FIELD REPORT

*Ann*a Plains and *Roe*buck Bay *B*enthic *I*nvertebrate *M*apping 20*16*

AnnRoeBIM16

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1. Abstract

1. This is a report on repeat surveys on the state of the benthic invertebrates at two internationally important areas of intertidal mudflats in northwest Australia (Roebuck Bay and Eighty Mile Beach) during October 2016. In the period 6-19 October 2016, we mapped the invertebrate macrobenthic animals (those retained by a 1 mm sieve) at the main intertidal sites of West Kimberley, WA: Eighty Mile Beach and Roebuck Bay. We revisited almost the entire intertidal area along Eighty Mile Beach that was 'benthically' mapped in October 1999. The benthic animals of the northern mudflats of Roebuck Bay had been mapped in 1997, 2000, 2002, and 2006; we revisited as many as possible of these previously established sampling stations along the northern shore.

2. Our team comprised close to 100 participants with greatly varying levels of experience, though similarly high motivation and enthusiasm. At Eighty Mile Beach we visited 816 sampling stations laid out in a grid of 200 m intersections over 7 separate areas along ca. 75 km of beach (from 10 km north of the Anna Plains Station beach access to 65 km south). In the northern part of Roebuck Bay, we visited 534 sampling stations also laid out in a grid with 200 m intersections (but with distance of 400 m in the southeast). We made notes on the surface features on the mud, including the presence or absence of seagrass and various macrofauna. In the course of digging up, sieving, and sorting the mud samples from all stations, we identified and measured 32,500 individual invertebrates. We tried to identify all animals groups up to the level of species if possible, all on the basis of morphological differences. These species were often given field names, as time and means (literature or access to internet) did not allow us to always attach a proper scientific name. In addition, it is very likely that some of the species are still undescribed. Animals were preserved on ethanol for a more thorough scientific identification at a later date.

3. This time we surveyed two very distinct sections of the West Kimberley coast. Roebuck Bay represents a true embayment that is semi-enclosed by mangroves along the eastern, and some of the western shores, and by cliff and pindan woodlands in the north. Eighty Mile Beach stretches over 200 km along the open Indian Ocean facing northwest. In this environment, the intertidal mud- and sandflat area stretches from 1-5 km wide from shore to sea and is enclosed by sand dunes and a few mangroves. Despite the two systems being very important as nonbreeding areas for the same species of long-distance migrant shorebirds, their geomorphology and ecology are very distinct.

4. At both areas the biodiversity of benthic animals was very high compared with other intertidal soft sediment areas across in the world. In Roebuck Bay, 368 species were found, and at Eighty Mile Beach 156 species, providing a total of 433 species/taxa. The most diverse group were the Polychaeta with 167 species, followed by Crustacea (74), Bivalvia (59), Gastropoda (59), and Echinodermata (35). All other groups total less than 12 species.

5. The two areas have 92 species in common, which in the case of Eighty Mile Beach means that 60% of the species also occur in Roebuck Bay. Major groups not found at Eighty Mile Beach were Asteroidea, Brachiopoda, Hirudinea, Oligochaeta, Platyhelminthes, Polyplacophora, and Pycnogonida. Most of these groups were also rare in Roebuck Bay, but the absence of Brachiopoda (lamp-shells) and Pycnogonida (seaspiders) at Eighty Mile Beach came as a surprise. Some species, including two species of Spionidae (Polychaeta) common at Eighty Mile Beach were either absent or extremely rare at Roebuck Bay. Furthermore, a small seacucumber with dark coloured spots all over its

body, another larger seacucumber *Paracaudina chilensis*, two bivalve species of the genus *Tellina*, and two species of anemones were not found in Roebuck Bay. Yet, Roebuck Bay had many more species (277) not found at Eighty Mile Beach, the most common of these was the relatively large bivalve *Tellina piratica*, followed by the smooth tusk shell (*Laevidentalium lubricatum*), and the polychaete family Sternaspidae.

6. The large difference in biodiversity between Roebuck Bay and Eighty Mile Beach may be caused by different factors. Roebuck Bay has a greater variety of sedimentary habitats than Eighty Mile Beach. Eighty Mile Beach is completely exposed to the waves of Indian Ocean, while Roebuck Bay is protected by the peninsula on which Broome is situated. Therefore, notorious 'ecosystem engineers' such as the seagrasses occur quite extensively on the intertidal area of Roebuck Bay, but are not found at Eighty Mile Beach. These seagrass mats of *Halodula uninervis* and *Halophila ovalis* form special habitat for e.g. the little snail *Smaragdia souverbiana.* The influence of Broome city by episodic sewage and fertilizer releases, of which blooms of the cyanobacteria *Lyngbya* are an indication, can may well have a negative influence; opportunistic widespread species other than *Lyngbya* may of course benefit from the additional nutrient inputs.

7. Local communities and the land-owners actively participated in both expeditions. Several DPAW ranger groups (Yawuru, Karajarri and Nyangumarta) joined the sampling and also aided in the identification of species. Angela Rossen (WAMSI) spearheaded a biodiversity project that involved pupils from Cable Beach Primary School. We believe that we have raised wide awareness and generated considerable enthusiasm for the ecology of a unique contribution of northwest Australia to the world.

8. Based on their outstanding universal values, we recommend that the WA government consider an application of the joint marine reserves of Eighty Mile Beach and Roebuck Bay for **World Heritage Status**, thus joining China and South Korea in acknowledging and protecting this shared heritage.

2. Introduction

Eighty Mile Beach and Roebuck Bay are world-renowned as non-breeding sites for migratory shorebirds. These small to medium-sized birds – sandpipers, plovers, curlews, knots, and the like – nest in the far northern hemisphere, in habitats ranging from Mongolian steppes to high arctic tundra. In the non-breeding season, they inhabit a very different world, depending on intertidal mudflats where they feed on benthic invertebrates. The rich and diverse benthos of the extensive intertidal flats in northwest Australia support a large and uniquely diverse migratory shorebird community. Hundreds of thousands of migratory shorebirds rely on these areas for their nonbreeding survival and preparation for northward migration. Indeed, there are few places on earth where soft bottom intertidal mudflats support larger numbers of migratory shorebirds. Roebuck Bay is one of less than only twenty comparable coastal areas scattered around the globe. The features that characterise this Bay and make it so outstanding are varied and complex (Rogers *et al.* 2003). They have also been the subject of considerable scientific and community investigation over the past 20 years. This unusual collaboration between science and community has been the catalyst for another effort to map the benthic diversity and distribution of the sediments of Roebuck Bay and Eighty Mile Beach, the survey in 2016 being the fifth survey of Roebuck Bay, again with a focus on the northern shores.

Shorebirds have been surveyed a number of times since Eighty Mile Beach was ‘discovered’ by shorebird biologists in 1981, and some variably complete shorebird counts were carried out in the early 1980’s by a combination of aerial survey and localised ground counts. The first complete ground-based summer count of the shorebirds was carried out in 1999 (Minton *et al*. 2013), and subsequent complete ground-based summer counts of the entire beach were carried out in 2001 (Minton *et al*. 2013), 2008 (Rogers *et al*. 2008), and 2015 (Rogers *et al*. in prep.). In addition, the northern 60-80 km of Eighty Mile Beach have been counted twice annually in summer, and once annually in winter, since 2004 (Rogers *et al*. 2006, 2011). These surveys confirmed the great importance of Eighty Mile Beach to shorebirds and revealed that most species are quite consistent in their distribution on the beach, with many species occurring in highest numbers in the section between 0 and 65 km south of the Anna Plains Homestead access point.

This broad pattern was known by 1999, when the first benthic survey was carried out on Eighty Mile Beach. The Annabim-99 expedition (Piersma *et al*. 2005) surveyed benthos in the tidal flats adjacent to the richest shorebird areas, with samples taken in a grid pattern in blocks spaced at 15 km intervals (with a few opportunistic samples also taken at the Anna Plains access point). In 2016, we sought to repeat this survey and discover if and how benthos abundance, diversity, and distribution changed.

This information is essential if we are to conserve the immense and internationally shared natural values of these important shorebird sites and find informed compromises with the increasing use of the foreshore by the ever increasing human population in the Kimberley Region. A considerable proportion of the world's Great Knots (*Calidris tenuirostris*) depends on (very specific portions of) Roebuck Bay for moult, survival, and fuelling for migration. This is also true for perhaps all the Red Knots (*Calidris canutus piersmai*) and Bar-tailed Godwits (*Limosa lapponica menzbieri*) of specific, reproductively isolated and morphologically and behaviourally distinct subspecies. The intertidal macrobenthic community of places like Roebuck Bay contains a unique assemblage of species. Some of these species will be new to science.

The 2016 project builds on the logistical methods and the techniques developed and used so successfully during previous expeditions to Roebuck Bay and Eighty Mile Beach, namely ROEBIM-97 (Pepping *et al*. 1999), ANNABIM-99 (Piersma *et al.* 2005), Tracking-2000 (Rogers *et al*. 2000), SROEBIM-02 (Piersma *et al.* 2002) and ROEBIM-06 (Piersma *et al.* 2006). During October 2016, we mapped the invertebrate macrobenthic animals (those retained by a 1 mm sieve) over the whole of the northern intertidal area of Roebuck Bay (Fig.

1) and blocks of Eighty Mile Beach from 10 km north of the Anna Plains access point to 65 km south of this point (Fig 2). We visited a total of 1350 sample stations (534 in Roebuck Bay and 816 at Eighty Mile Beach) (Figs. 1 and 2), laid out in grid with 200 m intersections, trying to cover as much as possible of the earlier grids (from 1997, 2000, 2002 and 2006 at Roebuck Bay and 1999 at Eighty Mile Beach). A few samples in the SE section of Roebuck Bay were sampled on a 400 m grid.

In the course of digging up, sieving and sorting the mud samples from all the stations, we identified and measured more than 32,500 individual invertebrates. These animals represented 433 taxa. We tried to identify all animals groups up to the level of species if possible, all on the basis of morphological differences. These species were often given field names, as time and means (no literature or internet) did not allow to always attach a proper scientific name. In a few instances we might have pooled species, e.g. in the case of *Macrophthalmus*, of which we encountered mainly juveniles which are difficult or impossible to identify to species. It is very likely that some of the species are still undescribed. Animals were preserved in ethanol for a more thorough scientific identification on a later date. In all we found representatives of many phyla, including Cnidaria (Anthozoa, Pennatulacea), Platyhelminthes, Nemertea, Annelida (Polychaeta, Oligochaeta, Hirudinea), Mollusca (Bivalvia, Gastropoda, Scaphopoda), Crustacea (Brachyura, Anomura, Stomatopoda, Caridea, Isopoda Mysida, Amphipoda, Tanaidacea, Ostracoda, Copepoda), Sipuncula, Echiura, Phoronida, Echinodermata (Ophiuroidea, Asteroidea, Holothuroidea, Crinoidea, Echinoidea), Tunicata, Enteropneusta and fish.

In this report, we aim to summarise the methods and the results based on preliminary analyses carried out at the Broome Bird Observatory and Anna Plains Station during and after the expedition in October 2016. During AnnRoeBIM 2016, the scientists worked closely with the traditional owners of Roebuck Bay, the Yawurru people, and the traditional owners of Eighty Mile Beach, the Nyangumarta and Karajarri people. We start this Field Report by brief summaries of their perspectives on land and on seasons. The report also enables us to thank the many individuals who put in so much of their expertise, time, and working power.

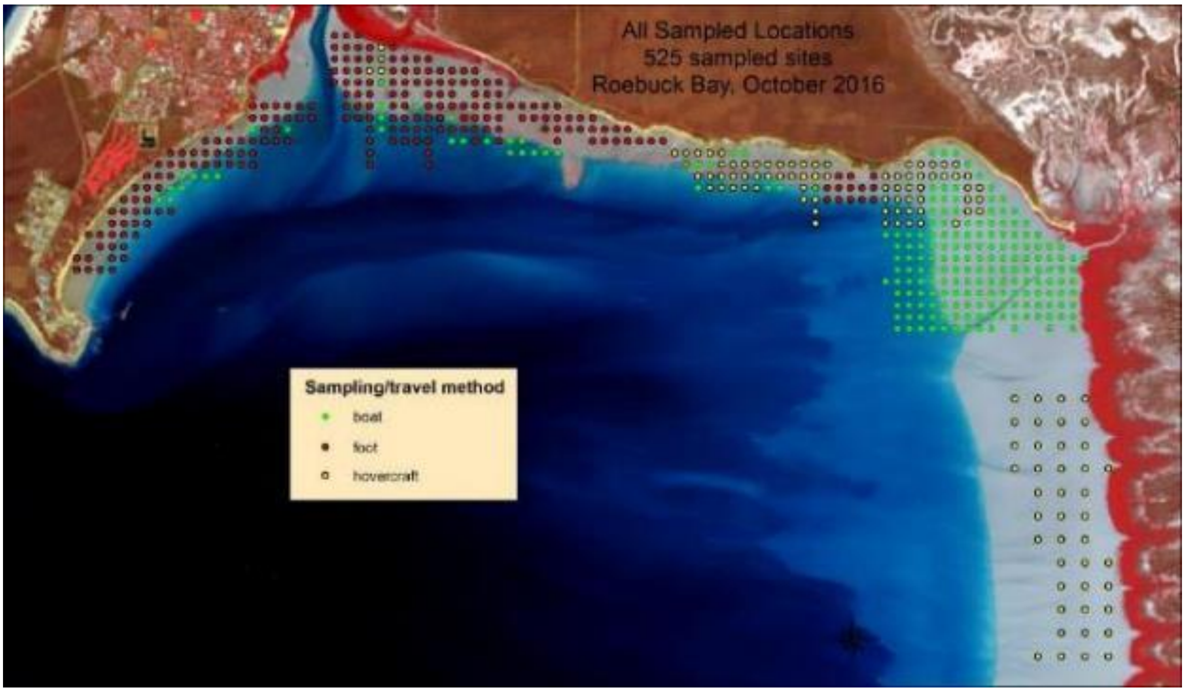


Fig. 1. Stations (200 m grid intersections) at Roebuck Bay from which samples of sediments and the macrozoobenthos community (i.e. animals retained on a 1 mm mesh) were obtained in October 2016. Gaps in coverage either refer to unvisited places, rocky outcrops that made sampling impossible or, in a few cases, lost samples. All sites sampled by boat were underwater, and thus lack observations regarding surface features and records of the benthic macrofauna.

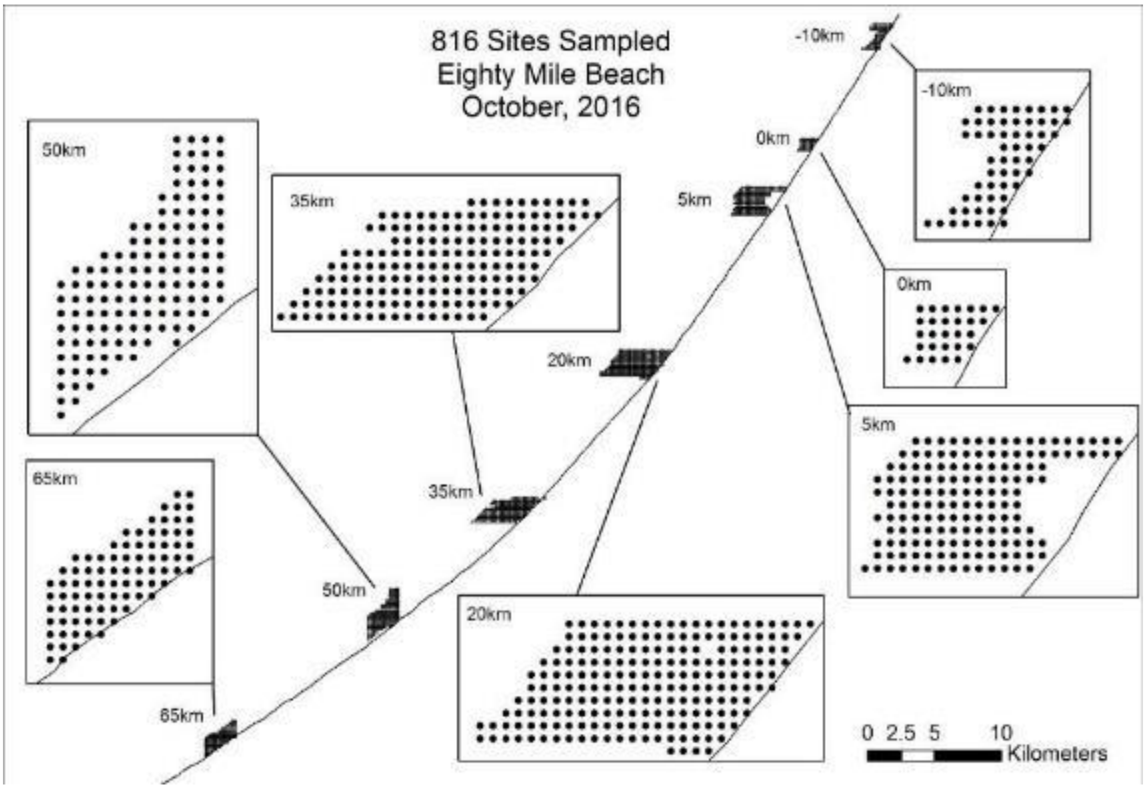


Fig. 2. Stations (200 m grid intersections) at Eighty Mile Beach from which samples of sediments and the macrozoobenthos (i.e. animals retained on a 1 mm mesh) were collected during October 2016.

Photo 1. Cheerful samplers in a muddy patch at Eighty Mile Beach. Photo by Hebo Peng.

3. Yawuru country

Yawuru country is land and sea, from *Wirkinmirre* (Willie Creek) to *Warrawan* (Barn Hill). The sea country of Yawuru people is *Yawuru Nagulagun Buru* (Roebuck Bay), where many *Gamirda-gamirda* (or *Gudirr gudirr* or *Didirr*, shorebirds) live. Roebuck Bay has always been an important area for Yawuru people. It provides food, there are dreamtime stories for the Bay and there are very strong culturally significant places that fringe its shores. Roebuck Bay traditional owners' connection to country defines how Yawuru Country is occupied, used, managed and protected. In 2006, the Federal Court handed down native title for this land and sea to Yawuru/Rubibi community.

Yawuru people live by six seasons that regulate traditional fishing and hunting:

- **Laja** (October-November): Hot season, turtles are mating and then laying eggs in November.
- **Man-Gala** (December-March): The Wet, reef fish and oysters are good to eat. Goannas are fat too.
- **Marrul** (April-May): Changing season, big tides and oyster and shellfish skinny. Salmon start biting and bonefish start flicking and schooling in Roebuck Bay.
- **Wirralburu** (May-June): Cooling down, salmon season.
- **Barrgana** (June -August): The Cold season, salmon still biting. Dugong and mullet are also fat.
- **Wirlburu** (September): Warming up – Oysters, crab and other shellfish start to get fat.

The present benthic work took place during *Laja* season. Dugong, turtle, mud crab, fish and stingray have always been hunted in the bay. There are remnants of old rock fishtraps still visible today. Many species found in the bay provide traditional food for the Yawuru people such as dugong, turtle (green turtle, chelonian mydas), stingray, salmon (bluenose and threadfin), barramundi, triple tail, grunter, skippy, mullaway, queenfish, trevally, whiting, finger mark, rock cod, mangrove jack, bone fish, mullet, tuna, mackerel, red perch, mud crab, sand crab, cockles, pippies, oysters and other shellfish. Yawuru people use several methods of fishing like handline, spearing, netting, rod fishing, mudcrab hooking and crab pots.

Yawuru people have traditions that are passed on to the new generations. The cultural rules about hunting methods and when the right time to go is passed on when young men are first taught for hunting turtle, dugong and fish species. Yawuru traditional owners have adapt cultural practices with western technology, using tin boats instead of rafts, steel rods for spear tip instead of bone, rock and hard wood. The way the traditional knowledge is recorded has changed as well. In order to preserve the culture, voice recording, video recordings and written stories of Yawuru culture have been made.

The work of Yawuru rangers will help to preserve Yawuru cultural knowledge and assist in educating others (non-indigenous people) about the cultural significance of Roebuck Bay as well as look after country. Yawuru people has noticed significant changes in their sea country in the last 20 years. The pindan cliffs have been eroded away, there has been a significant drop in the abundance of shellfish, significant increases in the amount of recreational boat users in the Bay and also the reoccurring presence of *Lyngbya majuscula*.

Based on an interview with Luke Puertollano, Yawuru Operations Officer, and the information found in the Yawuru web site.

4. Nyangumarta and Karajarri country

The sign at the entrance to the beach at Anna Plains station says: "*Eighty Mile Beach is part of the salt water country that belongs to the Nyangumarta and Karajarri people who have been connected to this land and sea for thousands of years. In 2012, the Federal Court handed down native title for this land and sea to Nyangumarta and Karajarri communities, two different tribal groups who share traditional laws and cultural connection to this country. Native title provides land rights for aboriginal people so they can continue to have meaningful connexions to country including to camp, hunt, gather, conduct ceremonies, enjoy and to make decisions about what happens on their ancestral lands. Today Nyangumarta and Karajarri people live in the nearby community and towns of Bidyadanga, Broome and Port Hedland. Both groups maintain connection to country by practising traditional management, speaking language, hunting and gathering, bush tucker and conducting ceremonies*."

On a southerly section of Eighty Mile Beach lies the land of the Nyangumarta people and to the north the land of the Karajarri people. Nyangumarta and Karajarri people share land in the middle section of the beach. Nyangumarta and Karajarri people are desert and saltwater people. The saltwater country is highly valuable for traditional hunting and fishing. Eighty Mile Beach songlines still exist about fishing. The traditional food from the sea is lemon sharks, sting rays, turtles, turtle eggs, salmon, big sea mullet, mud crabs and clams. There are four species of stingray, but only two are consumed, two species of salmon (blue nose and yellow thread fin) and three species of turtles (flat back, green, and olive red back). The traditional owners do not eat dolphins, and their seasons ensure that no animals are hunted during their reproductive cycle, respecting females and young animals. Seasons also ensure that the animals that are captured are fat. Nyangumarta and Karajarri people do not use boats for fishing, they walk along the long beach with spears. Another method of fishing is using rock pools that are filled with water and fishes at high tide. The fishes are collected when the tide is low. Cooking the food is almost the same between the two people but there are some small differences.

For the Karajarri people traditional fishing and hunting are regulated by six seasons. The expedition took place during **Laja** (October-November), the 'build up' hot season, when both stingray and lemon shark are fat and good to eat and the flatback turtle will come up to the beach to lay eggs. The other seasons are **Mankala** (December-March): The rainy season. Stingrays remain fat until the wet starts. Reef fish are fat and targeted with *Panjurta*/poison and *Kurrjungu*/stone fish traps; **Marul** (April-May): Season after the rain. Reef fish are skinny. Increase ceremonies for *Panganu*/salmon; **Wiralpuru** (May-June): The first cool southeast winds, *Wiralpuru* begin to blow. The sea becomes muddy. Reef fish remain 'skinny'. Salmon and mullet are running in shoals. *Yari*/ humpback whales begin to breach; **Parrkana** (July-August): 'Winter time' when cold southeast winds, *Wiralpuru* blow. No reef or poison, *Panjurta* fishing takes place. Instead woven fishtraps, *Marrku* are used in creeks to catch *Panganu*/salmon and *Kulpany*/ mullet and **Wilpuru** (September): A short warm period, before the hot weather returns. *Karanimarra*/ westerly winds are starting to blow. The sea becomes clear. Reef and shellfish begin to get 'fat'. Increase ceremonies for bluebone and other reeffish take place.

The Nyangumarta and Karajarri people have their own names for shorebirds. The Karajarri language name for seabirds and waders is *Tarrtarr*. The word for mud is *Kulji*. All stingray types are called *Pintany*. Whiptail stingray is *Mukwarl*, Coconuttail stingray is *Yupukurru*, Oysterback stingray is *Jankaparri*. All identification of turtle are called *Wilarrt*. Nyangumarta and Karajarri people have noticed a reduction in salmon and turtle numbers over the last few years.

Based on an interview with Nathan Hunter, Parks and Wildlife Trainee Ranger (Nyangumarta), and with Karajarri Rangers Wynston Shovellor and James" Shorty" Bellou and with Jackie Wemyss, Karajarri Ranger Coordinator. The Nyangumarta and Karajarri rangers are caring for their country by combining traditional knowledge and western science. They carry out flora and fauna monitoring, weed and feral animal management, cultural heritage, site protection, visitor surveys, patrols and fire activities. They pass down the knowledge to new generations going to schools and organising school holidayprograms in which the children learn about traditions, for example how to spear fish and to hunt.

5. Methods

Sampling set-up

The Roebuck Bay study took place largely between Crab Creek in the northeast and Town Beach in the northwest (Fig. 1) between the 5th and the 11th of October and along 80 km of Eighty Mile Beach between the 13th and the 19th of October, from 10 km north of the beach access to Anna Plains to 65 km south of it (Fig. 2). With a neap tide on the 11th of October and a spring tide on the 18th of October, sampling at Roebuck Bay took place with declining tidal ranges (eventually limiting the extent of sampling coverage), whereas at Eighty Mile Beach we worked with increasing tidal amplitudes.

Sampling stations were placed on a 200 m grid; the only exception being in the southeast part of Roebuck Bay where the grid was 400 m. We tried to cover as much as possible of the areas sampled in June, 2006 (the most extensive prior sampling of the northern foreshore of Roebuck Bay). Every sampling station received a unique station number composed of a row number (from south to north), a column number (from west to east) and an indicator of north (n) or south (s), and example being “r21c33n” (Fig. 3). Each station number combined with predetermined co-ordinates on a UTM zone 51 coordinate system grid (WGS 1984 datum). Navigating to the stations by GPS, teams of 2-4 people visited each of the stations based upon pre-assigned geographical co-ordinates (see Fig. 3 for an example of an individual team map). At Roebuck Bay, 213 samples were taken by teams on foot, but the whole area east of the BBO and the deep muddy areas around Crab Creek, were visited by a team on hovercraft (113 samples) or a team using the long core from a boat (just over 200 samples) (Fig. 1). The full workflow is shown in Fig. 4.

At Eighty Mile Beach, we did not have access to a boat, but the hovercraft was transported south to use for sampling on the first three days. Most samples (646) were taken by foot, especially at the sandy sampling sites at 20, 35, 50, and 65 km blocks. 170 samples were collected using the hovercraft in hard to reach, deep muddy locations sites at the -10 and +5 km blocks.

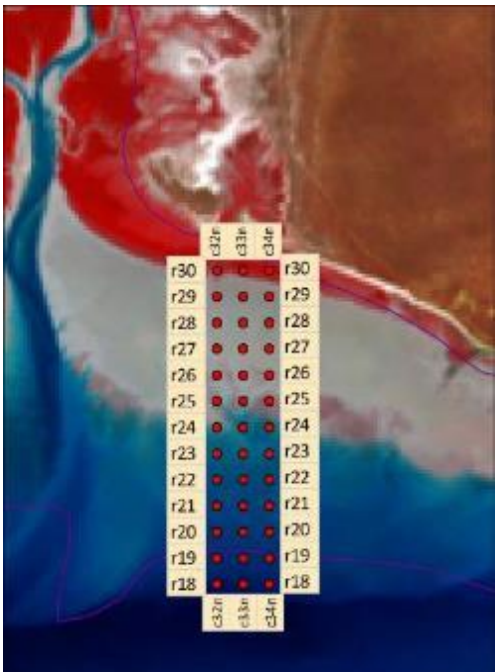


Fig. 3. Example of the field map with ‘hopeful’ sampling stations for a foot team on 7 October, 2016. Similar maps were created for every field team by Bob Hickey. Naming in rows (r) and columns (c).

Fig. 4. Workflow during the AnnRoeBIM16 expeditions. This is a summary of the scientific work and does not include the many necessary domestic chores that kept this expedition going. Compiled from photographs by Theunis Piersma and Angela Rossen.

At each station visited by foot or hovercraft, 100 mm diameter corers made of PVC-pipe were pushed down to a depth of 20 cm (less if the corer hit a hard shell layer below which we expect no benthic animals to live). Three individual core samples were taken, each covering 1/120 m^2, with the three cores pooled in a sieve of 1 mm mesh size. When sampling from the boat, a 2 meter long aluminium corer was used to take the 3 cores for the benthos, with an extra core taken for sediment composition analysis.. When using the long corer, sample sites with a water depth of 0.4 to 2.10 m can be reached, extending the time spent sampling by a few hours. Boat-based teams started around low tide at the deepest areas and working their way up the mudflat gradient with the incoming tide until it got too deep. On neap tides it was possible to sample from the boat even around high tide.

The three core samples from each site had a total surface area of 1/40 m². They were sieved over a 1 mm mesh and the remains retained on the sieve were placed into a plastic bag, to which a waterproof label indicating the station was added. At the same time, at all stations a sediment sample was taken to a depth of 10 cm with a diameter of 3.0 cm, either directly from the area (on foot or hovercraft), or from an extra core (boat sampling). This sample was stored in a labelled plastic vial and kept at outside temperature for transport to the laboratory. These sediment samples will be analysed on a Coulter LS 13 320 laser particle size analyser at NIOZ, Texel, The Netherlands.

In the field, records were made of the nature of the sediment (varying from mud to coarse sand) by way of penetrability (depth of footsteps made by a person, in cm) and the presence of visible larger (and less likely to be found in cores) animals on the mud surface (e.g. seagrass cover, sentinel crabs, anemones, or Ingrid-eating snails *Nassarius dorsatus*). 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 either the Broome Bird Observatory (Roebuck Bay) or Anna Plains Station (Eighty Mile Beach) and immediately sorted in white, low plastic trays. Most animals were still vividly alive, which made sorting quite efficient even by people without much knowledge of marine invertebrates. In a few cases, bagged samples were stored in a fridge at 4°C for half a day before sorting. 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. We developed a routine by which each tray was cross-checked by a second sorter before declared finished.

On the basis of morphological characteristics all invertebrates were assigned to a taxonomic category (preferably at the species level) to which a scientific name was given (if possible) or if not, a field name was coined (see Table 1). At the same time, the maximum length (in 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 of use in making predictions of the benthic biomass values using existing equations (NIOZ unpubl. data). We also upgraded the historical reference collection in ethanol for more detailed study of the species at a later stage. Representatives of polychaete species collected were preserved for later detailed examination by Chris Glasby of the Museum and Art Gallery Northern Territoryin Darwin, NT.

Photo 2. Busy samplers at a sandy spot along Eighty Mile Beach. Photo by Angela Rossen.

Mapping

Once more, maps were the foundation upon which a benthic sampling expedition was based. Fortunately, all prior datasets were available in geographic information system (GIS) format. Recent Landsat 7 images were downloaded and used as the primary base maps. The point grids were generated using a custom Visual Basic program and included UTM zone 51 (WGS 1984 datum) co-ordinates and a unique identifier. Custom maps were generated for every field mapping team on a Landsat image base (see Fig. 3 for an example). Each map included a printed spreadsheet showing the UTM coordinates and the unique identifier.

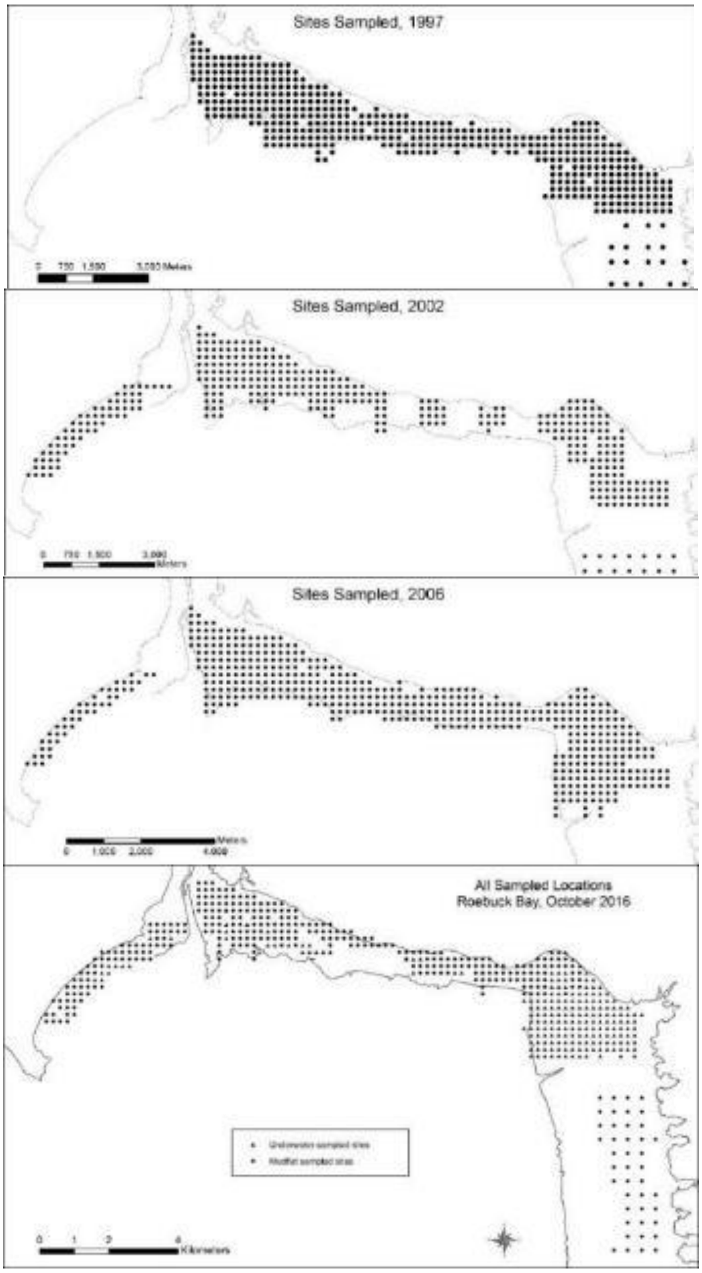


Fig. 5. The extent of the grids along the northern shore sampled in June 1997, June 2002, June 2006, and October 2016. In 1997, we did not cover Town Beach in the west, and in 2002 sampling along the northern shores was limited to bird mapping areas.

Sample points were located in the field using handheld Garmin GPS receivers of two different models. They were invaluable for finding sample sites on the otherwise nearly featureless mudflats. For those that were keen, sample points were entered as waypoints into GPS receivers – thereby making the finding of those points even simpler. Progress maps showing sites sampled to date were generated daily and used during evening briefings.

Once the field sampling was complete, all field and species data were entered into Excel files which formed the base of the GIS database. The extent of the areas surveyed in 2016 in comparison with earlier efforts are shown in Figs. 5 and 6. The lines on the black-and-white maps that more or less enclose the sampled stations represent the spring high and low water lines.

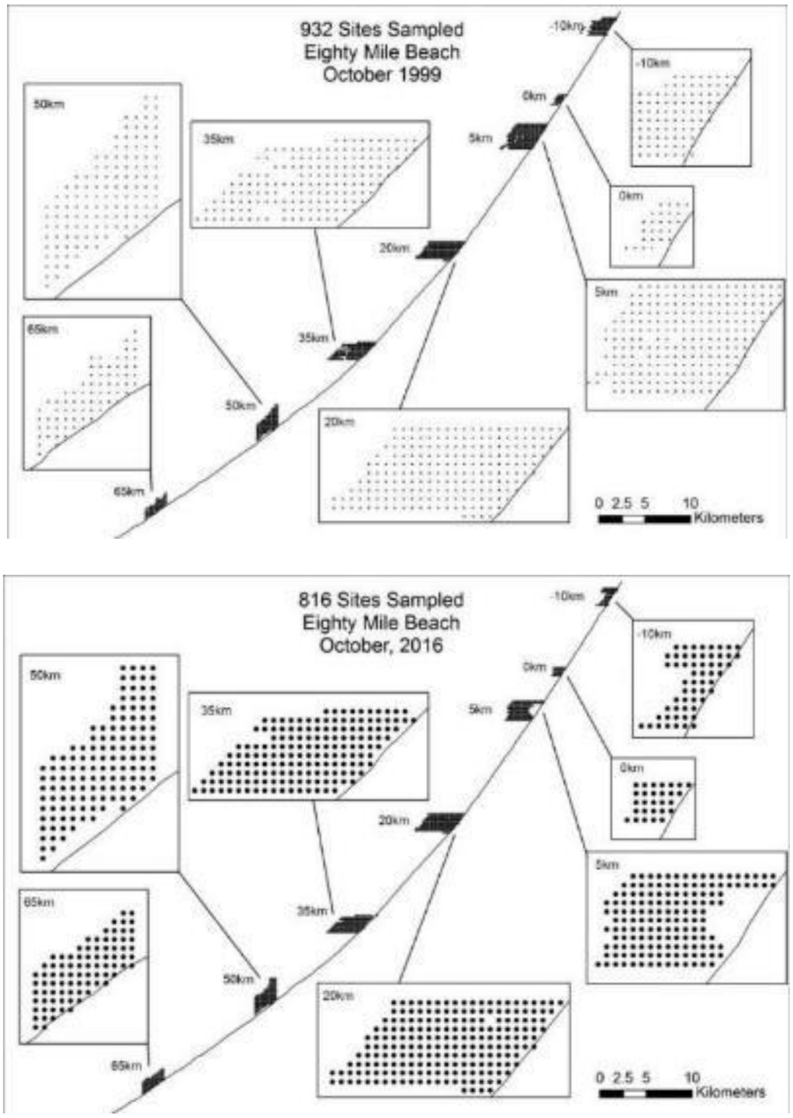


Fig. 6. Extents of the two intertidal benthic surveys along the Eighty Mile Beach foreshore in October 1999 and in October 2016.

Photo 4. Underway to the sections along Eighty Mile Beach to be surveyed. Photo by Hebo Peng.

Photo 5. Getting ready for the drive back to Anna Plains Station after a successful series of sampling transects on the sometimes deep mud along Eighty Mile Beach. Photo by Theunis Piersma.

Photo 6. Sample ID at the Broome Bird Observatory. Photo by Marc Lavaleye.

6. Results and discussions

What's the mud like? Mapping how deep benthic samplers sink!

In sedimentary environments, i.e. most ocean and sea floors including the sand- and mudflats of the intertidal areas of Roebuck Bay and Eighty Mile Beach, sediment characteristics are a defining part of life. To a buried bivalve, a sea star, or a sipunculid, it matters a great deal whether it finds itself on, and in, relatively coarse sand or very fine-grained mud. Sediment characteristics also matter to the people doing benthic mapping. Most sands provide stable, hard substrates to walk on; mapping is like a stroll on a sandy beach. Life as a sampler can be quite different in fine-grained soft muds, especially in conditions when one sinks deeper than the knees. Locomotion becomes tedious, or, for some of us, utterly impossible! In 2016 we had the good fortune to have the help of a hovercraft (both in Roebuck Bay and Eighty Mile Beach) and a boat (in Roebuck Bay) to access and sample such challenging areas of mudflat.

Again, we routinely recorded the depth of the footsteps on the field sheets, calling the measure 'penetrability'; a relative measure to differentiate areas of firm sand from those of shallow, or deep soft mud. Figure 7 shows how penetrability values are distributed over the northern shores of Roebuck Bay (mapped more extensively in 2006 as we were not using a boat then, and in boat-sampled sites in 2016 we were unable to record penetrability). The deep inshore mud between the BBO foreshore and Crab Creek stands out, as do the nearshore patches of mud along the northern foreshore (especially near the mangroves along Dampier Flats) where a person sank to depths of up to 15 cm, above ankle-deep. Town Beach, and actually most of the northern foreshore, was rather hard and sandy in 2006, and the pattern of penetrability does not appear to have changed significantly over the last decade.

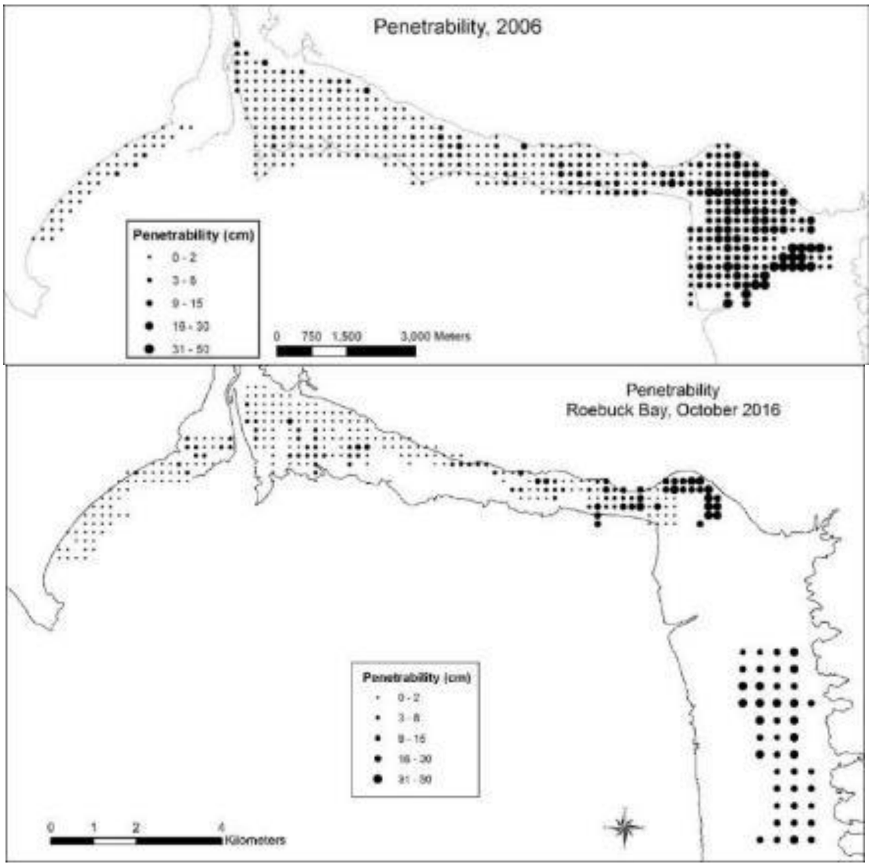


Fig. 7. Depths to which benthic samplers sank in the sediments (denoted with the term 'penetrability') in June 2006 (top) and in October 2016 (bottom) on the northern intertidal areas of Roebuck Bay.

Penetrability on the tidal flats of Eighty Mile Beach in 1999 and 2016 is compared in Fig. 8. There are some broad similarities in pattern. In both years, there was a tendency for the tidal flats to be muddier in the north and more sandy in the south. In both years, there was a tendency for upper levels of the tidal flats to be firm, for the mid-levels of the tidal flats (about 1-2 km from the beach) to be softer, and for the outer levels of the tidal flats (beyond 2 km from the beach) to become firmer again. And once again, the tidal flats were mostly very broad (up to 4 km wide), narrowing to the north of the access point to Eighty Mile Beach (at 0 km). Note that the full width of the tidal flats is not represented accurately for the survey block at 65 km S, which was only sampled on neap low tides. Nor is it represented accurately at 0 km S, which was only partially sampled, to the relief of the samplers floundering in the deep mud at that site. The tidal flats were some 4 km wide opposite the beach from 0 km S to at least 50 km S, representing a vast potential foraging area for shorebirds along a section of beach which has traditionally held the largest shorebird numbers. This section of beach has been listed as an "A Zone" in the new marine park and has been proposed as a sanctuary zone. Both shorebird numbers along this section, and the physical characteristics of the tidal flats, suggest that it is indeed an area of particularly high conservation value.

On a finer scale, there were some differences between penetrability in 1999 and 2016. From 20 km S to 65 km S, the tidal flats were more extensively firm, with fewer muddy sections. Some patches that were muddy in 1999 remained muddy in 2016 (notably the softer patches of the 20 km section), but otherwise the correspondence was not particularly close. In contrast, the northern parts of the tidal flats (at 5, 0 and -10 km S) became muddier, making these sections punishing for the teams that were sampling on foot. As in 1999, there were areas on the tidal flats with a complex jumble of small eroding mudbanks, raised a few cm around adjacent shallow pools (Photo 7). The penetrability maps suggest that the precise location of these mudbanks has changed over the years, consistent with impression in 1999 that these are dynamic features.

The overall impression was that the soft areas of the tidal flats became softer and the firm areas of the tidal flats became firmer. With only two sampling expeditions 17 years apart, we cannot be sure of what drives these patterns, and whether the changes are gradual, or sudden events caused by cyclones. At the time we sampled in 2016, there had been relatively few cyclones hitting Eighty Mile Beach in previous years. In contrast, the 1999 expedition followed some seasons in which several cyclones had hit the north-western Australian coast. On a practical level, the penetrability maps offer helpful guidance to planning future monitoring of the benthos of the tidal flats of Eighty Mile Beach. One conclusion we are sure of is that the tidal flats near the access point to Eighty Mile Beach are very soft and very broad. While we managed to sample large parts of them on foot, this kind of effort would not be sustainable or safe unless it is supported by a hovercraft. We consider this a priority, as these are also the tidal flats that are richest in shorebirds, and therefore a priority for monitoring.

Photo 7. Impression of the small patches of mud on a hard layer of muddy sand at Eighty Mile Beach. Photo by Theunis Piersma.

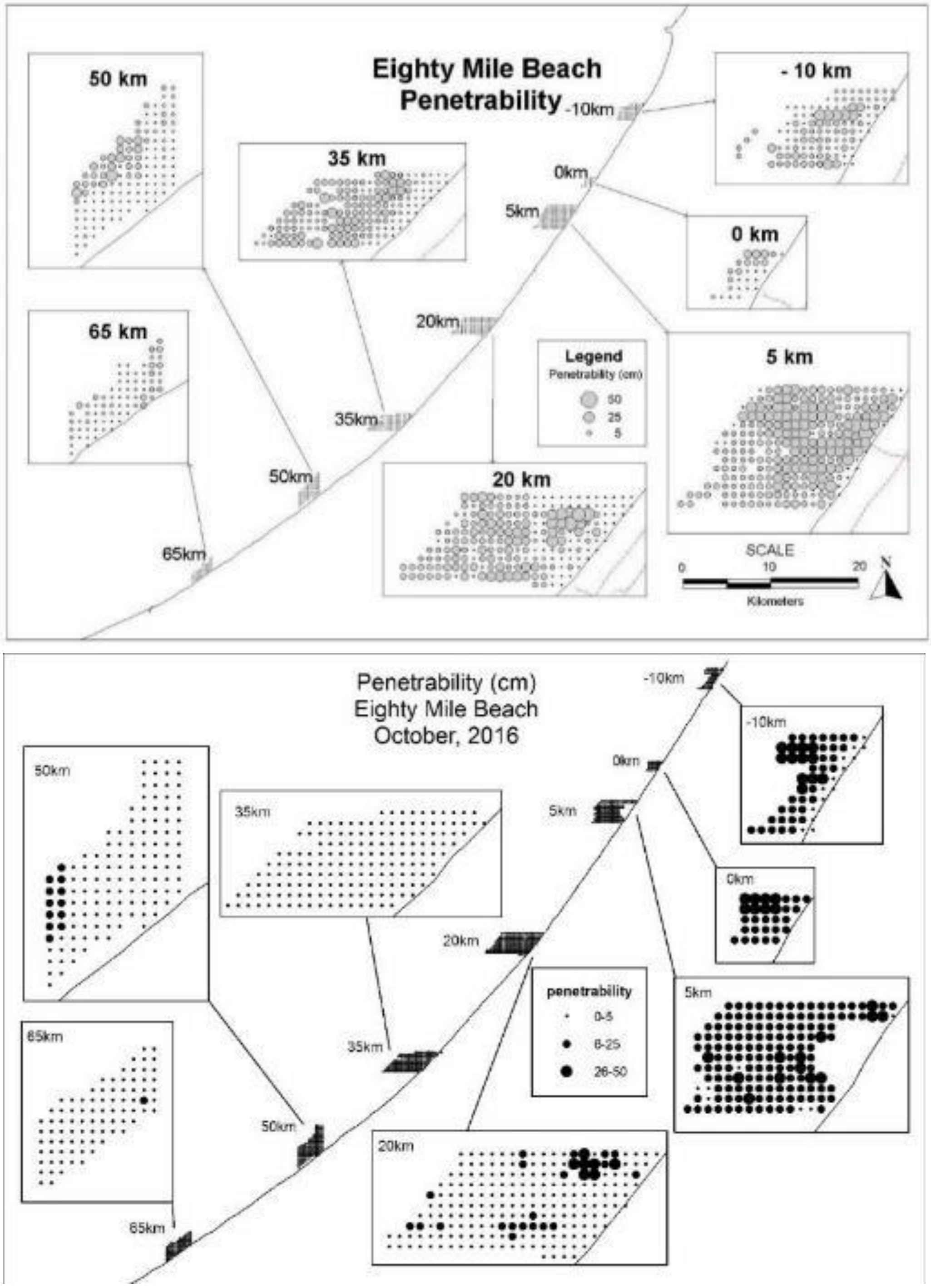


Fig. 8. Depths to which benthic samplers sank in the soft sediments (denoted with the term 'penetrability') in October 1999 (top) and 2016 (bottom) on the intertidal flats off Eighty Mile Beach.

Daunting levels of benthic biodiversity: the species list

The biodiversity of the animals found in the cores was very high compared with other intertidal areas of soft sediments in the world. In the Roebuck Bay survey 368 species were found, while in the Eighty Mile Beach survey this number was considerable lower, namely 156 species. The combined lists give a figure of 433 species. Some 30 names may be synonyms of other species in the list, but on the other hand other names or group names certainly contain more species (e.g. *Macrophthalmus*, Caridea). Taking this in consideration, the actual species number for both areas together will probably be higher than 433.

Major groups that were not found at Eighty Mile Beach compared with Roebuck Bay are Asteroidea, Brachiopoda, Hirudinea, Oligochaeta, Platyhelminthes, Polyplacophora and Pycnogonida. Most of these groups are rare in Roebuck Bay or too large (starfishes, Asteroidea) to collect quantitatively with our sampling technique, but for Brachiopoda (lamp-shells) and Pycnogonida (seaspiders) it is a surprise that they were not found at Eighty Mile Beach. The only major group not found in Roebuck Bay was the Branchiura (sea louse), represented by only one specimen at Eighty Mile. The most diverse group were the Polychaeta with 167 species, followed by Crustacea (74), Bivalvia (59), Gastropoda (59) and Echinodermata (35). All other groups contain less than 12 species.

The two areas have 92 species in common, which in the case of Eighty Mile Beach means that 60% of the species also occur in Roebuck Bay. Of course, this also means that 40% of the taxa of Eighty Mile Beach, i.e. 65 taxa, were not found in Roebuck Bay. Some of the most common of species at Eighty Mile Beach not found or very rare in Roebuck Bay were two species of Spionidae (Polychaeta), a small seacucumber with dark coloured spots all over its body, another larger seacucumber *Paracaudina chilensis*, two bivalve species of the genus *Tellina*, and two species of anemones. Clearly, Roebuck Bay had a lot of species (277) not found at Eighty Mile Beach. The most common of these was the relatively large bivalve *Tellina piratica*, followed by the smooth tusk shell (*Laevidentalium lubricatum*), and the polychaete family Sternaspidae. These last short thick worms with two brown-coloured shields on the backs were nick-named Mickey Mouse worms by our identification teams. Other examples are the bivalves *Solemya terraereginae*, *Anomalocardia squamosa* and *Ctena spec.*, the seasquirt which we called the rooted Tunicata, the snail *Isanda coronata*, and the small crab *Halicarcinus australis*. It is also remarkable that the small Ostracoda were almost absent at Eighty Mile Beach.

The large difference in biodiversity between Roebuck Bay and Eighty Mile Beach may be caused by several different factors. Roebuck Bay has a greater variety of sedimentary habitats than Eighty Mile Beach (Compton *et al*. 2008). Mapping makes it clear that e.g. mangroves have a clear influence on the flats that reaches up to 200 m out on to the open flats. Species like *Cerithidea cingulata*, *Salinator burmana* and the small Ingrid snail (*Nassarius* spec.) are only found in these areas. Rocky areas and larger creeks like Crab Creek and Dampier Creek have their influence too. These are all habitats that do not exist in Eighty Mile Beach. Furthermore, Eighty Mile Beach is completely exposed to wave action from the Indian Ocean, while Roebuck Bay is protected by the peninsula on which Broome is situated. Therefore, notorious ‘ecosystem engineers’ such as the seagrasses quite extensively occur on the intertidal area of Roebuck Bay, but are not found at Eighty Mile Beach. These seagrass mats of *Halodula uninervis* and *Halophila ovalis* form a special habitat for e.g. the little snail *Smaragdia souverbiana.* Influence of Broome city by episodic eutrophication, of which blooms of the cyanobacteria mats of Lyngbya are an indication, certainly can have a negative influence on the overall biodiversity of the bay. However, as opportunistic species can benefit from the additional extra input of nutrients there is a potential change the very nature of the Bay’s infauna.

We want to stress here that most the names for species that we use in this report have to be treated as field names and not as valid scientific names. A reference collection of all species has been made which, in due course, will be checked by taxonomic specialist. For the polychaetes, a special collection has been made by Chris Glasby and Amanda Lilleyman for the Northern Territory Museum, Darwin, and will be properly identified in due time by Chris Glasby. This work will be reported on separately in the future (C. Glasby in prep.). Further, a collection of many species is left at the Broome Bird Observatory for future reference. A collection of Echinodermata was assembled by Loisette Marsh for the Western Australian Museum Perth, were she will work on it. Furthermore, a reference collection of most species will be available at the NIOZ too. One of the groups that needs urgent attention is the group of sentinel crabs in the genus *Macrophthalmus.* We noticed that there are several distinct species, and tried to collect some extra material, as these relatively large crabs were rarely collected by our quantitative sampling with the cores. We hope to complete some positive identifications soon. The nearshore and beach-living fiddler crabs (*Uca* sp.) with at least 5 species in Roebuck Bay (Pepping *et al.* 1999) and ghost crabs (*Ocypode* sp.) with 2 species were not found in the samples collected, although they were all seen in their normal habitats and demonstrates that the bay hosts more species than we encountered in our samples.

Table 1. Species list of the 433 different taxa of intertidal macrobenthic invertebrates found in the quantitative samples during AnnRoeBIM16.

Field names	Family/Order	Class/Phylum	Roebuck Bay stations	80 Mile Beach stations
Acteonidae	Acteonidae	Gastropoda	2	16
Actiniaria	Actiniaria	Cnidaria	1	
Actiniaria white	Actiniaria	Cnidaria	1	
Actiniaria white spot	Actiniaria	Cnidaria		19
Alpheidae	Caridea	Crustacea	5	
Amaeana	Terebellidae	Polychaeta	2	
Ampharetidae	Ampharetidae	Polychaeta	3	
Ampharetidae 2	Ampharetidae	Polychaeta	10	
Ampharetidae 3	Ampharetidae	Polychaeta	3	
Ampharetidae Diplocirrus	Ampharetidae	Polychaeta	1	
Ampharetidae sp. 3	Ampharetidae	Polychaeta	1	
Ampharetidae with 4 tentacles	Ampharetidae	Polychaeta	1	
Amphinomidae	Amphinomidae	Polychaeta	14	
Amphinomidae-Pseudeurythoe	Amphinomidae	Polychaeta	50	
Amphipholis squamata	Amphiuridae	Ophiuroidea	5	
Amphipoda	Amphipoda	Crustacea	56	13
Amphipoda – Ampelisca	Amphipoda	Crustacea	1	
Amphipoda big claw	Amphipoda	Crustacea		1
Amphipoda black dots eyes	Amphipoda	Crustacea	2	
Amphipoda black eye	Amphipoda	Crustacea		1
Amphipoda fused eye	Amphipoda	Crustacea		1
Amphipoda pointed head	Amphipoda	Crustacea		13
Amphipoda red eye	Amphipoda	Crustacea		1
Amphipoda sp 1	Amphipoda	Crustacea	5	
Amphipoda sp 2	Amphipoda	Crustacea	1	
Amphipoda speckled eye	Amphipoda	Crustacea		2
Amphipoda white eye	Amphipoda	Crustacea		2
Amphipoda white head	Amphipoda	Crustacea	1	1
Amphipoda-Jassa	Amphipoda	Crustacea		1
Amphipoda-Urothoe	Amphipoda	Crustacea		6

Amphiura spotted	Amphiuridae	Ophiuroidea	50	
Amphiura tenuis	Amphiuridae	Ophiuroidea	199	540
Amphiuridae	Amphiuridae	Ophiuroidea	58	
Amphiuridae (small arms)	Amphiuridae	Ophiuroidea	1	
Amphiuridae dark disc	Amphiuridae	Ophiuroidea	1	
Anadara granosa	Arcidae	Bivalvia	7	
Anodontia omissa	Lucinidae	Bivalvia	62	22
Anomalocardia squamosa	Veneridae	Bivalvia	50	
Anthuridea	Isopoda	Crustacea	25	18
Aplysidae (grey speckled seahare)	Aplysidae	Gastropoda	1	
Arabelloneris	Oenonidae	Polychaeta	12	
Arachnoides tenuis	Clypeasteridae	Echinoidea	2	25
Armandia	Opheliidae	Polychaeta	20	
Armandia with eyes	Opheliidae	Polychaeta	7	
Asteroidea	Asteroidea	Asteroidea	2	
Astropecten granulatus	Asteroidea	Asteroidea	1	
Atys	Haminoeidae	Gastropoda	12	1
Balanoglossus		Enteropneusta	5	38
Balanoglossus long head		Enteropneusta		1
Bivalvia	Bivalvia	Bivalvia	4	1
blue pincer Macrophthalmus	Ocypodidae	Crustacea	1	
Brachyura	Brachyura	Crustacea	5	
Branchiura - sealice	Branchiura	Branchiura		1
Bullidae	Bullidae	Gastropoda	3	
Callianassidae	Callianassidae	Crustacea	2	45
Callionymus fish	Fish	Fish	1	
Calliostoma	Trochidae	Gastropoda	1	
Capitellidae	Capitellidae	Polychaeta	71	402
Capitellidae (Heteromastus)	Capitellidae	Polychaeta	2	
Capitellidae (Notomastus sp.1)			4	
Capitellidae (Notomastus sp.2)			21	
Capitellidae (Notomastus)	Capitellidae	Polychaeta	13	
Capitellidae black spot	Capitellidae	Polychaeta		1
Caridea			48	12
Cerithidea cingulata	Potamidae	Gastropoda	16	
Chaetopteridae	Chaetopteridae	Poychaeta	44	2
Chiton		Polyplacophora	2	
Cirolanidae	Isopoda	Crustacea	9	2
Cirratulidae	Cirratulidae	Polychaeta	16	30
Cirratulidae brown	Cirratulidae	Polychaeta		19
Cirratulidae red	Cirratulidae	Polychaeta	1	14
Cirratulidae sp. 1	Cirratulidae	Polychaeta	4	
Clementia papyracea		Bivalvia	1	
Columbellidae	Columbellidae	Gastropoda	5	
Columbellidae brown	Columbellidae	Gastropoda	1	
Columbellidae brown large	Columbellidae	Gastropoda	2	
Columbellidae small brown	Columbellidae	Gastropoda	5	
Columbellidae sp 1	Columbellidae	Gastropoda	2	
Columbellidae sp 2	Columbellidae	Gastropoda	1	

Cominella acutinodosa	Gastropoda	Gastropoda	1	
Copepoda	Copepoda	Crustacea		1
Corbula macgillivrayi	Corbulidae	Bivalvia	1	
Corophiidae	Amphipoda	Crustacea	14	
Corophiidae hermit	Amphipoda	Crustacea	12	47
Ctena	Lucinidae	Bivalvia	39	
Ctena flat	Lucinidae	Bivalvia	1	1
Cumacea	Cumacea	Crustacea	12	16
Cumacea 2 cross ribs	Cumacea	Crustacea	1	
Cumacea double eye	Cumacea	Crustacea	1	
Cumacea rough	Cumacea	Crustacea	2	
Cumacea smooth	Cumacea	Crustacea	4	
Cyathura	Anthuridae	Crustacea	1	
Cymatiidae	Cymatiidae	Gastropoda	1	
Cynoglossidae	Cynoglossidae	fish	1	4
Dentalium bartonae	Dentaliidae	Scaphopoda	19	
Dictenophiura stellata	Ophiuridae	Ophiuroidea	5	
Diopatra	Onuphidae	Polychaeta	13	
Diopatra amboinensis	Onuphidae	Polychaeta	21	
Diopatra hanleyi	Onuphidae	Polychaeta	2	
Diopatra white ringed	Onuphidae	Polychaeta	9	265
Divaricella irpex	Lucinidae	Bivalvia	87	177
Donax cuneatus	Donacidae	Bivalvia		1
Dorippe	Dorippidae	Crustacea	4	
Ebalia C	Leucosiidae	Crustacea	1	16
Echinoidea		Echinoidea	1	
Echiura		Echiura	1	1
Edwardsia sand	Actiniaria	Cnidaria	12	2
Edwardsia white spot	Actiniaria	Cnidaria		25
Ensiculus cultellus	Pharidae	Bivalvia	11	1
Epitonium	Epitoniidae	Gastropoda		1
Eulima	Eulima	Gastropoda	15	
Eulima sp. 2	Eulima	Gastropoda	1	
Eulimidae	Eulimidae	Gastropoda		1
Eunicidae	Eunicidae	Polychaeta	6	
Eurydice	Isopoda	Crustacea	7	14
Fabriciidae	Fabriciidae	Polychaeta	14	
Fasciolaridae	Fasciolaridae	Gastropoda	1	
Fenella	Diastomidae	Gastropoda	14	
Flabelligeridae	Flabelligeridae	Polychaeta	12	
Gafrarium dispar	Veneridae	Bivalvia	15	
Galeommatidae	Galeommatidae	Bivalvia		7
Galeommatidae round	Galeommatidae	Bivalvia	1	
Gari lessoni	Psammobiidae	Bivalvia	5	
Gastropoda	Gastropoda	Gastropoda	1	
Glycera nicobarica	Glyceridae	Polychaeta	19	
Glyceridae	Glyceridae	Polychaeta	79	
Glyceridae red line	Glyceridae	Polychaeta		269
Glyceridae sp.3	Glyceridae	Polychaeta	1	
Glycymeris	Glycymeriidae	Bivalvia		2

Gobiidae	Gobiidae	fish	13	4
Goneplacidae 8 legs	Goneplacidae	Crustacea	1	
Goniadidae	Goniadidae	Polychaeta	67	56
Goniadidae green	Goniadidae	Polychaeta	2	
Goniadidae small 2 black eyes	Goniadidae	Polychaeta	1	
Goniadidae sp. 1	Goniadidae	Polychaeta	13	
Goniadidae sp. 2	Goniadidae	Polychaeta	3	
Goniadidae sp. 3	Goniadidae	Polychaeta	2	
Halicarcinus australis	Hymenosomatidae	Crustacea	34	
Hermundura sp.	Pilargiidae	Polychaeta	1	
Hesionidae	Hesionidae	Polychaeta	1	
Heterocardia gibbosula	Mactridae	Bivalvia	19	70
Hexapus	Goneplacidae	Crustacea	32	9
Hirudinea	Hirudinea	Hirudinea	1	
Holothuroidea		Holothuroidea	15	47
Holothuroidea black			1	
Holothuroidea dark spot		Holothuroidea		67
Holothuroidea dendrochirate		Holothuroidea	3	
Holothuroidea green		Holothuroidea		1
Holothuroidea grey		Holothuroidea		2
Holothuroidea rose		Holothuroidea		20
Holothuroidea white		Holothuroidea	1	
Holthuroidea hairy		Holothuroidea	4	
Hyastenus	Majidae	Crustacea	15	
Isanda coronata	Trochidae	Gastropoda	20	
Isolda	Ampharetidae	Polychaeta	9	
Kellia	Kelliidae	Bivalvia	2	
Laevidentalium lubricatum	Dentaliidae	Scaphopoda	95	
Laternula creccina	Laternulidae	Bivalvia	1	
Ledella	Ledella	Bivalvia	2	
Leucosia D	Leucosiidae	Crustacea	3	1
Leucosia flatback	Leucosiidae	Crustacea	1	
Leucosia juv	Leucosiidae	Crustacea	1	
Leucotina	Pyramidellidae	Gastropoda	3	
Liloa		Gastropoda	7	
Lingula anatina	Lingulidae	Brachiopoda	8	
Lumbrineridae	Lumbrineridae	Polychaeta	65	3
Lumbrineridae sp.2	Lumbrineridae	Polychaeta	7	
Lumbrineridae sp.3	Lumbrineridae	Polychaeta	1	
Lumbrineridae sp.4	Lumbrineridae	Polychaeta	7	
Lumbrinidae (Arabellonereis)	Lumbrineridae	Polychaeta	1	
Lysidice	Eunicidae	Polychaeta	1	
Macrophiothrix	Ophiuridae	Ophiuroidea	1	
Macrophthalmus	Ocypodidae	Crustacea	241	182
Mactra brown	Mactridae	Bivalvia	1	
Mactra inflated	Mactridae	Bivalvia	2	
Mactridae	Mactridae	Bivalvia	1	
Magelonidae	Magelonidae	Bivalvia	6	
Magelonidae red tube new	Magelonidae	Polychaeta	1	
Maldanidae	Maldanidae	Polychaeta	70	

Maldanidae 2	Maldanidae	Polychaeta	3	
Maldanidae blocked	Maldanidae	Polychaeta	2	
Maldanidae brown/green	Maldanidae	Polychaeta	4	
Maldanidae no notch	Maldanidae	Polychaeta	1	36
Maldanidae soft tube	Maldanidae	Polychaeta	1	
Maldanidae sp. 3	Maldanidae	Polychaeta	7	
Maldanidae white head	Maldanidae	Polychaeta	1	
Maldanidae without notch	Maldanidae	Polychaeta	8	
Mangelia	Turridae	Gastropoda	5	
Marcia (Hemitapes) hiantina	Veneridae	Bivalvia	1	
Marginellidae	Marginellidae	Gastropoda	9	26
Mediomastus sp.	Capitellidae	Polychaeta	4	
Mictyris longicarpus	Mictyridae	Crustacea	11	13
Mitra	Mitridae	Gastropoda	1	
Mitrella essingtonensis	Columbellidae	Gastropoda	13	39
Mitrella marmor	Columbellidae	Gastropoda	6	
Mitridae	Mitridae	Gastropoda	4	
Modiolus micropterus	Mytilidae	Bivalvia	1	1
mole crab	Hippidae	Crustacea		5
Musculus	Mytilidae	Bivalvia	4	
Myra endactylus	Leucosiidae	Crustacea	1	2
Mysella	Montacutidae	Bivalvia		1
Mysella dirty	Montacutidae	Bivalvia	1	
Mysella ribbed	Montacutidae	Bivalvia	1	2
Mysidacea	Mysidacea	Crustacea	21	
Nassarius bicallosus	Nassariidae	Gastropoda		13
Nassarius dorsatus	Nassariidae	Gastropoda	49	148
Natica	Naticidae	Gastropoda	5	
Natica brown band	Naticidae	Gastropoda	1	
Natica dull	Naticidae	Gastropoda	5	
Natica pink marking	Naticidae	Gastropoda	2	
Natica with nice spots	Naticidae	Gastropoda	3	
Nemertea		Nemertea	32	32
Nemertea arrowhead		Nemertea	5	29
Nemertea brown		Nemertea		1
Nemertea green		Nemertea		1
Nemertea orange		Nemertea	6	1
Nemertea pale red spot on head		Nemertea	1	
Nemertea red		Nemertea	5	5
Nemertea rose		Nemertea		5
Nemertea white		Nemertea	2	5
Nemertea white eyes		Nemertea		1
Nemertina pink		Nemertea		1
Nephtyidae	Nephtyidae	Polychaeta	123	301
Nereididae	Nereididae	Polychaeta	55	7
Nucula	Nuculidae	Bivalvia	15	1
Nudibranchia	Nudibranchia	Gastropoda	1	1
Nudibranchia-Aeolidia	Nudibranchia	Gastropoda	1	
Nursia abbreviata	Leucosiidae	Crustacea	2	
Odostomia	Pyramidellidae	Gastropoda	1	1

Oenonidae	Oenonidae	Polychaeta	2	
Oenonidae sp. 3	Oenonidae	Polychaeta	1	
Oligochaeta	Oligochaeta	Oligochaeta	2	
Onuphidae	Onuphidae	Polychaeta	16	
Onuphidae (Onuphis sp.1-AL)	Onuphidae	Polychaeta	1	
Onuphidae 3	Onuphidae	Polychaeta	2	
Onuphidae 4	Onuphidae	Polychaeta	2	
Onuphidae 5	Onuphidae	Polychaeta	1	
Onuphidae 6	Onuphidae	Polychaeta	1	
Onuphidae white ring	Onuphidae	Polychaeta		7
Opheliidae	Opheliidae	Polychaeta	4	
Opheliidae sp. 2	Opheliidae	Polychaeta	1	
Opheliidae with eyespot	Opheliidae	Polychaeta	10	
Ophelina without eyes	Opheliidae	Polychaeta	12	
Ophiactidae	Ophiactidae	Ophiuroidea	1	
Ophiocentrus spiny disc		Ophiuroidea	11	
Ophiurid with eye spots		Ophiuroidea	1	
Ophiuroidea		Ophiuroidea	10	
Ophiuroidea large		Ophiuroidea	3	
Ophiuroidea large, blackwhite arms		Ophiuroidea	1	
Orbinidae new red dorsal cirri	Orbiniidae	Polychaeta	1	
Orbiniidae sp. 1	Orbiniidae	Polychaeta	3	
Orbiniidae sp. 2	Orbiniidae	Polychaeta	7	
Orbiniidae sp. 3	Orbiniidae	Polychaeta	2	
Orbiniidae-Heitoscoloplos	Orbiniidae	Polychaeta	3	
Orbiniidae	Orbiniidae	Polychaeta	73	65
Orbiniidae 1	Orbiniidae	Polychaeta	1	
Orbiniidae 2	Orbiniidae	Polychaeta	1	
Orbiniidae green	Orbiniidae	Polychaeta		12
Orbiniidae red	Orbiniidae	Polychaeta		4
Ostracoda	Ostracoda	Crustacea	51	1
Ostracoda 2 ribs	Ostracoda	Crustacea	3	
Ostracoda 2ridge	Ostracoda	Crustacea	1	
Ostracoda hairy	Ostracoda	Crustacea	21	
Ostracoda hairy puffy cheek	Ostracoda	Crustacea	1	
Ostracoda knobbed	Ostracoda	Crustacea	1	
Ostracoda long antenna	Ostracoda	Crustacea	1	
Ostracoda nose	Ostracoda	Crustacea	2	
Ostracoda oval	Ostracoda	Crustacea	20	
Ostracoda pointed	Ostracoda	Crustacea	4	
Ostracoda puffy cheek	Ostracoda	Crustacea	1	
Ostracoda rib and spine	Ostracoda	Crustacea	1	
Ostracoda ridged	Ostracoda	Crustacea	1	
Ostracoda round	Ostracoda	Crustacea	7	
Ostracoda smooth	Ostracoda	Crustacea	77	1
Ostracoda square	Ostracoda	Crustacea	2	
Oweniidae	Oweniidae	Polychaeta	75	287
Oweniidae (Gnathowenia sp. 2)	Oweniidae	Polychaeta	1	
Oweniidae (Owenia mirrawa)	Oweniidae	Polychaeta	27	
Oweniidae sp. 4	Oweniidae	Polychaeta	1	

Oweniidae tough tube	Oweniidae	Polychaeta	27	57
Oweniidae-Gnathowenia	Oweniidae	Polychaeta	2	
Oweniidae-Owenia	Oweniidae	Polychaeta	2	
Paguroidea - hermit crab	Anomura	Crustacea	82	74
Paphies altenai	Mesodesmatidae	Bivalvia		13
Paracaudina chilensis		Holothuroidea		35
Paraonidae	Paraonidae	Polychaeta	25	3
Paraonidae sp. 1	Paraonidae	Polychaeta	1	
Paraonidae sp. 2	Paraonidae	Polychaeta	3	
Pectinariidae	Pectinariidae	Polychaeta		1
Penaeidae	Caridae	Crustacea	7	
Pennatulacea	Pennatulacea	Cnidaria	1	
Peronella	Laganidae	Echinoidea		1
Peronella orbicularis	Laganidae	Echinoidea	8	
Peronella tuberculate	Laganidae	Echinoidea	2	
Phascolion	Phascolionidae	Sipuncula	4	
Phenellay sp 1		Polychaeta	1	
Phoronida	Phoronida	Phoronida	1	37
Phyllodocea noveahollandiae	Phyllodocidae	Polychaeta	8	
Phyllodocidae	Phyllodocidae	Polychaeta	3	5
Phyllodocidae black dots	Phyllodocidae	Polychaeta		4
Phyllodocidae brown	Phyllodocidae	Polychaeta	1	
Phyllodocidae brown blotched	Phyllodocidae	Polychaeta	1	
Phyllodocidae green	Phyllodocidae	Polychaeta	30	5
Phyllodocidae spotted	Phyllodocidae	Polychaeta	3	
Phyllodocidae white	Phyllodocidae	Polychaeta	5	4
Phyllodocidae white flaps	Phyllodocidae	Polychaeta		1
Phyllodocidae white/yellow	Phyllodocidae	Polychaeta	1	
Phyllodocidae yellow flaps	Phyllodocidae	Polychaeta		3
Pilargiidae	Pilargiidae	Polychaeta	19	
Pilargiidae club head	Pilargiidae	Polychaeta	2	2
Pilargiidae green	Pilargiidae	Polychaeta		25
Pilumnidae	Pilumnidae	Crustacea	14	1
Pinnotheres	Brachyura	Crustacea	8	
Pitar dirty	Veneridae	Bivalvia	5	
Placamen gravescens	Veneridae	Bivalvia	2	
Placamen without groove	Veneridae	Bivalvia	1	
Platyhelminthes	Platyhelminthes	Platyhelminthes	2	
Poecilochaetidae	Poecilochaetidae	Polychaeta	2	
Polinices conicus	Naticidae	Gastropoda	1	1
Polychaeta	Polychaeta	Polychaeta	14	7
Polycirrinae	Polycirrinae	Polychaeta	1	
Polycirrinae orange	Polycirrinae	Polychaeta	1	
Polycirrus	Polyciarus	Polychaeta	5	10
Polycirrus sp. 2	Polycirrus	Polychaeta	2	
Polynoidae	Polynoidae	Polychaeta	10	13
Polynoidae brown	Polynoidae	Polychaeta		2
Polynoidae dark spots	Polynoidae	Polychaeta		1
Polynoidae green	Polynoidae	Polychaeta		1
Polynoidae green spots	Polynoidae	Polychaeta		8

Polynoidae red	Polynoidae	Polychaeta	99	338
Polynoidae spotted	Polynoidae	Polychaeta	8	
Polynoidae white	Polynoidae	Polychaeta		3
Polynoidae white cirri	Polynoidae	Polychaeta		1
Polynoidae white spot	Polynoidae	Polychaeta	2	
Polynoidea red head	Polynoidae	Polychaeta	8	
Polyschides gibbosus	Gadilidae	Scaphopoda		11
Portunidae	Portunidae	Crustacea	13	5
Prionospio	Spionidae	Spionidae	1	
Pseudoeurythoe	Amphinomidae	Polychaeta	1	29
Pseudopolydoridae	Pseudopolydoridae	Polychaeta	1	
Pseudopythina macrophthalmensis		Bivalvia	27	1
Pycnogonida	Pycnogonida	Pycnogonida	18	
Pyramidellidae	Pyramidellidae	Gastropoda	1	
Retusa	Retusidae	Gastropoda	6	
Ringicula	Ringiculidae	Gastropoda		1
Sabellariidae	Sabellariidae	Polychaeta	4	
Sabellidae	Sabellidae	Polychaeta	33	
Sabellidae green	Sabellidae	Polychaeta	36	
Sabellidae sp. 3	Sabellidae	Polychaeta	1	
Salinator burmana	Amphibolidae	Gastropoda	1	
Sanddollar		Echinoidea	3	
Scintilla round	Galeommatidae	Bivalvia	3	
Scolelepis	Spionidae	Polychaeta	2	
Semelidae	Semelidae	Bivalvia	1	
Serpulidae red tentacles	Serpulidae	Polychaeta	1	
Sigalionidae	Sigalionidae	Polychaeta	27	1
Sigalionidae red head	Sigalionidae	Polychaeta		1
Sigalionidae sp. 3	Sigalionidae	Polychaeta	1	
Sigambra	Pilargiidae	Polychaeta	1	
Sigambra pettiboneae	Pilargiidae	Polychaeta	13	
Sigaretus ribbed	Naticidae	Gastropoda		1
Sigaretus smooth	Naticidae	Gastropoda	1	
Siliqua pulchella	Pharidae	Bivalvia	19	137
Sipunculus nudus	Sipuncula	Sipuncula	13	10
Smaragdia souverbiana	Neritidae	Gastropoda	19	1
Soleidae	Soleidae	fish		2
Solemya	Solemyidae	Bivalvia	52	
Solen	Solenidae	Bivalvia		14
Spionidae	Spionidae	Polychaeta	41	58
Spionidae (Paraprionospio)	Spionidae	Polychaeta	1	
Spionidae (Prionospio queenslandica)	Spionidae	Polychaeta	11	
Spionidae (Prionospio)	Spionidae	Polychaeta	4	
Spionidae pointed head	Spionidae	Polychaeta		46
Spionidae red cirri	Spionidae	Polychaeta		4
Spionidae red dorsal cirri	Spionidae	Polychaeta	13	
Spionidae speckled	Spionidae	Polychaeta	1	
Spionidae white eye	Spionidae	Polychaeta		123
Spionidae white tips antennae	Spionidae	Polychaeta	3	

Squilla	Stomatopoda	Crustacea	16	
Sternaspidae	Sternaspidae	Polychaeta	65	
Syllidae	Syllidae	Polychaeta	5	2
Syllidae brown	Syllidae	Polychaeta	1	
Syllidae sp. 1 (brown)	Syllidae	Polychaeta	1	
Syllidae sp. 2	Syllidae	Polychaeta	1	
Syllidae sp. 2 (orange)	Syllidae	Polychaeta	2	
Syllidae sp. 3	Syllidae	Polychaeta	1	
Syllidae spotted	Syllidae	Polychaeta	1	
Synaptidae	Synaptidae	Holothuroidea	12	1
Synaptidae orange	Holothuroidea	Holothuroidea		1
Syrnola	Pyramidellidae	Gastropoda	1	
Syrnola (brown line)	Pyramidellidae	Gastropoda	1	
Syrnola (straight)	Pyramidellidae	Gastropoda	1	
Tanaidacea	Tanaidacea	Crustacea	24	
Tapes	Veneridae	Bivalvia	4	
Tapes variegate	Veneridae	Bivalvia	2	
Tellina	Tellinidae	Bivalvia	2	4
Tellina 80 mile beach	Tellinidae	Bivalvia		24
Tellina amboynensis	Tellinidae	Bivalvia	25	4
Tellina capsoides	Tellinidae	Bivalvia	17	1
Tellina donax	Tellinidae	Bivalvia		2
Tellina exotica	Tellinidae	Bivalvia	42	66
Tellina fabula	Tellinidae	Bivalvia	5	
Tellina inflate	Tellinidae	Bivalvia	1	3
Tellina macoma	Tellinidae	Bivalvia	1	
Tellina mud	Tellinidae	Bivalvia	4	
Tellina mysia	Tellinidae	Bivalvia	2	
Tellina oval	Tellinidae	Bivalvia	1	
Tellina piratica	Tellinidae	Bivalvia	112	
Tellina pointed	Tellinidae	Bivalvia	14	
Tellina rose	Tellinidae	Bivalvia		35
Terebellidae	Terebellidae	Polychaeta	15	5
Terebellides	Terebellidae	Polychaeta	36	
Terebra spotted	Terebridae	Gastropoda	1	
Terebridae	Terebridae	Gastropoda	1	2
Terrebedida		Polychaeta	1	
Thelepus	Terebellidae	Polychaeta	2	
Thelepus sp. 2	Terebellidae	Polychaeta	1	
Trichobranchidae	Trichobranchidae	Polychaeta	4	
Trochidae	Trochidae	Gastropoda	1	
Tunicata colonial		Tunicata	2	
Tunicata mud		Tunicata		1
Tunicata rooted		Tunicata	23	
Tunicata solitary		Tunicata	1	1
Tunicata solitary sand		Tunicata	1	
Tunicate colonial grey		Tunicata	1	
Tunicate colonial orange		Tunicata	3	
Tunicate colonial red		Tunicata	1	
Turbinidae	Turbinidae	Gastropoda	1	

Turbonilla	Pyramidellidae	Gastropoda	1	4
Turridae spiral	Turridae	Gastropoda	2	
Uca	Ocypodidae	Crustacea	3	
Vexillum	Costellariidae	Gastropoda	10	
Vexillum radix	Costellariidae	Gastropoda	1	

Photo 8. This is a 'sand *Edwardsia'*, a unique little sea anemone that lives in the sandy mudflats of both Eighty Mile Beach and Roebuck Bay. Photo by Angela Rossen.

Photo 9. Chief Executive Taxonomist Marc Lavaleye (a.k.a. 'Lord of the Mud') working on the final list of the marine intertidal benthic species encountered during AnnRoeBIM16. Anna Plains Station 20 October 2016. Photo by Theunis Piersma.

Summary maps of biodiversity and the total densities of critters

Some geographic variation in species diversity within Roebuck Bay is revealed in Fig. 9. Diversity was high (10-20 species per sampling site) at the majority of sampling sites taken between Simpson's Beach and Broome Bird Observatory. The true diversity is likely to be even higher, given the limited knowledge of taxonomy of benthic animals in Roebuck Bay, that we only sampled animals large enough to be retained by a 1 mm sieve, and that in total the cores taken at each site only comprised 235 cm^2. Diversity was clearly lower in the tidal flats near and south of Crab Creek. We suspect that this may be related to heterogeneity of habitat. Substrates in Roebuck Bay range from coarse and sandy near the ocean side of the bay, to uniformly soft muds in the inner eastern sections of the bay, such as those near Crab Creek. In the 'intermediate' sections on the northern shores of Roebuck Bay the substrates are not uniform in grain size; there are muddy patches, east-west ridges of firmer sand, rocky sections, and variably meandering tidal creeklets with different sediment grain sizes in channels and pools. Much of this variation is rather subtle, only noticeable to humans after they have walked the flats repeatedly. But to benthic animals it represents a huge diversity of potential habitats.

There was no obvious tendency for benthic fauna to be more or less diverse in the outer tidal flats. More subtle effects may be revealed by further analyses, and as will be shown later in this report; there were some species with a clear preference for near-shore tidal flats, while some others preferred the outermost tidal flats.

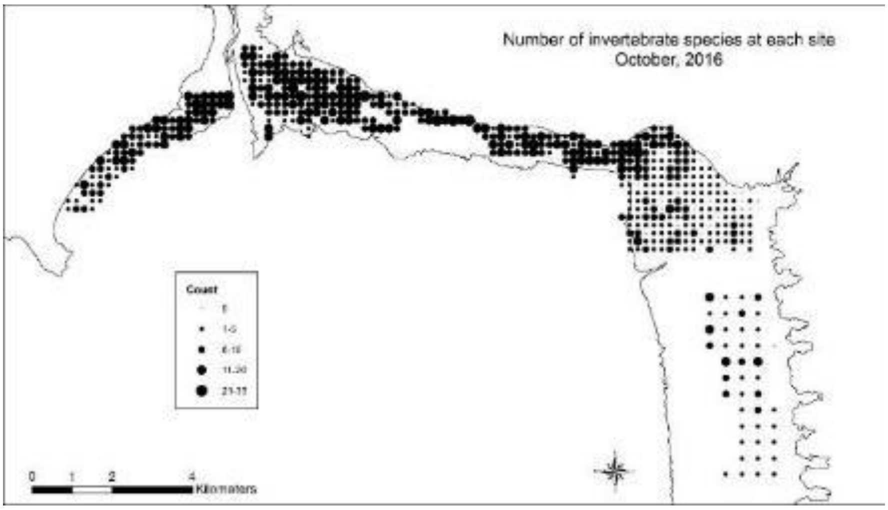


Fig. 9. Numbers of macrozoobenthic taxa per sampling point on the northern shores of Roebuck Bay in October 2016. Taxa are taxonomic units at the species level (Table 1).

The number of individual animals in core samples also varied geographically across the bay (Fig. 10).The highest densities were found on the tidal flats from Simpson's Beach to Broome Bird Observatory; the density was generally lower in the soft mudflats in the far east of the bay. The northern beaches of Roebuck Bay, internationally renowned for their flocks of roosting shorebirds, are where prey is most diverse and abundant. This does not mean that the more depauperate soft mudflats in the far east of the bay are without significance. For about 4 days per fortnight, during neap tides, the soft tidal flats in the east of Roebuck Bay are the only substantial exposed tidal flats in the bay. They are therefore used as the neap-tide feeding area by most shorebirds in the bay, despite the lower diversity and abundance of benthic species. It is possible that it is the invertebrate food resources in these tidal flats that limits the number of shorebirds in Roebuck Bay.

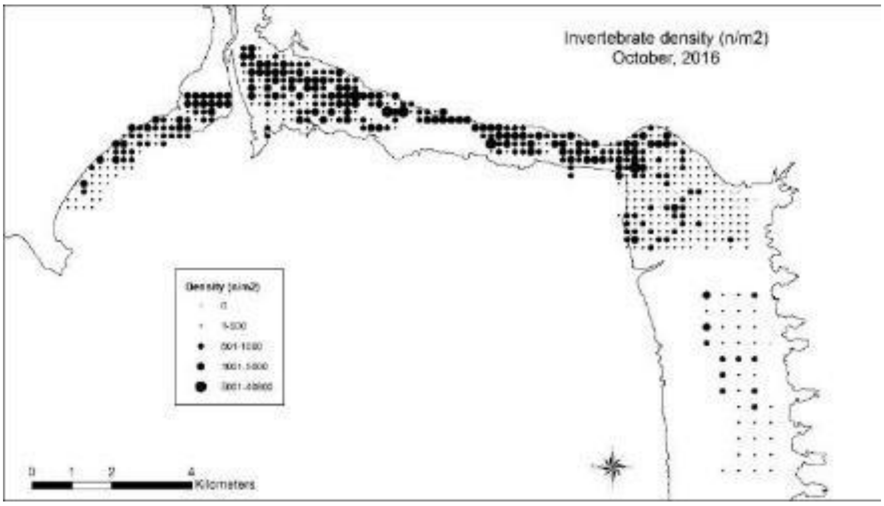


Fig. 10. Total numbers (recalculated as n/m²) of individual macrobenthic animals per sampling point on the northern shores of Roebuck Bay in October 2016. Taxa are taxonomic units at the species level (Table 1).

Photo 10. The sorters at work at Anna Plains Station. Photo by Angela Rossen.

Photo 11. The ID team at work at the Pearson Laboratory of the Broome Bird Observatory. Photo by Angela Rossen.

With up to 15 invertebrate species per sampling station (Fig. 11) rather than the 35 species per sampling station encountered in Roebuck Bay (Fig. 9), biodiversity was certainly lower along Eighty Mile Beach. This relatively low number of species (compared with Roebuck Bay) was 'compensated' by the higher densities of some of the taxa, with total densities per m² exceeding 60,000 animals (Fig. 12). There was a clear common offshore gradient of increasing densities of species and total invertebrate numbers, the upper kilometre of intertidal mudflat being poorer than the lower parts (see also Honkoop *et al*. 2006). The differences between the sections were small, although there was a tendency for the central three sections (-35 km, -20 km and -5 km) to have the highest species and numerical densities.

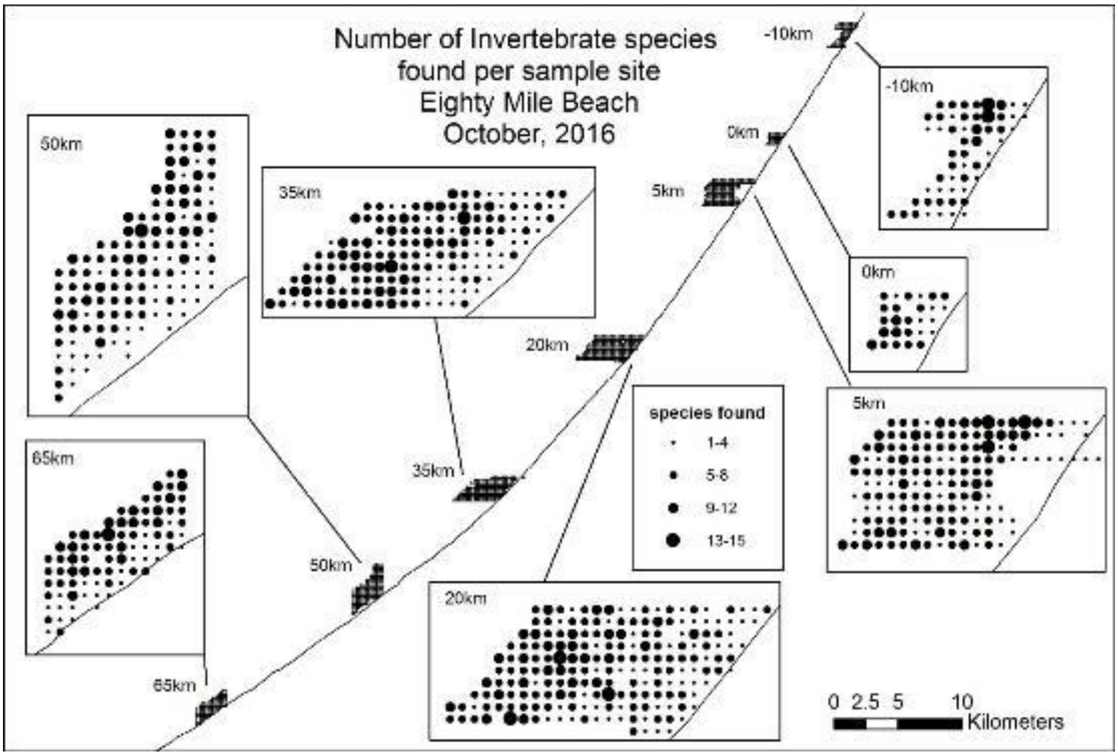


Fig. 11. Numbers of macrozoobenthic taxa per sampling point along Eighty Mile Beach in October 2016. Taxa are taxonomic units at the species level (Table 1).

Photo 12. Joint efforts at producing distribution maps the very day after the last of over 800 core samples have been taken on the mudflats. Anna Plains Station, 20 October 2016. Photo by Theunis Piersma.

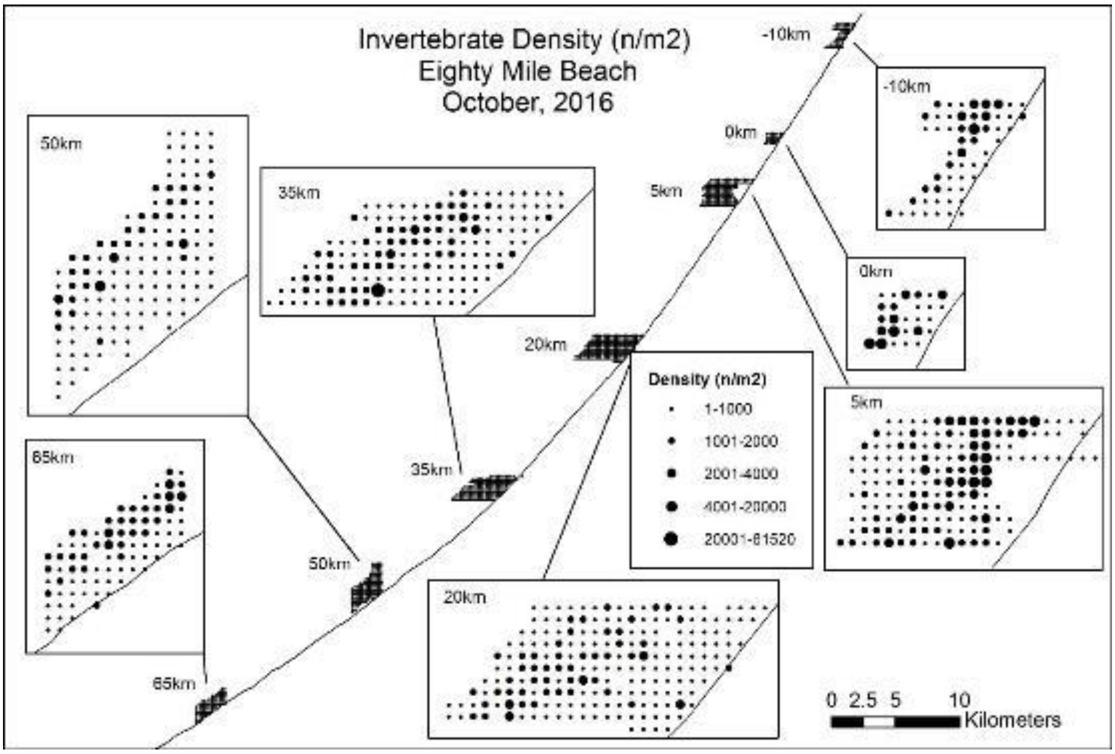


Fig. 12. Density (numbers per m²) of individual macrobenthic animals per sampling point along Eighty Mile Beach in October 2016. Taxa are taxonomic units at the species level (Table 1).

Photo 13. Kim Nguyen sieving a cored sample, with Chelsie Winchcombe taking notes on the surface-living fauna at Eighty Mile Beach. Photo by Angela Rossen.

Mapping organisms: a qualification of quantitative 'coring'

On the field sheets, we recorded the time/date of sampling per station, penetrability of the mud by an average person (see above), and notes on the presence of linear seagrass and oval seagrass as well as the surface presence of different animals. Data on penetrability were easy to record and seem very consistent. When present, seagrass always occurs on the surface of the sand and muds, and once an observer is used to recognising it, it is difficult to confuse or miss.

The same cannot be said for the animals on the surface. Some may be too scarce to be noticed by inexperienced or sometimes tired observers, whereas others show so much behavioural variation with respect to whether or not they show up on the surface, such that sometimes they may be seen and sometimes they may not be (i.e. crabs in or out of burrows). A comparison between the likelihoods of being listed on the field sheets or being found in the sieved core samples between three behaviourally contrasting species tells us something about the interactions between human samplers and the invertebrate species they are trying to record. It also tells us something about the extent to which detailed examinations of three core samples at a site) represent the benthic fauna of the 4 ha grids-square that each core sampling site is supposed to represent. Our core samples (covering 1/40 m² at each site) are a tiny fraction (a 1/1.6 millionth) of the study area; stated in another way, we would have to collect 4.8 million individual cores to completely cover the 4 ha of a single grids-square.

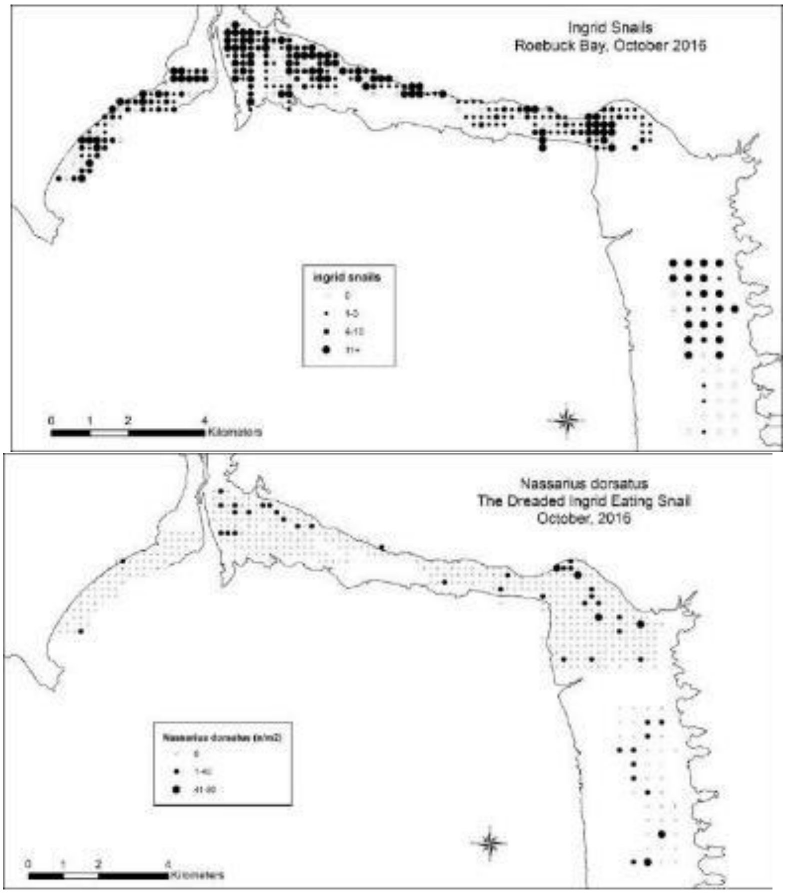


Fig. 13. The distribution in October 2016 of Ingrid-eating snails *Nassarius dorsatus* as apparent from the records in the field-sheets (visible, surface presence) (top) and in the mud cores (bottom). Field sheets were not available for sites that were sampled from boats, so boat-sampled points have been excluded from this map.

The most striking example of the interaction between surveys and the animals they attempt to record comes from a comparison between the surface records of large Ingrid-eating snails *Nassarius dorsatus* and their densities measured on the basis of sieved cores (making the - probably robust - assumption that with the latter method there is no escape from detection). On the basis of the field-records (Fig. 13 top) we would state that large ‘Ingrids’ are widespread and abundant on the western parts of the northern shore, but that they are much scarcer east of BBO, in the deep mud near Crab Creek. However, when we look at the map generated on the basis of the sediment cores (Fig. 13 bottom), the picture is almost reversed, with good densities recorded in the muds near Crab Creek and along Dampier Creek as well, and not much elsewhere! In this case we may tentatively conclude that on the sands the Ingrid-eating snails are much more surface-active and/or visible than in the soft muds, despite occurring in larger densities in the latter intertidal habitat.

Similar to the scavenging snails *Nassarius*, field data sheets suggested that sentinel crabs *Macrophthalmus* sp. seemed to be particularly thin on the ground in parts of Town Beach and parts of the northern shores (Fig. 14 top). However, according to the mud cores, they were very widespread throughout the intertidal (Fig. 14 bottom). Figure 14 (top) therefore reflects the presence of surface-active *Macrophthalmus* and/or astute field observers more than it does the true distribution of these crabs!

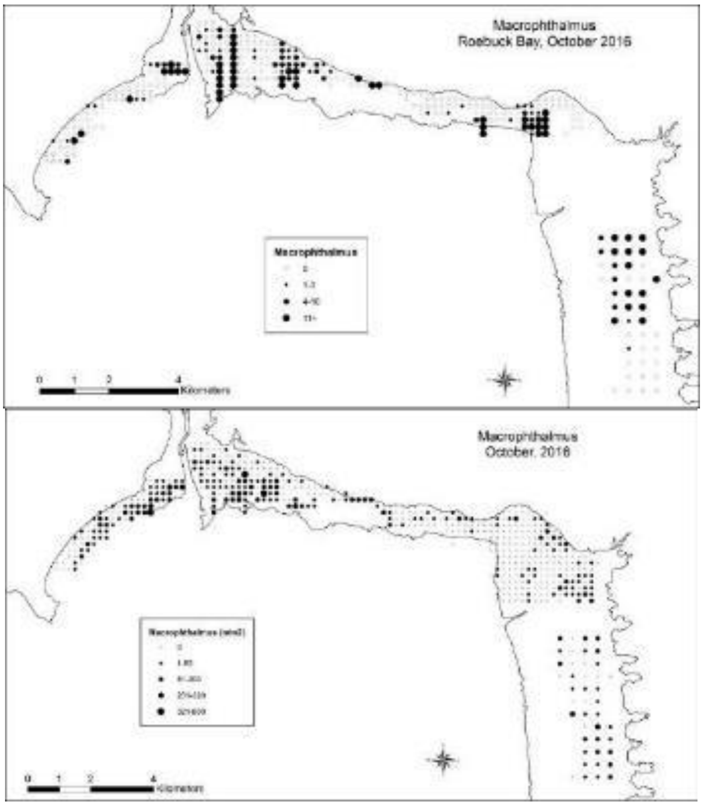


Fig. 14. Distribution in October 2016 of sentinel crabs *Macrophthalmus* sp. as apparent from the records in the field-sheets (visible, surface presence) (top) and in the mudcores (bottom). Field sheets were not available for sites that were sampled from boats, so boat-sampled points have been excluded from this map.

The pattern of relative observations by eye in the field or in the core samples taken back to the laboratory was very different in *Macrophthalmus* at Eighty Mile Beach (Fig. 15). This time the observers saw *Macrophthalmus* around twice the number of sampling stations as on which they were found in the cores. Whilst this could reflect the greater experience of our field observers in their second week of practise, we believe it is more likely that the differences between the results for Roebuck Bay and Eighty Mile Beach reflects genuine differences in surface behaviour of the sentinel crabs. Such behavioural differences could be driven by ecological differences between the two sites, but may also reflect differences in species composition; given their abundance, the species identity of *Macrophthalmus* along the Kimberley coast is actually an issue of taxonomy that needs urgent attention.

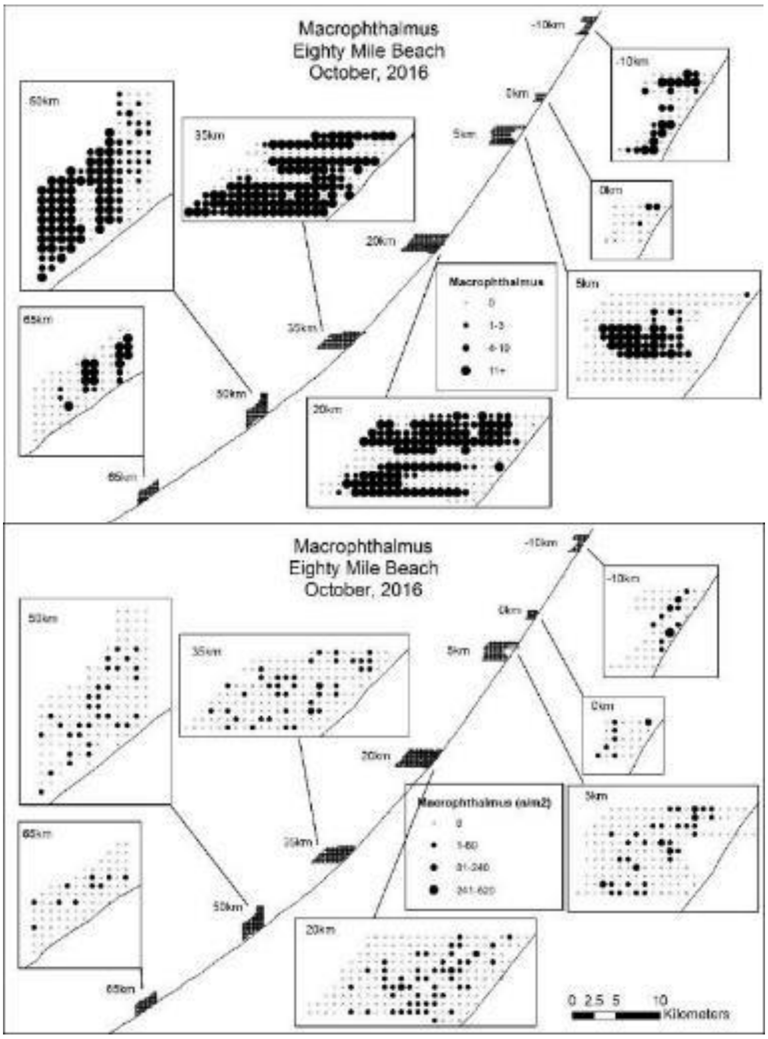


Fig. 15. Distribution in October 2016 at Eighty Mile Beach of sentinel crabs *Macrophthalmus* sp. as apparent from the records in the field-sheets (visible, surface presence) (top) and in the mudcores (bottom).

A striking example of surface-dwelling animals on the intertidal flats of Roebuck Bay are the green worms (Photo 13), belonging to the polychaete family Phyllodocidae. These worms are probably predators, and like all invertebrates exposing themselves before the very eyes of surface-predators like shorebirds, they are likely to be inedible (we have not tried this!). Whereas in the case of Ingrid-eating snails the inedibility probably stems from having a tough, heavy shell (and a tough constitution that enables them to eat themselves out of most gizzards they end-up in?), in green worms it is the production of large amounts of very sticky mucous produced when irritated, that prevents them from being eaten by shorebirds and crabs. When you are inedible and need to be on the surface, advertising this trait helps. This explains why green worms are a shiny green. Perhaps it also explains why the distributions of green worms based on surface observations and core sampling have many similarities, with both approaches suggesting the worms are widespread, but occur in quite low densities, with apparent hotspots near Broome Bird Observatory and on the tidal flats of Dampier Creek and Town Beach (Fig. 16).

Photo 14. The surface-dwelling green worm Phyllodocidae (*Phyllodoce* cf. *novaehollandiae*), here photographed on Dampier Flats, Roebuck Bay, is probably poisonous. Photo by Theunis Piersma.

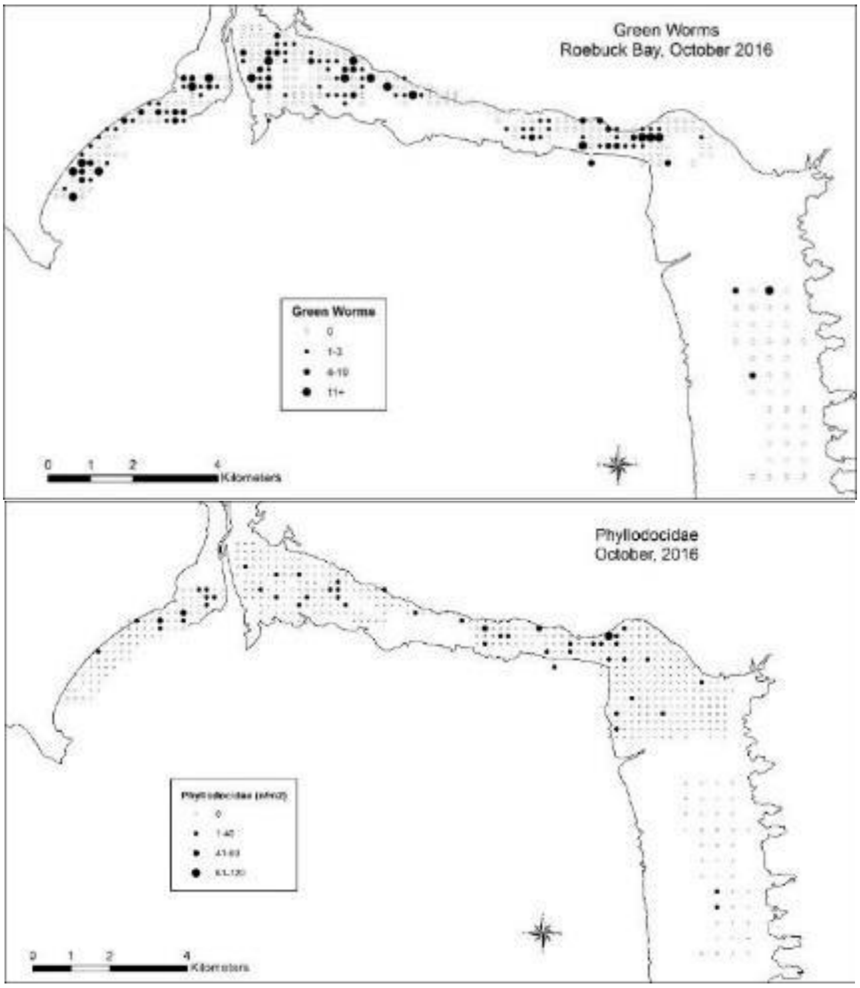


Fig. 16. The distribution in October 2016 of surface-dwelling green worms, also known as green Phyllodocidae, as apparent from the records in the field-sheets (visible, surface presence) (top) and in the mudcores (bottom). Field sheets were not available for sites that were sampled from boats, so boat-sampled points have been excluded from this map.

In a quantitative analysis (Table 2), Ingrid-eating snails were about 9 times more likely to be recorded on the field sheets than in the cores. Of course, this reflects the cores covering only 1/40 m² per sampling point, so that even in densities of 100-200 animals/m² the snails may be missed. However, it will also reflect the propensity of Ingrid-eating snails to be attracted to core samplers as the snails tend to pop up from the mud around the sampling station, surveying the disturbed mud within seconds for potential food.

For timid creatures like the sentinel crabs *Macrophthalmus*, in Roebuck Bay (but not at Eighty Mile Beach, see above), we only recorded them at ca. half the locations at which they were found in cores. Partially, this may reflect the core samples mainly containing small individuals (up to half a cm wide), but it will also reflect the tendency of *Macrophthalmus* to hide in the face of the obvious disturbance by a sampling crew (at least in Roebuck Bay)!

If green worms indeed care as little about human intruders of their territory as their behaviour suggests, then the fact that they are 3-4 times as likely to be recorded on field sheets than to be encountered in core samples (Table 2) may indicate that the odds to miss animals that live in densities of 10-100/m² are of the (expected!) order of magnitude. It also implies that the intertidal invertebrates are mostly quite evenly distributed!

Table 2. How the surface behaviour of three contrasting invertebrates (a scavenging snail, a grazing and vulnerable crab and a toxic surface living worm) in the presence of humans affect their likelihood to be visually observed during core sampling. The ratio in the right-most column indicate the chance to note the respective animal on the sediment surface relative to their presence in the core samples. This is computed for the 208 sampling sites along the northern shores of Roebuck Bay visited in both June 2006 and October 2016 and on the basis of 804 sampling sites along Eighty Mile Beach visited in October 2016.

Species	Area	Year	Positive visual observations in the field (n_{visual})	Present in the 3 core samples (on 1/40 m², n_{core})	$n_{visual}/n_{core\ sample}$
Ingrid-eating snail	Roebuck Bay	2006	146	16	**9.1**
Nassarius dorsatus	Roebuck Bay	2016	173	20	**8.7**
	80 Mile Beach	2016	666	147	**4.5**
Sentinel crabs	Roebuck Bay	2006	24	75	**0.3**
Macropththalmus	Roebuck Bay	2016	69	92	**0.7**
	80 Mile Beach	2016	402	182	**2.2**
Green worms	Roebuck Bay	2006	49	12	**4.1**
Phyllodocidae	Roebuck Bay	2016	84	29	**2.9**

Photo 15. The kind of activity that excites and attracts Ingrid-eating snails *Nassarius dorsatus* but frightens sentinel crabs into hiding deep into their burrows. Photo by Angela Rossen.

Changes over the last 10 years in Roebuck Bay

There were appreciable changes in abundance of some benthic organisms between the survey of northern Roebuck Bay in 2016 and the previous survey in 2006 (Table 3). Of the 31 most abundant taxa in 2016, average density of nine declined by >40%; average density of eleven had increased by >40%, and average density of about thirteen remained about the same. The causes of these changes are unclear. They are not clearly associated with the preferred substrate of the species in question or with their foraging methods (Photo 16). It is possible that a clearer pattern will emerge when our sediment samples are analysed and we can make a more precise comparison of rate of change with grain size.

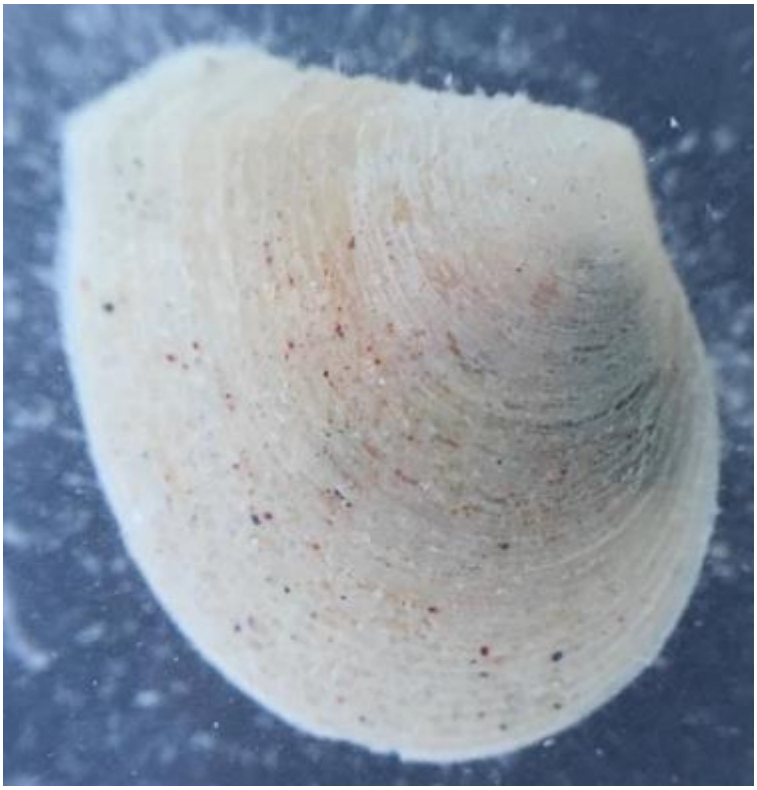


Photo 16. *Tellina piratica*, the single thin-shelled tellinid bivalve that has increased in numbers along the northern shores of Roebuck Bay during the last decade. In contrast to the other thin-shelled bivalves, *T. piratica* maintains a horizontal position in the sediment and for this reason is very hard to extract from the sand. Quite possibly, they have more to fear from moonsnails than from great knots. Photo by Angela Rossen.

One trend does seem clear, though we cannot explain it. Take for example the bivalves *Anodontia omissa* and *Divaracella irpex*. *Anodontia* has declined dramatically (to only 30% of its previous density), while *Divaracella* has undergone a five-fold increase! Both species are about the same size and form, and both belong to the family Lucinidae, which obtain much of their energy from a symbiosis with specialised bacteria that can convert sulphur-based molecules in deep mud into energy. The most obvious difference between the two species, that we are aware of, is that *Anodontia* has a thin shell, while *Divaracella* is thick-shelled and less attractive prey for shorebirds.

Indeed, the bivalves that have declined (*Anodontia omissa*, *Siliqua pulchella*, *Tellina amboynensis* and *exotica*) all happen to be particularly thin-shelled species. Their declines may be problematic for great knots and red knots, shorebird species known to feed largely on bivalves; as they swallow their prey whole and crush it in their gizzards, they have a strong preference for thin-shelled prey that is easy to digest.

Table 3. First assessment of the quantitative changes in macrozoobenthic species along the northern shores of Roebuck Bay between 2006 and 2016. This is based on 366 sampling sites visited in both years, and includes taxa of which at least 30 individuals have been found. Taxa showing more than a 40% change are shown in green (an increase) or red (a decrease). Two taxa were new to the area in 2016.

		2006			2016		Change
Taxon	n_{ind}	average density (n/m²)	maximum density (n/m²)	n_{ind}	average density (n/m²)	maximum density (n/m²)	Ratio of avg. density in 2016 over 2006
BIVALVES							
Solemya cf. *terraereginae*	37	**4.1**	160	69	**7.6**	240	**1.9**
Anodontia omissa	252	**27.6**	520	68	**7.5**	280	**0.3**
Divaricella irpex	34	**3.7**	120	183	**20.1**	800	**5.4**
Siliqua pulchella	71	**7.8**	160	15	**1.6**	120	**0.2**
Tellina amboynensis	36	**3.9**	120	22	**2.4**	80	**0.6**
Tellina capsoides	16	**1.8**	120	14	**1.5**	280	**0.9**
Tellina exotica	56	**6.1**	240	24	**2.6**	80	**0.4**
Tellina piratica	161	**17.6**	560	501	**54.9**	1040	**3.1**
Anomalocardia squamosal	98	**10.7**	520	76	**8.3**	400	**0.8**
SNAILS							
Isanda coronate	0	**0**	0	92	**10.1**	1280	**new**
Nassarius dorsatus	68	**7.5**	200	30	**3.3**	80	**0.4**
TUSK SHELLS							
Laevidentalium cf. *lumbricatum*	172	**18.8**	400	148	**16.2**	320	**0.9**
Dentalium bartonae	114	**12.5**	400	23	**2.5**	280	**0.2**
POLYCHAETE WORMS							
red Polynoidae	113	**12.4**	240	167	**18.3**	440	**1.5**
Onuphidae	57	**6.2**	280	58	**6.4**	560	**1.0**
Lumbrineridae	42	**4.6**	160	69	**7.6**	320	**1.6**
green Phyllodocidae	27	**3.0**	120	40	**4.4**	120	**1.5**
Glyceridae	97	**10.6**	120	96	**10.5**	160	**1.0**
Spionidae	182	**19.9**	240	61	**6.7**	200	**0.3**
Chaetopteridae	118	**12.9**	520	99	**10.8**	1240	**0.8**
Capitellidae	163	**17.9**	240	133	**14.6**	280	**0.8**
Maldanidae	56	**6.1**	120	114	**12.5**	400	**2.0**
Sternaspidae	117	**12.8**	1280	120	**13.2**	680	**1.0**
Oweniidae	586	**64.2**	4200	190	**20.8**	440	**0.3**
Fabriciidae	0	**0**	0	1032	**113.1**	40000	**new**
Ampharetidae	11	**1.2**	240	41	**4.5**	280	**3.7**
CRUSTACEANS							
Amphipoda	185	**20.3**	1240	80	**8.8**	240	**0.4**
Halicarcinus cf. *australis*	55	**6.0**	360	53	**5.8**	360	**1.0**
Hexapus sp.	35	**3.8**	80	46	**5.0**	160	**1.3**
Macrophthalmus sp.	251	**27.5**	400	307	**33.6**	800	**1.2**
ECHINODERMS							
Amphiura tenuis	556	**60.9**	1000	678	**74.3**	1560	**1.2**
Amphiuridae (incl. *A. tenuis*)	782	**85.7**	1200	822	**90.1**	1560	**1.1**
NEAR-VERTEBRATES							
rooted Tunicate	209	**22.9**	3880	284	**31.1**	8400	**1.4**

Changes over the last 17 years along Eighty Mile Beach

There were appreciable changes in average density of some benthic organisms between the survey of Eighty Mile Beach in 2016 and the previous survey in 1999 (Table 4). Of the 31 most abundant taxa in 2016, 7 increased by at least 40%; 6 remained about the same, and 16 (over half of them) increased by at least 40%. Moreover, two bivalves that were widespread in 2016, which we nicknamed 'Tellina rose' and 'Tellina 80MB' had not been found in 1999. On the whole, the news from Eighty Mile Beach seemed to be good, perhaps reflecting the isolation and pristine condition of the habitat. Without regular benthic monitoring and additional work, however, we will forever remain ignorant about the correlates and causes of these changes.

As was the case at Roebuck Bay, we are unable to identify the causes of these changes. There was no obvious association between relative changes in abundance of particular species and their preferred habitat attributes or feeding method. However, there were some interesting parallels between Roebuck Bay and Eighty Mile Beach. The thin-shelled bivalves *Siliqua* and *Anodontia* declined at both sites, while the thicker-shelled *Divaracella* increased dramatically;

Other changes observed at Eighty Mile Beach were not clearly matched at Roebuck Bay. One of the most striking examples were the Onuphid polychaete worm *Diopatra* sp., which increased tenfold in abundance. At Roebuck Bay *Diopatra amboinensis* and *D. lilliputiana* were equally common, but it appears that at Eighty Mile Beach the latter was by far the most common. At some sites they were found in remarkably high densities, something we have never seen in previous expeditions in north-western Australia. A number of other worm species also apparently increased on Eighty Mile Beach (Table 4).

Photo 17. Mudsampler Sander Holthuijsen at work on the 'endless' mudflats along Eighty Mile Beach. Photo by Hebo Peng.

Table 4. First assessment of the quantitative changes in macrozoobenthic species along Eighty Mile Beach between 1999 and 2016. This is based on 819 sampling sites visited in in 1999 and 804 sites visited in 2016, most of which show overlap. It includes the taxa of which at least 25 individuals have been found. Taxa showing more than a 40% change are shown in green (an increase) or red (a decrease).

		1999			2016		Change
Taxon	n_{ind}	average density (n/m²)	maximum density (n/m²)	n_{ind}	average density (n/m²)	maximum density (n/m²)	Ratio of avg. density in 2016 over 2006
BIVALVES							
Anodontia omissa	125	**6.1**	760	28	**1.4**	160	**0.2**
Divaricella irpex	185	**9.1**	760	1449	**72.2**	9000	**7.9**
Siliqua pulchella	2968	**145.1**	11600	383	**19.1**	720	**0.1**
Tellina exotica	78	**3.8**	120	79	**3.9**	120	**1.0**
Tellina 80 MB	0	**0**	0	25	**1.3**	80	**new**
Tellina rose	0	**0**	0	66	**3.3**	880	**new**
Heterocardia gibbulosa	31	**1.5**	90	100	**5.0**	240	**4.2**
SNAILS							
Nassarius dorsatus	288	**9.2**	680	178	**8.9**	120	**0.9**
Mitrella essingtonensis	6	**0.3**	80	43	**2.1**	80	**7.0**
POLYCHAETE WORMS							
red Polynoidae	979	**47.9**	960	1183	**58.9**	520	**1.2**
Onuphidae (*Diopatra*)	185	**7.1**	760	1449	**72.2**	9000	**10.2**
Glyceridae	298	**14.6**	240	369	**18.3**	280	**1.3**
Nepthtyidae	791	**38.7**	360	580	**28.9**	480	**0.7**
Spionidae	174	**8.5**	400	593	**29.5**	1160	**3.5**
Capitellidae	443	**21.7**	1200	1928	**96.0**	1960	**4.4**
Maldanidae	0	**0**	0	46	**2.3**	120	**new**
Oweniidae	2246	**109.8**	4480	3070	**152.9**	12960	**1.4**
Cirratulidae	147	**7.2**	4120	89	**4.4**	240	**0.6**
Amphinomidae	4	**0.2**	80	42	**2.1**	320	**10.5**
CRUSTACEANS							
Corophiidae	2013	**94.4**	48000	1527	**76.1**	56000	**0.8**
Callianassa sp.	4	**0.2**	8	58	**2.9**	240	**14.5**
Macrophthalmus sp.	653	**32.0**	480	263	**13.1**	520	**0.4**
small hermit crabs Paguroidea	41	**2.0**	80	246	**12.3**	4120	**6.2**
ECHINODERMS							
Amphiura tenuis	3550	**173.6**	2240	6331	**315.4**	3520	**1.8**
Arachnoides tenuis	2	**0.1**	40	32	**1.6**	80	**16.0**
Paracautina sand-tailed seacucumber	35	**1.7**	560	43	**2.1**	120	**1.2**
other seacucumbers	438	**21.4**	1120	222	**11.1**	120	**0.6**
NEMERTEA	22	**1.1**	80	94	**4.7**	160	**4.3**
PHORONIDA	342	**16.7**	1200	52	**2.6**	200	**0.2**
ENTEROPNEUSTA *Balanoglossus*	3	**0.2**	40	47	**2.3**	160	**11.5**
ANEMONA *Edwardsia* sp.	52	**2.5**	320	26	**1.3**	80	**0.5**

Seagrasses reconquered Town Beach during a decade without cyclones

Seagrasses represent one of the rare higher plants that are truly marine. They can cover much of shallow nearshore water areas and intertidal flats, but are quite susceptible to disturbances. Mechanical reworking of sediments usually herald the end of good seagrass coverage, and in tropical areas the passage of cyclones with the concomitant forceful stirring of water and sediments may not be a good thing. Our data on the cover of seagrasses on the northern shores of Roebuck Bay seem to provide a good illustration as to what happens after a cyclone event, in this case cyclone Rosita. The eye of Rosita passed just west of the bay in the morning of 20 April 2000.

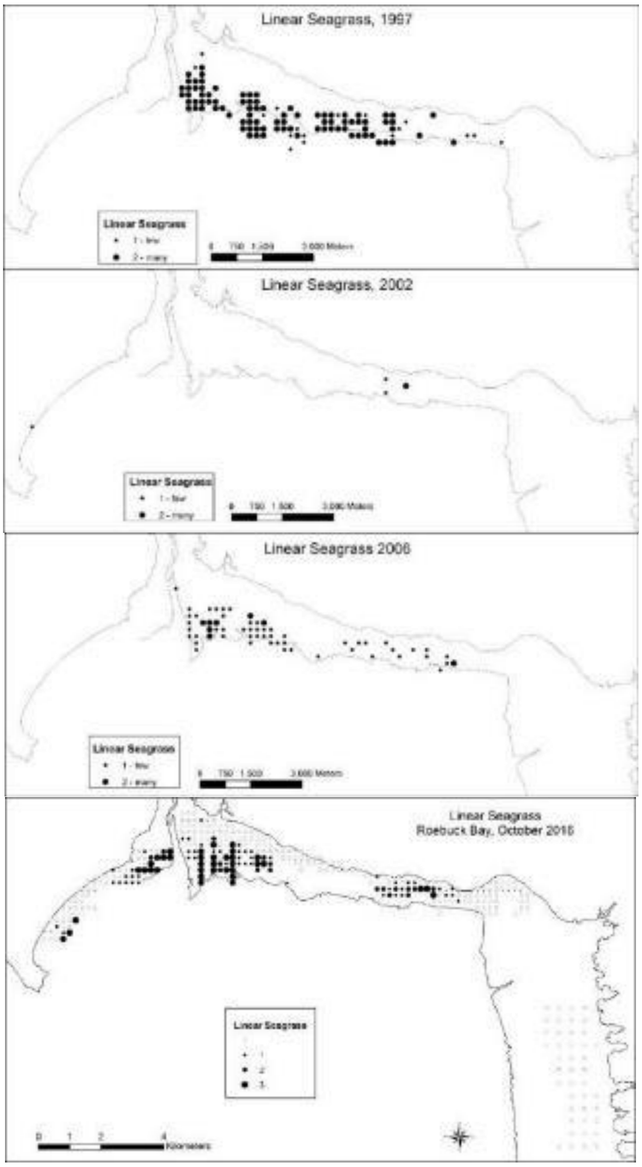


Fig. 17. Observations of linear seagrass *Halodula uninervis* on the northern shores of Roebuck Bay in June 1997, June 2002, June 2006, and October 2016.

Linear seagrass *Halodula uninervis* and oval seagrass *Halophila ovalis* were abundant over large extents of the lower northern shores in June 1997 (Figs. 17 and 18, top panels) and were still common during a benthic survey in March 2000 (not shown). Two years after the passage of cyclone Rosita, in June 2002, linear seagrass was encountered at only 3 sampling stations midway along the northern beaches (Fig. 16) and oval seagrass at only 4 sampling stations (Fig. 18). Four years later, in June 2006, the oval seagrass especially had made a spectacular come back, although the distribution had shifted slightly westward (Fig. 18). The recovery of linear seagrass (Fig. 17) has been somewhat slower, confirming a previously known difference in the potential for recolonisation between the two seagrass species. In the cyclone-free decade between 2006 and 2016, both species increased coverage and re-established themselves on parts of Town Beach, where on the lower parts extensive seagrass coverage occurred in the mid-1970s. These seagrass meadows were then visited by foraging dugong (Bob Prince, pers. comm. 2006).

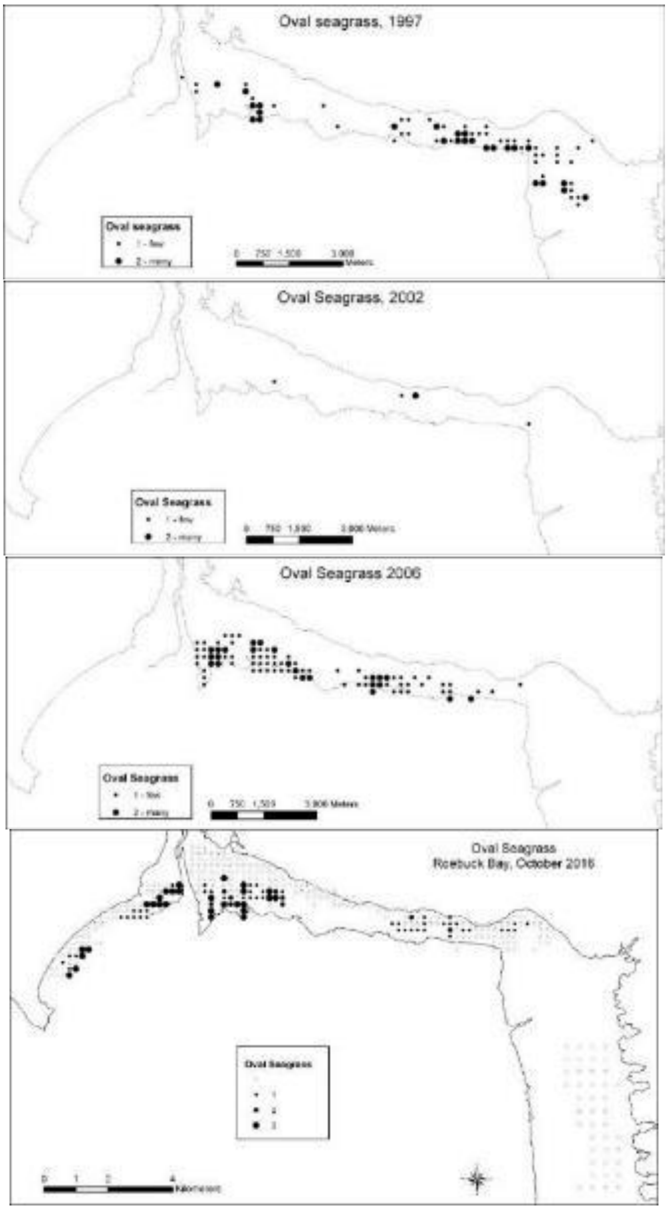


Fig. 18. Observations of oval seagrass *Halophila ovalis* on the northern shores of Roebuck Bay in June 1997, June 2002, June 2006, and October 2016.

Fierce creatures: a 20-year history of Ingrid-eating snails in Roebuck Bay

An examination of the surface distribution of *Nassarius dorsatus* on the field sheets in 2006 and 2016 (Fig. 19) suggest that Ingrid-eating snails became more rather than less numerous, the suggestion based on a comparison of densities found in core samples (Table 3). However, if surfacing behaviour remained the same between 2006 and 2016 (as it seemed to do, Table 2), then the impression of increase may mostly reflect changes in the extents of the distribution, rather than the actual numerical densities.

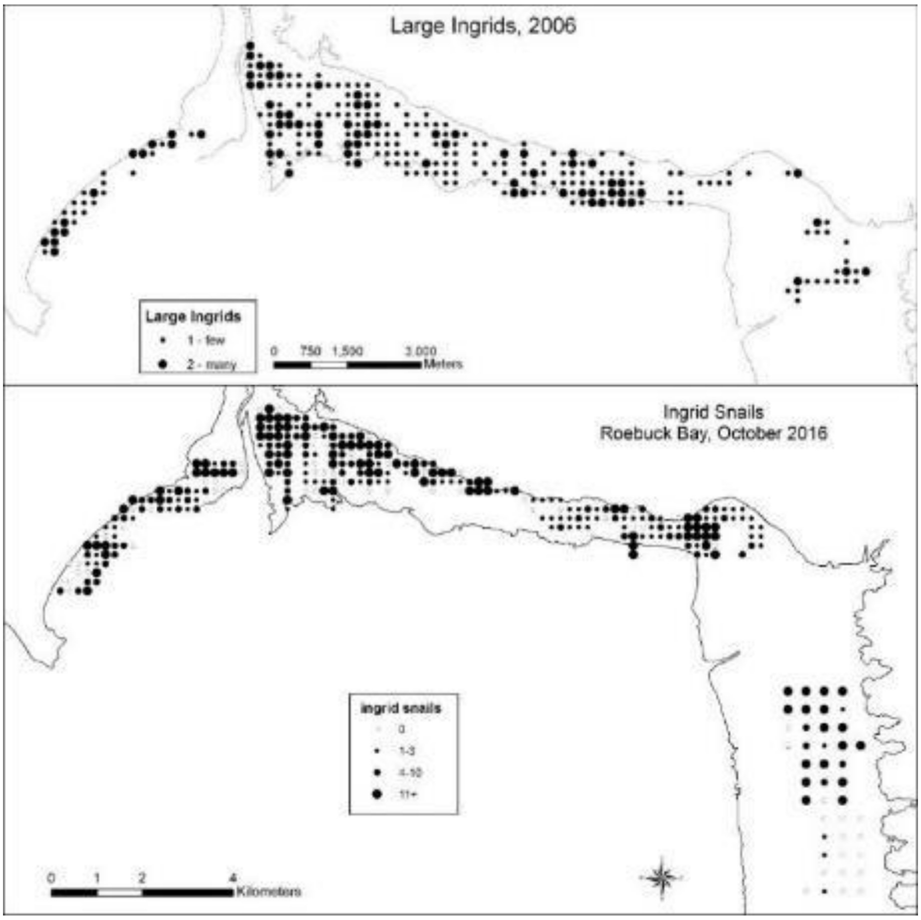


Fig. 19. Distributions of Ingrid-eating snails *Nassarius dorsatus* as apparent from the records in the field sheets (visible, surface presence) in 2006 (top) and in 2016 (bottom).

With four surveys now being available, we can look at the latter over a period of 20 years. When we compare the distributions of Ingrid-eating snails in 1997, 2002, 2006 and 2016 (Fig. 20), the patterns are consistent: occurring everywhere with the higher densities in the softer muds in the Crab Creek corner and near the mangroves at Dampier flats near the entrance of Dampier Creek.

Behaviourally, they remain as charismatic as they were when the first exploratory benthic studies were carried out in Roebuck Bay by Ingrid Tulp and Petra de Goeij in 1991 – Ingrid was the first of many mudbashers to find that these large snails are inquisitive and swarm in to nibble at any open wound. They also swarm in to eat fresh shorebird droppings, and during the 2016 expedition, there were a number of races between Ingrid-eating snails and shorebird biologists who were trying to collect intact droppings of Red and Great Knots to investigate their current diet in Roebuck Bay and Eighty Mile Beach.

Photo 18. Fierce creature: an Ingrid-eating snail, *Nassarius dorsatus*, on the prowl. Photo by Angela Rossen.

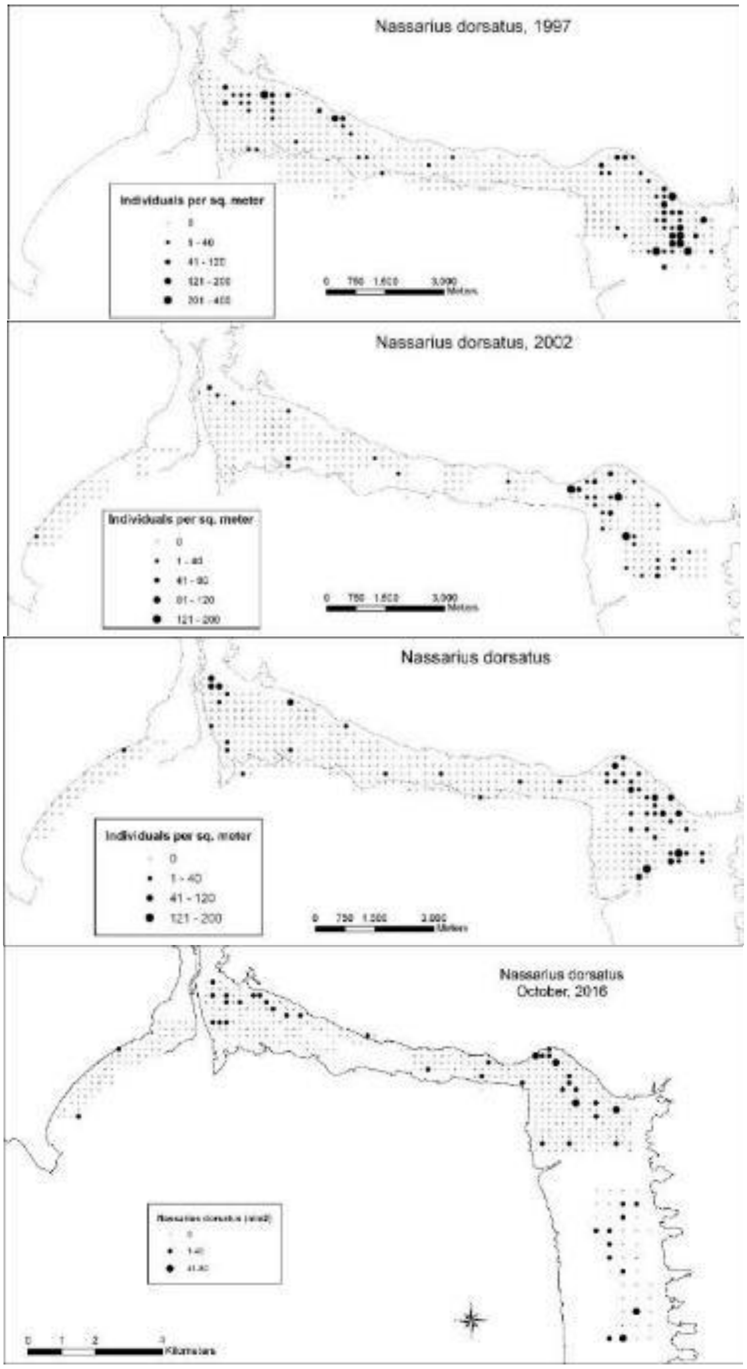


Fig. 20. Occurrence of Ingrid-eating snails *Nassarius dorsatus* in 1997 (top), 2002 (upper middle), 2006 (lower middle), and 2016 (bottom panel), based on the core-sampling efforts. Sampling effort is indicated by the circles and indicate stations where the snails were not found in a sampled surface of 1/40 m².

Siliqua - formerly known as the world's best known knot-food

One of the strikingly abundant and distinctive species of the deep blue mud in the Crab Creek corner in 1997 was the small, thin-shelled bivalve *Siliqua pulchella*. Although fast-moving, they seemed the ideal 'fast' food of the molluscivore shorebirds of the bay. When we repeated the surveys in 2000 (not shown), 2002, and 2006 (Fig. 21), we encountered *Siliqua* at far lower densities in the soft muds near Crab Creek. This decline was also apparent in the MONROEB benthic monitoring data collected over the same period of time (de Goeij *et al.* 2003). Following a report of *Siliqua* was rare in 2013 (M. Lavaleye & T. Compton pers. comm.), this year's survey confirmed that although *Siliqua* is still around, it has become rare along the northern shores. Different in many ways from the cockle *Anadara*, we nevertheless seem to have lost (in ecological terms) the second bivalve from Roebuck Bay since our first surveys in 1997.

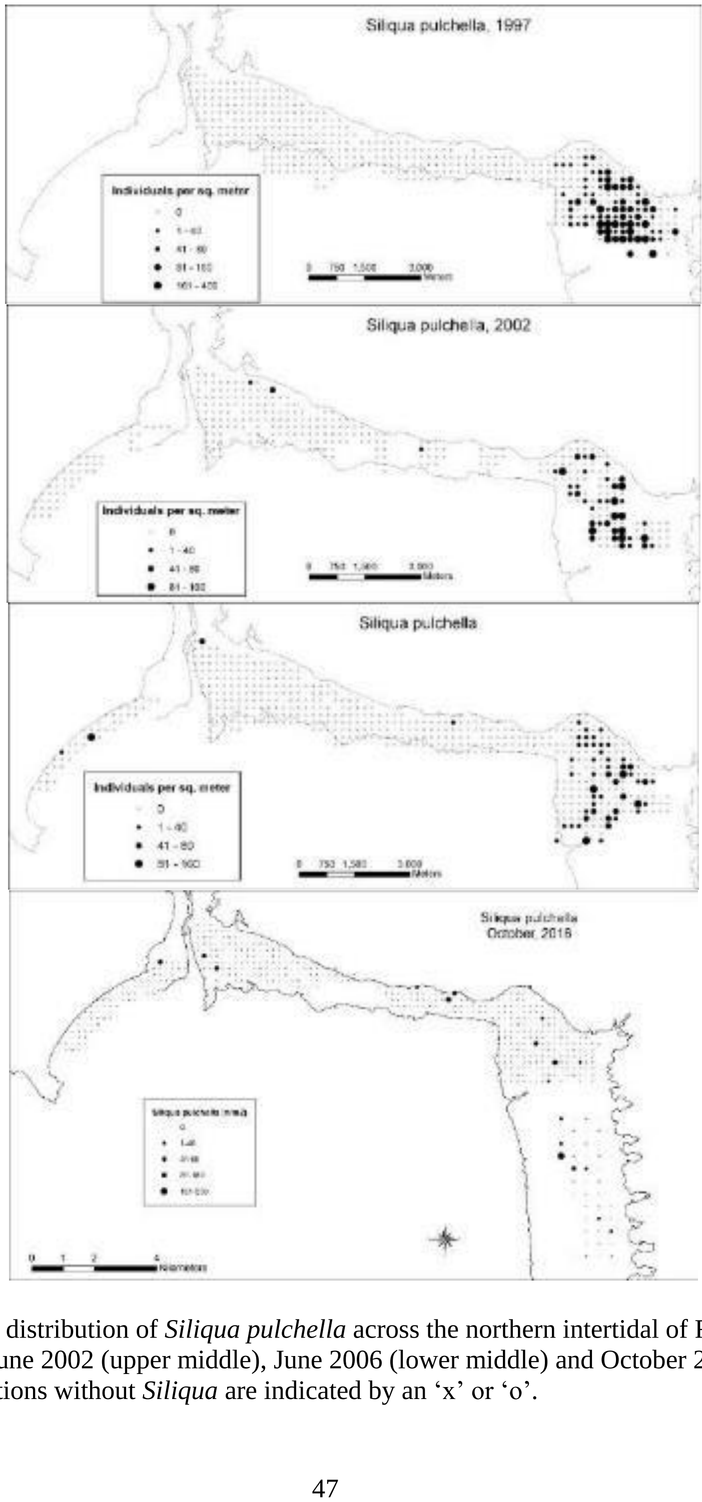


Fig. 21. Quantitative distribution of *Siliqua pulchella* across the northern intertidal of Roebuck Bay in June 1997 (top), June 2002 (upper middle), June 2006 (lower middle) and October 2016 (bottom panel). Sampling stations without *Siliqua* are indicated by an 'x' or 'o'.

Site-faithfulness in the bivalves of Roebuck Bay

Similarly to in 2006, we can now examine again if a pattern of relative site-faithfulness is characteristic of most of the common Roebuck Bay bivalves. The first bivalve species that is available for comparison is the tellinid *Tellina capsoides* (Fig. 22). In the first three years, *T. capsoides* occurred high on the Dampier Flats, and in both 1997 and 2006 it also occurred high in the intertidal in the Crab Creek corner where it was not observed in 2002.

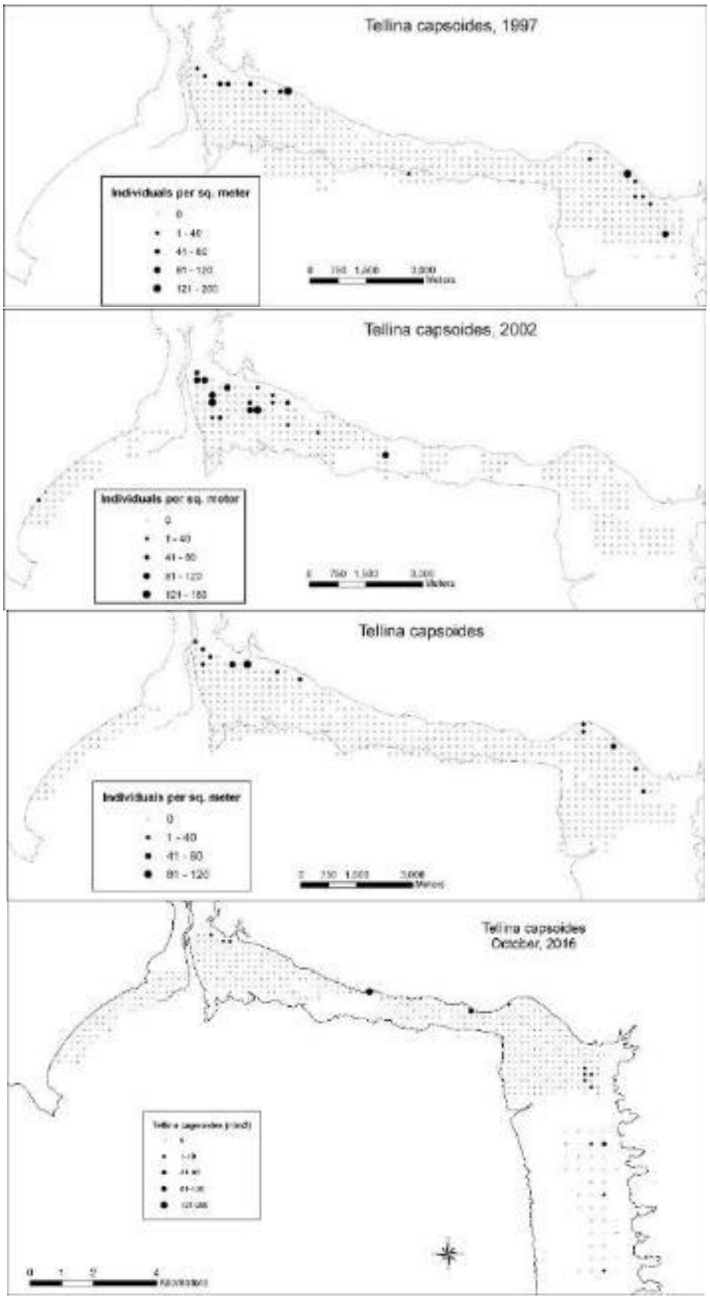


Fig. 22. Quantitative distribution of *Tellina capsoides* across the northern intertidal of Roebuck Bay in June 1997 (top), June 2002 (upper middle), June 2006 (lower middle), and October 2016 (bottom panel). Sampling stations without *T. capsoides* are indicated by the letter ‘x’ or ‘o’.

The closely related tellinid *Tellina piratica* occurred in large densities across the middle northern shore in June 1997 (Fig. 23 top), at similar spots but at much lower densities in June 2002 (but note their presence on Town Beach; Fig. 16 middle panel), a distribution pattern that resurfaced in June 2006, although with slightly increased densities on Dampier Flats (Fig. 23 bottom). In June 2006, densities of *T. piratica* at Town Beach seem to have decreased a little relative to 2002, but overall their distributions were similar. Here was a real come back in October 2016, with the distribution pattern being the same as in previous years, but with higher densities.

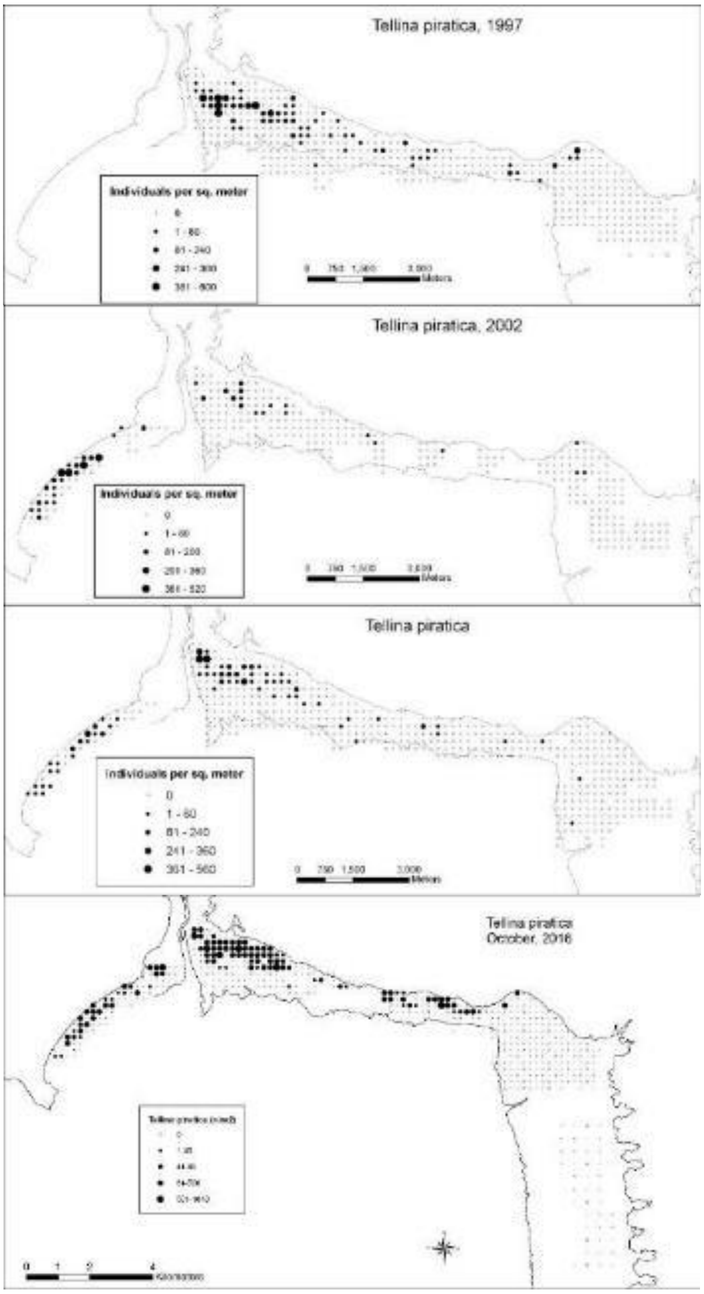


Fig. 23. Quantitative distribution of *Tellina piratica* across the northern intertidal of Roebuck Bay in June 1997 (top), June 2002 (upper middle), June 2006 (lower middle), and October 2016 (bottom panel). Sampling stations without *T. piratica* are indicated by the letter ‘x’ or ‘o’.

A third tellinid bivalve, *Tellina amboynensis*, shared the soft muds of the Crab Creek corner with *Siliqua pulchella* in 1997 (Fig. 24 top), and in fact was also found to do so in the present sampling (Fig. 24 mid and bottom)! As with *Siliqua*, densities of *T. amboynensis* were somewhat lower in 2002 and 2006 than in 1997, and *T. amboynensis* seem to have a slightly lower shoreline distribution in the more recent years. Apart from the Crab Creek corner, *T. amboynensis* has shown up in a few muddy spots on the upper Dampier Flats in all four surveys.

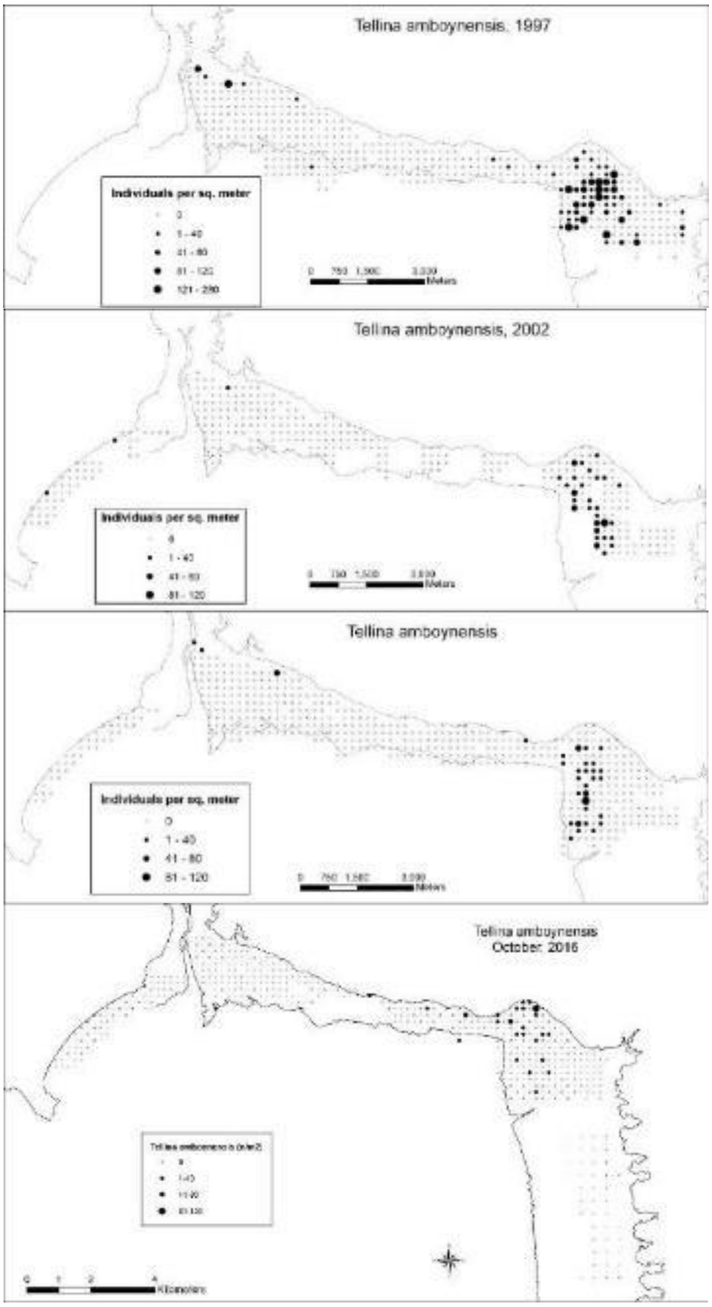


Fig. 24. Quantitative distribution of *Tellina amboynensis* across the northern intertidal of Roebuck Bay in June 1997 (top), June 2002 (upper middle), June 2006 (lower middle), and October 2016 (bottom panel). Sampling stations without *T. amboynensis* are indicated by the letter ‘x’ or ‘o’.

Like the previous two tellinids, *Tellina* cf *exotica* was more common in 1997 than in 2002 or 2006 (Fig. 25), but as in all bivalves examined so far, their overall distribution across the northern shore has remained similar across all mapping efforts, including this one. More wide and thinly spread than the previous three tellinids, *T.* cf *exotica* occurs over a wide range of sediment types, from the deep muds of the Crab Creek corner to the sandy muds of Town Beach and Simpson's Beach. Whether this reflects important intraspecific variation or whether we have identification problems with this species, remains to be seen. This is one of the common species fro which it is so important to establish the definitive identification.

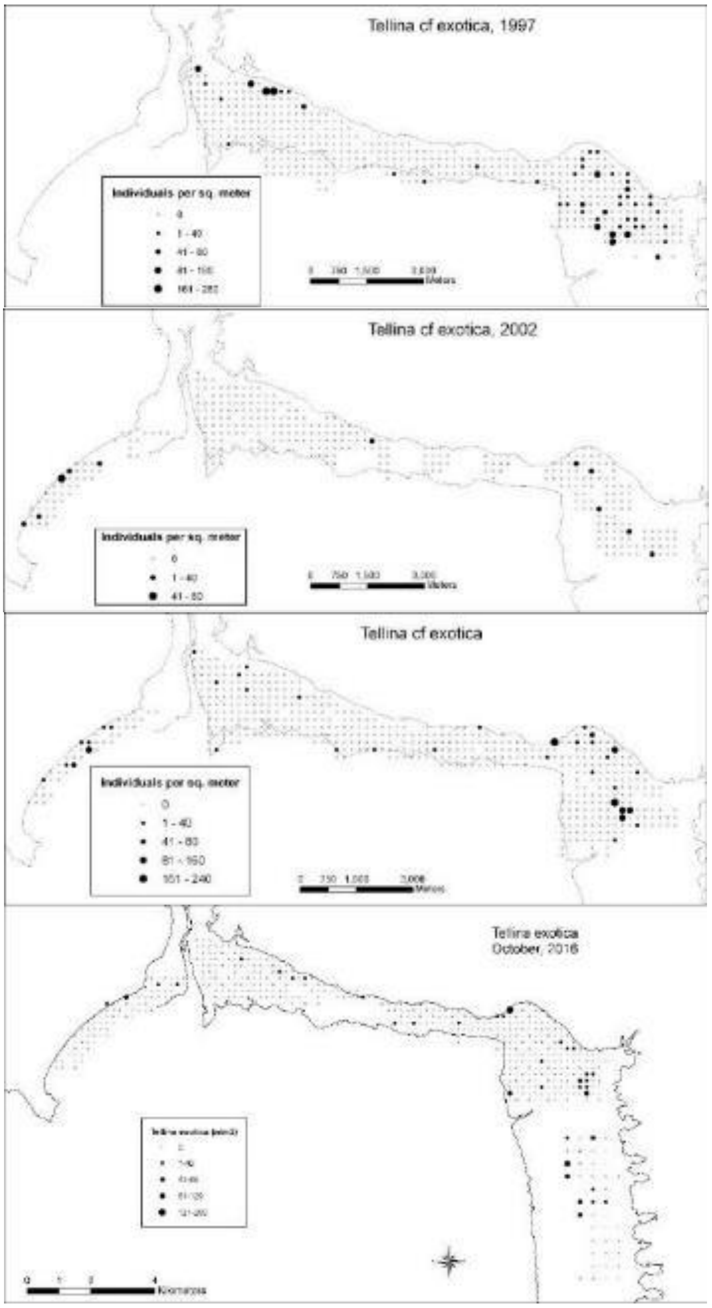


Fig. 25. Quantitative distribution of *Tellina* cf *exotica* across the northern intertidal of Roebuck Bay in June 1997 (top), June 2002 (upper middle), June 2006 (lower middle), and October 2016 (bottom panel). Sampling stations without *T.* cf *exotica* are indicated by the letter 'x' or 'o'.

The venerid *Anomalocardia squamosa* has the short-fused siphon typical of suspension-feeders (unlike the long separate inhalent and exhalent siphons that characterise deposit feeders like tellinids). It shows a distribution pattern (Fig. 26) that is consistent between the three years and quite similar to the distribution of *T. piratica* (Fig. 23). *Anomalocardia* consistently occurred in highest densities on the middle and higher parts of Dampier Flats and Town Beach, with slightly reduced densities in 2002 and 2006 compared with 1997, remaining at similar levels in 2016.

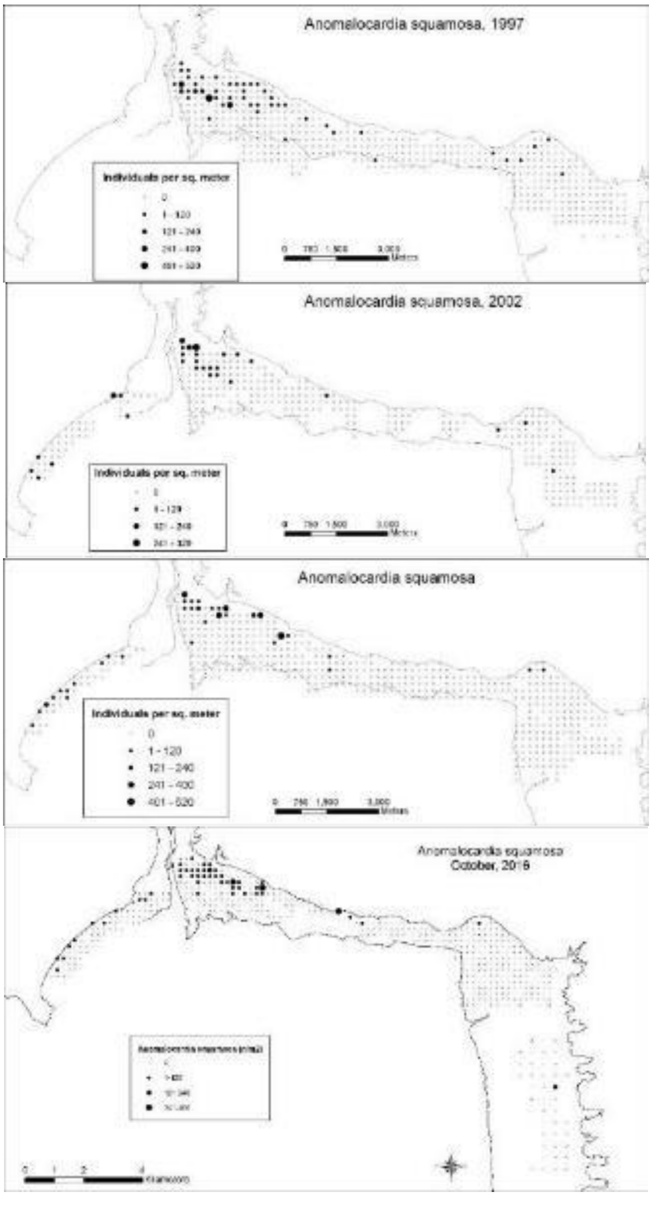


Fig. 26. Quantitative distribution of *Anomalocardia squamosa* across the northern intertidal of Roebuck Bay in June 1997 (top), June 2002 (upper middle) and June 2006 (lower middle), and October 2016 bottom panel). Sampling stations without *Anomalocardia* are indicated by the letter 'x' or 'o'.

In summary, in all six suspension-feeding (*Siliqua* and *Anomalocardia*) and deposit-feeding (*Tellina*) bivalves, the spatial distributions have been remarkably comparable between years. Given the stark and repeatable gradients in sediment type (see data on penetrability in Fig. 5) and tidal height (reflecting inundation times; T. Compton *et al.* in prep.) this is perhaps not surprising, but given their wide distributions across these gradients and variable recruitment patterns (de Goeij *et al*. 2003) perhaps it is.

Lucky Lucinidae: bivalves with chemoautotrophic endosymbiotic bacteria

There are two distinct ‘round’ species of bivalve in the West Kimberley, one with a thin shell and a smooth surface called *Anodontia omissa* and another with a thicker shell with crossing ridges called *Divaricella irpex*, belonging to a family of modern bivalves called Lucinidae.

Photo 19. Portraits of the shells of two Lucinid bivalves: the thin-shelled *Anodontia omissa* on the left, and the thicker-shelled *Divaricella irpex* on the right. Photos by Marc Lavaleye.

These ‘lucinids’ have achieved some degree of fame in marine biological circles via their very peculiar metabolic capacities which enables them to harvest chemical energy in what otherwise is a toxic breakdown product of the bacterial digestion of organic compounds in the oxygen-free environment of the deep mud (H_2S, hydrogen sulphide), whilst at the same time obtain food by the more standard filtering of diatoms and other algae from the upper layer of sediment and the overlying seawater (summary in van der Heide *et al*. 2012). The lucinids have specially enlarged gills in which they garden endosymbiotic chemoautotrophic bacteria that use hydrogen sulphide (harvested by the lucinid from the anoxic mud) to turn CO_2 (supplied by the lucinid from the overlying water) into sugars, which are then shared by the bacteria with their hosts. The removal of what is a very toxic compound from deep and characteristically smelly anoxic mud by the lucinids benefits organisms such as seagrasses!

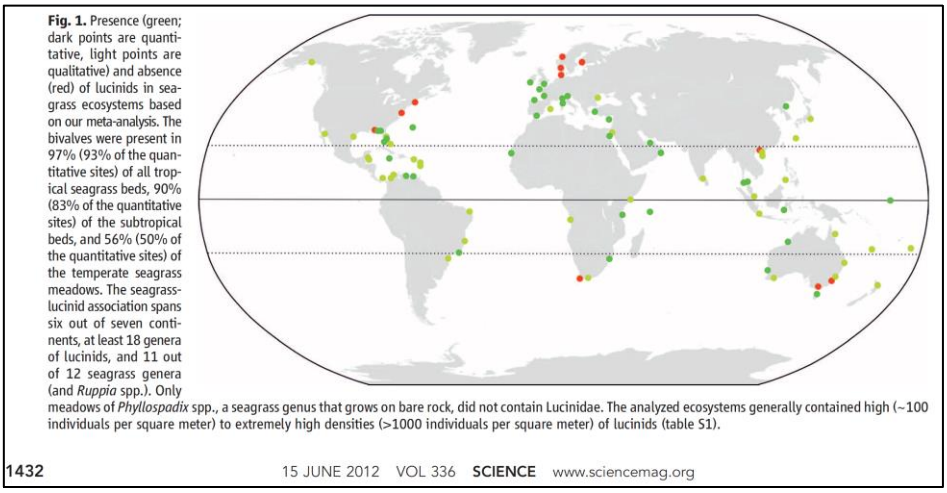


Fig. 27. Co-occurrence of Lucinid bivalves and seagrasses, especially in the tropics, based on a literature review published in *Science* which included our 1997 information from Roebuck Bay (Pepping *et al*. 1999)! From: van der Heide *et al*. (2012).

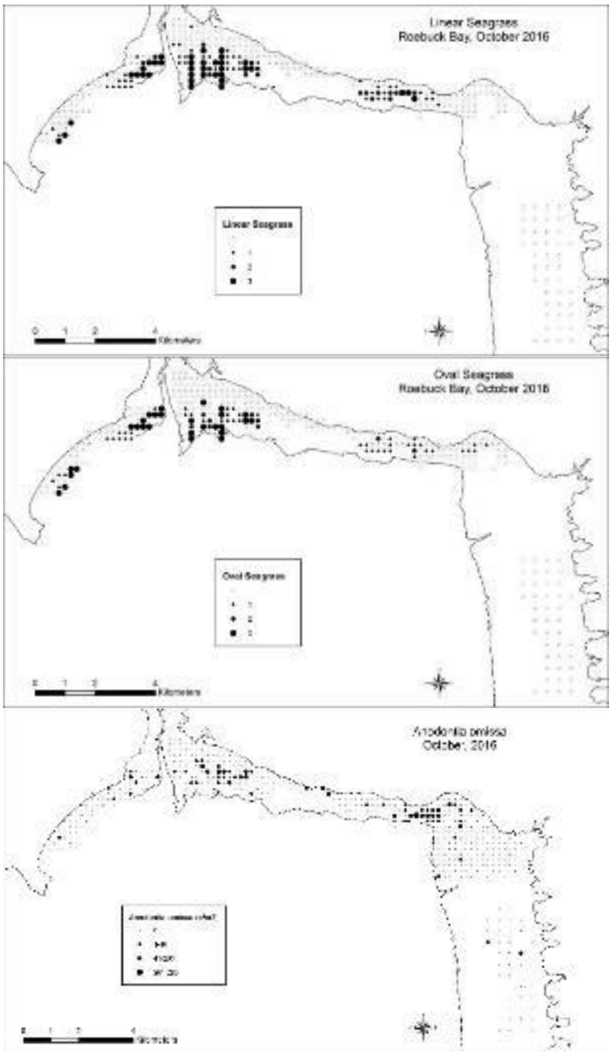


Fig. 28. Quantitative distribution of the two seagrass species (top two panels) and the lucinid *Anodontia omissa* across the northern intertidal of Roebuck Bay in October 2016 (bottom panel). Sampling stations without *A. omissa* are indicated by the letter ‘x’ or ‘o’.

In the *Science* paper of van der Heide *et al*. (2012), Roebuck Bay is listed as one of the tropical intertidal sites where seagrasses and lucinids occur together. However, close inspection of the distribution maps collected in October 2016 shows that although the distribution of *Anodontia omissa* indeed overlaps to a fair degree with the two seagrass species (Fig. 28), *Divaricella irpex* occurs higher in the intertidal than the seagrass beds, thus disobeying the global spatial association.

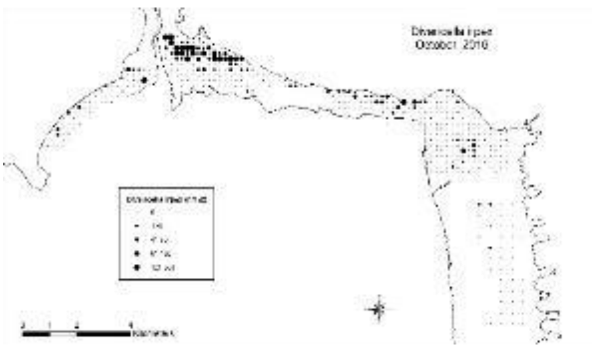


Fig. 29. Quantitative distribution of *Divaricella irpex* across the northern intertidal of Roebuck Bay in October 2016. Sampling stations without *D. irpex* are indicated by the letter ‘o’.

Interestingly, *Divaricella*, a species that has increased in Roebuck Bay over the last 10 years, also did very well on the Eighty Mile Beach foreshore (Fig. 30), again in areas without seagrass. This raises interesting questions about the degree of the dependence of seagrass and lucinids in the West Kimberley, and makes one also wonder whether *Divaricella* are as strongly dependent on the activities of endosymbiotic chemoautotrophic bacteria as some other lucinids are. There is a world of highly intertwined ecological and metabolic intricacies to be discovered here! And in unknown ways, one day this may even help us guide conservation and management efforts.

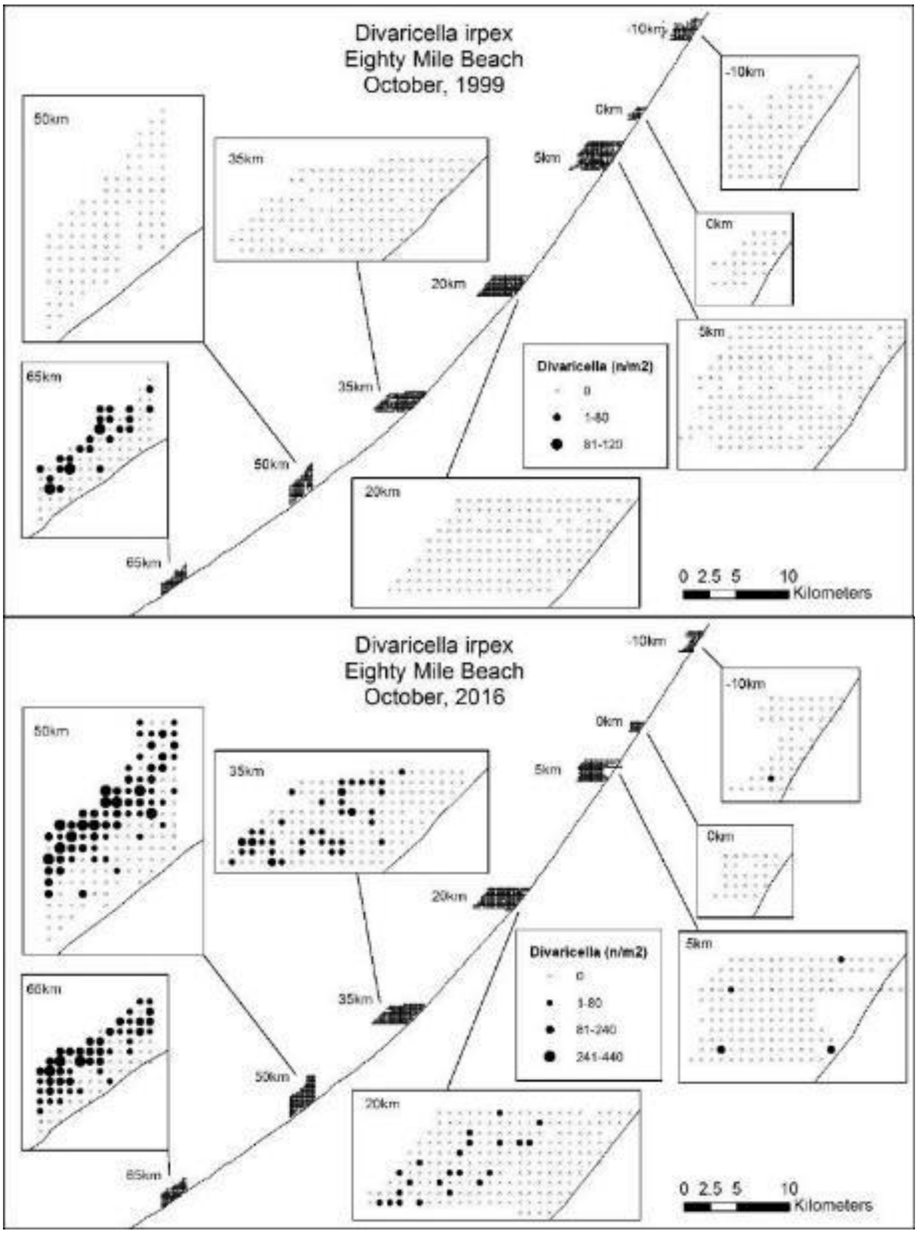


Fig. 30. Quantitative distribution of *Divaricella irpex* on the intertidal of Eighty Mile Beach in October 1999 (top) and in October 2016.

Bloody cockles have not made it back to Roebuck Bay

Arguably the most widely known and traditionally the most important bivalve of Roebuck Bay is the cockle *Anadara granosa*. Middens surrounding the bay testify to the historic importance of this bivalve for Aboriginal communities. During the first survey in 1997, cockles were found in good densities near the mangroves on the higher Dampier Flats and on the nearshore parts of the Crab Creek corner (Fig. 31). Indeed, it was common to see local people collecting cockles in the latter area. By 2002, the cockles had become very rare and the situation has not changed in the subsequent four years to 2006. Indeed, recovery has not happened over the past decade either. The good news is that *Anadara* are still present and with a potential high capacity for reproduction is could easily come back to prominence. It is suggested that *Anadara* are abundant in a mudflat offshore from the Port (J. Fong pers. comm. 2016).

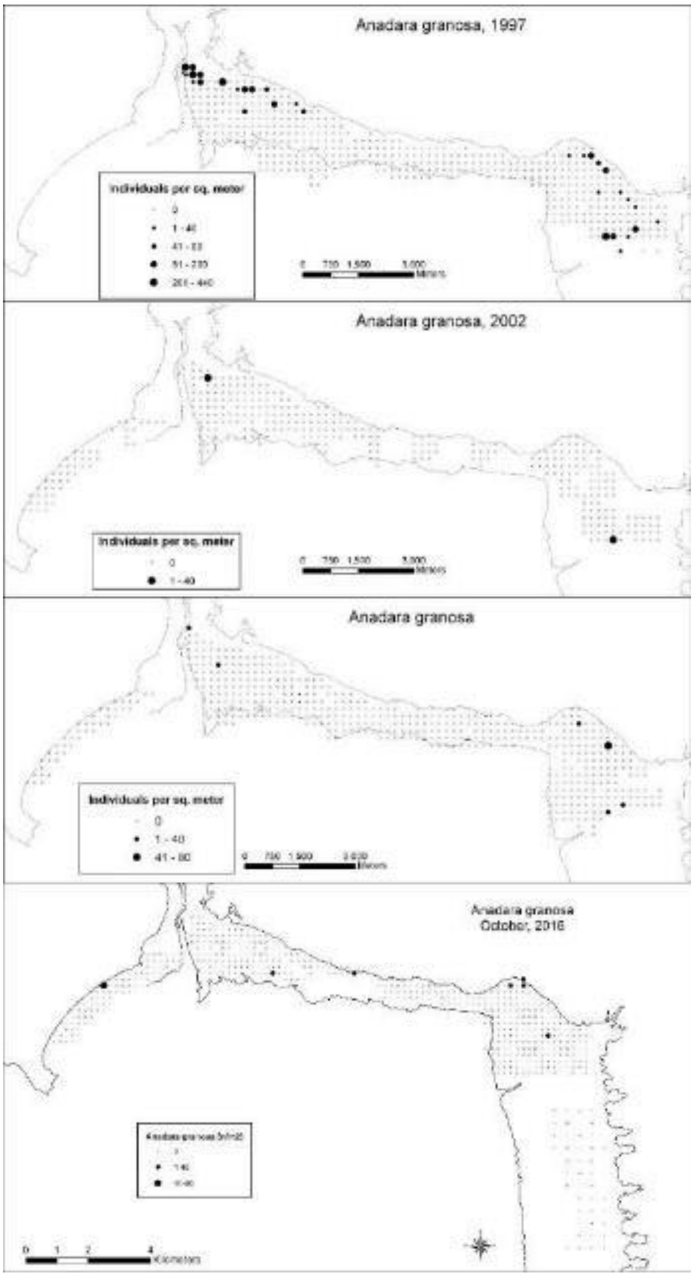


Fig. 31. Occurrence of bloody cockles *Anadara granosa* in June 1997 (top), June 2002 (upper middle), June 2006 (lower middle), and October 2016 (bottom panel) based on the core-sampling efforts.

Puncturing the mud: the tuskshells

Tuskshells (Scaphopoda) is one of the smaller mollusc classes, having only a few hundred species. Most of the species live in deep offshore waters (Edgar 1997). The animals live in curved tubular shells that taper towards one end. Their head and wedge-shaped foot extends from the wide end of the shell that is buried deep in the sediment; the narrow top end projects above the sediment surface. It is through this narrow chimney that water for respiration is passed in and out.

Of the three species found on the intertidal flats of Roebuck Bay, the very small *Cadulus* sp., was not encountered in October 2016. The two larger, 1-3 cm long, species are quite similar, but one has a smooth and the other a ribbed surface; they belong to two different genera. The smooth tuskshell *Laevidentalium* occurs over all parts of the intertidal flats, living in very muddy as well as quite sandy places (Fig. 32). The ribbed tuskshell *Dentalium* only occurs at the muddier sites in the Crab Creek corner and in the muds near Dampier Creek and the nearby mangal edge (Fig. 33). The smooth tuskshell has done particularly well in the decade since 2006, increasing their presence especially at Town Beach and on the Dampier Flats.

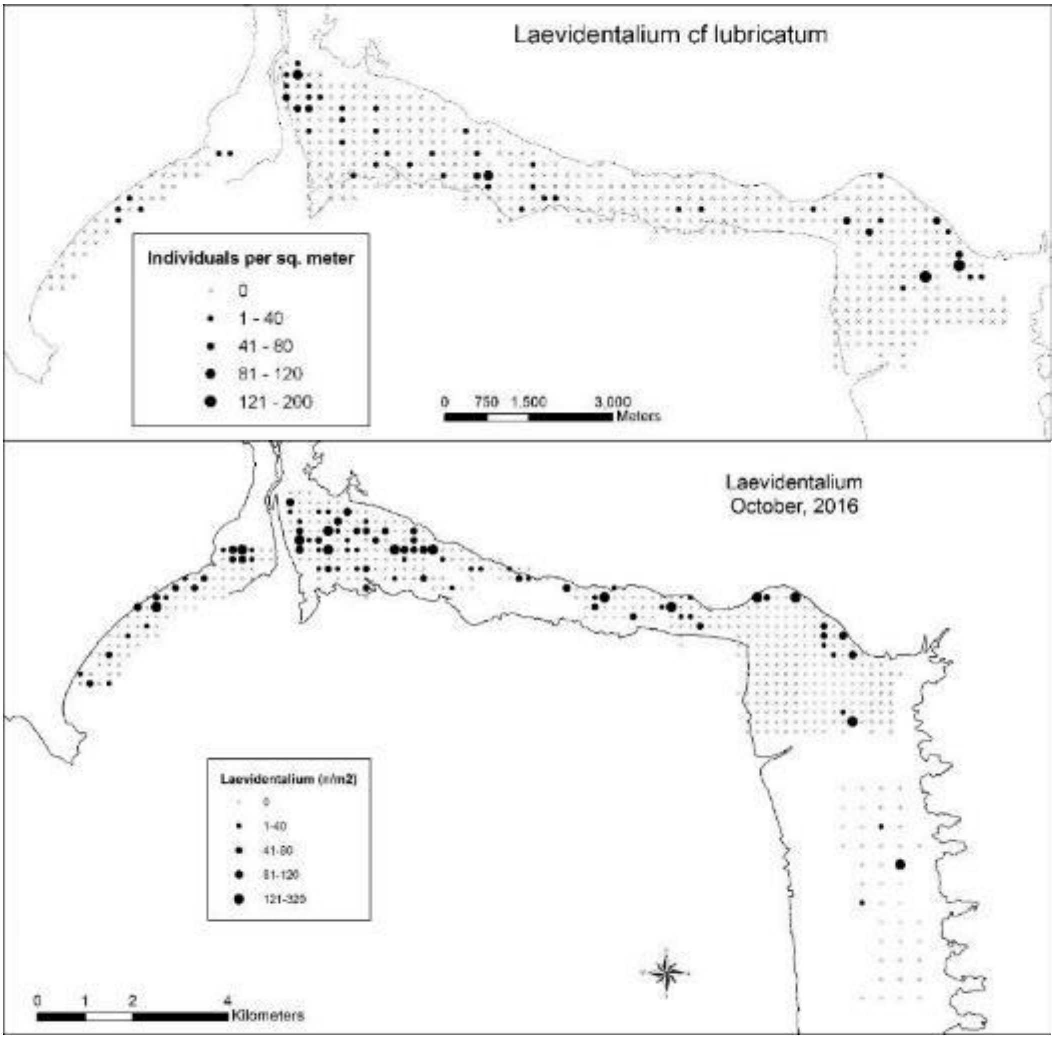


Fig. 32. Occurrence of the smooth tuskshell *Laevidentalium* cf *lubricatum* in June 2006 (top) and in October 2016 (bottom panel) based on the core-sampling efforts.

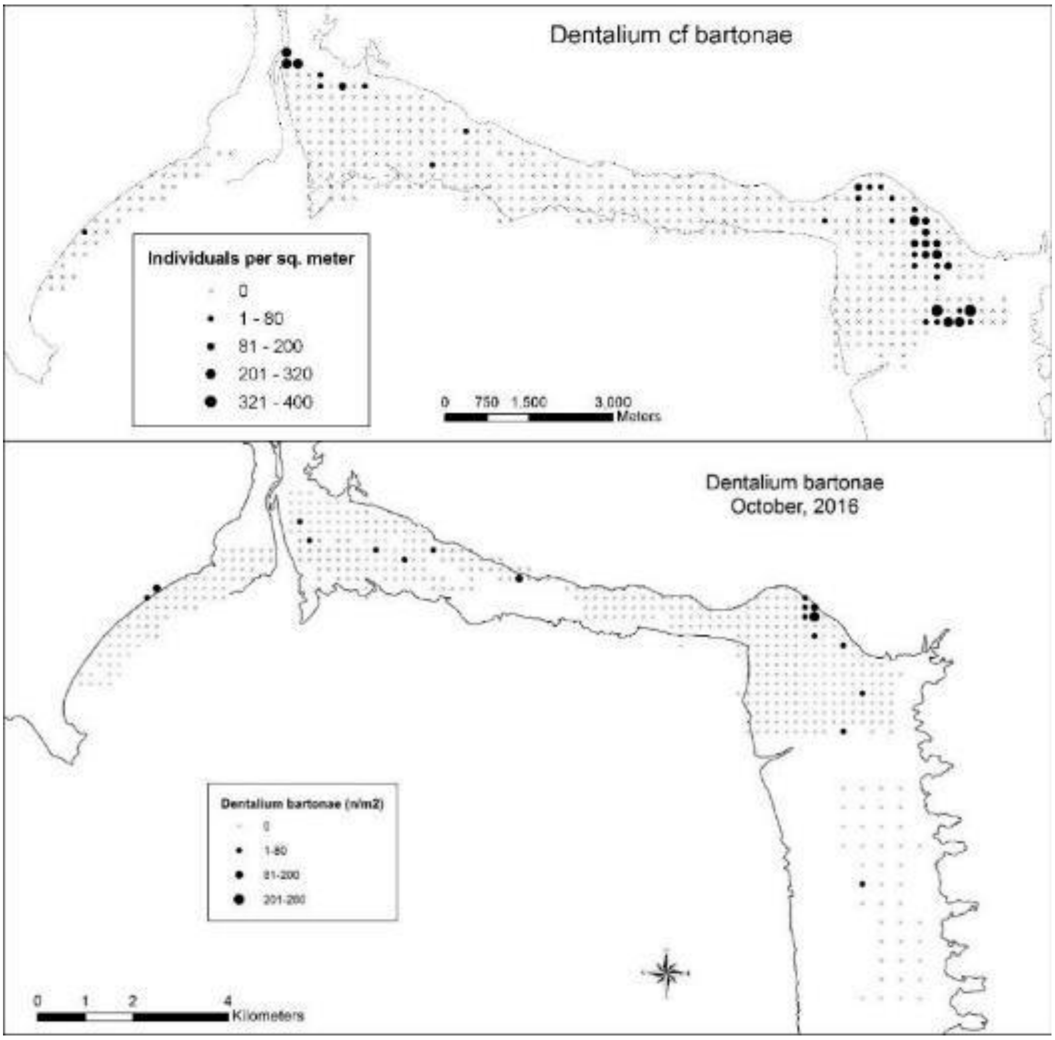


Fig. 33. Occurrence of the ribbed tuskshell *Dentalium* cf *bartonae* in June 2006 (top) and in October 2016 (bottom panel) based on the core-sampling efforts.

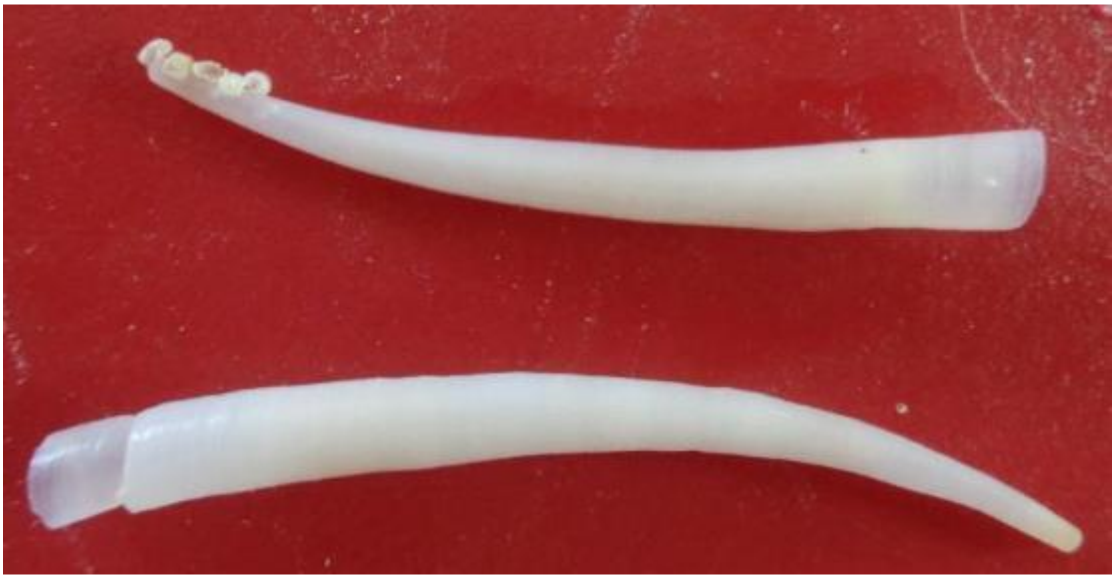


Photo 20. Smooth tuskshell *Laevidentalium* cf. *lubricatum*. Photo by Marc Lavaleye.

Brittlestars hold sandy mud in their arms and host little red worms

The long-armed brittle stars *Amphiura* sp. occurred throughout the mudflats. They are among the most widespread species of the bay. Despite, or due, to their similarity, *Amphiura tenuis* (Fig. 34) and *Amphiura catephes* usually occurred together, *A. catephes* being the less numerous species and largely absent in the soft muddy areas of Crab Creek Corner.

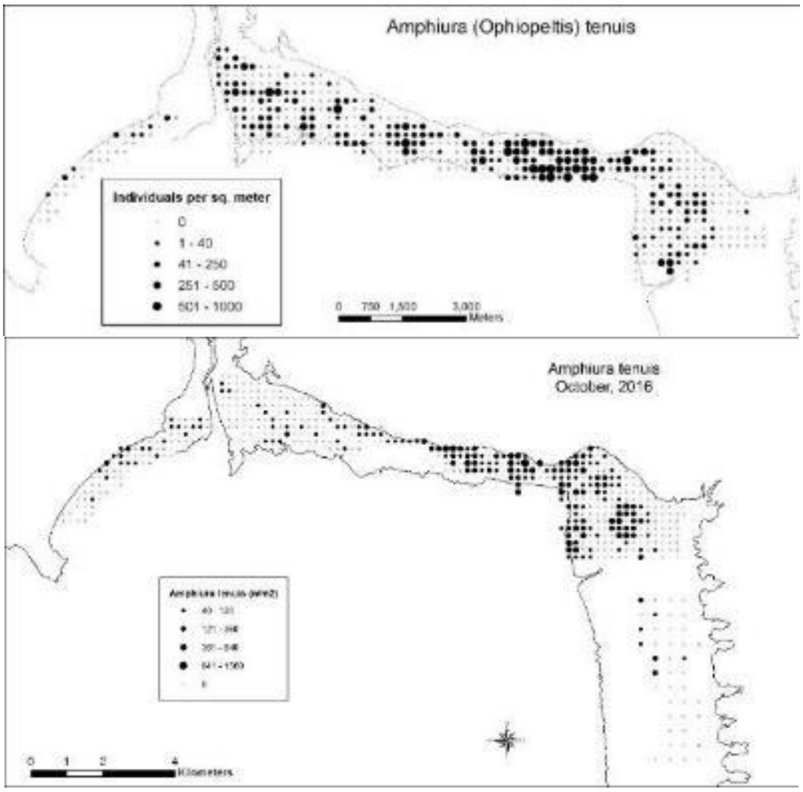


Fig. 34. Occurrence of the common brittlestar *Amphiura tenuis* across the northern intertidal flats of Roebuck Bay in June 2006 (top) and October 2016 (bottom panel) based on the core-sampling efforts.

Indeed, the distribution of the red polynoids largely overlaps with the distribution of amphiurids, although polynoids were not found at each of the sampling stations where amphiurids occurred (Fig. 35). Before too long, we hope to analyse the co-occurrence of these worms and the two kinds of brittlestars in more detail, both in Roebuck Bay and along the Eighty Mile Beach foreshore.

Photo 21. Red Polynoidae worm, a commensal with *Amphiura tenuis*. Photo by Chris Glasby.

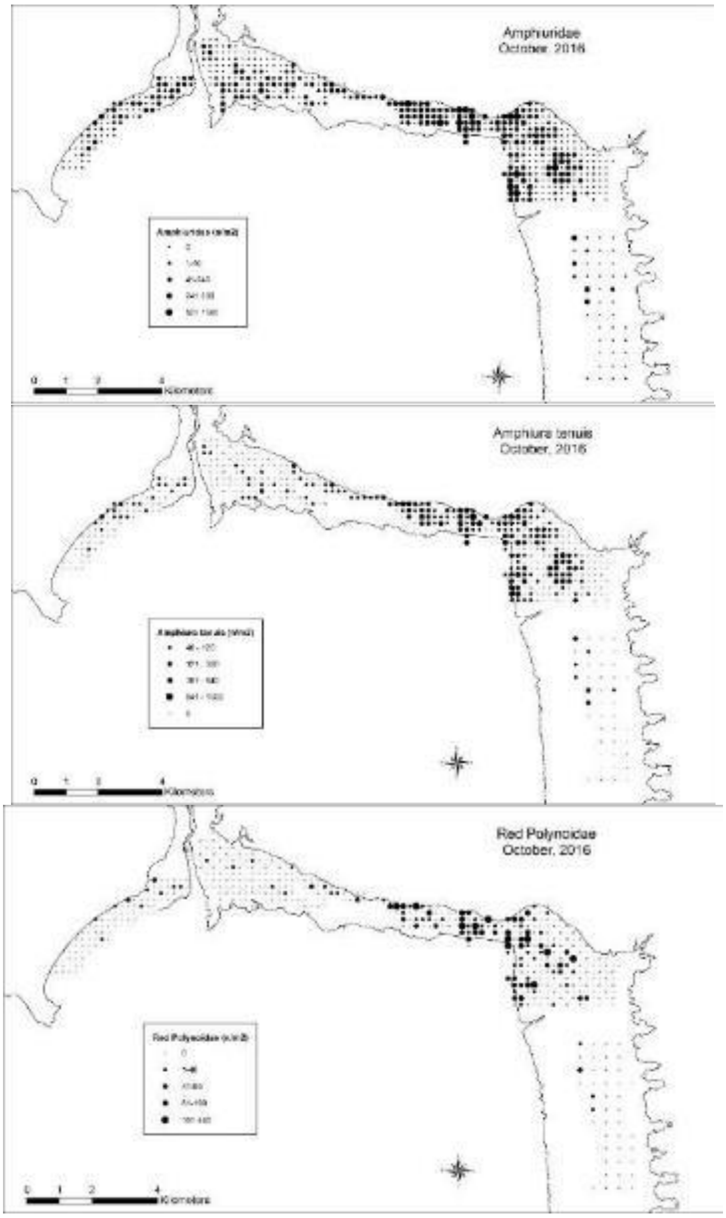


Fig. 35. Distribution across the northern intertidal flats of Roebuck Bay in October 2016 of members of the brittlestar family Amphiuridae (top panel), the common brittle star *Amhiura tenuis* (middle), and the half cm long red-coloured polychaete worm of the Polynoidae family that live symbiotically with brittlestars, based on the core-sampling efforts.

Photo 22. Close-up of the body of a small brittlestar, in this case of a 'spotted *Amphiura'*. Photo by Loran Kleine Schaars.

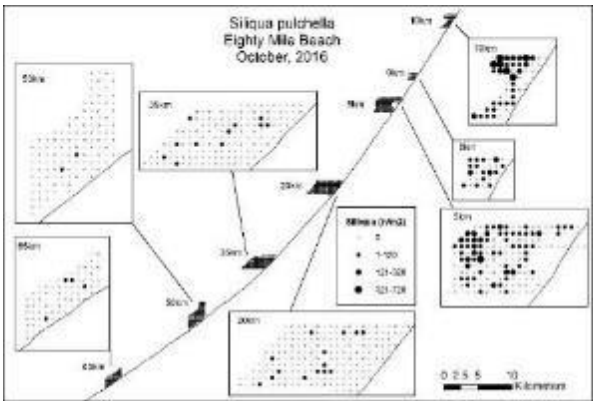
Edible bivalves at Eighty Mile Beach: we have news for the molluscivores

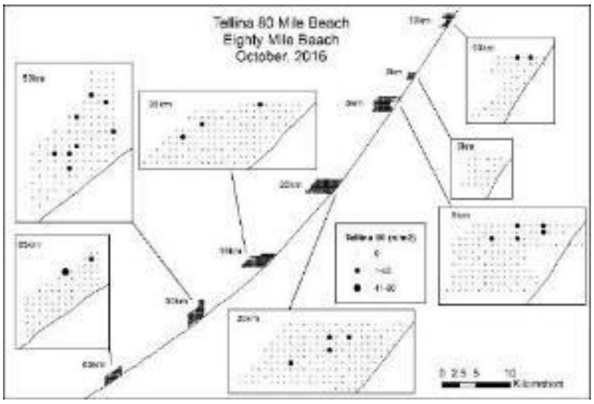
The West Kimberley coast is one of the few areas of the entire IndoPacific region where mollusc eating shorebirds are so abundant (Bom *et al*. MS). Specifically, this part of the Australian coastline hosts the largest proportion of the population of one species (great knots *Calidris tenuirostris*) and one of the six known subspecies of another (*Calidris canutus piersmai*). The paucity of mollusc eating shorebirds in other areas of the IndoPacific may be explained by the armoury of the molluscs. Especially the gastropods/snails, but also the bivalves, whom are so well defended after millions of years of exposure to molluscivore crabs, 'an evolutionary arms race' that went on undisturbed by the Ice Ages which so much affected the northern biota (Vermeij 1976, 1987). Why the West Kimberley coast should be an exception to the 'rule' of few molluscivores in IndoPacific intertidal areas remains a large biogeographic puzzle (Bom *et al*. MS).

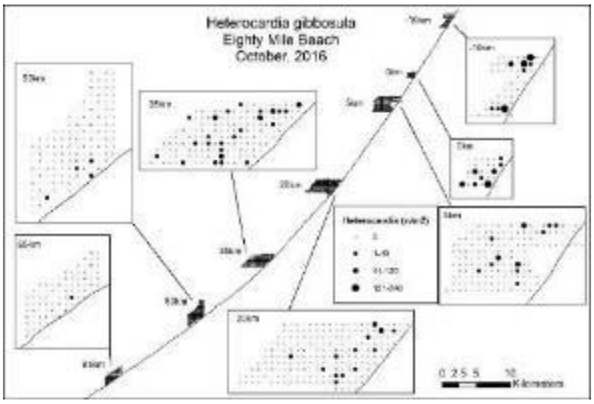
The great knots, and certainly the red knots, locate their mostly-bivalve prey by touch, and although they may be able to use surface-cues to a greater degree on the Kimberley mudflats (due to the high activity levels of the tropical invertebrates) than elsewhere in the world, it is likely that their flock-feeding also helps them to jointly locate the foraging areas with the highest abundances of bivalves. If only they could read our maps (Fig. 36) (or us theirs)!

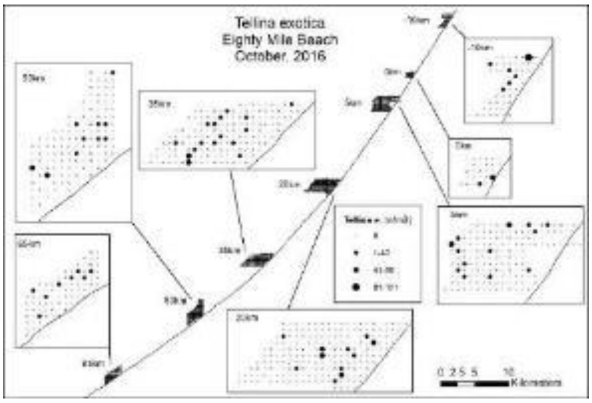
Photo 23. Roosting flocks of shorebirds just north of the Anna Plains beach access (great knots mixed with other shorebird species) during the outgoing tide, with a thin line of red knots foraging on the lower wet beach, probably in search of a small beach-bivalve *Paphies altenai*. Photo by Theunis Piersma.

The maps show that most of the attractive, thin-shelled bivalves are thinly spread along most of the surveyed Eighty Mile Beach foreshore. One ideal food source, *Siliqua pulchella*, reaches its highest densities in the muddy parts of the -5 km, 0 km and +10 km sections (Fig. 36). During the limited amount of time we spent observing shorebirds it was clear that the red knots, in particular (sometimes joined by some juvenile great knots), extended the low tide foraging time by feeding during both incoming and outgoing tide on wet areas of beach. In these areas, a small wedgeclam *Paphies altenai* occurs (mostly missed by our surveys), which may provide the staple food at these stages of the tide. Analyses of the droppings collected by PhD student Hebo Peng will tell us the story in the fullness of time.









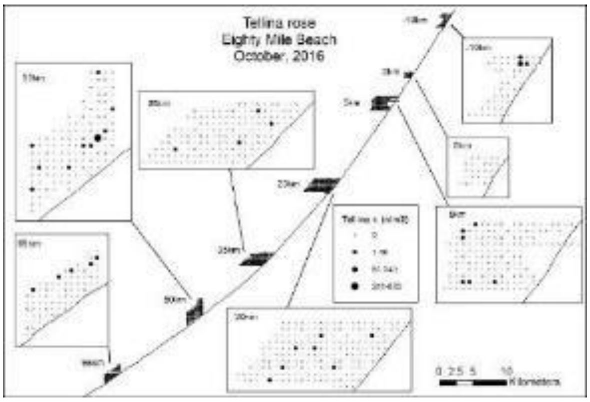


Fig. 36. Distribution maps of five species of bivalves that should provide good food for molluscivore shorebirds such as red and great knots in October 2016.

Slender invertebrates with elegant names: the polychaetes

Polychaete worms as a group are a bit of an 'acquired taste': polychaete lovers and connoisseurs are thin on the ground, and even these specialists have problems in easily assigning species names to the individuals, or the parts of individuals, found. Part of the problem may be that a fair percentage of the polychaete worms of intertidal flats in this corner of the world remain undescribed and unnamed, but it certainly also takes much time, skill and the availability of handbooks and specialised publications to make species assignments. For the mapping surveys, from the very start in 1997, we have chosen to identify polychaete worms to family level. During the present survey, material was collected for examination by Dr Chris Glasby of the Museum and Art Gallery Northern Territory for work on proper species designations.

We will now show some examples of the distributions of different families of polychaete worms, bearing in mind that each of these families may be represented by different species in different locations. Indeed, it is quite striking that all family distribution maps presented (Figs. 25-29) show particularly wide ranges, the polychaete taxa seemingly occurring over much broader ranges of sediment types and tidal heights than the bivalve species discussed above. These widespread distributions could perhaps be explained by being the result of the summation of much more limited species-specific distributions.

In the first three examples, we will compare distributions in June 2006 with those in October 2016. The family Syllidae shows a sparse, but widespread occurrence across the northern intertidal flats of Roebuck Bay (Fig. 37) with the highest densities at Town Beach in the west in 2006. During the present survey, Syllidae seemed to have declined along the northern shores and are now mostly found on Town Beach.

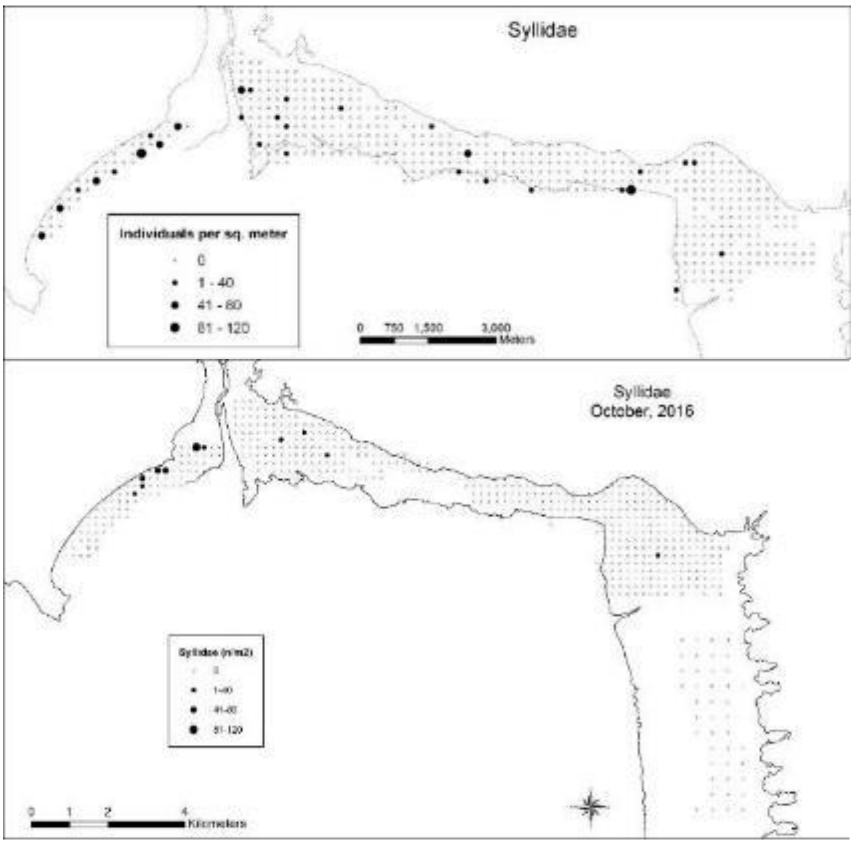


Fig. 37. Distribution of the polychaete family Syllidae across the northern intertidal flats of Roebuck Bay in June 2006 and in October 2016 based on the core-sampling efforts.

The Nephthyidae (Fig. 38) are a family of long and slender and agile predatory polychaetes with a tendency to occur in sandy sediments. They were widespread in June 2006. Comparison of the maps for 2006 and 2016 suggests that nephtids have lost territory on the lower shores, with a markedly high shore distribution in 2016.

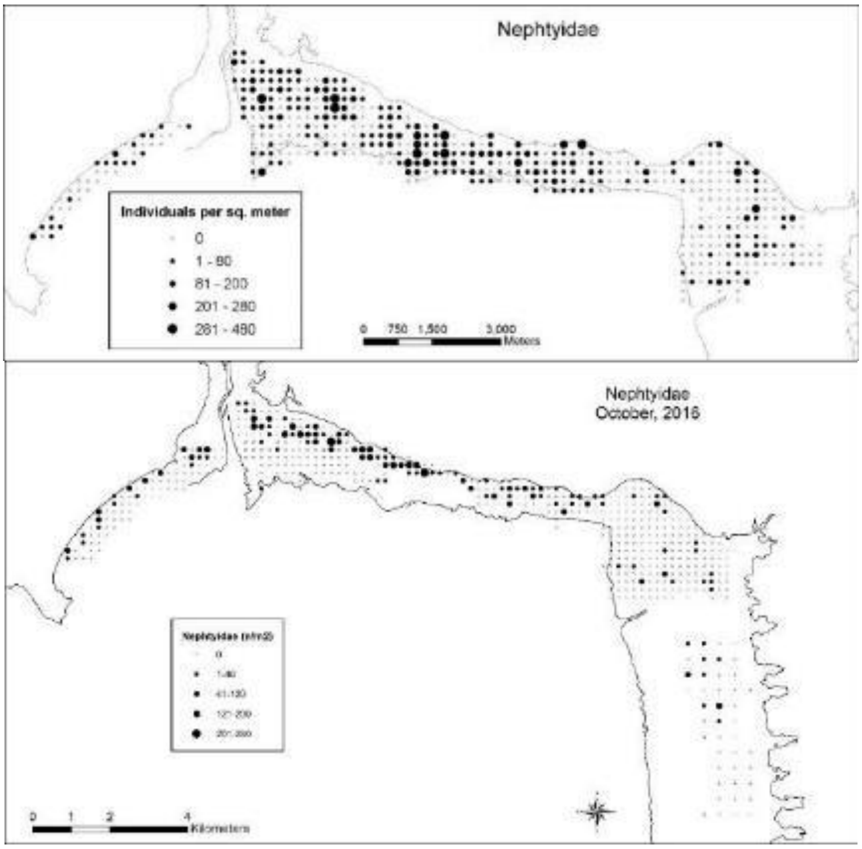


Fig. 38. Distribution of the polychaete family Nephthyidae across the northern intertidal flats of Roebuck Bay in June 2006 (top) and October 2016 (bottom) based on the core-sampling efforts.

Photo 24. Head ends of two worm families that 'moved upshore' in Roebuck Bay in 2016 compared to 2006: a Spionidae (*Paraprionospio* sp.) on the left and a Nephthyidae (*Nephtys* sp.) on the right. Larger nepthids may actually prey on smaller spionids. Photo by Loran Kleine Schaars.

In 2006 the Spionidae (Fig. 39) were just as widespread, but much thinner on the ground than the nephtids. And just as the nephtids, the spionids seemed to have reduced their distribution in the 10 years since 2006 to upper shore levels!

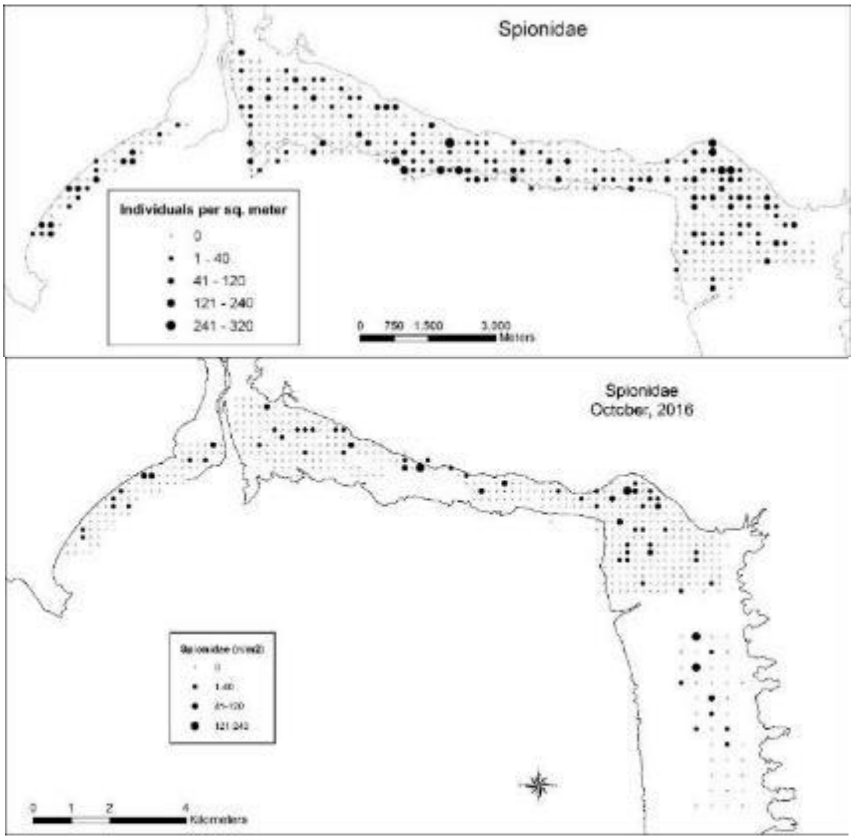


Fig. 39. Distribution of the polychaete family Spionidae across the northern intertidal flats of Roebuck Bay in June 2006 (top) and October 2015 (bottom) based on the core-sampling efforts.

Photo 25. Tubeworms of sorts! The Oweniidae with a strong tube made of sand and shell fragments (*Owenia mirrawa*) on the left and the ‘plastic worms’ Chaetopteridae (*Chaetopterus* sp.) on the right. Photos by Marc Lavaleye.

The Oweniidae are tubeworms with greyish tubes that come in a wide range of lengths. They were very abundant along the sandy northern shores during the first benthic survey in 1997 (Pepping *et al*. 1999). Since, they have declined greatly. Now they show the highest densities in the lower shore areas around Crab Creek (Fig. 40). It is striking that the Oweniidae have such a downshore distribution in the Crab Creek corner, as they seem to be living on the higher parts of the intertidal flats elsewhere along the northern shores. The contrast may well reflect the presence of different species with different habitat requirements.

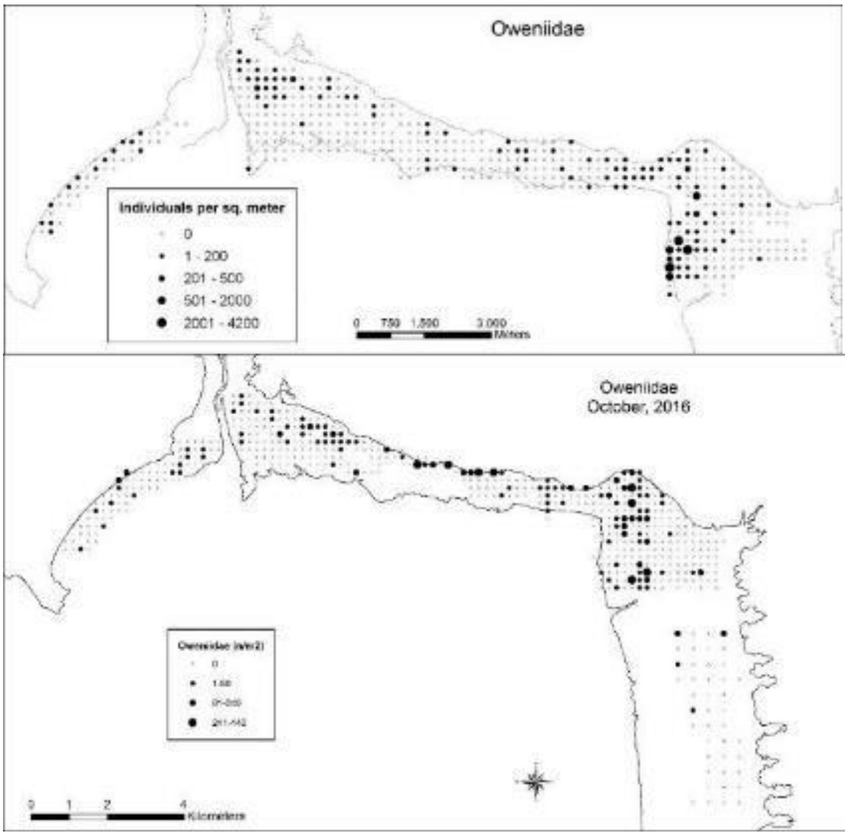


Fig. 40. Distribution of the polychaete family Oweniidae across the northern intertidal flats of Roebuck Bay in June 2006 based on the core-sampling efforts.

The Oweniidae and the 'plastic worms' Chaetopteridae were particularly abundant in June 1997 (much to the agony of the sorters who had to go through great masses of rapidly rotting tubeworms; Pepping *et al*. 1999) and were much reduced in numbers by 2002 (Piersma *et al*. 2002; and see de Goeij *et al*. 2003 who were able to document this trend at the monitoring sites). That the abundance of glycerids followed these trends to 2006 and on to 2016 (Fig. 41) is suggestive of a process where predators follow the abundance of their prey. This has been documented for the Dutch Wadden Sea, where a species of Nephtyidae (*Nepht\ys hombergii*) follows the abundance an Orbiniidae species, *Scoloplos armiger* (Beukema *et al.* 2000).

Figure 42 shows how different families of polychaete worms are distributed differentially over the northern intertidal flats of Roebuck Bay. The closely related tubeworm families Ampharetidae and Terebellidae occur in the sandier parts in the west. The Capitellidae were somewhat more widespread, and in 2016 the 'plastic worms' Chaetopteridae occurred especially in the muddier parts in the east, in a band just south of the Broome Bird Observatory.

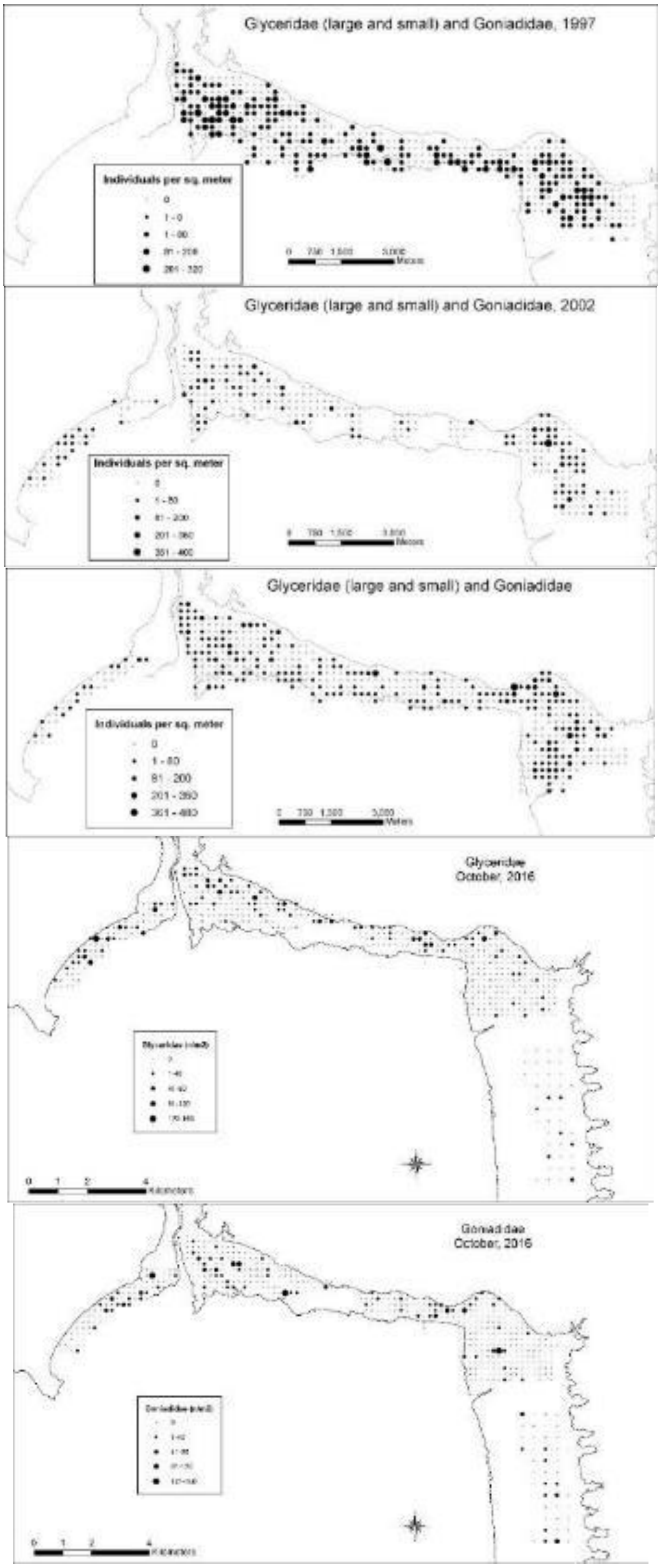


Fig. 41. Occurrence of the predatory worms belonging to the closely related polychaete families Glyceridae and Goniadidae combined in June 1997 (top), 2002 (2nd from top) and 2006 (3rd from top) and separately for the two families in 2016 (bottom two panels), based on the core-sampling efforts.

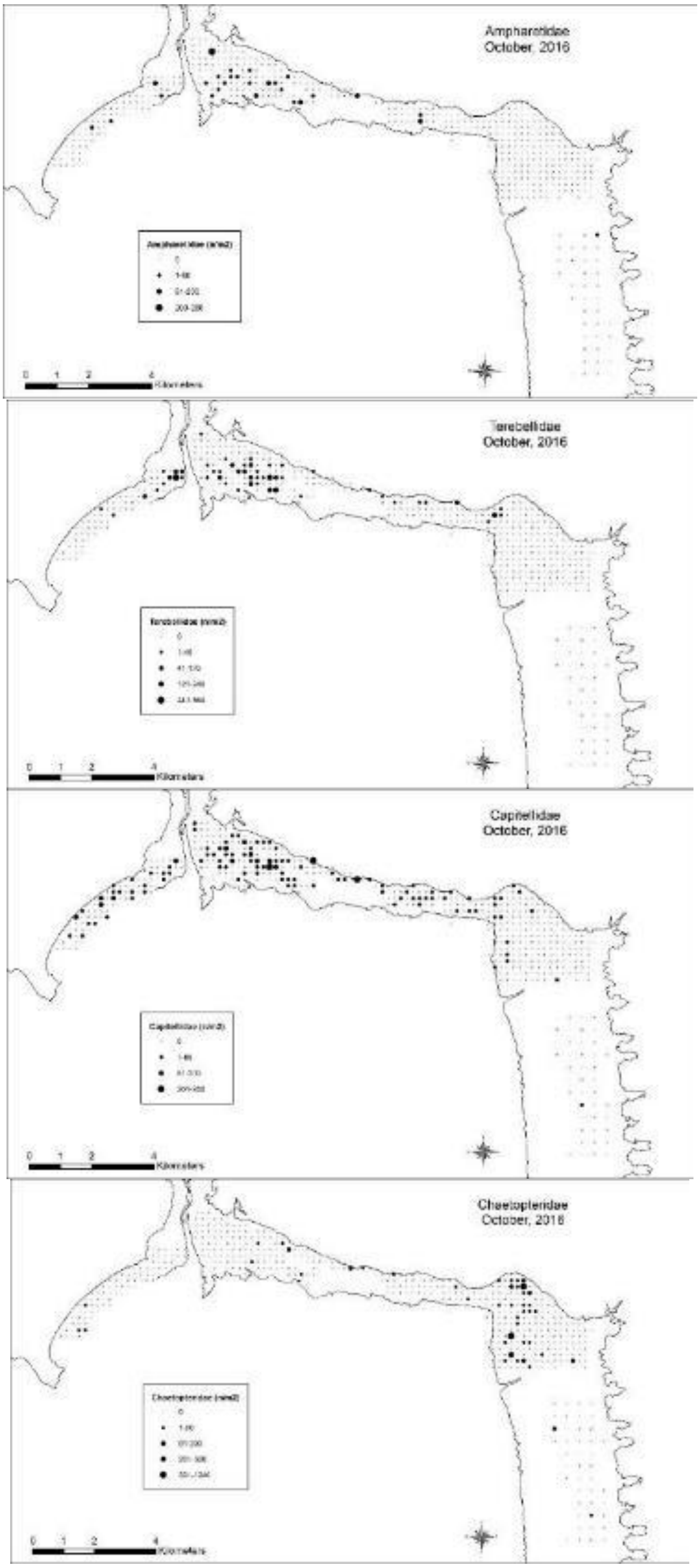


Fig. 42. Contrasting polychaete families with contrasting distributions along the northern shores of Roebuck Bay in October 2016. The Ampharetidae (top) and Terebellidae (upper middle) are both tube-dwelling worms with extensive and colourful filtering equipment which prefer sandy substrates such as those found west in the bay. The Capitellidae (lower middle) live inside the sediment and are deposit feeders and have a much wider range across the bay and the range of sediments. The ‘plastic worms’ Chaetopteridae (bottom panel) lives in a smooth plastic-looking tube and is a surface deposit feeder occurring in the sandy muds of Crab Creek corner.

Slender invertebrate beings rule the sands and shifting muds of 80 MB

As we have seen, from October 1999 to October 2016, the muds of Eighty Mile Beach experienced increasing densities of brittlestars *Amphiurus tenuis*, many families of polychaete worms, and several phyla of worm-like invertebrates. Eighty Mile Beach, more so than in 1999, in 2016 was a 'place of slender beings'. In this penultimate section of our preliminary report, we will show maps of the distribution of these taxa and in several cases compare these distribution maps with the ones from 1999. We start off with the common brittlestar *Amphiura tenuis* (Fig. 43) which shows a similar, but slightly expanded, distribution in 2016 compared with 1999, still avoiding the highest intertidal regions.

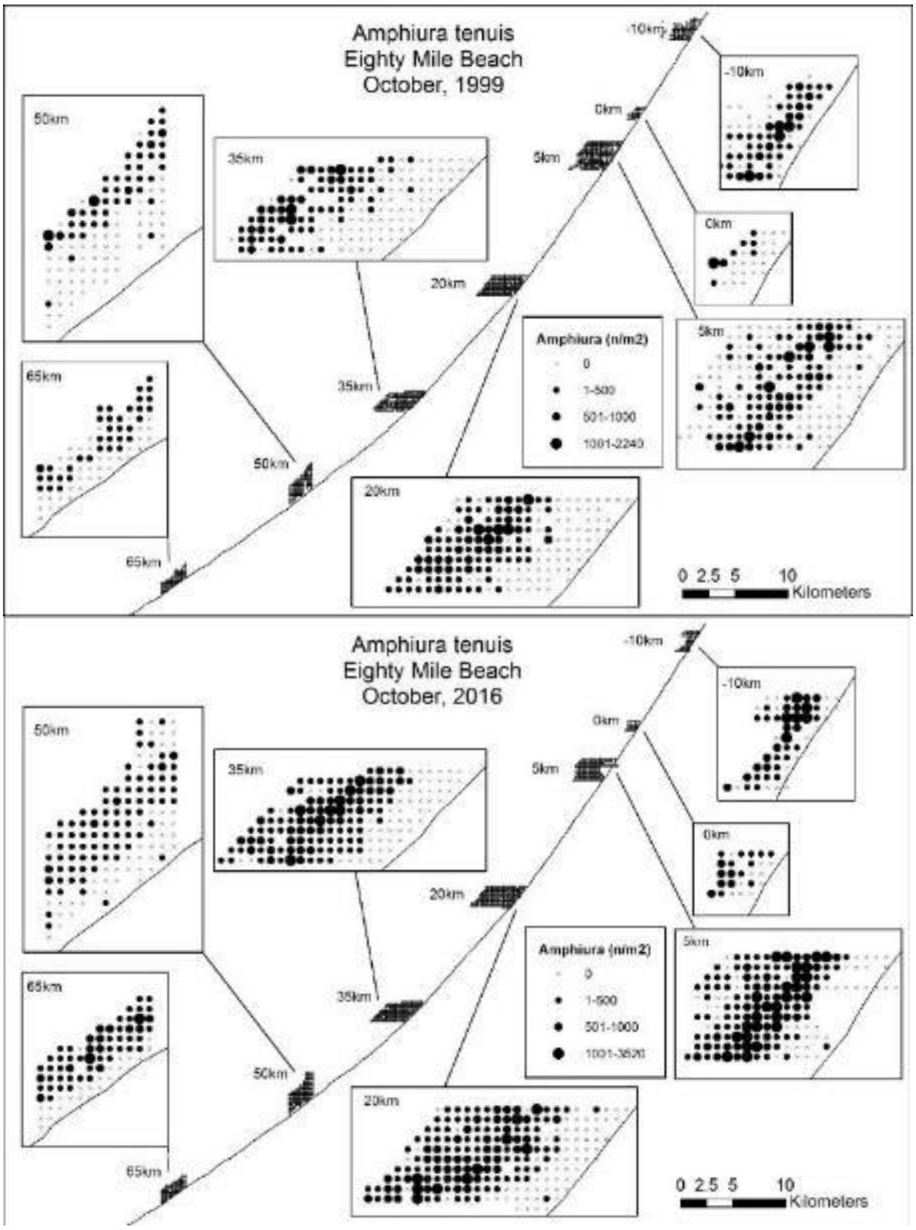


Fig. 43. Quantitative distribution of the brittlestar *Amphiura tenuis* on the intertidal flats of Eighty Mile Beach in October 1999 (top) and in October 2016.

At least three families of polychaete worms (the Capitellidae, Fig. 44; the Onuphidae represented by a single species of Diopatra, Fig. 45; and the Spionidae, Fig. 47) showed seriously expanded distributions - the Spionidae especially in the northern sections. The Glycerids (Fig. 46) were distributed quite similarly in 1999 and 2016.

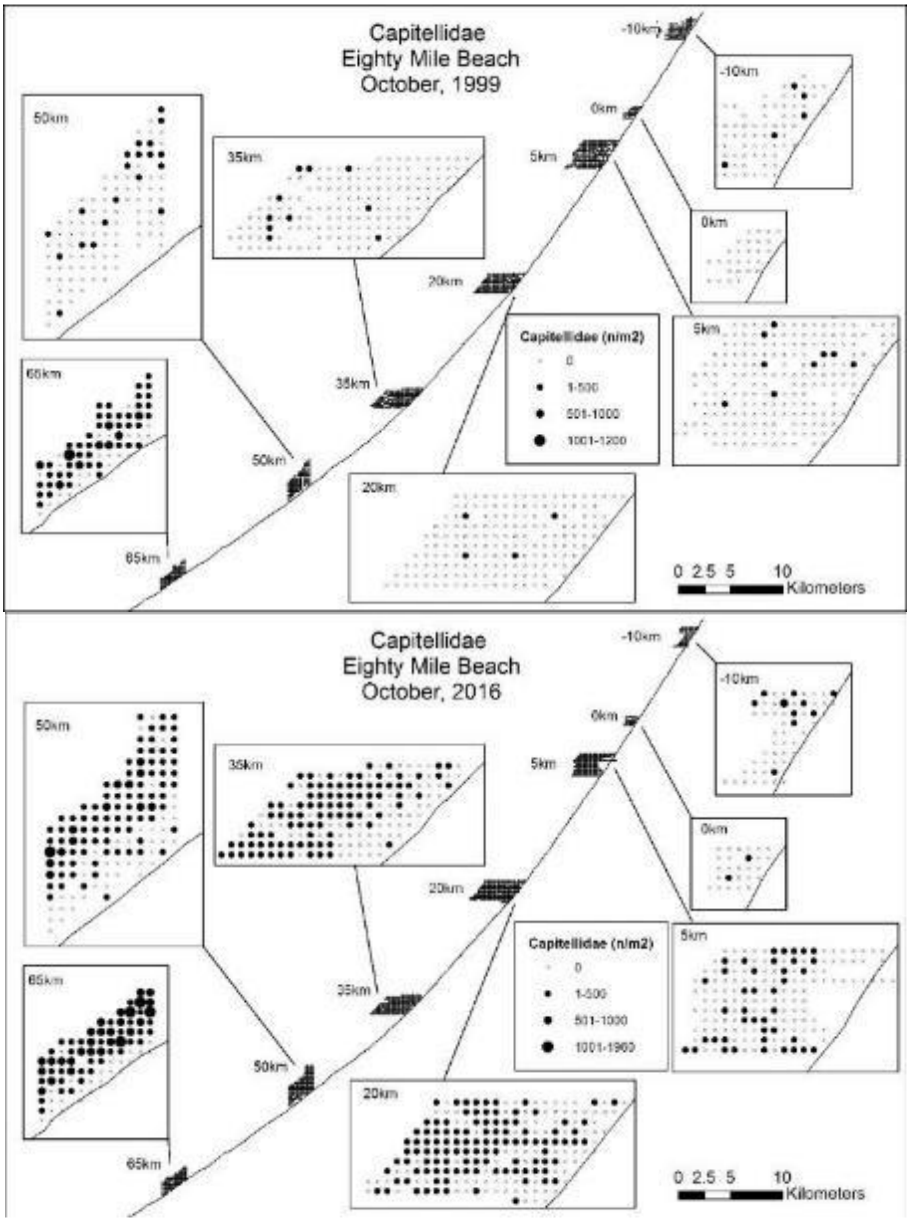


Fig. 44. Quantitative distribution of Capitellidae, a family of polychaete worms on the intertidal flats of Eighty Mile Beach in October 1999 (top) and in October 2016 (bottom panel).

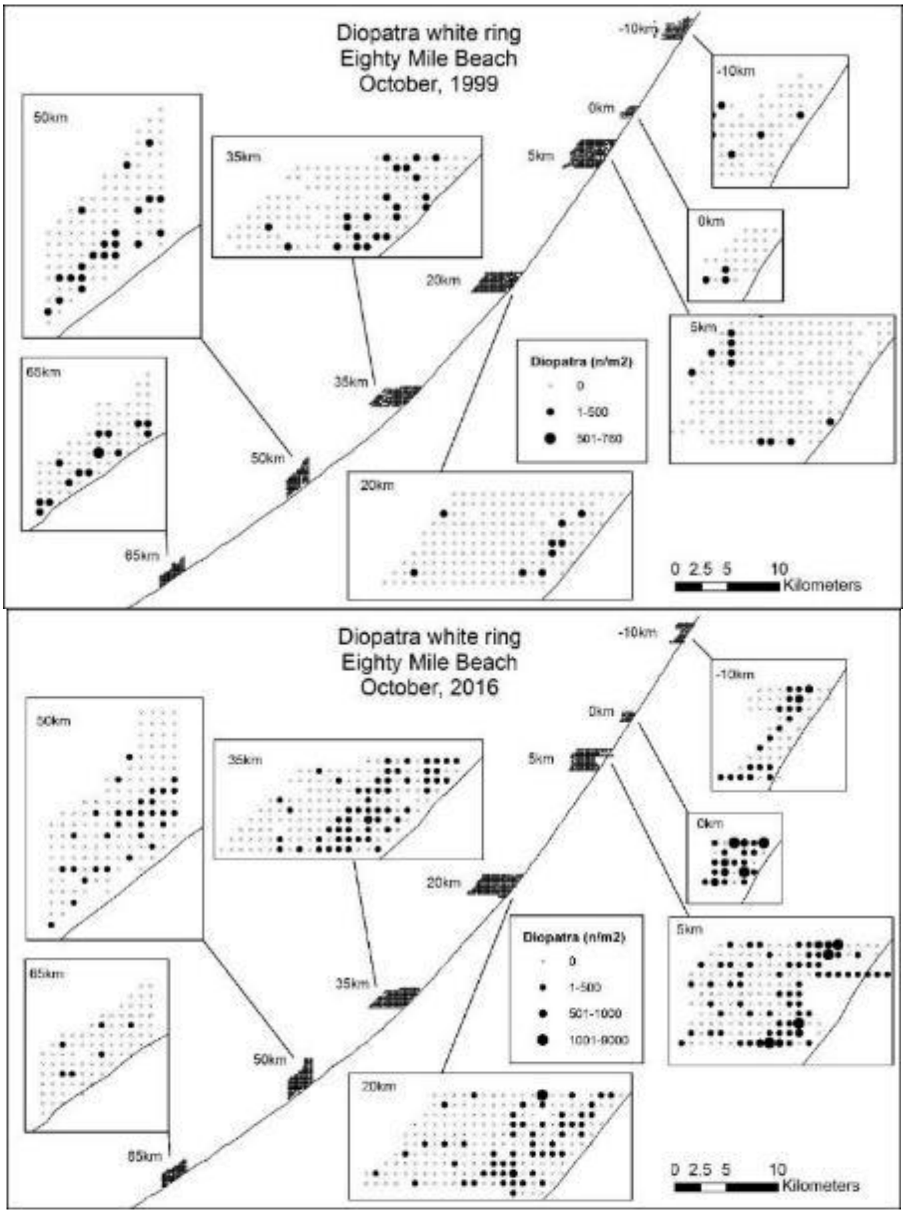


Fig. 45. Quantitative distribution of *Diopatra* sp., belonging to the Onuphidae family of polychaete worms on the intertidal flats of Eighty Mile Beach in October 1999 (top) and in October 2016 (bottom panel).

Photo 25. A *Diopatra amboinensis*, member of the polychaete family Onuphidae. Photo by Marc Lavaleye.

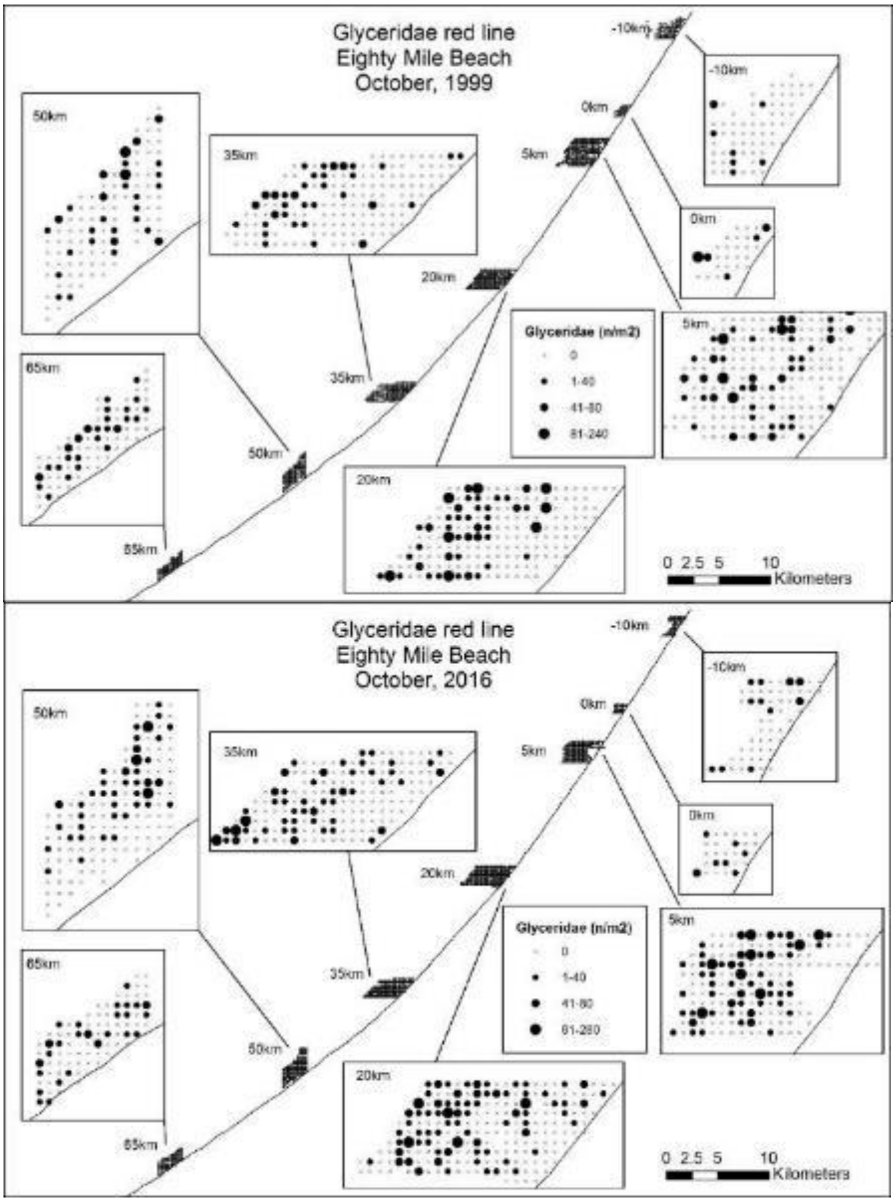


Fig. 46. Quantitative distribution of Glyceridae, a family of polychaete worms on the intertidal flats of Eighty Mile Beach in October 1999 (top) and in October 2016 (bottom panel).

Photo 26. The top-end (with the fierce jaws!) of the predatory worm belonging to the family Glyceridae. Photo by Marc Lavaleye.

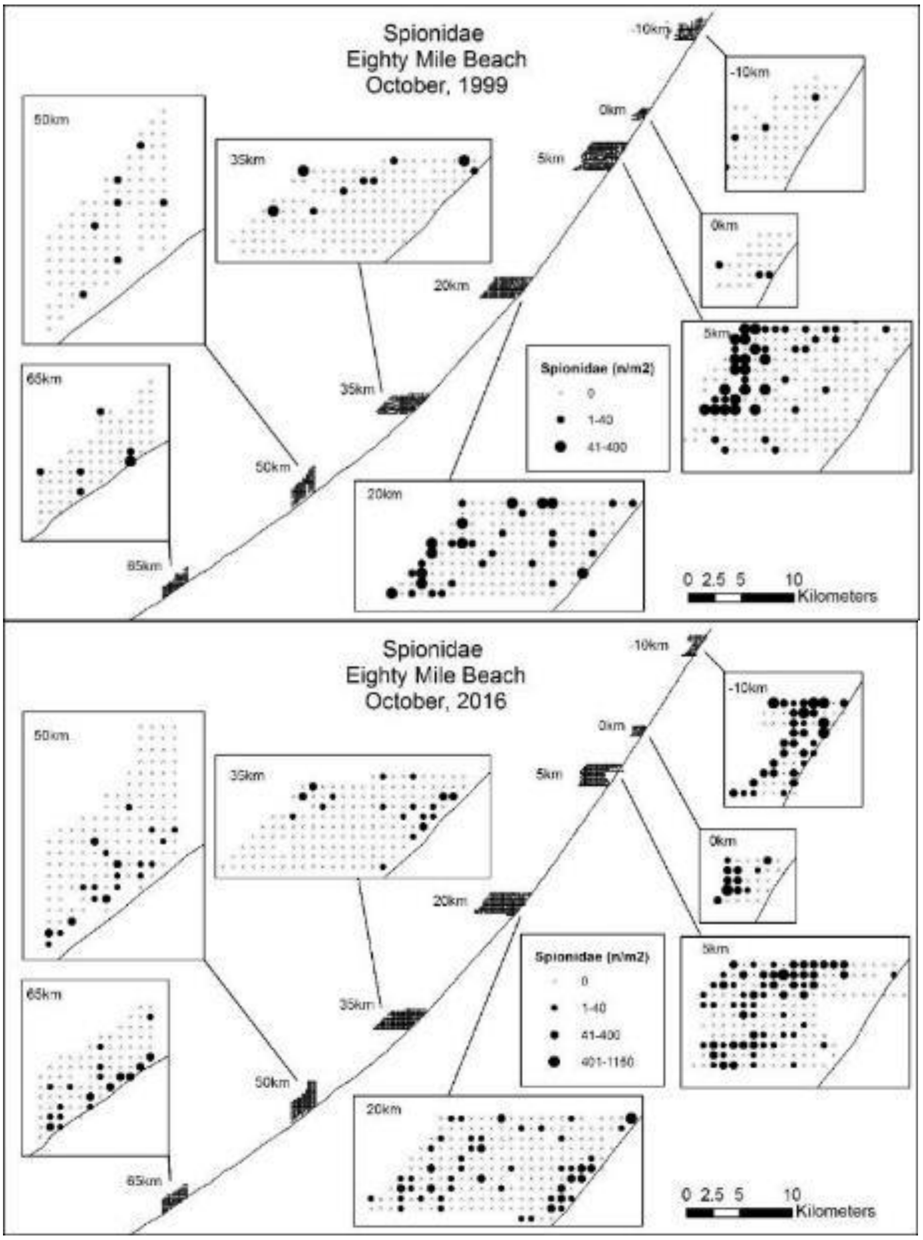


Fig. 47. Quantitative distribution of Spionidae, a family of polychaete worms on the intertidal flats of Eighty Mile Beach in October 1999 (top) and in October 2016 (bottom panel).

Photo 27. A polychaete worm belonging to the family Spionidae (*Scolelepsis* sp.). Photo by Marc Lavaleye.

Finally, we present a few maps of the worm-like creatures belonging to distinct lifeforms or phyla, organisms of which the overall shape may resemble worms, but in which everything from the details of morphology to reproduction etc. is different from the polychaete worms. Figure 48 shows the distributions in October 2016 of the penis-worm *Balanoglossus* and several species of ribbonworms or nemertines which occur thinly spread along Eighty Mile Beach. These two groups also occur in the intertidal of northern Roebuck Bay. The horseshoeworms or Phoronida seem to be unique to Eighty Mile Beach. Sea cucumbers (Holothuroidea) and even an anemone have worm-like shapes. Their distributions are shown in Fig. 49.

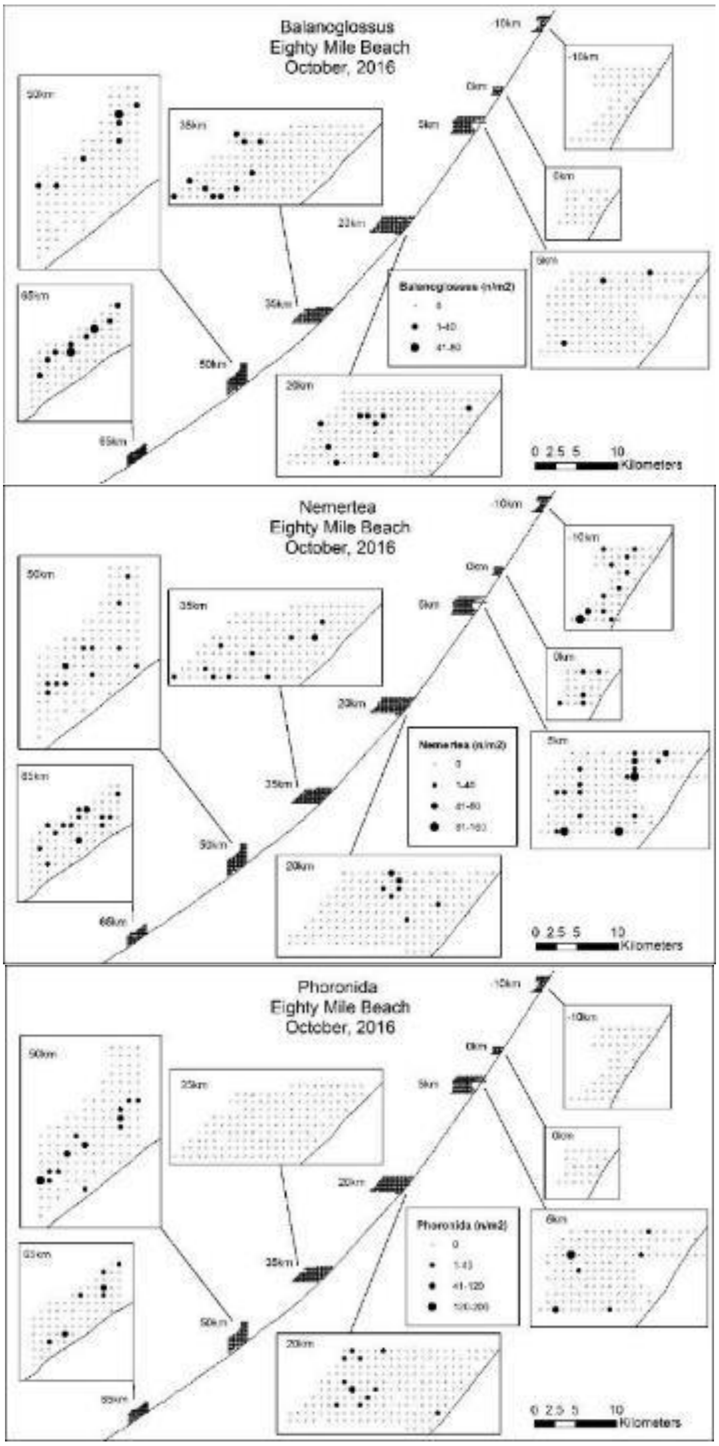


Fig. 48. Quantitative distribution of three worm-like phyla, the penis-worms Enteropneusta (represented by a *Balanoglossus* species; top), the ribbon-worms, nemertines or Nemertea (middle panel) and the horseshoeworms or Phoronida (bottom panel) at Eighty Mile Beach in October 2016.

Photo 28. A horseshoeworm (Phoronida) coming out of its tube. Photo by Marc Lavaleye.

Photo 29. Enjoy the subtle colours and shapes of the white-spotted *Edwardsia* anemone! Photo by Marc Lavaleye.

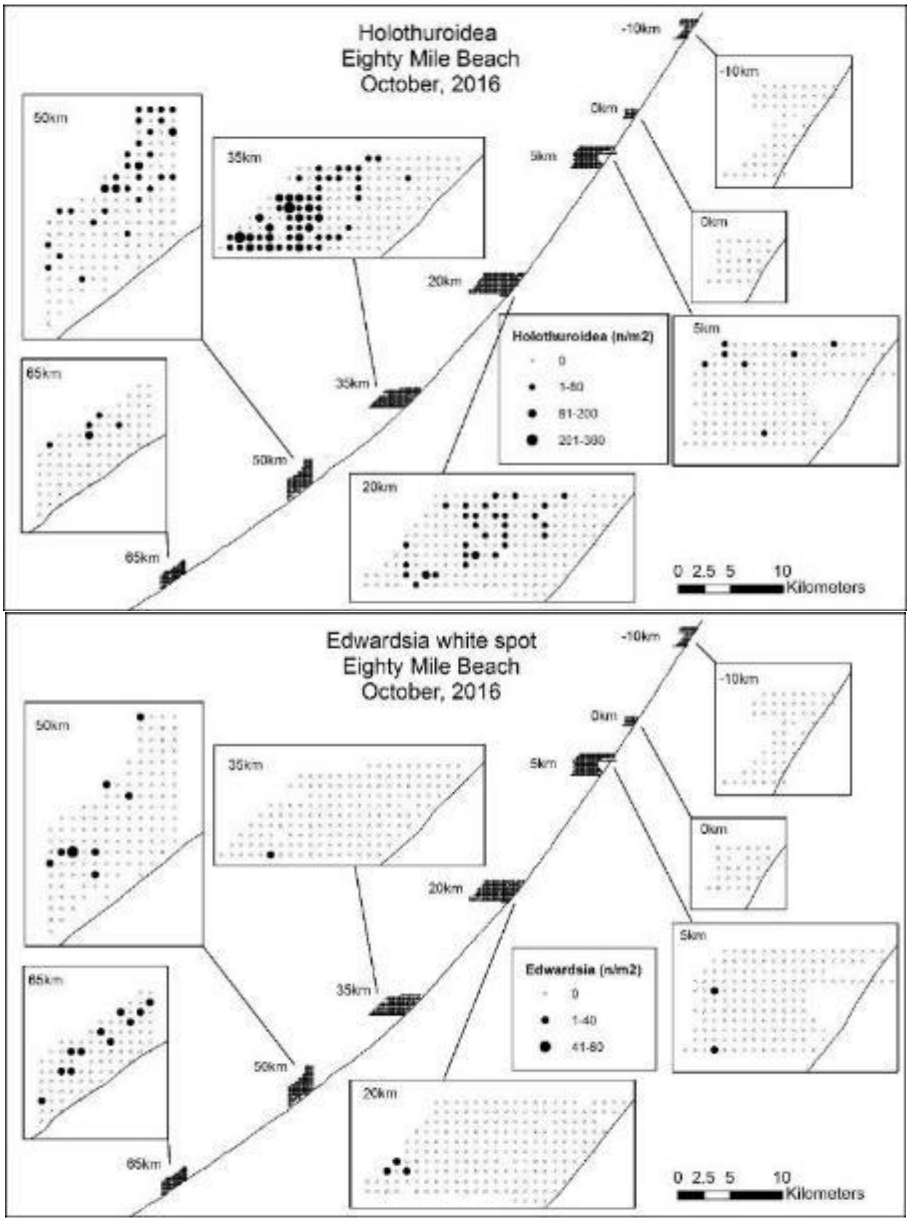


Fig. 49. Quantitative distribution of two more worm-like organisms, in this case the seacucumbers Holothuroidea (phylum Echinodermata, top panel) and the little sea anemone *Edwardsia* (phylum Anemona, bottom panel) at Eighty Mile Beach in October 2016.

A fast crab missing in the cores: ghost crabs, the hyaenas of the intertidal?

The hyaenas of the African savannah had a reputation for being cowardly scavengers, stealing the rewards of hard predatory work of more lovable carnivores such lions and cheetahs. This was demonstrated to be incorrect, as hyaenas routinely capture and subdue large prey themselves, sometimes losing them to lions as the scavengers. Ghost crabs *Ocypode* are well-known scavengers from tropical beaches. The ghost crabs of the Kimberleys, *Ocypode fabricii* (not in our species list, as we never found it in our core samples), is supposed to be a scavenger as well (and it can give rasping sounds by moving its claw over a little 'washboard' on the carapace!).

Photo 30. Portrait of a Kimberley ghost crab, *Ocypode fabricii*, on the intertidal of at Eighty Mile Beach. Photo by Fintan Angel.

The few observations we made in transit from one sampling point to the other suggest that ghost crabs are respectable predators, probably competing with crab-eating shorebirds such as eastern curlew and the tattlers for sentinel crabs *Macrophthalmus*, and with the molluscivore shorebirds such as red knots and great knots for bivalves such as *Heterocardia gibbulosa*.

Photo 31. Ghost crab munching on a big bivalve, *Heterocardia gibbulosa* (Mactridae), on the intertidal flats of Eighty Mile Beach. Photo by Ying-Chi Chan.

Photo 32. Ghost crab at Eighty Mile Beach holding an Ingrid-eating snail *Nassarius dorsatus* in its right claw whilst pulling (and eating) parts of a *Macrophthalmus* held in its left claw. It is not clear whether the ghost crab went on to eat the snail; the sampler had to march on and leave the dinner scene behind. Photo by Ying-Chi Chan.

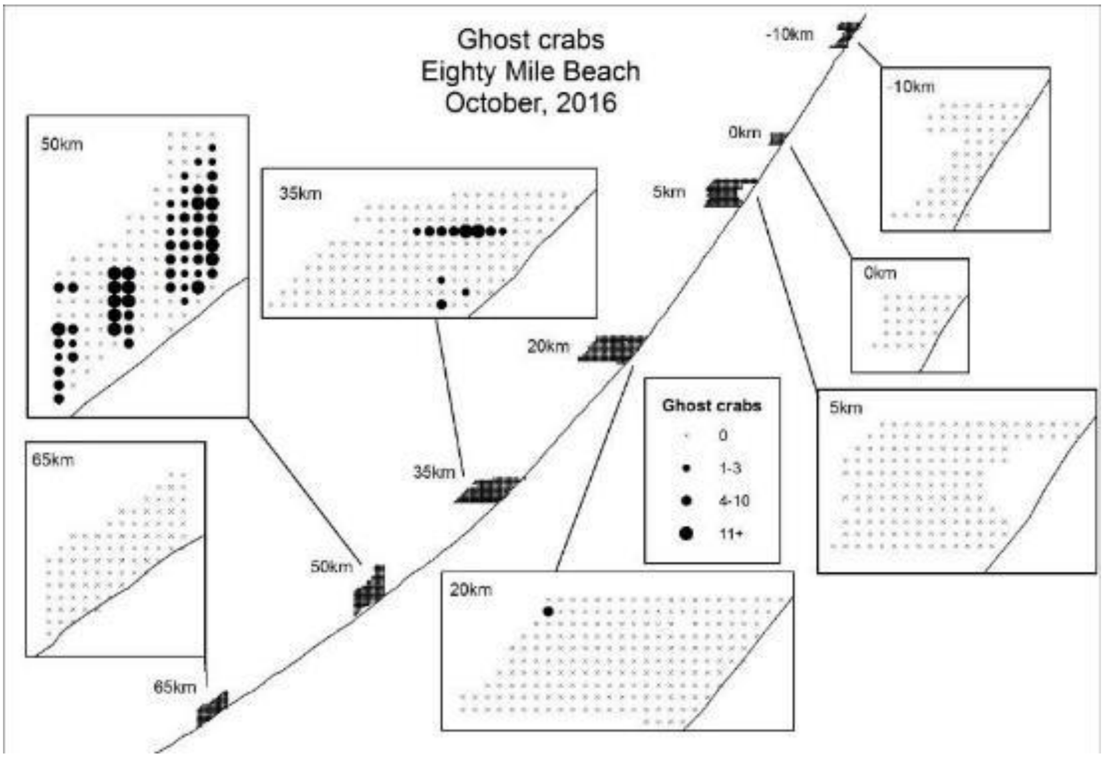


Fig. 50. Ghost crabs *Ocypode fabricii* were seen on the surface of the intertidal on the sandy sections along Eighty Mile Beach, notably at -50 km and at -35 km.

7. Acknowledgements

The area between Wirkinmirre (Willie Creek) and Warrawan (Barn Hill) are the traditional lands of the Yawuru people. We respectfully acknowledge the past and present traditional owners of the land on which we conducted our research, the Yawuru people.

The areas around Anna Plains Station are the traditional lands of the Karajarri and Nyangumarta people. We respectfully acknowledge the past and present traditional owners of the land on which we conducted our research, the Karajarri and Nyangumarta people.

This is the eighth survey of benthic invertebrate biomass and distribution on intertidal mudflats in the West Kimberley (RoeBIM97, DerBIM98, AnnaBIM99, Trackin'2000, SRoeBIM02, RoeBIM06, Roebuck13, AnnRoeBIM16). The process of collecting, collating, and curating the benthic organisms and the relationships to shorebirds has now become so practised that the sampling sites for the whole of the northern side Roebuck Bay plus parts of the western shores, were mapped in record time.

Many of the people involved in this project, in particular the indigenous participants, are now, and will be for the foreseeable future, the key components in the development, management and maintenance of benthic monitoring programs for Roebuck Bay and Eighty Mile Beach. A great deal of preparation time from a number of parties has been invested in this project over a considerable time. The expedition was the culmination of several years of behind the scenes work by Grant Pearson, Sora Estrella, Tanya Compton and Andrew Storey, attending numerous meetings and preparing lengthy proposals to secure the funds necessary to run the surveys. This was followed by six months of intense planning by Grant, Andrew and various staff members from Wetlands Research & Manaement to ensure all logistics were in place, travel booked for everyone from locations as distant as Seattle, Shanghai, Texel, Den Helder and Gaast, and locations closer to home, including Melbourne, Darwin, Busselton and Perth, OH&S was in place, local transport organised, and all the various minutae required by such an expedition were thought of and provided, from mueslie bars to microscopes, and tents to toilet paper. Grace Maglio is also thanked for her ongoing assistance, being our Broome-based organiser. A very big thank you to Tanya Compton of NIOZ, who would normally have joined us in the field but had to remain in The Netherlands. Full lists of participants and supporters of the two chapters to the AnnRoeBIM16 Expedition are provided below.

Project funding was provided by The Western Australian Department of Parks and Wildlife via an external partnership with BHP Billiton “Eighty Mile Beach and Walyarta Conservation Program” and Department of Parks and Wildlife.

We thank West Kimberley District Manager Alan Byrne for his continued support for benthic and shorebird research over the years. His leadership in the West Kimberley District has transformed the culture and conservation landscape in the West Kimberley. Chris Nutt, now the new Marine Park Coordinator for Rowley Shoals, Yawuru Ngulagun/Roebuck Bay marine parks, has provided valued input into discussions regarding benthic mapping projects over time and is thanked for his support in the field and office, but especially for his continued efforts to sort out the red tape and to ensure the success of this project. A major contributor to the organisation and funding for this project came from Naomi Findlay, the Project Officer for Eighty Mile Beach (BHPBIO) who demonstrated extraordinary energy, organisational skills, teamwork and commitment throughout the preparations and during the field operations. No task was too big or too small for Naomi and the successful coverage of 1350 sites at the two locations would not have been possible without her inspired input.Thanks also to Danny Stefoni, Fauna Licensing Officer, Nature Protection Branch, DPaW for his assistance with issuance of necessary licenses.

In addition to the always generous support for benthic surveys in Northwest Australia, the national institute for oceanographic and marine research in The Netherlands, Royal NIOZ, provided further important support to the project by allowing four highly skilled people with considerable experience in sampling benthos to participate for the full period of surveys at both locations. Their contribution cannot be overstated, especially in light of the relative inexperience of the rest of the AnnRoeBIM16 team.

Wetland Research and Management directed by Andrew Storey was responsible for project management but also provided assistance by allowing staff to assist with field work and project operations. Emma Thillainath was a highly organised always enthusiastic participant in the field and around the basecamps at Roebuck Bay and Eighty Mile Beach. Fintan Angel and Kim Nguyen were present at Eighty Mile Beach and provided quality support and enthusiastic, untiring (or so it seemed) legs throughout. Fintan is especially thanked for his contribution to the daily diary – a task he accomplished with wit and tenderness, qualities his rugged persona, at first glance, seemed to effectively conceal! Thanks also to Sue Davies for her help with provision of supplies and equipment for the expedition.

Central Washington University provided the release time and some funding for Bob Hickey to join the expedition as resident cartographer and GIS nerd.

Once again the Broome Bird Observatory provided a perfect venue and facility for the benthic survey at Roebuck Bay, and we received great hospitality from its wonderful team of wardens: Nigel and Jaime Jackett, and assistant wardens John Graff and Emilia Lai, as well as John and Anne Woollard. The very high value of the BBO mudlab was again demonstrated as sorters and identifiers worked into the nights to complete their tasks. This facility has been essential for all benthic surveys, and there is no doubt it has been a key to the great success of our benthic surveys.

At Eighty Mile Beach, John, David and Helen Stoate generously allowed us access to one of the Anna Plains Station houses that is occasionally occupied by itinerant researchers. This building provided shelter for the microscopes, comfort for the taxonomists, and a base for the caterers. We are, once again, most grateful to the Stoate family for their generosity but especially John for his inspired commitment to shorebird and benthic research that, through the creation of a dual-use nature strip along the foreshore some years ago, ensured the biodiverse northern half of Eighty Mile Beach retained some isolation from damaging human influence in recent years.

Previous experience has proven the value to benthic mapping surveys of a suitable hovercraft capable of traversing deep mud and open water. We thank and acknowledge Peter and Elaine Venn of Hovercraft Environmental Services for their participation in the work at Roebuck Bay and Eighty Mile Beach. Peter’s skilful use of the hovercraft enabled teams to access so many otherwise inaccessible sites at both locations. Peter and Elaine generously donated an additional sampling day to both locations that was very highly valued. Elaine is also thanked for her valued voluntary contribution to the daily sample sorting and her input into camp operations.

We also thank The Department of Parks and Wildlife for their commitment to the project by bringing the Venn hovercraft to Broome from Queensland, following the unexpected withdrawal of our original hovercraft operator.

Thanks to Parks and Wildlife Regional Fire Coordinator, Nathan Connor for the use of the Toyota Light Fire Unit that was essential for washing people and vehicles and to Nature Conservation Coordinator Tracy Sonneman’s Nature Conservation team (Karen Bettink, Philip de Bruyn, Bruce Greatwich) for their input and loan of Toyota Landcruiser dual cab and trailers.

The DPaW vessel Linygurra operated each of the six days of the Roebuck Bay segment. The vessel was crewed with a team of Anthony Richardson (Skipper) supported by a Yawuru deckhand plus two AnnRoeBIM16 members (Sander Holthuijsen taking core samples and one other assistant) and demonstrated the effectiveness of a properly equipped small boat for taking core samples.

This is the first BIM to incorporate a properly structured involvement from indigenous

groups associated with the two research sites. We thank the members of Yawuru (Anthony Richardson (Lingyurra Skipper), Jason Fong, Luke Puertolano, Jason Richardson, Curtis Robinson and Preston Manadu for their important roles in the Roebuck Bay surveys, outreach programs, and their willingness to embrace all aspects of the project. The Yawuru team participated on the Lingyurra, helped with the school groups at Town Beach, or drove out to the Bird Observatory each day for sampling and sorting. At times, Yawuru team members were involved in discussions with scientists about aspects of the specimen identification process and curation. The Nyamba Buru Yawuru Country Managers, whilst not involved in the daily operations, visited BBO to engage the scientists in discussions about monitoring and the work undertaken by AnnRoeBIM16.

We are very grateful for support and integration of the Indigenous Protected Area (IPA) Rangers from Karajarri and Nyangumarta and their supervisors at Eighty Mile Beach. Four Parks and Wildlife indigenous Trainee Rangers Nathan Hunter and Augustine Badal (Nyangumarta) and Stephen Brown and Jeffrey Brow (Ngarla) along with Trainee supervisor Nathan Kay, participated very effectively in all aspects of sample collection and sorting. Between sample collection periods the indigenous Rangers were able to sit with scientists to gain first-hand knowledge of the process involved in identification and curation of specimens collected. Two groups of Karajarri IPA Rangers joined the expedition between October 13 and 20 to assist with sample collection and sorting. Group A with coordinator Sam Bayley participated from October 13 to 16 with Kelvin Mitchelson, Braedon Taylor and Lyden Bangu. Group B with Coordinator Jackie Wemyss included Rangers Wynston Shovellor and James "Shorty" Bellou, Nyangumarta IPA Rangers Lynette Wilridge, Charmaine Wright and Ishmael Hunter are thanked for their contribution to the project and for sharing their knowledge with project managers.

For the first time after so many benthic surveys, it was with great anticipation AnnRoeBIM16 was able to proclaim their own resident artist and outreach specialist: Angela Rossen. Angela is an extraordinary artist and educator and rather opportunistically connected with us a few weeks before the expedition. It was immediately clear the technique Angela planned to use in Broome to portray a handful of wriggly things in a small dish viewed through a magnifying lens and an Ipad could assist in developing significant community outreach outcomes from our benthic mapping survey. The remarkable technique combined with the children's artistic impressions of the animals viewed through the iScopeStand delivered an outstanding level of community engagement and entry into the process of benthic intertidal studies and we are extremely grateful to Angela for her outstanding effort and to DPaW's Sarah Mullineux for ensuring Angela was well supported to maximise influence in the community. Well done indeed Angela, Sara, and the Department of Parks and Wildlife support team!

A high level of daily organisation is a key ingredient for success for these expeditions. Team Winchcombe, very capably lead by Yvonne Winchcombe following up on her outstanding effort in Roebim06 but this time assisted by Chelsie Winchcombe, Juliet Olsen, and Obelia Walker, combined to ensure the field equipment was always immaculately prepared and ready ahead of time for the daily sorties into the mud. Chelsie, often assisted by Obelia, ran a very efficient sorting tray preparation outfit that streamlined the sample sorting process at both locations. Apart from their natural high level of organisation they also possessed an enviable level of physical fitness that was a benefit in the mud and seemed (to some of the older people in the camp) unnatural! Yvonne also loaned a field microscope to the project for which we are most grateful.

It is said an army marches on its stomach, and our little band was no different. We were treated to extraordinarily high quality fare every day during the expedition so it must be said we are especially grateful for the extraordinary preparations from our own sous-chefs and caterer (the ever-cheery, super-organised and creative) Maurice O’Connor, (the indomitable, never-still and supportive) Helen Macarthur and (the workaholic and affable) Perth restaurateur and winemaker Warwick Lavis (who also happened to cater for the Dutch Royal couple during their visit to Perth in the first days of November). Helen continued to live up to the legend of her reputation by providing enormous amounts of cake and biscuits that kept the expedition energy levels at an all-time high and was welcome relief from the tedium of endless muesli bars! Helen also generously loaned a number of swags to overseas participants and transported popele to Anna Plains Station in her own verhicle.

Photo 34. Chief Chef Maurice O’Connor flanked by his marvellous assistants Helen McArthur and Warwick Lavis preparing one of the many nutritious evening meals that served so well to sustain the troups and distract them from the day’s arduous labours. Photo by Angela Rossen.

Once again, staff from NIOZ formed the backbone of the teams at both locations. Marc Lavaleye led the team of benthic specialists at Roebuck Bay including PhD student Ginny Chan of NIOZ, Chris Glasby from the Museum and Art Gallery of the Northern Territory, Petra de Goeij of NIOZ, Loisette Marsh (retired), PhD student Hebo Peng of NIOZ, Jane Prince, University of WA, Sora Marin-Estrella of Edith Cowan University, Danny Rogers of Arthur Rylah Institute, Grace Maglio from Broome, Amanada Lilleyman from Charles Darwin University, and Shirley Slack-Smith (retired) formerly of WA Museum all worked tirelessly to ensure the customary bottleneck for sample sorting did not occur in the lab this time. We thank all these contributors and their parent organisations for allowing us to use their very precious and expensive dissecting microscopes and light sources. Jan Lewis and Kim Ure provided capable assistance in the lab sorting and measuring the numerous brittlestars, especially at Eighty Mile Beach.

Logistics can be a complex issue when operating remote from normal facilities. However, the specialist (ex-military) team of Bart Mavrik and Bill Bryden ensured every little (and large) logistical issue was quickly dealt with, at times, remarkable ingenuity. Our thanks to Bart and Bill for their perseverance, hard work, and good humour. Bart extended his repertoire of skills by reading after dinner stories from time to time with great effect.

Thanks to Geoff and Rosemary Thunder for loaning us their superbly equipped and functional heavy duty trailer that transported our equipment safely to and from Broome. We are grateful to Ted Costello for his loan of a satellite telephone that provided emergency support if needed (it wasn't needed, but it was reassuring to have during trips to remote sites).

The team of samplers quickly developed strength and endurance. By the time we reached the end of the Roebuck Bay segment, people like Obelia Walker, Grace Maglio, Sora Marin-Estrella, Juliet Olsen, Chelsie and Yvonne Winchcombe, and Emma Thillainath were leading sampling teams and organising lab and camp duties. Similar results occurred at Eighty Mile Beach where sediment types had become much softer (and boggier) from those experienced in AnnaBIM99 and a brief visit in 2007 and teams showed tenacity and endurance throughout.

The Roebuck Bay Working Group - RBWG, through Kandy Curran, is thanked for their input into the project and for distributing information about the benthic project. Kandy secured a small amount of funding that would fund the production of a short film on the operations of the benthos expedition. Paul Bell was the producer/film maker who joined us at both locations to record interviews and obtain film of the activities and is thanked for his support. Our thanks to Australian Wader Studies Group - AWSG (Chris Hassell, Clive Minton, and Roz Jessop) for the loan of their camping equipment for Eighty Mile Beach and for assistance and advice for OH&S preparations for the expedition.

Some stalwart participants were present demonstrating that age is no barrier to participating in benthic surveys. Shirley and Loisette we have mentioned, but Mavis Russell who provided support over so many years was with us again at Roebuck Bay and continued to provide valued assistance around the camp and ensure the rules regarding muddy boots in the shadehouse, cleaning up, and helping with camp chores was rigidly enforced. Well done Mavis!

And last, but by no means least, a huge thank you to Danny Rogers who provides such high quality input into any expedition he participates in. When saying goodbye to Marc Lavaleye he mentioned he might visit NL some time and knew where he could find Marc. Marc suggested he could help him examine the hundreds of small paper dinner plates littered with the millions of shell fragments - the proceeds of the benthos samples that Marc insisted we save for him. Danny responded "I would love to and perhaps if you are in Melbourne some time I could show you a nice sewage farm"!

Such are the characters participating in benthic mudflat sorties!!!

Roebuck Bay Participants

First Name	Last Name	Role
Jaime	Jackett	Broome Bird Observatory
Nigel	Jackett	Broome Bird Observatory
Anne	Woollard	Broome Bird Observatory
John	Woollard	Broome Bird Observatory
Emilia	Lay	Broome Bird Observatory
John	Graff	Broome Bird Observatory
Paul	Bell	Camera
Warwick	Lavis	Catering
Helen	McArthur	Catering
Maurice	O'Connor	Catering
Alan	Byrne	DPaW District Manager West Kimberley
Naomi	Findlay	DPaW Project Officer Eighty Mile Beach
Bruce	Greatwich	DPaW KSCS Opps Officer
Chris	Nutt	DPaW Marine Park Coordinator
Karen	Bettink	DPaW Nat Cons Officer
Tracy	Sonneman	DPaW Nature Conservation Coordinator
Angela	Rossen	Education/Outreach
Steve	Reynolds	Environs Kimberley
Chris	Hassell	Global Flyway Network Leader
Helen	Fong	Global Flyway Network
Ivan	Tse	Global Flyway Network
Bob	Hickey	GIS
Peter	Venn	Hovercraft
Elaine	Venn	Hovercraft
Bart	Mavrick	Logistics
Grant	Pearson	Logistics/Science
Ginny	Chan	NIOZ/Science
Petra	de Goeij	NIOZ/Science
Sander	Holthuijsen	NIOZ/Science
Loran	Kleine Schaars	NIOZ/Science
Marc	Lavaleye	NIOZ/Science
Hebo	Peng	NIOZ/Science
Theunis	Piersma	NIOZ Science Directions
Chris	Glasby	Northern Territory Museum/Science
Kandy	Curran	RBWG
Grace	Maglio	Science
Sora	Marin-Estrella	Edith Cowan University/Science
Jane	Prince	UWA
Dianne	Bennett	Volunteer
Bill	Bryden	Volunteer
Jan	Lewis	Volunteer
Juliet	Olsen	Volunteer
Mavis	Russell	Volunteer
Obelia	Walker	Volunteer

Chelsie	Winchcombe	Volunteer
Yvonne	Winchcombe	Volunteer
Loisette	Marsh	WA museum
Shirley	Slack-Smith	WA museum
Andrew	Storey	WRM/Prjct Mngmt/ Science
Emma	Thillainath	WRM
Jason	Fong	Yawuru Ranger
Preston	Manado	Yawuru Ranger
Luke	Puertolano	Yawuru Operations Officer
Jason	Richardson	Yawuru Ranger
Curtis	Robinson	Yawuru Ranger
Anthony	Richardson	Yawuru staff

Eighty Mile Beach Participants

John	Stoate	Anna Plains
Helen	Stoate	Anna Plains
David	Stoate	Anna Plains
Danny	Rogers	Arthur Rylah Institute/Science
Paul	Bell	Camera
Art	Benke	Camera
Warwick	Lavis	Catering
Helen	McArthur	Catering / First Aid
Maurice	O'Connor	Catering / First Aid
Amanda	Lilleyman	CDU/Science
Alan	Byrne	DPaW District Manager West Kimberley
Augustine	Badal	DPaW EMB Trainee Ranger (Nyangumarta)
Stephen	Brown	DPaW EMB Trainee Ranger (Ngarla)
Jeffrey	Brown	DPaW EMB Trainee Ranger (Ngarla)
Nathan	Hunter	DPaW EMB Trainee Ranger (Nyangumarta)
Nathan	Kay	DPaW EMB Trainee Supervisor
Bruce	Greatwich	DPaW KSCS Operations Officer
Sonneman	Tracy	DPaW Nature Conservation Coordinator
Naomi	Findlay	DPaW Project Officer Eighty Mile Beach
Connor	Nathan	DPaW Regional Fire Coordinator
Sora	Marin-Estrella	ECU/Science
Angela	Rossen	Education

Malcolm	Lindsay	Environs Kimberley
Bob	Hickey	GIS
Wynston	Shovellor	Karajarri Ranger
James	Bellou	Karajarri Ranger
Lyden	Bangu	Karrajarri Ranger
Kelvin	Mitchelson	Karrajarri Ranger
Braedon	Taylor	Karrajarri Ranger
Sam	Bayley	Karrajarri Ranger Coordinator
Jackie	Wemyss	Karrajarri Ranger Coordinator
Bart	Mavrick	Logistics / First Aid
Grant	Pearson	Logistics/Science
Yvonne	Winchcombe	Logistics/science
Ginny	Chan	NIOZ/Science
Petra	de Goeij	NIOZ/Science
Sander	Holthuijsen	NIOZ/Science
Loran	Kleine Schaars	NIOZ/Science
Hebo	Peng	NIOZ/Science
Theunis	Piersma	NIOZ Science Directions
Marc	Lavaleye	NIOZ Taxonomy leader
Ishmael	Hunter	Nyangumarta Ranger
Lynette	Wilridge	Nyangumarta Ranger
Charmaine	Wright	Nyangumarta Ranger
Grace	Maglio	Science
Jane	Prince	UWA/Science
Kimberley	Ure	Volunteer/Science
Bill	Bryden	Volunteer
Jan	Lewis	Volunteer
Peter Venn	Venn	Volunteer
Elaine	Venn	Volunteer
Obelia	Walker	Volunteer
Chelsie	Winchcombe	Volunteer
Shirley	Slack-Smith	WA MUSEUM/Science
Andrew	Storey	WRM/Project Management/Science
Fintan	Angel	WRM/Science

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Appendix: **Diaries of events**

The Daily Diary of Eighty Mile Beach
by Fintan J. Angel

What follows is the actual account of one "Fintan Angel" and his experience on the long mud of the Eighty Mile Beach in Northern Australia, as he partakes in a scientific expedition to assist in the study in the intertidal area.

All needless matters have been eliminated so that history may stand forth as simple fact.

October 11th 2016

6:15pm
Late afternoon.
Touch down in Broome airport, Western Australia.
My travelling companion and I are approached by a strange man.
He explains he goes by "Bart" and will escort us to our intermediate destination of the Broome Bird Observatory.
The air here is thick and hot and my delicate constitution is already being tested in this environment.

7:30pm
Arrive at our accommodations.
Our expedition leader, a man named Grant Pearson, welcomes us and immediately we are overwhelmed with introductions.
And food.
After formalities we are dismissed.
It has been quite a day for me as I have not had a single cup of coffee.

October 12th 2016

4:30am
Early start.
I may struggle to get used to this lifestyle.
Found the coffee.
Day has drastically improved.

8:30am
Equipment has been packed and our convoy of vehicles is ready to depart.
My companion and I will now travel with our employer.
I have broken my fast but I think I shall need to eat again along the way.

1:30pm
Arrival at Anna Plains Station.
I may be a creature of comforts but overall I am quite satisfied with this establishment.
A makeshift lab has been erected in the guest house building and the scientists have expressed their excitement to begin their work.
I have picked out an area for my sleeping and personal affects.
I think the evening meal shall be brought out soon.

<u>October 13th 2016</u>

5:00am
Grant briefs the expedition over breakfast.
Teams have been distributed and roles assigned.
My travelling companion and I have been separated and she is to go the mudflats and I am to stay behind.

5:40am
Teams depart for the Zero block.
6 Cars, 23 People and a projected 76 sample sites.
It is quite a spectacular sight.

6:30am
Our team remains behind to attend to the equipment and collect fresh and salt water.
On our way to the shoreline we encounter the other teams.
Apparently they were a little late and have missed the low tide.
We now must wait until the afternoon.

7:30am
Teams return to the camp, sample-less and heartbroken.
We must drink quite a bit of tea to lift our spirits.

9:00am
8 Teams have been decided.
6 Shall travel down 65 kilometres to the furthest reach of our sampling area.
2 Teams shall remain behind to sample the Zero block we missed this morning.
My companion and I am in the latter we shall be together with our friend Bart and a man named Marc.

First Thoughts of The Eighty Mile Beach.

This place is absolutely crazy! The beach itself must be nearly 80 miles long at least!

The vast expanse of the mudflat stretches out like a desert and the ever retreating tide provides one with a feeling of spatial disorientation. The shore and the sea are in sight but both seem to be unreachable. The deep blue of the sky folds into the greys of the flats and I struggle to take step after step in the relentless, sucking mud. I think my initial resolve has quickly weakened.

In front of me the old mudman glides across the flats, not unlike the shorebirds that surround us on both sides. Every so often he will inspect something but he, at least to me, never seems to be satisfied with anything he finds. I am dressed in my standard issue environment apparel which is designed to protect me from the elements but the sun glare of the thin layer of water above the mud still reflects the heat onto my exposed face. I am thirsty and my water is running out quickly as my travelling companion came ill-equipped and has taken to drinking from my reserve.

Still we move ever forward into the unknown. The mudman complains about our pace as he eyes the distant tide which has now begun its turn. My companion and I exchange a formative glace as we are to our knees in this substrate and are incapable of moving any faster than these Ingrid snails which have moved to surround us on all sides and are awaiting our untimely demise. Our bones shall slowly sink to become one with the shell layer.

4:30pm
Arrive safely back at camp.
Shower Immediately.
Begin to sort the collected samples.
I may have been a little over dramatic earlier.

7:30pm
Dinner.
Excellent news was given to the expeditionary this evening – we may sleep until late tomorrow!

<u>14th October 2016</u>

7am
Breakfast.
I have overheard one of the crew exclaim that the mud is not as bad here as in Roebuck Bay. I can only imagine what it must be like over there!
A man with a hovercraft has arrived today which should mean I will not have to return, at least for now, to the deep mud.

12pm
Lunch.
Depart for the beach.
The section we sampled today was an absolute pleasure.
Spirits are at an all time high.

5pm
The local Karajarri Rangers who have been assisting us here in the sample collection have been allowed into the lab and are helping the taxonomists with their identification of the benthic invertebrates.
Speaking to the rangers they explained their roles in the area and the significance of the Eighty Mile mudflats to the people of this area.
The Karajarri share the country with the Nyangumarta people, a partnership which has spanned thousands of years and both people are responsible for ongoing maintenance of the area.
Turtle monitoring, wader bird counts, invasive weed control and beach patrols are just some of the roles the rangers tell me they have been involved in.

Speaking to the traditional owners on their own land it is hard not to marvel at the age and the scale of this ancient place.

15th October 2016

6:00am
I rose early this morning and roused the team to ensure we got a head start on the work of the day.

{Note from travelling companion: Fintan actually slept in over an hour and was one of the last people to turn up for breakfast. No one was surprised.}

9:45am
We have completed the sorting of yesterday's samples and the lab are working tirelessly to catch up on identifications.

11:30am
Lunch.
Teams are finalised and we are heading yet again back to that long mud.
This science business is getting awful repetitive.

7:00pm
Exhausted.
Famished.
Dinner.
Much needed.
Delicious.
So Grateful.

October 16th 2016

4am
Hovercraft team wake up.
I continue sleeping.
I must ensure I am well rested for the good of the team.

7am
Breakfast and Sorting.
Hovercraft Team return.
It seems to be that they are quite gladdened to see I have slept well and am in good spirits.

12:30pm
Head out later than planned to the 35km points.
Incredible sunset over the endless mudflats.
Mind sufficiently blown.

17th October 2016

12pm
4km walk out.
I cannot see land nor sea.
I have been assured the hovercraft will be gliding out to pick us up.

7pm
Dinner.
Expedition leaders sing “The Wild Rover” song with verses written by each crew member.
The beautiful harmony of these three men was so surprising. They sang in perfect tune and the melody soared and dipped and the unique qualities of each came together to create this musical masterpiece.
Sander played the ukulele.

<u>October 18th 2016</u>

6:30am
Breakfast.
Sorting.
This is my life now.

12pm
Before lunch Theunis talks to the members of the Karajarri and Nyangumarta Rangers about the state of the Eighty Mile Beach wetlands and the global state of the bird species that utilise their homeland.

1:00pm
Fortune has smiled on me and I was spared the deep mud.
Although I still endured an 8km round trip.
I have quite taken to this working life.

<u>October 19th 2016</u>
4am
Rise from the depths of my slumber.
Head to beach.
Retrieve final samples of the trip
Final count 816.
Final feelings – relief.

12pm
The previous evening I neglected to mention I had seen several species of shark close to the shore.
I shall lead an expedition to identify the species today.
I have a put together a team of the best of the best.
I think it shall be my last trip to the Eighty Mile mudflats.

5:00pm
We return to the Anna Plains station and with no samples to sort the team seem unsure of what to do with themselves this evening.
Everyone has taken to consuming the beer as an alternative.

7:30pm
Grant Pearson thanks the crew members, rangers and station owners for the incredible effort and sacrifice they have made to ensure a successful expedition.
He gets most of the names right.

<u>20th October 2016</u>

10:30am
Today is to be the final day we spend here at Anna Plains station. I get the sense, as everyone carefully pack away their microscopes, that they will all miss this place a great deal.
Here I sit and make my final entry, the breeze blows warm across the house veranda and the Miner birds flit from coconut tree to coconut tree.
Bartholomew and his commanding officer William are making the final preparations for departure and the rest of the lot recline on outside sofas.
Inside I imagine the feverish typing of our man, Theunis Piersma and his writing team, as they work against a near impossible deadline to complete their report.
As for me I will return to my daily life which, I imagine, will be a little more dull now I know what exists this far north of the sprawling city of Perth.
I guess I shall have to return when next they come to study the mud.

The final day: the mudfight!

AnnRoeBIM16 original, yet traditional, mudbashers song
(inspired [only] by 'The Wild Rover')

One should have known from 2000 and 6
That when Grant came a calling head for the sicks
Its just a few meals for a little mud group
Maybe 2 courses for dinner and we won't need a soup
We will have all the numbers well in advance
And with our great planning there'll be nothing left to chance.

Around 2000 meals stretch out ahead
and more litres of cold water than ever were said
Mrs Macs home bake cookies were ever a hit
And the other two cheffies they did their bit
The chiller she struggled to keep cool the meat
But rest quite assures the beer cooled a treat.

When sampling the mudflat by boat or by foot
I'm looking for benthos, like all of us would
But while sitting still in the big hovercraft
I can't see a thing cause I'm covered in mud.

There was Maurice, Warwick and Mrs Mac
Catering for carnivores, vegos and vegans
Tough tasteless beef and lumpy lentils
Old fashioned puddings and…
Cakes muffins and biscuits to die for.

Sharks and rays swimming around us
The rangers had a blast
Catching them one by one
Sampling really hard

Wind was blowing strong
The shore was 4 k away
More and more flies stuck along
Still another transect on our way

My craft is to hover
I am hovercraft
I am steered by dear Peter
But his crew do seem daft.

I flew up to Broome on the Qantas flight
And now here I am naught but mud in my sight
Marc glides ahead and I follow his track
I know I will die here and be food for these snails.

Mud sampling is my life, I go waist deep
But over here I cry about the shells I can't keep
Living down under, I want to migrate
What a beautiful trip we had together my mate!

With enthusiasm, smiles and a spring in our stride
We board the hovercraft in pursuit of low tide
But at One Tree we sink, our limbs are so sore
My bright plum shorts are pink no more.

Sorting through Samples long into the night
Dreaming of crabs, worms and Ingrids oh what a sight
Those paddles, those arms, those bristles and spines
Dancing in our heads, slowly destroying our minds!

Deep in the mud of Roebuck Bay and 80 Mile Beach
Live creatures with horns and feathers
Jaws and Claws
And iridescent bodies
Would we find them and offer them to the Lord of the Mud?

My new spirit animal, the humble Ghost Crab
An Ingrid snail in each claw he did grab
Startled easily, defensive at best
Hiding in mud holes to eat food and rest.

Every night she sets up her stall
We take the trays and sort through them all
"This water is not clear enough"
A tray is sent back
"We must find all the stuff"
"Stuff; what is stuff?" Remarks the Lord of the Mud
and then BANG, a thud
And we all go back to sorting, sifting and storing.

Tubeworms tubeworms
Too many to count
Take a quarter sample
And chuck the rest out.

Why do we save all of the damned grit
We sorted it all through twice
What is he doing with all that shit
He must be mad or very wise.

Quad banger trays
going on for days,
Stop pushing past the shell layer
Sora's hairs turning greyer.

The invertebrate experts
Were intrepid and bold
In the lab where we worked
The AC was quite cold

Marc with his Harem in the Antartic room
There was only laughter and never gloom
They talked about seta and bivalves and worms
Discussed shorebirds, snails crabs and echinoderms.

What am I doing, I'm going insane
With their flaps and white eyes
Polychaetes are turds
I WANT MY BIRDS!!

Their long bodies, segmented and bristly
They move through the mud ever so swiftly
These polychaetes are fun to identify
How very similar to waders that fly
Now what to do; do I merge the two?
A life-changing week; to the birding community do I dare to speak?
And say my goodbyes as I look for polychaete eyes.

Amphiura tenuis
Diopatra Diva-
ricella irpex
Capitellidea

Nassarius dorsa-
tus Tellina rose
Anadara Glycera
Dorippe granose

And its no nay never
No nay never no more
Will I enter more data
No never no more

We were led by a man named Grant
Who thought we should be up at 4
The plans ever changed, no one ever quite knew
But in the end it all worked out.
Heat humidity, flies and sweat
Defined the time out of the field
Get thyself out to the coast
Where relief came with a coat of mud.

Many thanks, dear friends
As our pleasure ends
And our thoughts are sad
As we leave our lab.
But we won't forget
The ways we met
And the fun we had
As we worked like mad
So we thanked the soles
Who managed the waves
And brought back the goodies
-They are the braves!

In gratefulness to the Yawuru, Karajarri (photo) and Nyangumarta rangers and their relatives for hospitality and help.