *Macrophthalmus latreille* (Desmarest, 1817). Later this species was also discovered in Japan and Thailand (Kosuge & Itani, 1994). These last authors also discovered that the shell can detach and re-attach itself to the crab, which is very handy when the crab moults. To the best of our knowledge, these are the first records for Australia.

SOLEN SPEC.

Species number	1881
Phylum	Mollusca
Class	Bivalvia
Family	Solenidae
Distribution	1 block, 1 station (65), no map.
Abundance	1 specimen
Density	1
Length	50 mm

Sediment characteristics	
Silt fraction	46%
Grain size	94 µm

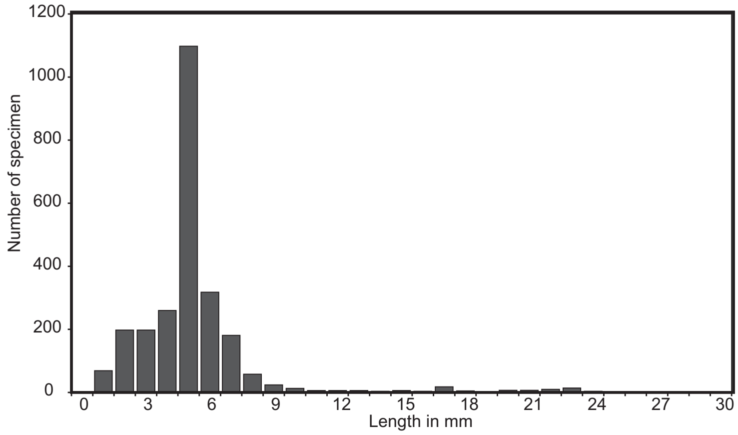
Remarks: We tried to identify the species with von Cosel (2002), but it differed from all species described there. The family Solenidae is very species rich in the Indo-Pacific, and still imperfectly known. Accordingly it would not be surprising to find an undescribed species in NW Australia. We had too little material to go deeper into the matter.

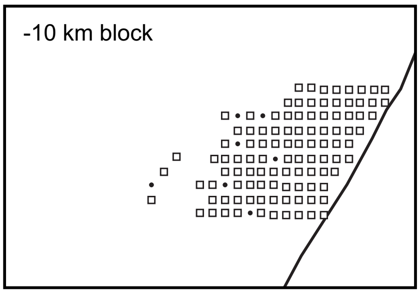
SILIQUA PULCHELLA

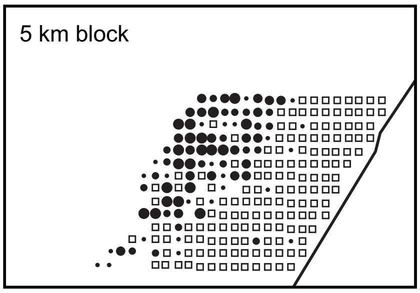
Species number	1711
Phylum	Mollusca
Class	Bivalvia
Family	Cultellidae
Distribution	7 blocks, 160 stations, map.
Abundance	2653 specimen
Density	1-208
Length	1-26 mm

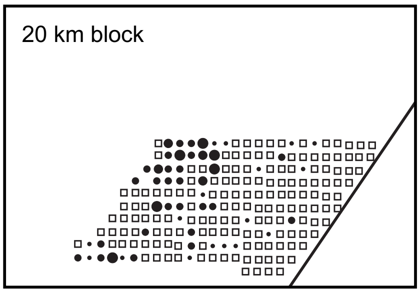
Sediment characteristics	
Silt fraction	16 - 99% (mean 73%)
Grain size	< 63 - 649 µm (mean < 81 µm)

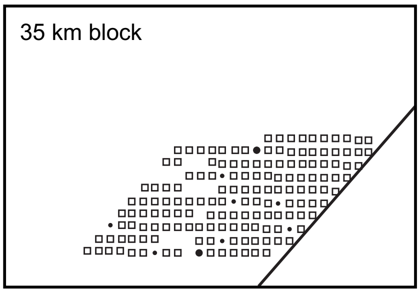
Remarks: This species was also found abundantly in Roebuck Bay. Lavaleye et al (1999), although mentioning the differences with the true *Siliqua winteriana* (Dunker,1852), tentatively identified it as *Siliqua* cf. *winteriana* as this name was already used for Roebuck Bay specimens by Tulp & De Goeij (1994). This bivalve is abundant in fluid mud. Peculiar is that it is adapted to predation by waders. The siphons are united and segmented and break off easily, which can save the animal. In addition it reacts on the slightest touch by frantically starting to burrow deeper (to get away from the bill of the predator). The strong burrowing capacity can be experienced by placing an animal on the mud surface. It then will burrow out of sight in only a few seconds. This filter-feeder was especially abundant in the muddy Blocs 5 and 20 in the lower half of the intertidal area.

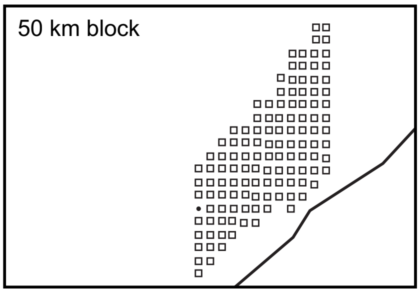


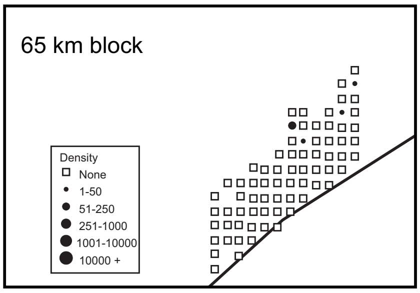










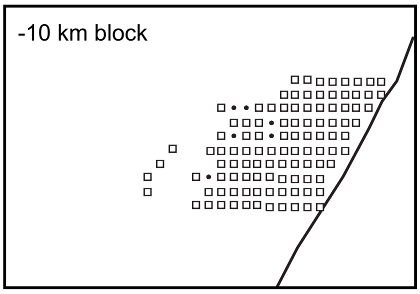


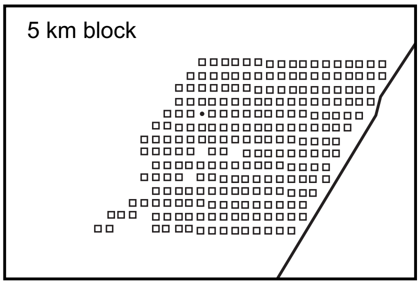
TELLINA INFLATA GMELIN,1791

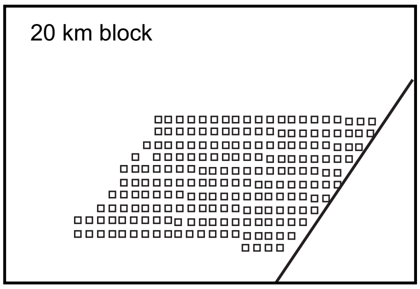
Species number	1803
Phylum	Mollusca
Class	Bivalvia
Family	Tellinidae
Distribution	3 blocks, 8 stations, map.
Abundance	8 specimen
Density	1
Length	7-40 mm

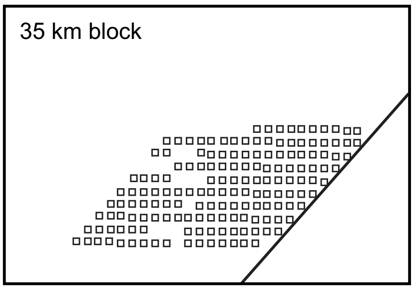
Sediment characteristics	
Silt fraction	16 - 84% (mean 41%)
Grain size	< 63 - 649 µm (mean < 224 µm)

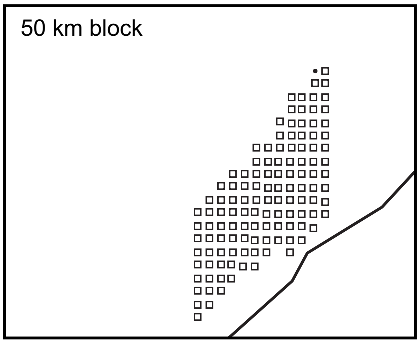
Remarks: It looks very much like a smooth *Tellina piratica*. Under the microscope a fine sculpture can be seen. Often the shell has an iridiscent shine. This shell was only found in the northern 3 blocs near the low water line. In Roebuck Bay it also was not very common.

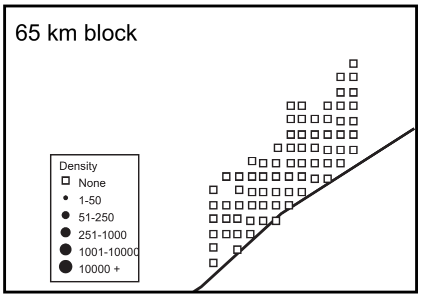


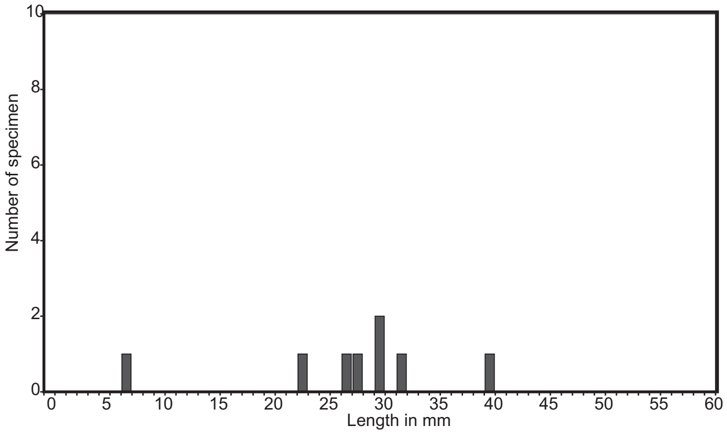










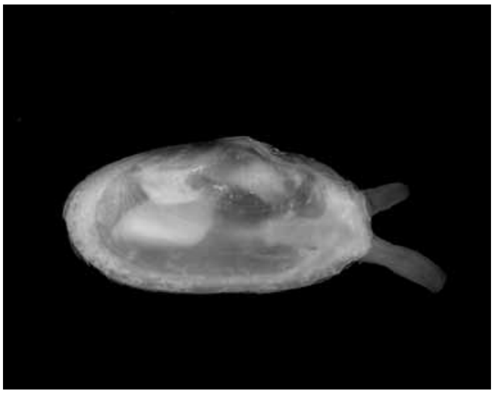


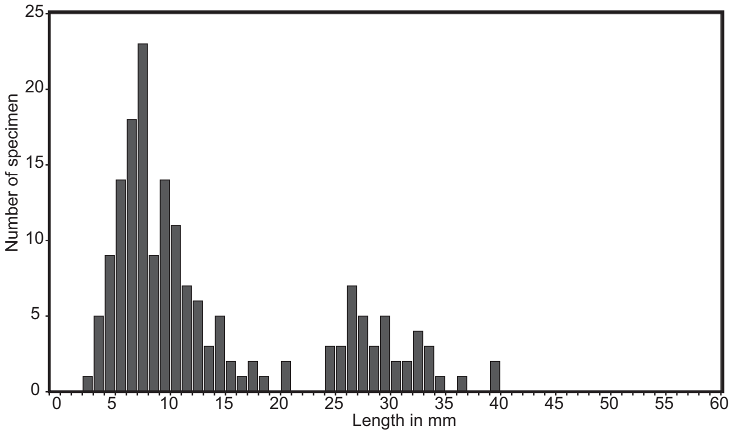
TELLINA AMBOYNENSIS (DESHAYES,1854)

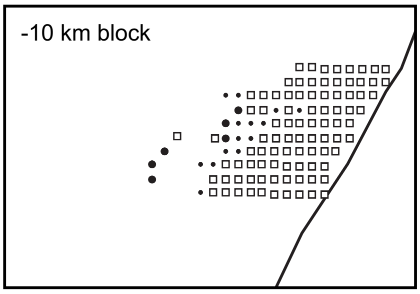
Species number	1804
Phylum	Mollusca
Class	Bivalvia
Family	Tellinidae
Distribution	6 blocks, 93 stations, map.
Abundance	174 specimen
Density	1-10
Length	3-40 mm

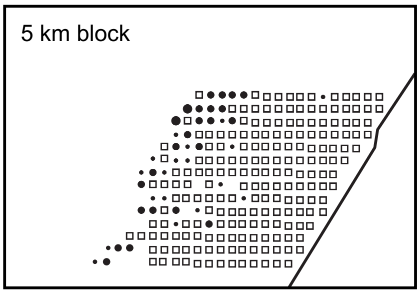
Sediment characteristics	
Silt fraction	14 - 99% (mean 66%)
Grain size	< 63 - 709 µm (mean < 112 µm)

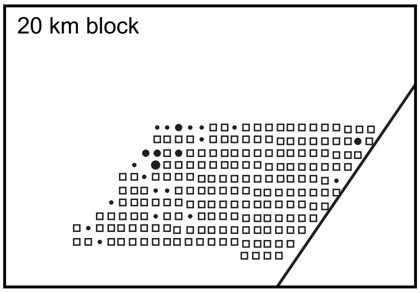
Remarks: Identified with Lamprell & Whitehead (1992: fig. 373). This species is very similar to *T. (Exotica)* spec. See for differences under *T. (Exotica)* spec. Tulp & de Goeij (1994) reported this species from Roebuck Bay under the name *Tellina* cf *ancilla*. It has long siphons, one of which acts as a vacuum cleaner to get food from the bottom surface. This is a common species near the low water line in the muddy Blocs -10, 5 and 20. The graph of the length distribution shows two year classes with a clear gab in between. This species is also rather frequent in Roebuck Bay. The shell has the typical form of the genus Gari, with a few radiating ridges.

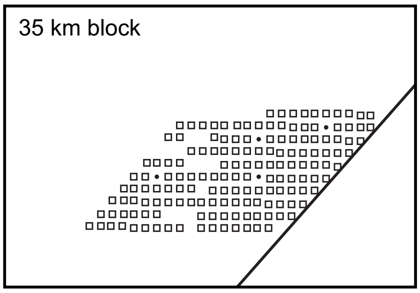


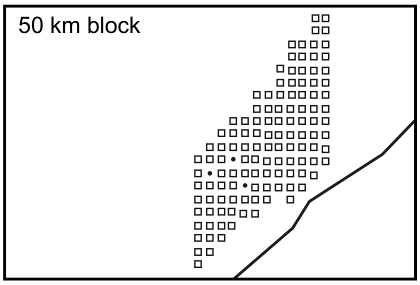


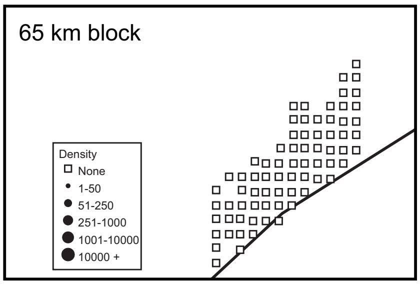










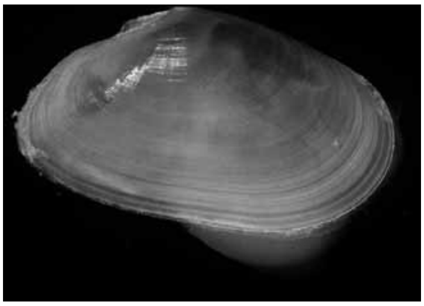


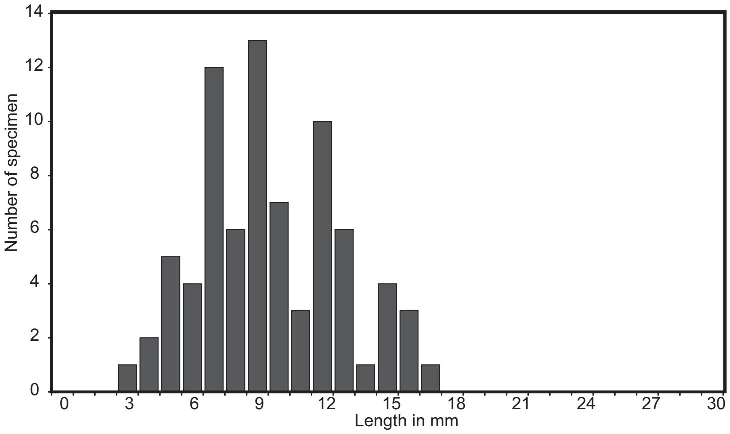
TELLINA SPEC. (TELLINA '*EXOTICA*')

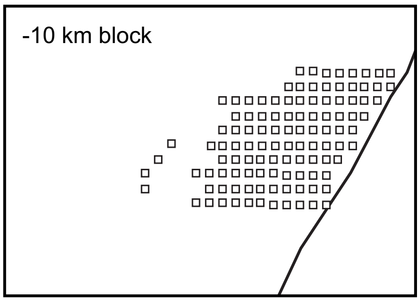
Species number	1821
Phylum	Mollusca
Class	Bivalvia
Family	Tellinidae
Distribution	7 blocks, 70 stations, map.
Abundance	81 specimen
Density	1-3
Length	3-17 mm

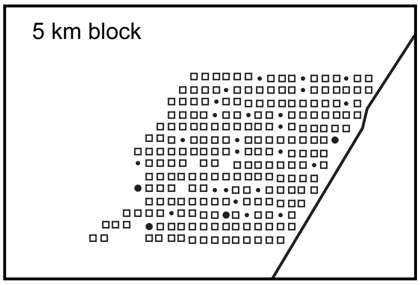
Sediment characteristics	
Silt fraction	6 - 98% (mean 57%)
Grain size	< 63 - 655 µm (mean < 92 µm)

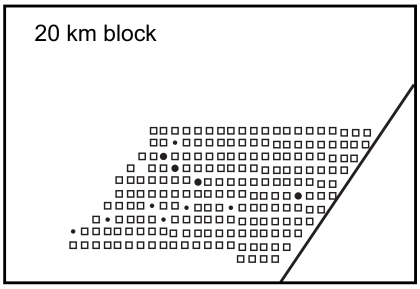
Remarks: This species is very similar to *T. amboynensis*. The dorso-posterior corner of the shell is hooked instead of rounded. In addition, the dorso-posterior area is not smooth but ribbed (microscope). Tulp & de Goeij (1994) reported this species from Roebuck Bay under the name *Macoma* spec. To some of their samples the name *Macoma exotica* was attached, and therefore that name got stuck and is still used here. However, the name "exotica" only exists as the name of a subgenus and not as a species name within the genus *Macoma*. This species is distributed over the whole intertidal area and over most of the sampled blocs, and does not seems to have a preference in these respects. From the graph it seems that this species has a life span of about 1 year. This is in accordance with our data from Roebuck Bay (De Goeij et al, 2003).

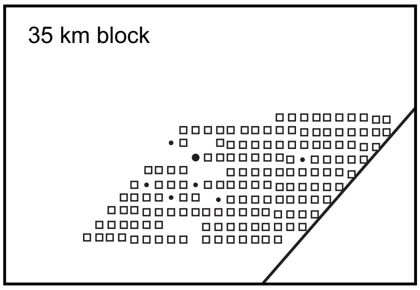


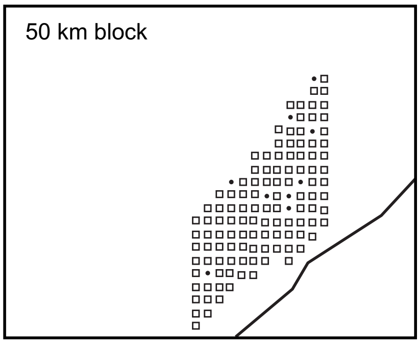


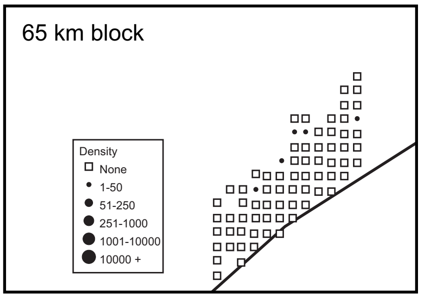












Tellina spec. 1 (Tellina "donax")

Species number	1813
Phylum	Mollusca
Class	Bivalvia
Family	Tellinidae
Distribution	1 block, 1 station (5E1), no map.
Abundance	1 specimen
Density	1
Length	9 mm

Sediment characteristics	
Silt fraction	0.8%
Grain size	266 µm

Remarks: A rather solid white smooth shell, of which the form is a bit similar to that of *Donax cuneatus*. Hence our fieldname. There is a small external ligament visible.

Gari spec.

Species number	(1810)
Phylum	Mollusca
Class	Bivalvia
Family	Psammobiidae
Distribution	1 block (-10), 1 station, no map.
Abundance	1 specimen
Density	1
Length	10 mm

Sediment characteristics	
Silt fraction	45%
Grain size	100 µm

Remarks:

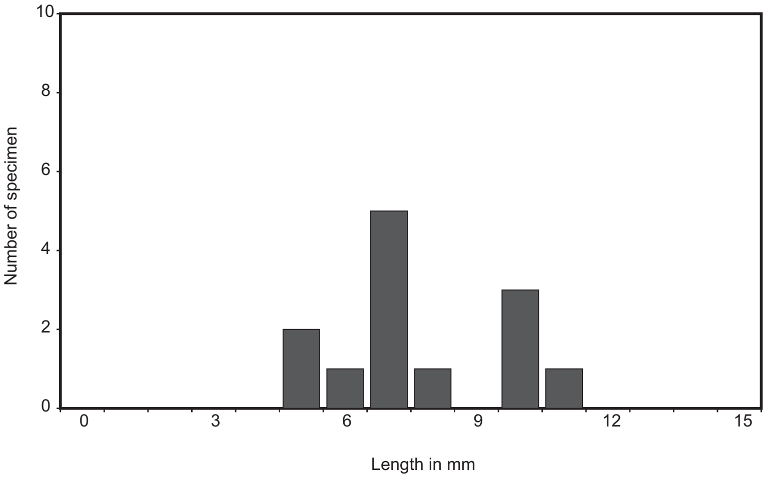
THEORA FRAGILIS (A.ADAMS,1855) (CLOG TELLINA)

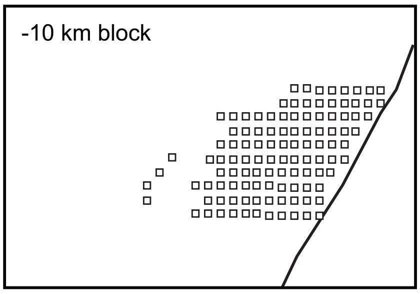
Species number	1815
Phylum	Mollusca
Class	Bivalvia
Family	Semelidae
Distribution	2 blocks (5+20), 10 stations, map.
Abundance	14 specimen
Density	1-3
Length	5-11 mm

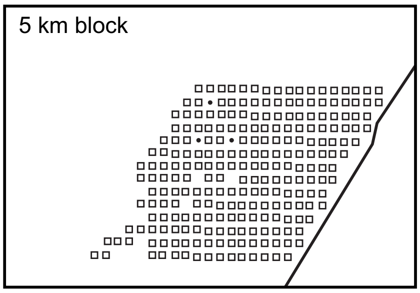
Sediment characteristics

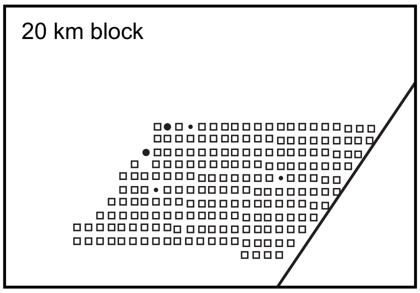
Silt fraction	84 - 98% (mean 90%)
Grain size	< 63 µm (mean < 63 µm)

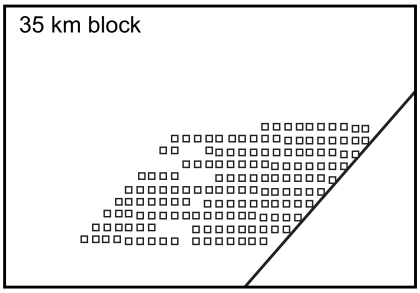
Remarks: An inflated elongated semitransparent shell with no sculpture. The external ligament is small. The internal ligament sits in a spoonlike projection of the hinge. The shell does not have the internal ridge that exists in the species *Theora lubrica* Gould,1861. The type of *T. fragilis* was pictured by Climo (1976).The highest abundance of this species was found at the low waterline in Bloc 20. We did not find it in Roebuck Bay during our surveys.

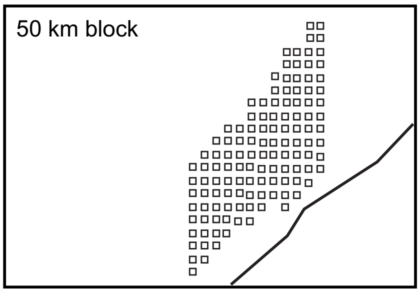


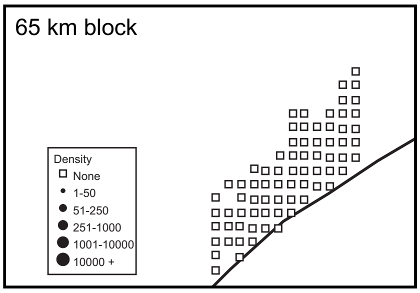












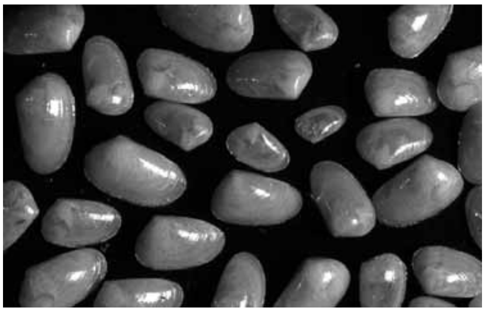
PAPHIES CF ALTENAI (DE ROOIJ-SCHUILING,1972)

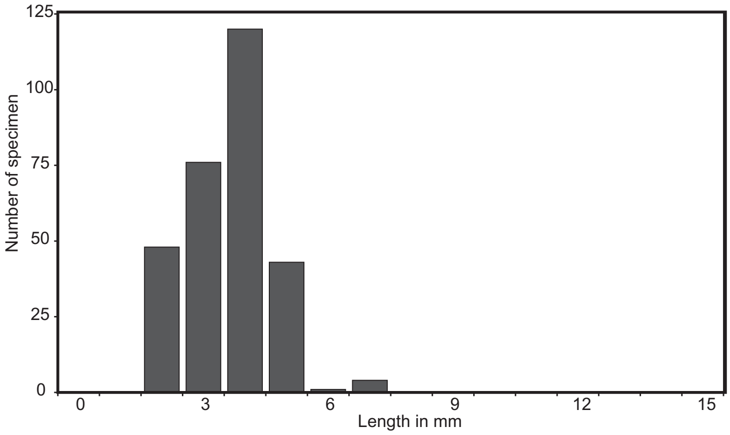
Species number	1851
Phylum	Mollusca
Class	Bivalvia
Family	Mesodesmatidae
Distribution	6 blocks, 20 stations, map.
Abundance	319 specimen
Density	1 - 80
Length	2 - 7 mm

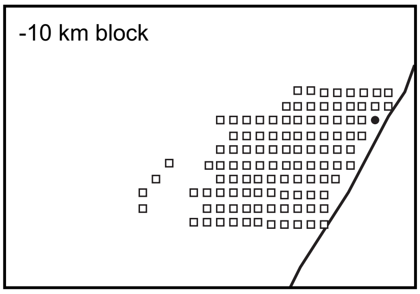
Sediment characteristics

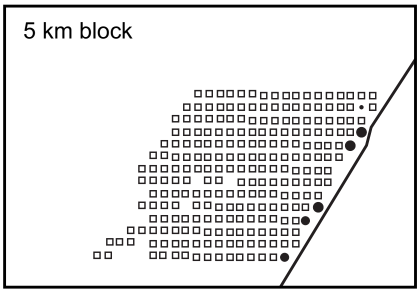
Silt fraction	0.1 - 79% (mean 25%)
Grain size	< 63 - 257 µm (< 167 µm)

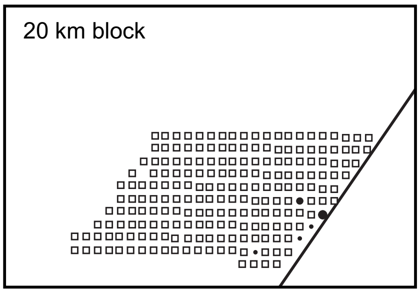
Remarks: This small shell with a yellow shiny periostracum looks very much like a juvenile *Donax*, but it lacks an external ligament, which is one of the characteristics for the family Mesodesmatidae. It was mostly found in high densities in the hard-packed sand at the base of the beach. Foraging birds, especially Great Knots, had discovered this shell too and were seen taking and swallowing it in large numbers on ebbing tides.

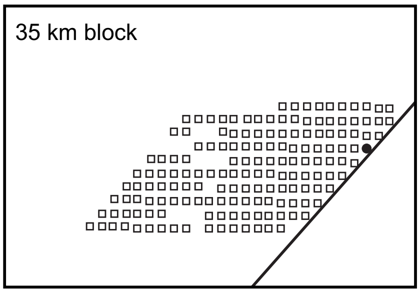


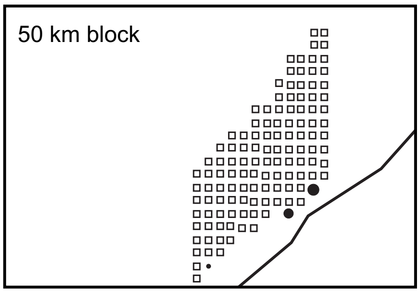


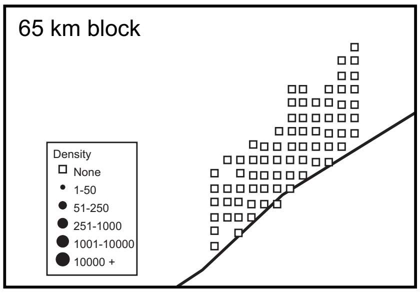












DONAX CUNEATUS L., 1758

Species number	1852
Phylum	Mollusca
Class	Bivalvia
Family	Donacidae
Distribution	2 blocks, 2 stations, no map.
Abundance	2 specimen
Density	1
Length	12 - 22 mm

Remarks: This species was also often found alive on the sandy wet beach near block 0. The specimens here were dug up, probably by a bird. They were otherwise undamaged, maybe because they were to hard or big to be eaten.

LAEVIDENTALIUM CF *LUBRICATUM* (G.B. SOWERBY,1860) (SMOOTH TUSKSHELL)

Species number	3101
Phylum	Mollusca
Class	Scaphopoda
Family	Dentaliidae
Distribution	1 block (20), 2 stations, no map.
Abundance	2 specimen
Density	1
Length	5 - 7 mm

Sediment characteristics

Silt fraction	63 - 93% (mean 78%)
Grain size	< 63 µm (mean < 63 µm)

Remarks: The shell looks similar to *L. lubricatum,* which also occurs in Roebuck Bay, but is much larger (6 cm) (Lamprell & Healy, 1998). The "smooth tuskshell" is common on the intertidal flats of Roebuck Bay.

POLYSCHIDES GIBBOSUS (VERCO, 1911) (TINY TUSKSHELL)

Species number	3201
Phylum	Mollusca
Class	Scaphopoda
Family	Cadulidae
Distribution	2 blocks, 4 stations, no map.
Abundance	4 specimen
Density	1
Length	5 mm

Sediment characteristics

Silt fraction	2 - 62% (mean 41%)
Grain size	< 63 - 168 µm (< 98 µm)

Remarks: The small curved shell is transparent, glossy and a bit inflated in the middle. The top of the shell (apex) is crenulated by four equal notches. This species was identified with Lamprell & Healy (1998). The only differences seem to be that our specimens are much smaller (5 instead of 17 mm) and that we found it intertidally. We collected many shells occupied by small crustaceans (Corophiidae) in shallow pools in the upper part of the intertida area (see page 124 under Hermit mud shrimp)

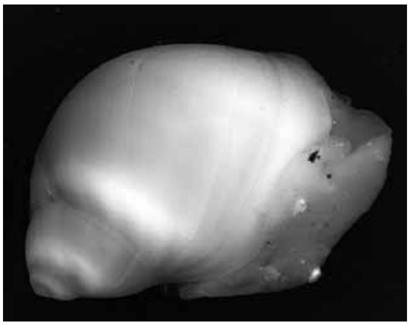
POLINICES CONICUS (LAMARCK,1822)

Species number	2501
Phylum	Mollusca
Class	Gastropoda
Family	Naticidae
Distribution	1 block (-10), 1 station, no map.
Abundance	1 specimen
Density	1
Length	11 mm

Sediment characteristics

Silt fraction	44%
Grain size	105 µm

Remarks: Surprisingly this moonshell was only found once, while in Roebuck Bay it is much more common. The shell is white and the operculum corneous. It preys on bivalves.



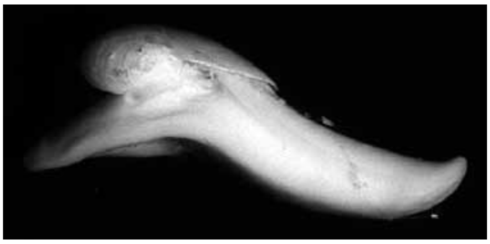
SINUM SPEC.

Species number	2516
Phylum	Mollusca
Class	Gastropoda
Family	Naticidae
Distribution	2 blocks (5+20), 2 station, no map.
Abundance	2 specimen
Density	1
Length	6-13 mm

Sediment characteristics

Silt fraction	87 - 98% (93%)
Grain size	< 63 - 105 µm (< 84 µm)

Remarks: The two specimens were both found near the spring low water line. The shell has a very large last whorl, is flattened, fragile and translucent. The elongated animal is more than twice as long as the shell and cannot retract itself into it.



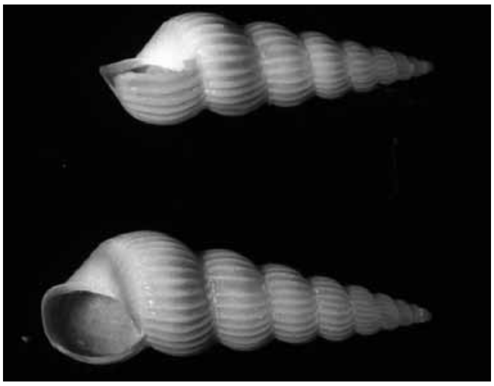
EPITONIUM SPEC.

Species number	2201
Phylum	Mollusca
Class	Gastropoda
Family	Epitoniidae
Distribution	1 block (20), 2 stations, no map.
Abundance	4 specimen
Density	1-3
Length	8-10 mm

Sediment characteristics

Silt fraction	16 - 45% (31%)
Grain size	101 - 130 µm (116 µm)

Remarks: The specimens were all found together with the large sand *Edwardsia* spec. (a digging sea anemone). It is known that many Epitoniidae that they parasitize on sea anemones. They suck out body fluids from the anemones with their long proboscis.



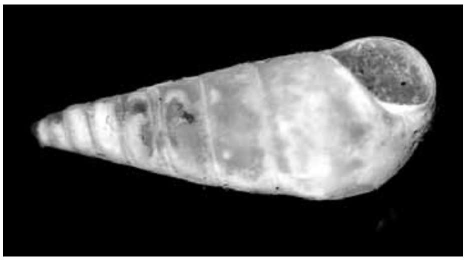
EULIMA SPEC.

Species number	2401
Phylum	Mollusca
Class	Gastropoda
Family	Eulimidae
Distribution	1 block (0), 1 stations, no map.
Abundance	1 specimen
Density	1
Length	2 mm

Sediment characteristics

Silt fraction	no data
Grain size	no data

Remarks: Eulimidae are ecto-parasitic. The host is often an echinoderm (sea cucumber, sea star etc). This snail has a smooth, white, shiny and slender shell of which the axis is a bit bent. Eulimidae are mostly ectoparasites of echinoderms (sea cucumbers, starfishes etc.).



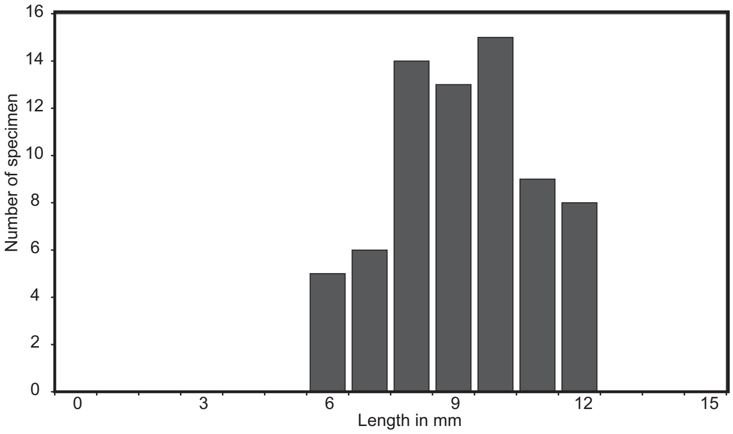
MITRELLA ESSINGTONENSIS (REEVE, 1859)

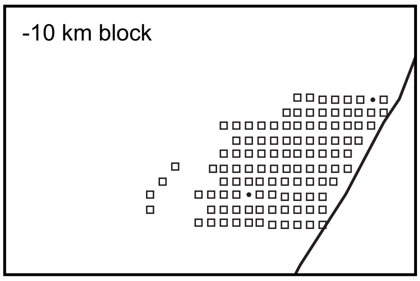
Species number	2553
Phylum	Mollusca
Class	Gastropoda
Family	Columbellidae
Distribution	6 blocks, 58 stations, map.
Abundance	70 specimen
Density	1-3
Length	6-12 mm

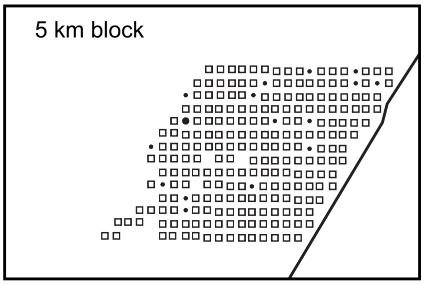
Sediment characteristics

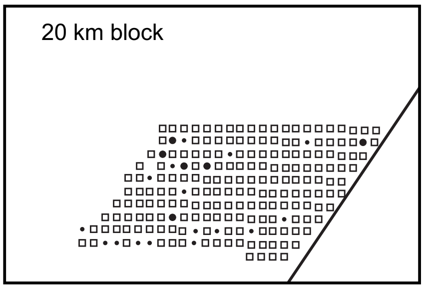
Silt fraction	13 - 96% (65%)
Grain size	< 63 - 139 µm (< 73 µm)

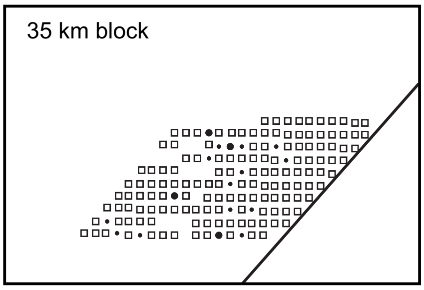
Remarks: This shell was found in two color varieties, either uniform purple-brown, or whitish with three yellow-brown spiral bands on the last whorl (see figure). These little active predators forage on the surface of the mudflats. With their flexible siphon they sense their prey. It is common on the muddy blocs, but totally absent form the two sandy Blocs 50 and 65. There was no clear preference for a height in the intertidal area.

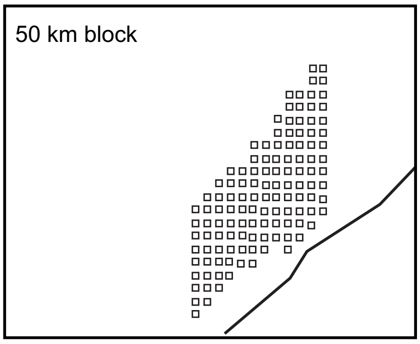


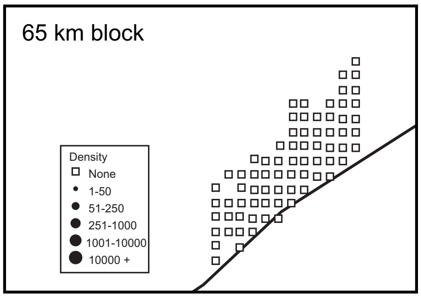












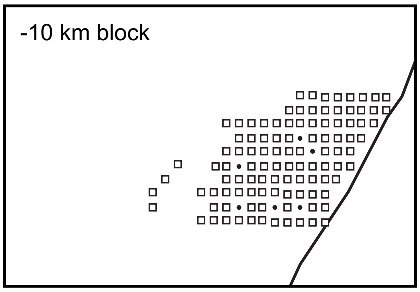
NASSARIUS DORSATUS (RÖDING,1798) (LARGE INGRID EATING SNAIL)

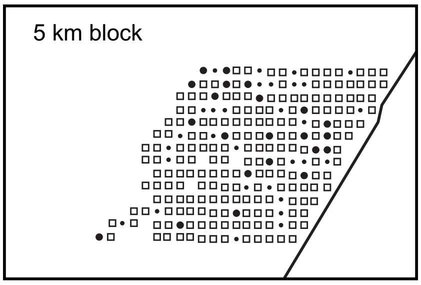
Species number	2601
Phylum	Mollusca
Class	Gastropoda
Family	Nassariidae
Distribution	7 blocks, 124 stations, map.
Abundance	184 specimen
Density	1-17
Length	3-30 mm

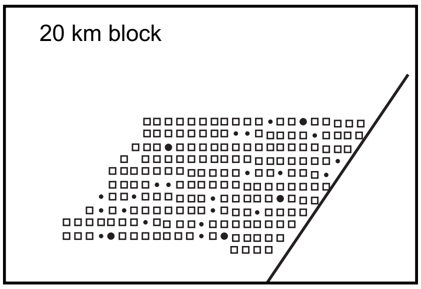
Sediment characteristics

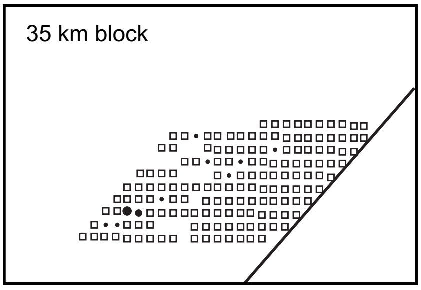
Silt fraction	4 - 99% (62%)
Grain size	< 63 - 655 µm (< 89 µm)

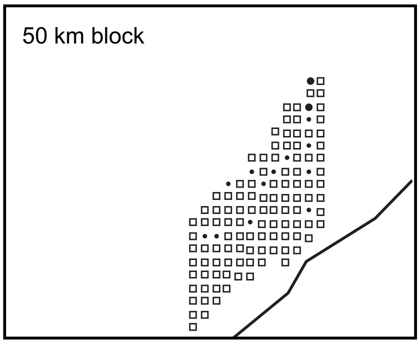
Remarks: Identified with Abbott & Dance (1982: p. 180), Wells & Bryce (1985: Fig. 347) and Wilson (1994: pl. 14). Very commonly seen everywhere on the flats crawling around looking for prey or carrion. The foot is very powerful, and when holding the shell in your hand it will wriggle a lot with its foot to free itself. Also known as a dogwhelk. The name “Ingrid-eating snail” was coined because these animals were particularly attracted to the legs of Ingrid Tulp, who did pioneering work on the benthos of Roebuck Bay in 1991 (Tulp & De Goeij, 1994).
Ingrid-eating snails were more often seen eating brid droppings than any other kind of prey or carrion There was a nice positive relationship between the number of snail-stations per sampling block, and the density of shorebirds in that feeding block.

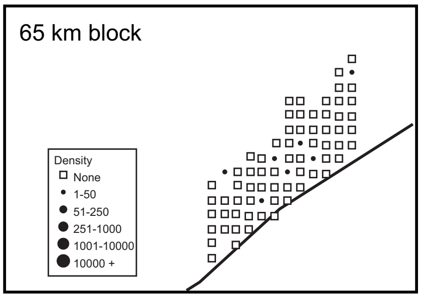

-10 km block


5 km block


20 km block


35 km block


50 km block


65 km block

RINGICULA SPEC.

Species number	2902
Phylum	Mollusca
Class	Gastropoda
Family	Ringiculidae
Distribution	2 blocks (5+20), 5 stations, no map.
Abundance	7 specimen
Density	1-2
Length	3-4 mm
Sediment characteristics	
Silt fraction	47 - 95% (76%)
Grain size	< 63 - 93 µm (< 69 µm)

Remarks: This species can walk backwards (personal observation).

CHRYSALLIDA SPEC.

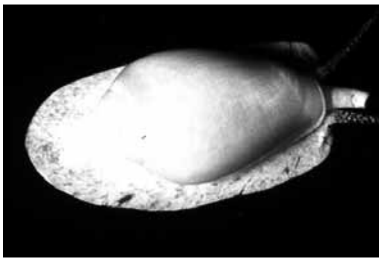
Species number	2993
Phylum	Mollusca
Class	Gastropoda
Family	Pyramidellidae
Distribution	1 block (20), 2 stations, no map.
Abundance	2 specimens
Density	1
Length	3 mm
Sediment characteristics	
Silt fraction	66 - 70% (mean 68 %)
Grain size	< 63 µm (mean < 63 µm)

Remarks: These animals are ectoparasites. The shell is relatively high spired with axial sculpture and a blunt apex. The mouth has a columellar tooth.

MARGINELLIDAE

Species number	2701
Phylum	Mollusca
Class	Gastropoda
Family	Marginellidae
Distribution	1 block, 2 stations, no map.
Abundance	2 specimen
Density	1
Length	6-7 mm
Sediment characteristics	
Silt fraction	24 - 66% (mean 45%)
Grain size	< 63 - 126 µm (mean < 94 µm)

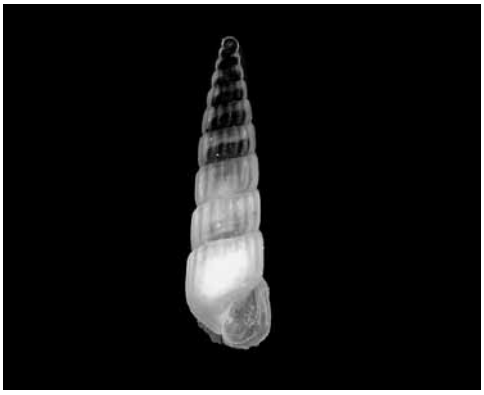
Remarks: Carnivorous and scavenging white snails, common on the mud flats, crawling over the mud flat during low tide looking for prey. It can breathe when it is buried in the mud by using its siphon, this flexible organ is also the “nose” of the animal. These snails can dye your fingers purple if you squeeze them.



TURBONILLA SPEC.

Species number	2994
Phylum	Mollusca
Class	Gastropoda
Family	Pyramidellidae
Distribution	1 block (35), 1 station, no map.
Abundance	1 specimen
Density	1
Length	2 mm
Sediment characteristics	
Silt fraction	42%
Grain size	107 µm

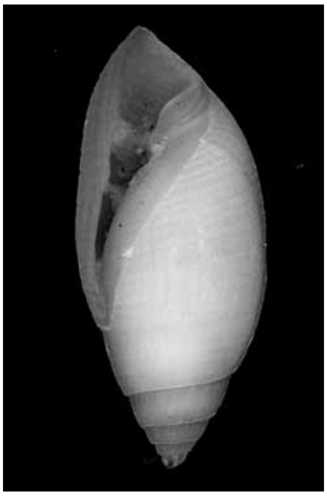
Remarks: The animal has an ectoparasitic life. The shell is high spired with many axial ribs. The apex is heterostrophic, which means that the first whorls of the shell are sinistral and sit at an angle (often 90°) to the rest of the dextral shell.



ACTEONIDAE SPEC.

Species number	2941
Phylum	Mollusca
Class	Gastropoda
Family	Acteonidae
Distribution	1 block (35), 1 station, no map.
Abundance	1 specimen
Density	1
Length	2 mm
Sediment characteristics	
Silt fraction	42%
Grain size	107 µm

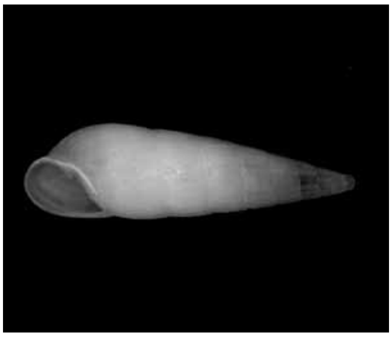
Remarks:



SYRNOLA SPEC.

Species number	2995
Phylum	Mollusca
Class	Gastropoda
Family	Pyramidellidae
Distribution	1 block (35), 1 station, no map.
Abundance	1 specimen
Density	1
Length	4 mm
Sediment characteristics	
Silt fraction	95%
Grain size	< 63 µm

Remarks: Also an ectoparasite. The shell is smooth and high spired. Like *Turbonilla* it has an heterostrophic top. The mouth has a columellar tooth.

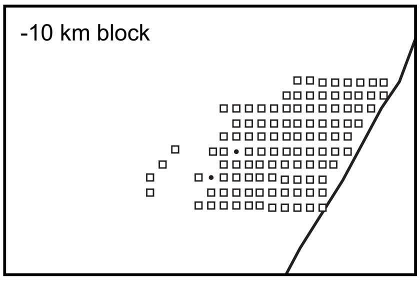


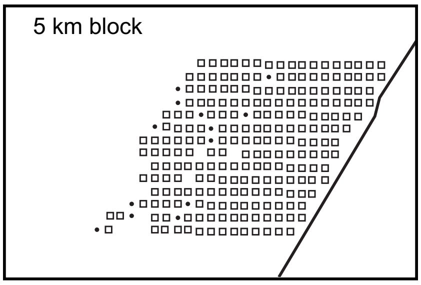
SIPUNCULUS CF. *NUDUS*

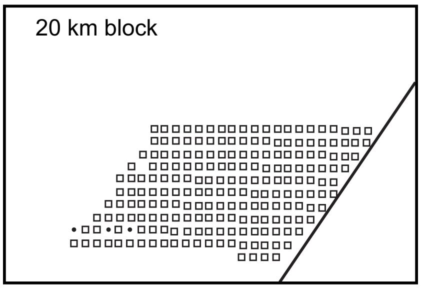
Species number	4502
Phylum	Sipuncula
Class	
Family	Sipunculidae
Distribution	4 blocks, 19 stations, map.
Abundance	19 specimen
Density	1
Length	4-50 mm

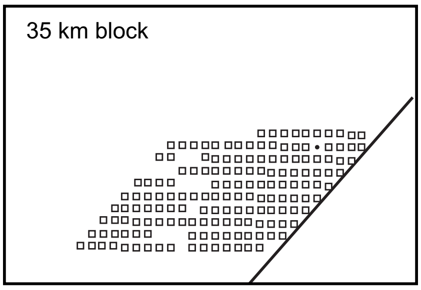
Sediment characteristics	
Silt fraction	30-90% (mean 68%)
Grain size	< 63 - 231 µm (mean < 68 µm)

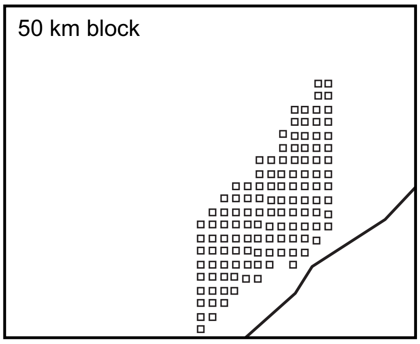
Remarks:
Uncommon- a remarkable constrast to Roebuck Bay, where Sipuncula are common.
The worm-like animal has no obvious characteristicson the outside. No bristles, no segmentation, no head, eyes or tentacles. The body has a rather tough skin with many longitudinal as well as transverse ribs. It was found in the muddy and lower part of the intertidal area, except for one station.

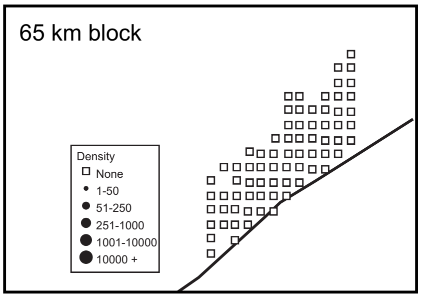


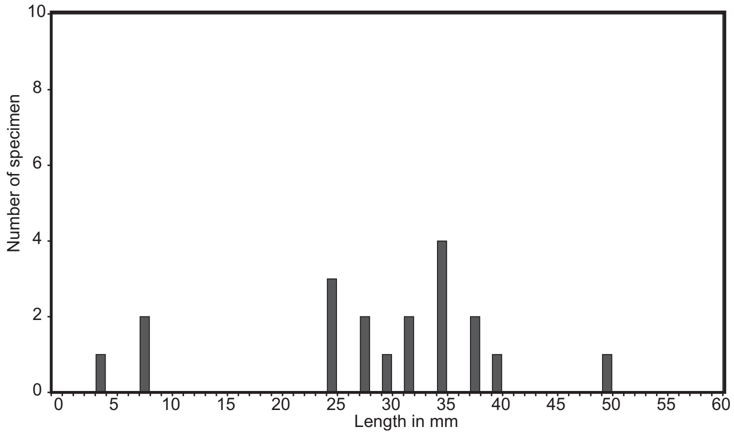












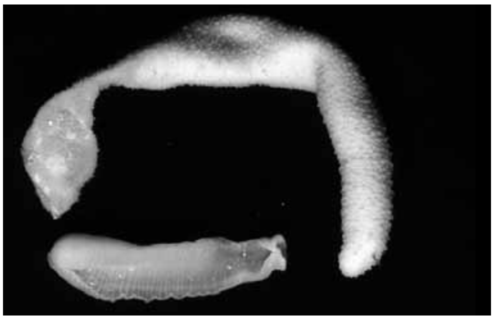
ECHIURUS SPEC. (SAND WORM)

Species number	4601
Phylum	Echiura
Class	
Family	
Distribution	2 blocks (20+65), 2 stations, no map.
Abundance	2 specimen
Density	1
Length	35-60 mm

Sediment characteristics

Silt fraction	43-91% (mean 67%)
Grain size	< 63 - 98 µm (mean < 80 µm)

Remarks: Only found near the spring low water line. The animal has a spoon-like proboscis for collecting its food. On disturbance this organ is easily detached (see figure). Our specimens have a knobbed skin and two strong yellowish hooks near the front that stick out of the body.



GREY *HARMOTHOE* SPEC.

Species number	5122
Phylum	Annelida
Class	Polychaeta
Family	Polynoidea
Distribution	3 blocks, 3 stations, no map.
Abundance	3 specimen
Density	1
Length	5-17 mm

Sediment characteristics

Silt fraction	47- 66% (mean 57%)
Grain size	< 63 - 93 µm (mean < 73 µm)

Remarks:

GREEN *HARMOTHOE* SPEC.

Species number	5123
Phylum	Annelida
Class	Polychaeta
Family	Polynoidea
Distribution	2 blocks, 2 stations, no map.
Abundance	4 specimen
Density	1-3
Length	3-10 mm

Sediment characteristics

Silt fraction	91%
Grain size	< 63

Remarks:

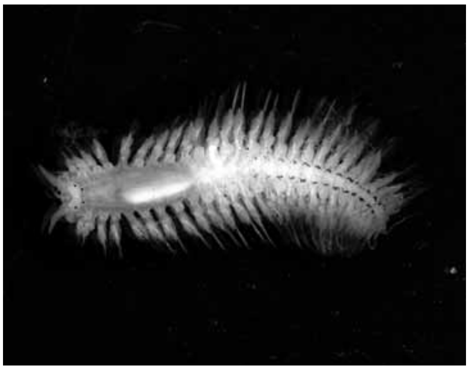
RED HEADED *HARMOTHOE* SPEC.

Species number	5124
Phylum	Annelida
Class	Polychaeta
Family	Polynoidea
Distribution	1 blocks, 2 stations, no map.
Abundance	3 specimen
Density	1-2
Length	5-7 mm

Sediment characteristics

Silt fraction	43- 57% (mean 50%)
Grain size	< 63 - 98 μm (mean < 80 μm)

Remarks:

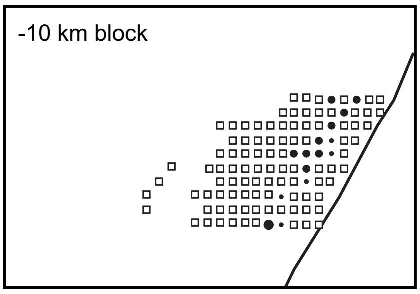


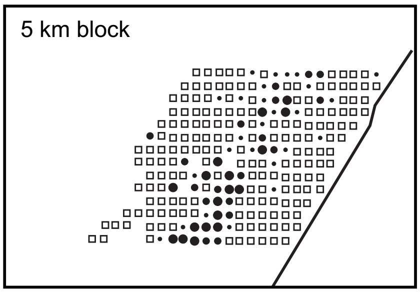
RED *HARMOTHOE* SPEC. (COMMENSAL POLYNOID)

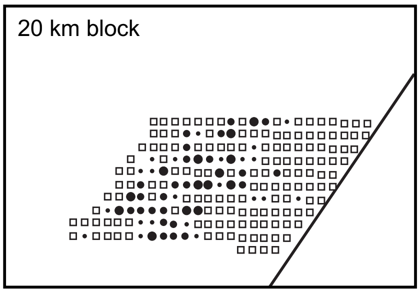
Species number	5121
Phylum	Annelida
Class	Polychaeta
Family	Polynoidea
Distribution	7 blocks, 244 stations, map.
Abundance	1002 specimen
Density	1-22
Length	1-20 mm

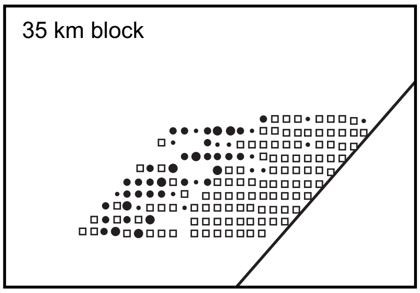
Sediment characteristics	
Silt fraction	4- 97% (mean 57%)
Grain size	< 63 - 144 µm (mean < 87 µm)

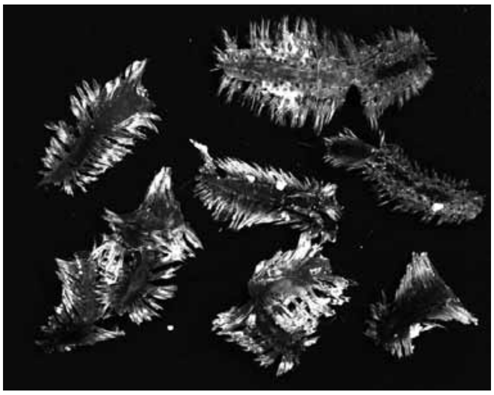
Remarks: This small bright red polychaete always lives in the burrows formed by the body and arms of the digging brittle star *Amphiura tenuis*. The body is flattened, and has 15 pairs of elytra (scales) on the back. It is a predator with large proboscis (evertable mouth with jaws). During collection some animals break spontaneously and shed their scales. The distribution pattern is comparable to that of the brittle star Amphiura tenuis, which is another indication that the commensal life stile is obligatory.

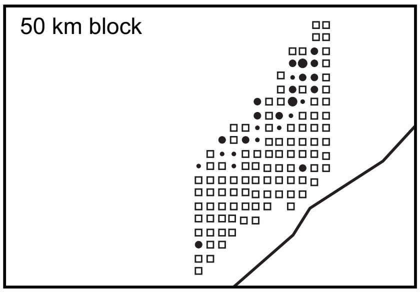


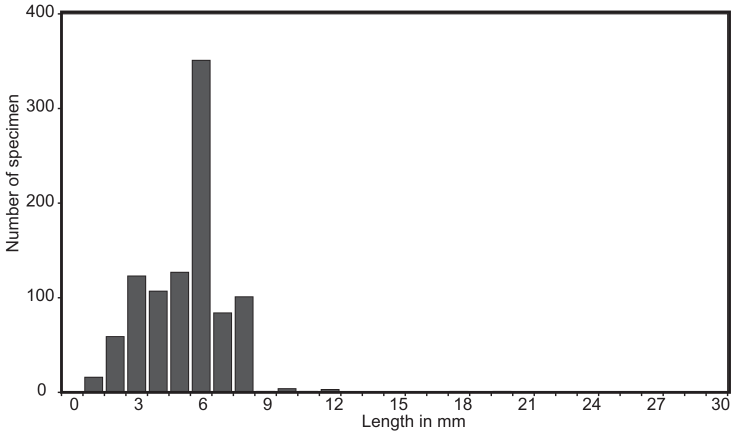


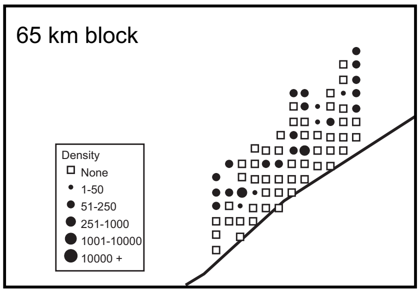










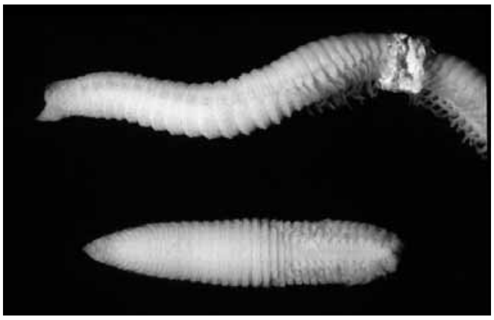


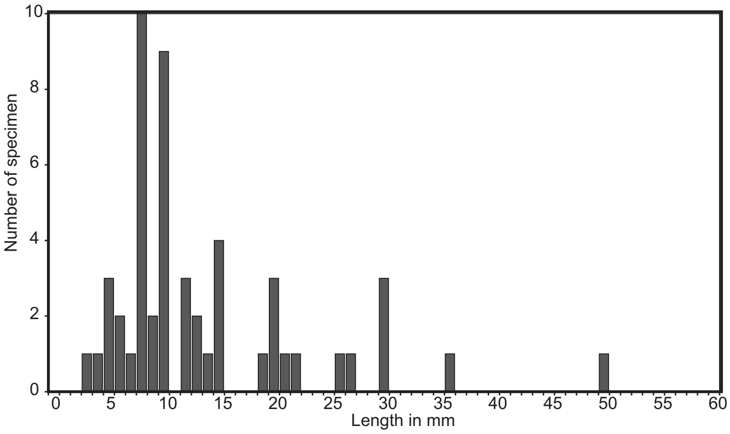
FAMILY ORBINIIDAE

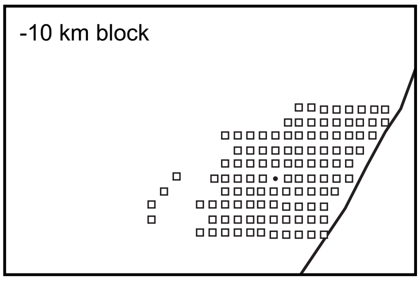
Species number	5051
Phylum	Annelida
Class	Polychaeta
Family	Orbiniidae
Distribution	5 blocks, 31 stations, map.
Abundance	53 specimen
Density	1-7
Length	3-50 mm

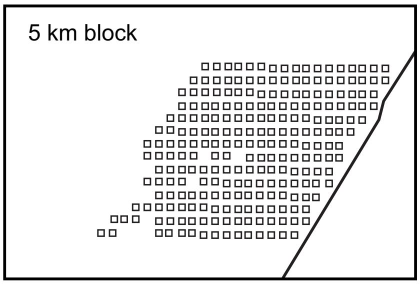
Sediment characteristics	
Silt fraction	0.6 - 93% (mean 31%)
Grain size	< 63 - 206 µm (mean < 121 µm)

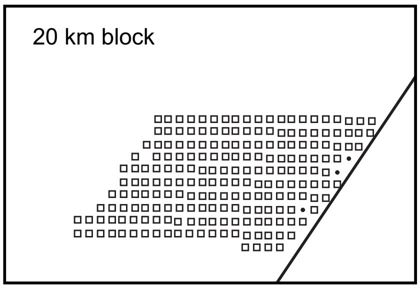
Remarks: These worms have a pointed head without appendages. They are often easily recognized by flattened papillae sitting on the back of most of the segments.
In our specimens these papillae started to become visible from about the 18th segment. The pharynx, when everted, shows a deeply lobed margin. From the distribution maps it is clear that they prefer a sandy environment.

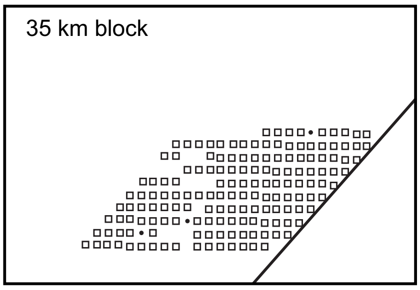


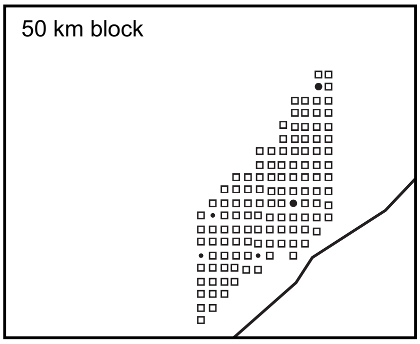


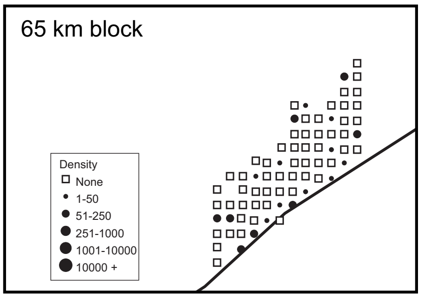










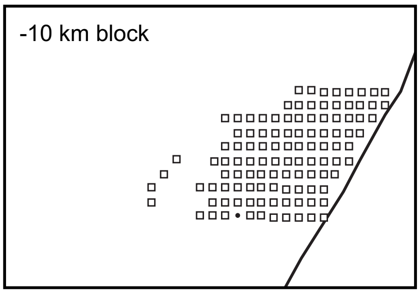


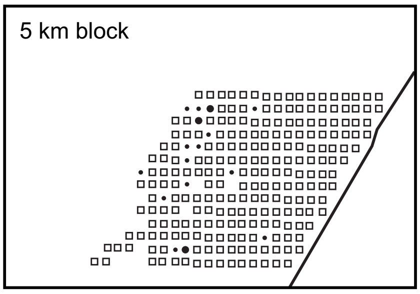
SIGALIONIDAE

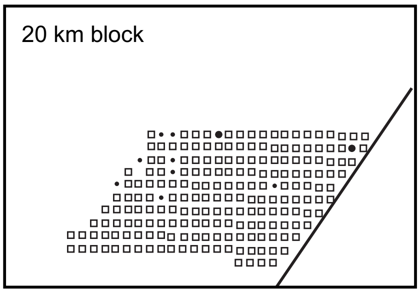
Species number	5150, 5151
Phylum	Annelida
Class	Polychaeta
Family	Sigalionidae
Distribution	6 blocks, 34 stations, map.
Abundance	40 specimens
Density	1-3
Length	4-44 mm

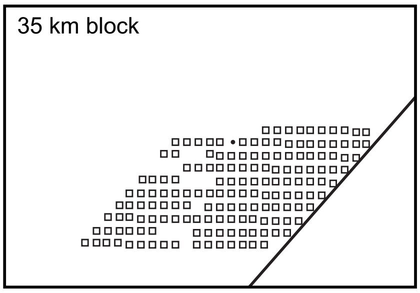
Sediment characteristics	
Silt fraction	2- 100% (mean 78%)
Grain size	< 63 - 300 µm (mean < 72 µm)

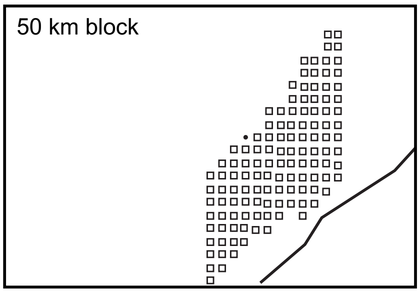
Remarks: Polychaetes that have elytra (scales) like the family Polynoidae, but the number of elytra is much larger. The body is also long, slender and worm-like.
The head has four eyes and one antenna. The first segment has two pairs of long cirri of which the ventral ones are more than twice as long as the dorsal ones.

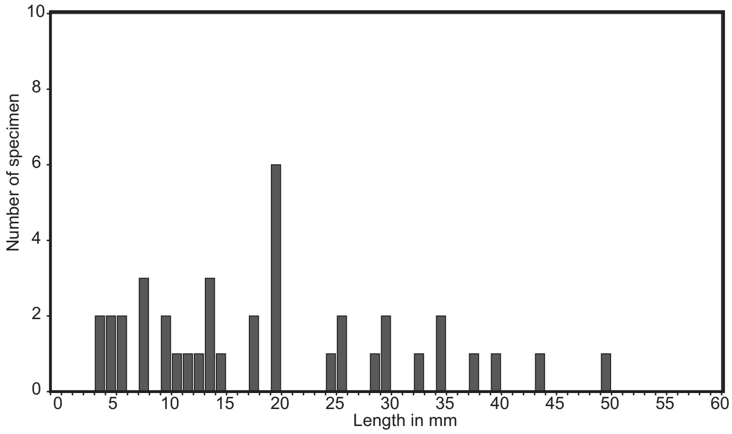


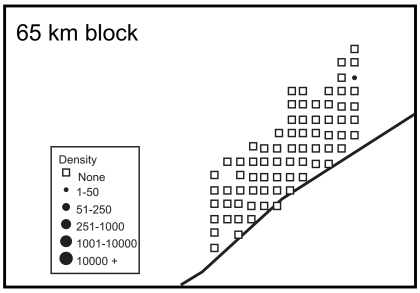












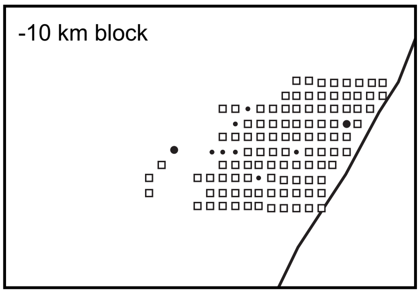
DIOPATRA SPEC.

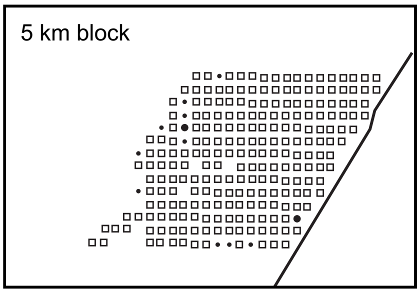
Species number	5301
Phylum	Annelida
Class	Polychaeta
Family	Onuphidae
Distribution	7 blocks, 96 stations, map.
Abundance	190 specimen
Density	1-19
Length	5-100 mm

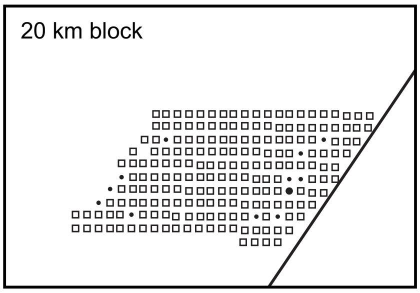
Sediment characteristics

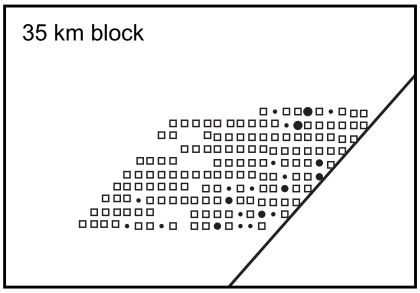
Silt fraction	0.5- 98% (mean 45%)
Grain size	< 63 - 709 µm (mean < 121 µm)

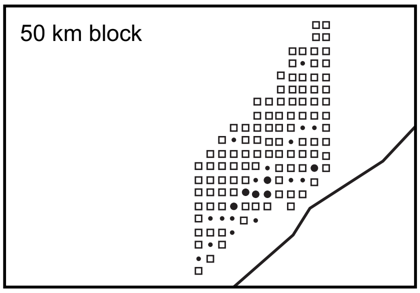
Remarks: This family is sometimes incorporated in the family Eunicidae. The worms have a distinct head with five long antennae. The bases of these antennae are annulated (with rings). This species has nice comb-like gills on their backs. Further the worms have powerful jaws and live in a sand and shell encrusted tube, that often sticks out of the sediment like a periscope. The animal does not leave the burrow but stretches itself to catch prey and algae. In general the animals were found in the upper part of the intertidal area with some preference for the sandier sediment.

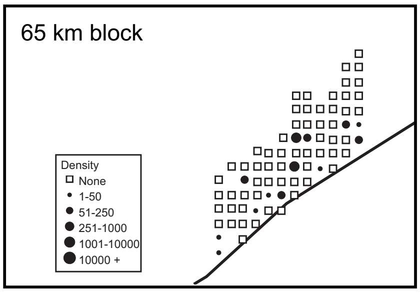


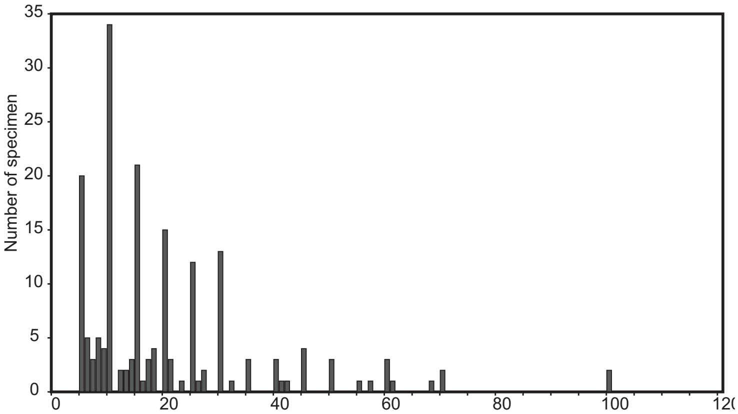










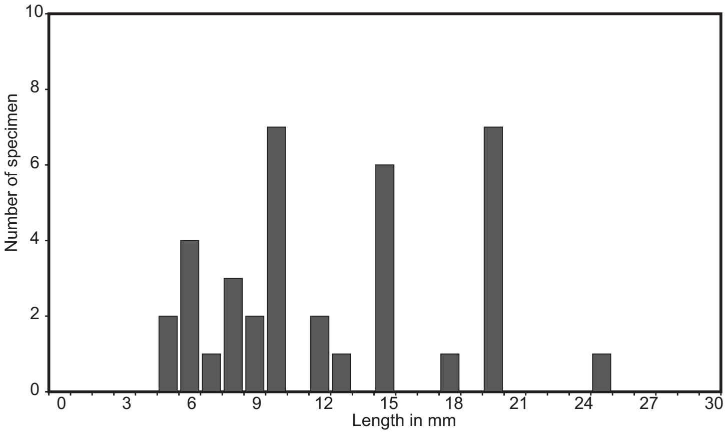


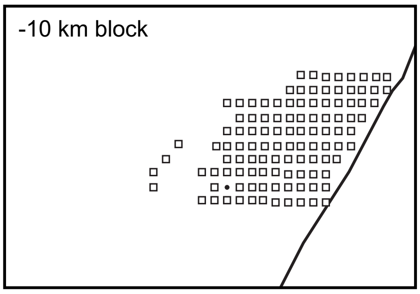
PILARGIDAE (VELCRO WORM)

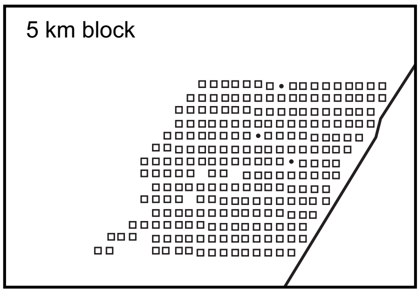
Species number	5401
Phylum	Annelida
Class	Polychaeta
Family	Pilargidae
Distribution	5 blocks, 28 stations, map.
Abundance	37 specimen
Density	1-3
Length	5-25 mm

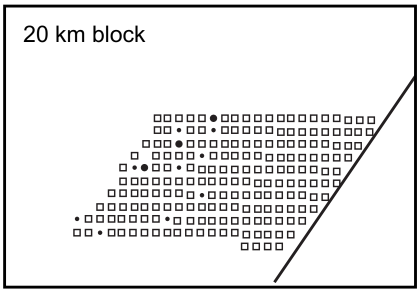
Sediment characteristics	
Silt fraction	5- 98% (mean 67%)
Grain size	< 63 - 196 µm (mean < 76 µm)

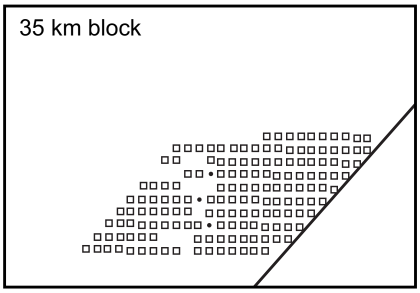
Remarks: These worms are most easily recognized by the large curved spine in the dorsal part of the parapodium. The spines look much like a fish hooks (without a barb), and they are often curved over the dorsal side of the animal as a kind of protection. The animals were found in the lower part of the intertidal area.

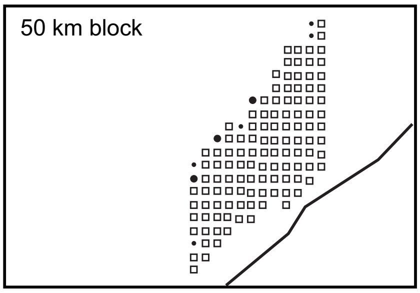


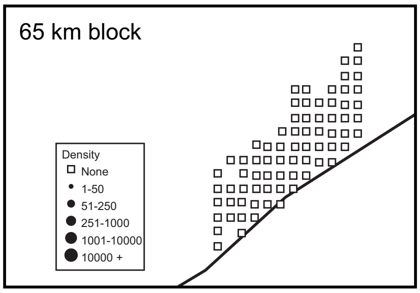












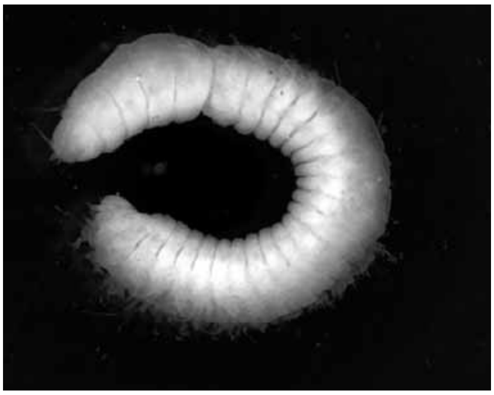
AMPHINOMIDAE (FIRE WORM)

Species number	5201
Phylum	Annelida
Class	Polychaeta
Family	Amphinomidae
Distribution	1 block (35), 3 stations, no map.
Abundance	3 specimen
Density	1
Length	10-15 mm

Sediment characteristics

Silt fraction	52- 72% (mean 59%)
Grain size	< 63 µm (< 63 µm)

Remarks: The most peculiar characteristic is the possession of bundles of brittle glass-like setae, which mostly look whitish. However, some Spionidae have similar setae. The notopodia (the dorsal part of the parapodia) have branched or multiple cirri, which Spionidae lack. The hollow glassy setae of large specimens can pierce the skin of humans and inject a poison, causing a painful burning feeling.



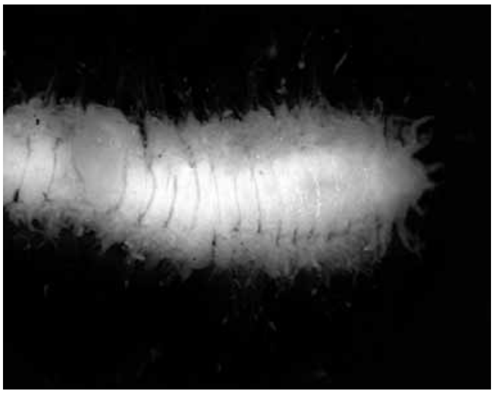
HESIONIDAE

Species number	5411
Phylum	Annelida
Class	Polychaeta
Family	Hesionidae
Distribution	2 blocks, 4 stations, no map.
Abundance	6 specimen
Density	1-2
Length	7-10 mm

Sediment characteristics

Silt fraction	34- 96% (mean 63%)
Grain size	< 63 - 151 µm (mean < 100 µm)

Remarks: Animals with a relatively short body and a small head with 3 small tentacles. The cirri of the first segment are much longer than the head tentacles.



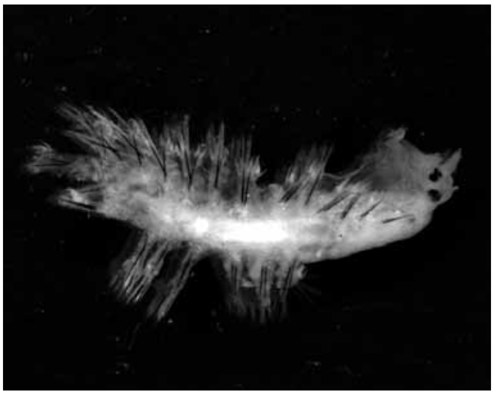
NEREIDAE (RAGWORM)

Species number	5451
Phylum	Annelida
Class	Polychaeta
Family	Nereidae
Distribution	1 block (20), 1 station, no map.
Abundance	1 specimen
Density	1
Length	15 mm

Sediment characteristics

Silt fraction	94%
Grain size	< 63 µm

Remarks: The head has 4 eyes, 8 tentacles, and two thick palps at the front of the head. Furthermore it has two powerful jaws, and the parapodia clearly have two bundles of setae.



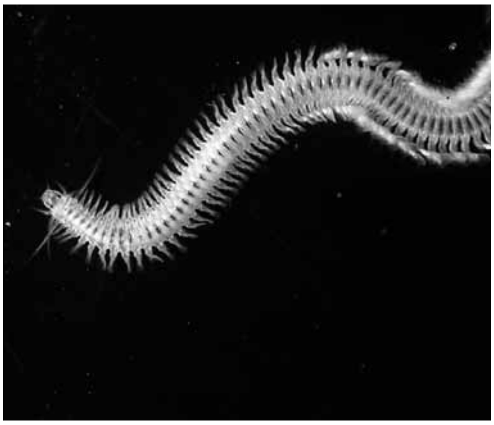
GREEN PHYLLODOCIDAE

Species number	5211
Phylum	Annelida
Class	Polychaeta
Family	Phyllodocidae
Distribution	1 block (35), 1 station, no map.
Abundance	1 specimen
Density	1
Length	12 mm

Sediment characteristics

Silt fraction	3%
Grain size	150 µm

Remarks: This species is bright green, and crawls openly over the sediment. Its defence against predator is to secrete an enormous amount of sticky mucous.



BROWN PHYLLODOCIDAE

Species number	5502
Phylum	Annelida
Class	Polychaeta
Family	Phyllodocidae
Distribution	3 blocks, 3 stations, no map.
Abundance	3 specimen
Density	1
Length	4-10 mm

Sediment characteristics

Silt fraction	47%
Grain size	93 µm

Remarks: The body has a brown color.

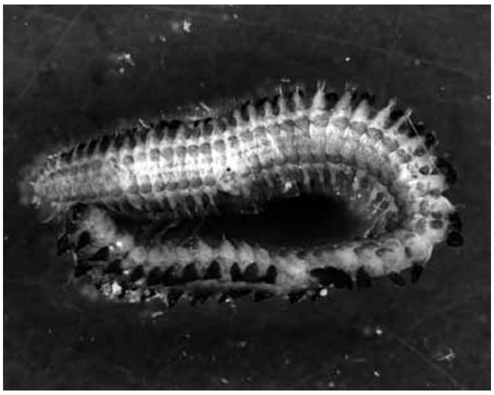
SPOTTED PHYLLODOCIDAE (TRAIN WORM)

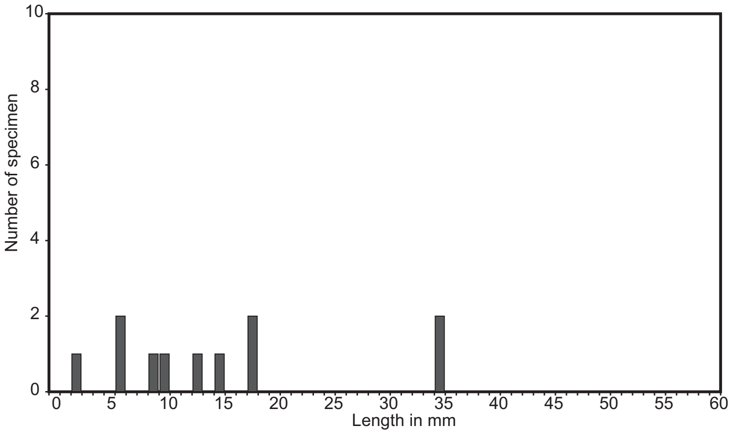
Species number	5501
Phylum	Annelida
Class	Polychaeta
Family	Phyllodocidae
Distribution	3 blocks, 6 stations, map.
Abundance	11 specimen
Density	1-6
Length	2-35 mm

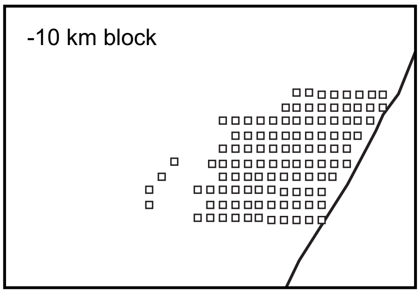
Sediment characteristics

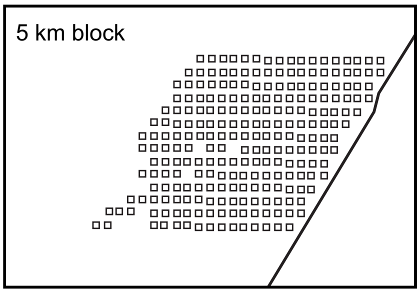
Silt fraction	16- 93% (mean 56%)
Grain size	< 63 - 268 μm (mean < 114 μm)

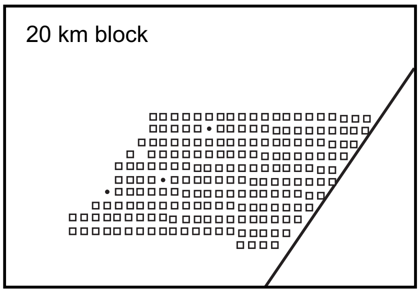
Remarks: The name is coined because they have the habit of crawling over the surface of the mud flats during the day. The animals of this family are often brightly colored. We encountered a green species that is also common in Roebuck Bay, a brown species and this nice red-brown spotted species. The head has two dorsal eyes and four short tentacles at the front. Conspicious are the bright-colored flat triangular dorsal cirri of the parapodia of all segments.

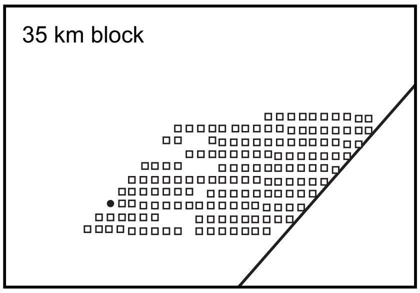


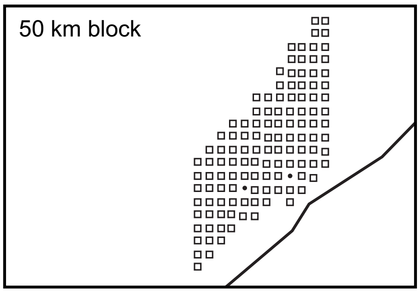


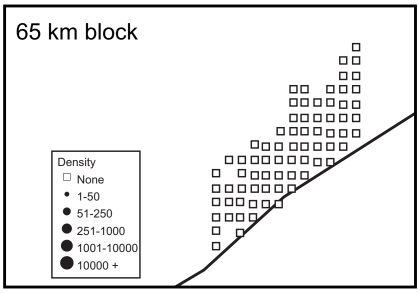










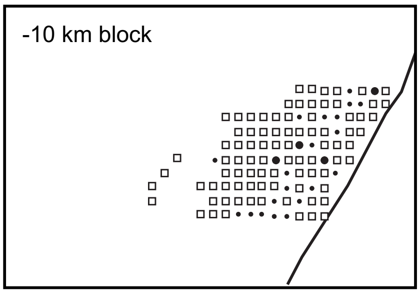


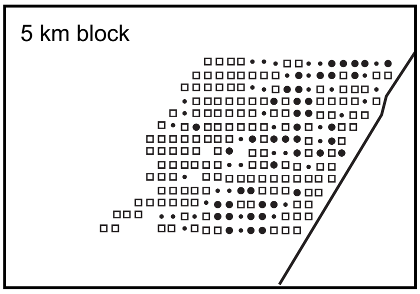
NEPHTYIDAE (CATWORM)

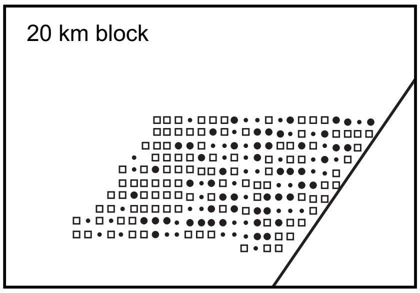
Species number	5601
Phylum	Annelida
Class	Polychaeta
Family	Nephtyidae
Distribution	7 blocks, 398 stations, map.
Abundance	797 specimen
Density	1-9
Length	3-55 mm

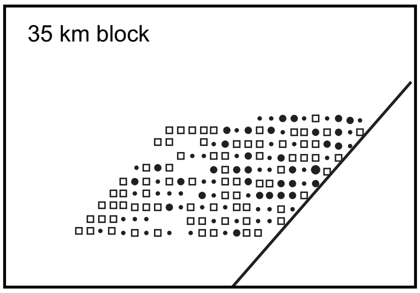
Sediment characteristics	
Silt fraction	0.2 - 99% (mean 52%)
Grain size	< 63 - 802 µm (mean < 93 µm)

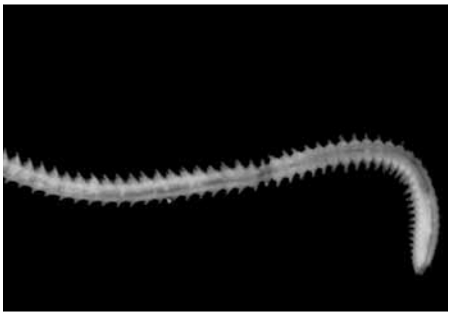
Remarks: These worms often have a dirty yellow color, the head is rather indistinct, without eyes and without long tentacles. Each parapodium is clearly divided into two parts.
The animals burrow actively, strangely enough, by means of the eversible proboscis. They are carnivorous or omnivorous, and possess a pair of small nodular jaws. Normally these worms live in a sandy mud environment, but from the distribution maps no particular preference for a sediment type is clear. It is highly likely that more than one species is involved.

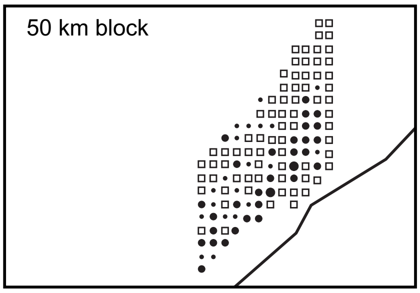


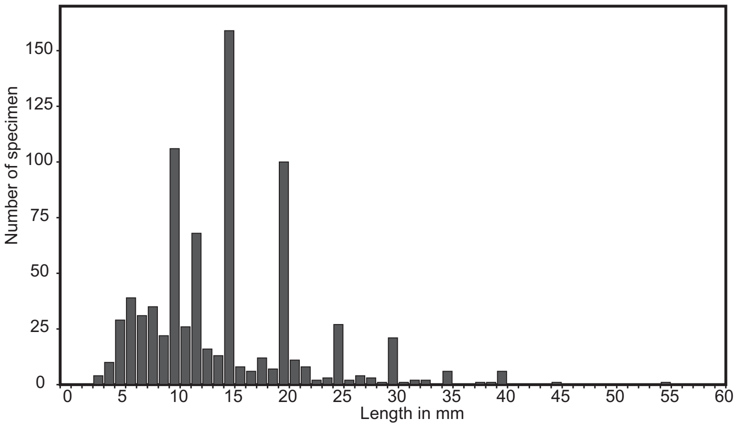


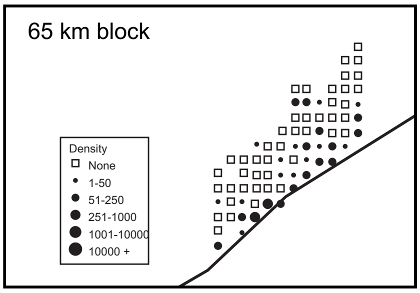










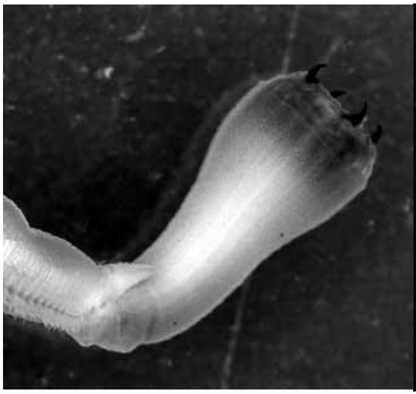


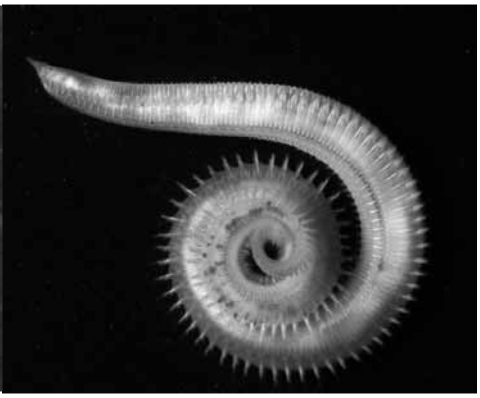
GLYCERIDAE

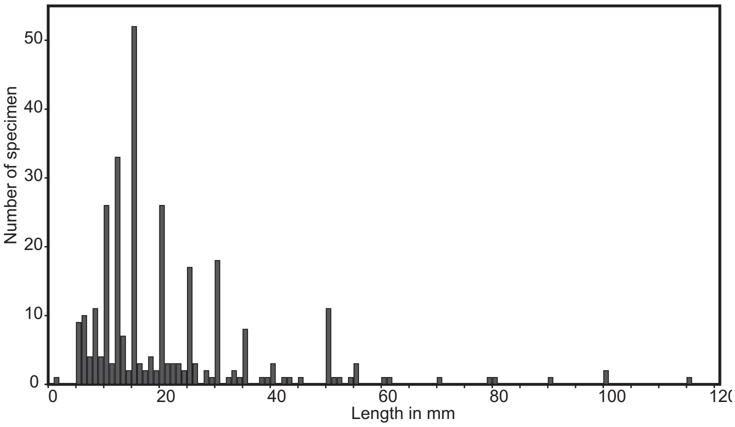
Species number	5701
Phylum	Annelida
Class	Polychaeta
Family	Glyceridae
Distribution	7 blocks, 212 stations, map.
Abundance	299 specimen
Density	1-6
Length	1-115 mm

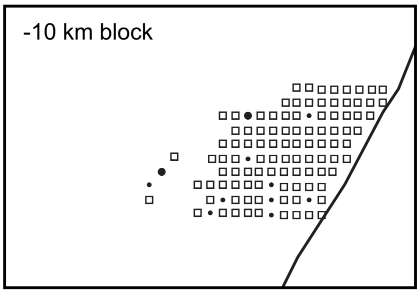
Sediment characteristics	
Silt fraction	0.2 - 98% (mean 56%)
Grain size	< 63 - 287 µm (mean < 91 µm)

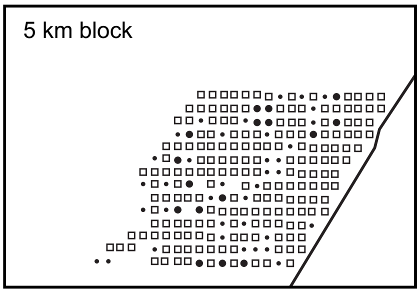
Remarks: These worms look similar to the Lumbrineridae, but the cone shaped head is long and slender. At the top of the cone they have four small antennae that can only been seen under a high magnification. Another peculiar feature is that every segment can be divided into 2 or 3 pseudosegments, only one of these having a pair of parapodia. These worms burrow actively through the sediment looking for prey. The black jaws, are easily seen through the body wall and are situated far behind the mouth, can be protruded completely when grabbing prey. There is no clear pattern in their distribution over the tidal flats, which could mean that more than one species is involved.

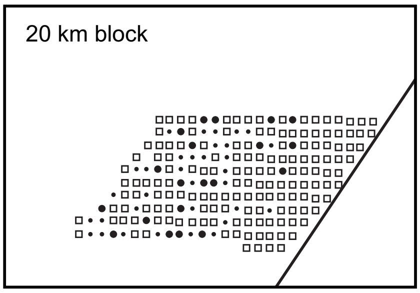


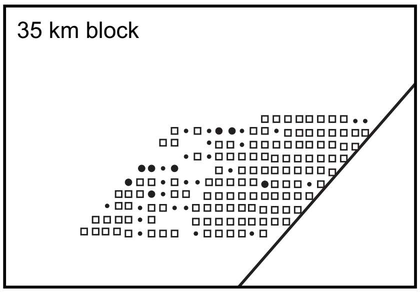


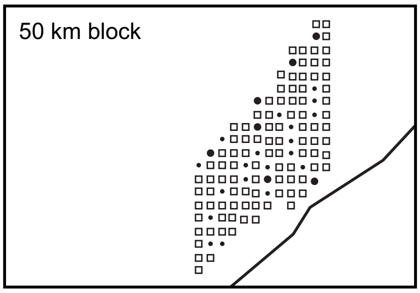


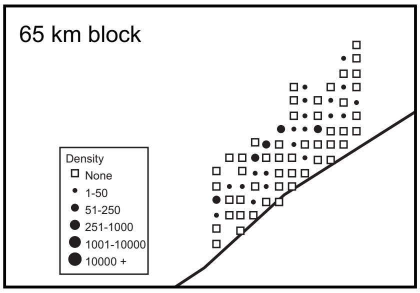












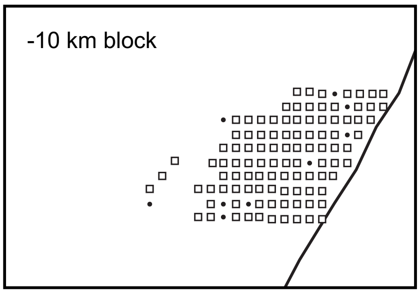
CAPITELLIDAE

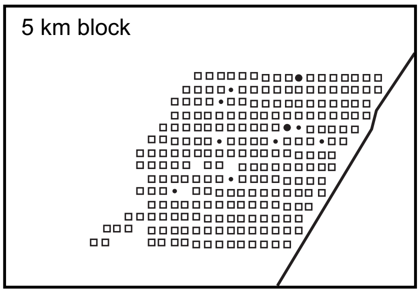
Species number	6301
Phylum	Annelida
Class	Polychaeta
Family	Capitellidae
Distribution	6 blocks, 105 stations, map.
Abundance	463 specimen
Density	1-45
Length	2-60 mm

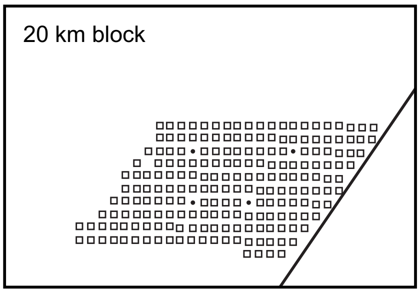
Sediment characteristics

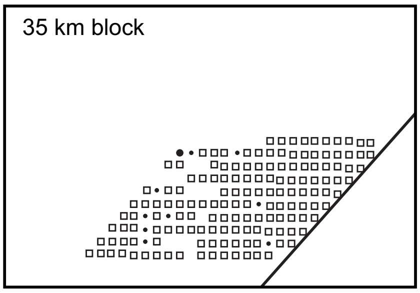
Silt fraction	0.6- 98% (mean 47%)
Grain size	< 63 - 216 µm (mean < 94 µm)

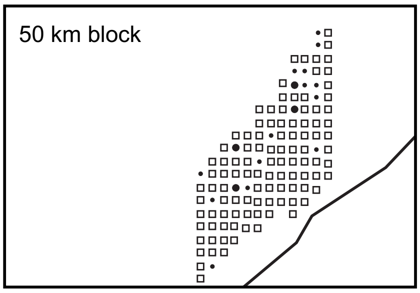
Remarks: Reddish worms without obvious parapodia. The thorax segments (around 10) have mostly four bundles of short setae, while the abdomen has rows of hooked setae that barely protrude from the body wall. The small pointed head looks like a nose-like knob. This family was very common in Block 65, with the sandiest sediment.

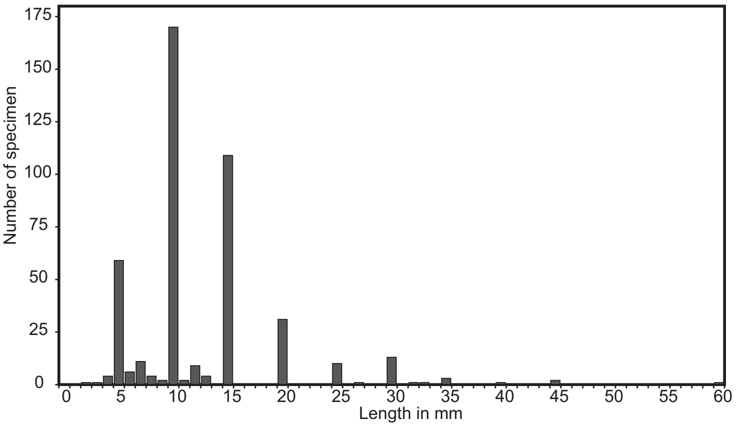


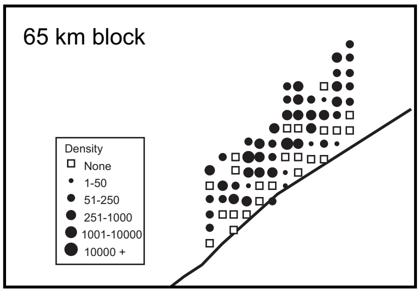










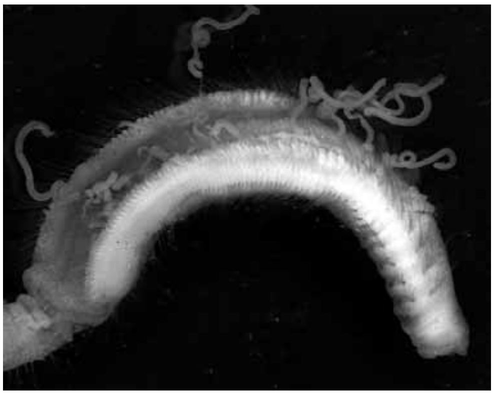


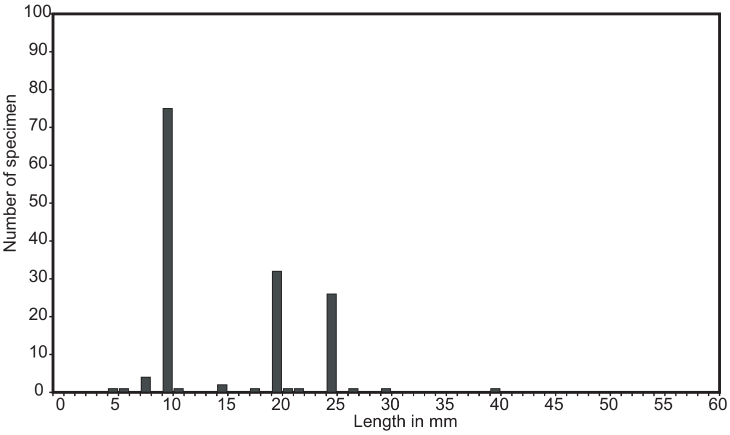
CIRRATULIDAE

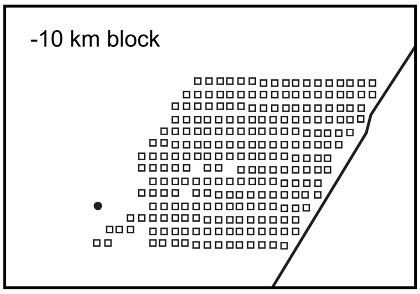
Species number	6001
Phylum	Annelida
Class	Polychaeta
Family	Cirratulidae
Distribution	7 blocks, 21 stations, map.
Abundance	147 specimen
Density	1-103
Length	5-40 mm

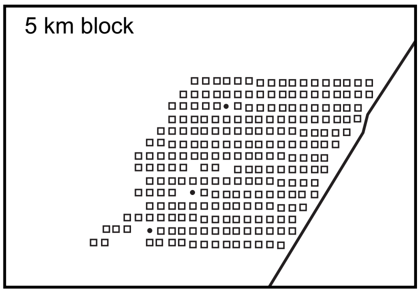
Sediment characteristics	
Silt fraction	13 - 99% (mean 53%)
Grain size	< 63 - 133 µm (mean < 87 µm)

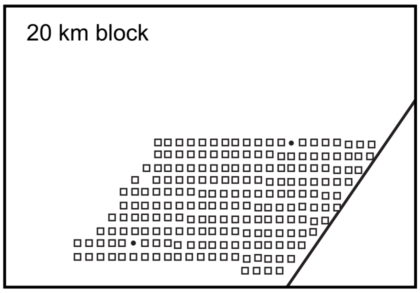
Remarks: Long cylindrical worms with a pointed or rounded head. The parapodia mainly consist of two bundles of setae that seem to arise directly from the sides of the body. Often many segments have a pair of very long cirri, that easily break off. The head has a cone-like form without tentacles or eyes. The distribution over the different blocks seems rather random.

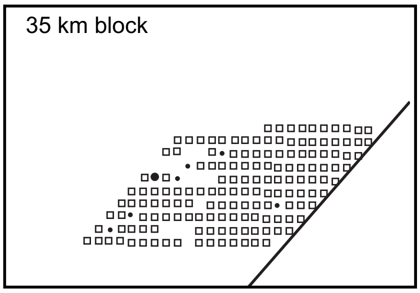


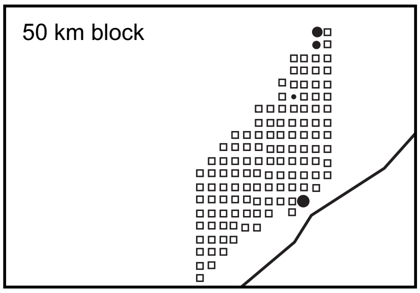


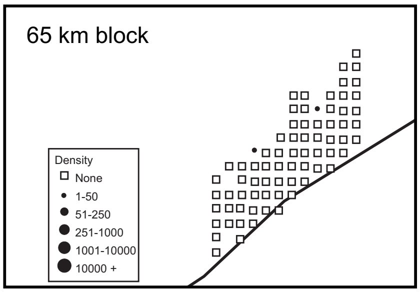










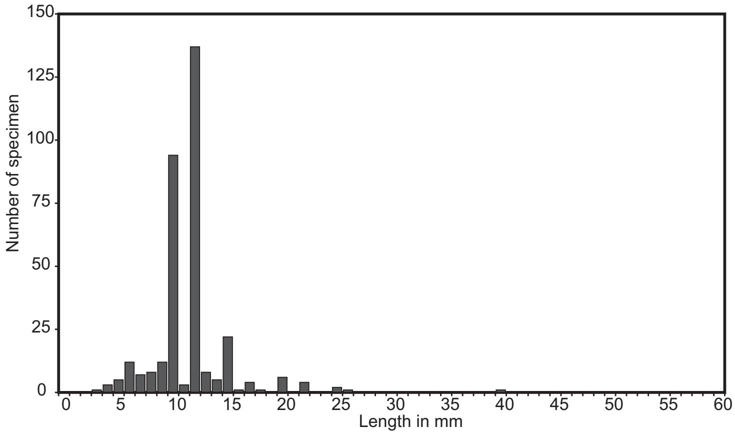


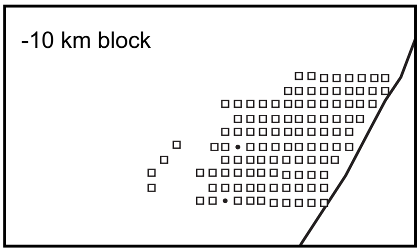
MALDANIDAE (BAMBOO WORM)

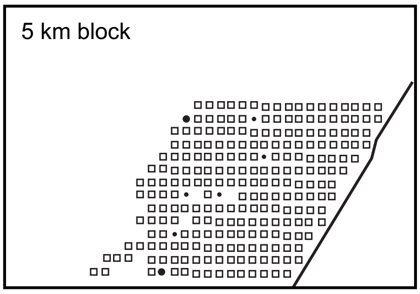
Species number	6401
Phylum	Annelida
Class	Polychaeta
Family	Maldanidae
Distribution	7 blocks, 95 stations, map.
Abundance	339 specimen
Density	1-80
Length	4-40 mm

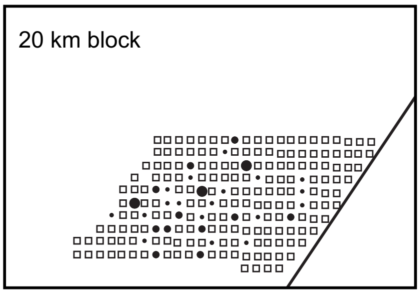
Sediment characteristics	
Silt fraction	13 - 99% (mean 53%)
Grain size	< 63 - 268 µm (mean < 88 µm)

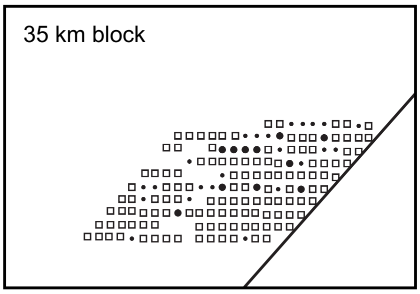
Remarks: These worms are characterized by greatly elongated segments, hence the English name. The head has no appendages, but often has a more or less circular oblique shield, which looks a bit like a head of a horse. The parapodia do not stand out but are mainly represented by setae. These worms are characterized by greatly elongated segments, hence the English name. The head has no appendages, but often has a more or less circular oblique shield, which looks a bit like a hoof of a horse. The parapodia do not stand out, but are mainly represented by setae. The last segment, called the pygidium, looks like a crown because the anal cirri of different lengths stand in a circle.This species was common in Block 20 to 50 with no clear preference for a height in the intertidal zone.

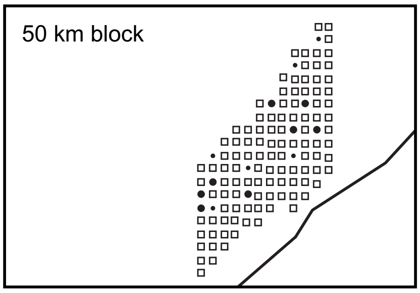


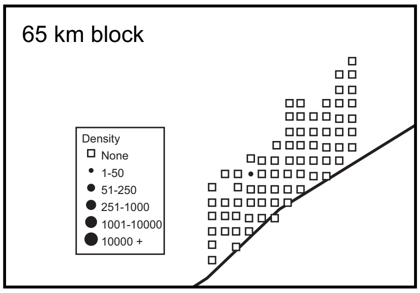












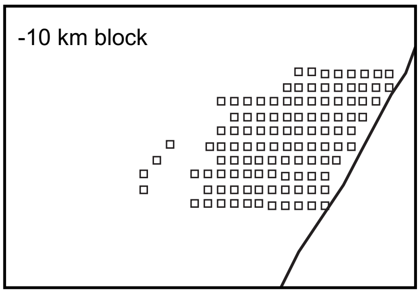
MALDANIDAE WITH TOUGH TUBE (BAMBOO WORM)

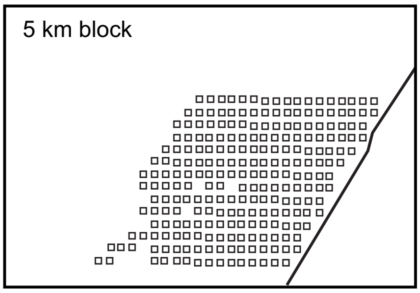
Species number	6402
Phylum	Annelida
Class	Polychaeta
Family	Maldanidae
Distribution	2 blocks, 7 stations, map.
Abundance	7 specimen
Density	1
Length	10-30 mm

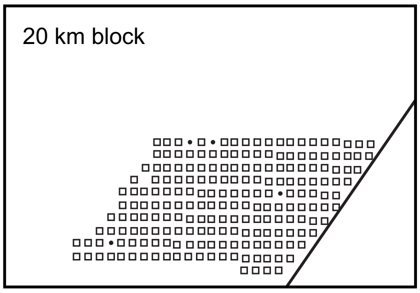
Sediment characteristics

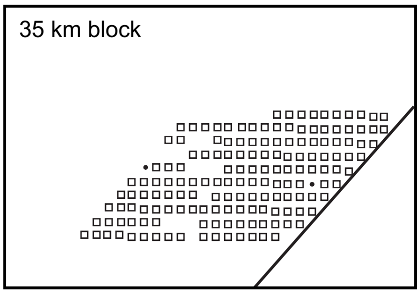
Silt fraction	46 - 93% (mean 75%)
Grain size	< 63 - 94 µm (mean < 67 µm)

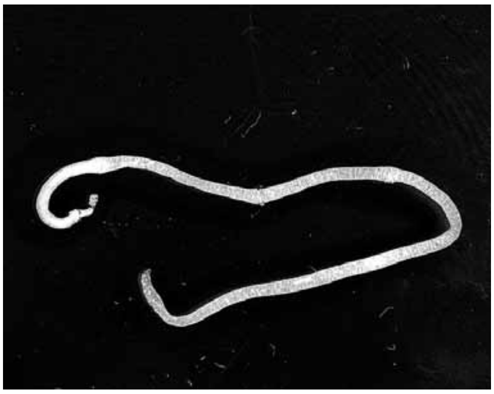
Remarks: These very thin worms are characterized by a thin strong flexible tube covered with small sand grains. At first we expected these to be juveniles of Oweniidae, but microscopical inspection proved otherwise.

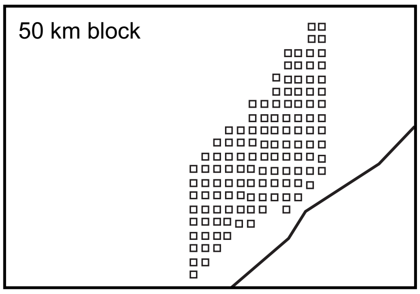


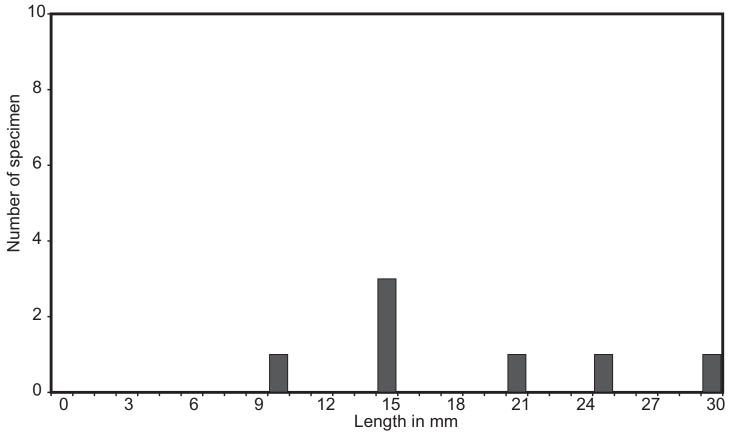


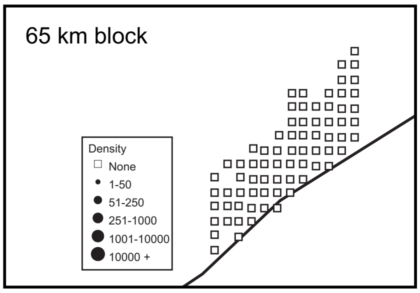












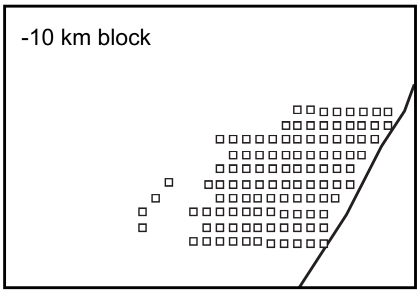
STERNASPIDAE (MICKEY MOUSE WORM)

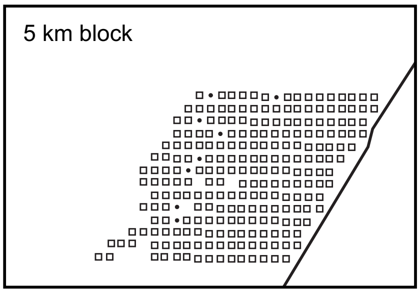
Species number	6501
Phylum	Annelida
Class	Polychaeta
Family	Sternaspidae
Distribution	1 block, 8 stations, map.
Abundance	8 specimens
Density	1
Length	4-13 mm

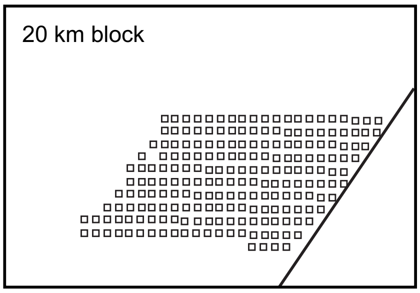
Sediment characteristics

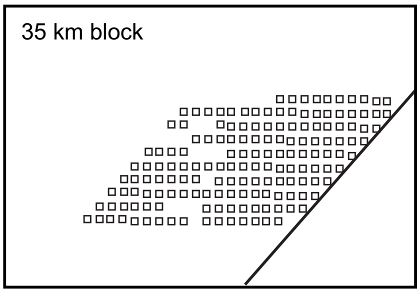
Silt fraction	69 - 98% (mean 89%)
Grain size	< 63 µm (mean < 63 µm)

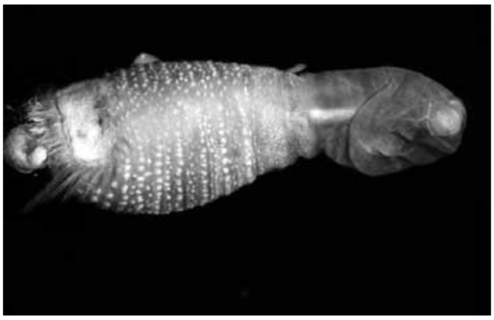
Remarks: Animals with a short swollen body. The last segments are covered by a large flat bi-lobed shield. The worm digs in mud with the head down, the shield at the back is to close off the burrow for protection. for protection. This species was found only in Bloc 5 and also in a very narrow zone low in the intertidal area. It preferred a high content of silt and a small grainsize of the sediment.

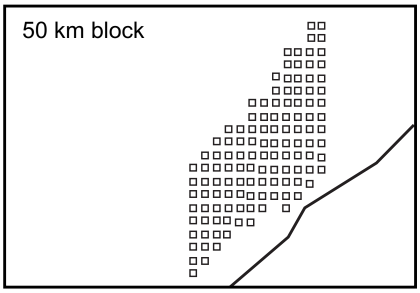


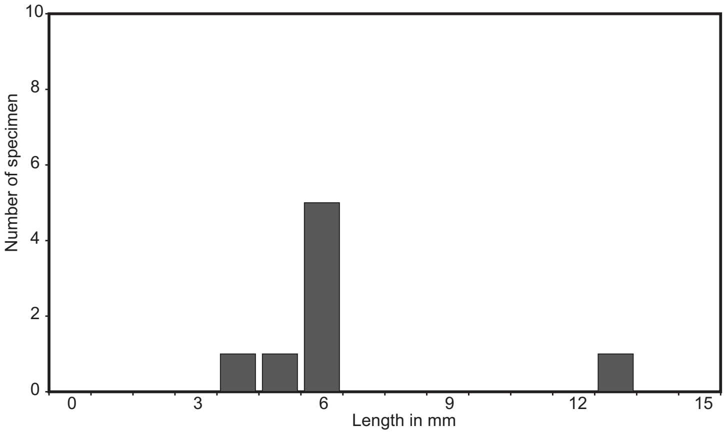


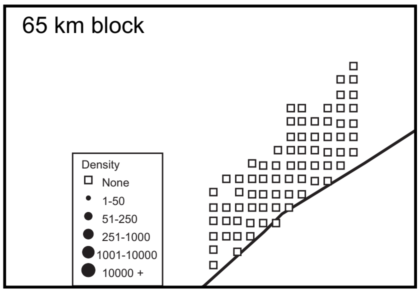












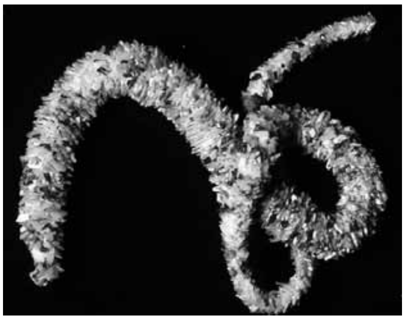
OWENIIDAE

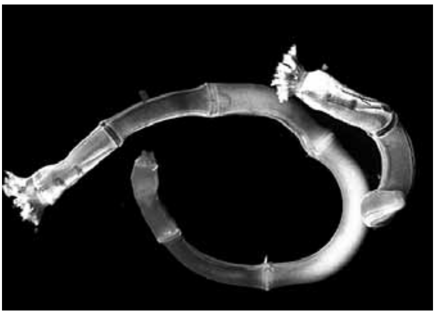
Species number	6601
Phylum	Annelida
Class	Polychaeta
Family	Oweniidae
Distribution	7 blocks, 324 stations, map.
Abundance	2292 specimen
Density	1 -115
Length	4-100 mm

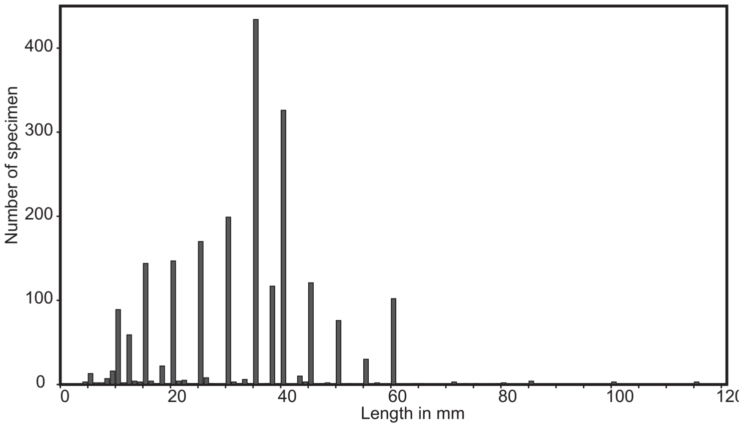
Sediment characteristics

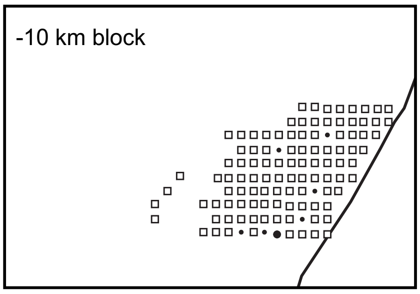
Silt fraction	2 - 95% (mean 51%)
Grain size	< 63 - 249 µm (mean < 90 µm)

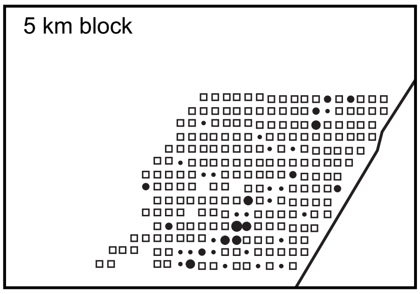
Remarks: The thorax of the animal has greatly elongated segments like in the family Maldanidae. Numerous minute hook-like setae form conspicuous transverse bands on the thorax segments. Around the head is a crown of short branched tentacles. These tiny worms are very abundant in places, and conspicuous because of their flexible sand-encrusted tubes that taper on both ends. With their tentacular crown they can filter-feed or pick up small particles from the substrate. Their tubes can be confused with these of the Phoronida, so identification involves extraction of the worm from the tubes to see their segmented body or frilly heads. Especially the distribution in Block 35 shows a preference for a near-shore habitat, though they can live in the whole intertidal area.

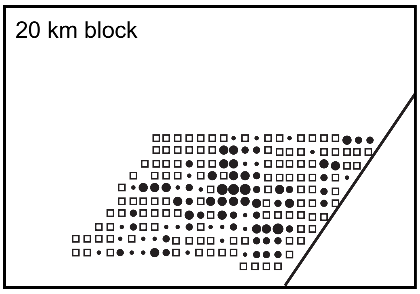


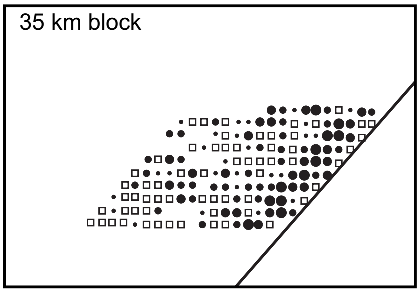


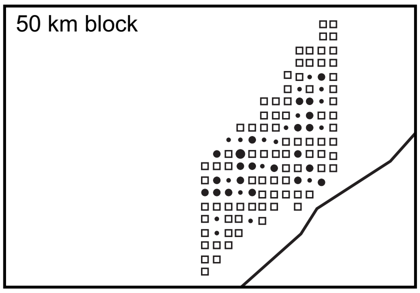


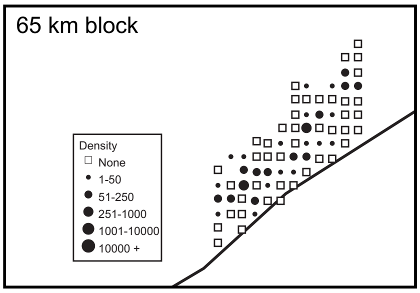










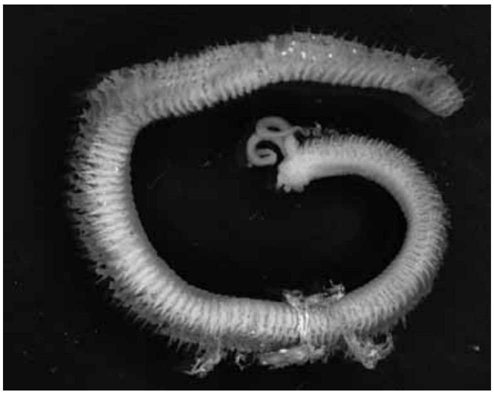


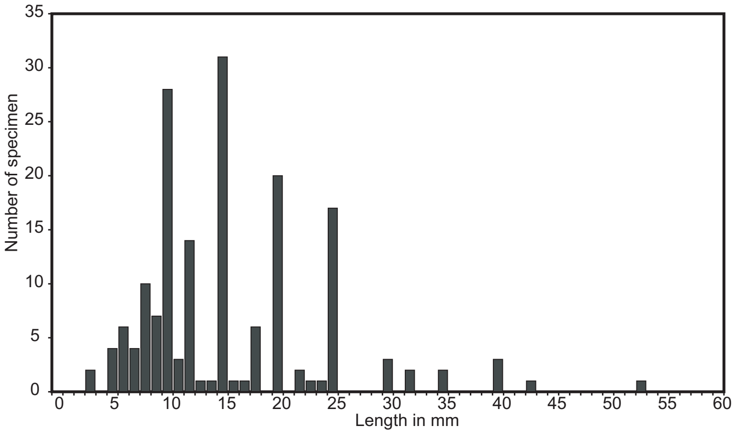
SPIONIDAE

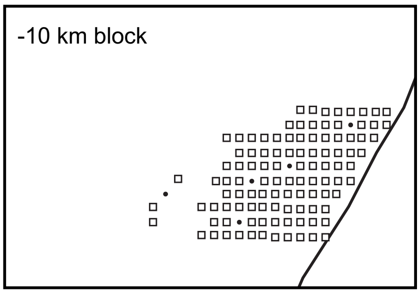
Species number	5801
Phylum	Annelida
Class	Polychaeta
Family	Spionidae
Distribution	7 blocks, 112 stations, map.
Abundance	173 specimens
Density	1-10
Length	3-43 mm

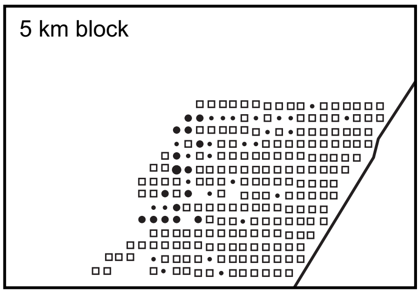
Sediment characteristics	
Silt fraction	0.3- 99% (mean 60%)
Grain size	< 63 - 235 µm (mean < 85 µm)

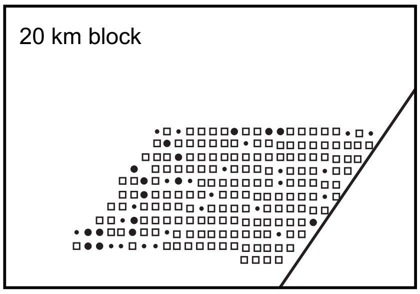
Remarks: The head is small and elongated and sits on the dorsal side of the first segment(s). It has no antennae. However, behind or at the sides of the head, are two big grooved tentacles. Unfortunately these tentacles break off easily in the process of collecting. The parapodia are clearly divided into two parts. Mostly all the anterior parapodia have dorsal cirri. From the distribution in Block 5 to 35 it may be concluded that it mainly prefers to live near the low water line. This family has many species that are very similar in appearance, and difficult to identify. The finds near the high waterline suggests that more than one species is involved.

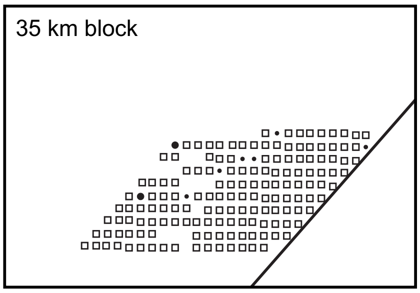


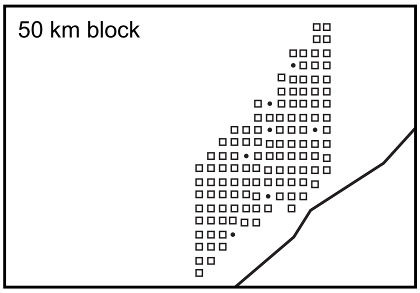


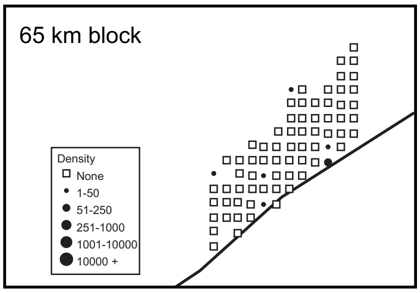












Spionidae with red cirri

Species number	5802
Phylum	Annelida
Class	Polychaeta
Family	Spionidae
Distribution	1 block, 1 station, no map.
Abundance	2 specimens
Density	2
Length	15 mm

Sediment characteristics

Silt fraction	35%
Grain size	108 µm

Remarks: Similar to the previous species, but the dorsal cirri of the parapodia have a bright red color.

Sabellariidae

Species number	6851
Phylum	Annelida
Class	Polychaeta
Family	Sabellariidae
Distribution	2 blocks, 4 stations, no map.
Abundance	17 specimen
Density	1 - 14
Length	8-18 mm

Sediment characteristics

Silt fraction	18 - 59% (mean 37%)
Grain size	< 63 - 308 µm (mean < 168 µm)

Remarks: These worms live in tubes made of sandgrains. The tubes do not have the neat conical form of the family Pectinariidae. The head has a mostly circular shield of golden thick setae, that functions as a protective lid for the tune they live in. These animals mostly live attached to hard objects or together form reefs. Near the low water line clumps of these tubes were sometimes found, suggesting that these animals live mostly in the sublittoral zone of Eighty-mile Beach.

Terebellidae

Species number	6871
Phylum	Annelida
Class	Polychaeta
Family	Terebellidae
Distribution	1 block (65), 1 station, no map.
Abundance	1 specimen
Density	1
Length	15 mm

Sediment characteristics

Silt fraction	49%
Grain size	91 µm

Remarks: These animals are very similar to the family Ampharetidae, but the mouth tentacles are not retractable. The segments 2 to 4 often have branched gills or lobes, and the anal part of the body does not have appendages.

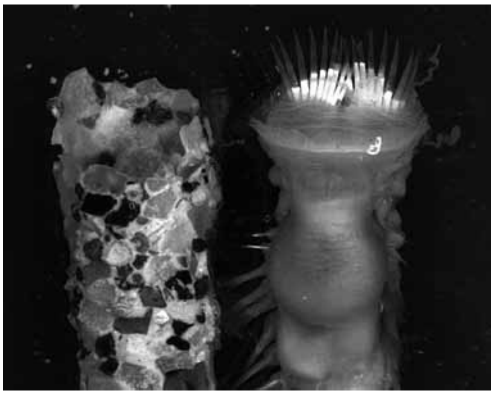
PECTINARIIDAE (GOLD COMB)

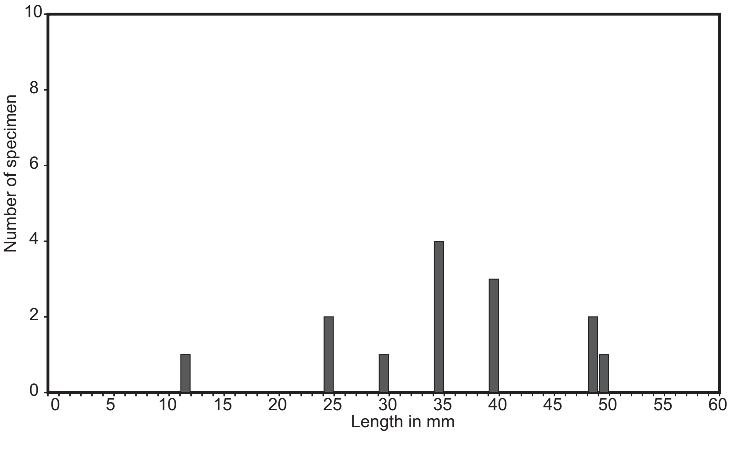
Species number	6861
Phylum	Annelida
Class	Polychaeta
Family	Pectinariidae
Distribution	4 blocks, 10 stations, map.
Abundance	11 specimen
Density	1-2
Length	12-50 mm

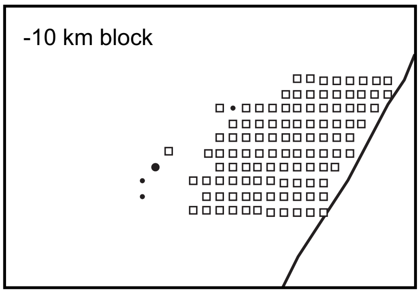
Sediment characteristics

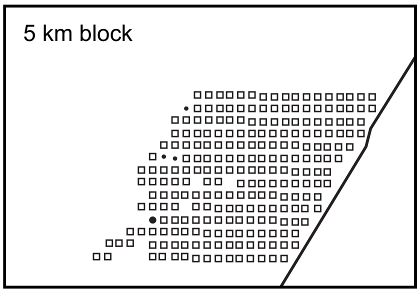
Silt fraction	16 - 63% (mean 39%)
Grain size	< 63 - 649 µm (mean < 245 µm)

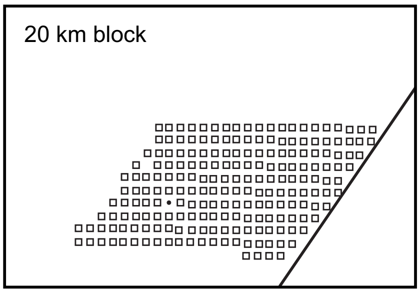
Remarks: These rather large worms have a chimney-shaped conical tube, open at both ends, and made of rather coarse pieces of sand and shell fragments cemented together and neatly ordered in one layer thick. The animal sits vertical in the sediment with the tip of the tube projecting above the surface. The head is pointed down and has two combs of stiff flattened golden hairs with which it can burrow. It collects food particles from the sand. The animal was only found near the low water line were the sediment gets sandy.

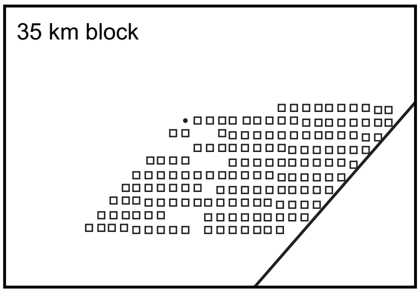


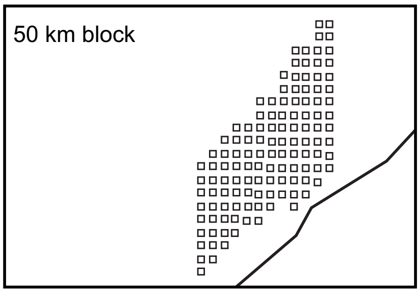


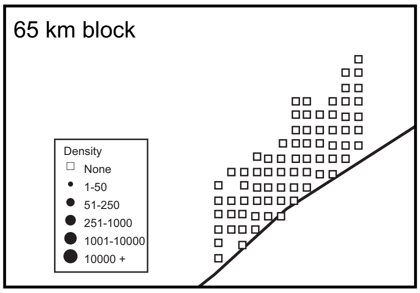












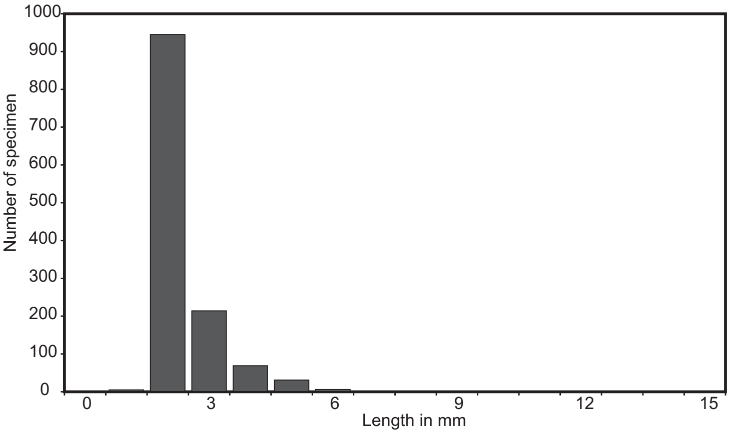
OEDICEROTIDAE (SANDHOPPER)

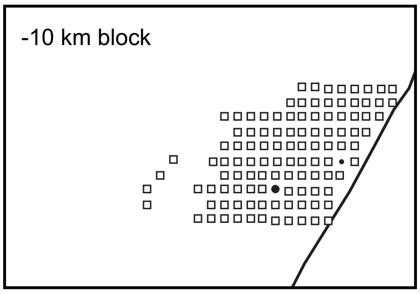
Species number	7201
Phylum	Arthropoda
Subphylum	Crustacea
Class	Amphipoda
Family	Oedicerotidae
Distribution	7 blocks, 66 stations, map.
Abundance	1274 specimen
Density	1 - 300
Length	1-11 mm

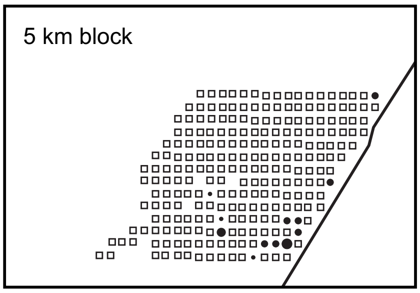
Sediment characteristics

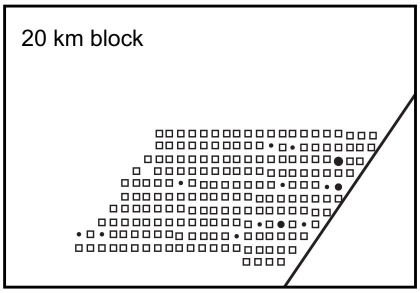
Silt fraction	0.2 - 92% (mean 30%)
Grain size	< 63 - 250 µm (mean < 122 µm)

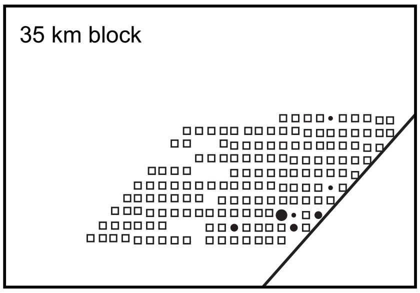
Remarks: The majority of the specimens belonged to the family Oedicerotidae, characterized by a head like a base-ball cap with large eyes, and a very long last pair of walking legs (pereiopods). We also encountered specimens belonging to the family Platyischnopidae with the peculiar long pointed head on which the antennae sit on the ventral side. The distribution shows that they prefer the upper part of the intertidal area.

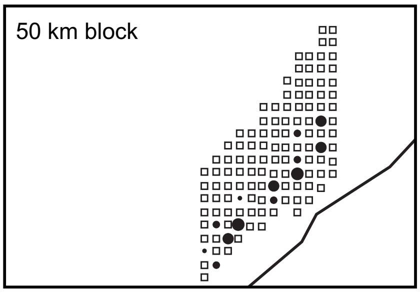


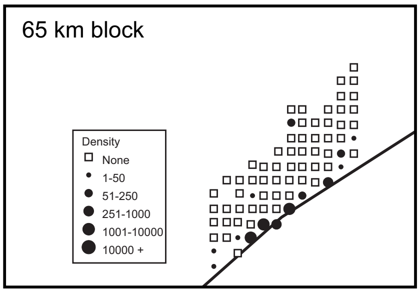












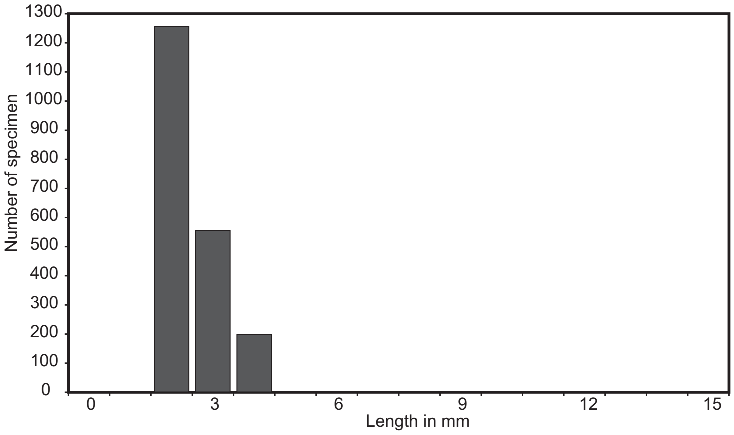
COROPHIIDAE (HERMIT MUD SHRIMP)

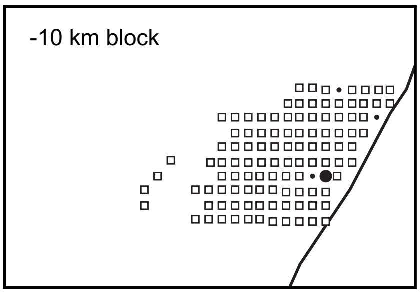
Species number	7221
Phylum	Arthropoda
Subphylum	Crustacea
Class	Amphipoda
Family	Corophiidae
Distribution	6 blocks, 44 stations, map.
Abundance	2013 specimen
Density	1 - 1200
Length	1-10 mm

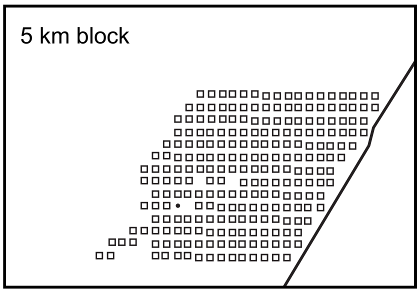
Sediment characteristics

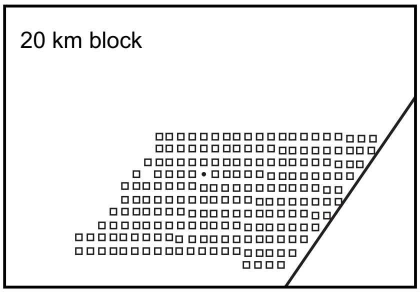
Silt fraction	0.4 - 92% (mean 37%)
Grain size	< 63 - 228 µm (mean < 112 µm)

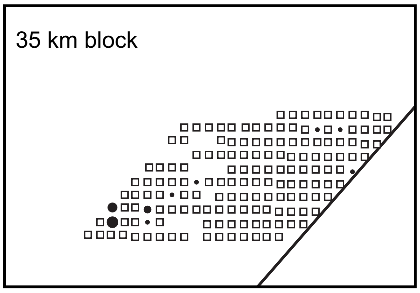
Remarks: At low water this small species aggregates during low water in shallow pools in high densities. It has the same habit as hermit crabs, while it occupies empty gastropods, tusk shells, empty joints of crab legs and any other object with a hole in it. They have a peculiar jerking way of moving by way of their large antennae,dragging the shell or other hollow object behind it. The species looks much like *Siphonoecetes sabatiori* (De Rouville, 1894) from the Mediterranean. This last species lives in small empty gastropod shells (Myers, 1982). In most cases our species was found abundantly in small pools, gathered together, in the higher parts of the intertidal area.

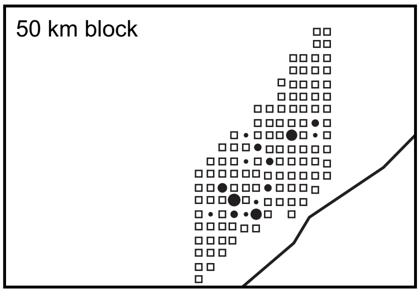


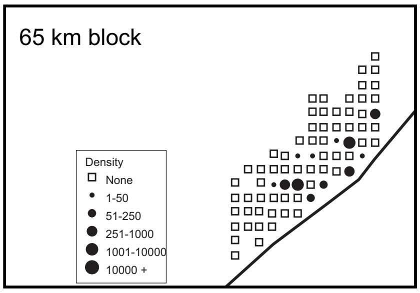












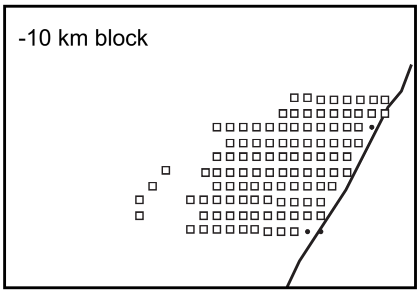
EURYDICE SPEC.

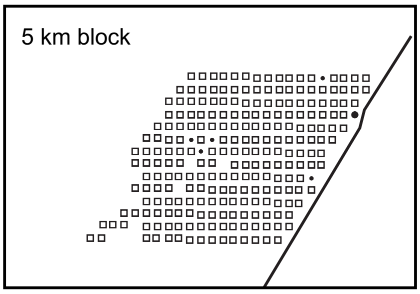
Species number	7311
Phylum	Arthropoda
Subphylum	Crustacea
Class	Isopoda
Family	Cirolanidae
Distribution	4 blocks, 11 stations, map.
Abundance	12 specimen
Density	1 - 2
Length	2-23 mm

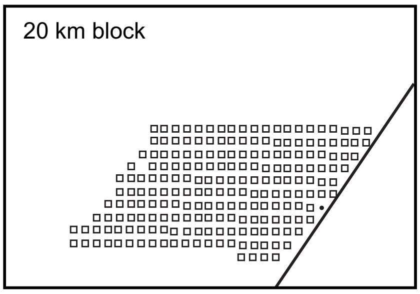
Sediment characteristics

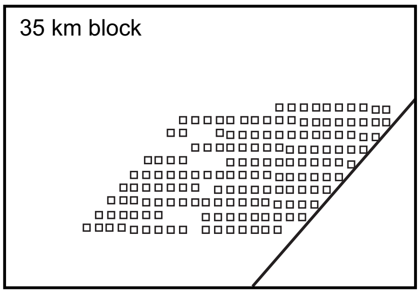
Silt fraction	0.3 - 94% (mean 31%)
Grain size	< 63 - 250 µm (mean < 166 µm)

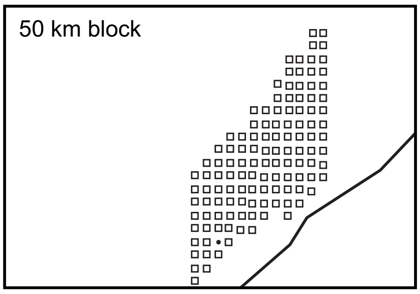
Remarks: These animals are swift swimmers, and therefore actually belong more to the pelagic fauna, than to the benthic fauna. They are carnivorous, and some species even attack human legs. In appearance they look similar to terrestrial wood-lice. Most animals were found high in the intertidal zone.

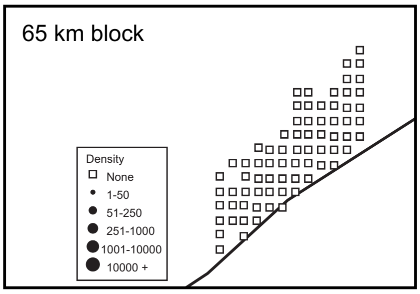


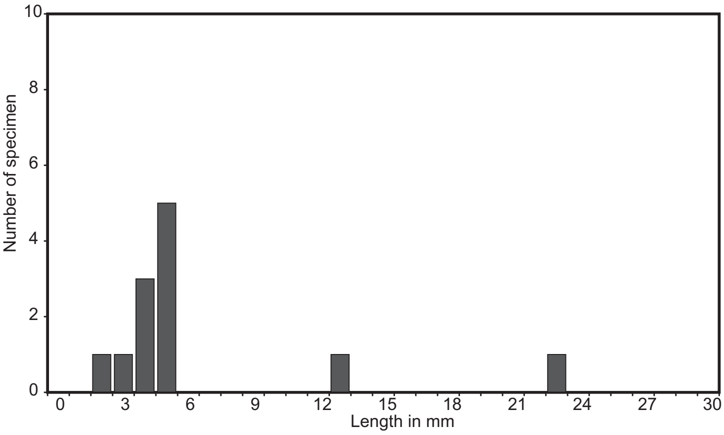












ANTHURIDAE

Species number	7301
Phylum	Arthropoda
Subphylum	Crustacea
Class	Isopoda
Family	Anthuridae
Distribution	2 blocks, 4 stations, no map.
Abundance	5 specimen
Density	1 - 2
Length	5-13 mm

Sediment characteristics

Silt fraction	51 - 75% (mean 63%)
Grain size	< 63 µm (mean < 63 µm)

Remarks: These isopods have a long and slender body. The body segments are longer than wide. The head has small eyes and short antennae. The first pair of legs have a powerful and thick claw.

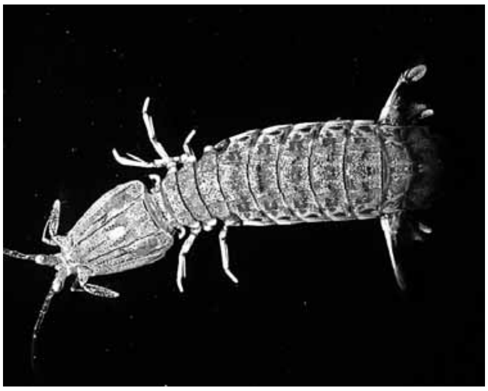
SQUILLA SPEC. (MANTIS SHRIMP)

Species number	7601
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Stomatopoda
Family	Squillidae
Distribution	1 block (20), 1 station, no map.
Abundance	1 specimen
Density	1
Length	25 mm

Sediment characteristics

Silt fraction	74%
Grain size	< 63 µm

Remarks: Peculiarly we only found one tiny specimen of this group, while in Roebuck Bay this is a very common animal. There the large perpendicular holes on the mud flats are made by this shrimp. During high tide they leave their burrow to look for prey. Their folded claws are spear like and can be stretched with an enormous speed to pierce their victim. So do not put your hand in these burrows. The larger specimens sit too deep in the sediment to be reached by our sampling method.



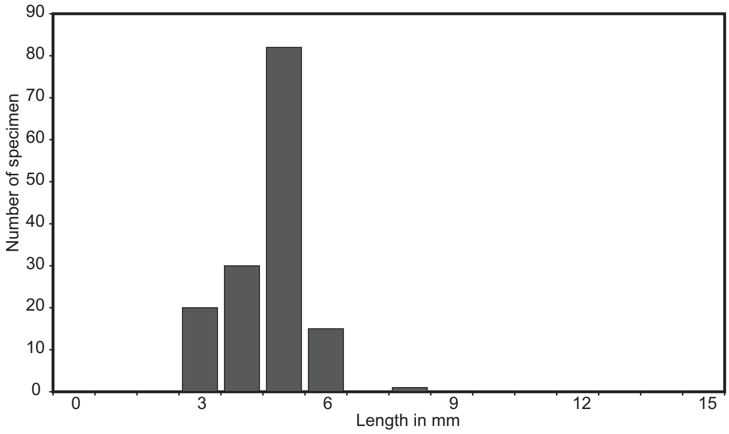
CUMACEA (COMMA SHRIMPS)

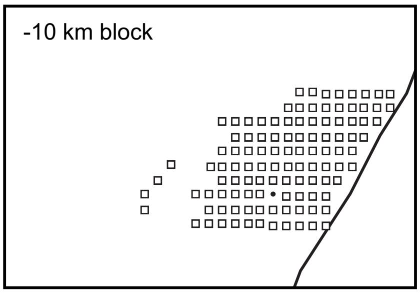
Species number	7501
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Cumacea
Family	not identified
Distribution	6 blocks, 25 stations, map.
Abundance	148 specimen
Density	1-75
Length	3-8 mm

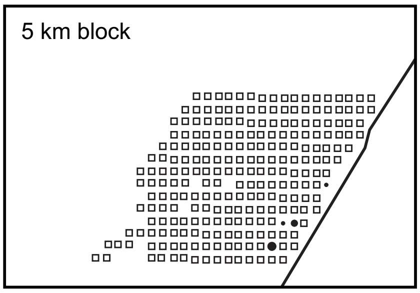
Sediment characteristics

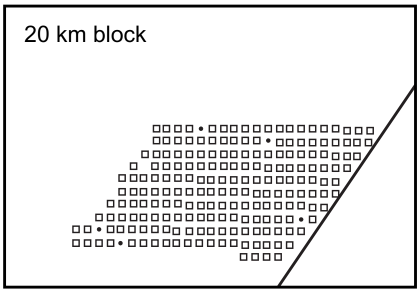
Silt fraction	1 - 94% (mean 31%)
Grain size	< 63 - 250 µm (mean < 125 µm)

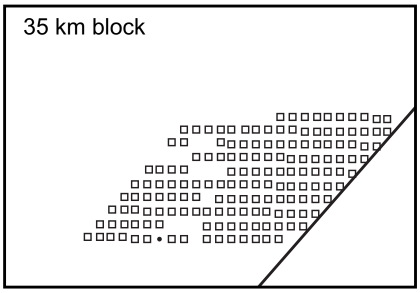
Remarks: Comma shrimps have a thick body and a long slender tail. We sampled at least three different species. Most of the specimen were found in the upper part of the intertidal zone, especially in the sandier Block 50.

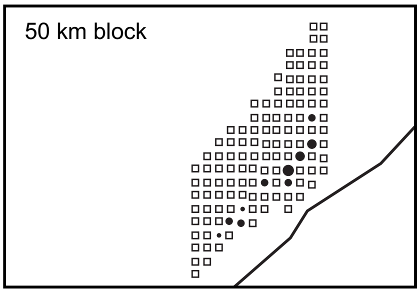


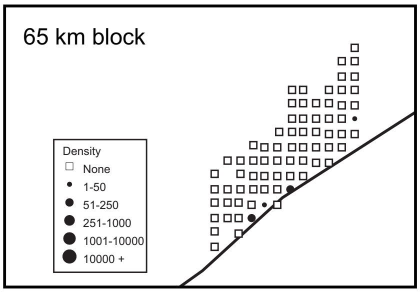












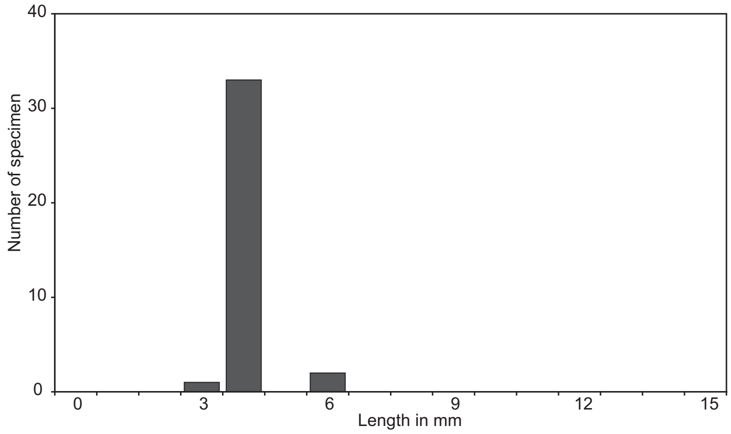
MYSIDACEA

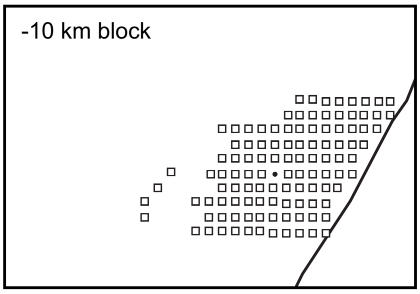
Species number	7551
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Mysidacea
Family	not identified
Distribution	3 blocks, 5 stations, map.
Abundance	36 specimen
Density	1 - 21
Length	3-6 mm

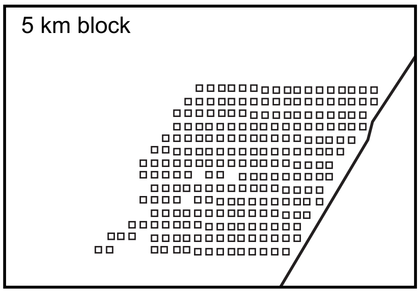
Sediment characteristics

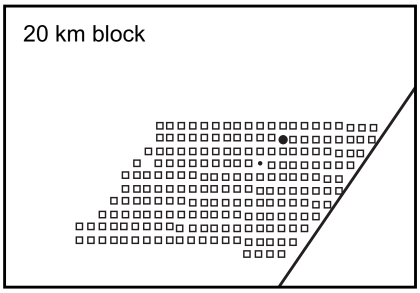
Silt fraction	17 - 70% (mean 44%)
Grain size	< 63 - 125 µm (mean < 96 µm)

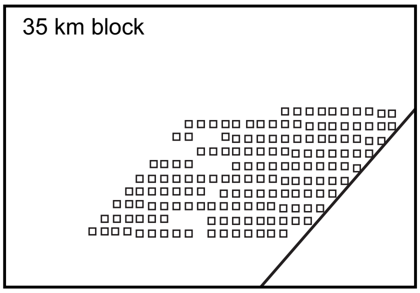
Remarks: These little shrimps are planktonic, and are not normally found in benthic samples.

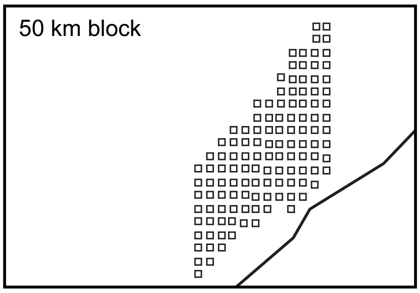


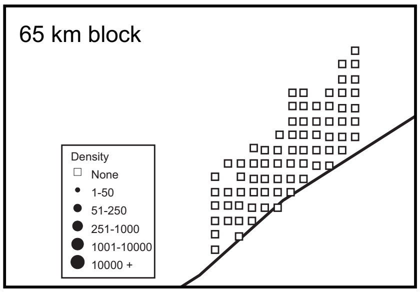












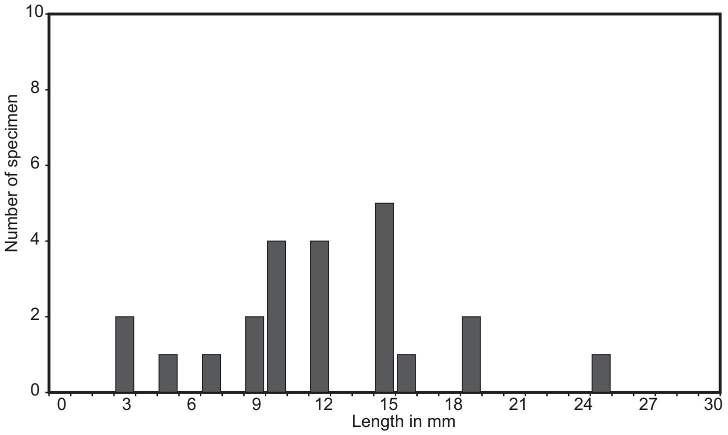
CARIDEA (SHRIMPS)

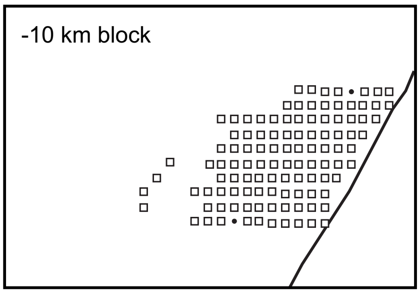
Species number	7701
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Decapoda
Family	not identified
Distribution	7 blocks, 21 stations, map.
Abundance	23 specimen
Density	1 - 2
Length	3-25 mm

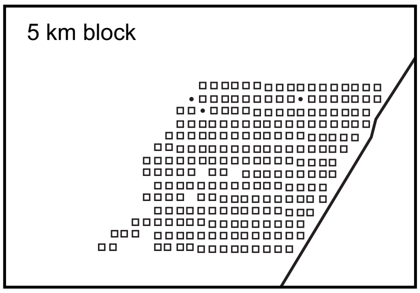
Sediment characteristics

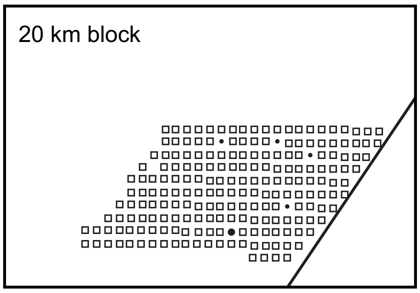
Silt fraction	18 - 93% (mean 60%)
Grain size	< 63 - 155 µm (mean < 82 µm)

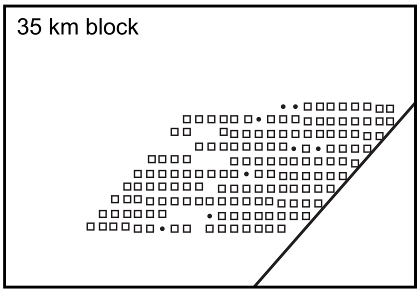
Remarks: These small shrimps often hover in small pools above the sediment surface. Although not belonging to the benthic infauna these shrimps were found at several stations. We found at least two different species, both having a serrated rostrum and two pairs of tiny claws.

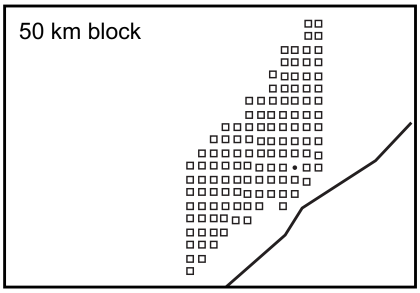


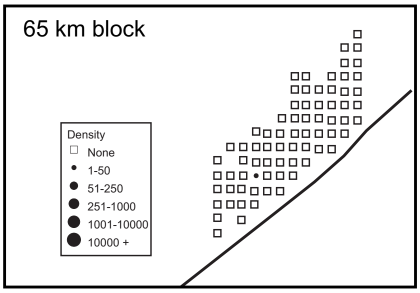












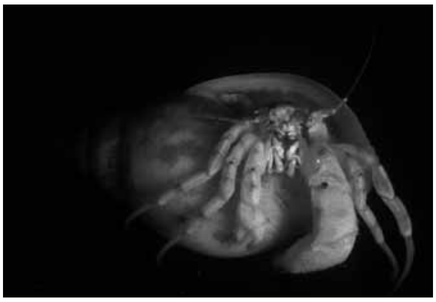
HERMIT CRAB

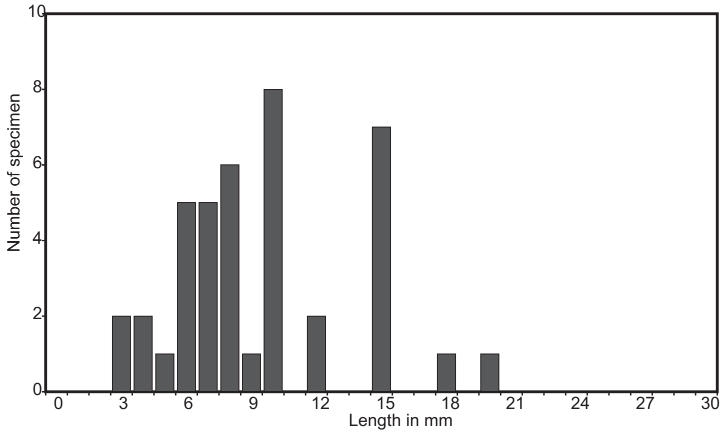
Species number	7901
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Decapoda
Family	not identified
Distribution	6 blocks, 39 stations, map.
Abundance	42 specimen
Density	1 - 2
Length	3-20 mm

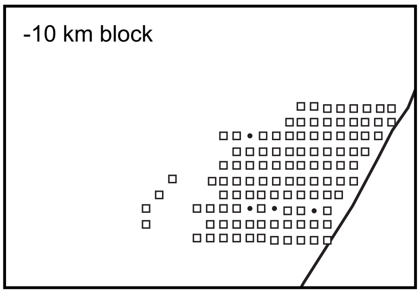
Sediment characteristics

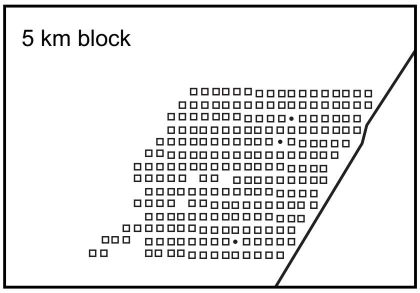
Silt fraction	0.5 - 94% (mean 48%)
Grain size	< 63 - 362 µm (mean < 100 µm)

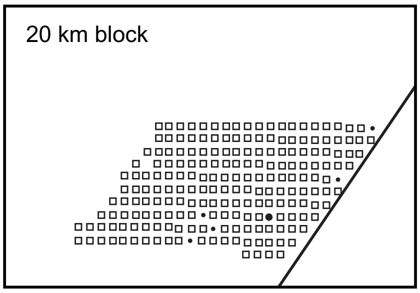
Remarks: At least 21 species of hermit crabs of three families can be found in NW Australia (MLs personal compilation of Crustacea). Only small species were encountered during the survey. It is known that hermit crabs can aggregate for some reason perhaps to rest until the water is returning. Another possibility is that these scavengers were initially attracted to a food source

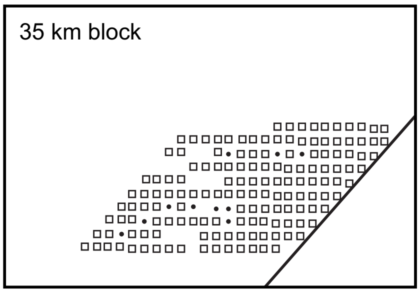


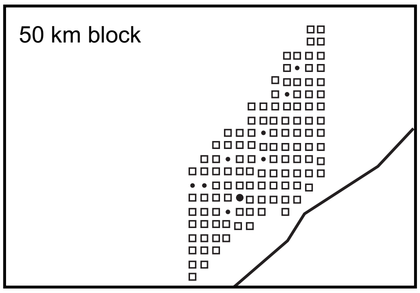


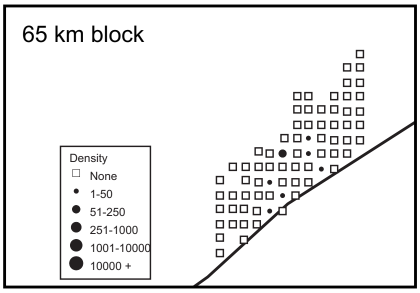

-10 km block


5 km block


20 km block


35 km block


50 km block


65 km block

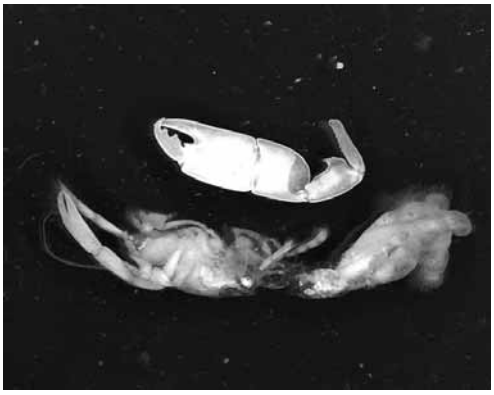
Callianassa spec. (burrowing shrimp)

Species number	7802
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Decapoda
Family	Callianassidae
Distribution	3 blocks, 3 stations, no map
Abundance	3 specimen
Density	1
Length	15-28 mm

Sediment characteristics

Silt fraction	32 - 70% (mean 48%)
Grain size	< 63 - 152 µm (mean < 108 µm)

Remarks: Identified with Poore & Griffin (1979). This is a burrowing shrimp, which is rather helpless and easy prey when extracted from its burrow.



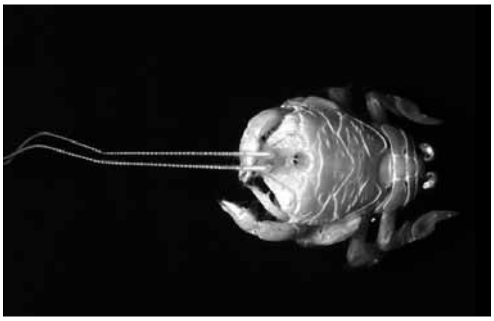
Raninidae (Frog crab)

Species number	8071
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Decapoda
Family	Raninidae
Distribution	1 block (35), 1 station, no map.
Abundance	1 specimen
Density	1
Length	12 mm

Sediment characteristics

Silt fraction	53%
Grain size	< 63 µm

Remarks: This species has very long antennae, that together probably form a breathing snorkle for the crab when it is burried in sediments with a low oxygen content.



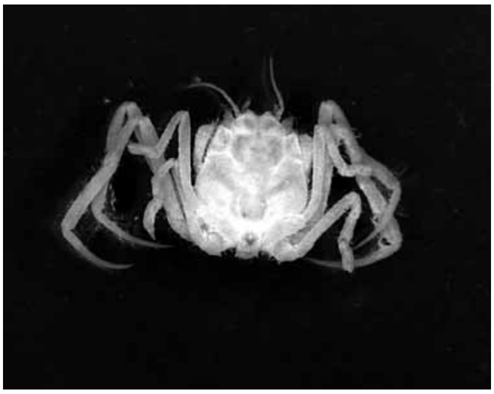
Dorippe australiensis Miers, 1884 (Umbrella crab)

Species number	8051
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Decapoda
Family	Dorippidae
Distribution	1 block, 2 stations, no map.
Abundance	2 specimen
Density	1
Length	3-4 mm

Sediment characteristics

Silt fraction	32 - 92% (mean 62%)
Grain size	< 63 - 110 µm (mean < 87 µm)

Remarks: This soft shelled crab carries a shell on its back to protect and hide it self. The four hind legs have special hooks to hold the shell. It slowly walks over the mud, and holds the shell very firmly even when you pick it up.



CF MYRODES EUDACTYLUS BELL, 1855 (HELMET CRAB, *LEUCOSIA* SPEC. A.)

Species number	8201
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Decapoda
Family	Leucosiidae
Distribution	2 blocks, 3 stations, no map.
Abundance	3 specimen
Density	1
Length	2-16 mm

Sediment characteristics

Silt fraction	25 - 65% (mean 43%)
Grain size	< 63 - 120 µm (mean < 98 µm)

Remarks: Small hard shelled crabs (Pebble Crabs) which bury in the mud and sand. The carapace of this species is granulated, and has posteriorly two short spines and a dorsal blunt one.

LEUCOSIA SPEC. D

Species number	8231
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Decapoda
Family	Leucosiidae
Distribution	2 blocks, 2 stations, no map.
Abundance	2 specimen
Density	1
Length	3-9 mm

Sediment characteristics

Silt fraction	29 - 55% (mean 42%)
Grain size	< 63 - 116 µm (mean < 90 µm)

Remarks: This is a real representative of the genus *Leucosia* with a polished carapace and large granules on the arm of the nippers.

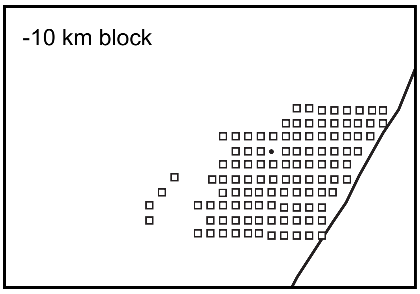
EBALIA SPEC. (*LEUCOSIA* SPEC. C)

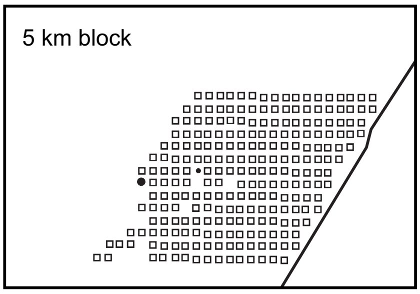
Species number	8221
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Decapoda
Family	Leucosiidae
Distribution	5 blocks, 10 stations, map.
Abundance	13 specimen
Density	1 - 3
Length	2-55 mm

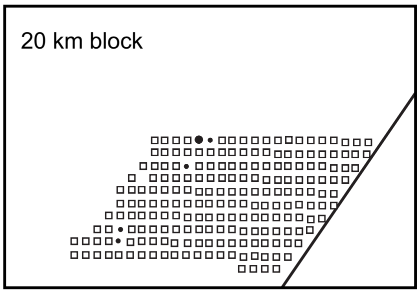
Sediment characteristics

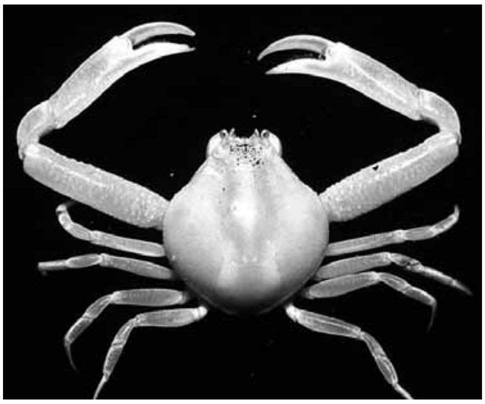
Silt fraction	31 - 94% (mean 53%)
Grain size	< 63 - 249 µm (mean < 108 µm)

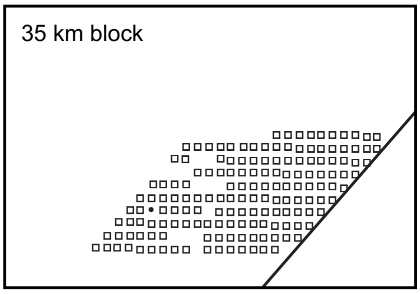
Remarks: Carapace more or less circular with the anterior and posterior part straight. This species prefers the lower part of the intertidal area.

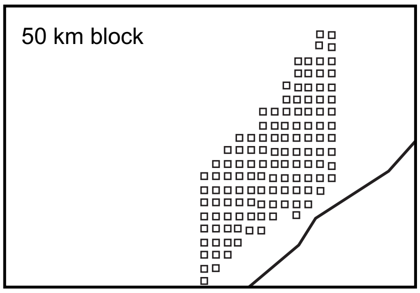


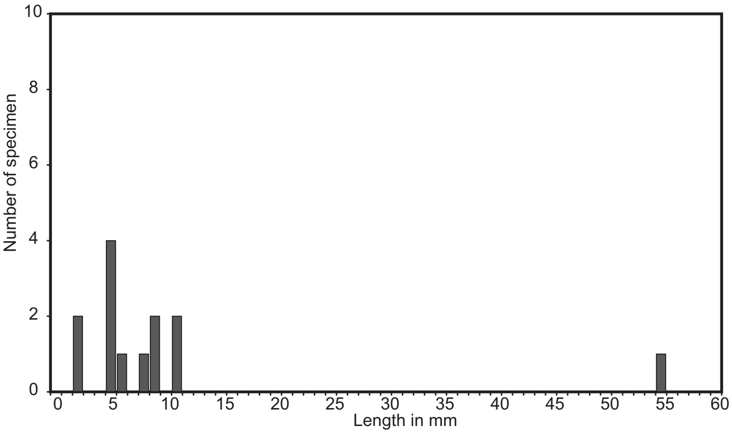


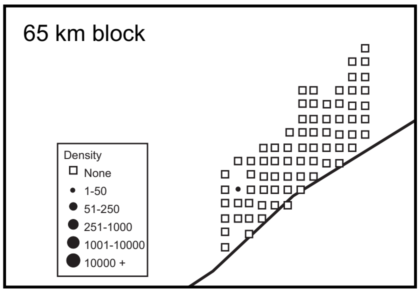












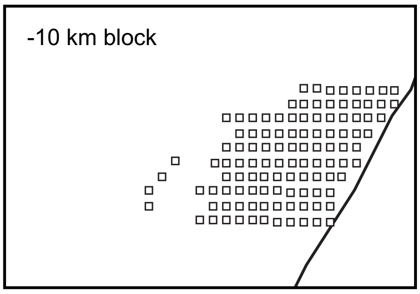
PORTUNIDAE (SWIMMING CRAB)

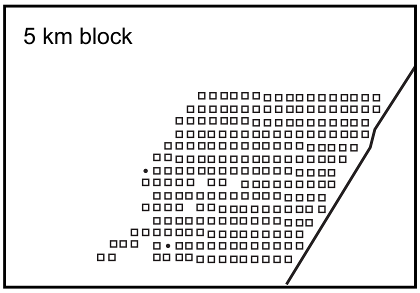
Species number	8291
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Decapoda
Family	Portunidae
Distribution	4 blocks, 8 stations, map.
Abundance	8 specimen
Density	1
Length	4-22 mm

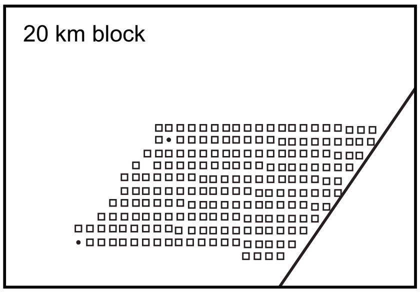
Sediment characteristics

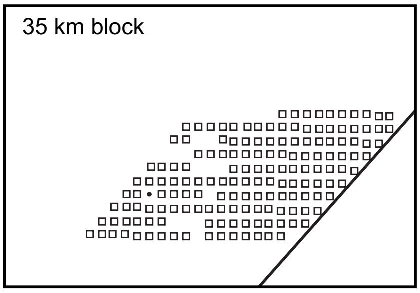
Silt fraction	31 - 96% (mean 57%)
Grain size	< 63 - 135 μm (mean < 70 μm)

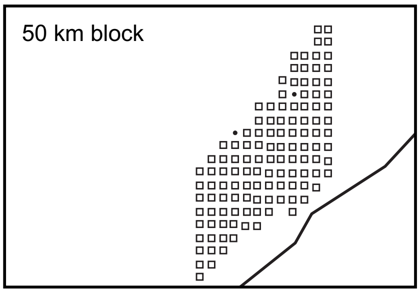
Remarks: Only small specimens were caught or seen. The carapace (body shield) of these animals has serrated sides with 9 teeth on each side. The last of these teeth is enlarged like a dagger. The last pair of legs has an oval swimming blade at the end. They were always found near the low water line.

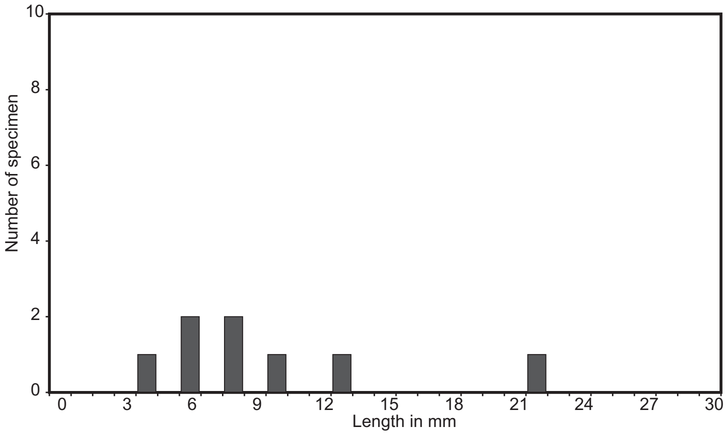


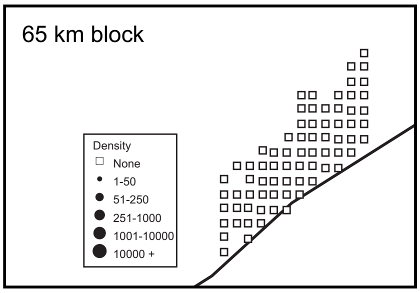












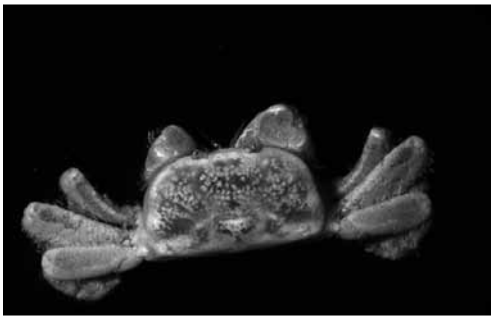
HEXAPUS SPEC. (6-LEGGED CRAB)

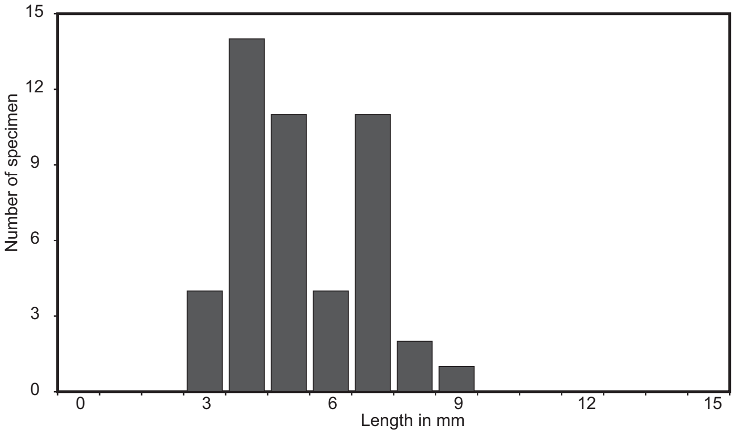
Species number	8501
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Decapoda
Family	Goneplacidae
Distribution	5 blocks, 37 stations, map.
Abundance	48 specimen
Density	1 - 4
Length	3-9 mm

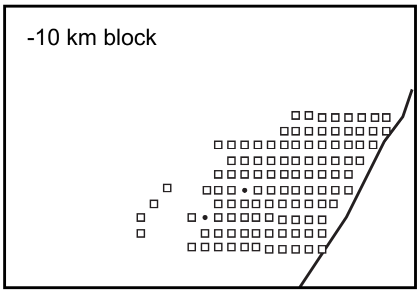
Sediment characteristics

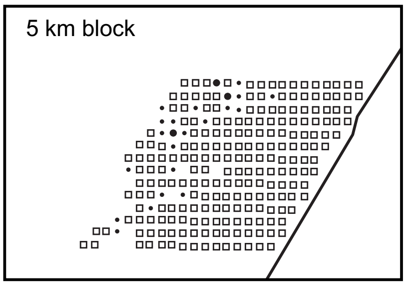
Silt fraction	31 - 99% (mean 74%)
Grain size	< 63 - 231 µm (mean < 78 µm)

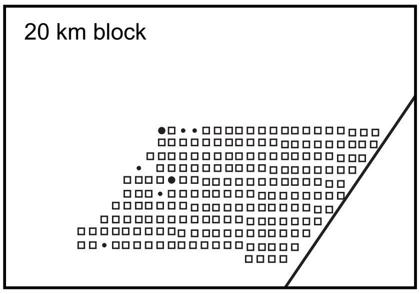
Remarks: These small crabs have a rectangular smooth carapace that is wider than long. The front corners are rounded and the eyes are tiny. The most obvious characteristic is that they only have 3 pairs instead of four walking legs, which is a very unusual phenomenon for crabs. When touching the animal it stiffens to a peculiar posture, and will relax only after some minutes.These animals were only found near the low water line.

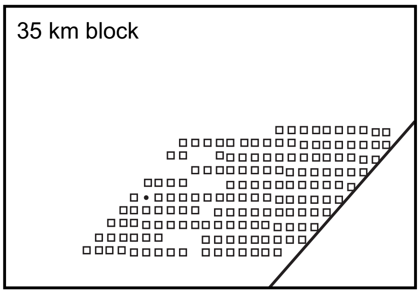


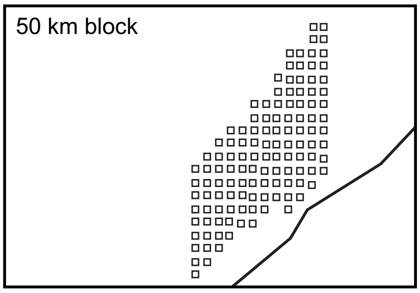


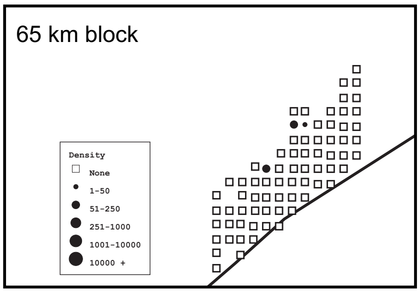










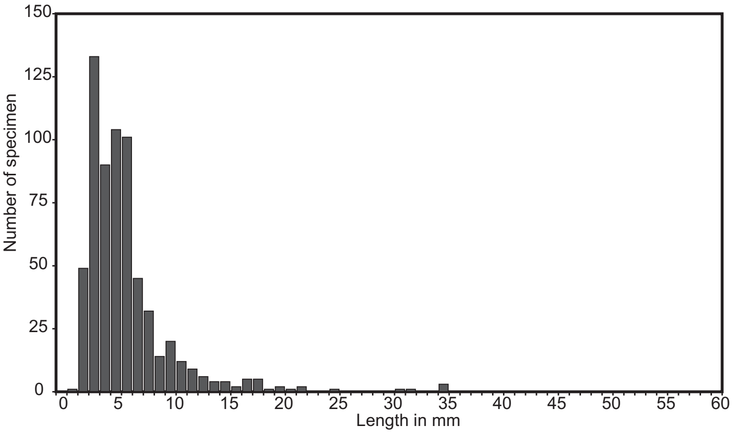


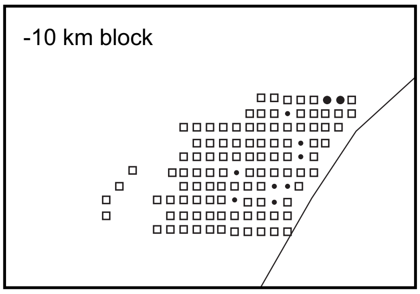
MACROPHTHALMUS SPEC. (SENTINEL CRAB)

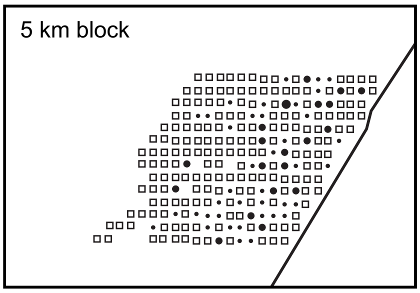
Species number	8601
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Decapoda
Family	Ocypodidae
Distribution	7 blocks, 359 stations, map.
Abundance	649 specimen
Density	1 - 12
Length	1-35 mm

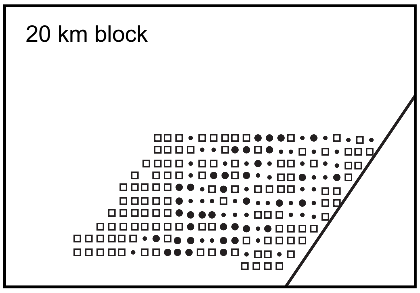
Sediment characteristics	
Silt fraction	0.5 - 99% (mean 54%)
Grain size	< 63 - 206 µm (mean < 85 µm)

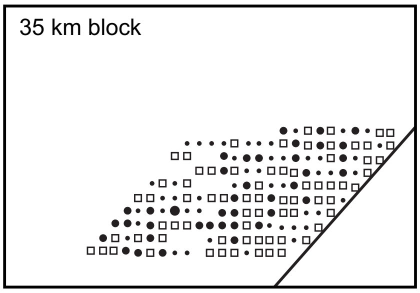
Remarks: Several species occur on Eighty-mile Beach. Very similar to the fiddler crabs which have the long stalked eyes in common. However, *Macrophthalmus* are much flatter, have both claws of the same size and live lower on the mud flats in oblique burrows. Their abundant tracks are visible almost everywhere on the flats dispersing from these oblique holes. The male is recognizable by the small triangular abdomen and the more developed nippers. We encountered several species, but we were unable in identifying these animals with certainty with the key of Barnes (1967, 1971). As ìn Roebuck Bay the animals are common everywhere on the flats, and even our small core-samples give a rather good impression of the distribution of these relatively large animals.

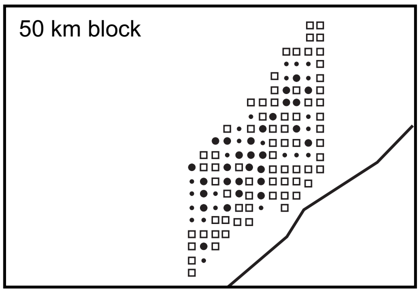


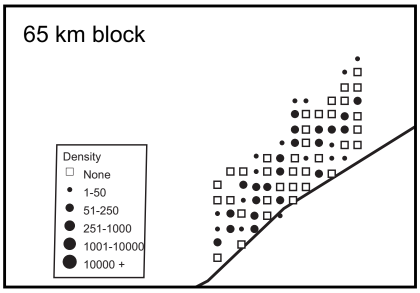












MICTYRIS LONGICARPUS (SOLDIER CRAB)

Species number	8311
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Order	Decapoda
Family	Mictyridae
Distribution	4 blocks, 4 stations, no map.
Abundance	5 specimen
Density	1 - 2
Length	2-9 mm

Sediment characteristics

Silt fraction	4 - 70% (mean 28%)
Grain size	< 63 - 132 µm (mean < 107 µm)

Remarks:. The body of these animals has more or les the shape of a ball with some thin legs, a pair of small claws, and two dark eyes. With their tiny legs they can burrow in a screw-like manner quickly in and out of the sand. A few hours after the tide is out these crabs appear out of the sandy sediment and aggregate to form large herds that wander over the flats (hence their name). They eat tiny food particles.

CHIRONIMIDAE LARVAE

Species number	8801
Phylum	Arthropoda
Subphylum	Insecta
Class	
Order	Diptera
Family	Chironimidae
Distribution	1 block (50), 1 station, no map.
Abundance	1 specimen
Density	1
Length	3 mm

Sediment characteristics

Silt fraction	2%
Grain size	182 µm

Remarks: The larvae of mosquitos can be very abundant in brackish waters, but are rare in the marine tidal zone.

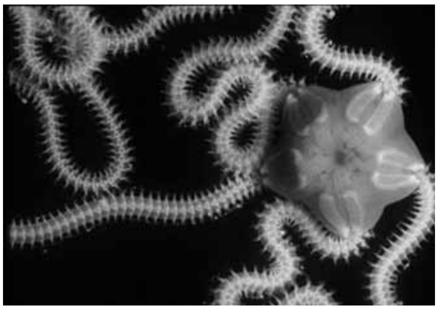
AMPHIURA (OPHIOPELTIS) TENUIS (H.L.CLARK,1938)

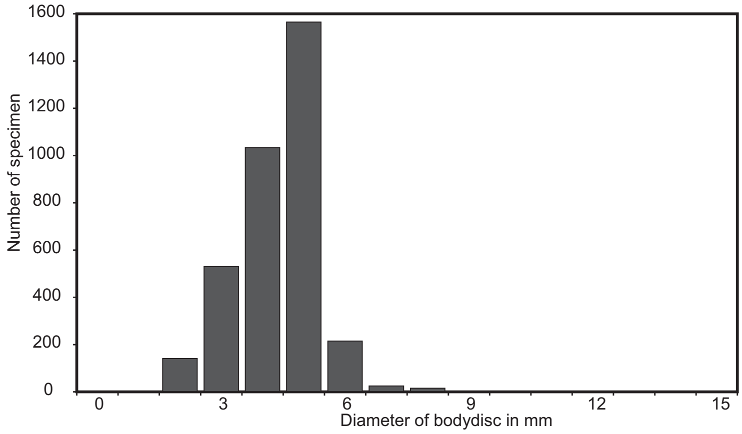
Species number	9401, 9402
Phylum	Echinodermata
Class	Ophiuroidea
Family	Amphiuridae
Distribution	7 blocks, 418 stations, map.
Abundance	3566 specimen
Density	1-56
Length	1-10 mm (diameter of body disc)

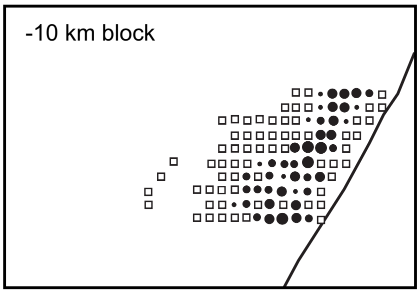
Sediment characteristics

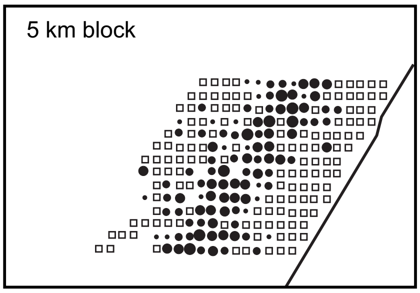
Silt fraction	1.5 - 99% (mean 57%)
Grain size	< 63 - 802 µm (mean < 87 µm)

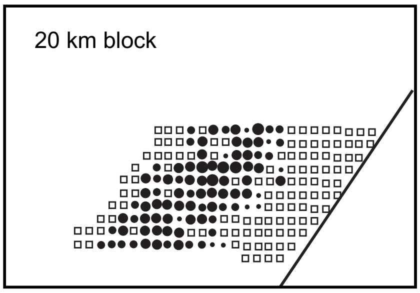
Remarks: Long armed brittle stars. The arms can be more than 10 cm long. This animal is buried deep in the sediment. Its very long arms stick out of the sediment in the water column to catch tiny food particles that are then transported to the mouth. Arms with black spots were first thought to belong to a different species, but from rare complete specimens we discovered that the ends of the arms typically have these spots.A small red polychaete (Polynoidae) lives commensally with this brittle star. This family of polychaetes is often associated with ophiuroids (Pettibone, 1993). Their similar distribution is striking. Amphiura tenuis prefers the mid intertidal zone, but does not have a preference for a certain grain size or silt content of the sediment

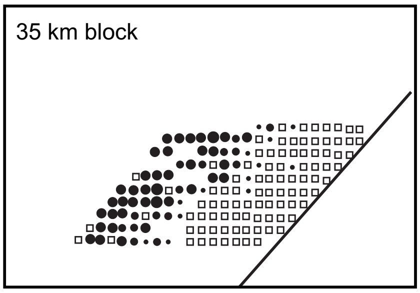


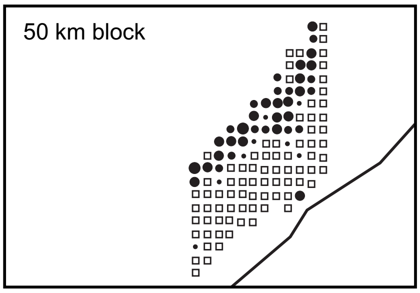


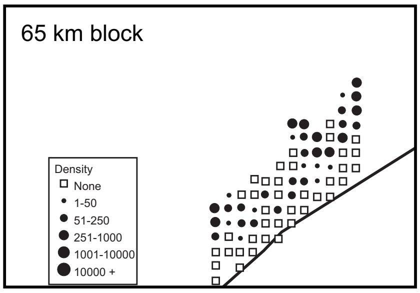










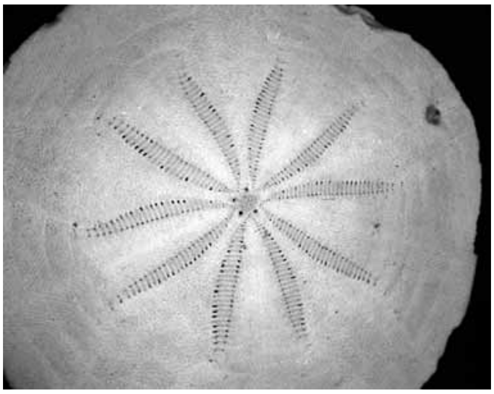


Arachnoides tenuis (flat sand dollar)

Species number	9552
Phylum	Echinodermata
Class	Echinoidea
Family	Arachnoididae
Distribution	2 blocks, 2 stations, no map.
Abundance	2 specimen
Density	1
Length	36 - 38 mm

Sediment characteristics	
Silt fraction	2 - 48% (mean 25%)
Grain size	92 - 182 µm (mean 137 µm)

Remarks: Shallow burrower in fine sand. It devours large amounts of sediment to extract and digest the labile organic material. The white skeletons without the short spines were seen abundantly at some spots and often a lot them were flipped by a shorebird, the Ruddy Turnstone, which sought for small crustaceans underneath.



Leptopentacta grisea H.L.Clark,1938 (Digging seacucumber)

Species number	9601
Phylum	Echinodermata
Class	Holothuroidea
Family	Cucumariidae
Distribution	1 block (35), 1 station, no map.
Abundance	1 specimen
Density	1
Length	15 mm

Sediment characteristics	
Silt fraction	38%
Grain size	103 µm

Synaptidae spec. 2 (uncolored Synaptidae)

Species number	9604
Phylum	Echinodermata
Class	Holothuroidea
Family	Synaptidae
Distribution	1 block (5), 2 stations, no map.
Abundance	8 specimen
Density	1-7
Length	5-12 mm

Sediment characteristics	
Silt fraction	55-92% (mean 73%)
Grain size	< 63 µm (mean < 63 µm)

Remarks: This could be the same species as *Protankyra verrilli*, but it did not have the orange color.

Synaptidae spec. 3 (green Synaptidae)

Species number	9605
Phylum	Echinodermata
Class	Holothuroidea
Family	Synaptidae
Distribution	1 block (-10), 1 station, no map.
Abundance	1 specimen
Density	1
Length	36 mm

Sediment characteristics	
Silt fraction	23%
Grain size	139 µm

Remarks: Very similar to the two previous species, but with a distinct light green color.

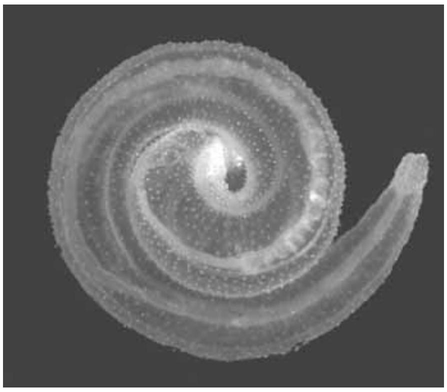
PROTANKYRA VERRILLI (THÉEL,1886) (ORANGE SYNAPTIDAE)

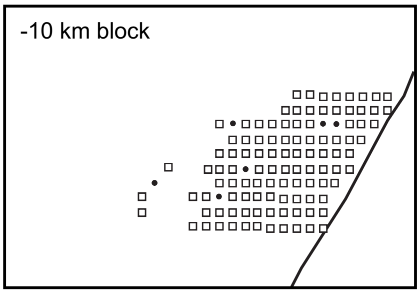
Species number	9602
Phylum	Echinodermata
Class	Holothuroidea
Family	Synaptidae
Distribution	6 blocks, 105 stations, map.
Abundance	410 specimen
Density	1-25
Length	2-38 mm

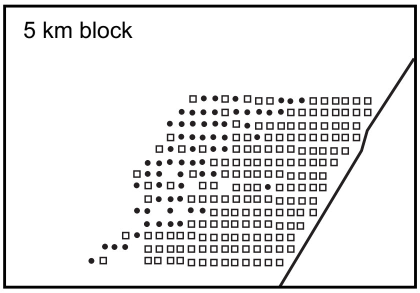
Sediment characteristics

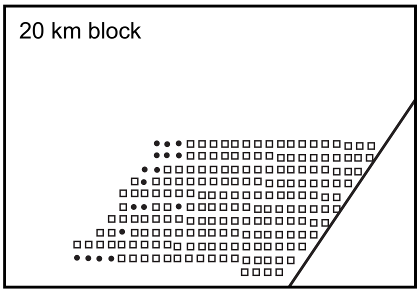
Silt fraction	16 - 99% (mean 76%)
Grain size	< 63 - 649 µm (mean < 76 µm)

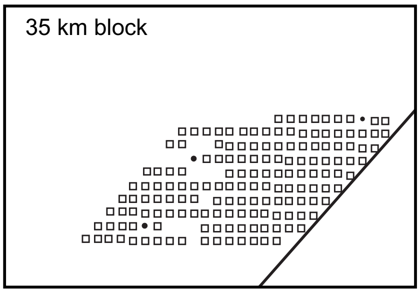
Remarks: A lot of juveniles of this burrowing sea cucumber were found. The adult animals have many tiny anchor-like objects in their skin. These anchors look like they are made of glass but actual are calcareous. Because of the sharp hooks of the anchors that stick out of the skin, the animal fells sticky when touching it. This animal was especially abundant in Block 5 and 20, and they preferred the lower part of the intertidal area. The maps only indicate presence or absence.

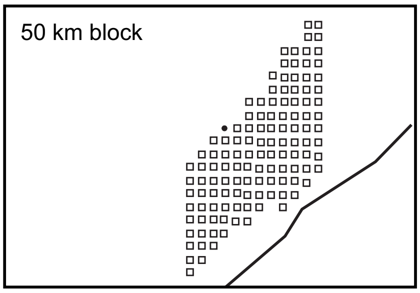


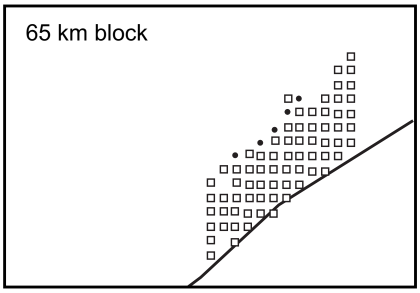












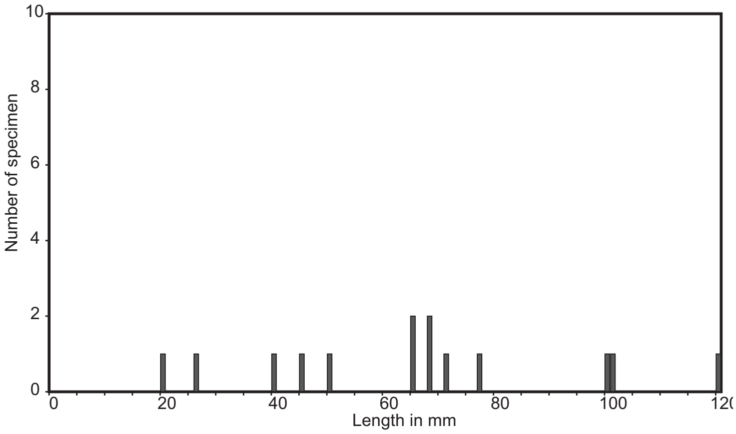
PARACAUDINA CHILENSIS (MÜLLER,1850) SAND-TAILED SEA CUCUMBER

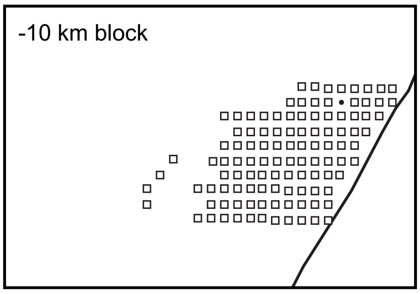
Species number	9606
Phylum	Echinodermata
Class	Holothuroidea
Family	Caudinidae
Distribution	4 blocks, 13 stations, map.
Abundance	15 specimen
Density	1-2
Length	20-120 mm

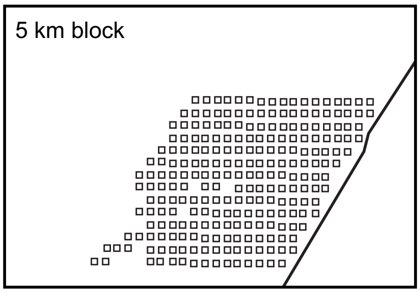
Sediment characteristics

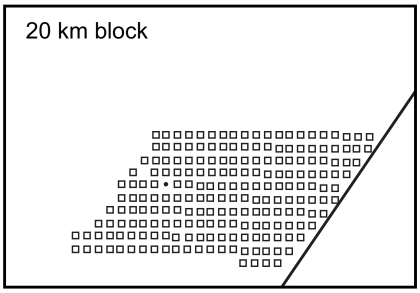
Silt fraction	25 - 72% (mean 46%)
Grain size	< 63 - 139 µm (mean < 92 µm)

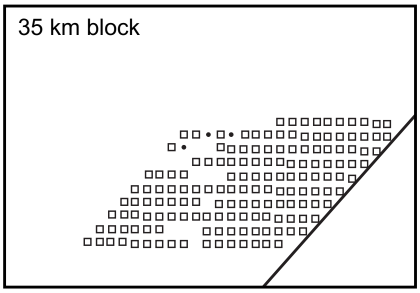
Remarks: This rather large burrowing sea cucumber has a long slender tail that is encrusted with sandgrains. It was not found during our expeditions in Roebuck Bay of 1997, 2000 and 2002, but has been recorded from the Bay previously.

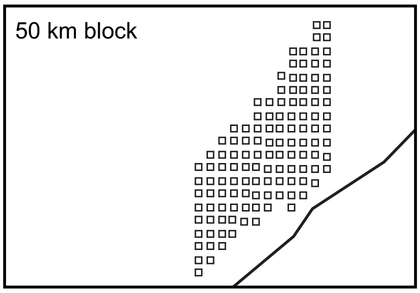


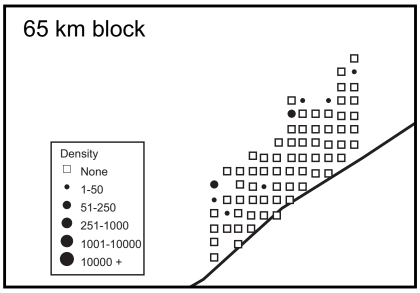












BIG SEA CUCUMBER WITH SLENDER TAIL

Species number	9603
Phylum	Echinodermata
Class	Holothuroidea
Family	not identified
Distribution	1 block (5), 3 stations, no map.
Abundance	13 specimens
Density	1-7
Length	8-120 mm
Sediment characteristics	
Silt fraction	75 - 87% (mean 81%)
Grain size	< 63 µm (mean < 63 µm)
Remarks:	

BROWN SPECKLED SEA CUCUMBER

Species number	9607
Phylum	Echinodermata
Class	Holothuroidea
Family	not identified
Distribution	1 block (50), 1 station, no map.
Abundance	1 specimen
Density	1
Length	5 mm
Sediment characteristics	
Silt fraction	31%
Grain size	112 µm
Remarks:	

PURPLE SEA CUCUMBER

Species number	9608
Phylum	Echinodermata
Class	Holothuroidea
Family	not identified
Distribution	1 block (65), 1 station, no map.
Abundance	1 specimen
Density	1
Length	30 mm
Sediment characteristics	
Silt fraction	no data
Grain size	no data
Remarks:	

BIG PINK SEA CUCUMBER

Species number	9609
Phylum	Echinodermata
Class	Holothuroidea
Family	not identified
Distribution	1 block (65), 1 station, no map.
Abundance	1 specimen
Density	1
Length	60 mm
Sediment characteristics	
Silt fraction	12%
Grain size	155 µm
Remarks:	

BALANOGLOSSUS SPEC. (ACORN WORMS)

Species number	4901
Phylum	Hemichordata
Class	Enteropneusta
Family	Balanoglossidae
Distribution	2 blocks, 3 stations, no map.
Abundance	3 specimen
Density	1
Length	10-28 mm
Sediment characteristics	
Silt fraction	37-92% (mean 54%)
Grain size	< 63 - 106 µm (mean < 91 µm)
Remarks:	

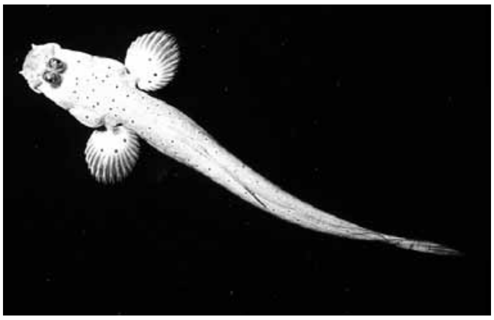
SCARTELAOS HISTOPHORUS (BEARDED MUDSKIPPER)

Species number	9801
Phylum	Chordata
Class	Osteichthyes (bony fish)
Family	Periophthalmidae
Distribution	2 blocks, 2 stations, no map.
Abundance	2 specimen
Density	1
Length	18-25 mm

Sediment characteristics

Silt fraction	87 - 96% (mean 92%)
Grain size	< 63 µm (mean < 63 µm)

Remarks: These fish graze off the surface of the sediment with their broad mouths. These grazing traces together with imprints made by the walking or leaping activities of their pectoral fins are a common sight. At Eighty-mile Beach, as in Roebuck Bay, they are commonly associated with the muddiest sediment: They hide in deep burrows, often made by other animals, during disturbance or during high tide. They have a territory that they defend, often just by raising their dorsal fin to scare off intruders. Rarely found in the quantitative samples, because they easily escape by their swiftness or ability to hide in deep burrows. In the fish book of Allen & Swainston (1988), which is useful for this area, this family is included in the family Gobiidae.



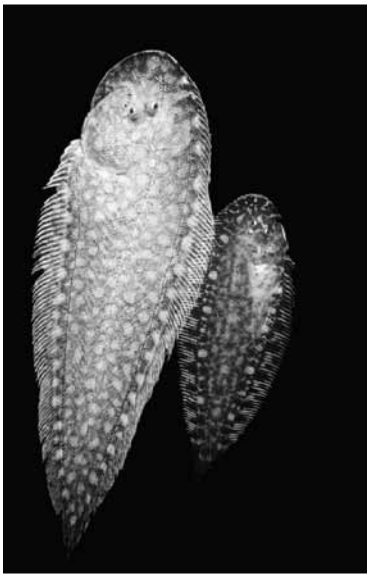
CYNOGLOSSIDAE AND SOLEIDAE (SMALL SOLE)

Species number	9821
Phylum	Chordata
Class	Osteichthyes (bony fish)
Family	Cynoglossidae/Soleidae
Distribution	4 blocks, 6 stations, no map.
Abundance	6 specimen
Density	1
Length	18-30 mm

Sediment characteristics

Silt fraction	46 - 92% (mean 68%)
Grain size	< 63 - 102 µm (mean < 70 µm)

Remarks: Members of these two families are very similar in appearance. But Soleidae have the eyes on the right side, while Cynoglossidae have these on the left side. We only found one Soleidae (left on the figure). The Cynoglossidae belonged to one species, which has 3 lateral lines on the eyed side, clearly visible in the figure.



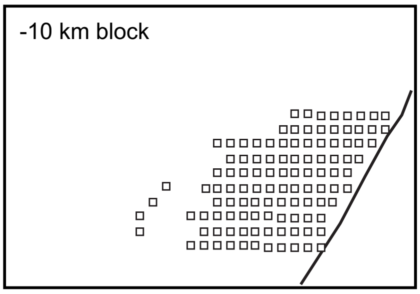
GOBIIDAE

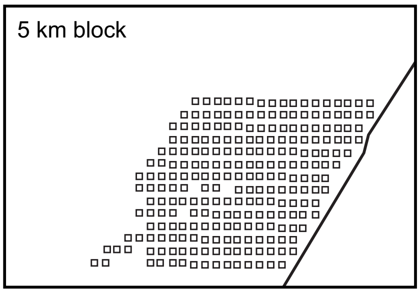
Species number	9810
Phylum	Chordata
Class	Osteichthyes (bony fish)
Family	Gobiidae
Distribution	2 blocks, 7 stations, map.
Abundance	8 specimen
Density	1-2
Length	12 - 33 mm

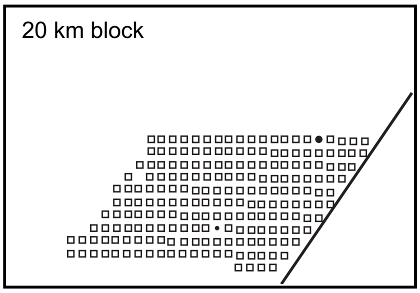
Sediment characteristics

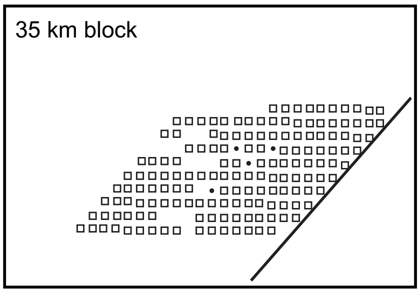
Silt fraction	50 - 90% (mean 74%)
Grain size	< 63 µm (mean < 63 µm)

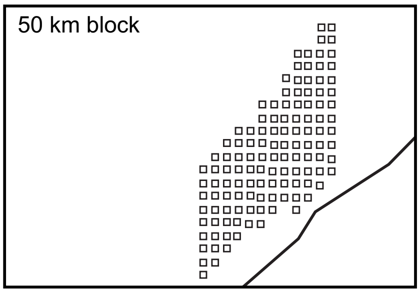
Remarks: This small species lives in shallow pools or in the water of larger burrows. It is very similar to the mudskippers, but the pelvic fins are grown together to form a short cone-like tube with which the fish rests on the bottom.

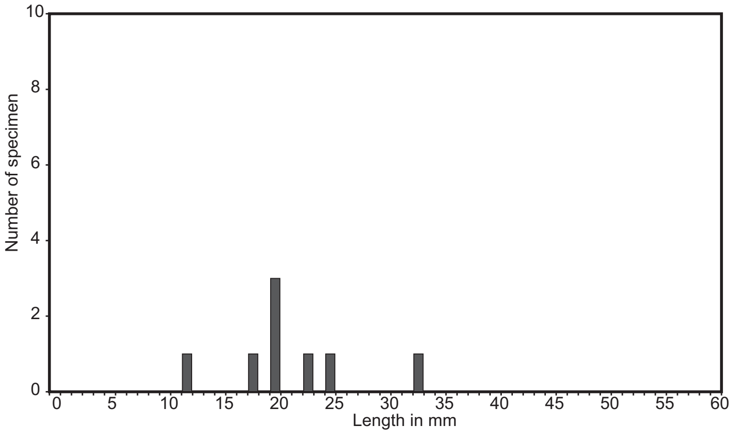


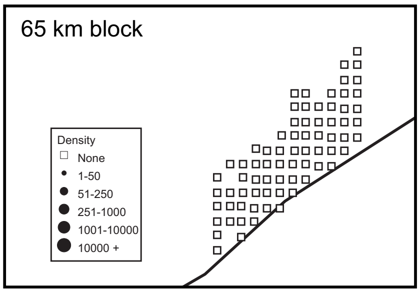












9. INTERTIDAL BENTHIC COMMUNITY STRUCTURE: ROLE OF SEDIMENT CHARACTERISTICS

Pieter Honkoop, Grant Pearson, Marc Lavaleye & Theunis Piersma

ABSTRACT

The distribution of species or groups of species of benthic invertebrates living in intertidal mud and sandflats is often associated with characteristics of the sediment they live in. In October 1999, we studied such associations along the shores of Eighty-Mile Beach in Western Australia. This beach seems to be monotonous and homogeneous and is not divided by physical structures such as bays, estuaries or headlands and is, therefore, a perfect beach to study spatial patterns of characteristics of sediment (size-classes and median grain-size) and of the benthic assemblages within a single beach rather than between beaches. Benthic invertebrates were sampled at parts (blocks) of Eighty-mile Beach, each block separated by 15 km of unsampled beach. Per block, 10 - 14 offshore transects 200 metres apart and sampled every 200 metres offshore in order to determine grain-size characteristics of the sediment and the structure of benthic assemblages. To test for offshore (according to tidal height) and longshore (according to the place along 80-Miles Beach) gradients, data from four adjacent sampling points were grouped to get sufficient statistical replication. To test for effects of tidal height on characteristics of sediment and on the composition of benthic assemblages, each block was divided into three alongshore sections each containing sampling points at three tidal heights. Sediment was coarser at the highest intertidal level and became finer towards the low water line. Benthic assemblages also differed among tidal heights, a difference mainly caused by echinoids and polychaetes that increased in number towards the lower tidal levels. There was also an alongshore gradient in characteristics of sediment and benthic assemblages. Although each section along the beach supported a unique collection of benthic invertebrates, the distribution of sediments and the structure of benthic assemblages were not very well correlated. This may be partly explained by tropical cyclone Vance, which hit the coast of Western Australia only a few months before our study and may have led to extensive reworking of the sediment.

9.1. INTRODUCTION

Animals and plants on intertidal rocky shores often show a vertical distribution (Underwood 1981, 1984) which can be caused by various processes such as recruitment and larval preferences (Grosberg 1982), settlement, selective mortality, and habitat-structure (Raimondi 1988). Similar patterns are found in intertidal sand- and mudflats, mangroves, and beaches where invertebrates are able to modify the physical environment and, in that way, contribute to spatial differences in the structure of sediment and of benthic assemblages. The effects of the ability to modify the environment are most pronounced in sheltered beaches (McLachlan 1987).

Biological causes for the existence of zonation or patchiness in intertidal areas can be that (1) some benthic species of invertebrates need to be submerged for a relatively long period of the tidal cycle to be able to feed and meet energetic requirements. (2) Sensitivity to air-exposure. Some species cannot cope with the increased physical stress associated with exposure to air and, therefore, prefer to live at lower tidal levels. (3) Predation. Submersion enables predation by fish and crabs which is thus more severe at lower tidal levels. During emersion, however, avian predators come in and feed on benthic invertebrates (Quammen 1984). This may also lead to variations in the distribution of benthic animals in intertidal flats. (4) Benthic animals themselves can also contribute to patterns of distribution as a consequence of interspecific interactions (Beukema & Flach 1995). Benthic filter-feeders may compete for food, especially at higher tidal levels (Peterson & Black 1987). Modification of sediment characteristics by bioturbation may provide new habitats (Warren & Underwood 1986, Warwick *et al.* 1990, Schratzberger & Warwick 1999) and enables new species to settle or to survive better and simultaneously prevent settlement or survival of others (Warwick *et al.* 1986, Flach 1996). All these interacting factors and processes (see the review of Peterson 1991) can shape the environment of intertidal flats and make these systems very dynamic.

An abiotic factor causing zonation or patchiness can be the dissipation of energy generated by waves. This may affect sediments and, hence, the fauna. Closer to the shore, the waves transfer energy to the seafloor and affect sorting of sediments. Generally, finer sediments are deposited at lower tidal levels where wave action is less severe; coarser particles can only be deposited at higher tidal levels. Some species have preferences for a certain distribution of grain-sizes (Rhoads & Young 1970, Levinton 1972). Small-scale effects of local currents can change the availability of food (Kamermans 1993, Thrush *et al.* 2001), thus limiting the numbers of species or individuals in certain areas and competition for food may become important.

The aim of this study was to measure offshore and longshore gradients in the distribution of sediments and the structure of benthic assemblages at Eighty-mile Beach (Western Australia). This beach, with its northernmost point 200 km south of Broome, is about 230 km long. It is an almost continuous sandy beach interrupted by only a few small,shallow, muddy bays with mangrove trees. Going seawards there is a steep slope from the beach to the intertidal mud- and sandflats, a characteristic of reflective beaches (McLachlan 1987). At very low tides the maximum width of the air-exposed flats is 4 - 5 km. The physical appearance of the total length of the beach seems homogeneous, making it an ideal location to study gradients in benthic assemblages and characteristics of the sediments. This study aimed to test whether there were spatial differences in the composition of benthic assemblages and in the structure of the sediment among different tidal heights and among different (alongshore) parts of the beach.

9.2. MATERIAL AND METHODS

9.2.1. Sampling and treatment of sediment samples

Six blocks along Eighty-mile Beach, 15 km apart from each other, were sampled (Fig. 3.1). Each block consisted of 10 - 14 transects between the beach and low water level. Transects and sampling points along transects were 200 m apart. At each sampling point, a sediment core was taken with a diameter of 4.4 cm and a depth of 10 cm. The samples were transferred to plastic bags, labelled and stored until further treatment.

In the laboratory, the sediments were removed from the bags and transferred to clean buckets. All aggregates of clay and sand were disaggregated in tap water by swirling and kneading. After disaggregation the larger particles were allowed to sink. After 30 - 60 seconds, the smaller particles were carefully decanted onto pre-weighed Schleicher & Schuell folded filter (type 595½, diameter 385 mm, retention 4 - 7 µm). Water was added to the remaining sediment and the content of the bucket was stirred thoroughly. The water was decanted onto the same filter paper and the process repeated until the water remained clear after stirring. After filtration, the filters were folded and allowed to air-dry for 48 h. They were then dried at 80 ºC until constant weight. Filters were allowed to cool in a desiccator and weighed to the nearest 0.01 g. The mass of the sediment retained on the filters was the difference between the two weighings. All material retained onto the filters was assumed to be < 63 µm.

The sediment left in the bucket (grain-size > 63 µm) was transferred to a beaker and dried at 80 ºC for four days (constant weight). The dried sediment was then transferred to a stack of sieves with mesh sizes of 63, 125, 250, 500 and 1000 µm. Each sample was sieved for 15 minutes with an electrical sieve-shaker. The material retained onto each sieve was weighed to the nearest 0.01 g. The weight of the smallest fraction (silt, < 63 µm) was added to the weight of the material retained by the corresponding filter paper. Percentages of weight of each size class were used rather than absolute weights. Rather than using the logarithmic millimetre scales of the sieves, a $\log_2$ transformed scale, the phi (ϕ)-scale, was used to calculate the median grain-size (Table 9.1)

Table 9.1. Size classes of the sediment distribution in millimetre and phi (ϕ) values. The midpoint (*d*) values are used to calculate skewness and kurtosis. Note that for the largest size class (> 1 mm), no value for the midpoint can be given (see text). Also noted is name of the size class (Folk, 1980).

Size class (mm)	Size class (ϕ)	midpoint (d in ϕ)	name of size class
> 1	? - 0	-	very coarse sand
0.5 - 1	0 - 1	0.5	coarse and
0.25 - 0.5	1 - 2	1.5	medium sand
0.125 - 0.25	2 - 3	2.5	fine sand
0.063 - 0.125	3 - 4	3.5	very fine sand
< 0.063	4 - 5	4.5	silt and mud

Benthos were sampled, sorted and identified according the procedures described in elsewhere in this report.

9.2.2. Statistical analyses

To test hypotheses about an offshore gradient in distribution of sediment and benthos, data from four nearby individual sampling points were treated as replicates within sites. The validation of this procedure is described in the next paragraph. Each transect was divided into three areas according to distance from low water. These were the two sampling points closest to the sea on each transect, the two farthest from the sea on each transect and two towards the middle of each transect (Fig. 9-1). In Blocks -10, 5, 20, 35 and 50, data from these three tidal heights were combined for two transects along each of the edges of the block and for two transects in the middle of each block. At each of the five blocks, there were thus nine sites (i.e. a combination of distance offshore and distance alongshore); three

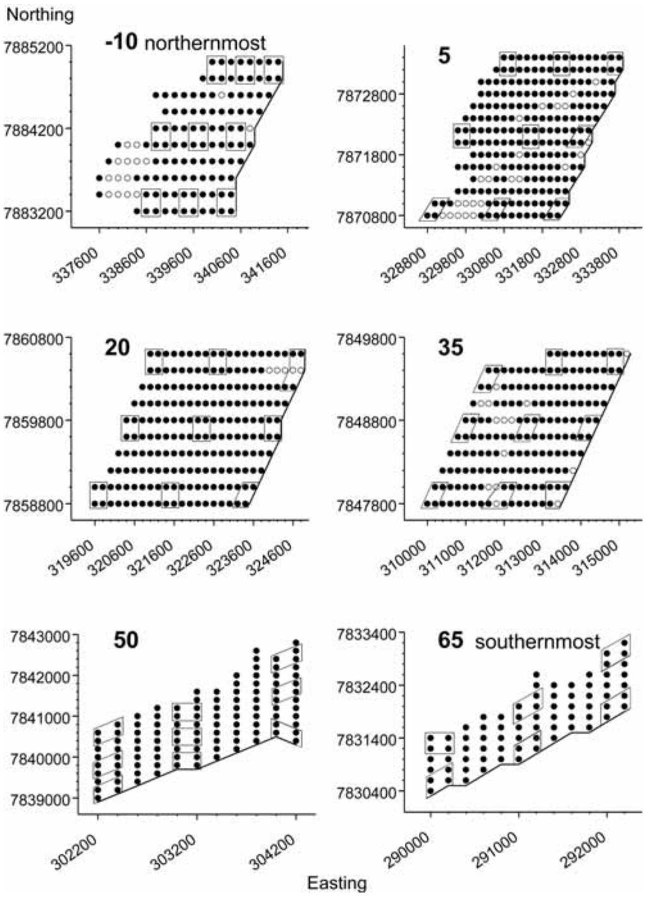


Figure 9.1. Locations from which sediment and benthos were collected and processed (solid points). The open points represent the locations from which information about sediment is missing (these include the 37 unidentified or lost samples). Distance between adjacent transects and sampling points is 200 m. The four sampling points grouped within a small box are the replicates used to test the hypothesis concerning the gradient in tidal height.

replicates at each of three tidal levels. Each site contained four individual sampling points, 200 m apart. Because transects at block 65 were relatively short, only differences between the highest and lowest tidal levels were examined (Fig. 9.1).

If the four samples from each group were taken from the same population (i.e. scale of spatial variability is larger than 200 m), replicate samples would not have been statistically independent. If the samples were taken from different populations (i.e. scale of spatial variability is smaller than 200 m) then they could be considered to be statistically independent. A way to test independence is to examine patterns of faunal distribution between adjacent transects. Patterns will be different and samples statistically independent if the scale of spatial distribution is smaller than 200 m and will be similar and samples statistically dependent if the scale of spatial distribution is larger than 200 m. To test which was true, five adjacent transects of Block -10 were used. The sampling points of each transect were numbered from 1 (or 0, when taken above mean high water level) closest to the shore. PRIMER (Plymouth Routines In Multivariate Ecological Research) was used for multivariate analyses of the data. Two-dimensional non-metric multidimensional scaling (n-MDS) on the similarity matrices of sediment (Euclidean distances; Fig. 9.2A) and benthos (Bray-Curtis (dis)similarities; Fig. 9.2B) was done according to Clarke (1993) and Clarke and Ainsworth (1993) to examine the patterns along the horizontal and vertical axis of the plots. Data were not transformed. Ordination of the characteristics of sediment from the five adjacent transects resulted in a distinct pattern (Fig. 9-2A). The sampling points closest to the shore are on the left-hand site of the plot, whereas the sampling points closest to

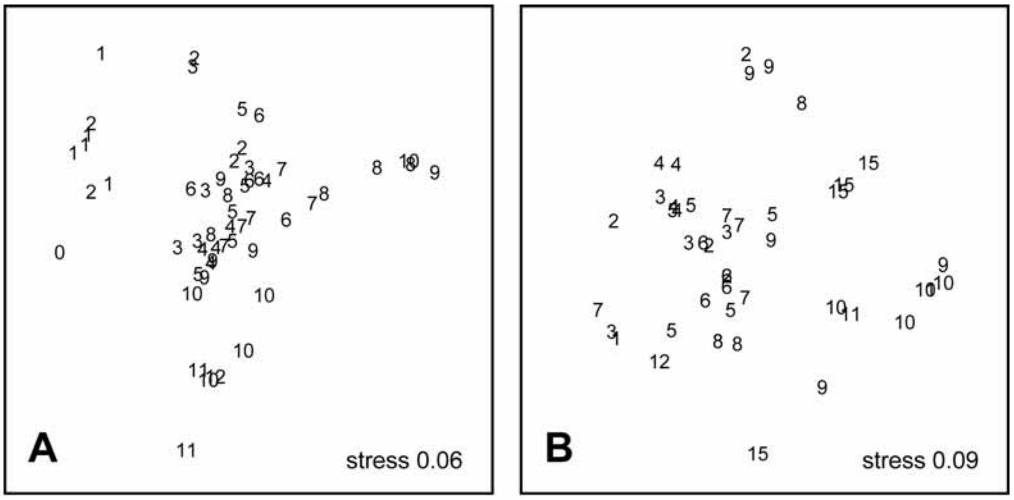


Figure 9.2. n-MDS ordination of the characteristics of sediment (A) and benthos (B) of up to 11 sampling points on each of 5 transects of block -10. The smallest numbers are located closest to the beach, the largest numbers closest to the low water line.

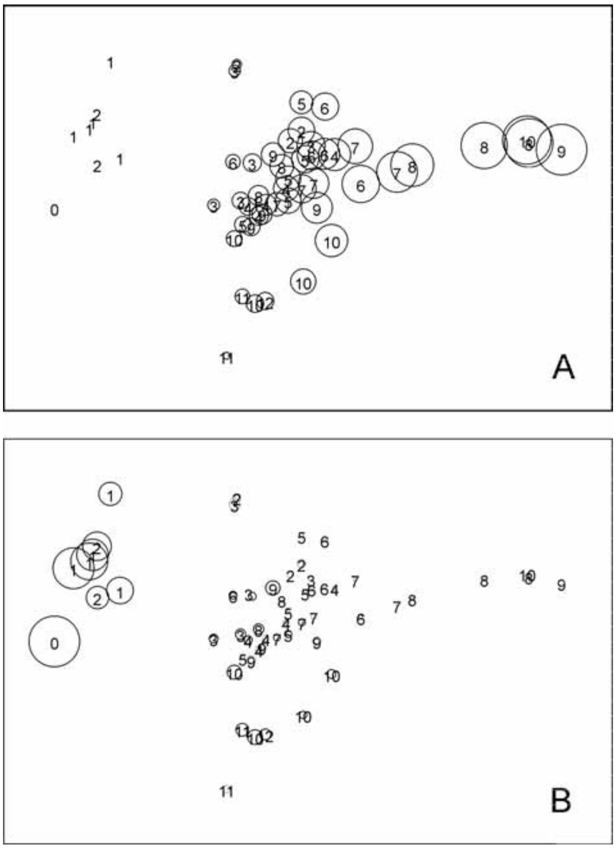


Figure 9.3. n-MDS ordinations of the sediments of 5 transects of block -10 with superimposed the < 0.063 mm (A) and 0,125 - 0.250 mm (B) sediment fraction.

the low-water line are located on the right-hand side of the plot. Although the points in the middle of the plot are mixed, there appears to be an offshore gradient particularly when the < 63 µm (Fig. 9.3A) or the 125 - 250 µm fraction (Fig. 9.3B) is superimposed on the sampling points (the larger the bubble, the larger the percentage of the grain-size-class). The data strongly suggest that the sampling point closer to the shore contain coarser sediments than the point closer towards the low-water line. The pattern was not so clear with respect to the ordination of the benthos, although there seemed to be an offshore gradient in patterns of benthos as well (Fig. 9.2B). The data points along the vertical axis of the plots (Figs 9.2A, B) were not arranged in a discernible pattern, which indicated that each transect 'behaved' in a different way and that the offshore gradient was not correlated among transects. From these results it was, therefore, decided to group the sampling points according to tidal height and transect in order to obtain replication at 2 (block 65) or 3 (all other blocks) offshore and 3 alongshore portions.

Offshore differences of characteristics of the sediment and of benthic fauna were visualised with n-MDS plots. Similarity matrices of benthos (Bray-Curtis (dis)similarities) and sediment (Euclidean distances) were calculated according to Clarke (1993) and Clarke and Ainsworth (1993). To test the differences in benthos among tidal levels, Non-Parametric Multivariate Analysis Of Variance (NP-MANOVA) of untransformed data was used (Anderson 2001). This calculation not only tests for main effects (in our case, tidal height and distance alongshore) but also allows evaluation of the interaction between the two main effects. Because a maximum of two factors can be tested in these analyses, they were done for each block separately. The offshore distance was treated as a fixed factor and transects as a random factor. If significant effects of tidal level on characteristics of the sediments or benthos were observed, a posteriori comparisons were done to reveal differences between any two levels of the tidal height. Taxa responsible for differences in assemblages at different tidal heights were examined with the SIMPER routine in PRIMER (Clarke 1993).

Table 9.2. Composition of the grouped taxa used in the statistical analyses.

Group	Taxon	Number of finer taxa included
1	Anthozoans	4 species
2	Polychaetes	21 families
3	Other worms	3 Phyla (nemerteans, Sipunculans)
4	Crustaceans	9 families
5	Decapods	9 species
6	Gastropods	8 species
7	Bivalves	13 species
8	Scaphopods	1 species
9	Ophiuroids	1 species
10	Holothurians	4 species
11	Hemichordates	1 species
Total	11	74

To examine differences among the alongshore parts of the beach, only data from the sampling points were used to test the offshore gradient (see previous paragraph). Data from each of these four replicate sampling points were summed and individual species or families were grouped into coarser taxa (Table 9.2). Each block, except block 65, thus had 9 replicate samples, each consisting of the number of species found in 4 sampling points. Block 65 had only 6 replicate samples. Alongshore differences among characteristics of the distribution of sediment (grain-size) and benthos (numbers of individuals per species or per group of species and presence/absence data) were visualised and analysed using routines in PRIMER. Because es-

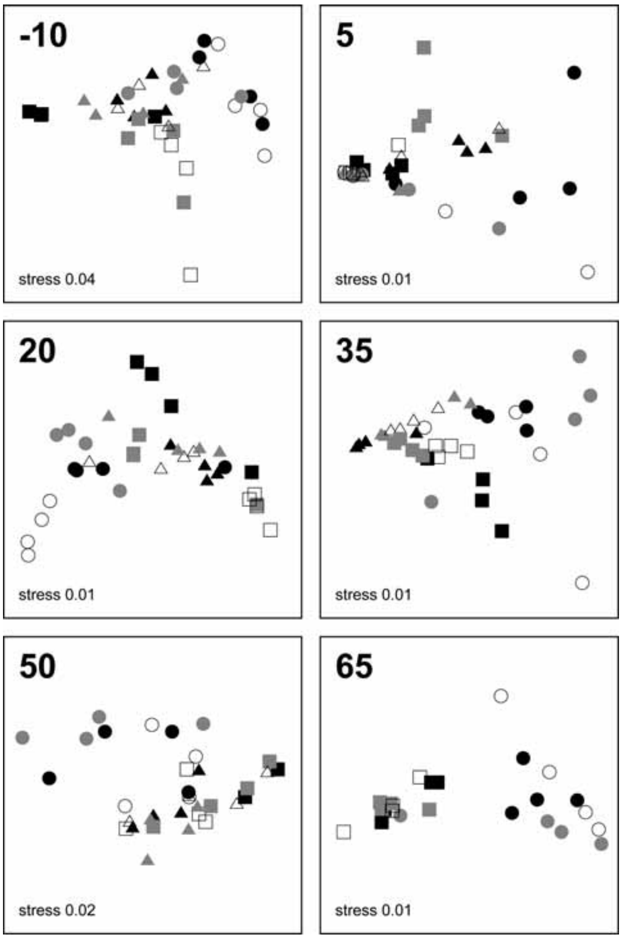


Figure 9.4. n-MDS ordinations of the characteristics of sediment at three tidal height and three parts of transects within each block ●, ●, and ○ highest tidal level, ▲, ▲ and △ intermediate tidal level and ■, ■ and ☐ lowest tidal level. Solid symbols = southernmost transect, grey symbols = middle transect and open symbols = northernmost transect.

timating differences among beaches did not involve evaluation of an interaction term, they were tested by analysis of similarities (ANOSIM, Clarke & Green 1988, Clarke 1993). The SIMPER routine (Clarke 1993) was then used to identify the relative contribution of different taxa to differences between blocks. Offshore and alongshore differences in median grain-size and total number of invertebrates per sample were also examined using standard ANOVA techniques.

The correlation of the patterns found in the distribution of the sediment and of the benthic assemblages in each block was examined using the BIO-ENV routine (Clarke & Ainsworth 1993). Spearman rank correlation (r) was used to describe the matching of the patterns. Note that the resulting rank correlation does not indicate how much of the change in the benthic assemblages is explained by the change of the characteristics of sediment. It is only a measure of how well the observed patterns of difference among samples correlate to each other. Possible gradual differences in sediment and benthos from block to block were tested with the RELATE routine (Clarke and Ainsworth, 1993). This method measures the degree to which possible changes in assemblages or sediments conform to a linear sequence (i.e. distance between any two blocks).

Table 9.3. Non-parametric analysis of variance of effects of tidal height and transect on characteristics of the sediment in the different blocks. Significant values are in bold. Number of permutations = 4999.

		-10	5	20	35	50	65
Source	df	P	P	P	P	P	P
Height	2	0.02	0.38	0.06	0.01	0.08	< 0.01
Transect	2	0.01	0.11	0.30	0.74	0.23	0.50
Height * transect	4	< 0.01	0.04	0.01	< 0.05	0.01	0.48

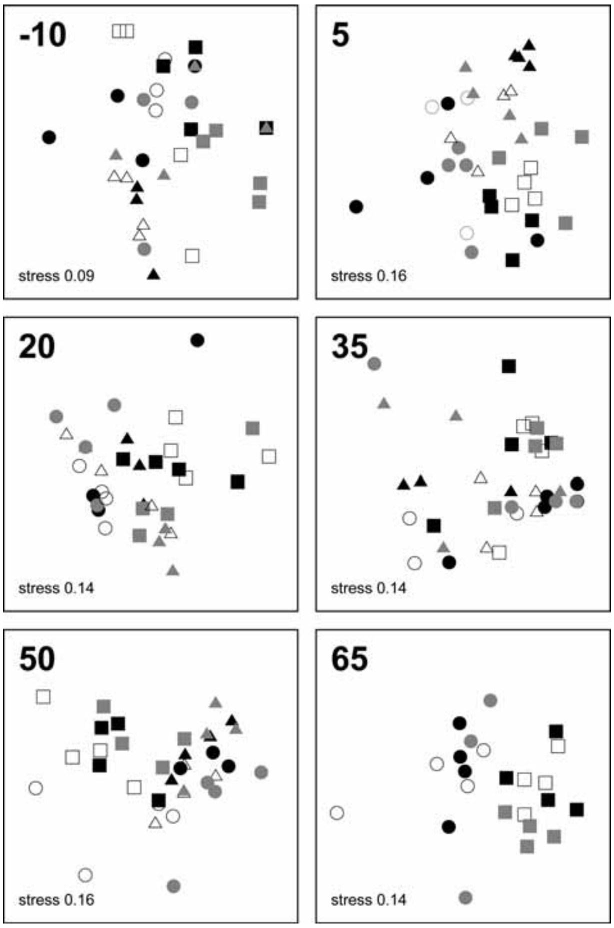


Figure 9.5. n-MDS ordinations of the benthic assemblages at three tidal height and three transects within each block. ●, ● and ○ highest tidal level, ▲, ▲ and △ intermediate tidal level and ■, ■ and ☐ lowest tidal level. Solid symbols = southernmost transect, grey symbols = middle transect and open symbols = northernmost transect.

Table 9.4. Non-parametric analysis of variance of effects of tidal height and transect on characteristics of the benthic assemblages in the different blocks. Significant values are in bold. Number of permutations = 4999.

Source	df	-10 P	5 P	20 P	35 P	50 P	65 P
Height	2	**0.03**	< **0.01**	< **0.01**	**0.01**	< **0.01**	< **0.02**
Transect	2	**0.03**	0.11	0.38	0.63	< **0.03**	0.10
Height * transect	4	0.12	< **0.01**	0.13	0.34	0.85	0.19

9.3. RESULTS

A total of 895 sediment samples were collected, 858 of which could later be properly allocated to a sampling point (the remaining 37 samples had an illegible label or were lost during processing). From the 858 assignable samples, 108, 214, 196, 159, 108, and 73 samples were analysed from blocks -10, 5, 20, 35, 50, and 65, respectively (Fig. 9.1). Most of the samples consisted of silt and mud (median grain-size < 63 µm in 469 cores) or very fine sand (63 - 125 µm in 228 sam-

Table 9.5. Contribution of the four most important taxa (Contr. in %) to the dissimilarity between any combination of two tidal heights within each block. H = high, M = medium and L = lowest tidal height. The taxa can be found in Table 9.2. Data from block 5 were omitted from analysis. Block 65 had only two tidal heights, H and L.

Block	-10				5			
Tidal level	H		M		H		M	
	Taxon	Con. (%)	Taxon	Con. (%)	Taxon	Con. (%)	Taxon	Con. (%)
M	Ophiuroids	64.89			N/A			
	Polychaetes	19.49						
	Decapods	4.45						
	Bivalves	3.74						
L	Ophiuroids	33.93	Ophiuroids	58.31	N/A		N/A	
	Polychaetes	29.43	Polychaetes	22.77				
	Bivalves	17.31	Bivalves	10.23				
	Decapods	7.78						
Location	20				35			
Tidal level	H		M		H		M	
	Taxon	Con. (%)	Taxon	Con. (%)	Taxon	Con. (%)	Taxon	Con. (%)
M	Polychaetes	42.17			Polychaetes	70.48		
	Ophiuroids	33.72			Ophiuroids	8.23		
	Decapods	11.31			Decapods	7.94		
	Bivalves	4.73			Crustaceans	5.35		
L	Bivalves	36.69	Bivalves	33.20	Polychaetes	38.22	Ophiuroids	33.61
	Ophiuroids	25.58	Polychaetes	25.98	Ophiuroids	30.65	Polychaetes	30.38
	Polychaetes	19.78	Ophiuroids	23.92	Bivalves	8.58	Bivalves	9.90
	Decapods	8.93	Holothurians	7.33	Crustaceans	8.21	Crustaceans	8.45
Location	50				65			
Tidal level	H		M		H		M	
	Taxon	Con. (%)	Taxon	Con. (%)	Taxon	Con. (%)	Taxon	Con. (%)
M	Polychaetes	35.99			N/A			
	Crustaceans	24.81						
	Bivalves	14.71						
	Decapods	14.08						
L	Echinoids	40.80	Echinoids	52.69	Polychaetes	26.73	N/A	
	Polychaetes	19.84	Polychaetes	17.00	Echinoids	21.53		
	Crustaceans	13.45	Decapods	10.55	Crustaceans	21.25		
	Bivalves	12.51	Bivalves	8.63	Other worms	11.32		

ples). Fine sand (125 - 250 µm) was found in 130 samples, medium sand (250 - 500 µm) in 12 samples, coarse sand (500 - 1000 µm) in 9 samples. Only one sample contained very coarse sediment (> 1000 µm).

9.3.1. Offshore gradients in sediment characteristics and benthic communities

Variability among replicate sampling points in the sediment characteristics was relatively large (Fig. 9.4). Nevertheless, a separation of the highest (circles) and lowest (squares) tidal level can be seen in all blocks. The points at the intermediate tidal level are generally more similar to points at the lowest tidal level than to those at the highest tidal level. Non-parametric MANOVA revealed that in most cases, the interaction between tidal heights and transect was significant, indicating different offshore trends along each block (Table 9.3). An a-posteriori test to search for differences among tidal heights within transects was not always conclusive. Generally, they occurred between the characteristics of the sediment at the highest and lowest tidal levels. The only case where the interaction between tidal height and transect was not significant was at block 65. Here, a consistent difference between the two tidal heights was observed. Because of the significant interaction between tidal height and transect (Table 9.3), it was not possible to find the size-class or classes of the sediment responsible for the patterns within each block.

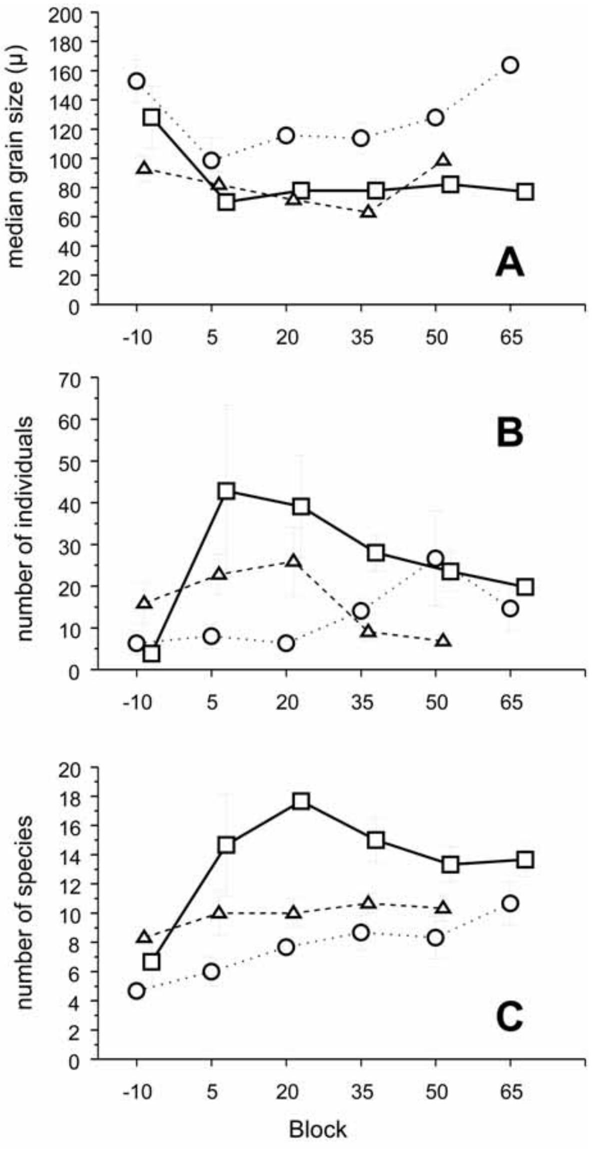


Figure 9.6. (A) Median grain-size (B) total number of individuals of all species and (C) total number of species at the different tidal height at the different blocks. At each block data from all sampling points per tidal height were pooled. Mean ± SE. ○ = highest, △ = intermediate and □ = lowest tidal level.

The structure of the assemblages of grouped taxa (Table 9.2) showed similar patterns to those observed for characteristics of the sediment (Fig. 9.5) but, in only one case (block 5) was the interaction term significant (Table 9.4). In all other cases, assemblages at the different tidal heights were significantly different (Table 9.4). Transects within blocks -10 and 50 were also significantly different, but because these are essentially random positions alongshore, there is no logic in exploring those differences any further. A posteriori tests revealed that the assemblages at each tidal level were significantly different from the assemblages at the other tidal heights, in almost all cases. In block 20, the assemblages at the higher and intermediate tidal level were similar, but different from those lowest on the shore.

Polychaetes and echinoids contributed most to differences between any two tidal heights and generally explained more than 60% of the dissimilarity (Table 9.5). Occasionally other groups were important, such as the bivalves in block 20 and the crustaceans in block 50. Because the significant interaction between tidal height and transect in block 5 (Table 9.4), it was not possible to ex-

Table 9.6. ANOVA results of the effects of block (Bl), tidal height (He) and transect (Tr) on the Ln-transformed median grain-sizes of the sediment. Only blocks -10, 5, 20, 35, and 50 are included in this analysis. Cochran's test *C* = 0.0943, *P* > 0.05, n = 4.

Source	*SS*	df	*MS*	*F*-ratio	*P*
Block	3.6663	4	0.9166	4.29	0.0282
Tidal height	5.4448	2	2.7224	18.13	0.0011
Transect(Bl)	2.1375	10	0.2137	2.99	0.0019
Bl * He	1.2014	8	0.1502	0.87	0.5593
He * Tr(Bl)	3.4651	20	0.1733	2.43	0.0015
Error	9.6421	135	0.0714		

Table 9.7. ANOVA results of the effects of block (Bl), tidal height (He) and transect (Tr) on (A) the total number of individuals of all species combined and of (B) the total number of species. Only block -10, 5, 20, 35 and 50 are included in this analysis.

A Source	*SS*	df	*MS*	*F*-ratio	*P*
Block	18.66	4	4.67	5.23	0.0155
Tidal height	20.64	2	10.32	3.09	0.1015
Transect(Bl)	8.92	10	0.89	1.19	0.3049
Bl * He	26.75	8	3.34	2.77	0.0306
He * Tr(Bl)	24.11	20	1.21	1.60	0.0599
Error	101.47	135	0.75		
B					
Block	115.86	4	28.96	10.45	0.0014
Tidal height	213.38	2	106.69	10.04	0.0066
Transect(Bl)	27.72	10	2.77	0.61	0.8030
Bl * He	85.01	8	10.63	4.21	0.0043
He * Tr(Bl)	613.25	20	2.52	0.56	0.9361
Error	1105.66	135	4.54		

amine which taxa differed between tidal heights within this block.

Multivariate analyses revealed off-shore differences in sediment characteristics. However, what was different could not be examined (see previous paragraphs). Therefore, all sediment data from one sampling point were used to calculate the median grain-size, a univariate variable easier to interpret than a multivariate set of data. However, because of the significant interaction between tidal height and transect (Table 9.6), offshore and alongshore differences in median grain-size were not easily interpreted. This significant interaction indicated that patterns within one block were not always consistent. An a posteriori test on the interaction showed that, within each block, the median grain-size at the highest level generally was larger than at the lowest tidal level, but that the median grain-size at the intermediate tidal level was sometimes similar to that at the highest and sometimes to that of the lowest tidal level. Occasionally differences in median grain-size among the tidal heights within transect were insignificant. Because this pattern was observed, data from each tidal height within a block were pooled and an average value for the median grain-size was calculated. The median grain-size at the lowest tidal level was significantly smaller than at the intermediate and higher tidal level, except in block 5, where differences were not significant. At most places, but not in block -10, the median grain-size was similar at the lowest and intermediate tidal level (Fig. 9.6A). Because block 65 had only two tidal heights, data had to be analysed separately. The median grain-size at the two tidal heights were significantly different, the lowest tidal level having the finer sediment ($F_{1,2}$ = 107.88, $P < 0.01$). The interaction between tidal height and transect was not significant ($F_{2,18}$ = 0.41, $P > 0.05$).

The total number of invertebrates per sample was different at each tidal height but, just as for the median grain-size, was not consistent in each block, resulting in a significant interaction between blocks and tidal height (Table 9.7A). The number of individuals was significantly smaller at the highest tidal level at blocks 5 and 20, while all other comparisons were not significantly different

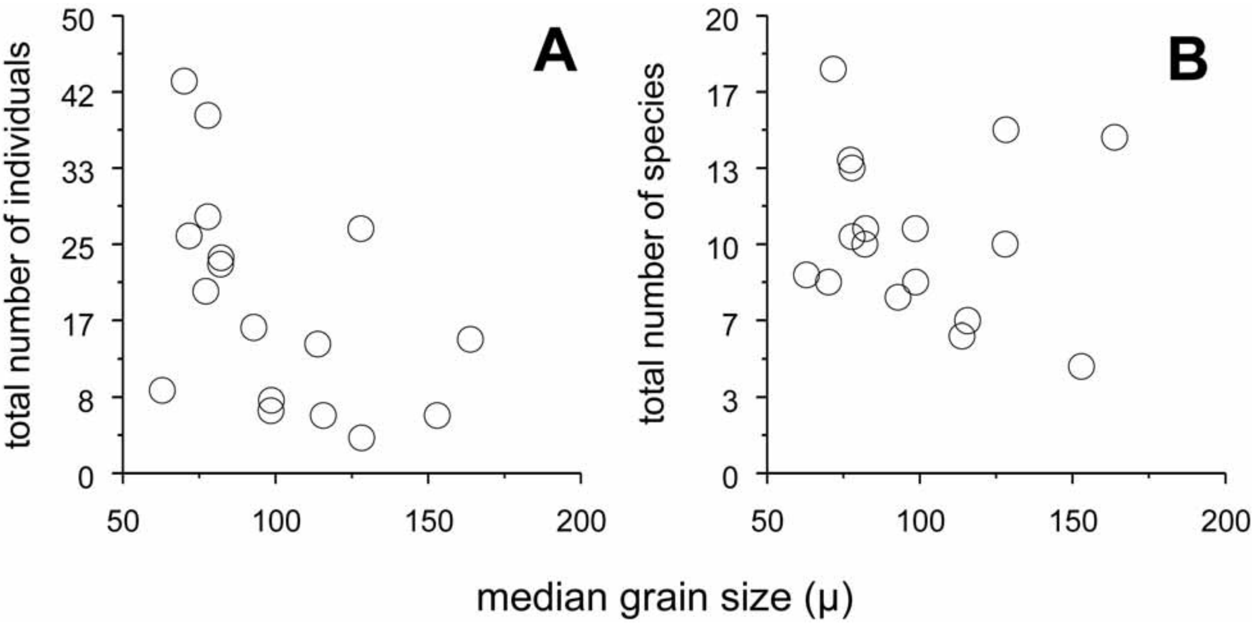


Figure 9.7. Relationship between median grain-size and (A) total number of individuals and (B) total number of species per tidal height per block. Each data point represents the average median grain-size and average number of individuals or species at each tidal height at each block.

Table 9.8. Differences among blocks (beaches) in the distribution of size-classes of the sediment based on the Euclidean dissimilarity measures and of the grouped benthos based on the Bray-Curtis dissimilarity measures. (*r* = statistical value, * significantly different at $P < 0.05$, from ANOSIM, number of permutations = 9999). Adjacent beaches are in bold.

blocks	sediment *r*	benthos grouped *r*
-10 vs. 5	0.239*	0.163*
-10 vs. 20	0.053	0.173*
-10 vs. 35	0.049	0.360*
-10 vs. 50	0.139*	0.111
-10 vs. 65	-0.019	0.309*
5 vs. 20	0.068	0.059
5 vs. 35	0.006	0.315*
5 vs. 50	0.582*	0.091
5 vs. 65	0.494*	0.102
20 vs. 35	-0.073	0.064
20 vs. 50	0.156*	-0.070
20 vs. 65	0.150	-0.051
35 vs. 50	0.187*	0.069
35 vs. 65	0.165	-0.020
50 vs. 65	0.216*	-0.088

(Fig. 9.6B). A separate analysis of the effects of tidal height on the total numbers of individuals at block 65 showed that there was no significant difference between tidal heights ($F_{1,2} = 6.77$, $P > 0.05$), or was there a significant interaction between tidal height and transect ($F_{2,18} = 1.08$, $P > 0.05$). Total numbers were generally largest at the blocks 5 and 20 and smallest at blocks -10 and 65 (Fig. 9.6B). The total number of species showed a similar pattern than that for the total number of individuals (Fig. 9.6C). A significant interaction between height and block was observed (Table 9.7B) caused by the data from block 10. In this block, there were no differences among the number of species at different tidal heights, whereas in all other blocks, the number of species was smallest at closer to the shore and gradually increasing towards the lower tidal levels. A separate analyses for the data from block 65 showed only a significant difference for the effect of tidal height ($F_{1,2} = 49.00$, $P < 0.05$), the high tidal level having less species than the low tidal level.

Plots of median grain-size (Fig. 9.6A) and total numbers of individuals and of species per tidal height at each block (Figs 9.6B, C) showed roughly an opposite pattern. When the median grain-size was small (in the middle blocks), the number of individuals and species was large and when the median grain-size was large (the southern and northernmost blocks), the number of individuals and species was small. A plot of median grain-sizes on the total number of individuals and

Table 9.9. Contribution of the four most important taxa (Con. in %) on the dissimilarity between any combination of two beaches (blocks). The taxa can be found in Table 9-2. Data from beaches that had a significantly ($P < 0.05$, from SIMPER, see Table 9-3) different structure of the assemblage are in bold.

Block	-10		5		20		35		50	
	Taxon	Con. (%)	Taxon	Con. (%)	Taxon	Contr. (%)	Taxon	Contr. (%)	Taxon	Contr. (%)
5	**Ophiuroids**	**31.00**								
	Bivalves	**26.99**								
	Polychaetes	**13.97**								
	Crustaceans	**10.27**								
20	**Ophiuroids**	**29.69**	Polychaetes	33.26						
	Polychaetes	**29.19**	Ophiuroids	23.38						
	Bivalves	**26.25**	Bivalves	20.12						
	Decapods	**6.17**	Crustaceans	8.04						
35	**Polychaetes**	**46.12**	**Polychaetes**	**32.20**	Polychaetes	30.86				
	Ophiuroids	**31.79**	**Bivalves**	**21.95**	Bivalves	26.22				
	Bivalves	**5.90**	**Ophiuroids**	**21.12**	Echinoids	24.63				
	Crustaceans	**5.84**	**Crustaceans**	**9.86**	Crustaceans	6.27				
50	Ophiuroids	36.50	Bivalves	24.76	Bivalves	26.646	Polychaetes	36.63		
	Polychaetes	23.84	Ophiuroids	23.54	Polychaetes	24.81	Ophiuroids	27.47		
	Crustaceans	12.16	Polychaetes	18.70	Ophiuroids	23.66	Crustaceans	12.90		
	Bivalves	10.94	Crustaceans	13.75	Crustaceans	10.16	Bivalves	10.01		
65	**Polychaetes**	**29.22**	Polychaetes	23.41	Polychaetes	24.52	Polychaetes	28.04	Polychaetes	24.54
	Ophiuroids	**27.82**	Bivalves	21.63	Bivalves	20.97	Ophiuroids	24.76	Crustaceans	24.42
	Crustaceans	**21.30**	Crustaceans	18.92	Ophiuroids	19.78	Crustaceans	24.16	Ophiuroids	24.29
	Decapods	**6.41**	Ophiuroids	17.13	Crustaceans	17.69	Bivalves	7.76	Bivalves	9.19

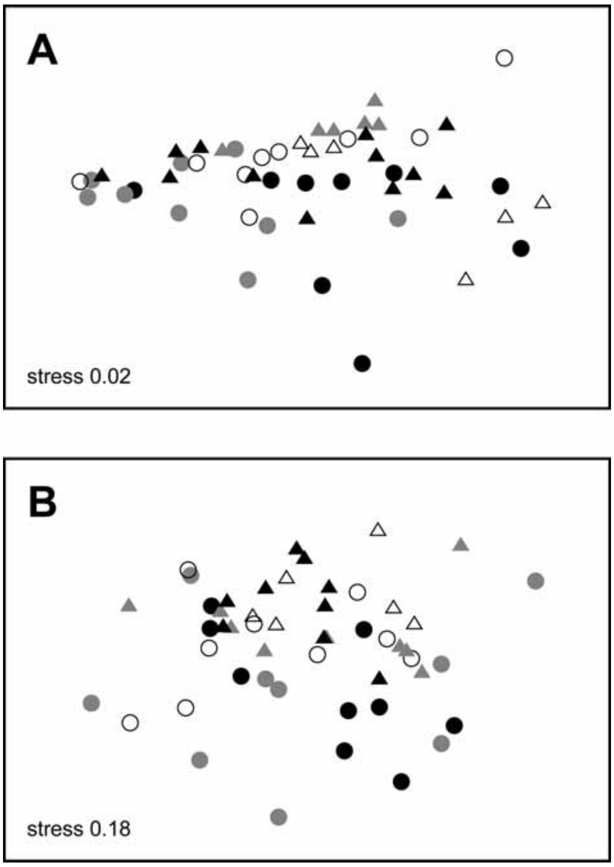


Figure 9.8. n-MDS ordination comparing the (A) size-classes of the sediments and (B) the benthic assemblages of the different beaches (blocks). Block -10 = ●, block 5 = ●, block 20 = ○, block 35 = ▲, block 50

species (Fig. 9.7A) confirmed this pattern. In both cases there were significant negative correlations between median grain size and numbers of individuals or species, significantly fewer individuals (F1,15 = 4.82, $P < 0.05$, $R^2 = 0.243$, Fig. 9-8A) and species (F1,15 = 8.49, $P < 0.05$, $R^2 = 0.362$, Fig. 9-8B) in coarser sediments than in finer sediments.

9.3.2. Alongshore gradients in sediment characteristics and benthic communities

Despite the similarity of sediments at each block, resembled by the poor separation of the sampling points in the n-MDS plot (Fig. 9.8A), analysis of similarity revealed that there were significant differences (ANOSIM, $P < 0.05$) between many of the blocks, but because blocks was a random factor, not logically interpretable (Table 9-8). The differences of the structure of the sediment among beaches were significantly ($P < 0.05$, from RELATE) related to the actual distance between any two beaches, the further away from each other, the greater the difference.

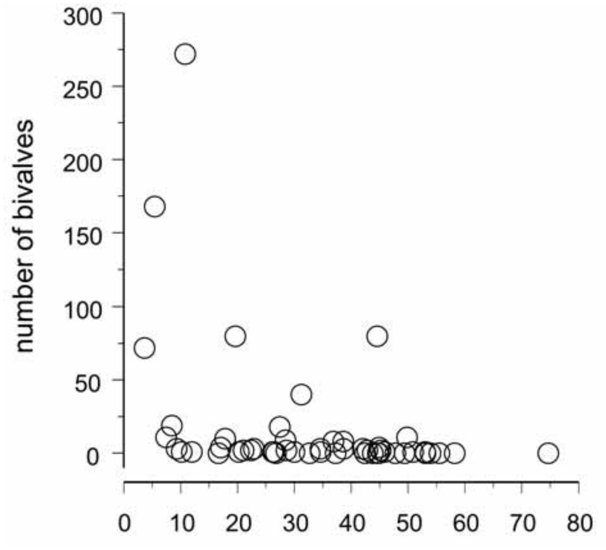


Figure 9.9. The relationship between the total number of individuals of bivalves and the relative amount (%) of sediment in the 0.063 - 0.125 mm size class. Each point is a replicate sample from each of one of the 6 blocks (beaches).

Benthic assemblages were compared among blocks in three different ways. First, the total number of individuals at the finest taxonomic resolution was examined. As a result of the large number of taxa (74, see Table 9.2) compared to the small number of replicates, the stress-value of the 2-dimensional ordination was relatively large (0.20). Observed patterns using untransformed data can be mainly driven by abundances of a few species in a few samples. Therefore, to reduce the impact of patchy and abundant species, data were transformed to only presence (= 1) or absence (= 0). This transformation resulted in an even larger stress-value (0.22) than using abundances, indicating that the description of the assemblages in a 2-dimensional space is a poor one. The smallest stress-value (0.18) was obtained by grouping the individuals into coarser taxa (Table 9.2, Fig. 9.8B). Nevertheless, the separation of the blocks was only slightly better

Table 9.10. Combination of the 6 size classes taken 1 - 6 (all) classes at a time resulting in the best matching of the abiotic and biotic similarity matrices as measured by the Spearman rank correlation (*r*). Only the size-class resulting in the largest rank correlation within each number of combinations is given. Size classes are given as the midpoint (*d*) of the phi (ϕ) scale (see table 9-1). The midpoint of the > 1 mm class is arbitrarily set to 0.

number of size-classes	best combination of size-classes (d in ϕ)	r
1	3.5	0.229
2	2.5; 3.5	0.259
3	0; 2.5; 3.5	0.269
4	0; 1.5, 2.5, 3.5	0.268
5	0; 0.5; 1.5; 2.5; 3.5	0.267
6	all	0.269

than for characteristics of the sediment. Variability within blocks was relatively large, especially within block 5. Analysis of similarity (ANOSIM) revealed differences between blocks (Table 9.8) but these were difficult to interpret. Generally, block -10 was different from the other blocks, which were similar to each other. The observed pattern was significantly correlated to the spatial distances among the beaches ($P < 0.05$, from RELATE). This correlation is also reflected in the general similarity of the assemblages of two adjacent beaches (the exception being block -10 and block 5; Table 9.8).

The taxa that caused differences between any two beaches were examined using the SIMPER routine. It was found that 4 taxa, echinoids, polychaetes, bivalves and crustaceans mainly caused these differences (Table 9.9). Generally, the two most important taxa causing the difference explained more than 50 % of that difference and the four most important taxa explained more than 85%.

Matching the pattern found in characteristics of the sediment with these found in benthic assemblages (BIO-ENV routine) gave relatively small Spearman rank correlation coefficients for any combination of size-classes. The pattern of the single size-class correlating best with the patterns of the benthos was the 0.063 - 0.125 mm fraction of the sediment, but still r was only 0.229. Addition of a second size class (0.125 - 0.250 mm) improved the correlation slightly (r = 0.259). Adding more size-classes improved the correlation only marginally (r = 0.269), or worsened it (r = 0.239) (Table 9.10).

Thus, four taxonomic groupings were mainly responsible for the patterns observed in the assemblages and the 0.063 - 0.125 mm class of grain-size was most important to describe patterns in distribution of sediment. Therefore, total numbers of individuals of these four taxa were each correlated to the relative amount of sediment in the 0.063 - 0.125 mm size-class. The same data as used in the multivariate assessment of the blocks were used. It was found that the correlations were weak (R^2 = 0.02, 0.01, 0.14 and 0.03 for polychaetes, crustaceans, bivalves and echinoids, respectively) and not significant ($P > 0.05$), except for bivalves ($F_{1,49} = 7.79$, $P < 0.05$). Bivalves occurred in significantly larger numbers in areas where the relative amount of the 0.063 - 0.125 mm size class was relatively small (Fig. 9.9).

9.4. DISCUSSION

The scale of spatial variability in distribution of species and sediments can vary from metres to kilometres or even larger scales. Differences in geography may cause differences in the hydrodynamics of the system, causing in turn differences in sediments and benthic assemblages (Desroy & Retière 2000). Other important factors operating at different scales are recruitment (Gray 1974) and mortality (Underwood & Chapman 1996). Generally, sediment of the studied blocks along Eighty-mile Beach was very fine, 55 % of all samples contained more than 50 % mud and silt (median grain-size < 63 µm). In a similar study (Roebuck Bay Invertebrate Mapping in 1997, ROEBIM 97), larger grain-sizes were found, particularly in the east-west stretch of the northern part of the Bays' intertidal mudflats. The eastern and south-eastern parts of the flats, however, were very muddy and similar to the sediments found in the present study (Pepping *et al.* 1999). Sediments at most of the other sampling points consisted mainly of very fine and fine sands. The sediments from only 23 sampling point had a median grain-size larger than 250 µm (mainly the points highest in the intertidal area) which makes the studied blocks along Eighty-mile Beach, on average, very muddy.

Multivariate representation of data from the distribution of grain-size and from benthic assemblages collected from adjacent transects sediment revealed that data from sampling points at a similar tidal height but from adjacent transects were independent from each other (Fig. 9.2). If these sampling points (represented with the same numbers) had been closer together in the plots (i.e. were very similar), it would have indicated some dependency among adjacent transects and grouping of points for testing hypotheses concerning an offshore gradient would not have been possible. Grouping was, however, possible and sampling points were grouped in order to get replication of different tidal heights within each block according to a design graphically represented in Figure 9-1.

Although the pattern of distribution of grain-size (Fig. 9.2A) already indicated that there was an offshore pattern, i.e. as expected coarser sediments close to the shore and finer sediments at the lower tidal levels (Fig. 9.3), this was not more than a correlation. To confirm the generality of this pattern, a multivariate analysis of variance on sediment data from the grouped sampling points was done revealing that the sediments at the higher tidal levels were indeed coarser than at the lower tidal levels (Fig. 9.4). The small stress values indicated that the multivariate data of grain-sizes fitted very well in a two-dimensional space, meaning that a single grain-size class drove the pattern; similar results would have been obtained if that particular size class was analysed in a univariate sense. Sampling points at the intermediate tidal level had an intermediate grain-size distribution. Thus, the hypothesis of a tidal gradient in sediment characteristics with coarser sediments closer to shore and finer towards the low-water line could be confirmed.

Except at block 5, benthic assemblages were also different among tidal heights, showing a gradational change from the shore towards the lowest tidal level. The species or groups of species causing that difference were not the same at each block (Echinoids in blocks 5 and 20 and polychaetes in blocks 35 and 65), indicating that the alongshore benthic communities change. After simplifying the multivariate sediment and benthos data to univariate variables (median grain-size, number of species and number of individuals), a few general offshore patterns emerged. Sediments at the higher tidal levels were coarser (i.e. had a larger median grain-size) than at the lower tidal levels and the number of individuals and species was larger at the lower tidal levels than close to the shore. The total number of individuals appeared to be negatively correlated with the median grain-size and consequently, with the tidal height. It appears that tidal height is important to explain the number of individuals but variation in grain-size within each tidal height explains part of the variability in numbers of individuals too. The total number of species was not correlated with grain-size (Fig. 9.7B), but tidal height was (Fig. 9.6C). This means that the observed differences in assemblages at the different tidal heights are caused by differences in total numbers of individuals and in species.

Alongshore differences in characteristics of the sediment and of benthic assemblages were also observed. Significant differences between blocks were found (Table 9.8, Fig. 9.6) and appeared to be related to the distance between them. As for the offshore differences in the benthic assemblages, echinoids and polychaetes were important as well as polychaetes and bivalves. Surprisingly, the pattern observed for benthic invertebrates was only weakly correlated with the pattern found in characteristics of benthic assemblages. The largest correlation coefficient found was $r = 0.269$, a value much smaller than that found in a similar study done in Roebuck Bay two years earlier. In that study, distribution patterns of silt (sediment < 63 μm) and benthos were found to be correlated much better ($r = 0.553$) than in our study ($r < 0.229$, Table 9.10). A reason for the low correlation found in our study might be that the coast of Western Australia was hit by a cyclone (Severe Tropical Cyclone Vance) in March 1999. During this cyclone, the fastest wind speeds ever recorded above mainland Australia were measured, 267 km/h (source: Australian Bureau of Meteorology web page). It is likely that the structure of the sediment was dramatically changed during this storm and that the whole intertidal area was still in a recovery phase. Some observations confirming this hypothesis are the presence of a thin layer (about 5 cm) of coarse sediment on top of muddy sediment, suggesting it was recently deposited, and the disappearance of the characteristic huge ridges of shell material that normally occurred on the highest parts of the beach. Therefore, the small correlation between sediment characteristics and the structure of benthic assemblages may have to do with cyclone Vance that changed the abiotic environment such that the benthic community still was recovering from this event.

Whether the significant negative relationship between the number of bivalves and median grain-size is causal is hard to assess because this group contains deposit-feeders as well as filter-feeders and these two trophic groups generally show an opposite relationship with grain-size. Filter-feeders prefer sandy and deposit-feeders prefer muddy sediments (Rhoads & Young 1970). The mixture of these groups within the taxonomic group of the bivalves may have obscured any relationship functional groups have with characteristics of sediment and the observed pattern (Fig. 9.9) may be caused by a few sampling points.

Acknowledgements. We would like to thank the many people who collected sediment and benthos samples in the field. Benson Holland processed many of those samples which was very much appreciated. Many thanks to Tony Underwood from the Centre for Research on Ecological Impacts of Coastal Cities (University of Sydney) for giving permission to allocate time and use equipment in order to process sediment samples. Gee Chapman gave statistical advice and valuable comments on earlier drafts of the chapter.

10. DISTRIBUTION OF SHOREBIRDS ALONG EIGHTY-MILE BEACH

Danny I. Rogers

ABSTRACT

During the Annabim expedition in October 1999, shorebird distributions were mapped on the intertidal flats of Eighty-mile Beach. Mapping was done on a 200 m grid contiguous with that of the concurrent benthos sampling program. In addition, shorebird counts were performed on the adjacent beaches at high tide. Sampling and count methods are described and discussed, and early results are presented in this chapter. The distribution of each shorebird species on the intertidal flats of Eighty-mile Beach is also described and discussed. Despite the superficially uniform appearance of Eighty-mile Beach and the adjacent flats, it transpired that different stretches of the coast were important for different shorebird species. On a broad scale, the distribution of most shorebird species was positively related to the abundance of their presumed prey. The number of birds counted on Eighty-mile Beach at high tide and their species composition, corresponded fairly well with the numbers and species composition of shorebirds seen on the adjacent intertidal flats at low tide. This suggests that shorebirds on Eighty-mile Beach roost on the area of beach closest to their feeding areas, at least on high tides of low to intermediate height. In general, diversity and density of shorebirds and the abundance of their prey were lower on Eighty-mile Beach than Roebuck Bay, an important shorebird site some 200 km north which has been studied over the past three years. However, Eighty-mile Beach is so long, and the off-lying mudflats so broad, that Eighty-mile Beach in fact holds many more shorebirds than Roebuck Bay. The vastness of the intertidal flats of Eighty-mile Beach makes them difficult places to monitor. It is suggested that once Annabim results are fully analysed, it may be possible to monitor shorebird populations adequately through a logistically feasible combination of high tide counts of a limited stretch of the beach in conjunction with remote sensing of intertidal habitat.

10.1. INTRODUCTION

To a shorebird enthusiast, Eighty-mile Beach at high tide is one of the wonders of the world – a glistening white and apparently endless beach punctuated evenly and only by huge dense flocks of roosting shorebirds. Standing on the beach and scanning the nearest flock with a telescope, the observer will soon find that it has an impressive diversity of species; scanning the next couple of flocks along the beach will demonstrate that the flocks are quite consistent in size (with many thousand birds in each) and quite consistently spaced (each a kilometre or two apart). Scanning into the distance in either direction, the observer will see many more such flocks – dark masses of birds evenly spaced along the tideline for as far as the eye can see. In a migratory flyway where shorebirds are seriously threatened by rampant habitat destruction, Eighty-mile Beach offers the most comforting illusion of infinite shorebird numbers that can possibly be imagined.

First impressions can be misleading, and Eighty-mile Beach is not as endless or as uniform as it might initially appear. With 220 km, it is a long beach, and it does support large numbers of shorebirds – almost half a million have been counted in single high-tide counts performed by the Australasian Wader Studies Group, making it the premier shorebird site in Australia in terms of absolute shorebird numbers. In February 2004, 2.8 million Oriental pratincols were counted by AWSG. These counts have shown that shorebird distribution along Eighty-mile Beach is far from uniform, and that some stretches hold far more birds than others. Exactly why this is so is far from clear. Could the answer lie on the adjacent intertidal flats, the feeding grounds for the great majority of shorebirds of Eighty-mile Beach? As an early step towards finding out what makes Eighty-mile Beach so special for shorebirds, and whether some bits of it are more special than others, the Annabim expedition attempted to get some answers to the following questions:

Where are the preferred feeding grounds of each shorebird species on Eighty-mile Beach?

How well does the distribution of these preferred feeding areas correspond with the distribution of food on the intertidal flats?

How well does the distribution of shorebirds on the intertidal flats correspond with their distribution on Eighty-mile Beach when roosting at high tide?

This chapter summarises progress made so far on answering the above questions. In addition, I take the opportunity to compare the shorebird community of Eighty-mile Beach with that of northern Roebuck Bay, another extremely important shorebird site where studies of similar design have been in progress since 1997 (Pepping *et al.* 1999, Rogers & Taylor 2002).

10.2. METHODS

10.2.1. Mapping shorebird distribution on the intertidal flats

The methods used for mapping shorebird distribution on the intertidal flats of Eighty-mile Beach were essentially those used in Roebuck Bay and described by Rogers (1999). Briefly, the mapping method was based around the 200 m grid used for the benthos-sampling program; it is summarised in Fig. 10.1. Each benthos sampling point was treated as the centre of a 200 m grid-square in which shorebird numbers were counted. Shorebirds were mapped in a series of transects in which the observer (or observers) walked from the beach to the sea-edge, stopping every 200 m at a point located by GPS. Each transect was performed on a receding tide and timed so that the observer/s began mapping when the tide had receded about 200 m from shore, reaching the sea-edge at the slack water period of low tide. From each observation point, shorebird numbers were recorded in four grid-squares: the one lying immediately to the west (0-200 m away), the one to the west of that (200-400 m away), and the two 'mirror-squares' to the east. The boundaries of the grid-squares were located using an optical method described in Rogers (1999). This sampling design was adopted with several considerations in mind. Firstly, the resultant shorebird data is readily compared with data on prey abundance obtained from the benthos-sampling program. The method is fast, enabling the observer/s to map a large area during the course of a single low-tide period. The reasonably disciplined timing of the transect relative to tide levels is necessary to prevent the resultant data being inconsistently biased by tide-related movements of shorebirds. Finally, because the observer walks out along a line between rather than through grid-squares, the chances are reduced that the observer will flush birds out of their quadrats before they are mapped.

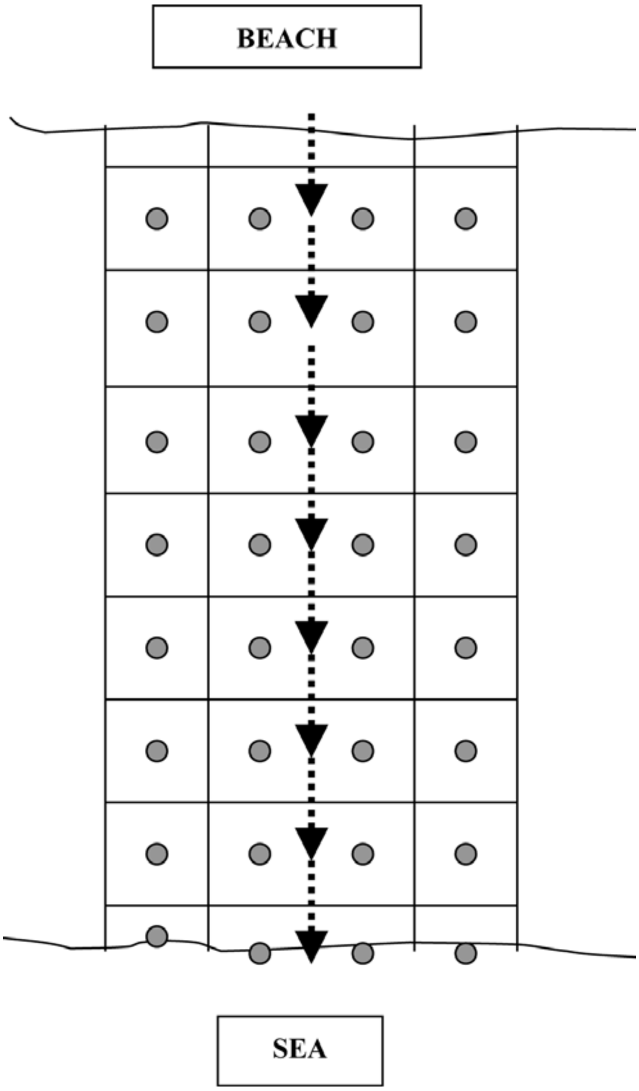


Figure 10.1. Design of shorebird-mapping transects on the intertidal flats of Eighty-mile Beach. The grid-squares depicted are each 200 m in diameter. A benthos sampling point, depicted by a grey circle, occurs in the centre of each grid-square. The path of the observers is shown by a dotted heavy line; the observers moved from the beach to the sea. Observation points (at the lower tip of the depicted black triangles) were 200 m from one another. At each observation point, shorebird numbers were counted in the two grid-squares to the left, and the two grid-squares to the right, of the observers.

Some modifications to the methods used on Roebuck Bay were needed to fit in with the geography of Eighty-mile Beach and the logistics of the Annabim expedition:

1. Eighty-mile Beach is enormous, and it was not possible to map the shorebirds or benthos of the entire system. Accordingly, we did our mapping in several different sampling blocks, which we named using the distance in kilometres south from our access point to Eighty-mile Beach: these were Block –10 (10 km north of our access point to Eighty-mile Beach); Block 5 (5 km south of the access point); Block 20, Block 35, Block 50 and Block 65. A single shorebird-mapping transect was performed on a receding tide in each block; we did not have time to map shorebird distribution in all of the grid-squares from which benthos had been sampled.
2. In Roebuck Bay, shorebird mapping was done by a single observer. On Eighty-mile Beach it was possible to dispatch a team of 2-6 observers to map shorebirds. This had the advantage of safety and speeded up the data-recording; however, it may have increased disturbance to the shorebirds. To avoid observ-

er biases, I did all judging of quadrat boundaries and counting of shorebirds.

3. Ideally, shorebird transects should take the observers from the beach to the sea-edge via the shortest route possible. This was not practical at Eighty-mile Beach, as this route would have required observers to walk north-west; however GPS location of benthos sampling points and shorebird observation points was only straightforward if we walked due north or due west. We performed westward transects for Blocks –10, 5, 20 and 35. Eighty-mile beach swings westwards towards the south, and in Blocks 50 and 65 we performed northwards transects because these gave us a shorter route from the beach to the sea-edge.
4. An early field impression while mapping on the intertidal flats was that some shorebird species preferred a habitat which we referred to as "mudbanks" – slightly raised areas of mud containing many small, steep-sided, shallow pools. These mudbanks were easily distinguished from the flat surrounding sediments, so in each grid-square we recorded whether or not mudbanks were present.

A final difference between mapping on Eighty-mile Beach and northern Roebuck Bay was that the intertidal flats of the former are considerably broader. This made it difficult to map from the beach to the sea-edge in the three or so hours available between when the tide receded from the beaches, and the slack-water period of low tide. We usually managed, but Blocks 5 and 20 posed problems as they were exceptionally muddy and were mapped on springy low tides. In both sites unusual measures had to be taken to ensure that the density of shorebirds was mapped in the important sea-edge quadrats:

1. In Block 5, I had to leave the other observers behind to make a dash to the sea-edge before the light failed. Although I left the standard shorebird transect in order to get to the closest patch of sea-edge available, I only found time to record shorebird densities in one sea-edge quadrat; even this quadrat was mapped from considerable distance in rather poor light. For the purposes of consistent comparisons of shorebird density and abundance in Block 5 with other study blocks, I have multiplied the densities of the three species identified in this single mapped sea-edge quadrat by four. The implicit assumption here is that the densities of the three species identified in the single mapped sea-edge quadrat would have been the same in the adjacent three sea-edge quadrats. Even with these corrections the density and abundance of sea-edge-following shorebirds in Block 5 was probably underestimated because such birds also tend to have relatively high densities in the quadrats immediately to shoreward of the sea-edge quadrats.
2. In Block 20, we did reach the sea-edge, but the tide had started to turn by the time we got there. As I was worried that the unpredictable movements of birds at this stage of the tide might have influenced the shorebird densities we observed at the sea-edge, we mapped sea-edge densities again the following day, this time using a hovercraft to get close to the sea-edge at slack water.

Table 10.1 Summary of dates and tide conditions during shorebird-mapping transects.

Block	Date(s)	Height of low tide
-10	10 Oct.	0.28 m
5	11 Oct.	0.28 m
20	14 + 15 Oct.	0.5 m + 0.91 m
35	17 Oct.	2.18 m
50	19 Oct.	3.67 m
65	21 Oct.	2.90 m

Table 10.1 summarises the dates and tide conditions on which shorebirds were mapped on the intertidal flats. When we started the program in the north of the study area we enjoyed spring tides, but tides became progressively more neapy as we moved south. This was particularly worrying at Block 65, where the exposed intertidal flats were narrow; it was only possible to map 20 grid-squares. Radio-tracking work at Roebuck Bay suggests that in such tide conditions waders may move several kilometres to areas where the intertidal flats are broader; if this also applies at Eighty-mile Beach it is quite likely that the bird densities observed at Block 65 were an underestimate.

10.2.2. High tide counts

At high tide, shorebirds are forced from the intertidal flats and gather on Eighty-mile Beach to roost. While concentrated in this (relatively!) small area they can be counted much more easily than they can at low tide. The Australasian Wader Studies Group and Broome Bird Observatory have been performing counts at Eighty-mile Beach for more than twenty years – initially these counts occurred only during banding expeditions, but in the last few years two surveys have been carried out each year. Thanks to these efforts, the best approach to use when counting shorebirds at Eighty-mile Beach is now reasonably clear. Counts have to be done from vehicles; the beach is far too long to be counted on foot, and shorebirds are in general less wary of cars than they are of pedestrians. The shorebirds typically roost at the tide edge rather than at the top of the beach (Rogers et al. 2000a, Battley et al. 2003), a behaviour thought to be related to their reluctance to roost on dry substrates where they could become heat-stressed. This behaviour means that shorebird flocks will usually be situated to the west of beach-based observers, so the best light conditions for counting will be experienced in the morning rather than the late afternoon. It is best to perform counts on rather low high tides of about 5.5 to 6.5 m. On more neapy high tides, some mud is still exposed beneath the beach and shorebirds concentrate there; although this strip of mud is narrow (sometimes no more than 100 to 200 m), it is too broad for ready location and counting of every shorebird. On spring high tides (about 8-10 m high), Eighty-mile Beach becomes relatively narrow and such conditions are not good for counting: vehicles are forced to the soft sand at the top of the beach, where travel is slower and the likelihood of getting bogged is higher. More seriously, the disturbance to shorebirds is greater when the beaches are narrow, and roosting shorebirds can be flushed ahead of the car, thus being double-counted. A final problem with counts done on springy high tides is that waders may move several kilometres along the shore to roost in places where the beach is widest; in general they become uneasy if forced to roost too close to sand dunes which may be used as cover by predators.

On the Annabim expedition, we did a high tide survey as we were interested in comparing the distribution of roosting shorebirds with that of the feeding distribution of shorebirds on the intertidal flats at the same time of year. Fitting the high tide survey in with all of the other work on the Annabim expedition was tricky. In the event, we were only able to count the shorebirds along 47 km of the beach: from 12 km north of our beach access point to 35 km south. The northernmost section (from 12 km north to 8.2 km south of the beach access point) was counted on 13 October 1999, on a mid-day high tide of 8.2 m (tide levels obtained from a tide timetable for Roebuck Bay; correspondence between the tides of Roebuck Bay and Eighty-mile Beach is undoubtedly close but we do not know if it is exact). The southern section, from 10 to 35 km south, was counted during an afternoon high tide of about 5.9 m on 20 October 1999. On both days, we recorded the shorebirds along five kilometre stretches of beach; every five kilometres we started a fresh count.

Neither of these count days was ideal from a tide perspective. The first (northern) count was done on a rather springy tide. We could get away with this as it is one of the easiest patches of Eighty-mile Beach to drive along. As a check on whether we were double-counting birds, I counted shorebirds while they were on the beach ahead of the vehicle. After flocks were counted and we drove on, these flock invariably took to the air. Another observer, Dusty Millar, counted the number of airborne shorebirds which flew behind the car, thus gaining an idea of how many shorebirds returned to their original roosting point rather than settling ahead to be double-counted. As it happened, my counts corresponded closely with Dusty's, suggesting that double-counting was not a problem. I do still worry though that counts for the northernmost section of this count may have been inflated by birds that flew to roost here from well to the south. Casual observations made in the past suggest that on springy tides, shorebirds are more likely to fly north past the beach access point to roost on beaches that they do not use on more neapy tides.

The count on 20 October was performed on an afternoon high tide. In theory, the afternoon light conditions might have caused difficulties, but the weather turned out to be glorious – clear skies, but not hot enough for a heat-haze to develop. I do not think that the light conditions affected our results. The biggest potential source of error was that the count was performed by two separate vehicles: my team started at 35 km South and headed north; a team lead by Theunis Piersma started at 10 km South and headed south, and we met at 25 km South. As far as we are aware, counts performed by Theunis and me (both experienced counters) are consistent, but we did not have an opportunity to test this.

As it turned out, the high tide count data we gathered on Annabim appeared to generate sensible data (see results). In retrospect though, we should probably have given high tide counts a higher priority and attempted to count the entire beach from 15 km N to 65 km S in optimum tide conditions. Next time, we will be prepared!

10.2.3. Biomass estimation and analysis

In the species accounts below, I often compare the intertidal distributions of shorebirds that we observed on Eighty-mile Beach with the biomass of their preferred prey in the same areas. The methods used to do this are described in Rogers (1999) and Pepping (1999) and they are not repeated in full here. Essentially, an educated guess was made about the favoured prey of selected shorebird species on the basis of published literature and on unpublished field observations in Roebuck Bay. The biomass of the presumed preferred prey in the study area was calculated using data from our benthos survey, which included an identification (to some extent!) and measurement of every captured invertebrate.

The published literature includes several equations describing the relationship of length to ash-free dry mass for different types of benthic invertebrate (Pepping et al. 1999). These were used to estimate the ash-free dry mass of each animal that we encountered. The estimates of biomass of prey involved a number of untested assumptions, both about the preferred prey of most shorebird species (only Great and Red Knots have received detailed study in North-western Australia) and about the relationship of length to mass (mainly calibrated in studies performed overseas). Accordingly, they cannot be regarded as authoritative but they are the most plausible models we have about prey biomass at present and are used to give us some insight as to how shorebirds might select their feeding areas.

Frequent comparisons are made between the low-tide distributions of birds on Eighty-mile Beach and Roebuck Bay. The Roebuck Bay data used were collected in October 1997 (the same time of year as the Annabim data) and have been described in Rogers (1999). During the October 1997 trip, data on shorebird distribution were collected on both ebbing and rising tides. On the Annabim expedition we only mapped shorebird distribution on ebbing tides. To make the Roebuck Bay and Eighty-mile Beach data more comparable, I have only used data from Roebuck Bay if they were collected on ebbing tides.

Analyses performed for this report were simple and are more or less self-explanatory; where explanation is needed, it is given in the body of the text. Much more sophisticated and powerful analyses should be possible on the large Annabim dataset, and these are being performed or planned for subsequent publication.

10.3. RESULTS

10.3.1.Broad comparisons with Roebuck Bay

Species composition and shorebird densities

The abundance of shorebirds on the intertidal flats of Eighty-mile Beach and northern Roebuck Bay are summarised in Table 10.2 and the series of maps included at the end of this chapter. It is readily apparent that species diversity is higher in Roebuck Bay. To some extent this is explained by the paucity of fish-eating birds (in foraging guilds 7 and F) on the intertidal flats of Eighty-mile Beach. However, all foraging guilds were better represented in Roebuck Bay than Eighty-mile Beach except for Guild 4, visual surface hunters of small active prey. Only a few species occurred in higher densities on the flats of Eighty-mile Beach than they did on the intertidal flats of Roebuck Bay: Marsh Sandpiper, Red-capped Plover and Oriental Plover. A few other species also seem to occur in higher densities on the Eighty-mile Beach flats but were mapped so rarely that it is difficult to tell if any differences are real: Pied Cormorant, Pacific Golden Plover, Lesser Crested Tern, Crested Tern and Roseate Tern.

Table 10.2 also suggests that birds were more spread out on the broad intertidal flats of Eighty-mile Beach than on the narrower intertidal flats of northern Roebuck Bay. Accordingly, differences in bird density at the two sites (average, and maximum in any grid-square) are quite striking, but differences between the sites are less marked when abundance is expressed as number of birds per transect (i.e. birds per 800 m of coastline). Birds generally occupied a higher proportion of mapped grid-squares in Roebuck Bay than on the intertidal flats of Eighty-mile Beach.

Sea-edge following

One of the most striking trends in the distribution of shorebirds of Roebuck Bay is the tendency for some species to feed at the sea-edge, therefore following the tideline for several kilometres during a low tide. This trend is also strongly marked on the intertidal flats of Eighty-mile Beach (Table 10.3). As at Roebuck Bay, the birds which showed the strongest tendency to follow the sea-edge were tactile hunters of macrobenthos: Bar-tailed Godwit, Great Knot and Red Knot (see also the maps at the end of this chapter).

Disturbance effects

The design of the shorebird mapping transects was such that birds in half of the quadrats mapped were 0-200 m from the observers, while in the other half of the quadrats shorebirds were 200m to 400 m from the observers. Eyeballing maps of shorebird distribution on the intertidal flats of Eighty-mile Beach suggested there may be a tendency for shorebirds to be more numerous in those quadrats most distant from the observer; this impression is reinforced by the summary presented in Table 10.4. There were indeed more birds in the more distant transects, and this trend appeared to be more marked in Eighty-mile Beach than it was in transects of similar design in Roebuck Bay.

Several ideas might explain this trend. First, it is possible that at Eighty-mile Beach I developed an undesirable talent for initiating shorebird-mapping transects in places where there were not very many birds. Secondly, it may be that the use of a rather rough optical method for judging where the boundaries of shorebird quadrats lie is involved. Testing of the distance-judging method in Roebuck Bay did not suggest there was any systematic difference in my assessment of the size of near and distant quadrats, but we did not find the time to replicate these tests on Eighty-mile Beach.

Table 10.2. Summaries of bird abundance on the intertidal flats of Northern Roebuck Bay (normal typeface) and Eighty-mile Beach (bold, in italics). Data come from mapping transects performed on receding tides: In Roebuck Bay 9 transects were mapped in October 1997 and 182 grid-squares were sampled; off Eighty-mile Beach, 6 transects were mapped in October 2000 and 241 grid-squares were sampled.

Bird abundance is expressed as: (1) Total number of birds mapped; (2) Average number of birds seen per 200 x 200 m grid-square; (3) Average number of birds seen in a complete coast-to-sea transect; (4) Maximum number of birds seen in a single grid-square; (5) The number of grid-squares in which birds were seen, expressed as a percentage of the total number of grid-squares sampled. Foraging guilds are those identified by Rogers (1999), except for “F” (fish-eaters) and “unkn” (unknown):
1. Tactile macrobenthos hunters, 2. Tactile microbenthos hunters, 3. Visual surface foragers (hunters of slow moving prey), 5. Visual surface foragers (hunters of large burrowing prey), 6. Kleptoparasites, 7. Pelagic hunters of nekton and neurton.

Guild	Species	No. of birds (1)		Mean per 200 m (2)		Mean per transect (3)		Maximum in a grid-square (4)		% grid-squares occupied (5)	
1	Bar-tailed Godwit	3599	***492***	19.77	***2.04***	399.9	***82.0***	475	***63***	59.3	***30.7***
1	Great Knot	3125	***934***	17.17	***3.87***	347.2	***155.7***	420	***132***	41.8	***17.4***
1	Red Knot	742	***32***	4.08	***0.13***	62.4	***5.3***	164	***7***	29.1	***6.2***
1	Black-tailed Godwit	577		3.17		64.1		300		3.3	
1	Asian Dowitcher	2		0.01		0.22				1.1	
2	Red-necked Stint	1163	***624***	6.39	***2.59***	129.2	***104.0***	86	***79***	37.4	***34.9***
2	Curlew Sandpiper	461	***247***	2.53	***1.02***	51.2	***41.2***	80	***18***	27.5	***22.8***
2	Marsh Sandpiper	36	***54***	0.20	***0.22***	4.0	***9.0***	10	***16***	6.0	***6.6***
2	Redshank	1	***1***	0.05	***0.004***	0.11	***0.2***	1	***1***	0.5	***0.4***
2	Broad-billed Sandpiper	2		0.01		0.22		1		1.1	
3	Silver Gull	173	***31***	0.95	***0.13***	19.2	***5.2***	49	***13***	13.2	***5.8***
3	Ruddy Turnstone	172	***23***	0.95	***0.095***	19.1	***3.8***	19	***4***	22.5	***5.8***
3	Pied Oystercatcher	41		0.20		4.6		12	***2***	6.6	***0.8***
3	Common Sandpiper	3		0.02		0.3		1		1.7	
4	Grey-tailed Tattler	593	***115***	3.26	***0.48***	65.9	***19.2***	44	***11***	52.2	***20.7***
4	Greater Sand Plover	644	***533***	3.54	***2.21***	71.6	***88.8***	55	***26***	72.0	***52.3***
4	Terek Sandpiper	222	***196***	1.22	***0.81***	24.7	***32.7***	12	***10***	41.2	***28.6***
4	Red-capped Plover	32	***87***	0.17	***0.36***	3.6	***14.5***	4	***6***	12.1	***18.7***
4	Grey Plover	51	***16***	0.28	***0.07***	5.7	***2.7***	5	***6***	12.6	***3.3***
4	Lesser Sand Plover	12	***2***	0.07	***0.01***	1.33	***0.3***	2	***1***	4.9	***0.8***
5	Whimbrel	417	***3***	2.29	***0.01***	46.3	***0.5***	38	***1***	58.2	***1.2***
5	Greenshank	192	***46***	1.06	***0.19***	1.3	***7.7***	12	***16***	42.9	***8.3***
5	Eastern Curlew	104	***3***	0.57	***0.01***	11.6	***0.5***	26	***1***	22.0	***1.2***
5	White Ibis	24		0.32		2.7		6		6.0	
5	Striated Heron	11		0.06		1.2		2		5.5	
5	Black-necked Stork	2		0.01		0.2		1		1.1	
6	Gull-billed Tern	43	***24***	0.24	***0.10***	4.8	***4.0***	8	***3***	11.0	***7.1***
7	Little Egret	12		0.07		1.3		3		5.5	
7	Great White Egret	2		0.01		0.2		1		1.0	
7	Royal Spoonbill	1		0.005		0.1		1		0.5	
7	Black-winged Stilt	1		0.005		0.1		1		0.5	
7	Reef Egret	2		0.01		0.2		1		0.5	
F	Whiskered Tern	129	***18***	0.71	***0.07***	14.3	***3.0***	52	***4***	5.0	***4.6***
F	Little Tern	30	***3***	0.17	***0.01***	3.3	***0.5***	4	***1***	9.9	***1.2***
F	Lesser Crested Tern	13	***34***	0.07	***0.14***	1.4	***5.7***	12	***14***	1.1	***2.1***
F	Caspian Tern	2		0.01		0.2		1		1.1	
F	Common Tern	1		0.005		0.1		1		0.5	
F	Crested Tern	0	***9***		***0.04***		***1.5***		***3***		***2.1***
F	Little Pied Cormorant	1		0.005		0.1		1		0.5	
F	Osprey	1		0.005		0.1		1		0.5	
F	White-bellied Sea Eagle	1		0.005		0.1		1		0.5	
F	Pied Cormorant	0	***3***		***0.01***		***0.5***				
F	Roseate Tern	0	***2***		***0.01***		***0.3***		***1***		***0.8***
Unkn	Unid small waders	577	***445***	3.17	***1.85***	64.1	***74.1***	116	***445***	8.2	***0.4***
Unkn	Pacific Golden Plover	4	***10***	0.02	***0.04***	0.4	***1.7***	1	***4***	2.2	***2.1***
Unkn	Oriental Plover	1	***42***	0.005	***0.17***	0.1	***7.0***	1	***20***	0.5	***3.7***
	TOTAL BIRDS	13222	***4029***	72.6	***16.72***	1469.1	***671.5***	1003	***445***	95.1	***71.8***

Table 10.3. Percentage of birds feeding within 200 m of the sea-edge. Only shorebird species for which more than 30 individuals were mapped at both Roebuck Bay and Eighty-mile Beach are included.

Guild	Species	Eighty-mile Beach	Roebuck Bay
Tactile hunters of macrobenthos	Bar-tailed Godwit	67.1	86.1
	Great Knot	84.7	89.0
	Red Knot	72.4	89.7
Tactile hunters of microbenthos	Red-necked Stint	36.5	69.8
	Curlew Sandpiper	24.3	73.1
	Marsh Sandpiper	0	75.6
Visual hunters of small active prey	Grey-tailed Tattler	39.1	50.2
	Greater Sand Plover	28.7	36.8
	Terek Sandpiper	21.9	27.5
	Red-capped Plover	12.6	26.5
Visual hunters of large prey	Greenshank	13.0	50.1

A final possibility, and the one I consider most plausible, is that observer disturbance is involved. On several occasions, we noticed birds flying from our path to resettle in more distant shorebird quadrats. The species at Eighty-mile Beach showing the strongest tendency to occur in distant rather than nearby transects (Grey Plover and Greenshank) happen to be notoriously wary. Most birdwatchers would probably consider Red-necked Stints and Red-capped Plovers to be the tamest of the species in Table 10.4, and they indeed show no tendency to avoid shorebird quadrats close to observers.

Table 10.4. Comparison of the number of birds seen in 'near' gridsquares (within 200 m of the observer/s) and 'far' gridsquares (more than 200 m from the observer/s). Number of birds seen in 'far' transects is expressed as a percentage of the total number of birds seen. On Eighty-mile Beach number of observers ranged from 2 to 6; all surveys on Roebuck Bay were performed by one person.

Species	Eighty-mile Beach	Roebuck Bay
Grey Plover	87.5%	82.7%
Greenshank	87.2%	57.5%
Marsh Sandpiper	79.4%	38.5%
Terek Sandpiper	76.7%	62.0%
Bar-tailed Godwit	73.9%	67.6%
Grey-tailed Tattler	70.4%	44.7%
Red Knot	64.2%	28.6%
Greater Sand Plover	61.1%	61.0%
Curlew Sandpiper	55.7%	39.4%
Great Knot	53.6%	63.3%
Red-capped Plover	52.8%	55.9%
Ruddy Turnstone	52.5%	50.0%
Red-necked Stint	48.7%	35.8%
Total	62.8%	58.3%

It is of interest that the tendency for birds to occur in relatively low densities in shorebird quadrats near to the observer appears to be stronger on Eighty-mile Beach than in Roebuck Bay (Table 10.4). While I cannot rule out the possibility that the birds of Eighty-mile Beach are of a more bashful disposition, I suspect that the real cause of the difference is the number of observers present; on Eighty-mile Beach, the number of observers performing shorebird transects ranged from 2-6, while on Roebuck Bay all surveys were performed by a single observer. Whatever the cause, it is clear that some caution is needed in detailed comparisons of shorebird numbers with the abundance of prey. Luckily, most birds we know we flushed from nearby quadrats only flew short distances to land in adjacent shorebird quadrats, so coarse analyses of shorebird distribution on the flats are unlikely to be compromised by observer disturbance.

10.3.2. Correspondence of low-tide and high-tide counts

A comparison of the total numbers of shorebirds counted on the intertidal flats at low tide, and on the beach at high tide suggests there is a relationship between the numbers of birds counted at low and high tide (Fig. 10.2).

Species composition found on low tide surveys was compared with that on adjacent beach on high tide (Fig. 10.3). Again, there is a generally good correspondence between low and high tide counts. The main discrepancies between high and low tide counts occurred for Red Knots and Red-necked Stints. Far fewer Red Knots were found on the intertidal flats on Block 20 than were found on the adjacent beach at high tide. I suspect that this was because Red Knots have a patchy foraging distribution and no rich patch of Red Knots happened to occur on our small sam-

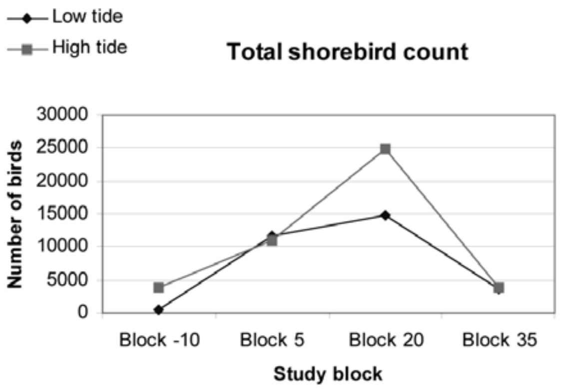


Figure 10.2. Line chart comparing total number of shorebirds counted on low tide surveys and during high tide counts. Block –10 was 10 km north of our beach access point; Blocks 5, 20 and 35 were respectively 5, 20 and 35 km south of our beach access point. High tide counts on adjacent stretches of beach were performed as follows:
Block –10 (From 12 to 54 km north of beach access point)
Block 5 (From 0 to 10 km south of beach access point)
Block 20 (From 15 to 25 km south of beach access point)
Block 35 (From 30 to 35 km s of beach access point).

Low tide surveys were performed in transects 800 m wide at each of the above blocks. For comparison with the high tide data, absolute counts were modified to low tide totals using the formula:
Low tide total = 0.8 (length of adjacent high tide block in km) x absolute low tide count.

pling area on the intertidal flats at Block 20. I am not so confident about the cause of the discrepancy between high and low tide counts for Red-necked Stints, which was especially marked at Blocks 20 and 35; in these sites we did not find as many stints roosting on the beaches as might have been expected. Many north-western Australian field-workers have had the general impression that Red-necked Stints are easily undercounted at high tide because they occur in mixed flocks with much larger wader species. I do not doubt that this is true, but I do not know if this source of error has a sufficiently large effect to produce the peculiar patterns seen in Fig. 10.3.

Despite the discrepancies mentioned above, the correspondence between high and low tide counts is suprisingly good, bearing in mind that we only mapped shorebirds on a small fraction of the intertidal area of Eighty-mile Beach and that the high-tide count data were not collected in ideal circumstances. It seems very likely that feeding shorebirds on the intertidal flats of Eighty-mile Beach typically roost on the nearest bit of adjacent beach.

Table 10.5. Total numbers of birds in different low-tide sampling blocks along Eighty-mile Beach.

Species	-10	5	20	35	50	65
Bar-tailed Godwit	4	62	35	38	63	28
Great Knot	3	187	120	16	132	85
Red Knot	0	31	1	2	2	4
Red-necked Stint	0	13	79	25	46	11
Curlew Sandpiper	0	14	18	6	16	1
Marsh Sandpiper	0	16	0	1	0	0
Silver Gull	1	13	1	1	0	1
Ruddy Turnstone	0	1	4	2	1	3
Grey-tailed Tattler	1	5	5	2	11	2
Greater Sand Plover	2	17	25	14	26	9
Terek Sandpiper	0	9	8	7	10	1
Red-capped Plover	2	2	4	3	6	5
Grey Plover	0	1	0	6	4	1
Greenshank	0	16	3	2	2	0
Gull-billed Tern	2	1	3	3	1	3

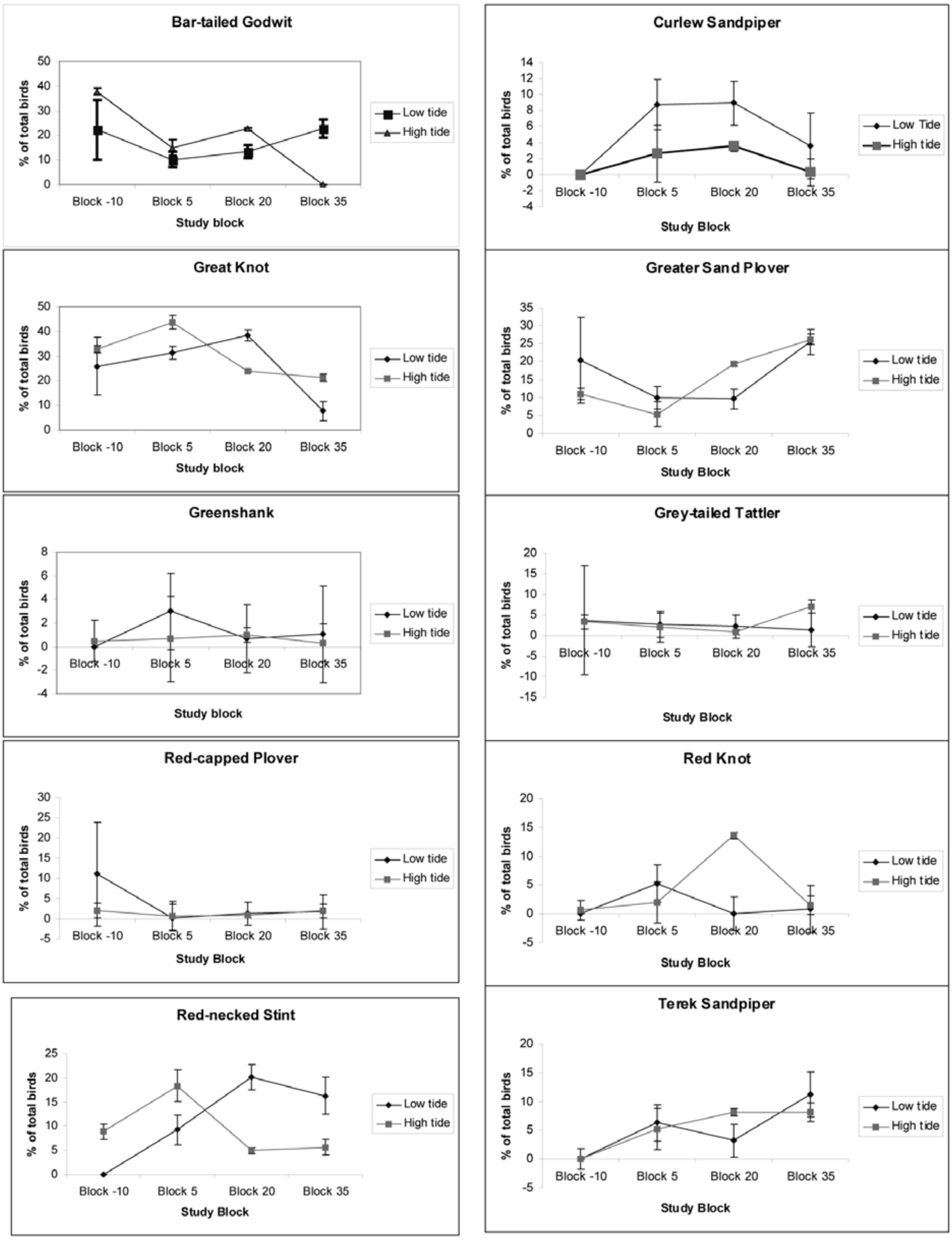


Figure 10.3. Line charts comparing the species composition found in different study blocks during low tide surveys and high tide counts. Low tide surveys were performed in transects 800 m wide; high tide counts were performed in the adjacent 5-10 km stretch of beach (see methods). The error bars depict 1 standard error, calculated using the equation: $SE(p) = [(p(1-p)/n]^{0.5}$

Table 10.6: Density of birds (no. per 4 ha) in different low-tide sampling blocks along Eighty-mile Beach.

Species	-10	5	20	35	50	65
Bar-tailed Godwit	0.2	2.91	3.3	3.0	2.6	2.5
Great Knot	0.3	8.9	9.4	1	4.8	6.3
Red Knot	0	1.48	0	0.1	0.1	0.2
Red-necked Stint	0	2.6	4.9	2.2	4.3	1.7
Curlew Sandpiper	0	2.5	2.2	0.5	1	0.1
Marsh Sandpiper	0	1.5	0	0.1	0	0
Silver Gull	0	0.8	0	0	0	0.1
Ruddy Turnstone	0	0.1	0.2	0.1	0.2	0.3
Grey-tailed Tattler	0	0.8	0.5	0.2	1.3	0.2
Greater Sand Plover	0.2	2.8	2.4	3.4	3	2.3
Terek Sandpiper	0	1.8	0.8	1.5	0.8	1
Red-capped Plover	0.1	0.1	0.3	0.2	1.1	0.5
Grey Plover	0	0.1	0	0.2	0.1	0.2
Greenshank	0	0.8	0.2	0.1	0.1	0
Gull-billed Tern	2	1	3	3	1	3

Table 10.7: Percentage of grid-squares occupied by shorebirds in different low-tide sampling blocks along Eighty-mile Beach.

Species	-10	5	20	35	50	65
Bar-tailed Godwit	9%	39%	35%	50%	28%	35%
Great Knot	14%	27%	25%	16%	13%	10%
Red Knot	0%	24%	2.1%	7%	8%	5%
Red-necked Stint	0%	42%	58%	46%	38%	35%
Curlew Sandpiper	0%	49%	44%	18%	2%	5%
Marsh Sandpiper	0%	39%	0%	7%	0%	0%
Silver Gull	1.8%	27%	2%	5%	0%	5%
Ruddy Turnstone	0%	6%	6%	9%	5%	15%
Grey-tailed Tattler	4%	33%	33%	14%	33%	10%
Greater Sand Plover	14%	67%	63%	82%	50%	50%
Terek Sandpiper	0%	55%	35%	46%	33%	5%
Red-capped Plover	7%	6%	19%	18%	45%	20%
Grey Plover	0%	6%	0%	4.5%	2.5%	15%
Greenshank	0%	27%	8%	11%	5%	0%
Gull-billed Tern	4%	6%	6%	9%	13%	5%

Table 10.8: Maximum number of birds seen in a single grid-square in different low-tide sampling blocks along Eighty-mile Beach.

Species	-10	5	20	35	50	65
Bar-tailed Godwit	4	62	35	38	63	28
Great Knot	3	187	120	16	132	85
Red Knot	0	31	1	2	2	4
Red-necked Stint	0	13	79	25	46	11
Curlew Sandpiper	0	14	18	6	16	1
Marsh Sandpiper	0	16	0	1	0	0
Silver Gull	1	13	1	1	0	1
Ruddy Turnstone	0	1	4	2	1	3
Grey-tailed Tattler	1	5	5	2	11	2
Greater Sand Plover	2	17	25	14	26	9
Terek Sandpiper	0	9	8	7	10	1
Red-capped Plover	2	2	4	3	6	5
Grey Plover	0	1	0	6	4	1
Greenshank	0	16	3	2	2	0
Gull-billed Tern	2	1	3	3	1	3

10.4. ANNOTATED SPECIES LIST

Guild 1, Tactile hunters of macrobenthos:
This was the most abundant foraging guild at both Eighty-mile Beach and Roebuck Bay (Table 10.2). However, birds in this foraging guild occurred in considerably lower densities on Eighty-mile Beach than they do on Roebuck Bay, and two Roebuck Bay species were not mapped on the intertidal flats of Eighty-mile Beach. The absence of Asian Dowitchers doesn't mean much; even on Roebuck Bay the species is rare and easily overlooked (Rogers *et al*. 2000b). However, Black-tailed Godwits are genuinely less common on Eighty-mile Beach. The reasons for this are unknown. Even on Roebuck Bay, Black-tailed Godwits are very localised, so maybe they have very specific intertidal habitat requirements that are not met along Eighty-mile Beach. Another possibility is that habitat has nothing to do with it; Black-tailed Godwits in north-western Australia tend to move (presumably inland) after wet season rains begin (Higgins & Davies 1996, pers. obs.) but their destinations are poorly known. It is possible that Eighty-mile Beach is not as strategically located for an inland movement as is Roebuck Bay.

Bar-tailed Godwit
The highest densities of Bar-tailed Godwits were observed in sampling Blocks 20 and 35 (Tables 10.5-10.8). They showed a strong tendency to follow the sea-edge when feeding (Table 10.3; see maps at the end of this chapter, p. 187).

Bar-tailed Godwits are the most abundant shorebirds of Roebuck Bay. Although they are not rare on Eighty-mile Beach, they do occur in much lower densities (Table 10.2) and are outnumbered by several other shorebird species. Fig. 10.4 suggests that the lower densities observed on Eighty-mile Beach may be related to lower food densities. The estimates of biomass of potential prey are based on the assumptions of Rogers (1999) that Bar-tailed Godwits select thin-shelled bivalves and *Lingula* of any size, and large annelids of at least 50 mm. According to this rough estimate, a greater proportion of Eighty-mile Beach is 'prey-free' than in Roebuck Bay, and when prey is present it tends to occur in lower densities (Fig. 10.4).

The comparison of Eighty-mile Beach and Roebuck Bay suggests that food densities play a role in determining how many Bar-tailed Godwits will occur in an area. However, this idea is not strongly supported by a comparison of Bar-tailed Godwit and food densities within Eighty-mile Beach (Fig. 10.4). This graph is distorted by a couple of unusual points, depicting Blocks –10 and 5. At Block 5, the real density of Bar-tailed Godwits could well have been underestimated because of the trouble we had mapping shorebird densities at the sea-edge. This was not the case at Block –10, where there were simply very few Bar-tailed Godwits. I suspect the problem lies in the classification of what prey was suitable for Bar-tailed Godwits. The calculation of prey biomass for Bar-tailed Godwits at Blocks 5 and –10 was dominated by large *Tellina amboyensis*, 25 to 35 mm long. While Bar-tailed Godwits in north-western Australia undoubtedly eat lots of bivalves and have large enough mouths to ingest large individuals, no detailed studies have been made of their diet and there is no confirmation that they will eat large *Tellina amboyensis*. Possibly large individuals of this species are too thick-shelled to be palatable.

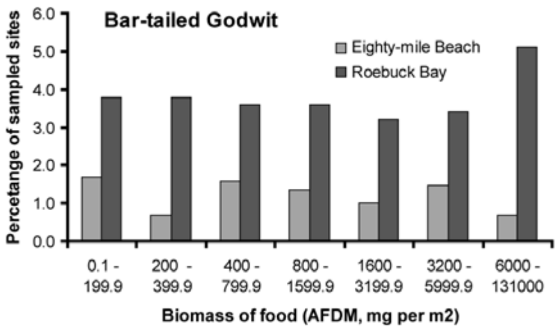


Figure 10.4. Frequency distribution of biomass of potential Bar-tailed Godwit prey at Eighty-mile Beach and Roebuck Bay. No potential prey was found in 91.6 % of the 889 sites sampled at Eighty-mile Beach and 73.5 % of the 529 sites sampled in Roebuck Bay; these prey-free sites are not shown in this graph.

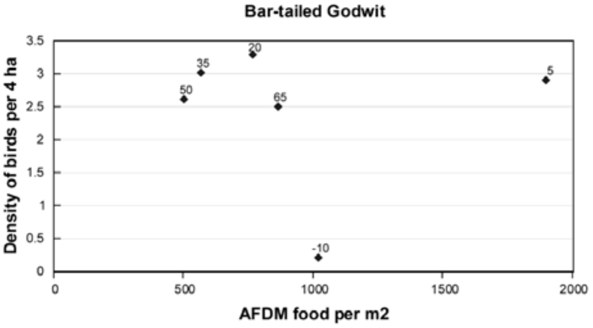


Figure 10.5. Comparison of density of Bar-tailed Godwits and the biomass of their presumed prey on the intertidal flats of Eighty-mile Beach. Each point represents the average for one of the sampling blocks; the number of each sampling block is given next to each point.

Great Knot

The highest densities of Great Knots were recorded in Blocks 5 and 20 (Tables 10.5-10.8). In general they followed the sea-edge closely (maps on p. 188), the one real exception to this trend being a small concentration closer to the beach at Block 5. Some of these birds were hunting small mesodesmatid bivalves which occurred in reasonable concentrations on the lowermost beach (DR and P. de Goeij, unpublished foraging observations and collections of droppings). This was not true of the adjacent quadrats on the uppermost mudflats, and we do not know what the knots were hunting there; those quadrats did not seem to hold large numbers of potential prey items.

Although Great Knots are the most numerous waders of Eighty-mile Beach, they do not occur in such high densities as the Great Knots of Roebuck Bay (Table 10.2). This difference may be related to the food resources available; suitable prey (bivalves not exceeding the size limits identified by Tulp & de Goeij (1994), cumaceans, shrimps and *Lingula*, and *Leucosia* crabs <16 mm; Rogers 1999) is much more widespread on the intertidal flats of Roebuck Bay, and when present, it tends to be more abundant than at Eighty-mile Beach (Fig. 10.6). A comparison of bird densities with biomass of their preferred prey (Fig. 10.7) hints even more strongly at a tendency for birds to feed in areas where prey densities are high, especially when it is borne in mind that the density of Great Knots in Block 5 (the right-hand point on the graph) was probably underestimated because of the difficulties we had getting to the sea-edge.

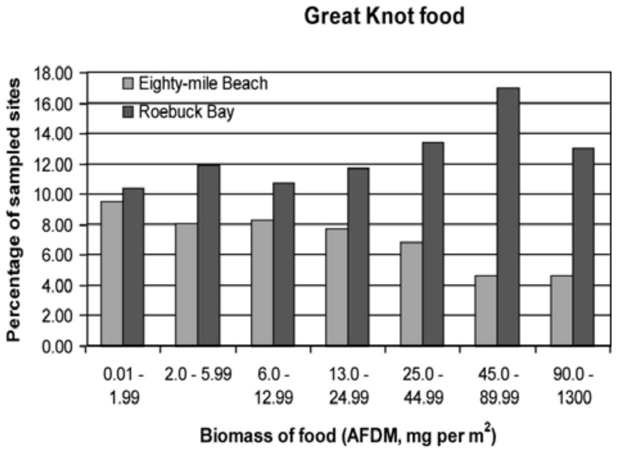


Figure 10.6. Frequency distribution of biomass of potential Great Knot prey at Eighty-mile Beach and Roebuck Bay. No potential prey was found in 50.2 % of the 889 sites sampled at Eighty-mile Beach and 11.8 % of the 529 sites sampled in Roebuck Bay; these prey-free sites are not shown in this graph.

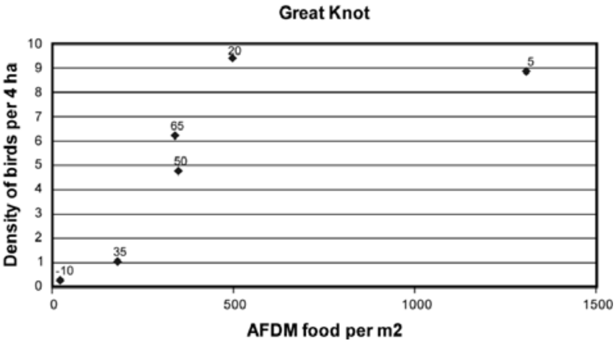


Figure 10.7. Comparison of density of Great Knots and the biomass of their presumed prey on the intertidal flats of Eighty-mile Beach. Each point represents the average for one of the sampling blocks; the number of each sampling block is given next to each point.

Red Knot

We didn't find the mother lode of Red Knots on the intertidal flats of Eighty-mile Beach. High tide counts indicated that there were plenty around – we counted nearly 5000 on the 45 km of beaches at the northern end of our study area – yet only 63 birds were mapped on the intertidal mudflats (Tables 10.5-10.8). A plausible interpretation is that the feeding distribution of Red Knots on Eighty-mile Beach is patchy, and that the best patches for Red Knots did not happen to occur along any of our shorebird mapping transects.

Red Knots follow the sea-edge closely in Roebuck Bay. I suspect they do at Eighty-mile Beach too. The few data available neither confirm nor deny this possibility (maps on p. 189), but it is perhaps noteworthy that the only quadrat in which reasonable Red Knot numbers were found happened to be at the sea-edge in Block 5; this block also happened to have more abundant Red Knot prey than any others. Red Knot prey was assumed to comprise: bivalves not exceeding the size limits identified by Tulp & de Goeij (1994); cumaceans, shrimps, hermit crabs, spider crabs, *Lingula* and *Leucosia* crabs less than 14 mm in diameter. In most respects, the distribution and abundance of potential Red Knot prey along Eighty-mile Beach was similar to that of the prey of Great Knots (Fig. 10.8), which makes the difference in foraging distribution of the two knot species somewhat surprising. In Block 5, Red Knots had a similar feeding distribution to Great Knots (indeed the two species fed in mixed flocks) but in the other study blocks, there were very few Red Knots interspersed with the many Great Knots seen. Could Red Knots require prey in higher densities than do Great Knots? This would seem consistent with the fact that most were seen in Block 5 where prey was most abundant. If this hypothesis does have legs, it would be interesting to see if it had some link with morphology – Red Knots have shorter bills than Great Knots, and therefore cannot reach such deeply buried prey, so much of the apparently suitable prey that we sampled may not really have been available to Red Knots.

As with Great Knots, density of prey and density of Red Knots was higher at Roebuck Bay than at Eighty-mile Beach (Fig. 10.9; Table 10.2).

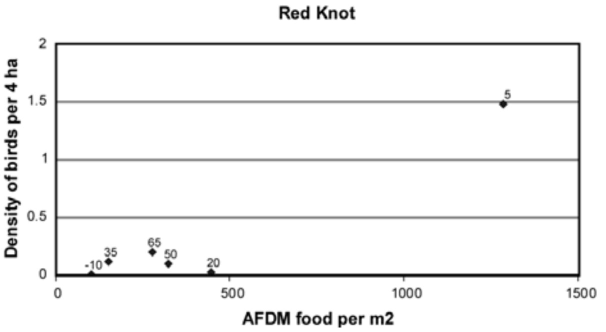


Figure 10.8: Comparison of density of Red Knots and the biomass of their presumed prey on the intertidal flats of Eighty-mile Beach. Each point represents the average for one of the sampling blocks; the number of each sampling block is given next to each point.

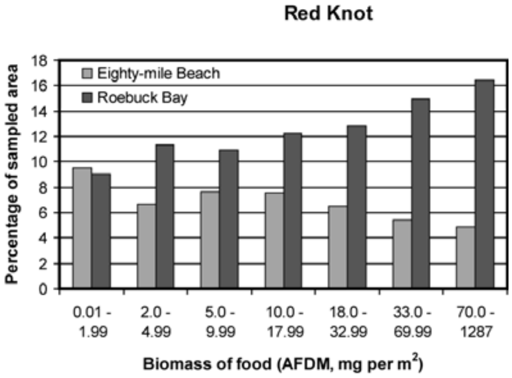


Figure 10.9. Frequency distribution of biomass of potential Red Knot prey at Eighty-mile Beach and Roebuck Bay. No potential prey was found in 51.8 % of the 889 sites sampled at Eighty-mile Beach and 12.09 % of the 529 sites sampled in Roebuck Bay; these prey-free sites are not shown in this graph.

Guild 2, Tactile hunters of microbenthos:
Birds of this foraging guild were slightly more common on Roebuck Bay than on Eighty-mile Beach (Table 10.2), but the difference was not striking. All but one of the Roebuck Bay species in this guild were also mapped on Eighty-mile Beach. The exception was Broad-billed Sandpiper, which is even in Roebuck Bay an uncommon and localised species; we might easily have missed concentrations elsewhere on Eighty-mile Beach.

Red-necked Stint
Red-necked Stints on the intertidal flats of Eighty-mile Beach showed no strong tendency to follow the sea-edge (Table 10.3; maps on p. 190). They were most common in the study blocks between 5 and 50 km south of the access point to Eighty-mile Beach (Tables 10.5-10.8). None at all were mapped in Block –10, a region that was also virtually devoid of suitable food for Red-necked Stints (i.e. polychaetes and soft-bodied arthropods 3-12 mm long; bivalves, gastropods and hard-bodied arthropods less than 5 mm long). A relationship between Red-necked Stint abundance and that of their preferred prey is hinted at by the plot in Fig. 10.9. There is however a point in this graph which does not fit in well: prey densities were considerably higher at 65 km S than anywhere else, but few Red-necked Stints were found here. The high biomass of prey in this study-block was caused by enormous densities of capitellid worms, and I see no reason why these should not be taken by Red-necked Stints. It is possible that that Red-necked Stint density was underestimated at this point. The transect here was mapped on a neap tide, when relatively little mud was exposed. As a result the potential feeding area was rather small and the density of Annabim mudbashers was rather high. I do not know whether these circumstances would have caused Red-necked Stints to change their feeding areas.

Within the constraints mentioned above, the distribution of Red-necked Stints appeared somewhat patchy. The reasons for this are unknown; there was no obvious difference between grid-squares with and without Red-necked Stints in terms of penetrability, biomass of Red-necked Stints, or presence or absence of mudbanks.

The abundance of both Red-necked Stints and their benthic prey was quite similar to that of Roebuck Bay by some measures (Tables 10.5-10.8, Fig. 10.10).

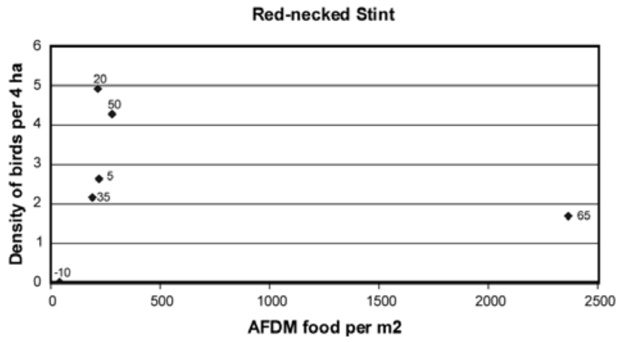


Figure 10.9. Comparison of density of Red-necked Stints and the biomass of their presumed prey on the intertidal flats of Eighty-mile Beach. Each point represents the average for one of the sampling blocks; the number of each sampling block is given next to each point.

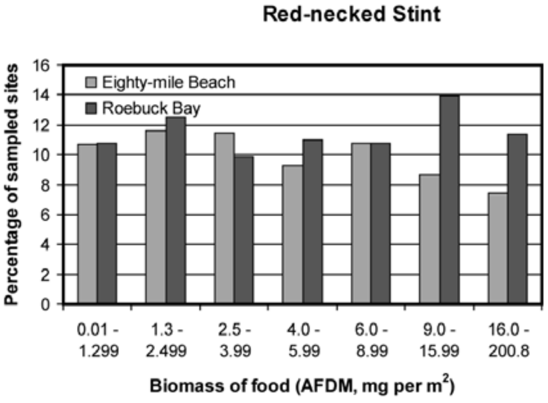


Figure 10.10. Frequency distribution of biomass of potential Red-necked Stint prey at Eighty-mile Beach and Roebuck Bay. No potential prey was found in 30.1 % of the 889 sites sampled at Eighty-mile Beach and 19.8 % of the 529 sites sampled in Roebuck Bay; these prey-free sites are not shown in this graph.

Curlew Sandpiper

This species was most abundant in Blocks 5 and 20 (Tables 10.5-10.8). Within these study blocks the distribution was rather patchy (maps on p. 191). This seemed in part to be related to a tendency for them to feed on eroding mudbanks: e.g. in Block 20, of the 14 grid-squares sampled that contained mudbanks, 12 also held Curlew Sandpipers, while only one of the 12 grid-squares sampled without mudbanks held Curlew Sandpipers. Curlew Sandpipers also seemed to be more common in soft substrates: e.g. in Block 20 m average penetrability of grid-squares with Curlew Sandpipers was 12.4 cm (± 6.31; n =19), while that in grid-squares without Curlew Sandpipers was only 4.3 cm (± 4.15; n =23). These trends might have been related, with mudbanks being generally softer. Curlew Sandpiper prey was assumed to comprise: polychaetes 3-80 mm long; soft-bodied crustacea 3-12 mm long; bivalves, gastropods and hard-bodied arthropods 3-5 mm long. Mudbanks did not appear to be richer in potential prey than other areas of mud: e.g. in Block 20, biomass of presumed Curlew Sandpiper prey on mudbanks was 14.1 mg per sample (± 13.2; n =14) and on other areas of mud was 25.1 mg per sample (± 13.2; n =14). It is possible that the varied substrates of eroding mudbanks, with many pools, made prey easier to hunt even though it was no more abundant there than on flat areas of mud. On a broader scale, there did appear to be a weak relationship between the numbers of Curlew Sandpipers and abundance of their prey (Fig. 10.11).

Curlew Sandpipers did not show a strong tendency to follow the sea-edge on Eighty-mile beach (Table 10.3); in this respect they differed from the Curlew Sandpipers of Roebuck Bay, which often occur on the landward side of sea-edge flocks, especially in sandy areas. In other respects, the Curlew Sandpipers of Eighty-mile Beach appear to have much in common; Roebuck Bay has slightly higher densities of both Curlew Sandpipers (Table 10.2) and their benthic prey (Fig. 10.12), but the differences are relatively slight.

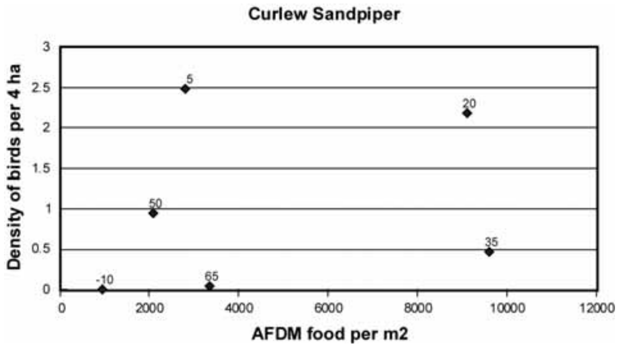


Figure 10.11. Comparison of density of Curlew Sandpipers and the biomass of their presumed prey on the intertidal flats of Eighty-mile Beach. Each point represents the average for one of the sampling blocks; the number of each sampling block is given next to each point.

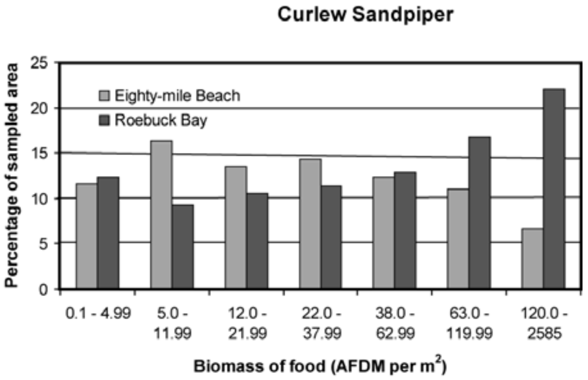


Figure 10.12. Frequency distribution of biomass of potential Curlew Sandpiper prey at Eighty-mile Beach and Roebuck Bay. No potential prey was found in 14.3 % of the 889 sites sampled at Eighty-mile Beach and 4.7 % of the 529 sites sampled in Roebuck Bay; these prey-free sites are not shown in this graph.

Marsh Sandpiper

This species was slightly more common than on Roebuck Bay. The distribution was restricted, with almost all birds being seen on the mudbanks of Block 5 (Tables 10.5-10.8; map on p. 198). In the absence of any adequate data on their diet in Australia it is difficult to tell if this restricted foraging range is caused by a prey preference.

Redshank

Only a single bird was mapped, on a mudbank in Block 5 (map on p. 198). A single Redshank also dropped in briefly to examine the churned up area of mud left by the end-of-expedition mudfight, less than an hour after mudbashers had left the arena.

Guild 3: Surface foragers of slow-moving prey:

This rather poorly defined guild was uncommon on Eighty-mile Beach. Five species were identified as part this guild in Roebuck Bay, but two of these, Common Sandpiper and Sooty Oystercatcher, were not recorded on Eighty-mile Beach. In both cases this was probably due to a lack of suitable habitat; Common Sandpipers are usually associated with mangroves in Roebuck Bay, and Sooty Oystercatchers with rock platforms. Both habitats are in short supply along Eighty-mile Beach.

Silver Gull

Silver Gulls were less common than at Roebuck Bay (Table 10.2; map on p. 199). The only concentration found was in Block 5 (Tables 10.5-10.8), where most birds occurred near shore. I am not sure what the attraction of this region was. It also had concentrations of Great Knots and Red Knots, some of which were hunting mesodesmatid bivalves on the lowermost beach. However, most Silver Gulls were slightly further from shore, and none seen were particularly active; it is possible that they were using this area to loaf rather than for feeding.

Ruddy Turnstone

Ruddy Turnstones were uncommon on the intertidal flats of Eighty-mile Beach; a few were seen on mudbanks and the species appeared not to follow the sea-edge (Tables 10.5-10.8; maps on p. 192). In Roebuck Bay, Ruddy Turnstones are suspected to feed on amphipods or in sites with large Brittle-stars or Sand-dollars. The biomass of potential prey appears lower on Eighty-mile Beach (Fig. 10.13), where Ruddy Turnstones are less abundant. A link between prey abundance and Ruddy Turnstones is also perhaps suggested by the plot of average prey biomass versus Ruddy Turnstone density in the different study blocks on Eighty-mile Beach (Fig. 10.14). The relationship would look more convincing were it not for the unusual data from Block 20, a site which had plenty of Turnstones but apparently very little Turnstone prey. It seems quite likely that our understanding of the diet of Ruddy Turnstones is imperfect.

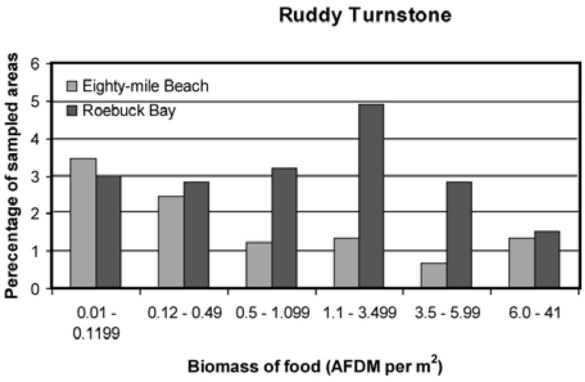


Figure 10.13. Frequency distribution of biomass of potential Ruddy Turnstone prey at Eighty-mile Beach and Roebuck Bay. No potential prey was found in 89.4 % of the 889 sites sampled at Eighty-mile Beach and 81.7 % of the 529 sites sampled in Roebuck Bay; these prey-free sites are not shown in this graph.

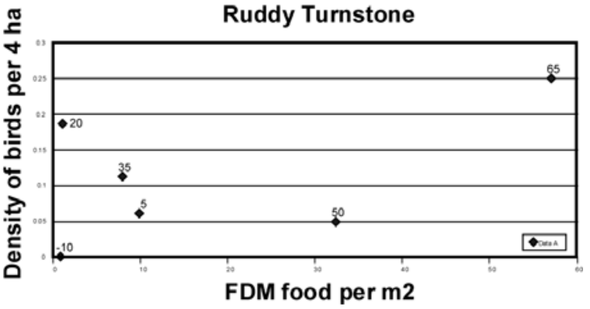


Figure 10.14. Comparison of density of Ruddy Tunrstones and the biomass of their presumed prey on the intertidal flats of Eighty-mile Beach. Each point represents the average for one of the sampling blocks; the number of each sampling block is given next to each point.

Pied Oystercatcher

Pied Oystercatchers were much less common than on Roebuck Bay. Only three were seen on the intertidal flats; two in Block 5, one in block –10 (map on p. 199). No speculation on distributional trends is possible on this scanty data.

Guild 4: Surface-foragers: hunters of small active prey.

This was the only foraging guild which seemed about as well represented on Eighty-mile Beach as it is in Roebuck Bay. Birds in this foraging guild hunt small active prey (such as small crabs) which are located by sight.

Grey-tailed Tattler

The main concentrations of Grey-tailed Tattlers observed were in Blocks 5, 20 and 50, where birds fed on or near mudbanks, or followed the sea-edge to some extent (Tables 10.5-10.8; maps on p. 193). Densities of foraging birds were lower than in Roebuck Bay (Table 10.2); so too was the biomass of what is presumed to be their preferred prey, soft-bodied arthropods greater than 5 mm long, and crabs less than 16 mm in diameter (Fig. 10.15). Within Eighty-mile Beach, a plot of prey biomass and density of Grey-tailed Tattler suggests a positive relationship between the two (Fig. 10.16). The odd-looking point (with high biomass of potential prey but low densities of Tattlers) was at Block 65, where the neapy tide conditions during sampling might have led to an underestimate of the densities of Grey-tailed Tattlers.

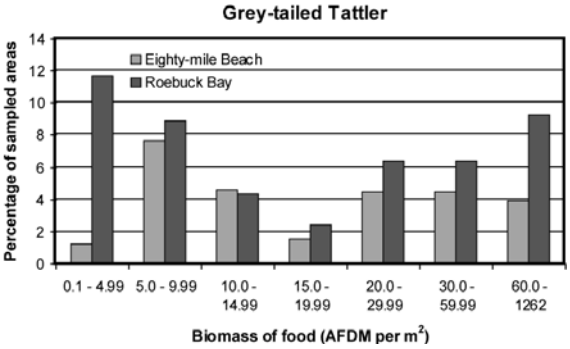


Figure 10.15. Frequency distribution of biomass of potential Grey-tailed Tattler prey at Eighty-mile Beach and Roebuck Bay. No potential prey was found in 72.0 % of the 889 sites sampled at Eighty-mile Beach and 50.5 % of the 529 sites sampled in Roebuck Bay; these prey-free sites are not shown in this graph.

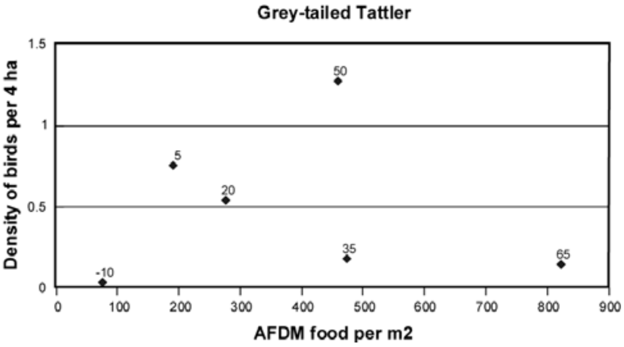


Figure 10.16. Comparison of density of Grey-tailed Tattlers and the biomass of their presumed prey on the intertidal flats of Eighty-mile Beach. Each point represents the average for one of the sampling blocks; the number of each sampling block is given next to each point.

Greater Sand Plover

This species was widespread on Eighty-mile Beach, but clearly most common in Block 35 and least common in Block –10 (Tables 10.5-10.8, maps on p. 194). Greater Sand Plovers did not appear to have any inclination to follow the sea-edge closely (Table 10.3). The high densities in Block 35 were a little unusual; few other shorebird species were found at high relative abundance in this block. A plot comparing the density of presumed preferred prey in each block (arthropods less than 12 mm long) with the density of Greater Sand Plovers (Fig. 10.17) suggests the observed distribution of Greater Sand Plovers may be related to the prey distribution. Substrate type may also be a consideration; except on the depauperate Block –10, Greater Sand Plovers tended to be most common in sandy quadrats of low penetrability.

Densities of Greater Sand Plovers on Eighty-mile Beach were similar to those observed in Roebuck Bay (Table 10.2). This also applied to the biomass of their presumed prey (Fig. 10.18).

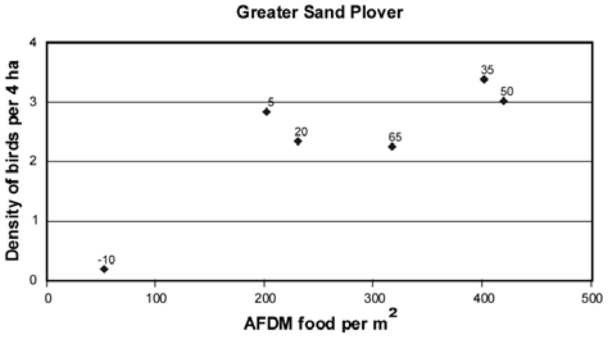


Figure 10.17. Comparison of density of Greater Sand Plovers and the biomass of their presumed prey on the intertidal flats of Eighty-mile Beach. Each point represents the average for one of the sampling blocks; the number of each sampling block is given next to each point.

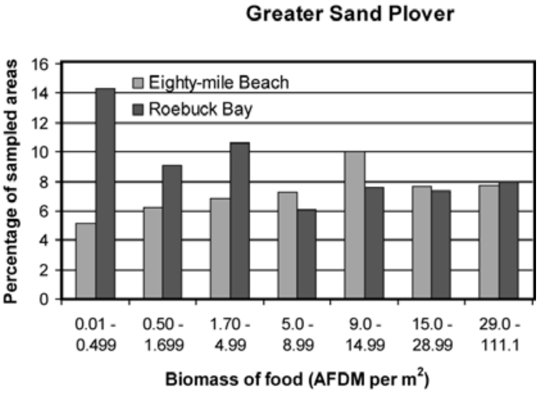


Figure 10.18. Frequency distribution of biomass of potential Greater Sand Plover prey at Eighty-mile Beach and Roebuck Bay. No potential prey was found in 49.0 % of the 889 sites sampled at Eighty-mile Beach and 37.1 % of the 529 sites sampled in Roebuck Bay; these prey-free sites are not shown in this graph.

Terek Sandpiper

Terek Sandpipers were reasonably common in most blocks, but not in Block -10 and Block 65 (Tables 10.5-10.8; maps on p. 195), which happened to be the sandiest of the Annabim study blocks. There was no strong tendency to follow the sea-edge (Table 10.3) and no obvious tendency either associate with or avoid mudbanks. Nor, within study blocks, could I find any obvious link between Terek Sandpipers numbers and sediment penetrability - rather unlike the situation at Roebuck Bay, where Terek Sandpipers are most common in sandy areas (or at least in areas with a mixture of sand and mud).

Overall, both the densities of Terek Sandpipers and the biomass of their presumed prey (crabs with a carapace less than 12 mm in diameter) were quite similar on Eighty-mile Beach and in Roebuck Bay (Table 10.2, Fig. 10.19). A plot of Terek Sandpiper density versus prey biomass along Eighty-mile Beach (Fig. 10.20) hints at a positive relationship between the two.

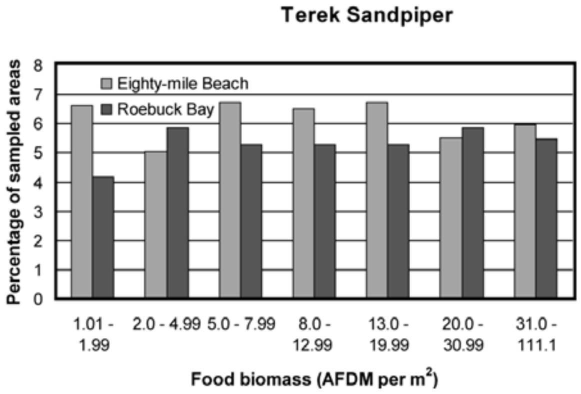


Figure 10.19. Frequency distribution of biomass of potential Terek Sandpiper prey at Eighty-mile Beach and Roebuck Bay. No potential prey was found in 56.8 % of the 889 sites sampled at Eighty-mile Beach and 62.8 % of the 529 sites sampled in Roebuck Bay; these prey-free sites are not shown in this graph.

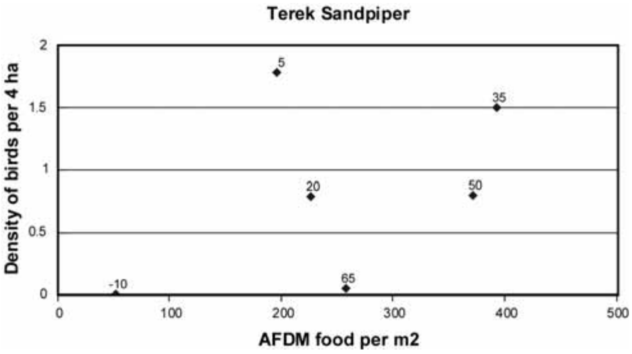


Figure 10.20. Comparison of density of Terek Sandpipers and the biomass of their presumed prey on the intertidal flats of Eighty-mile Beach. Each point represents the average for one of the sampling blocks; the number of each sampling block is given next to each point.

Red-capped Plover

By all measures, Red-capped Plovers were more abundant in the southern sites of our study area, with much the highest densities occurring in Block 50 (Tables 10.5-10.8). The birds were widely dispersed and tended to be most common in near-shore areas of the intertidal flats (maps on p. 196), as is also the case in Roebuck Bay. Densities of Red-capped Plovers were slightly higher than on Roebuck Bay, and this species was also one of the few species for which the abundance of presumed prey was slightly higher than in Roebuck Bay (Fig. 10.21; preferred prey were assumed to be arthropods less than 6 mm , excluding hermit crabs). Within the study area at Eighty-mile Beach, the foraging distribution of Red-capped Plovers also seemed to be loosely associated with that of their presumed prey (Fig. 10.22). A few breeding pairs of Red-capped Plovers were seen on Eighty-mile Beach, so the observed distribution on the intertidal flats may have been influenced by breeding habitat preferences: Red-capped Plovers cannot nest on beaches which are flooded by spring tides, and they tend to like sandy open areas for nesting. The habitat behind Eighty-mile Beach might also affect where Red-capped Plovers nest; around Roebuck Bay the breeding stronghold is on open saline claypans (Rogers *et al*. 2001). Suitable habitat certainly occurs to the south of the study area around the Mandorah Marshes (about 90 km S of the access point we used to Eighty-mile Beach) but I do not know how far north such habitat extends.

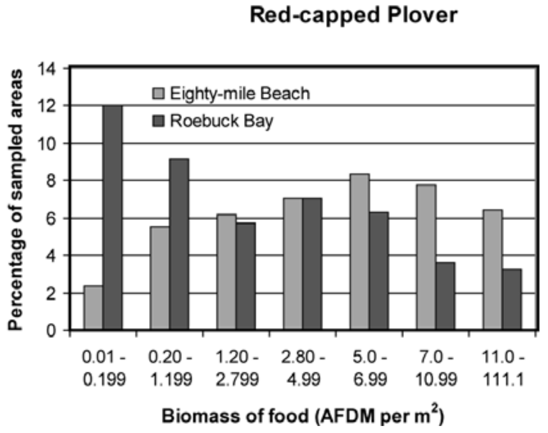


Figure 10.21. Frequency distribution of biomass of potential Red-capped Plover prey at Eighty-mile Beach and Roebuck Bay. No potential prey was found in 56.4 % of the 889 sites sampled at Eighty-mile Beach and 52.9 % of the 529 sites sampled in Roebuck Bay; these prey-free sites are not shown in this graph.

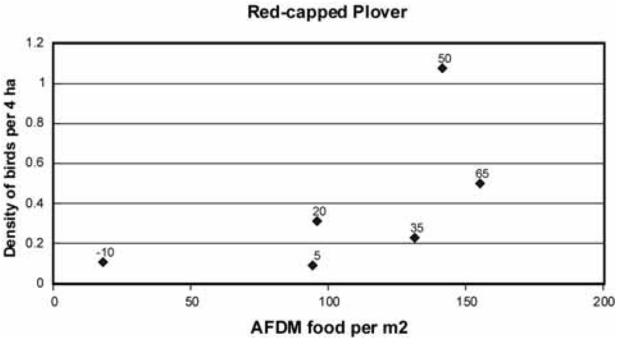


Figure 10.22. Comparison of density of Red-capped Plovers and the biomass of their presumed prey on the intertidal flats of Eighty-mile Beach. Each point represents the average for one of the sampling blocks; the number of each sampling block is given next to each point.

Grey Plover

There were few obvious trends in the scattered distribution of Grey Plovers along Eighty-mile Beach (Tables 10.5-10.8; maps on p. 197), except for a tendency to be more common in the south. They showed no tendency to follow the sea edge (only 2 of the 16 individuals mapped were in a sea-edge quadrat). As in Roebuck Bay, the presence of several Grey Plover in some quadrats seemed inconsistent with the finding in some overseas studies (reviewed in Byrkjedal & Thompson 1998) that Grey Plovers may defend feeding territories. Grey Plovers occurred in lower densities at Eighty-mile Beach than in Roebuck Bay (Table 10.2) and this was also true of their presumed prey, polychaetes > 50 mm and crabs (excluding hermit crabs) between 7.5 and 15 mm long (Fig. 10.23). Within Eighty-mile Beach there was no convincing relationship between prey abundance and density of Grey Plovers (Fig. 10.24); the factors governing the scattered feeding distribution of Grey Plovers on Eighty-mile Beach remain obscure.

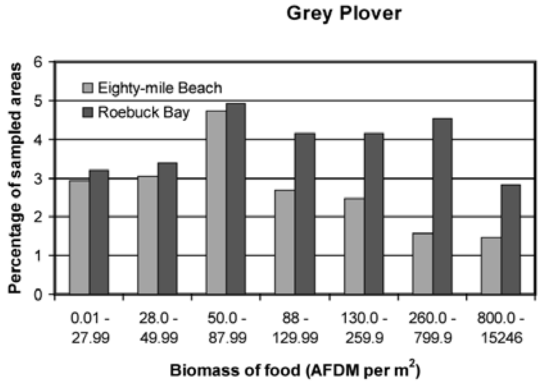


Figure 10.23. Frequency distribution of biomass of potential Grey Plover prey at Eighty-mile Beach and Roebuck Bay. No potential prey was found in 81.1 % of the 889 sites sampled at Eighty-mile Beach and 72.8 % of the 529 sites sampled in Roebuck Bay; these prey-free sites are not shown in this graph.

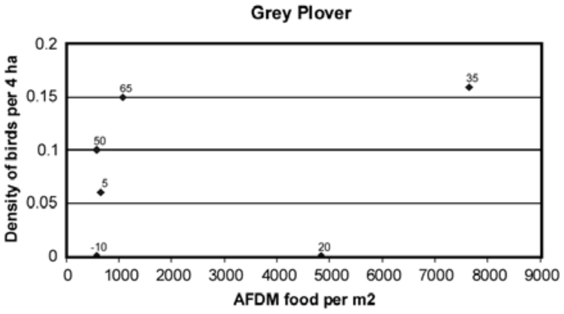


Figure 10.24. Comparison of density of Grey Plovers and the biomass of their presumed prey on the intertidal flats of Eighty-mile Beach. Each point represents the average for one of the sampling blocks; the number of each sampling block is given next to each point.

Lesser Sand Plover

Only two Lesser Sand Plovers were mapped on the intertidal flats, both in Block 50 (map on p. 200). With so few data it is not worth speculating about their preferred feeding areas or whether they occur in lower densities than in Roebuck Bay.

Guild 5: visual surface foragers.
(hunters for large burrowing prey)

Whimbrel

Whimbrels were remarkably scarce on Eighty-mile Beach; only three individuals were mapped, two on Block 65 and one on Block –10 (map on p. 200). The species is far more abundant in Roebuck Bay (Table 10.1). This difference is not easy to explain in terms of food supply; north-western Australian Whimbrels feed on large Macrophthalmus crabs, and these seemed plentiful on the intertidal flats of Eighty-mile Beach. I suspect that the lack of mangroves along Eighty-mile Beach may be involved in the discrepancy. Most of Roebuck Bay is fringed by mangroves which in turn back on to saltmarshes; Whimbrels use both habitats, and importantly, can continue to hunt large crabs there when the tide is high. It is likely that no such opportunities to forage at high tide occur at Eighty-mile Beach, which is simply backed by sand dunes.

Greenshank

Greenshanks occurred in lower densities than in Roebuck Bay. Nevertheless, reasonable numbers were seen, mainly in Block 5 (Tables 10.5-10.8). They were often encountered around mudbanks (map on p. 201) and this would seem consistent with their feeding behaviour – as in Roebuck Bay, most of the Greenshanks seen feeding on the intertidal flats of Roebuck Bay appeared to be hunting fish. The mudbanks of Eighty-mile Beach would seem to be a logical place to do this, as they hold plenty of mudskippers and many pools that can hold fish through a low tide period. In Roebuck Bay many Greenshanks fed along creeklines. This is not an option along most of Eighty-mile Beach (the flatter intertidal zone receives little overland runoff and has very few creeklines), which might go some way to explaining the lower densities of Greenshanks.

Eastern Curlew

Only three individuals were seen, two on Block 35, one on Block 65 (map on p. 201). The Eastern Curlews of North-western Australia appear to have much in common with Whimbrels (see above): they appear to feed on large crabs and they occur in far lower densities on Eighty-mile Beach than in Roebuck Bay. In Roebuck Bay, Eastern Curlews often move to saltmarshes at high tide and sometimes they hunt crabs there; this option is not open to the Eastern Curlews of Eighty-mile Beach. As with Whimbrels, I suspect the reason that Eighty-mile Beach supports so few Curlews has little to do with the quality of the intertidal mudflats available, but a great deal to do with the supralittoral habitats available.

Guild 6: klepto parasites

Gull-billed Tern

In Roebuck Bay, the distribution of Gull-billed Terns is closely associated with that of Whimbrels, from which they steal crabs; they may also steal crabs from Eastern Curlews. This cannot be the sole determinant of Gull-billed Tern distribution on Eighty-mile Beach, as Gull-billed Terns outnumber both Whimbrels and Eastern Curlews (Tables 10.5-10.8; map on p. 202). Kleptoparasitism of these species by Gull-billed Terns probably occurs on Eighty-mile Beach too, given that all three Eastern Curlews mapped, and two of the three Whimbrels mapped, occurred in the same or adjacent gridsquares to Gull-billed Terns which kept them under close observation. Nevertheless, Gull-billed Terns were seen in 13 other quadrats where there were no nearby Whimbrels or Eastern Curlews. The birds simply appeared to be loafing, usually on mudbanks, and I do not know why they selected their chosen areas. It is possible that some of them were the Asian subspecies *affinis*, which is commoner on Eighty-mile Beach than on Roebuck Bay, and unlike the Australian subspecies *macrotarsa* does not rob crabs from whimbrels (Rogers et al., in prep)

Guild 7: fish-eaters

Whiskered Tern

A few Whiskered Terns were seen loafing in Blocks 20, 35 and 50; there was no obvious pattern to their distribution (map on p. 202).

Little Tern:

One Little Tern was seen in each in of Blocks 50, 65 and –10; there was no obvious pattern to their distribution (map on p. 203).

Lesser Crested Tern

Lesser Crested Terns were only mapped in southern blocks: there were six loafing in Block 50 and 28 in Block 65 (map on p. 203).

Crested Tern

Small numbers of Crested Terns were mapped in the southern blocks: one in Block 35, two in Block 50, and 6 in Block 65 (map on p. 204).

Guild unknown possibly inland feeders, using the intertidal flats as roosting area

Roseate Tern

Two were mapped in Block –10 (map on p. 204).

Oriental Plover

Oriental Plovers seemed to have a southerly distribution on the intertidal flats of Eighty-mile Beach; eleven were mapped in Block 35, 27 in Block 50 and four in Block 65 (map on p. 205). It is unlikely that this reflected any particular habitat preference. All birds seen were inactive; I suspect they had inland feeding grounds and simply chose to roost on the intertidal flats as they were relatively cool and because the brown dorsal plumage of Oriental Plovers is inconspicuous on the mud (compared to the alternatives, white beach or dry grasslands immediately behind). The abundance of Oriental Plovers in the south during Annabim might have something to do with date. These were the last three sites we sampled and it is possible that a flock had simply migrated in. Oriental Plovers appear to be passage migrants on Eighty-mile Beach and move inland once the wet season rains begin.

Pacific Golden Plover

Five were mapped in Block 5, two each in Blocks –10 and 65,one in Block 35. There was no obvious pattern to their distribution (map on p. 205).

DISCUSSION

By many measures, neither the shorebird nor benthic fauna of Eighty-mile Beach are as rich as those of Roebuck Bay. The diversity of shorebird species is lower than that of Roebuck Bay, an important contributor to this probably being the lack of adjacent mangroves and saltmarshes apparently essential to birds such as Striated Herons, Whimbrels, Eastern Curlews and Common Sandpipers. The lack of extensive creek systems may well be involved in the generally low numbers of fish-hunting wading birds such as herons and egrets. Overall, the density of shorebirds per square kilometre of mudflat at low tide is also lower than in northern Roebuck Bay, this difference being strongly marked in the foraging guilds which hunt large buried prey by touch (e.g. knots and godwits), large crabs (e.g. Curlews and Whimbrels) and fishes (e.g. most terns and large Ciconiiformes); the trend is still present, though less marked, in foraging guilds which hunt small buried prey (e.g. stints and Curlew Sandpipers) and small active surface prey (e.g. Terek Sandpipers and most plovers). In general, the biomass of benthic prey per m^2 available to waders in Eighty-mile Beach and northern Roebuck Bay mirrored these trends – northern Roebuck Bay typically had more prey, but the difference was least strongly marked for those birds that hunt small surface-dwelling active prey.

Eighty-mile Beach also has fewer shorebirds per low-tide transect (i.e. per 800 m of coastline) than Roebuck Bay, but by this measure, the difference between the sites is less strongly marked than when bird abundance is expressed as density per ha of mudflat exposed at low tide. For example in the foraging guild comprising shorebirds that hunt small active surface-dwelling prey by sight, the number of birds per low-tide transect in Eighty-mile Beach is 90% that of Roebuck Bay, but the density of birds per hectare at Eighty-mile Beach is only 50% that of Roebuck Bay (data in Table 10.1). This discrepancy between sites is undoubtedly in part related to the broader intertidal flats of Eighty-mile Beach, but the exact effect of mudflat width on shorebird numbers at Eighty-mile Beach is unclear. A possibility worth considering is that shorebird numbers on both Eighty-mile Beach and Roebuck Bay are limited by the feeding opportunities on neap low tides. In such situations, only a narrow band of the intertidal flats is exposed in either site, so the length of undisturbed coastline might bear a close relationship to the number of waders that each area can support.

Although shorebirds and their prey occur in higher densities in Roebuck Bay than Eighty-mile Beach, it does not follow that Eighty-mile Beach should be considered an inferior site. What it does have going for it is size – despite the relatively low densities the intertidal flats are so extensive, and the beach is so long, that Eighty-mile Beach supports many more shorebirds than Roebuck Bay.

The tendency for Roebuck Bay to have higher densities of both shorebirds and their prey than Eighty-mile Beach suggests that prey abundance affects the number of shorebirds. This idea is also supported to some extent by comparisons of shorebird density and prey biomass in the different sampling blocks within Eighty-mile Beach: the study blocks with most prey tended to be those with most birds. On a smaller scale, no neat match was found between the number of shorebirds and the density of potential prey, in individual grid-squares. More sophisticated multivariate analyses might help to establish why this was the case. My suspicion is that there is some kind of resolution problem. The multiple observers during shorebirds mapping transects probably flushed some birds from their original quadrat to an adjacent one before they were mapped (results above; Table 10.4). Another potential problem is that during benthos sampling, we may not have taken enough core samples per study block to develop a sound understanding of total benthos density. An obvious course of action to test these possibilities would be to try grouping bird data from adjacent grid-squares and benthos data from adjacent study sites to see how coarse a resolution is required before a relationship between bird numbers and benthos abundance becomes clear. Such an approach might provide insights to how many core samples should be taken per site at Eighty-mile Beach. In addition, it would probably be worth performing some small-scale sampling to develop a better understanding of the patchiness of benthos in the intertidal flats of north-western Australia.

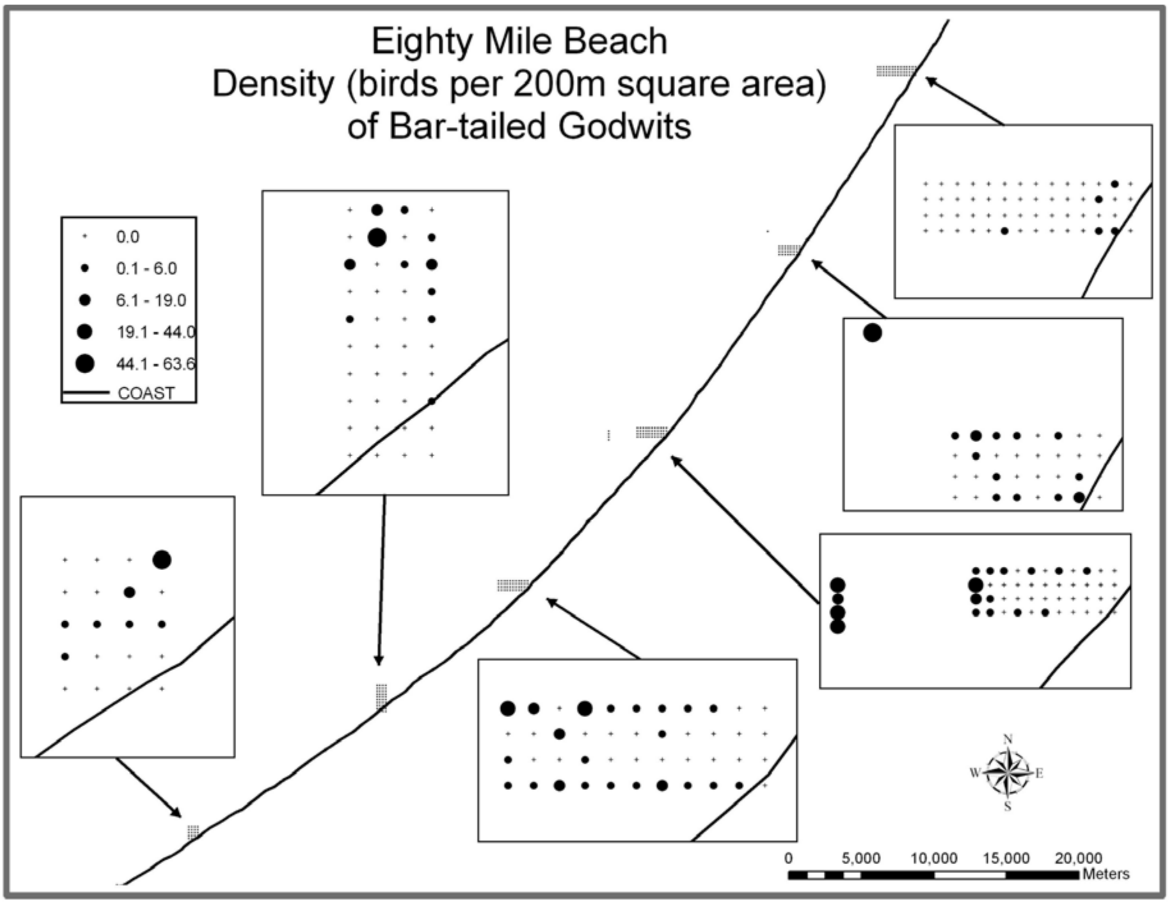
The sampling performed along Eighty-mile Beach indicates that neither shorebirds or their benthic prey are uniformly distributed. The areas that stood out as most important for shorebirds were Blocks 5, 20 and 35 (and presumably the intervening mudflats); this is where we found the highest densities of most godwits and other sandpipers – notably Great Knot, which is the most abundant shorebird of Eighty-mile Beach. About 50% of the world population of Great Knots is estimated to occur on Eighty-mile Beach (Watkins 1993), so this 30 kilometre stretch of coastline may indeed be extremely important to global conservation of this handsome species. Further south, shorebird numbers declined somewhat, but there were larger numbers of crab eating shorebirds like plovers and Terek Sandpipers from 35 to 65 km south. In the northern part of our study area, the intertidal flats of Block –10 had very few shorebirds and the biomass of potential prey was correspondingly low, although this stretch of coastline had several interesting benthic animals that we did not find elsewhere (e.g. *Pectinariidae* tubeworms).

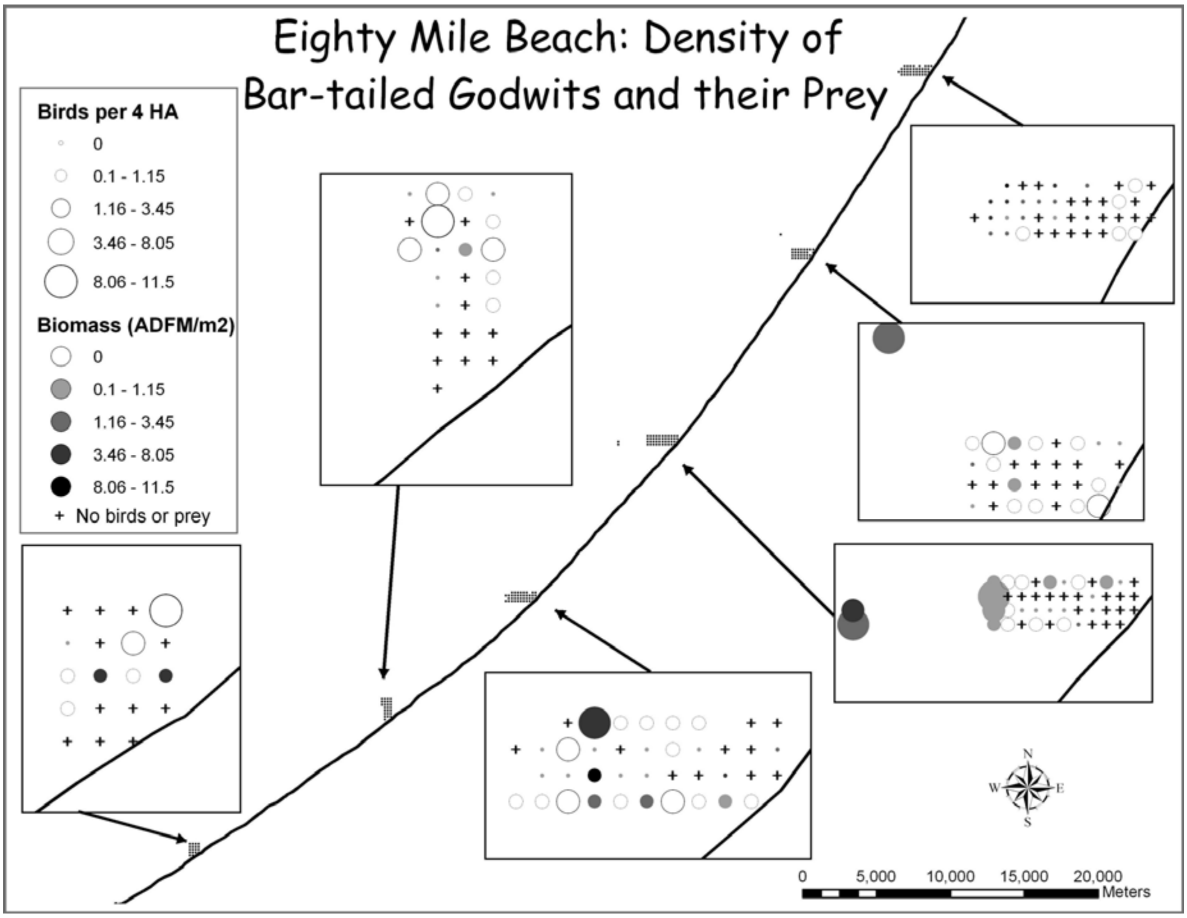
It would be interesting to know if the geographical trends in shorebird distribution along Eighty-mile Beach are consistent over time. This is something we can look forward to testing, for the data in this chapter are consistent with the idea that the shorebirds of Eighty-mile Beach roost on the stretch of beach closest to their feeding areas (except perhaps on spring tides). High-tide counts of shorebirds at Eighty-mile Beach have been performed intermittently for 20 years, and the results are currently being analysed and written up by David Price, Clive Minton and colleagues. When available, these results should help to establish whether the strongholds of wader species along the beach have changed over time. It is not impossible that they have changed; at Roebuck Bay changes in benthos distribution have been recorded over time (Rogers et al. 2000b). Even the microhabitats on Eighty-mile Beach may change over time – for example the mudbanks in some sites (notably Blocks 5 and 20) were strongholds for Curlew Sandpipers (and were possibly preferred by some other species) and they could well be transitory structures that are changed when cyclones hit Eighty-mile Beach.

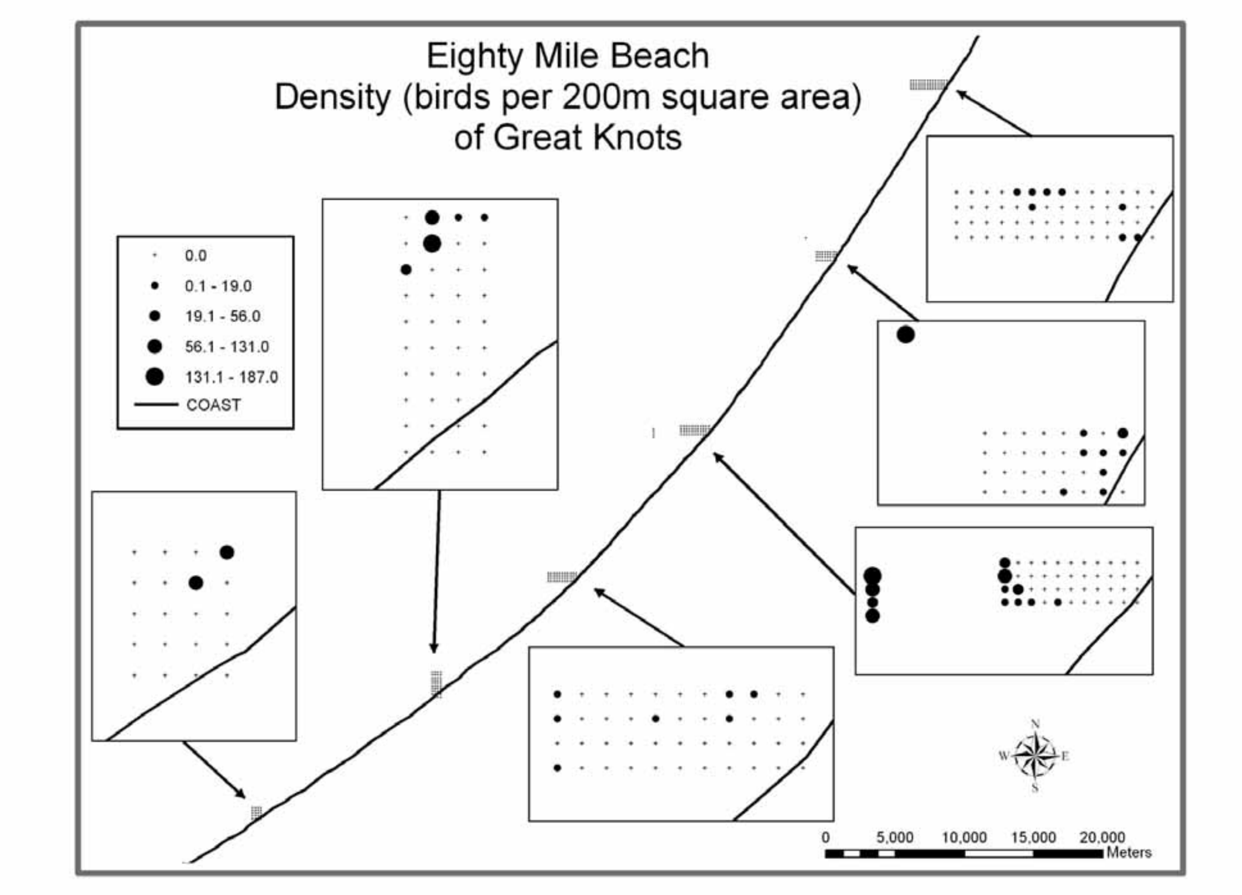
Monitoring the welfare of shorebird and benthos populations at Eighty-mile Beach is problematic because the site is so big. Low-tide surveys are time-consuming, and we mapped the shorebirds on only a tiny fraction of the intertidal flats. While it would be nice to repeat such surveys to find if shorebird feeding distribution changes on the intertidal flats of Eighty-mile Beach over time, the cost and time required to do subsequent surveys means they are not likely to happen. However, the correspondence of high tide counts and low tide counts is encouraging, as it suggests that regular high-tide counts might provide a means of telling not only how the shorebird populations fare over time, but also whether their feeding strongholds change over time. Even if high-tide surveys are performed, Eighty-mile Beach is so large that performing complete surveys is difficult. A single car-load of counters can count along perhaps 15 km of beach in a single high tide period, and because high-tide counts at Eighty-mile Beach should be done on rather small tides (about 5.8 to 7 m), ideal counts are only possible on 2-3 consecutive days. Accordingly, several teams in several vehicles are needed for a complete count of the 220 km Eighty-mile Beach, and resources like that are seldom available. It is, however, practical for a single vehicle of counters to perform two counts a year along a twenty km section of Eighty-mile Beach; this has been done by the Broome Bird Observatory for the last few years. The problem with interpreting data from such counts is that when changes in shorebird numbers are detected, it is very difficult to tell whether they reflect global population changes, or just local movements along Eighty-mile Beach. Perhaps the path ahead here would be to analyse high-tide count data on shorebirds in conjunction with remote-sensing data from satellites (see Chapter 7) which could be used to tell if high impact events like cyclones have changed the distribution of spectral reflectance patterns (and consequently habitats) on the intertidal flats. Early analyses already suggest a link between spectral reflectance patterns and penetrability on the intertidal flats, and a link between penetrability and the distribution of some shorebirds such as Greater Sandplover, suggesting that remote sensing can detect habitat characteristics relevant to the feeding distribution of shorebirds.

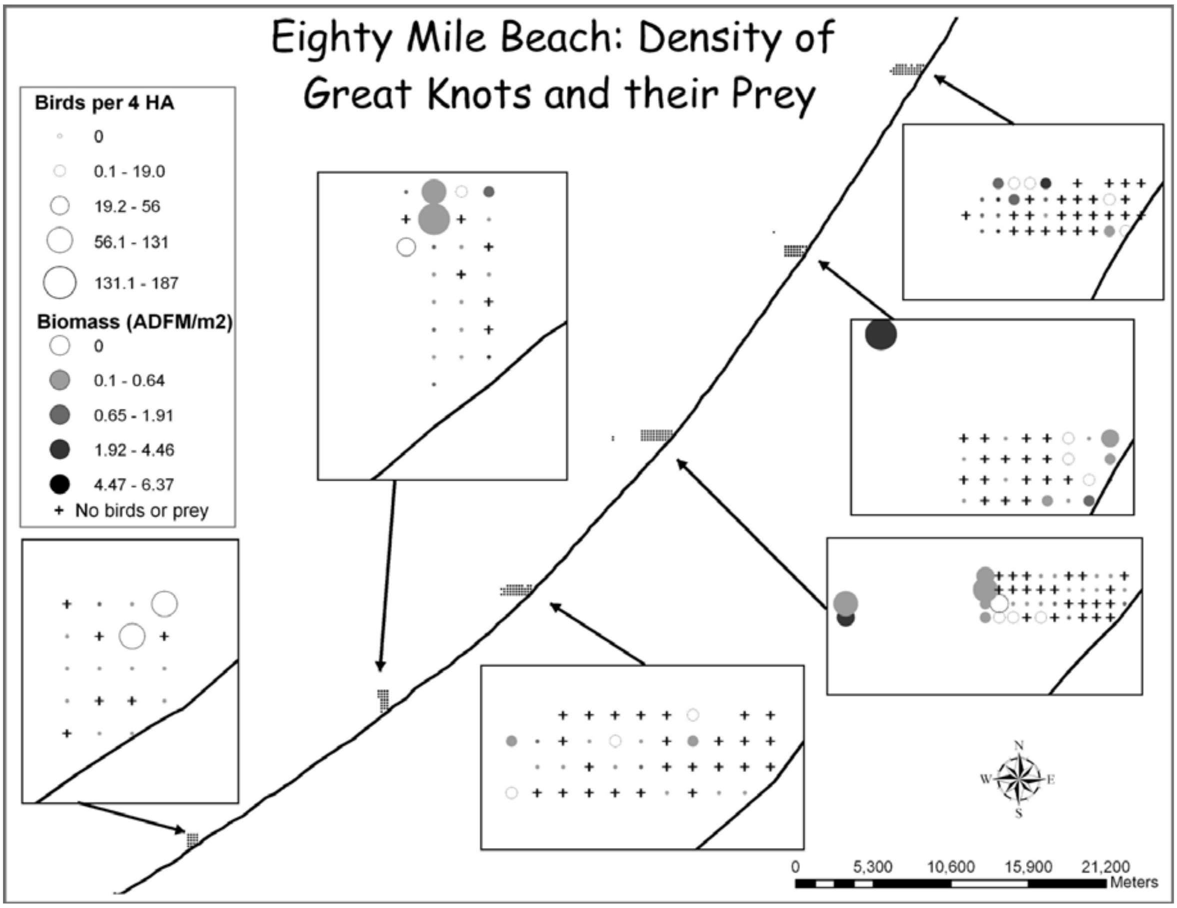
ACKNOWLEDGEMENTS

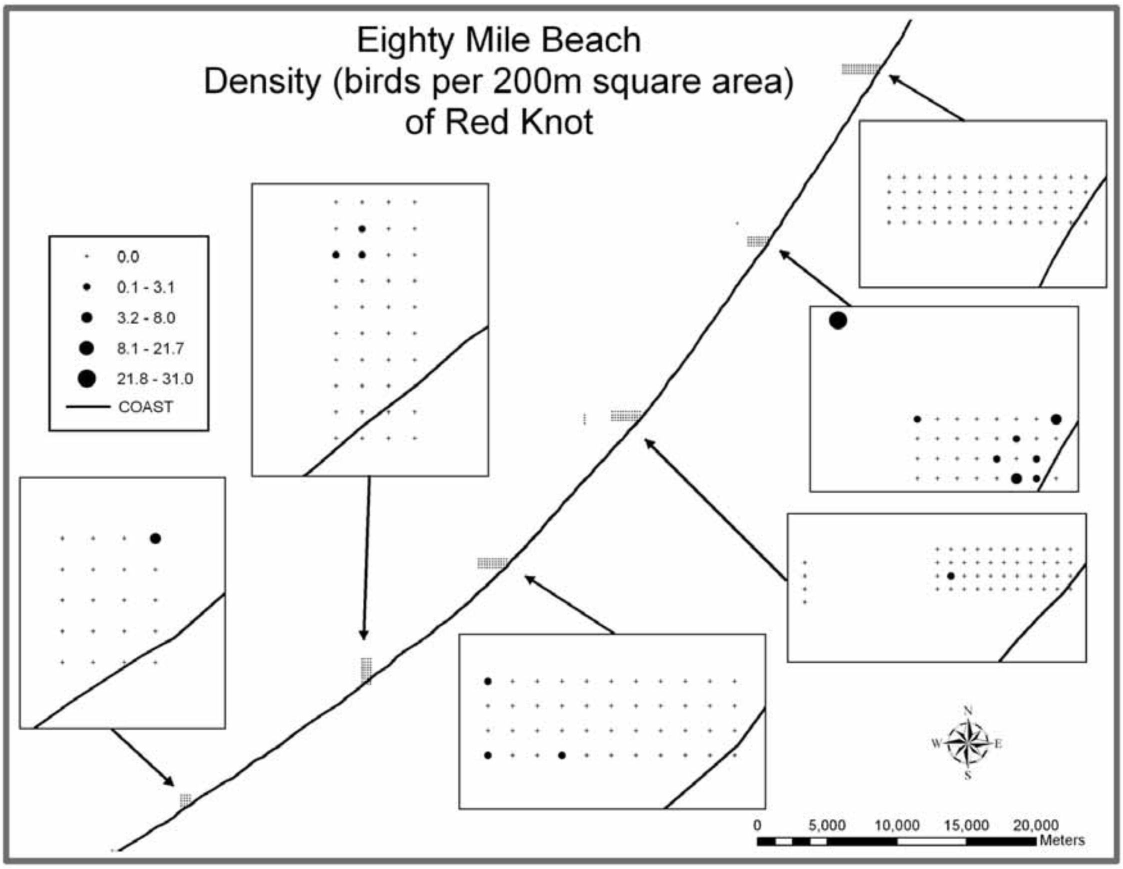
A big thank-you to Grant Pearson (data, logistics) and Bob Hickey (map preparation). Theunis Piersma led a vehicle of wader counters during the high-tide surveys. Assistance in bird-mapping at low tide: David Seay, Dusty Millar, Shapelle McNee and Jacqui Cochrane braved the experience more than once; lots of others were involved in mapping once, or in high tide surveys. Comments on a draft of this chapter were provided by Ken and Annie Rogers, Pieter Honkoop, Theunis Piersma and Bob Hickey.

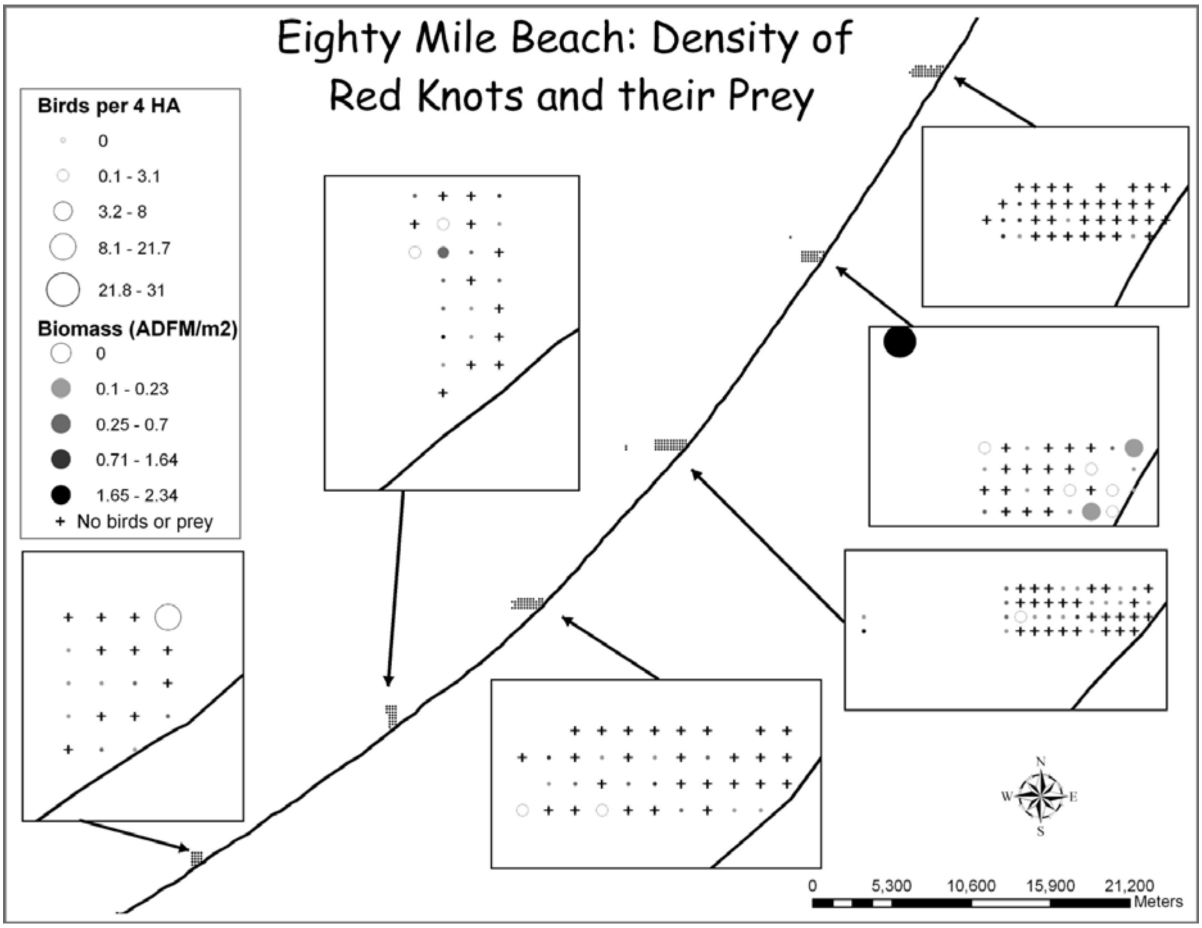

Eighty Mile Beach
Density (birds per 200m square area)
of Bar-tailed Godwits
0.0
0.1 - 6.0
6.1 - 19.0
19.1 - 44.0
44.1 - 63.6
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

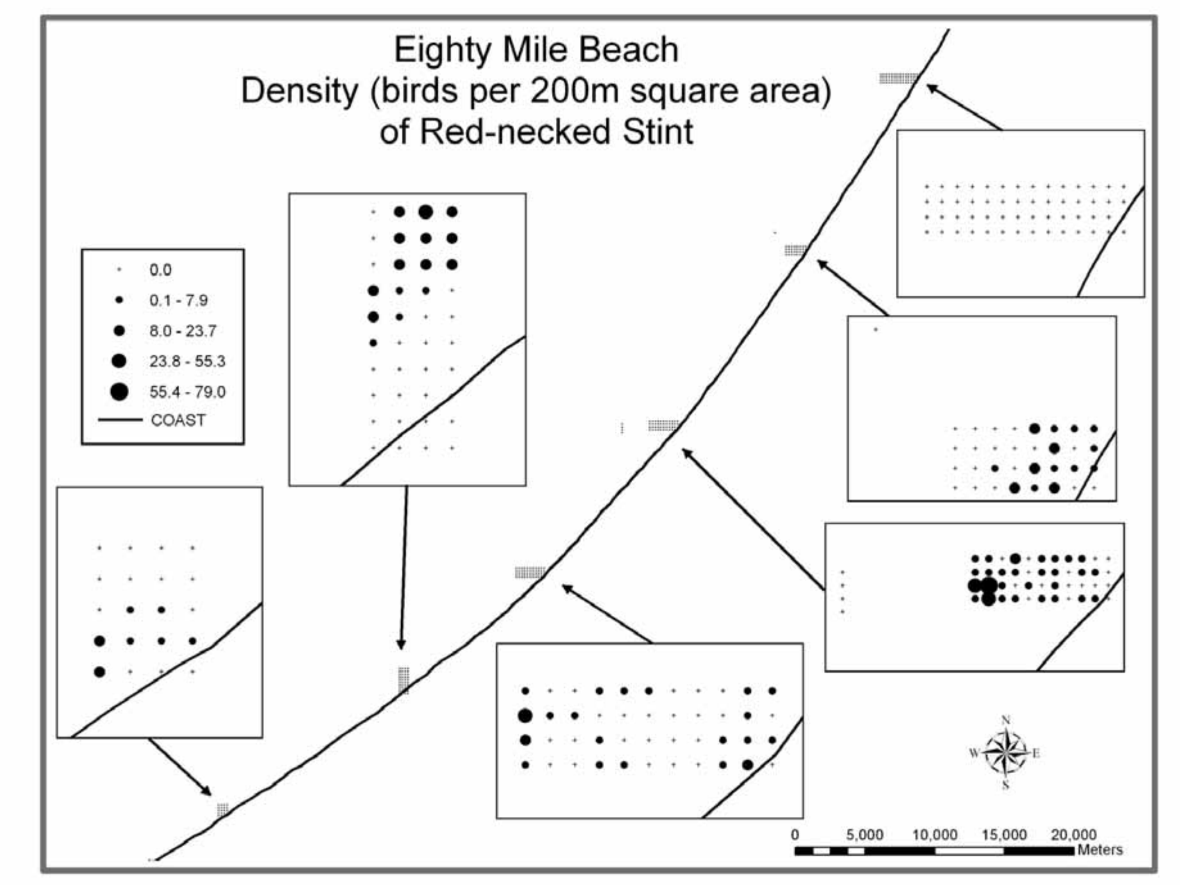

Eighty Mile Beach: Density of
Bar-tailed Godwits and their Prey
Birds per 4 HA
0
0.1 - 1.15
1.16 - 3.45
3.46 - 8.05
8.06 - 11.5
Biomass (ADFM/m2)
0
0.1 - 1.15
1.16 - 3.45
3.46 - 8.05
8.06 - 11.5
+ No birds or prey
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

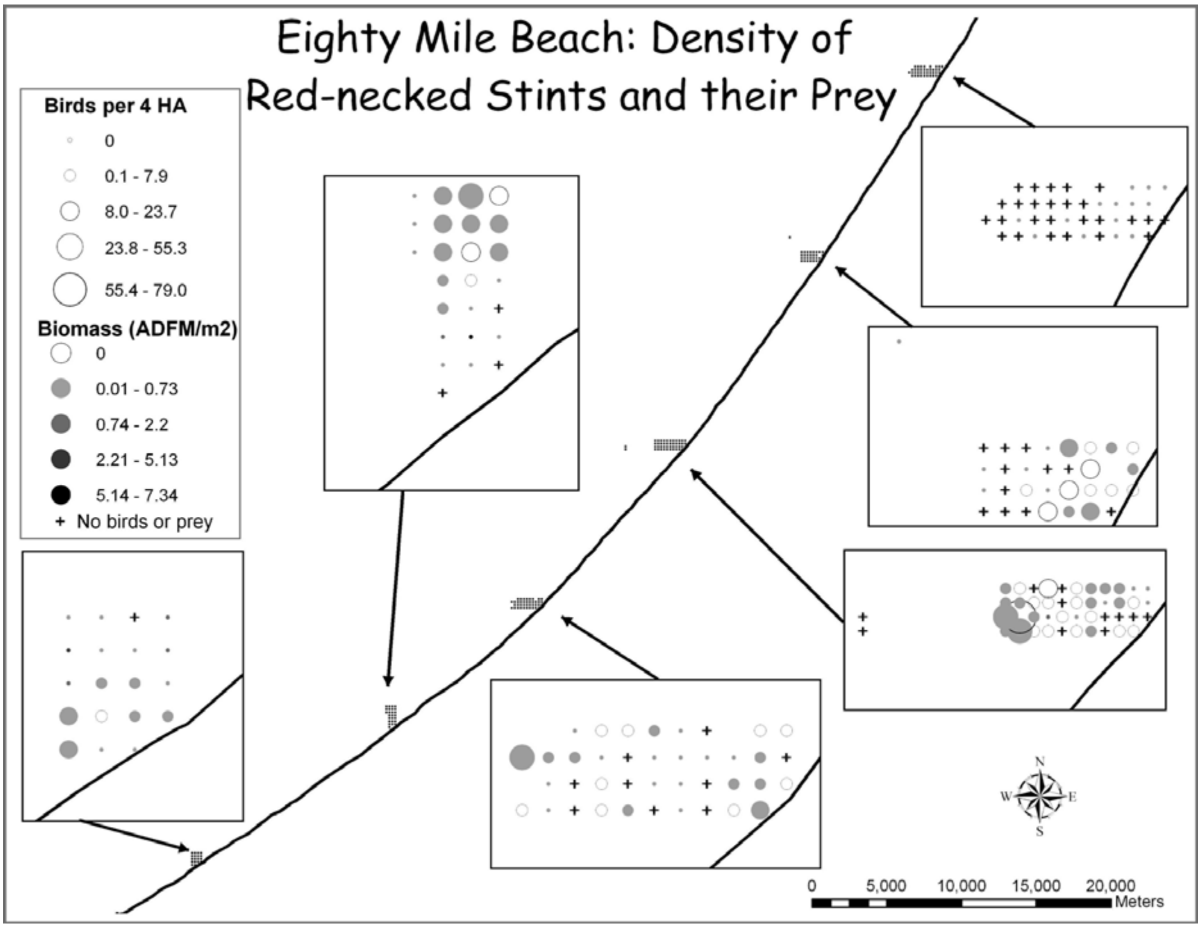

Eighty Mile Beach
Density (birds per 200m square area)
of Great Knots
0.0
0.1 - 19.0
19.1 - 56.0
56.1 - 131.0
131.1 - 187.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

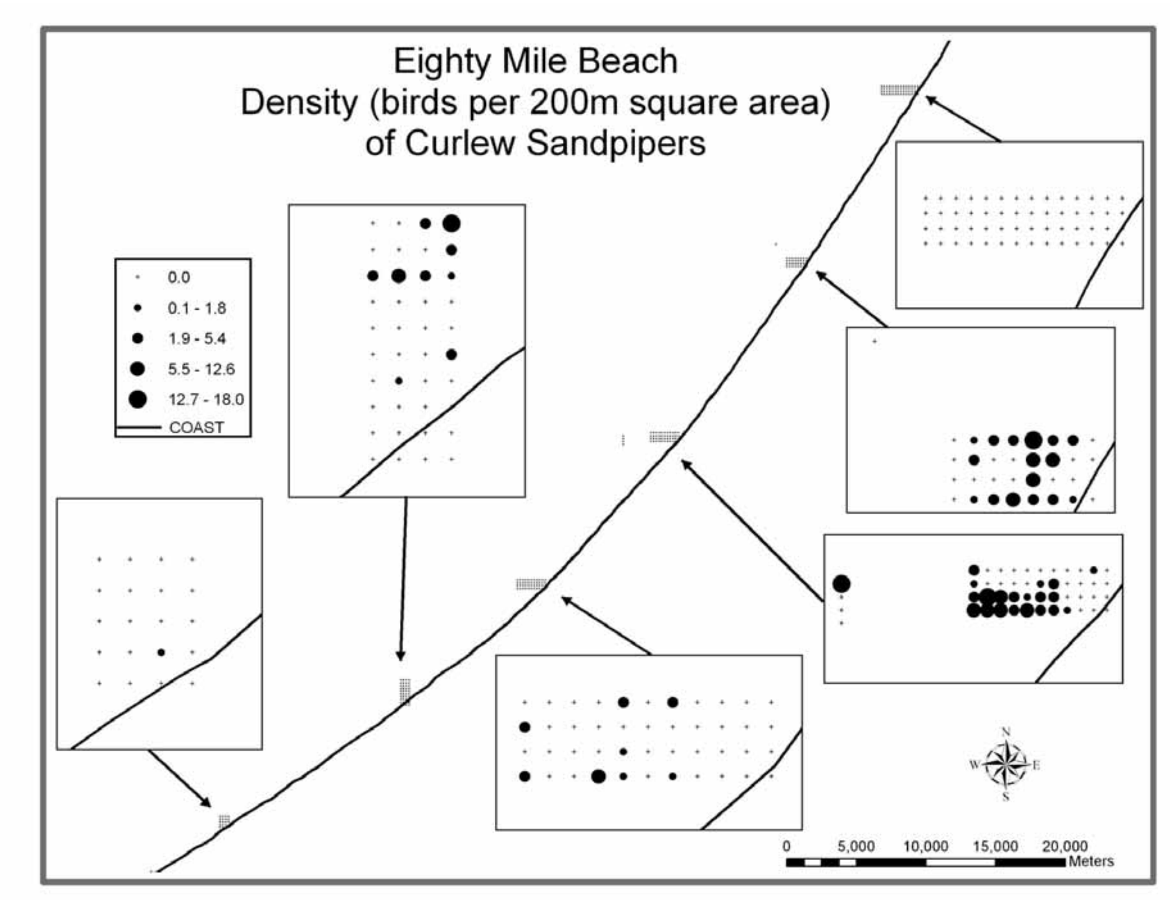

Eighty Mile Beach: Density of
Great Knots and their Prey
Birds per 4 HA
0
0.1 - 19.0
19.2 - 56
56.1 - 131
131.1 - 187
Biomass (ADFM/m2)
0
0.1 - 0.64
0.65 - 1.91
1.92 - 4.46
4.47 - 6.37
+ No birds or prey
N
W
E
S
0
5,300
10,600
15,900
21,200
Meters

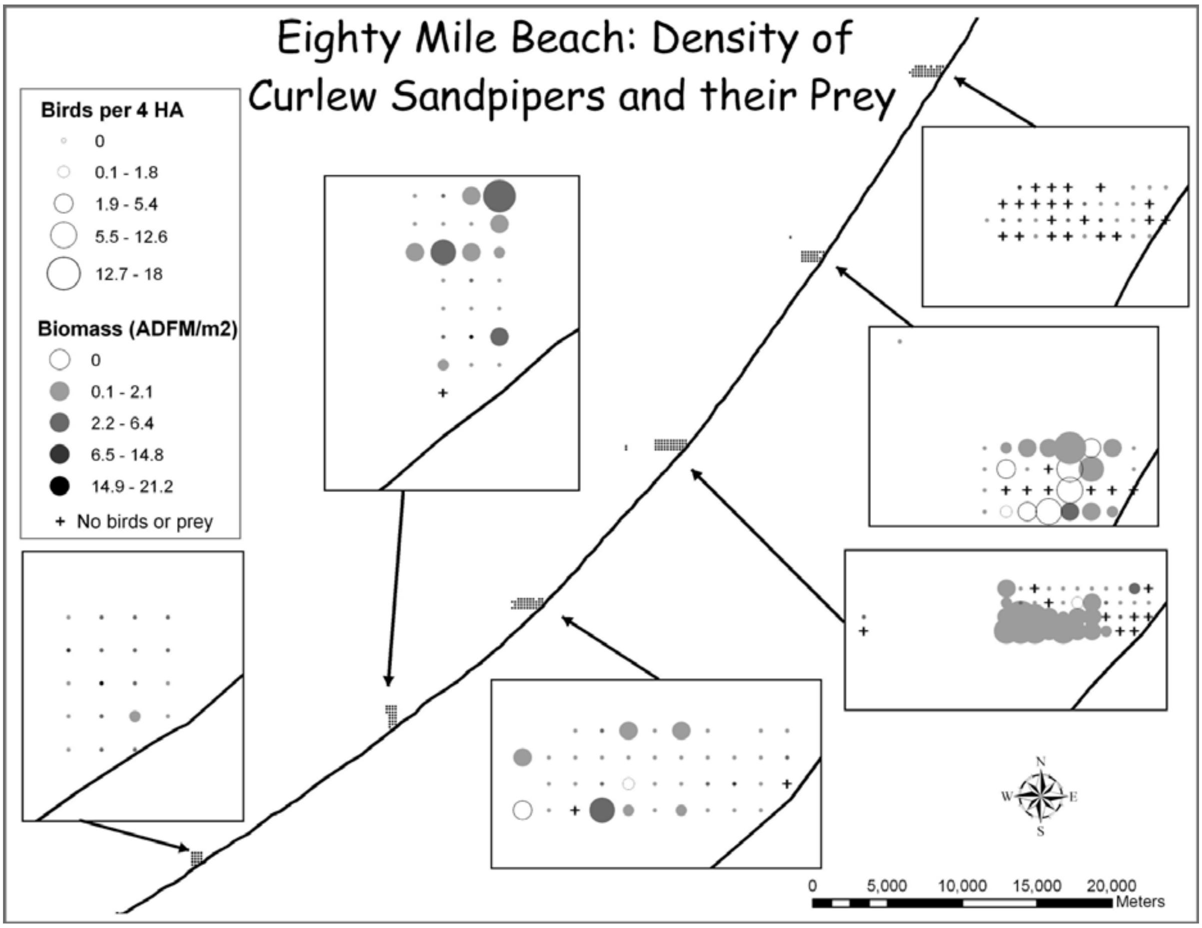

Eighty Mile Beach
Density (birds per 200m square area)
of Red Knot
0.0
0.1 - 3.1
3.2 - 8.0
8.1 - 21.7
21.8 - 31.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

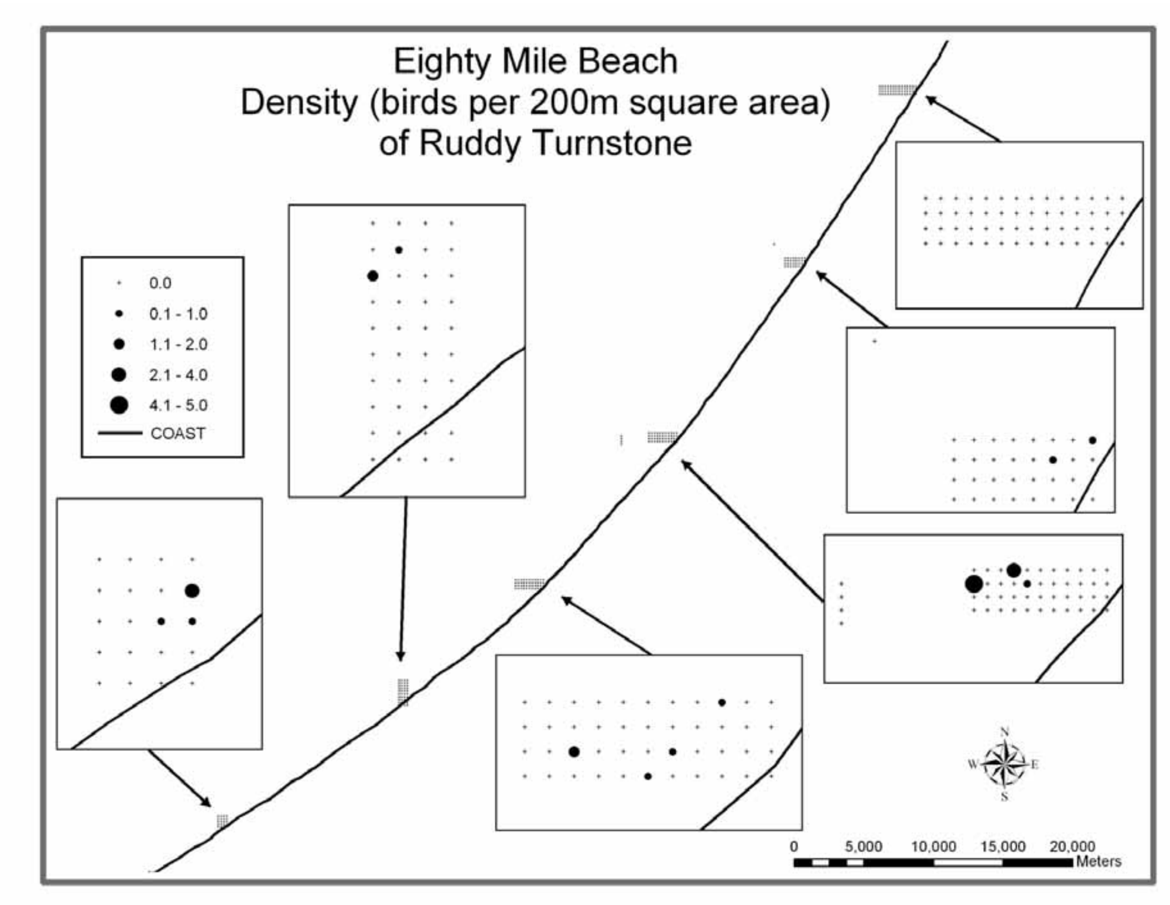

Eighty Mile Beach: Density of
Red Knots and their Prey
Birds per 4 HA
0
0.1 - 3.1
3.2 - 8
8.1 - 21.7
21.8 - 31
Biomass (ADFM/m2)
0
0.1 - 0.23
0.25 - 0.7
0.71 - 1.64
1.65 - 2.34
+ No birds or prey
N
W
E
S
0
5,300
10,600
15,900
21,200
Meters

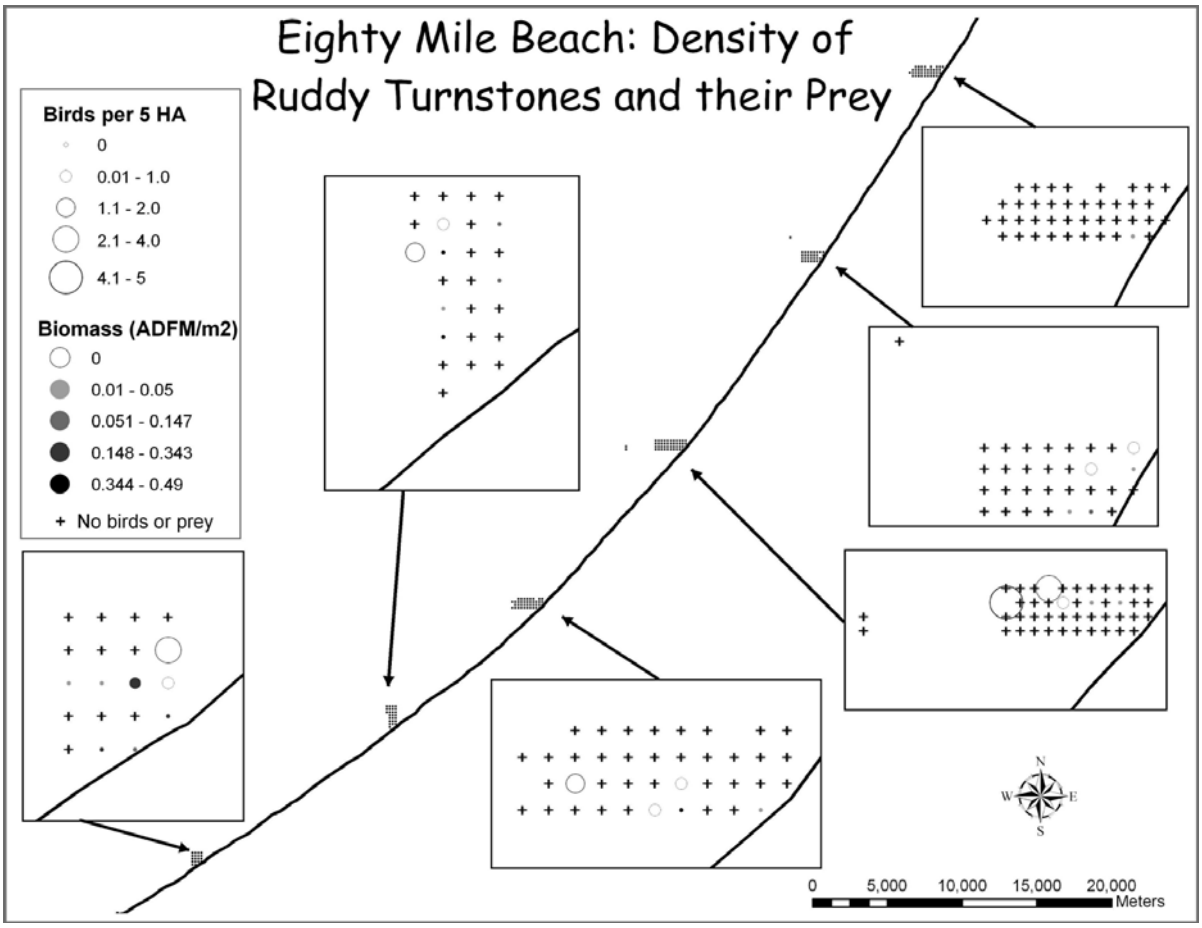

Eighty Mile Beach
Density (birds per 200m square area)
of Red-necked Stint
0.0
0.1 - 7.9
8.0 - 23.7
23.8 - 55.3
55.4 - 79.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

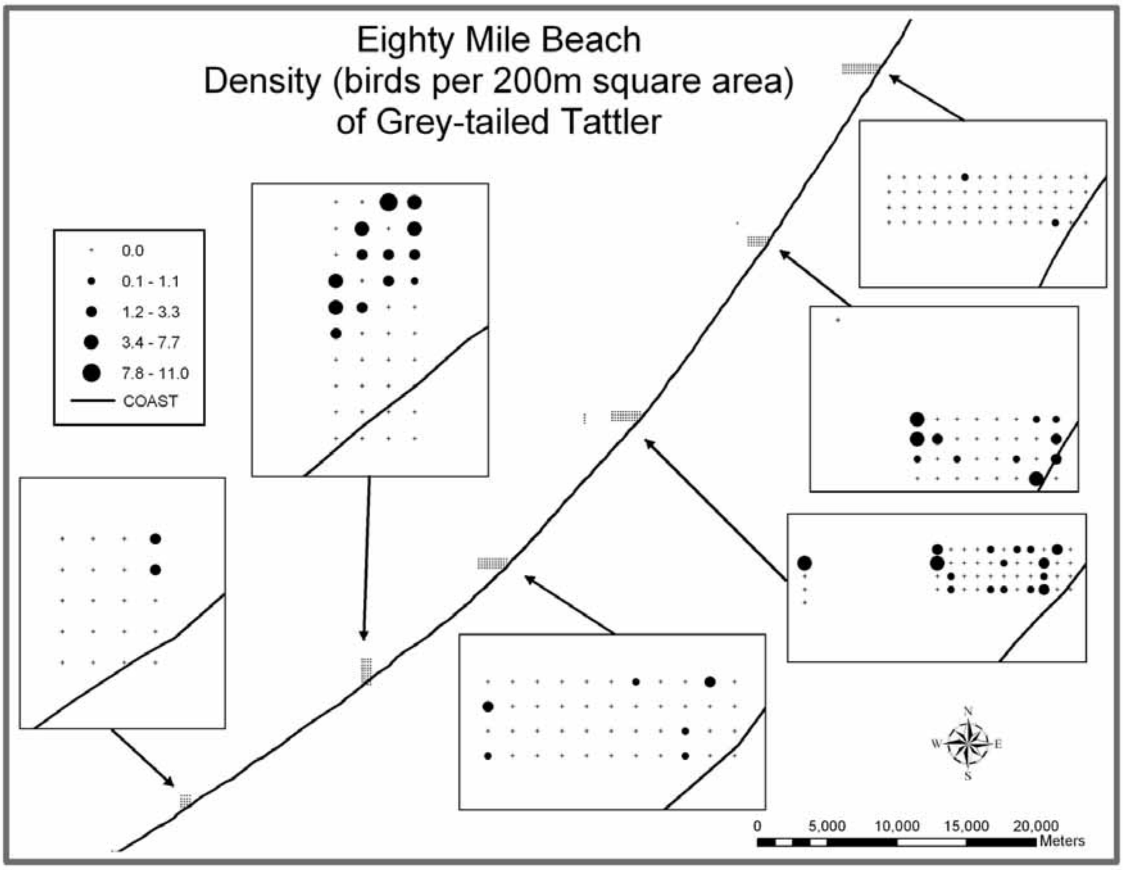

Eighty Mile Beach: Density of
Red-necked Stints and their Prey
Birds per 4 HA
0
0.1 - 7.9
8.0 - 23.7
23.8 - 55.3
55.4 - 79.0
Biomass (ADFM/m2)
0
0.01 - 0.73
0.74 - 2.2
2.21 - 5.13
5.14 - 7.34
+ No birds or prey
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

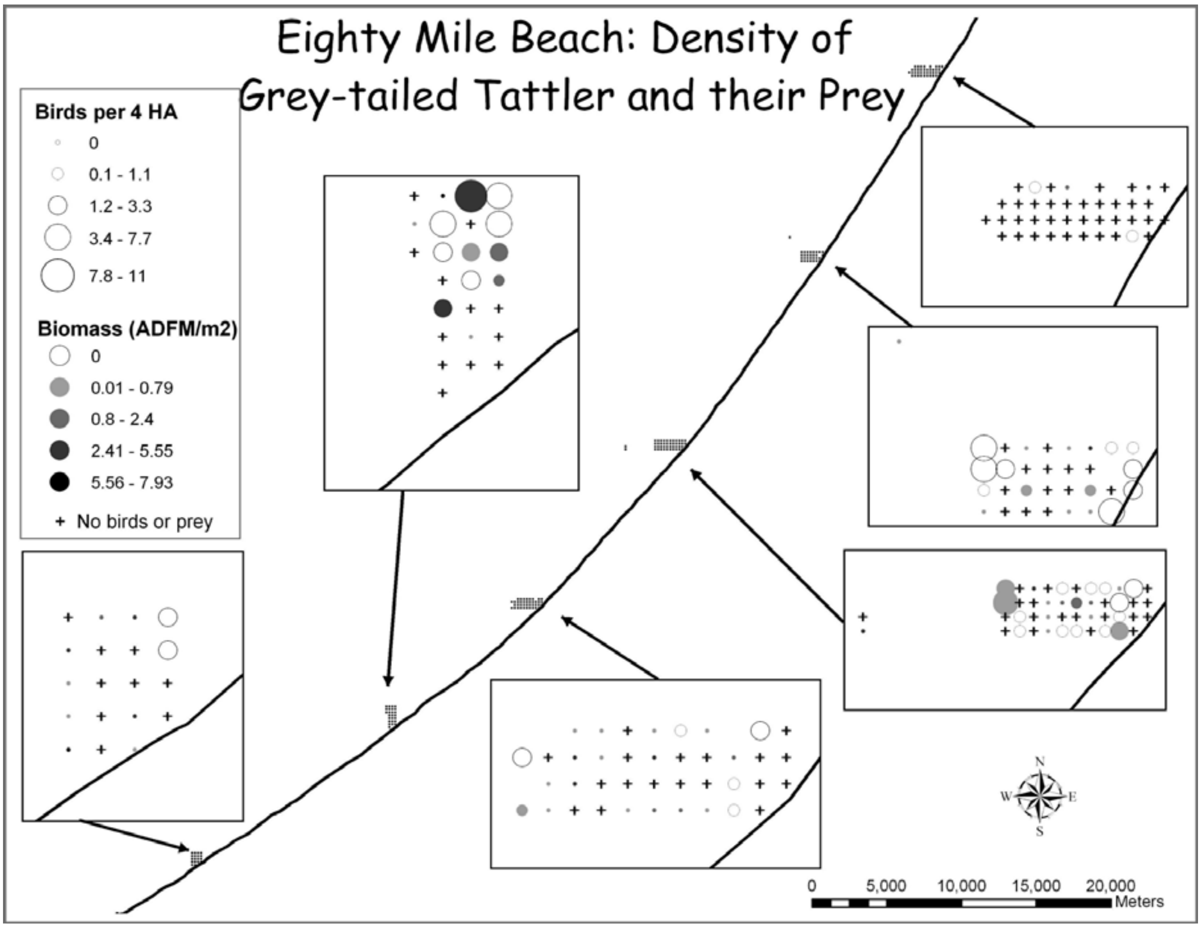

Eighty Mile Beach
Density (birds per 200m square area)
of Curlew Sandpipers
0.0
0.1 - 1.8
1.9 - 5.4
5.5 - 12.6
12.7 - 18.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

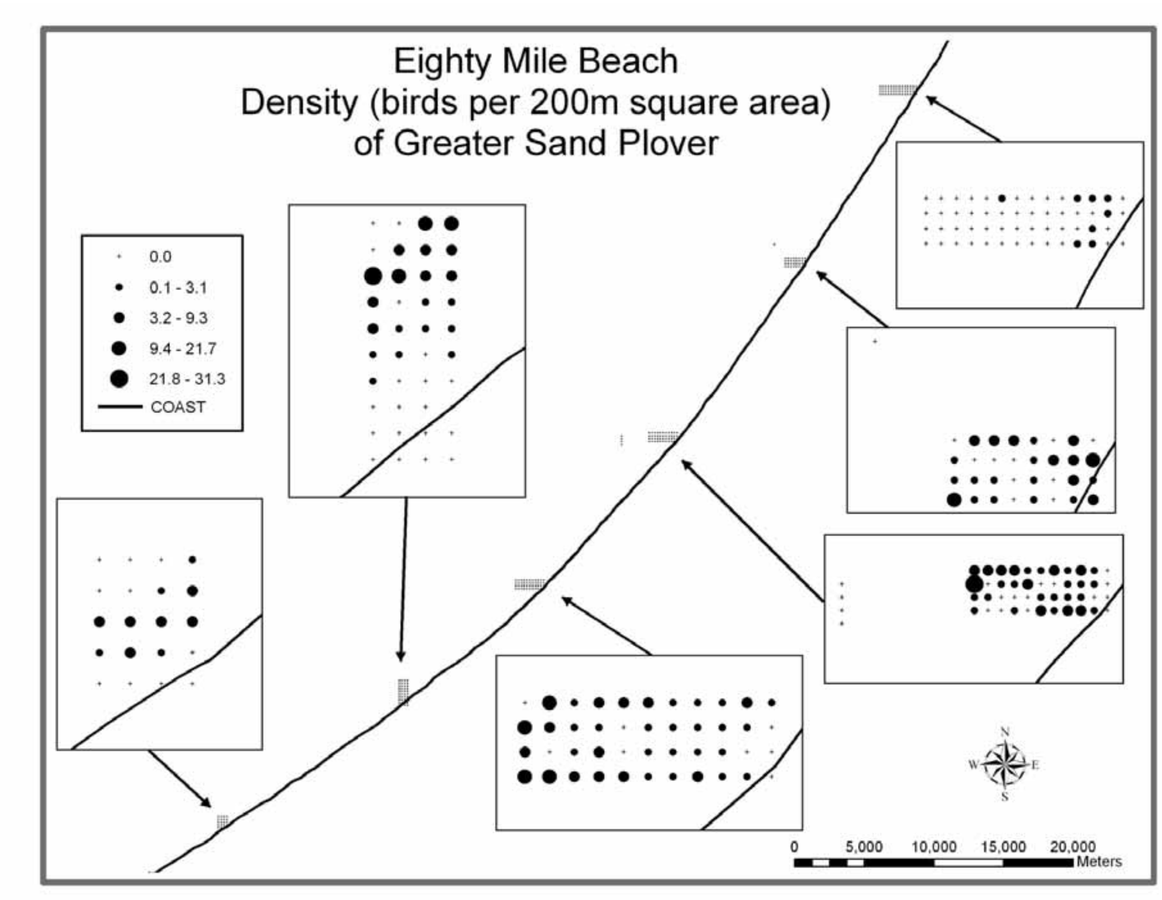

Eighty Mile Beach: Density of
Curlew Sandpipers and their Prey
Birds per 4 HA
0
0.1 - 1.8
1.9 - 5.4
5.5 - 12.6
12.7 - 18
Biomass (ADFM/m2)
0
0.1 - 2.1
2.2 - 6.4
6.5 - 14.8
14.9 - 21.2
+ No birds or prey
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

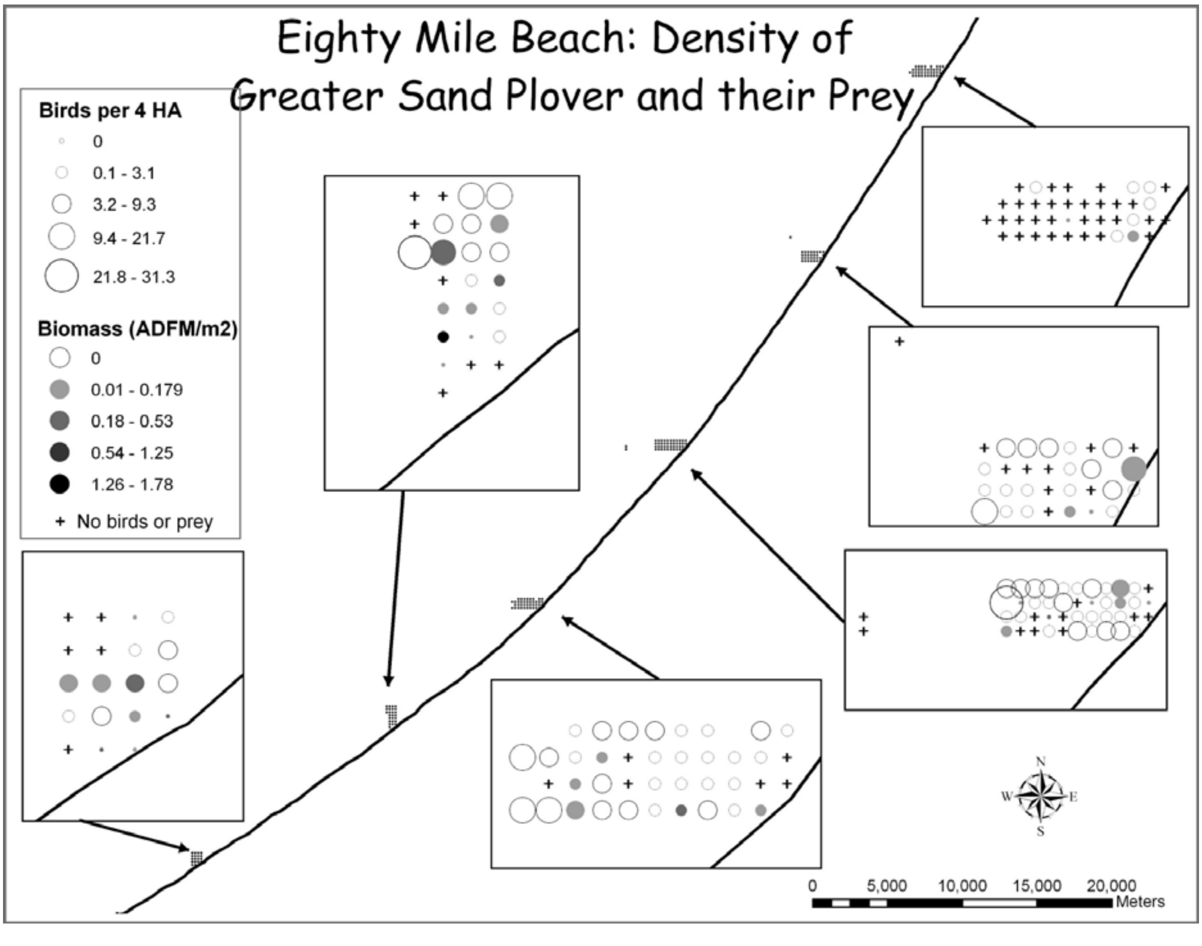

Eighty Mile Beach
Density (birds per 200m square area)
of Ruddy Turnstone
0.0
0.1 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 5.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

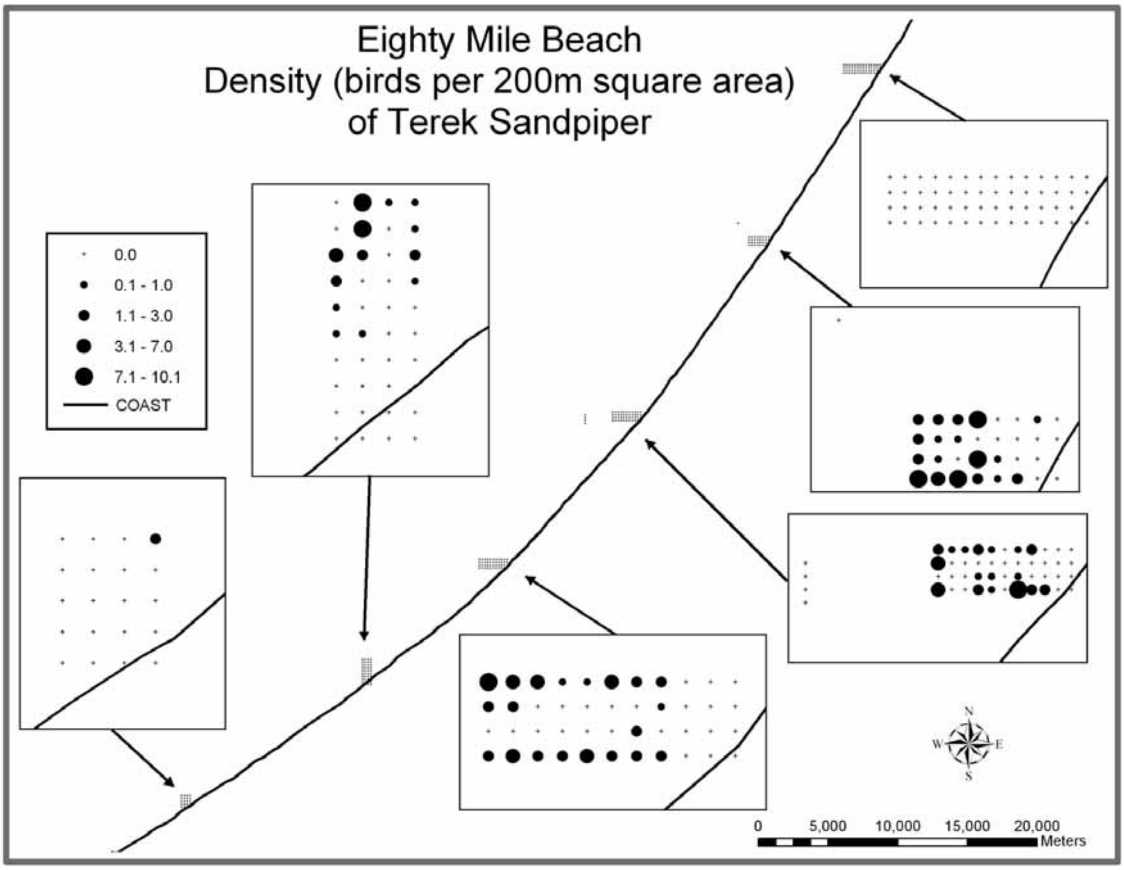

Eighty Mile Beach: Density of
Ruddy Turnstones and their Prey
Birds per 5 HA
0
0.01 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 5
Biomass (ADFM/m2)
0
0.01 - 0.05
0.051 - 0.147
0.148 - 0.343
0.344 - 0.49
+ No birds or prey
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

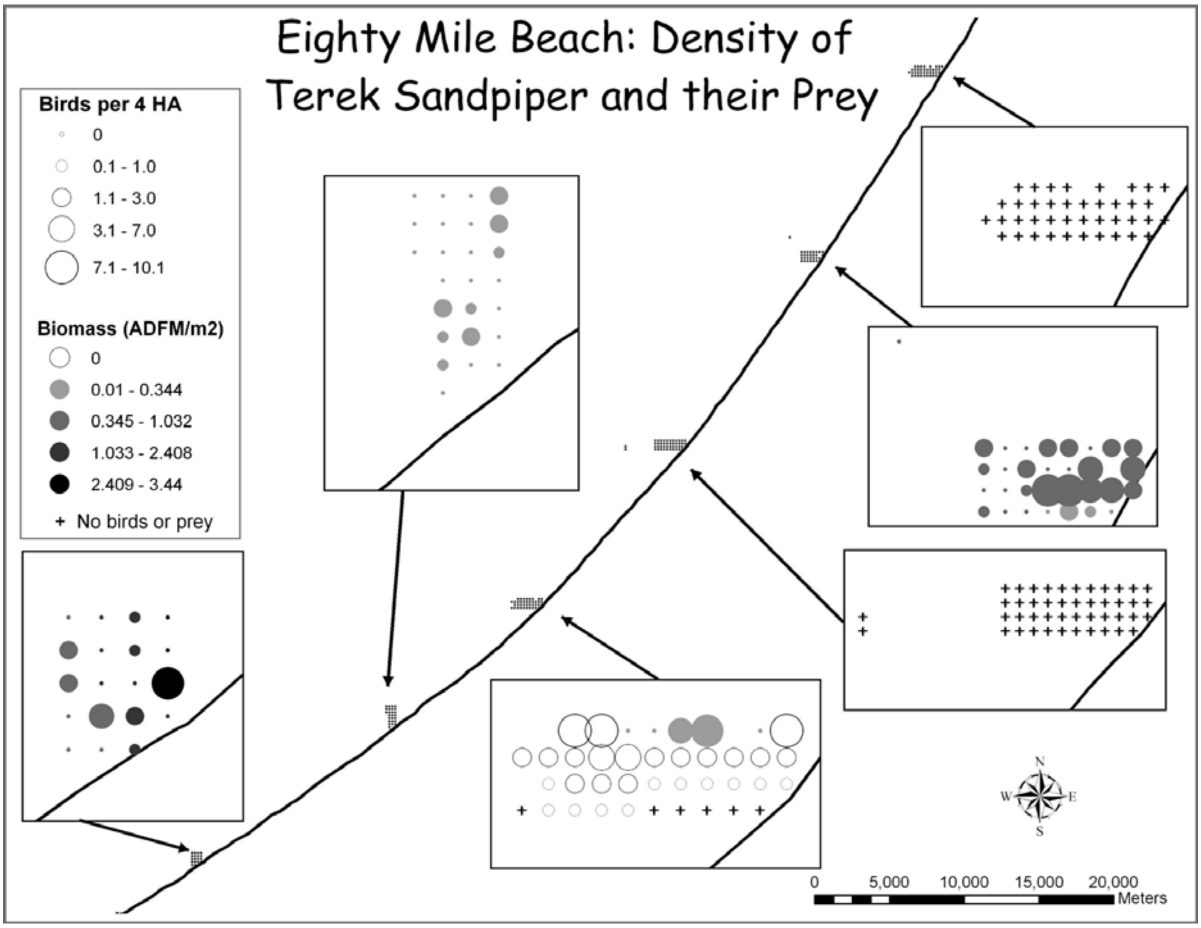

Eighty Mile Beach
Density (birds per 200m square area)
of Grey-tailed Tattler
0.0
0.1 - 1.1
1.2 - 3.3
3.4 - 7.7
7.8 - 11.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

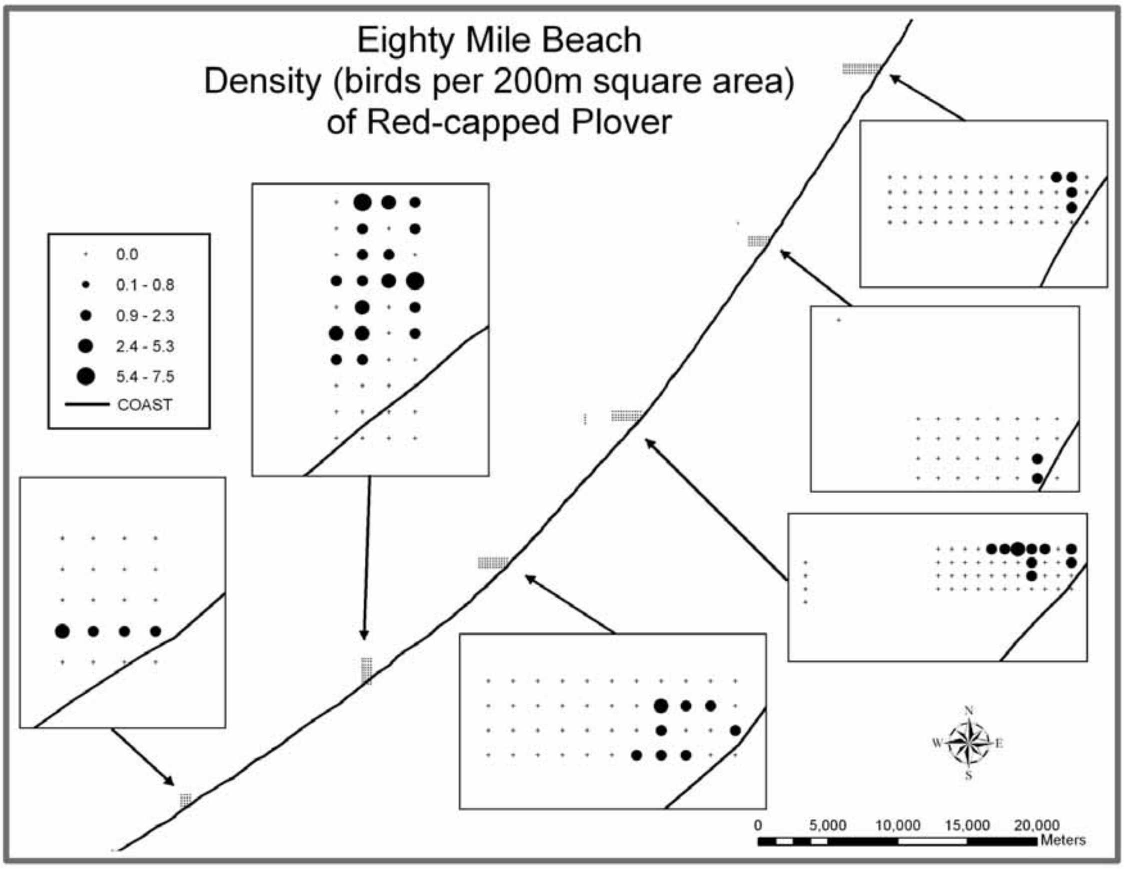

Eighty Mile Beach: Density of
Grey-tailed Tattler and their Prey
Birds per 4 HA
0
0.1 - 1.1
1.2 - 3.3
3.4 - 7.7
7.8 - 11
Biomass (ADFM/m2)
0
0.01 - 0.79
0.8 - 2.4
2.41 - 5.55
5.56 - 7.93
+ No birds or prey
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

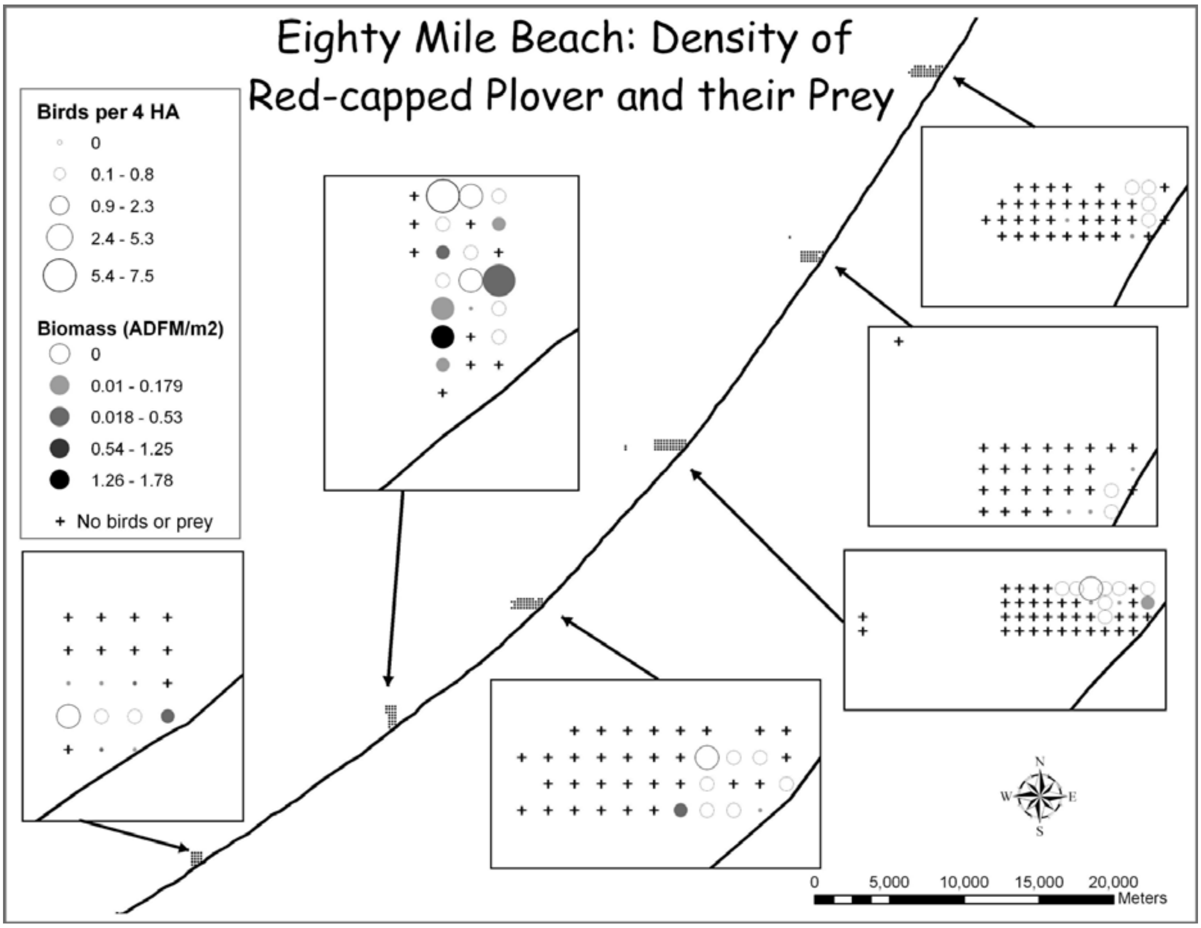

Eighty Mile Beach
Density (birds per 200m square area)
of Greater Sand Plover
0.0
0.1 - 3.1
3.2 - 9.3
9.4 - 21.7
21.8 - 31.3
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

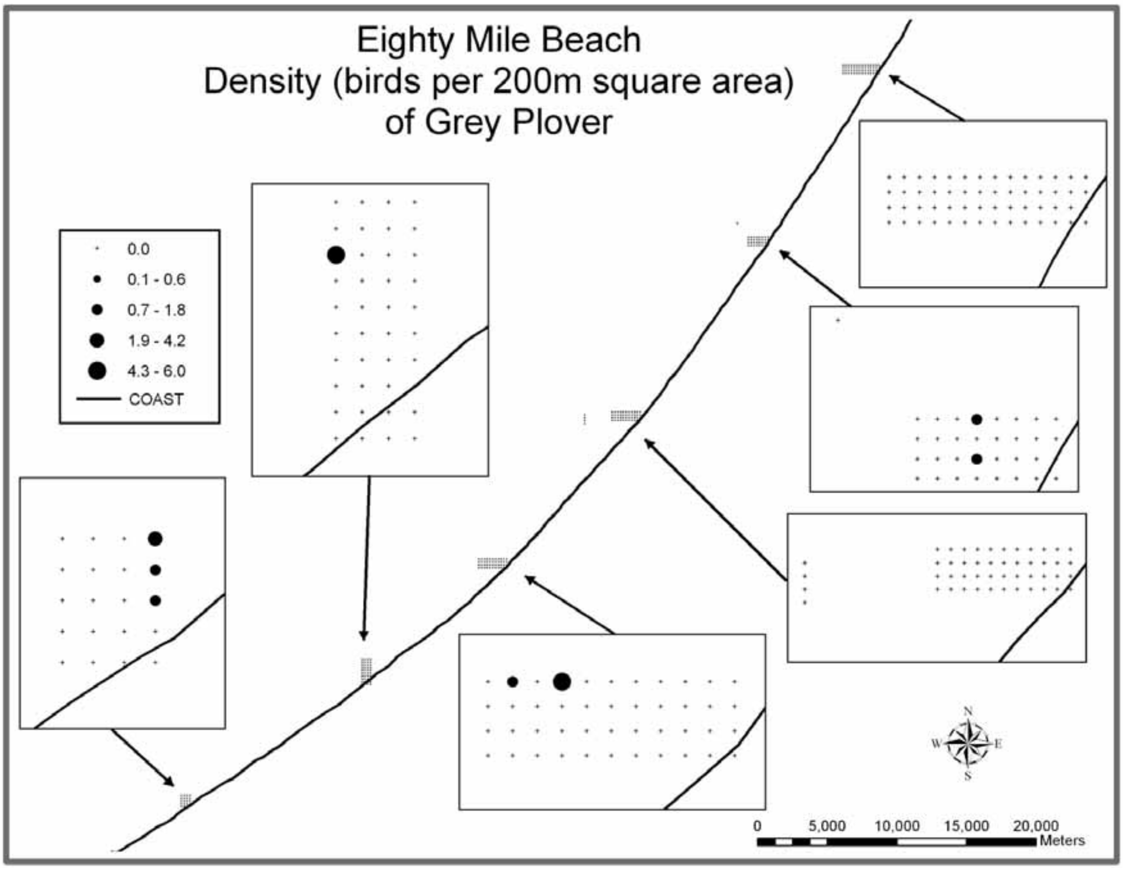

Eighty Mile Beach: Density of
Greater Sand Plover and their Prey
Birds per 4 HA
0
0.1 - 3.1
3.2 - 9.3
9.4 - 21.7
21.8 - 31.3
Biomass (ADFM/m2)
0
0.01 - 0.179
0.18 - 0.53
0.54 - 1.25
1.26 - 1.78
+ No birds or prey
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

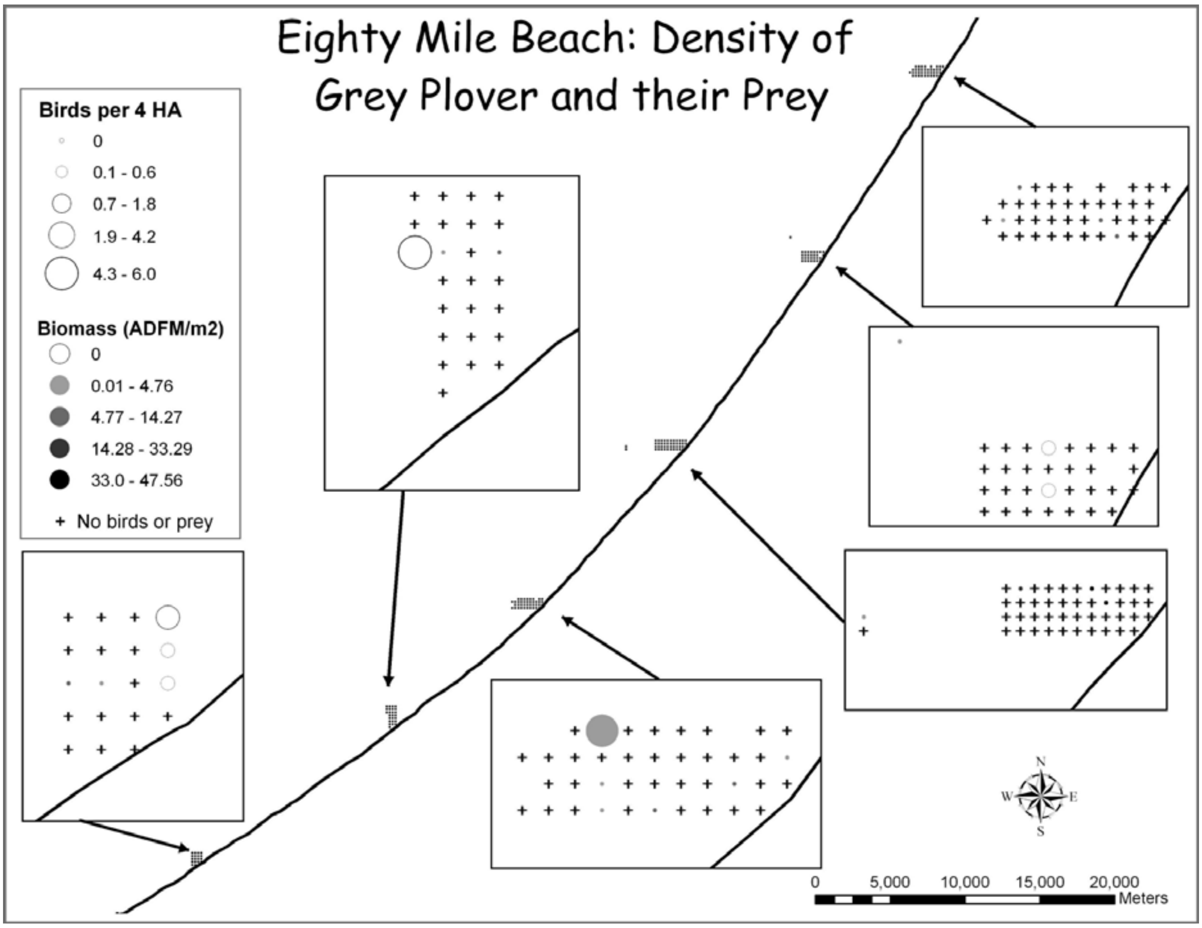

Eighty Mile Beach
Density (birds per 200m square area)
of Terek Sandpiper
0.0
0.1 - 1.0
1.1 - 3.0
3.1 - 7.0
7.1 - 10.1
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

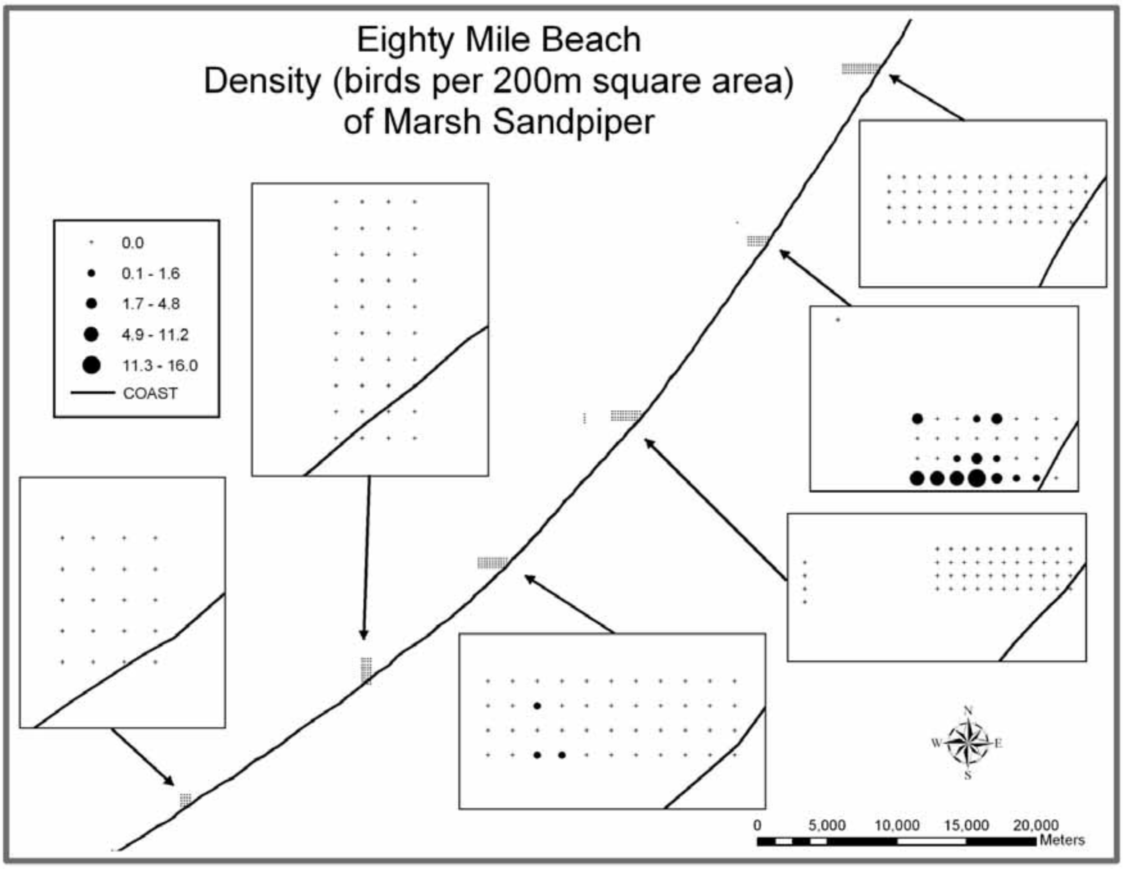

Eighty Mile Beach: Density of
Terek Sandpiper and their Prey
Birds per 4 HA
0
0.1 - 1.0
1.1 - 3.0
3.1 - 7.0
7.1 - 10.1
Biomass (ADFM/m2)
0
0.01 - 0.344
0.345 - 1.032
1.033 - 2.408
2.409 - 3.44
+ No birds or prey
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

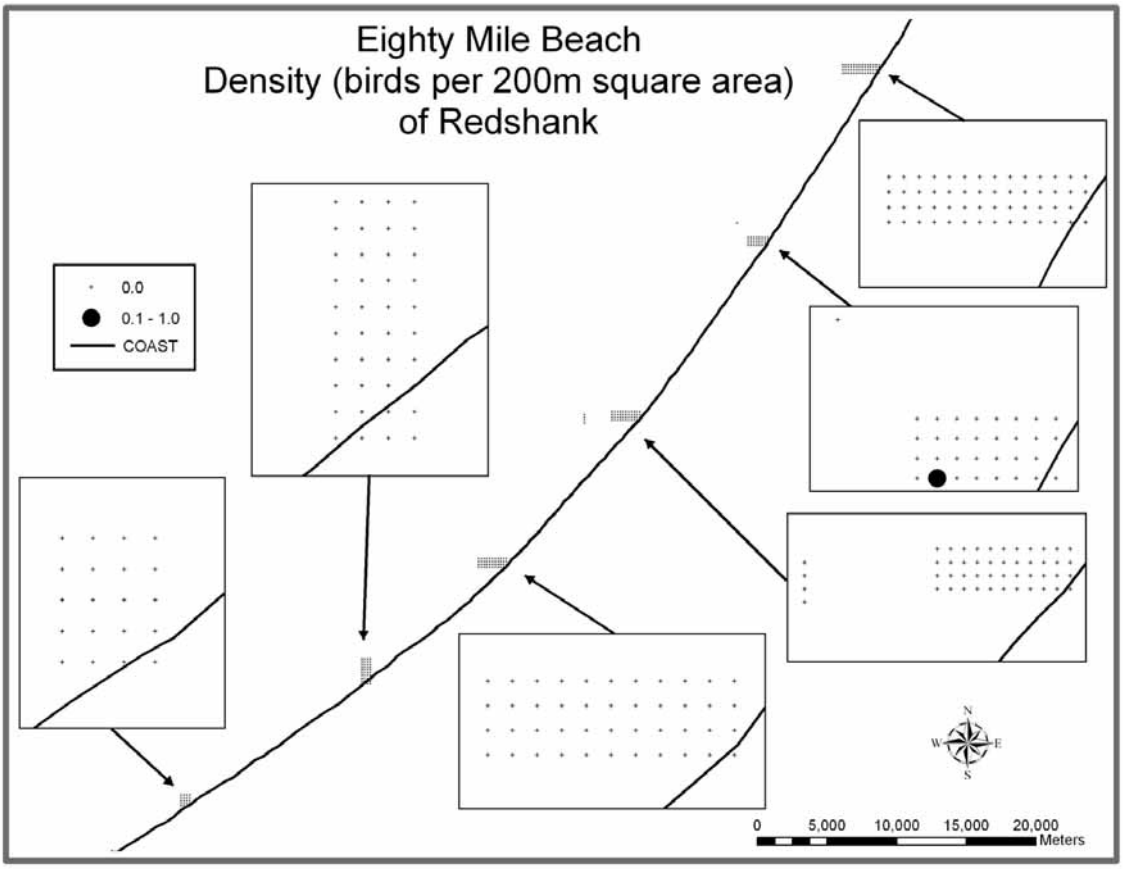

Eighty Mile Beach
Density (birds per 200m square area)
of Red-capped Plover
0.0
0.1 - 0.8
0.9 - 2.3
2.4 - 5.3
5.4 - 7.5
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

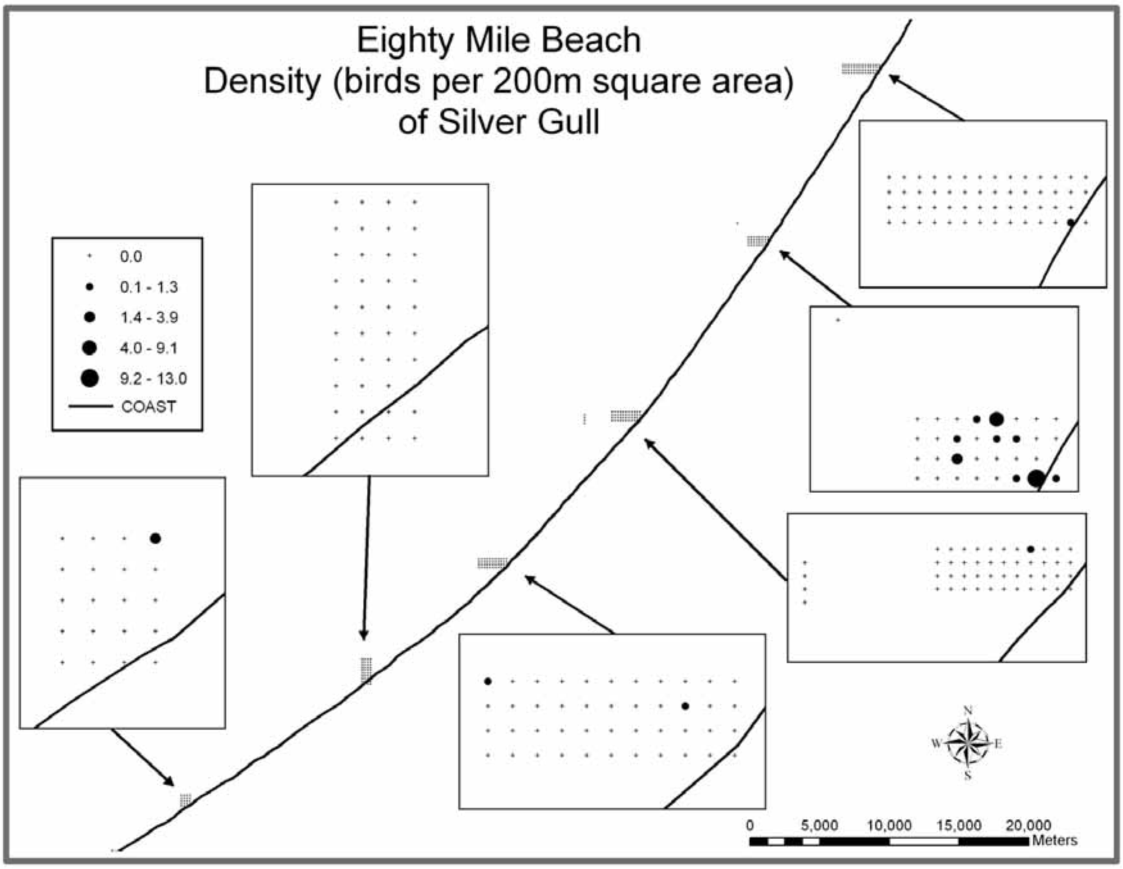

Eighty Mile Beach: Density of
Red-capped Plover and their Prey
Birds per 4 HA
0
0.1 - 0.8
0.9 - 2.3
2.4 - 5.3
5.4 - 7.5
Biomass (ADFM/m2)
0
0.01 - 0.179
0.018 - 0.53
0.54 - 1.25
1.26 - 1.78
+ No birds or prey
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

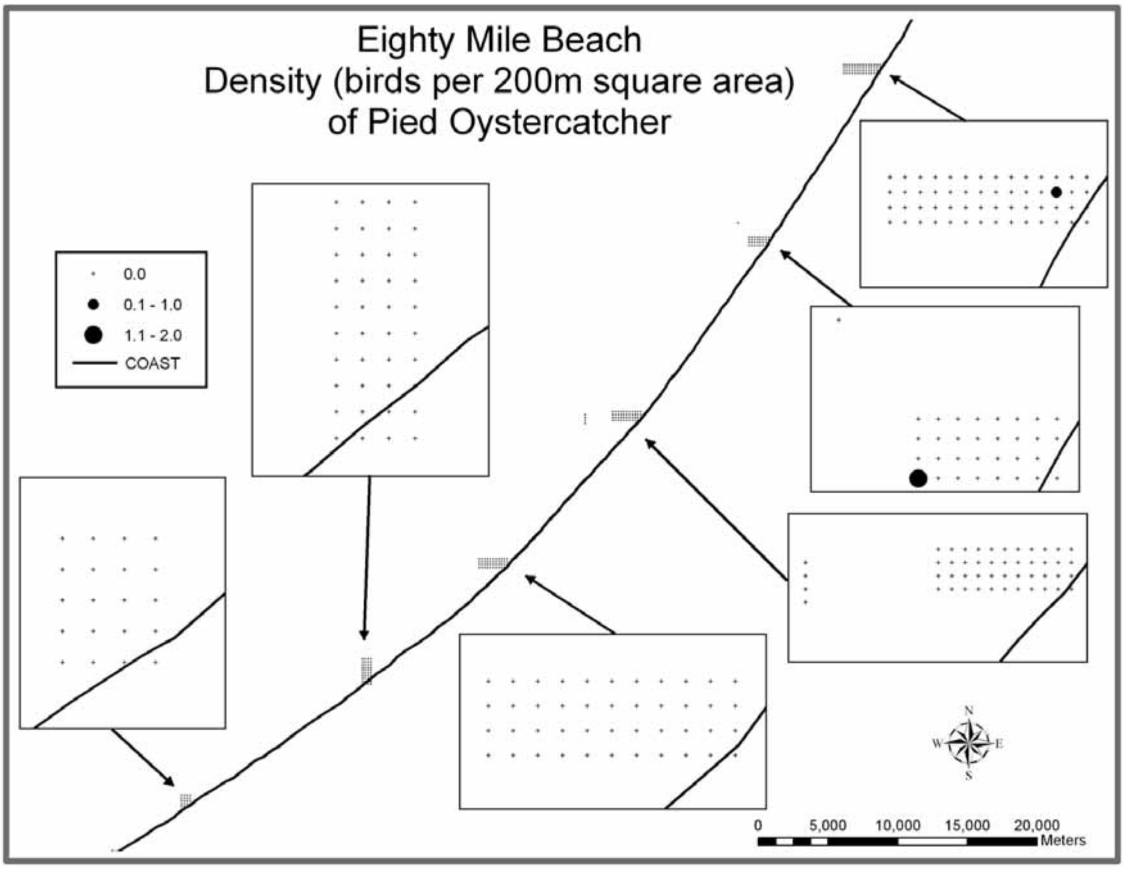

Eighty Mile Beach
Density (birds per 200m square area)
of Grey Plover
0.0
0.1 - 0.6
0.7 - 1.8
1.9 - 4.2
4.3 - 6.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

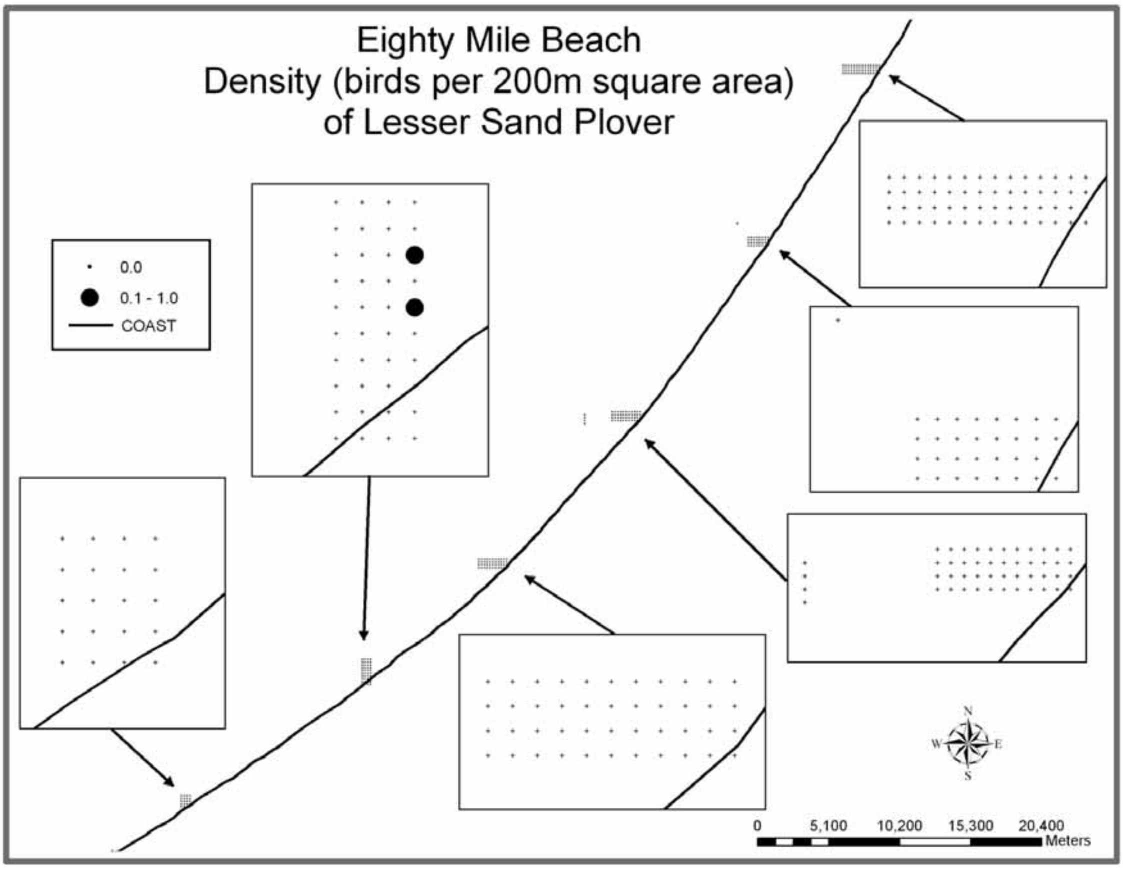

Eighty Mile Beach: Density of
Grey Plover and their Prey
Birds per 4 HA
0
0.1 - 0.6
0.7 - 1.8
1.9 - 4.2
4.3 - 6.0
Biomass (ADFM/m2)
0
0.01 - 4.76
4.77 - 14.27
14.28 - 33.29
33.0 - 47.56
+ No birds or prey
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

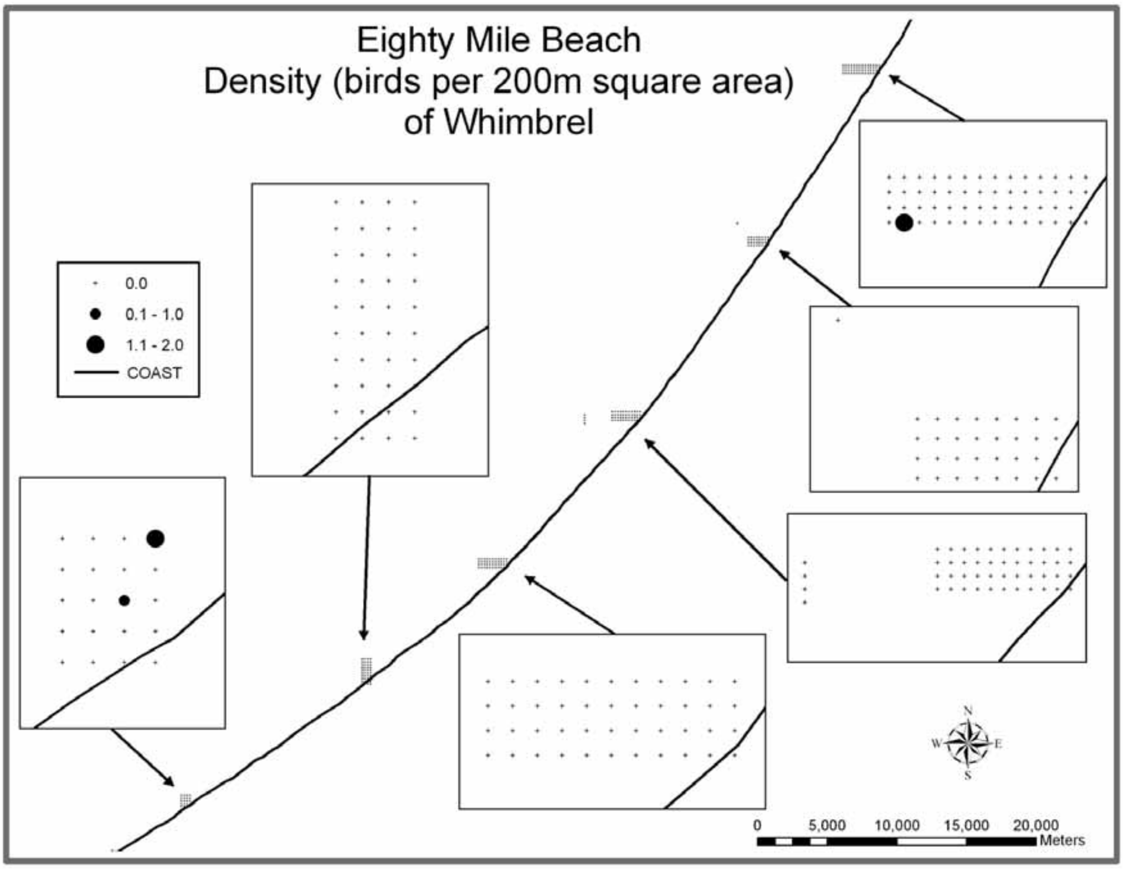

Eighty Mile Beach
Density (birds per 200m square area)
of Marsh Sandpiper
0.0
0.1 - 1.6
1.7 - 4.8
4.9 - 11.2
11.3 - 16.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

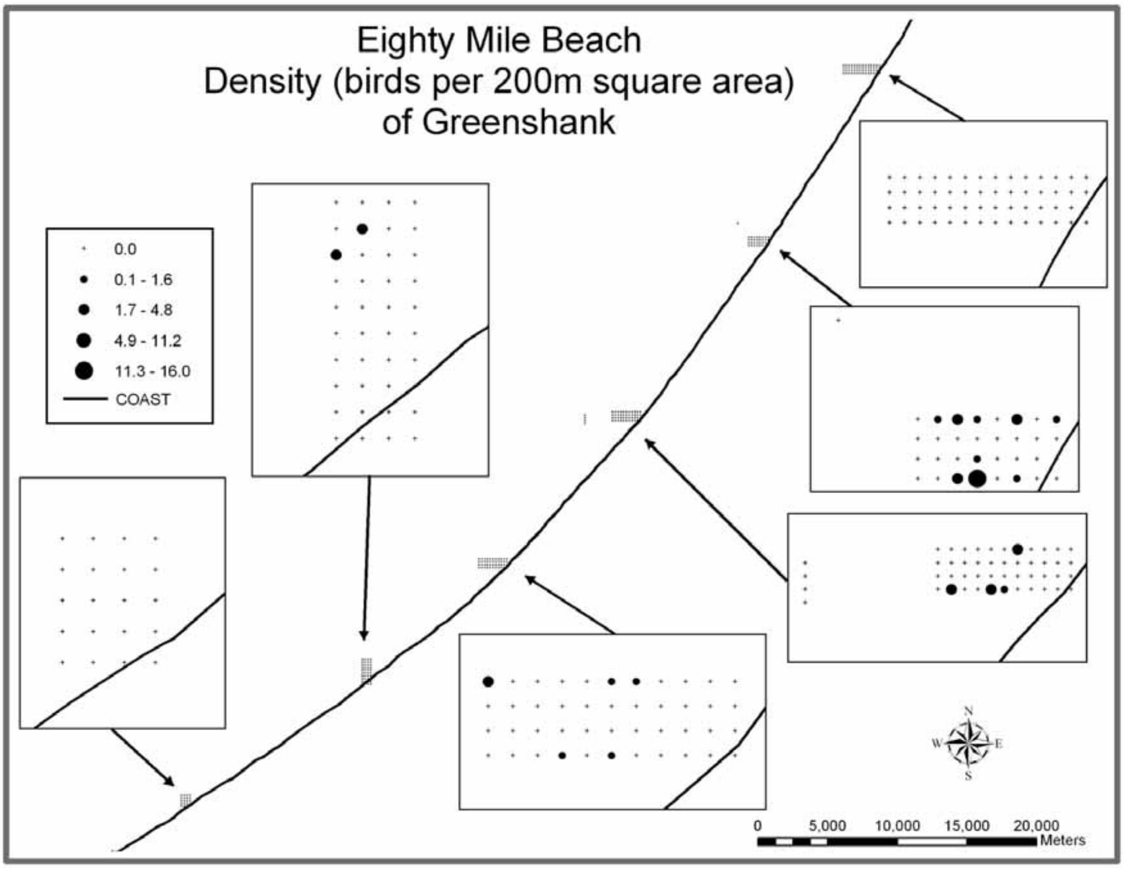

Eighty Mile Beach
Density (birds per 200m square area)
of Redshank
0.0
0.1 - 1.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

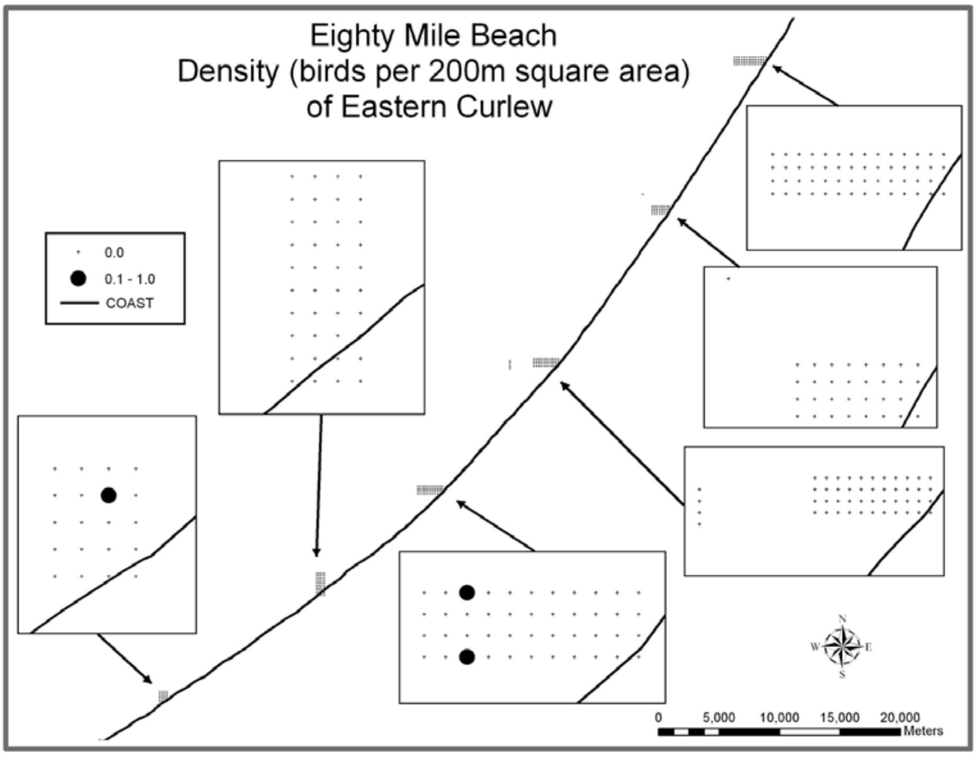

Eighty Mile Beach
Density (birds per 200m square area)
of Silver Gull
0.0
0.1 - 1.3
1.4 - 3.9
4.0 - 9.1
9.2 - 13.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

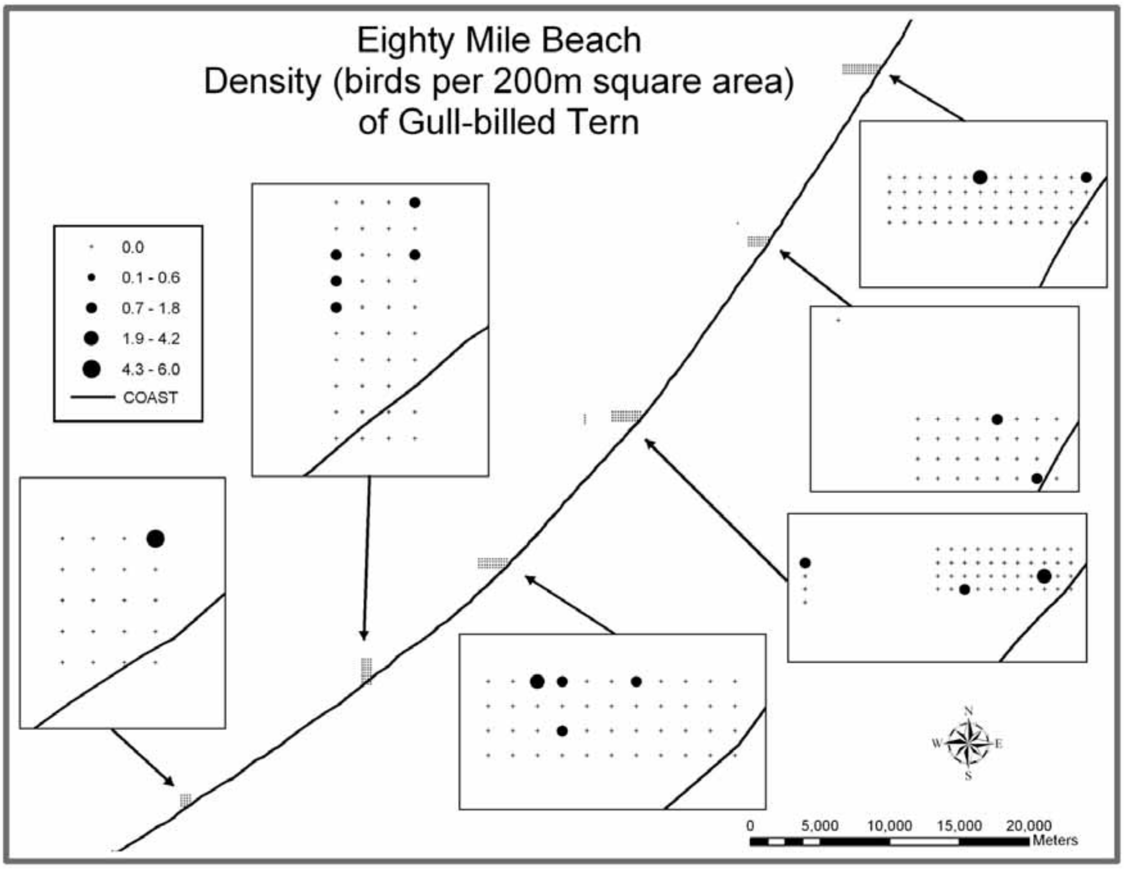

Eighty Mile Beach
Density (birds per 200m square area)
of Pied Oystercatcher
0.0
0.1 - 1.0
1.1 - 2.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

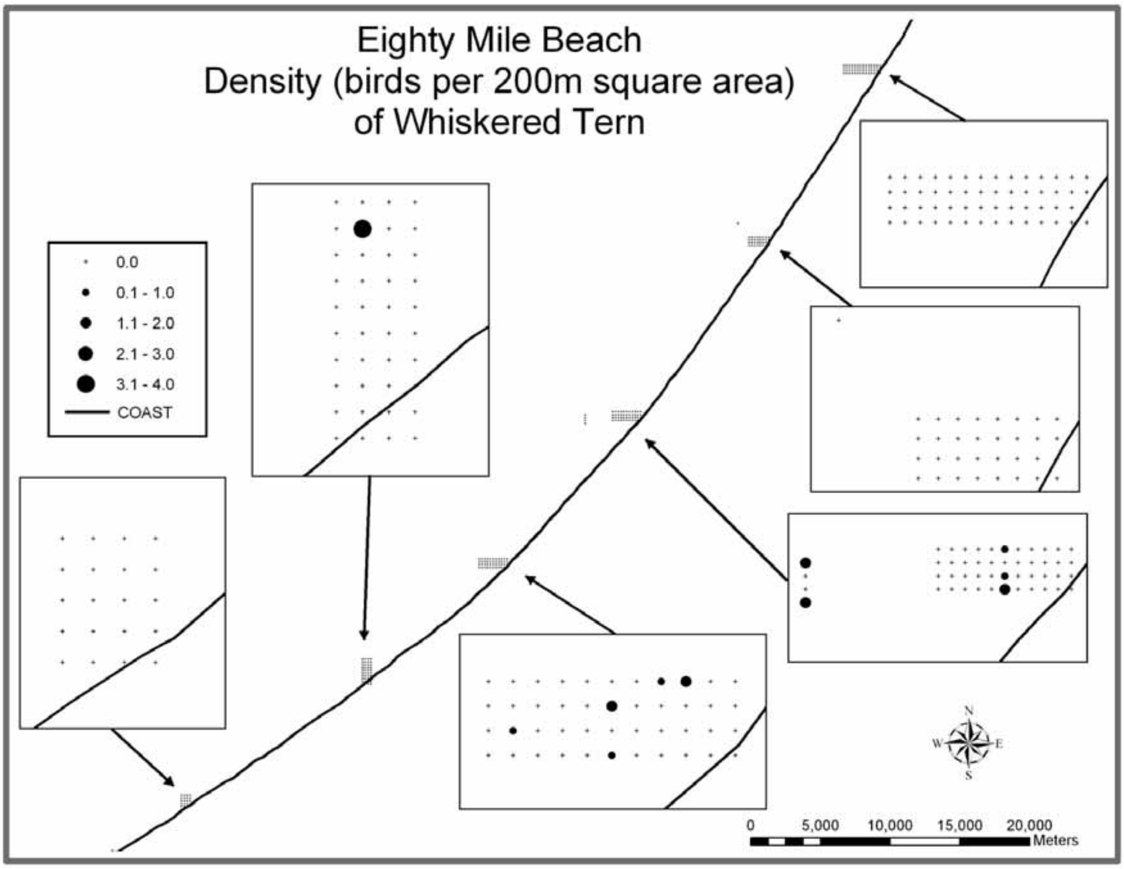

Eighty Mile Beach
Density (birds per 200m square area)
of Lesser Sand Plover
0.0
0.1 - 1.0
COAST
N
W
E
S
0
5,100
10,200
15,300
20,400
Meters

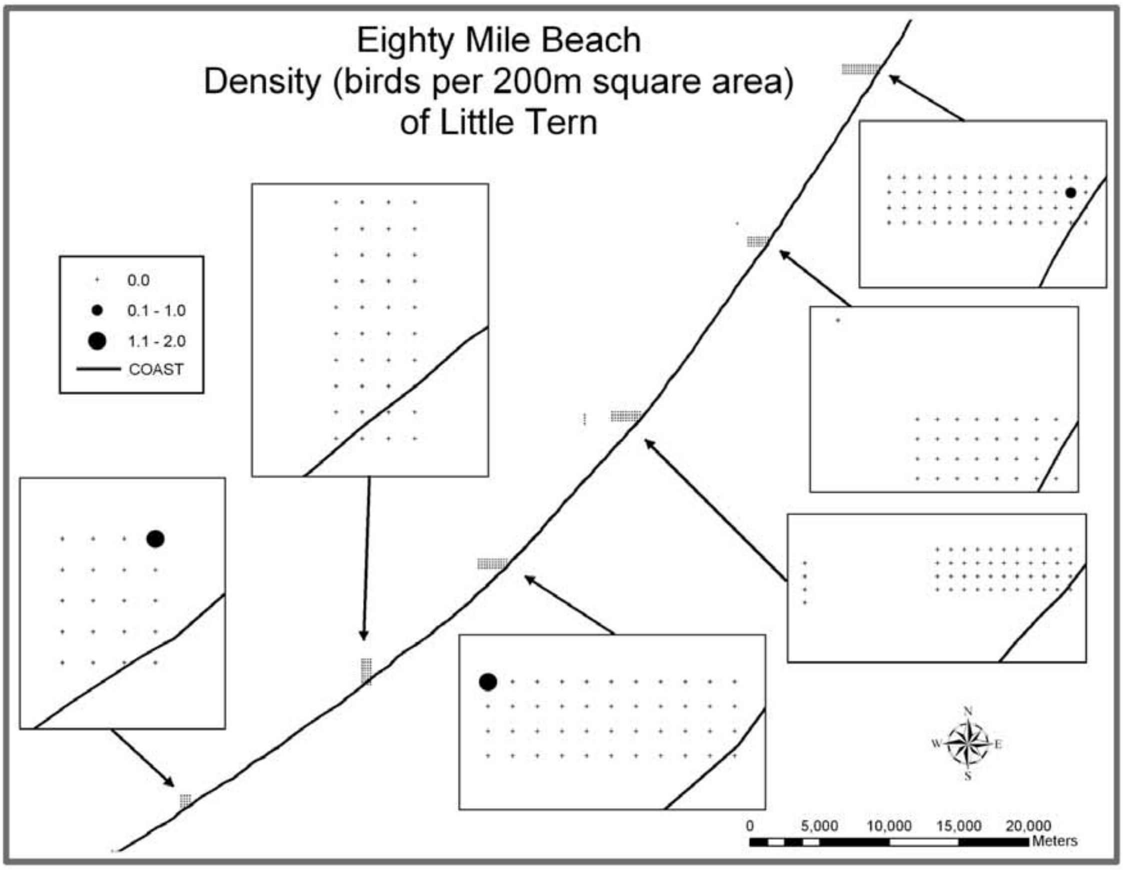

Eighty Mile Beach
Density (birds per 200m square area)
of Whimbrel
0.0
0.1 - 1.0
1.1 - 2.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

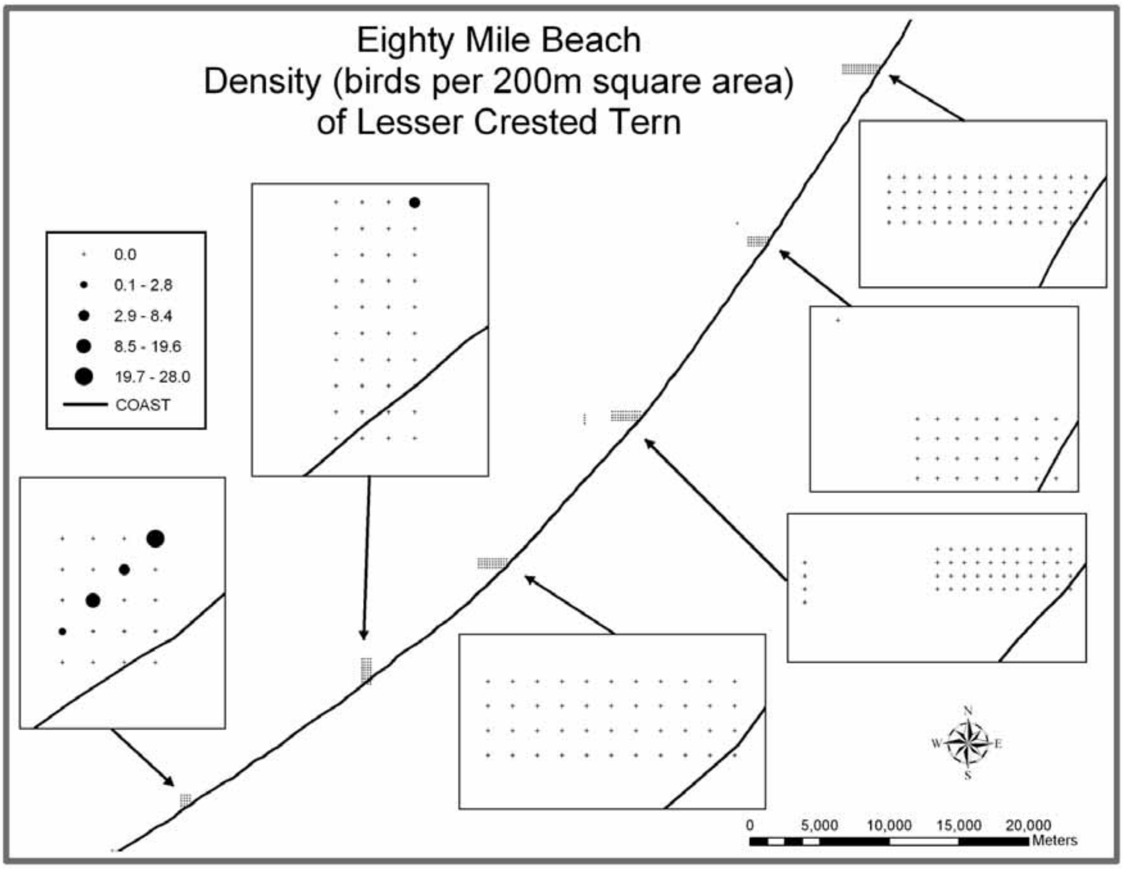

Eighty Mile Beach
Density (birds per 200m square area)
of Greenshank
0.0
0.1 - 1.6
1.7 - 4.8
4.9 - 11.2
11.3 - 16.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

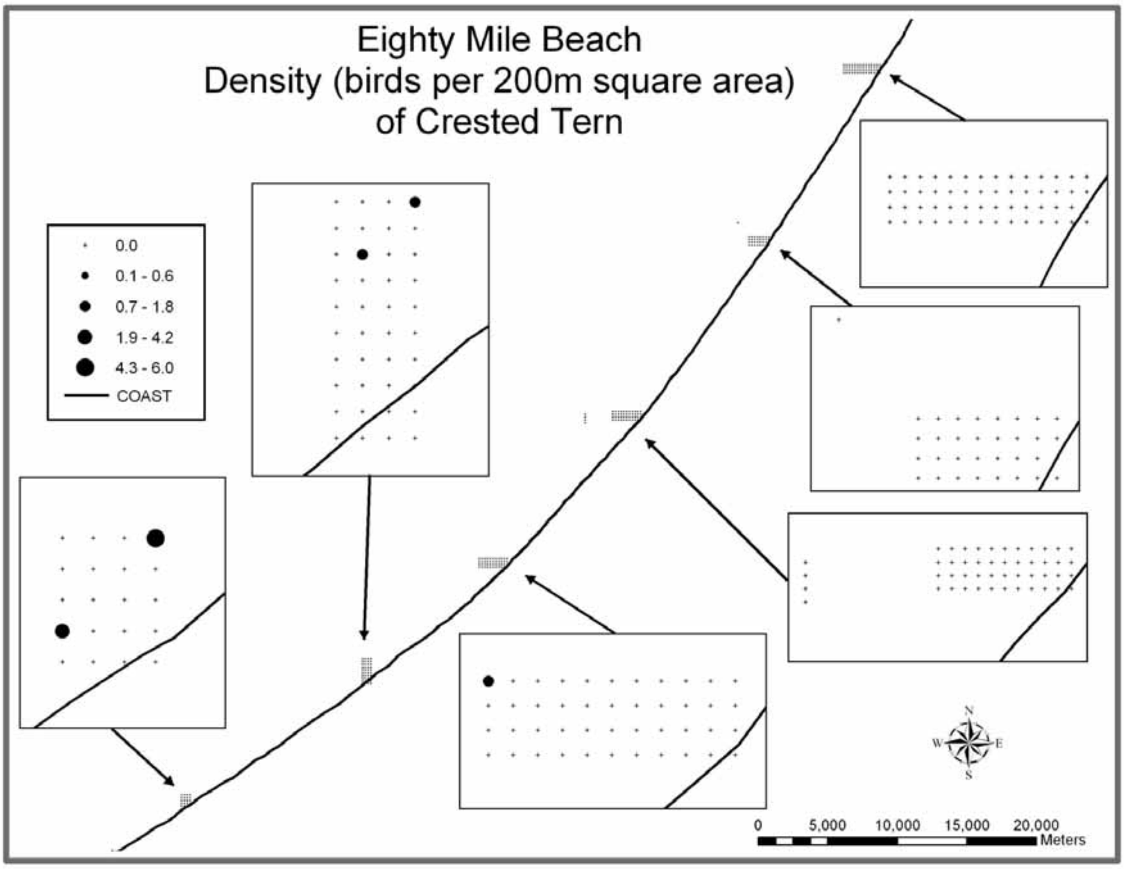

Eighty Mile Beach
Density (birds per 200m square area)
of Eastern Curlew
0.0
0.1 - 1.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

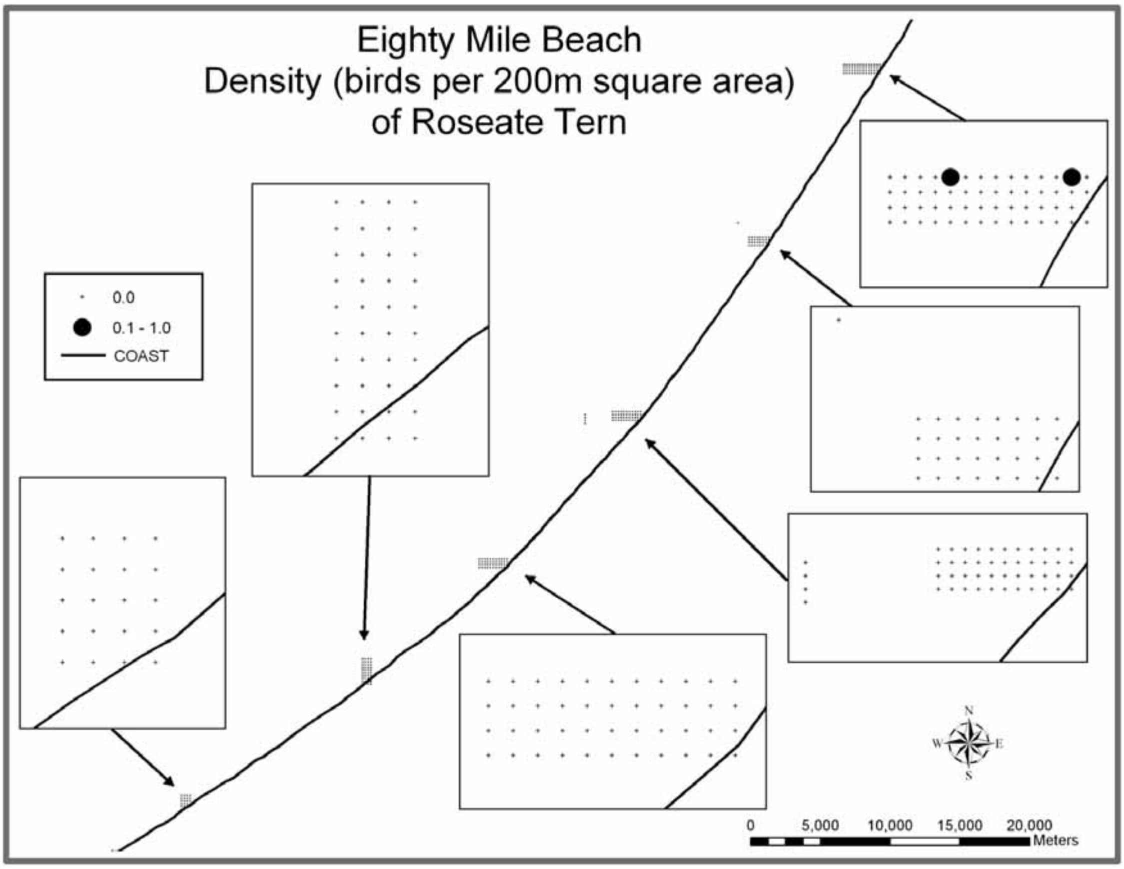

Eighty Mile Beach
Density (birds per 200m square area)
of Gull-billed Tern
0.0
0.1 - 0.6
0.7 - 1.8
1.9 - 4.2
4.3 - 6.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

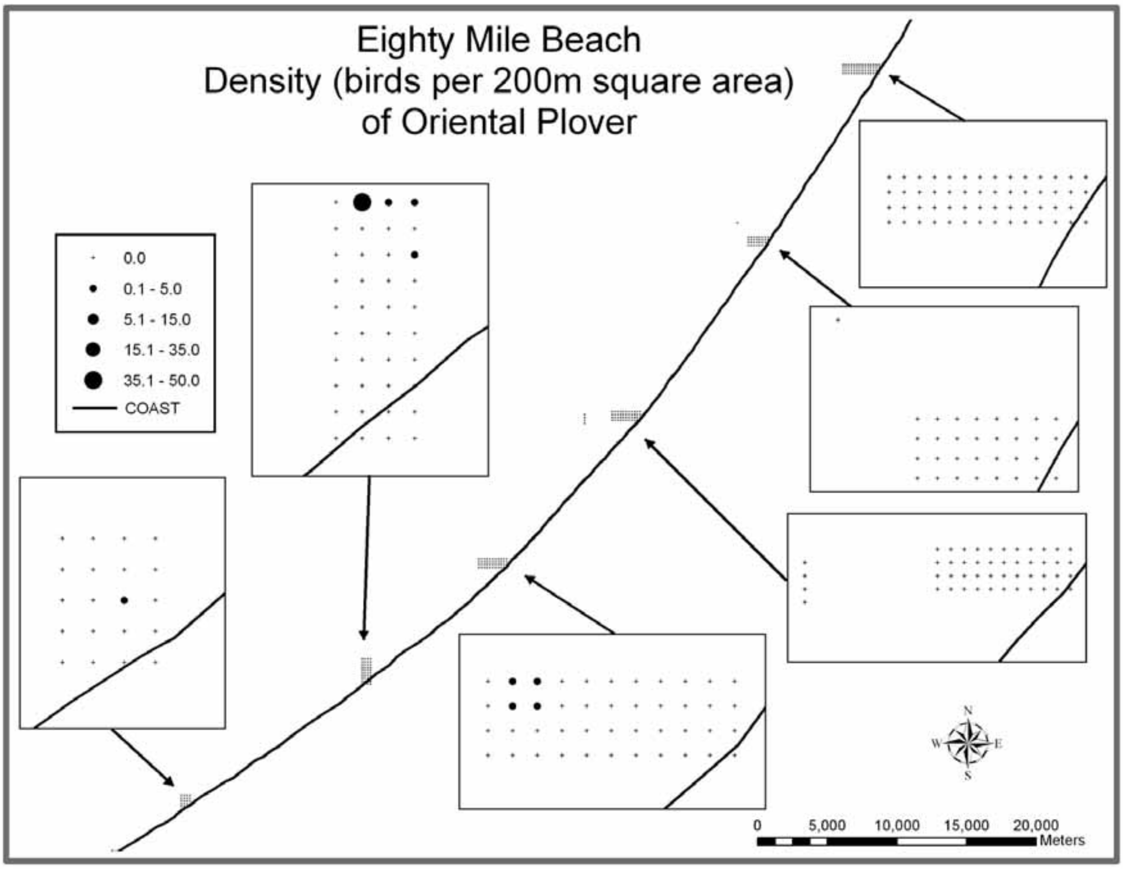

Eighty Mile Beach
Density (birds per 200m square area)
of Whiskered Tern
0.0
0.1 - 1.0
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

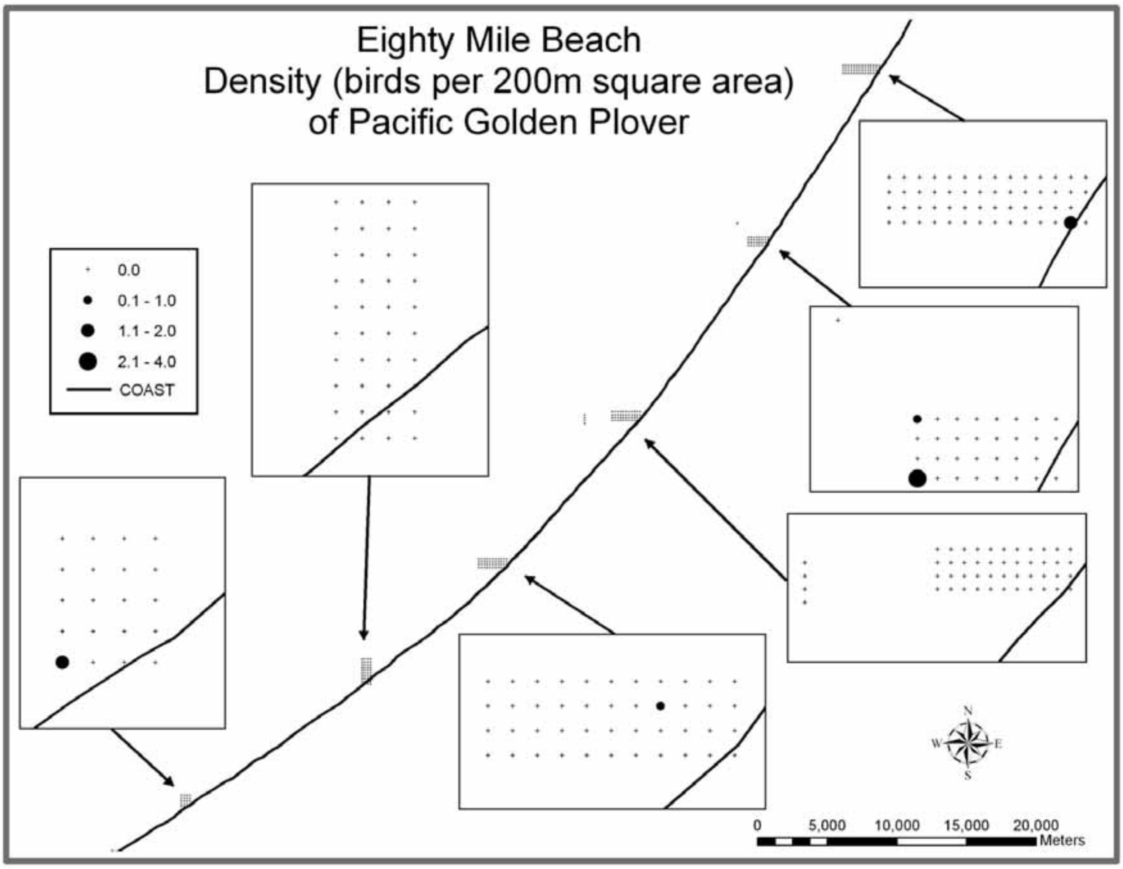

Eighty Mile Beach
Density (birds per 200m square area)
of Little Tern
0.0
0.1 - 1.0
1.1 - 2.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters


Eighty Mile Beach
Density (birds per 200m square area)
of Lesser Crested Tern
0.0
0.1 - 2.8
2.9 - 8.4
8.5 - 19.6
19.7 - 28.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters


Eighty Mile Beach
Density (birds per 200m square area)
of Crested Tern
0.0
0.1 - 0.6
0.7 - 1.8
1.9 - 4.2
4.3 - 6.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters


Eighty Mile Beach
Density (birds per 200m square area)
of Roseate Tern
0.0
0.1 - 1.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters


Eighty Mile Beach
Density (birds per 200m square area)
of Oriental Plover
0.0
0.1 - 5.0
5.1 - 15.0
15.1 - 35.0
35.1 - 50.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters


Eighty Mile Beach
Density (birds per 200m square area)
of Pacific Golden Plover
0.0
0.1 - 1.0
1.1 - 2.0
2.1 - 4.0
COAST
N
W
E
S
0
5,000
10,000
15,000
20,000
Meters

11. MANAGING THE UNIQUE MARINE BIODIVERSITY AT EIGHTY-MILE BEACH

Grant Pearson, Theunis Piersma & Robert Hickey

12.1. INTRODUCTION

In the bat of an eye, the known population of many species of shorebirds in Australia took an extraordinary turn for the better around 1981. For example, the known world population of one of the rarer shorebirds, the Great Knot Calidris tenuirostris, was suddenly increased from 5,000 to 20,000 (it now numbers around 270,000) (C.D.T. Minton pers comm). In the interim period since the recognition that Roebuck Bay and Eighty-mile Beach were more than just a pair of apocryphal locations in the far northwest of Western Australia, a great deal has been achieved. Shorebirds in their thousands have been counted, caught, measured, filmed, photographed, talked about, written about, and eulogised in redoubtable places. Poems have been composed about them and observatories have celebrated their comings and goings. Their habitats have been mentioned in high places and state, national, and foreign governments have recognised their virtues. But in spite of all these admirable measures of concern, many of the risks that threatened their existence in 1981 are present today – only more so.

Eighty-mile Beach, together with Roebuck Bay and their associated hinterlands form the single most important wintering shorebird habitats in Australia. When compared to the vast expanses of mudflats in the Yellow Sea (22400 km^2 and 2 million shorebirds (Shorebird Conservation in Australia, 2002) the density of birds per hectare is significantly greater at Eighty-mile Beach (600 km^2 , 440,000 shorebirds) leading to suggestions that combined with Roebuck Bay, these sites are, quite possibly, amongst the richest known intertidal mudflats in the world!

How then should they be treated to ensure proper consideration of all the aspects of conservation of the diverse wildlife values? Both wetlands have been listed in the Ramsar Convention of 1990 and are registered as Wetlands of International Importance. What level of protection does this provide the high conservation values of Eighty-mile Beach and what else can be done?

Management guidelines have not been formulated for either wetland. although, at the time of writing, there is progress towards development of management plans for both sites. A major achievement and a progressive step towards identifying and managing the State's wetland resources has been the release of the Wetland Conservation Policy for Western Australia in 2000. The five principal objectives stated in this policy are relevant to the management of Eighty-mile Beach and are listed as:

1. To prevent the further loss or degradation of valuable wetlands and wetland types, and promote wetland conservation, creation and restoration.
2. To include viable representatives of all major wetland types and key wildlife habitats and associated flora and fauna within a State wide network of appropriately located and managed conservation reserves which ensure the continued survival of species, ecosystems and ecological functions.
3. To maintain, in viable wild populations, the species and genetic diversity of wetland-dependant flora and fauna.
4. To maintain the abundance of water bird populations, particularly migratory species.
5. To greatly increase community awareness and appreciation of the many values of wetlands, and the importance of sound management of the wetlands and their catchments in the maintenance of those values.

(This commitment is made in accordance with the conservation objectives of the State Conservation Strategy for Western Australia (1987) and contributes towards its implementation)

The work of projects such as Annabim99 addresses many of these policy objectives:

In particular, apart from the obvious benefit of the collection of baseline data from a wetland where little benthic macrofauna data has been collected before, this project is a first in the incorporation of local community participation in benthic studies in the Kimberley. Community awareness is an essential criterion in the application of management protocols for the protection of intertidal ecosystems.

Management plans for Eighty-mile Beach should have clear objectives if they are to work. Without these, it is impossible to judge the success or failure of management or to design a management strategy (Jennings *et al* 2001). It should be easy for managers and conservation or interest groups to identify the strategy and determine if it is being followed. In order to determine whether objectives are met, indicators are necessary. Tables 12.1 list, some of the objectives that may be pertinent for Eighty-mile Beach.

Table 12.1. Possible objectives with respect to different realms of human entrerprise, for the management of Eighty-mile Beach

OBJECTIVE	BIOLOGICAL	ECONOMIC	SOCIAL	POLITICAL
Protect habitat	*		*	*
Increase scientific knowledge	*	*	*	*
Prevent species loss	*	*	*	*
Maintain benthic community structures	*	*	*	
Improve community knowledge	*		*	*
Monitoring	*		*	
Communication			*	
Liaison			*	
Disseminate information			*	*

We also need indicators to evaluate management success (Table 12.2). Indicators that are purely quantitative are much easier to measure than those that relate to emotional well being or lack of community displeasure. Management actions are taken to implement strategies.

Habitat protection at Eighty-mile Beach includes the foreshore, intertidal mudflats, the coastal dunes east of the beach, and the floodplain.

Some objectives may not be independent. Thus, an attempt to meet one objective may jeopardise another. Conflict between groups may be a natural result of the management plan process, especially over sensitive issues such as the closure of sections of the beach for various reasons.

12.2. MANAGING IMPACTS

Bottom trawl fishing on the seabed can alter infaunal communities (organisms that live in or on the benthic layer) and although this may not be a current practice near Eighty-mile Beach it is important to understand the impacts that this type of disturbance can have on soft bottom communities. Fishing techniques that can affect benthic fauna and habitats can be divided into two groups – active and passive (Jennings 2001). Active fishing includes dragging trawls across the seabed, drive netting, spearing or fishing with chemicals or explosives. Passive fishing includes techniques such as pots, traps, gill nets, longlines and drift nets. The impacts of this equip-

Table 12.2 Indicators that tell us about the success in reaching various stated objectives for the management of Eight-mile Beach.

OBJECTIVE	INDICATOR
Protect habitat	Proportion of habitat affected by human activity (for example; vehicles, fishing, recreation, industry)
Increase scientific knowledge	Number of reports, publications.
Prevent species loss	Monitoring of species abundance and distribution. (Implies a knowledge of the biota)
Maintain benthic community structures	Monitoring of community structures. (Implies a knowledge of the biota)
Increase community knowledge	Number of enquiries on shorebird/benthos topics; Press releases, seminars, workshops; Survey of public and/or industry opinion, Number of leaflets distributed, press releases, number of seminars and workshops
Monitoring	Number of sites and times visited.

ment on non-target biota and habitats will vary between different habitats and according to the manner in which they are used (Jennings 2001).

Physical disturbance of the seabed results from direct contact with fishing gear. In soft sediments, this will lead to the turbulent re-suspension of surface sediments that may remobilise contaminants or expose anoxic lower sediment layers (Jennings 2001).

Kaiser and Spencer (1994) found that beam trawling in stable sediments that contain a rich infauna reduced the number of species and individuals by two or three times. Detailed analyses of changes in particular types of infauna revealed that less common species were most severely depleted. Tube building worms such as Sabellaridae, amphipods and bivalves were among the most sensitive animals affected by the beam trawl disturbance. There is evidence that these worms (*Sabellaria spinulosa*) occurred commonly in the Wadden Sea off the coast of The Netherlands and Germany in the 1920s. A comparative survey 55 years later found no evidence of these reefs. Active trawling had apparently completely eliminated that species from its habitat. Species of Sabellaridae were found at a number of sites at Eighty-mile Beach and would be vulnerable to any form of trawl netting (Fig. 12.1).

Figure 12.1 At low tide the small “reef” of the polychaete Sabellaridae at Eighty-mile Beach near Anna Plains Station are visible around the hovercraft. Photo by Grant Pearson.

Deeper burrowing fauna may not be adversely affected by severe natural disturbances such as episodic storms that only affect the upper surface layers of the sediment. Fauna living in the top few centimetres of the sediment may be greatly depleted in the short term while the deeper living fauna remained undisturbed (Jennings *et al.* 2001). Sedimentary habitats may become more stable, so the effects of disturbance (fishing) can be more dramatic in the short term and may last far longer. This principle can apply to both the structure and composition of the benthic assemblage and the topography and physical structure of the sediment (Jennings *et al.* 2001).

From discussions with many of the people associated with the Australian Wader Studies Group there is anecdotal evidence that suggests the small shark and stingray population along Eighty-mile Beach was far greater in the early 1980s than it is today. One of the explanations for this decline may be the presence of a net fishing operation south of the entrance road from Anna Plains Station. The by-catch of the target fish species is reported to include large numbers of small sharks and rays.

The occurrence of a small mangal community at the junction of the Mandora Marshes confluence

Figure 12.2. A blow-out caused by vehicles at Eighty-mile Beach near Wallal Station. Photo by Grant Pearson.

provides an interesting and important physical feature. The channels formed by the drainage of the linear floodplain waters offer some protection to the northern stretches of important shorebird habitat from human activity. The caravan park at Wallal Station and tracks south of Mandora provide potential or casual explorers ready access to the beach. The impact of this has not been quantified in this report, but a brief visit to the caravan park during the survey revealed a disturbing level of destruction of sand dunes, beach habitats and frontal dune vegetation (Fig. 12.2). It is important to redress this problem and to protect the northern stretches of beach from a similar fate.

The “usual suspects” of environmental, social, economic, and aesthetic loss apply to the values at risk at Eighty-mile Beach. However, there has been a significant and measurable level of protection afforded the site as a consequence of its remoteness. It is fortunate there has been reluctance displayed by local pastoralists, notably Anna Plains Station, to tolerate ad hoc vehicle access to the beach that has increased this level of protection. Anecdotal evidence suggests that the beach adjacent to Wallal Downs Caravan Park was once rich in relic shells and possessed a crab fauna similar to that of the northern beach. However, the presence of a busy tourist amenity only metres from Eighty-mile Beach that provides unrestricted access for off road vehicles has resulted in unacceptable levels of coastal landform disturbance and may have contributed to the loss of wildlife and aesthetic appearance. Measures are in place to rectify this situation, but experience has shown that coastal dunes in tropical areas are notoriously difficult to rehabilitate.

The role played by traditional owners in the conservation of the wildlife values of the northern reaches of the beach is unclear. Certainly in the discussions that have taken place between traditional owners at Roebuck Bay and the 1997 Roebim Mapping Group, there has been a high level of accord on the objectives of the study group and Aboriginal communities. There is no reason to suspect that this does not apply to the communities that reside near Eighty-mile Beach

12.3. WILDLIFE VALUES

The benthos

One of the dilemmas facing current management authorities of intertidal mudflats at Roebuck Bay and Eighty-mile Beach is the lack of scientific knowledge concerning these sites. Evidence of the high biological diversity of Roebuck Bay was gathered in 1997 and published in 1999 (Pepping *et al*. 1999). Not surprisingly, few of the documents written in recent times that refer to the wildlife values of either site adequately recognise the importance or the extent of the infaunal biodiversity at each site. Management strategies will need to include reference to this biodiversity that lies in and on the intertidal mudflats.

Given the accelerating rate of development in the Kimberley potential risks to the integrity of the ecosystems and survival of the fauna of the soft sediments include:

- Mechanical harvesting of marine food resources by professional fisheries.
- Damage of fragile marine organisms by mechanical means such as fishing nets, boats, recreational vehicles.
- Damage to the invertebrate fauna by chemical agents such as oil, petrol, pesticides and fertilisers.
- Pollution of habitats with airborne pollutants from industry.
- Uncontrolled recreational or professional harvesting of fisheries or mud dwelling organisms.
- Uncontrolled interruption of tidal movement.
- Interruption of subterranean ground water flow.
- Pollution of the algal mats and other benthic organisms with agricultural runoff.
- Unlawful or uncontrolled impoundment for fish farming.
- Failure to recognise the value of the biodiversity contained within benthic ecosystems.
- Changes to the distribution or abundance of species due to impacts from human activity.

Shorebirds

Eighty-mile Beach is possibly the first landfall in Australia for many shorebirds on their southward migration and the last as they migrate north. The large number of Sharp-tailed Sandpipers reported earlier recuperating on the beach following their exhausting southern migration is an indication of the role the beach can play in the lives of shorebirds.

Potential risks to the integrity and maintenance of the shorebird populations include:

- Uncontrolled use of recreational or 4x4 vehicles on the beach, especially at high tide.
- Reckless use of hovercraft, aircraft, airboats, or recreational toys close to groups of shorebirds.
- Pollution from vehicle residues such as oil, fuel, body panels, and tyres.
- Pollution from food scraps and packaging residue such as plastic strapping.
- Unlawful shooting or trapping.
- Uncontrolled dogs pets and stock on the beach at any time.
- Disturbance from camping.

- Uncontrolled fishing on tidal flats – tablefish, shellfish, and infauna invertebrates.
- Any other activity that might impact upon the bird's ability to survive their migration flights.

12.4. SOCIAL VALUES

The State Wetland Conservation policy (1997) states "The Government will encourage community participation by promoting wetland conservation, and by facilitating voluntary efforts to conserve, restore and enhance wetlands, principally through the development and provision of sound advice concerning wetland values and the management of wetlands and their catchments."

The objectives (and results) of the three survey expeditions to Roebuck Bay, King Sound and Eighty Mile Beach present a high level of agreement with the aims of this statement. Certainly community involvement in the processes of mudflat management has increased with each survey. Community groups now facilitate and run regular and ongoing monitoring projects at the two southern sites and actively seek funding for ongoing monitoring and research.

Aboriginal participation in the projects has been encouraged and fostered by various organisations involved in the mapping and monitoring projects. However, although the level of participation has increased with each project, there is room for improved liaison from project managers and the Aboriginal Community administrators. Recognition by all parties of the values of co-operative involvement in projects such as the 1999 mapping project at Eighty-mile Beach is essential for conservation of the wildlife values at Eighty-mile Beach.

12.5. VARIOUS POSSIBLE THREATS

There is evidence of declining populations of a number of shorebird species in North America. Of 35 species for which analyses are available, Morrison *et al*. (1994) found that 28 (80%) show negative trend values with 19 showing statistically significant or persistent declines. One showed a significant increase. The report comments that there is no single factor that can be shown to be a major issue in the declines of these species. Shorebirds are especially vulnerable to environmental degradation or change. In view of the life history characteristics of many species, which often involve long migrations, concentrations of major portions of the population at a restricted number of sites and/or habitats that are often targets of industrial or recreational development is an issue (Morrison *et al* 1994). This has particular relevance to shorebird management at Eighty-mile Beach.

The effects of increased access to wetlands can be drastic (Roggeri 1995). In the Indonesian Wasur Wildlife Reserve, the extension of the local road network provided greater access to the reserve. As a consequence of an increase in poaching facilitated by the better access, rusa deer numbers dropped from 20,000 in 1980 to 2,000 animals in 1983 - despite the reserve status and the legal protection of this species in Indonesia.

Although there is no current shell fishing industry on the intertidal flats at Eighty-mile Beach, there can be no guarantee that as world demands for protein increase, interest in some part of the infauna may arise. Furthermore, anglers compete with birds for shellfish and, although this is not an issue at present at Eighty-mile Beach, there is potential for angler/bird competition in the future.

Cumulative effects of small increases in mortality (of shorebird populations) over a period of years can have large effects on population size because (shell) fishing has disproportionately large effects on inexperienced and subdominant birds that would otherwise contribute to future generations (Jennings et al. 2001).

The small net fishing activity south of Anna Plains is believed to have had an impact on the occurrence of small sharks that used to be very common on the intertidal flats. Anecdotal evidence suggests that numbers have declined markedly in recent years. This reduction in the population of an upper level food chain predator is unacceptable and could have significant and detrimental impacts on the ecology of the mudflats. The impact on the ecosystem of such an imbalance should be addressed through:

- Regulatory mechanisms that protect the fishery and shorebird habitat
- Increase requirements for minimal disturbance of fish and shorebird habitat in important shorebird sites
- Improve community and land manager understanding of the impacts of such fisheries .

Many wading birds winter in the estuaries of northern Europe, and feed on mussel and cockle beds. These beds are also fished. Disturbance from these fishers can drive birds away from areas where they would otherwise feed. This reduces time and increases energy use because birds have to fly to new feeding areas. Disturbances also increase competition between birds as it forces them to feed in smaller areas

(Jennings *et al*. 2001). This has clear implications for human use on Eighty-mile Beach, especially at times when migrating shorebirds need maximum time feeding with minimum disturbance.

The northern parts of Eighty-mile Beach experience low levels of use by four wheel drive vehicles (J Stoate, pers com). The southern parts, however, are accessed by residents and visitors via the access roads at Wallal and Cape Keraudren. The extent to which this has effected wildlife values and, in particular, invertebrate communities of the adjacent foreshore is unknown. Management plans for Eighty-mile Beach should include provisions for the exclusion of vehicles onto the beach between Cape Missiessy and the muddy channels associated with Mandora Marshes – a naturally occurring limiting factor for vehicles. The impact of this on the lifestyles of the nearby Aboriginal Communities and the pastoralists who carry out their business on the land surrounding the foreshores needs to be considered in the setting of regulations for this.

Present levels of disturbance may or may not be acceptable for the shorebirds and invertebrate communities. During the migration period, continued disturbance may have an effect on individual bird's migration performance and, hence, chances of survival. Nil disturbance levels may be the preferable option.

Consultation with traditional users of the beach is necessary to foster community support that will, eventually, be the most effective form of control. Interventions that deprive local communities of their livelihood can result in consequences that can be particularly harmful to the community and the environment (Roggeri 1995). This is pertinent in the context of traditional pursuits on wetlands in the Kimberley including Eighty-mile Beach and Roebuck Bay.

In many parts of the world, estuaries have become the foci of large parts of the country's populations. They are often at the headwaters of large rivers or harbours that initially provide them with a means of transport and food. In Australia, 60% of the population are centred on estuaries and rivers. These soft sediment estuaries can become contaminated with wastes from major cities because the time it takes to flush out contaminants is generally longer than the rate of accumulation of pollutants (Little, 2000).

The north-west of Australia is relatively untouched by these influences and the remoteness of the location of Eighty-mile Beach has already been discussed in terms of the level of protection it has provided. There is always potential for changes to the species composition of a habitat resulting from contaminants from large-scale industrial or horticultural activities. The pathways for introduction of chemicals into the intertidal ecosystem have not been established and require further examination. The impact of proposals for intensive agricultural pursuits on the hinterland of Eighty-mile Beach should be closely examined for their potential to cause changes to the tidal ecosystems. Notwithstanding the economic value of such projects for local communities, the loss of biological diversity on the tidal foreshores of Eighty-mile Beach should be recognised as a non-negotiable option.

Freshwater seeps, clearly visible in many places at low tide, may have an important role in the lives of some forms of algae and the invertebrate fauna of the intertidal mudflats. Activities that may affect the continuity or integrity of these include the abstraction of ground water, impoundments, and interruptions to the underground streams, pollutants reaching the shallow aquifer, contamination with sea/salt water as a result of over pumping. Further work is necessary to qualify the nature, importance and extent of this aspect of Eighty-mile Beach

The reclamation or destruction of intertidal area, although unlikely in the foreseeable future at Eighty-mile Beach, can have an impact on shorebirds ability to find sufficient prey items. Little (2000) reports that a reduction of surface area of a feeding ground results in a reduction of carrying capacity. Birds unable to find sufficient to eat in a given area are forced to find more productive mudflat or face starvation. The area of mudflat most suited to shorebirds occurs between Cape Missiessy and about 85 km south of the Cape. Beyond this point, shorebirds were less common in 1999, probably due to the lack of suitable food as a consequence of changes in sediments. The loss of portions of this feeding area will have an impact on the survival of some of the shorebirds. It may not be as simple as moving to another feeding area for birds suffering from increased competition on reduced feeding grounds. The benthic survey of King Sound in 1998 demonstrated that the presence of large areas of intertidal flats does not necessarily guarantee productive shorebird feeding habitat. Although flocks of shorebirds have been recorded around King Sound (Halse and Pearson 2000), its massive area of intertidal flats are dominated by the Fitzroy River system and have proved quite depauperate for shorebirds. This may apply to intertidal habitats north and south of the preferred feeding grounds at Eighty-mile Beach.

12.6. MONITORING AND EVALUATION

The work that took place at Eighty-mile Beach in 1999 (Fig. 12.3) was the first attempt to investigate the nature and distribution of the sediments and the intertidal macrofauna along that foreshore. It was limited by the vastness of the site and the time available during the survey. The resources, though considerable were insufficient for a survey of the entire 220 km. The extent of suitable foreshore for shorebird habitat is unclear at this stage. Further surveys are needed to fully determine this. Work on the distribution and abundance of shorebirds along Eighty-mile Beach continued in October 2001 and will provide valuable information that can be linked to present knowledge of benthos abundance and distribution.

This ongoing monitoring of Eighty-mile Beach will provide a picture of seasonal and spatial changes in time. Specimens collected by the monitoring groups are separated from nonorganic material and sent to the Royal Netherlands Institute for Sea Research for identification. Funds have been provided through the CALM Wetlands Conservation Projects for their proper identification and analysis.

This report has provided the scientific and wider community with a basic understanding of the macro-faunal relationships and wildlife values of Eighty-mile Beach. The work that has taken place, however, has provided only a hint of the true importance of the biological diversity of the mudflats of Eighty-mile Beach and Roebuck Bay.

Figure 12.3. Theunis Piersma is surrounded by attentive volunteers and members of his NIOZ team discussing the day’s events

ADDENDUM TO LONG MUD, EIGHTY-MILE BEACH REPORT

It's never too late to be who you
might have been.

George Eliot (1819 - 1880)

Since this report was compiled a significant amount of mud has flowed beneath the bridge. Recent developments include:

Considerable dialogue between Traditional Owners and land managers such as The Department of Conservation and Land Management (CALM) and The Department of Planning and Infrastructure has facilitated the emergence of the Karajarri Coastal Management Plan. This will cover the Karajarri Native Title area, Cape Missiessy south to the boundary of Karajarri country at or near Quandong Point. The development of this management plan may provide opportunity to progress the restriction of vehicle access to the high conservation value portion of Eighty-mile Beach north of Mandora. Exclusions from this would include Traditional Owner, Anna Plains Pastoral and research activities.

Anna Plains Station and Department of Conservation and Land Management and Anna Plains Station have concluded negotiations for a Section 16A dual management conservation reserve between the old coastal highway and the intertidal zone. This will provide a buffer between activities east of the coastal dunes and the conservation areas.

The Department of Conservation and Land Management has initiated the CALM Rivercare project with the objective "to contribute to the resource assessment phase of the Canning coast, West Kimberley, to support the planning process to consider marine conservation reserves". (R Stewart pers comm.)

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