MARINE BIOTA OF PARENGARENGA HARBOUR, NORTHLAND, NEW ZEALAND

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Abstract. Four hundred and fifty-two species of marine fauna are recorded from Parengarenga, New Zealand's northernmost harbour. This tally comprises 266 molluscs (13 chitons, 179 gastropods, 73 bivalves, 2 cephalopods), 86 crustaceans (including 33 crabs and shrimps, 22 amphipods, 16 isopods, 7 barnacles), 50 polychaete worms, 32 fish, 8 echinoderms and 10 species from other groups.

The fauna in Parengarenga's subtidal channels exhibits a zonation corresponding to decreasing salinity and wave exposure from the harbour mouth to the headwaters. The slightly deeper lower harbour channels have a benthic faunal association characterised by four common bivalves *(Tawera spissa, Felaniella zelandica, Myadora striata, Gari stangeri),* hermit crabs, the whelk *Cominella quoyana,* polychaete *Oweniafusiformis,* and amphipod *Proharpinia.* The subtidal upper harbour faunal association is characterised by three common bivalves *(Nucula hartvigiana, Austrovenus stutchburyi, Paphies australis),* whelks *Cominella adspersa* and *C. glandiformis,* pillbox crab *Halicarcinus varius,* cumacean *Cyclaspis thomsoni* and a wide diversity of amphipods and polychaetes.

The intertidal flats are dominated by *Zostera* seagrass meadows with smaller areas of bare quartz sand near the harbour entrance. Around the upper reaches of the harbour there is extensive mangrove forest between mid and high tide levels, with salt marsh and minor salt meadow mostly above mean high tide. Extensive areas of intertidal *Zostera-covered* quartz sand flats bathed in clear, warm water and periodically influenced by eddies from the East Auckland Current provide an unusual habitat for New Zealand. It is home to low numbers of subtropical gastropods, seldom seen intertidally or on sand elsewhere in the country (e.g. *Charonia lampas, Cymatium exaratum, Cymatium parthenopeum, Sassia parkinsonia, Ranella australasia, Cabestana spengleri, Conus lischkeanus, Polinices simiae, Natica migratoria, Bullina lineata* and *Hydatina physis).* Many brightly coloured nudibranchs live at and below low tide at Paua, Te Hapua and Ngatehe Point.

KEYWORDS: New Zealand; Northland; Parengarenga Harbour; biogeography; subtidal channel benthic associations; intertidal communities; Zostera flats; nudibranchs; warm-water molluscs.

INTRODUCTION

OBJECTIVES'

The objectives of this study were to compile an inventory of the macrofauna (> 1 mm) of New Zealand's northernmost harbour for biogeographic purposes and to document and map the

intertidal and subtidal marine communities of one of New Zealand's more pristine harbours for comparison with other northern harbour ecosystems that have been heavily impacted by human activities (e.g. Waitemata Harbour). It was also hoped that the present study would provide a snapshot of Parengarenga Harbour in the mid 1990s as a benchmark for the documentation of future natural or human-induced changes.

LOCATION AND DESCRIPTION

Parengarenga Harbour (latitude 34030'S, longitude 173058'E), on the east coast just south of North Cape (Fig. 1), is the northernmost harbour in New Zealand. The harbour is a drowned valley system with many meandering branches, that were flooded by rising sea level 6,500-7,000 years ago, following the end of the Last Glaciation. The harbour is sheltered from the

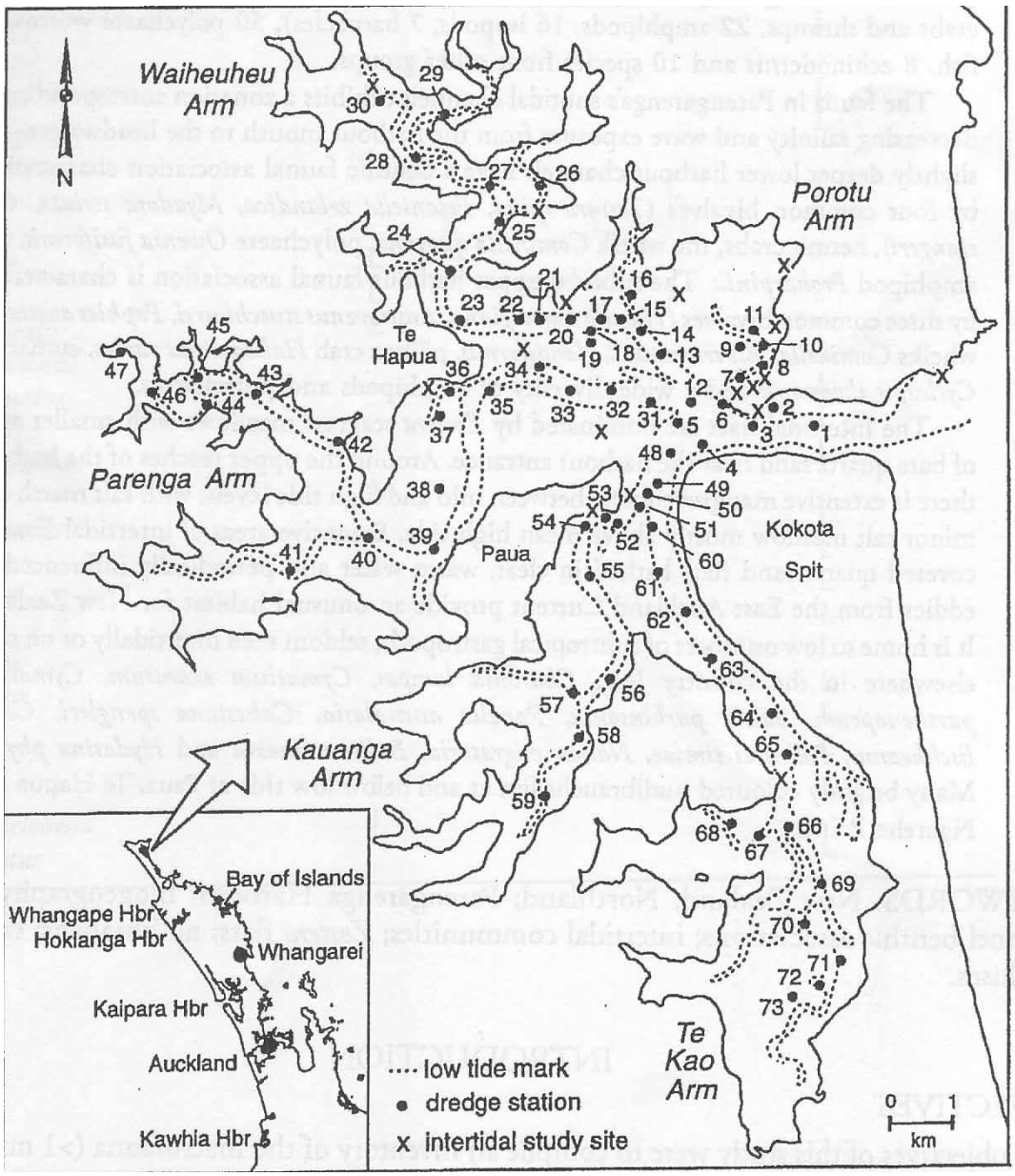


Fig. 1. Location of subtidal (dredge) and intertidal benthos sampling stations in Parengarenga Harbour,

Pacific Ocean by a large Pleistocene and Holocene sand dune barrier (Kokota Spit) of pure white quartz sand.

Parengarenga Harbour is in a relatively remote area with little evidence of pollution resulting from human activities. The harbour is surrounded by gently rolling farmed grassland (southern and western catchments), scrub regenerating to forest (northern catchment), and unvegetated or pine-forested sand dunes (eastern barrier). There are two small centres of human occupation at Te Hapua on the harbour edge and at Te Kao, in the southern catchment. There is no evidence of artificial reclamation or mangrove or seagrass clearance. The extensive wooden structures of an oyster farm (established in the 1970s) are present intertidally on the northern Waiheuheu Arm. Sand mining at the northern end of Kokota Spit in the vicinity of the harbour entrance has been carried out for some decades and has undoubtedly resulted in geomorphic changes.

PREVIOUS WORK

The only previously published observations on the biota of Parengarenga is Gardner (1978), who recorded 53 gastropod and 19 bivalve species dredged from the main channel between Dog Island and the harbour entrance. He dredged to determine the abundance and extent of the newly-recorded Australian bivalve *Myochama tasmanica* (Powell 1974, Gardner 1976).

There have been no previous ecological surveys of the biota of Parengarenga Harbour, although there have been several previous studies on the ecological distribution of the bottom-dwelling biota of other harbours and estuaries around northern New Zealand. These have mainly dealt with the larger harbours - Manukau Harbour (Grange 1979, 1982; Henriques 1980) and Waitemata Harbour (Powell 1937; Hayward *et al.* 1997, 1999), although Grace (1966) and Brook et al. (198 1) documented the subtidal fauna of the smaller Whangateau and Tutukaka Harbours on Northland's east coast and Hayward & Hollis (1993) and Hayward *et* al. (1995) described the fauna of Waimamaku estuary and Whangape Harbour on Northland's west coast.

METHODS

This survey was undertaken during two Auckland Institute and Museum field trips in October 1992 and March 1996.

DREDGING

Samples (Appendix 1) were collected using a small, 10-litre capacity bucket dredge, hand-hauled from a 4 m aluminium dinghy powered by a 18 horse-power outboard motor. The sediment was sampled to a depth of 50-100 mm. The sediment grain-size was visually estimated and recorded, washed over a 2 mm. sieve in 1992 and a 1 mm sieve in 1996 to remove mud and sand and then all live organisms were picked out, identified, counted and mostly returned to .the sea. The finer mesh size used in 1996 resulted in more comprehensive sampling of small organisms such as amphipods, isopods and smaller polychaete worms.

INTERTIDAL AND SUBTIDAL OBSERVATIONS

Shoreline searches in the range of habitats and niches present were undertaken at numerous locations (Appendix 1) during spring low tides. Species encountered live or dead were separately recorded. Low-tide snorkeling was undertaken by MSM at several locations (Appendix 1) to search for subtidally-restricted organisms. Descriptions of biotas on subtidal rocky reefs at

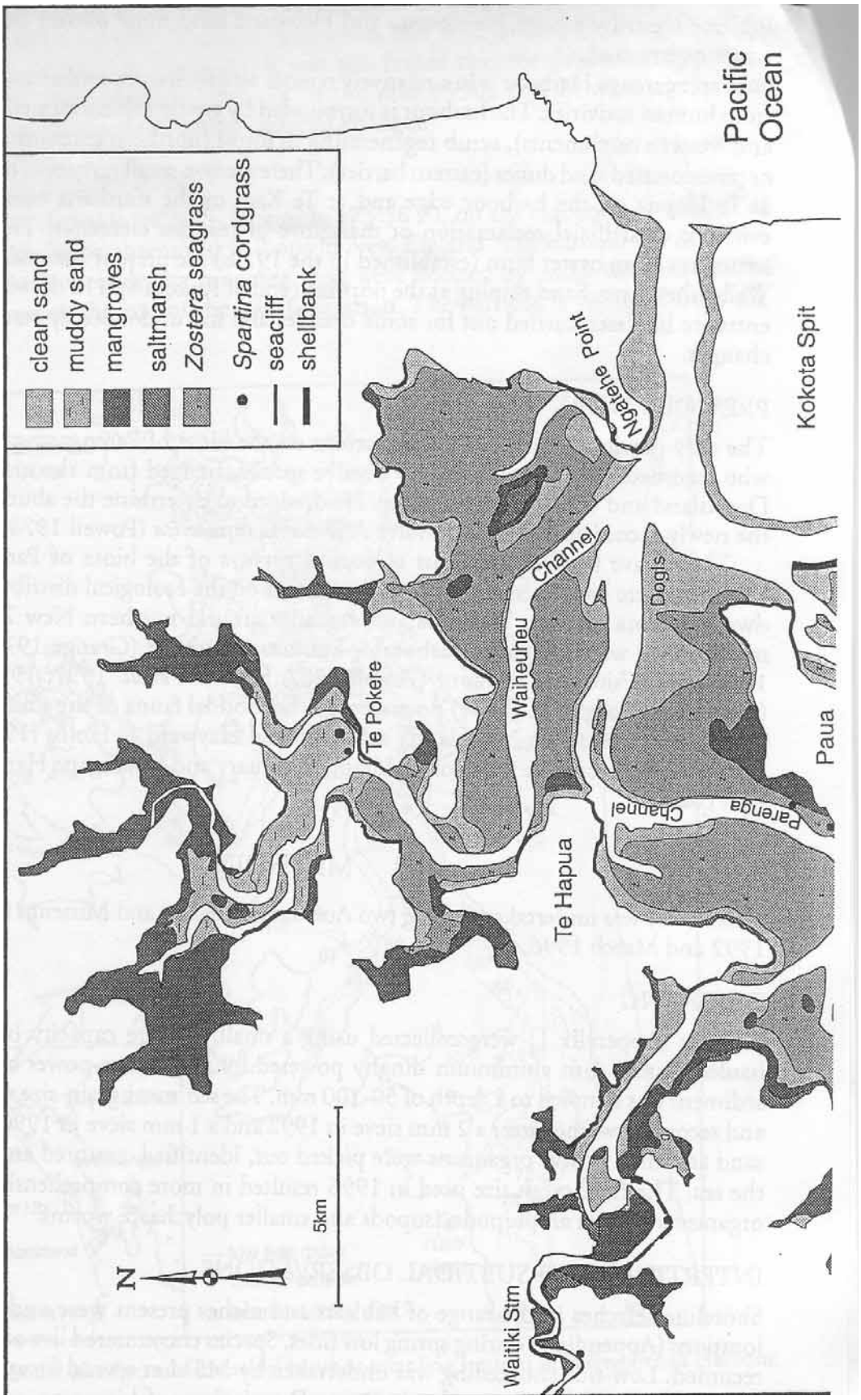
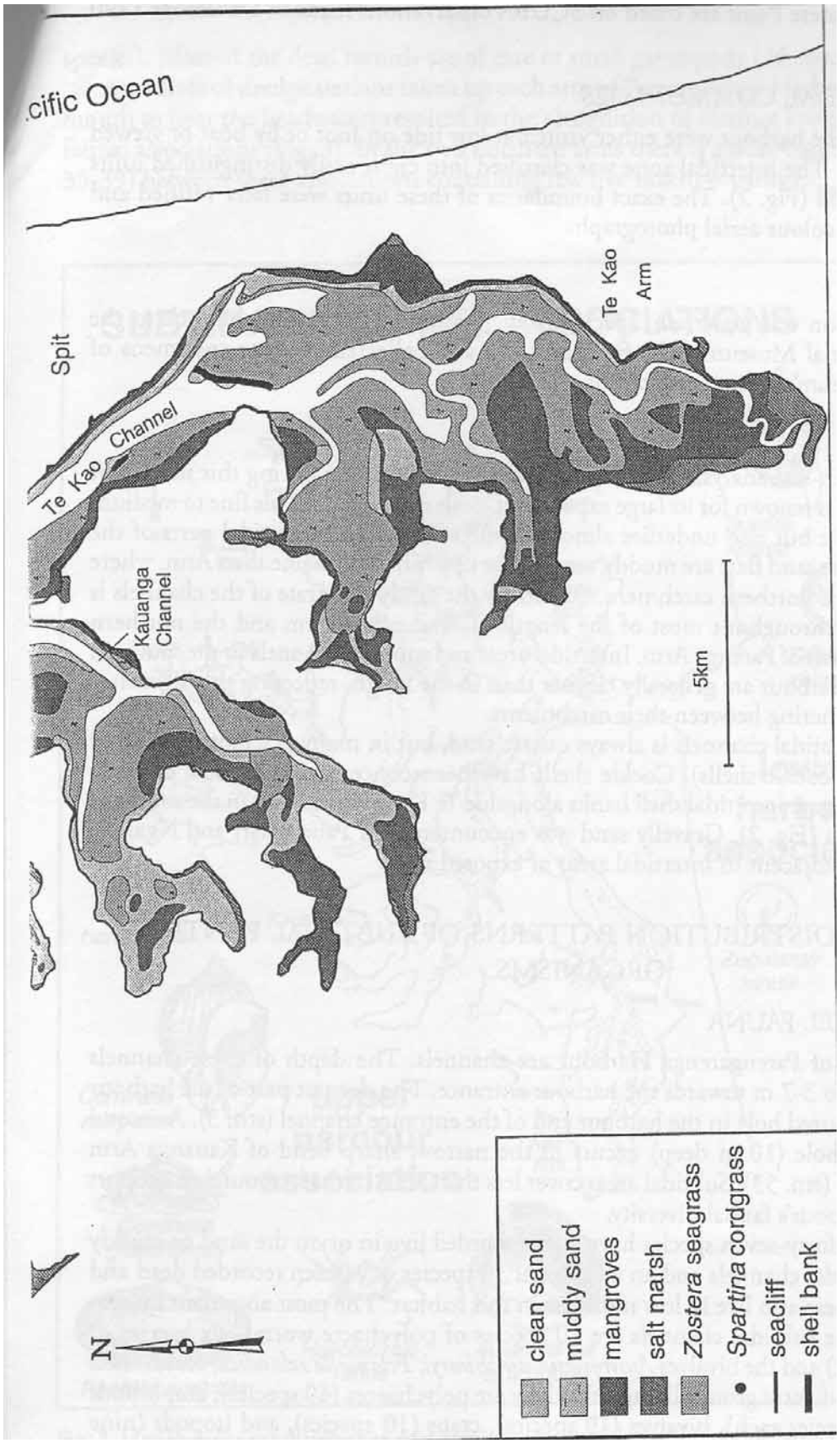


Fig. 2. Map of the major intertidal communities in Parengarenga Harbour.


cific Ocean
Spit
Te Kao Channel
Kauanga Channel
Te Kao Arm
5km
N
clean sand
muddy sand
mangroves
salt marsh
Zostera seagrass
Spartina cordgrass
seacliff
shell bank

Ngatehe Point and Akatere Point are based on SCUBA observations made in December 1990 by FJB.

MAPPING INTERTIDAL COMMUNITIES

All intertidal areas of the harbour were either visited at low tide on foot or by boat or viewed from a nearby hillside. The intertidal zone was classified into eight easily distinguished units for mapping in the field (Fig. 2). The exact boundaries of these units were later verified and corrected using recent colour aerial photographs.

SPECIMENS

Where the identification was uncertain, specimens were preserved and brought back to the Auckland War Memorial Museum (AK) for study. We also collected voucher specimens of most taxa for the museum's marine collections.

SEDIMENTS

Detailed sediment grain-size analysis and mapping was not undertaken during this study, but Parengarenga Harbour is renown for its large expanses of clean quartz sand. This fine to medium sand forms Kokota Spit but also underlies almost all the subtidal and intertidal parts of the harbour. Intertidally the sand flats are muddy sand in the upper half of Waiheuheu Arm, where mud washes in from the northern catchment. Subtidally the sandy substrate of the channels is also mixed with mud throughout most of the length of Waiheuheu Arm and the northern branch (Waitiki Channel) of Parenga Arm. Intertidal areas and subtidal channels in the southern half of Parengarenga Harbour are generally cleaner than in the north, reflecting the difference in rock types and weathering between their catchments.

Sediment in the subtidal channels is always quartz sand, but in many places it is shelly or slightly shelly (mostly cockle shells). Cockle shells have been concentrated by tidal currents and waves to form elongate intertidal shell banks alongside Te Kao channel and in the southern branch of Parenga Arm (Fig. 2). Gravelly sand was encountered off Paua wharf and Ngatehe Point (stns. 53 and 7) adjacent to intertidal areas of exposed rock.

ECOLOGICAL DISTRIBUTION PATTERNS OF SUBTIDAL BENTHIC ORGANISMS

SUBTIDAL CHANNEL FAUNA

All the subtidal areas of Parengarenga Harbour are channels. The depth of these channels increases from 0-4 m to 3-7 m towards the harbour entrance. The deepest part of the harbour (25 m) is a current-scoured hole in the harbour end of the entrance channel (stn. 3). A second tidal-current-scoured hole (10 m deep) occurs in the narrow, sharp bend of Kauanga Arm adjacent to Paua wharf (stn. 53). Subtidal areas cover less than 25% of the harbour, but support nearly 50% of the harbour's faunal diversity.

One hundred and forty-seven species have been recorded live in or on the sand or muddy sand floor of the subtidal channels and an additional 36 species have been recorded dead and presumably most of these also live in low numbers in this habitat. The most abundant macroorganisms living in the subtidal channels are 10 species of polychaete worms, six species of amphipod (Appendix 2) and the bivalves *Austrovenus stutchburyi, Felaniella zelandica,* and *Nucula hartvigiana.* The most diverse groups living subtidally are polychaetes (40 species), amphipods and gastropods (21 species each), bivalves (19 species), crabs (10 species) and isopods (nine

species). Most of the dead records are of rare or small gastropods (26 species).

A transect of dredge stations taken up each arm of Parengarenga Harbour from the harbour mouth to near the headwaters resulted in the recognition of distinct lower and upper harbour faunal associations (Fig. 3). In the two northern arms there is a near-barren zone (stns. 24-26, 35-39) between these associations containing few live macro-organisms.

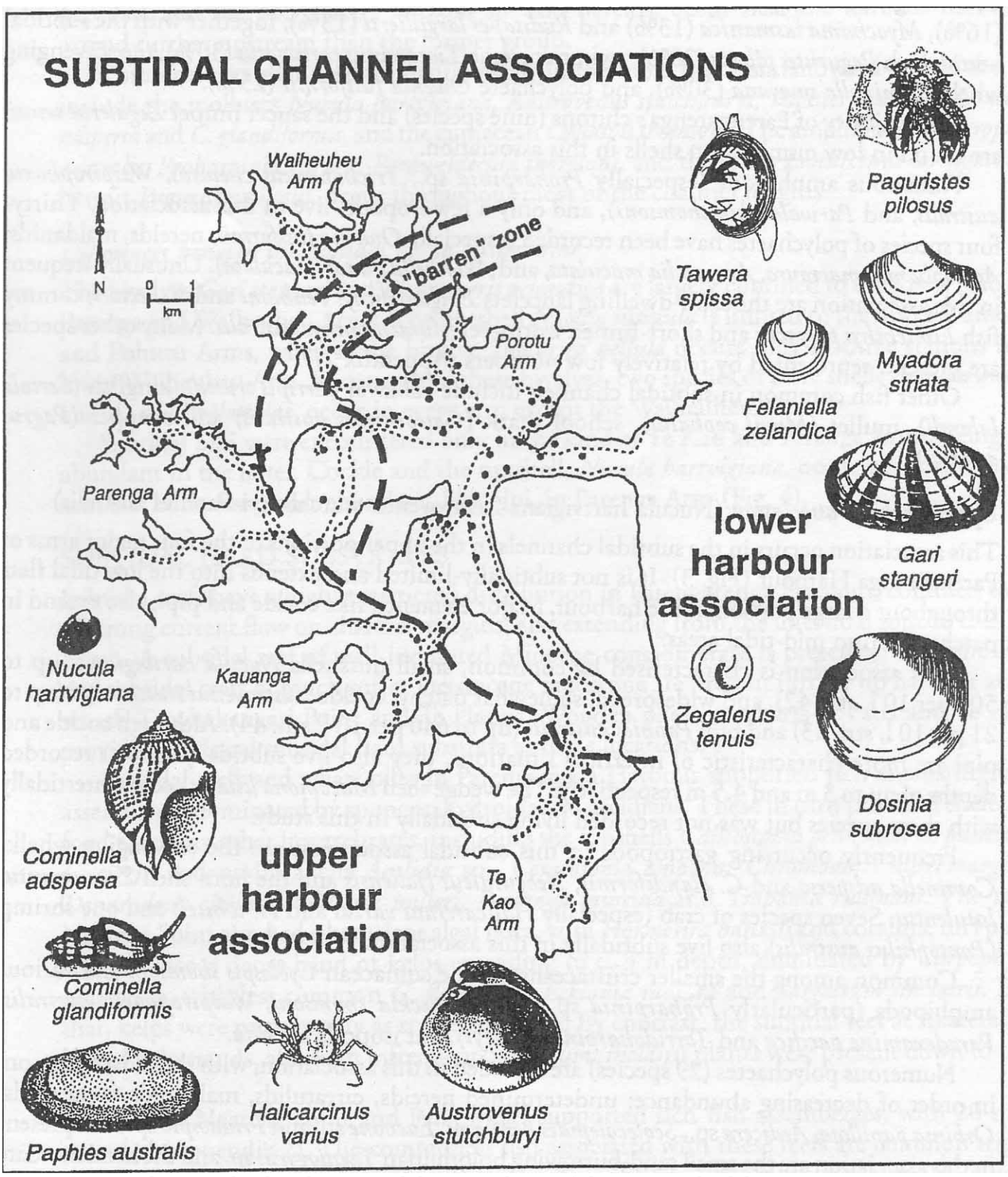


Fig. 3. Map showing the distribution and dominant biota of the major subtidal associations in Parengarenga Harbour channels. Drawings by MSM and ABS.

Lower harbour association (Tawera spissa-Felaniella zelandica)

This association extends up the subtidal channel of each arm from a "barren" zone in the harbour mouth where there is coarse sand swept clean by strong tidal currents (Fig. 3). It extends further up the Te Kao Arm (6 km) than the others, and its shortest penetration is up the Parenga Arm (2.5 km)

The fauna is characterised by variable combinations of bivalves, in decreasing order of abundance Tawera spissa (60% of stations), Felaniella zelandica (60%), Myadora striata (33%), Gari stangeri (30%), Soletellina nitida (28%), Dosinia subrosea (20%), Pleuromeris zelandica (16%), Myochama tasmanica (13%) and Ruditapes largillierti (13%), together with the subtidal hermit crab Paguristes pilosus (28%), swimming crab Liocarcinus corrugatus (30%), the scavenging whelk Cominella quoyana (30%), and polychaete Owenia fusiformis (25%).

The majority of Parengarenga's chitons (nine species) and the saucer limpet Zegalerus tenuis are found in low numbers on shells in this association.

Numerous amphipods (especially Proharpinia sp., Trichophoxus chelatus, Waipirophoxus australis, and Parwaldeckia thomsoni), and only a few isopods, live in this association. Thirtyfour species of polychaetes have been recorded (especially Owenia fusiformis, nereids, maldanids, Aglaophamus macroura, Armandia maculata, and Axiothella quadrimaculata). Unusually frequent in this association are the sand-dwelling lancelets Epigonichthys benhami and E. hectori, tommy fish Limichthys polyactis and short-finned worm-eel Muraenichthys australis. Many other species are present, represented by relatively low numbers (Appendix 2).

Other fish common in subtidal channels include kahawai (Arripis trutta), kingfish (Seriola lalandi), mullet (Mugil cephalus), school shark (Galeorhinus australis) and snapper (Pagrus auratus).

Upper harbour association (Nucula hartvigiana-Austrovenus stutchburyi-Paphies australis)

This association occurs in the subtidal channels in the upper portions of the four major arms of Parengarenga Harbour (Fig. 3). It is not subtidally-limited and extends into the low tidal flats throughout a large portion of the harbour. Major elements, like cockle and pipi, also extend in patches up into mid-tidal areas.

This association is characterised by common, small nutshells Nucula hartvigiana. (up to 500 per 10 l, stn. 42), and widespread, somewhat patchy, cockle Austrovenus stutchburyi (up to 21 per 10 l, stn. 43) and pipi Paphies australis (up to 640 per 10 1, stn. 44). Although cockle and pipi are more characteristic of intertidal situations, they also live subtidally here at recorded depths of up to 3 m and 4.5 m respectively. The wedge shell Macomona liliana occurs intertidally with these species but was not recorded living subtidally in this study.

Frequently occurring gastropods in this subtidal association are the scavenging whelks Cominella adspersa and C. glandiformis, Neoguraleus lyallensis and the horn shell Zeacumantus lutulentus. Seven species of crab (especially Halicarcinus varius and H. whitei) and one shrimp (Pontophilus australis) also live subtidally in this association.

Common among the smaller crustaceans are the cumacean Cyclaspis thomsoni and various amphipods (particularly Proharpinia sp., Parawaldeckia thomsoni, Waipirophoxus australis, Paradexamine pacifica and Torridoharpinia hurleyi), but isopods are rare.

Numerous polychaetes (29 species) are recorded in this association, with the most common, in order of decreasing abundance: undetermined nereids, cirratulids, maldanids, capatellids, Orbinia papillosa, Aedicera sp., Scolecolepides benhami, Euchone sp. and Prionospio sp. Also present in this association are the small sand-burrowing holothurian Taeniogyrus sp. and the hemichordate Balanaglossus australiensis.

Zonation along the subtidal channels

The subtidal biotic distribution shows a zonation from the harbour mouth towards the head of each arm (Fig. 4). Common taxa that are largely restricted to the more saline seaward regions include the molluscs *Tawera spissa, Pleuromeris zelandica, Myadora striata., Myochama tasmanica* and *Gari stangeri,* the polychaetes *Owenia fusiformis, Axiothella quadrimaculata, Armandia maculata* and *Aglaophamus macroura,* and the amphipods *Trichophoxus chelatus* and the phoxocephalids. The molluscs *Felaniella zelandica, Dosinia suhrosea* and *Cominella quoyana quoyana,* and the polychaetes *Euchone sp.* and nereids, occur near the harbour mouth but extend further upstream than the former group.

Common taxa that predominantly occur in the more brackish landward end of the arms include the molluscs *Nucula hartvigiana, Austrovenus stutchburyi, Paphies australis, Cominella adspersa* and C *glandiformis,* and the cumacean Cyclaspis *thomsoni.* The amphipods *Waipirophoxus australis, Proharpinia sp.* and *Paraweldeckia thomsoni,* and the crabs *Liocarcinus corrugatus* and hermit *Paguristes pilosus,* occur throughout most of the channel lengths.

Differences between the subtidal fauna of the arms

The bivalves *Gari stangeri* and *Pleuromeris zelandica* are largely confined to the lower reaches of Parenga and Waiheuheu Arms. The nutshell *Nucula nitidula* is limited to the lower Waiheuheu and Pohutu Arms, whereas the bivalve *Talabrica bellula* occurs only in three stations in the lower Waiheuheu Arm. In contrast to these bivalves, two species of olive shells *Amalda australis* and *A. novaezelandiae,* occur in every arm except the Waiheuheu.

Subtidal pipi were encountered only in the sandier Te Kao and Parenga Arms, being most abundant in the latter. Cockle and the nutshell, *Nucula hartvigiana,* occur subtidally in every arm but both were most abundant, like pipi, in Parenga Arm (Fig. 4).

SUBTIDAL HARD SUBSTRATES

Subtidal reefs have a highly restricted distribution in Parengarenga Harbour, confined to sites of strong current flow on channel margins, and extending from the intertidal zone to c. 2-10 m depth. A subtidal reef of well-indurated Miocene conglomerate is present at Ngatehe Point, and subtidal reefs of much softer Pleistocene sandstone are present further up harbour at Paua wharf, Tiawhakangari Point and Te Hapua. Wooden piles on wharfs at Paua and Te Hapua provide additional subtidal hard substrata at these locations.

Subtidal reefs and wharf piles in Parengarenga Harbour supported rich encrusting faunal assemblages dominated by sponges, hydroids and ascidians. These in turn provided shelter and food for many other invertebrates, including the topshells *Calliostoma pellucida, C. punctulata, C. tigris,* and nudibranchs *Aeolidia sp., Ceratosoma amoena, Chromodoris aureomarginata, Dendrodoris citrina, Phidiana milleri, Rostanga muscula* and *Trapania rudmani.* The reef at Ngatehe Point also had a luxuriant algal flora, with *Hormosira banksii* and coralline turf passing seaward into a dense band of kelps extending to c. 3 m depth, dominated by *Carpophyllum plumosum,* with less common *C. flexuosum, Ecklonia radiata* and *Sargassum sinclairii.* Below that, kelps were present only as scattered plants. By contrast, the subtidal reef at Akatere Point lacked kelp stands, although infrequent *Sargassum sinclairii* plants were present down to c. 5 m depth.

Reefs at Ngatehe Point and Paua wharf supported rich fish assemblages, with 20. species recorded (Appendix 2). The commonest fish associated with these reefs are common triplefin *Forsterygion lapillum*, leatheriacket *Parika scaber,* oblique-swimming triplefin *Obliquichthys maryannae,* parore *Girella tricuspidata,* spotted triplefin *Grahamina capito,* spotty *Notolabrus*

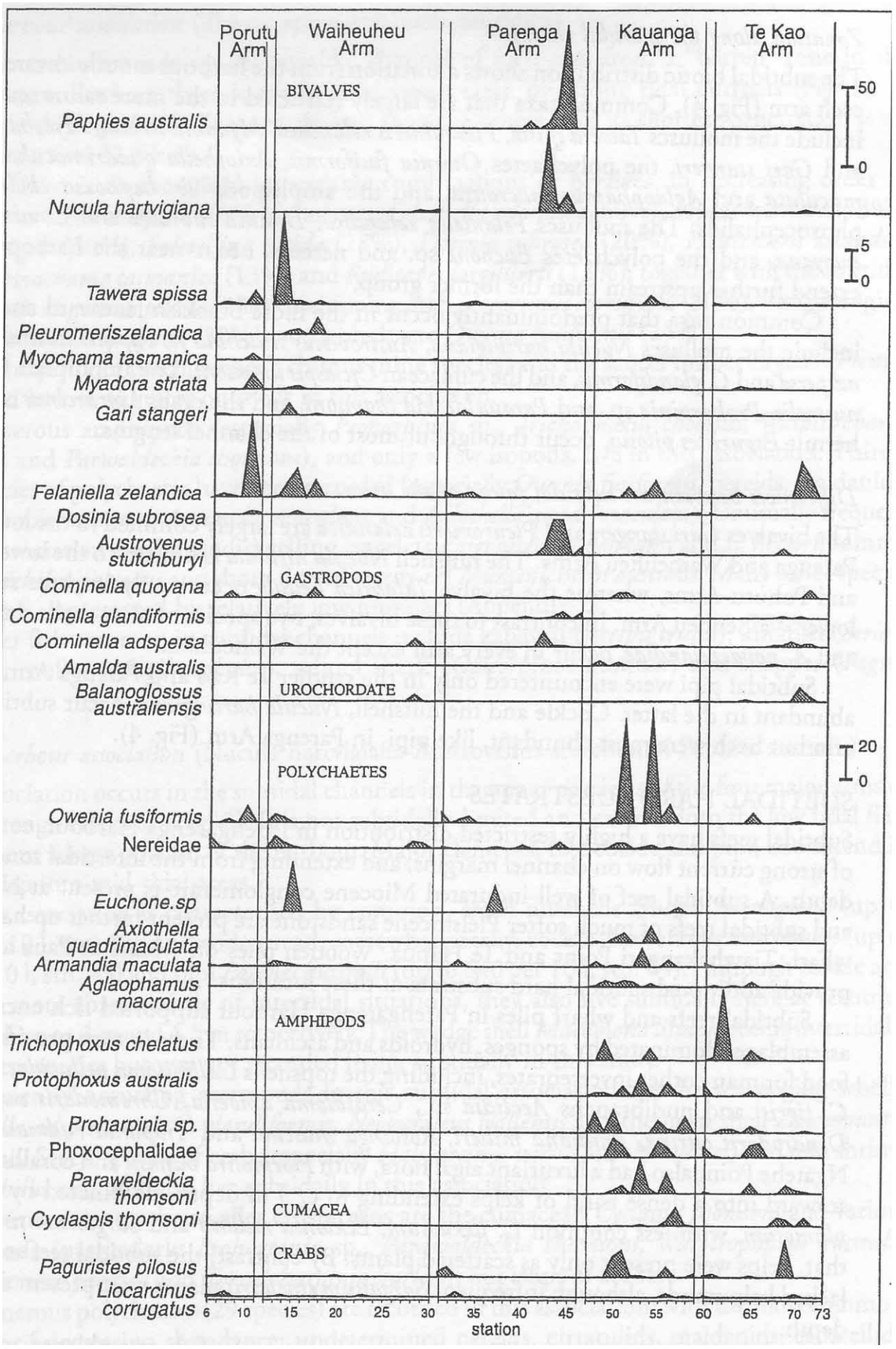


Fig. 4. Graphs showing number of individuals per 10 l of dredged sediment of the more common subtidal organisms with distance from the sea along the five arms of Parengarenga Harbour. In each arm the left hand side of the graph is nearest the harbour mouth and the right hand side is nearest the headwaters.

celidotus and sweep Scorpis lineolatus. As well as common coastal fish, two subtropical species were also recorded in December 1990. Two small juvenile mado Atypichtyhs latus (length c. 1.5 cm) were found sheltering amongst kelp at Ngatehe Point, and a few juvenile spotted black grouper Epinephelus daemelii (length c. 30 cm) were found in rock crevices at Ngatehe Point and Paua wharf

ECOLOGICAL DISTRIBUTION PATTERNS OF INTERTIDAL BENTHIC ORGANISMS

SALT MARSH AND SALT MEADOW (Fig. 5)

Small areas of high tidal salt marsh and salt meadow vegetation occur at the heads of the many harbour arms and sometimes as a narrow strip between mangrove forest and the land. The largest areas of salt marsh are around the heads of the Parenga and Te Kao arms (Fig. 2). The salt marsh consists of various rushes and sedges, such as orange-tinted, jointed 'rush' *Leptocarpus similis*, sea rush *Juncus maritimus*, and *Scirpus medianus*. Sometimes occurring around the extreme high tidal mark above the taller salt marsh are salt meadow areas of low, prostrate plants dominated by the glasswort *Sarcocornia quinqueflora*, but frequently accompanied by other small plants, such as sea primrose *Samolus repens*, remuremu *Selliera radicans* and sea blite *Suaeda novae-zelandiae*.

The most obvious animals living in the salt marsh and meadow are the burrowing mud crab *Helice crassa*, and the mud snail *Amphibola crenata*. Also recorded living in the sediment are the isopod *Eurylana cookii* and the amphipod *Hyale grenfielli*. Sometimes present in large numbers at higher tidal levels in more brackish situations is the small, high-spired snail *Potamopyrgus estuarinus*. Occasionally found living high on the shore in the salt meadow, usually hiding beneath driftwood, stones or in clumps of rushes, are the small high tide ellobiid snails *Opbicardelus costellaris* and *Marinula filholi*, and the fast-running isopod *Ligia novaezelandiae*.

MANGROVE FOREST (Fig. 5)

Mangrove forest (*Avicennia marina*) covers large areas of Parengarenga Harbour above mid tide level. It is most extensive at the head and around the margins of all the arms (Fig. 2). The forest is generally 2-4 m high, with areas of lower, stunted forest often present above mean high tide level. The aerial roots, trunks and lower branches of mangroves are often encrusted with acorn barnacles *Austrominius modestus*, small black mussels *Xenostrobus pulex*, and clumps of Pacific oysters *Crassostrea gigas*. Cat's eyes *Turbo smaragdus*, the shell-less "slug" *Onchidella nigricans*, and *Nerita atramentosa* are sometimes found on the lower branches grazing algae. The sandy or muddy substrate beneath the mangroves is often pock-marked with the burrow openings of the mud crab *Helice crassa*, and inhabited by numerous mud snails *Amphibola crenata*, mudflat top shells *Diloma subrostrata*, and less commonly by the horn shell *Zeacumantus lutulentus*, and scavenging whelks *Cominella adspersa* and *C glandiformis*,

At high tide, mangrove forests provide feeding areas for several fish species including kahawai *Arripis trutta*, grey mullet *Mugil cephalus*, parore *Girella tricuspidata*, and snapper *Pagrus auratus*.

ZOSTERA SEA GRASS FLATS (Fig. 5)

Extensive beds of seagrass, *Zostera*, cover over half the area of Parengarenga Harbour, mostly growing between low and mid tide levels. The only areas where seagrass is not well developed are around the harbour entrance and in the upper, muddier parts of Waiheuheu Arm (Fig. 2).

The sandy substrate beneath the seagrass is home to abundant cockles *Austrovenus stutchburyi*,

tiny nutshells *Nucula hartvigiana,* and five polychaete species, *Lumbrineris coccinea, Perinereis camiguinoides, Flabelligera bicolor* and unidentified species of *Terebellanice* and nereid. Also commonly present are the burrowing shrimps *Alpheus richardsoni, Heterosquilla tricarinata* and *Upogebia sp.,* and the burrowing crab *Macrophthalmus hirtipes.*

A more diverse fauna, dominantly of gastropods, lives epifaunally among and on the grass blades. Most common are the bubble shells, *Bulla quoyii* and *Haminoea zelandiae,* the mudflat topshell *Diloma subrostrata,* and the scavenging whelks *Cominella adspersa* and C. *glandiformis,* but also present are 13 other snail species including the small herbivorous limpets *Notoacmea helmsi* f. *scapha* on the *Zostera* leaf blades, the opisthobranch *Bursatella leachii,* and the predatory snails *Charonia lampas, Conus lischkeanus, Cymatium e. exaratum, C. p. parthenopeum* and *Natica migratoria.* Other frequent members of the epifauna in tidal pools among the seagrass are the small fish *Favonigobius lateralis* and *Grahamina capito,* and the hermit crabs *Paguristes barbatus* and *Pagurus spinulimanus.*

SAND FLATS (Fig. 5)

Unvegetated, clean, white, quartz sand flats cover extensive intertidal areas in Parengarenga Harbour (Fig. 2). They are particularly prominent around the harbour entrance and the heads of the Parenga and Kauanga arms. Bare sand flats are infrequent in the upper parts of Waiheuheu and Te Kao arms.

A diverse fauna of 53 species (Appendix 2) was found living in or on the Parengarenga sand flats. The most abundant infaunal taxa are the bivalves *Austrovenus stutchburyi, Macomona liliana* and *Nucula hartvigiana,* the crabs *Helice crassa, Hemigrapsus crenulatus* and *Liocarcinus corrugatus,* the shrimps *Alpheus richardsoni* and *Palaemon affinis,* the isopod *Isocladus armatus,* and the polychaetes *Orchestia sp.* and unidentified nereids. Abundant epifaunal species are the cushion star *Patiriella regularis,* the gastropods *Cominella adspersa, C. glandiformis* and *Zeacumantus lutulentus,* and the chiton *Chiton glaucus* grazing algal films on shells.

The characteristic feeding excavations left by eaglerays, *Myliobatis tenuicaudatus,* are obvious at low tide showing that the sand flats are important feeding areas when they are covered by the tide.

ROCKY HARBOUR SHORES (Fig. 6)

Low cliffs or banks of relatively soft, limonite-cemented Quaternary sandstone occur sporadically at mid and high tide levels around the shores of the Te Kao, Kauanga and Parenga Arms. Intertidal platforms and cliffs of harder Miocene mudstone, sandstone or conglomerate occur around the shores of Porotu and Waiheuheu Arms in the north.

Ninety-three species have been recorded alive from in, on and under intertidal rocks around the edge of the harbour (Appendix 2). The Quaternary sandstone of the southern shores is soft enough to be tunnelled by numerous crabs *(Helice crassa)* and isopods *(Isocladus armatus)* or occupied by the shrimps *(Palaemon affinis),* and nestling bivalve *Irus reflexus.* It is generally too soft to provide a suitable substrate for encrusting organisms like barnacles and oysters, or for grazing limpets or chitons. Common gastropods living on these soft mid-tidal rocks around Paua wharf are *Melagraphia aethiops, Lepsiella scobina* and *Dicathais orbita* and there are patches of Neptune's necklace *Hormosira banksii.* Since the normal food of L. *scobina* and D. *orbita* (e.g. barnacles, oysters and flea mussels) is absent here, it is a puzzle what they are eating. Under the wharf on shaded low to mid-tidal rocks is an established population of the trumpet shell *Ranella australasia australasia. A* few polychaete worms and purple rock crabs *(Leptograpsus variegatus)* find shelter beneath loose boulders of this soft sandstone in several places. Common small white gastropods (*Sinuginella pygmaea)* were living in sand in intertidal rock pools at Te

Fig. 5. Typical transect through the intertidal communities of Parengarenga Harbour with illustrations of the more common organisms of each habitat. Illustrations by. MSM.

Hapua in the 1970s (Noel Gardner pers. comm.).

The harder Miocene rocks of the northern shores support a more diverse fauna, rich in gastropods and chitons. Particularly abundant are the grazing topshell *Melagraphia aethiops* and pulmonate limpet *Siphonaria australis*, and the encrusting Pacific oyster *Crassostrea gigas*. The hermit crabs *Paguristes pilosus* and *Pagurus novizelandiae* are abundant in shallow rock pools.

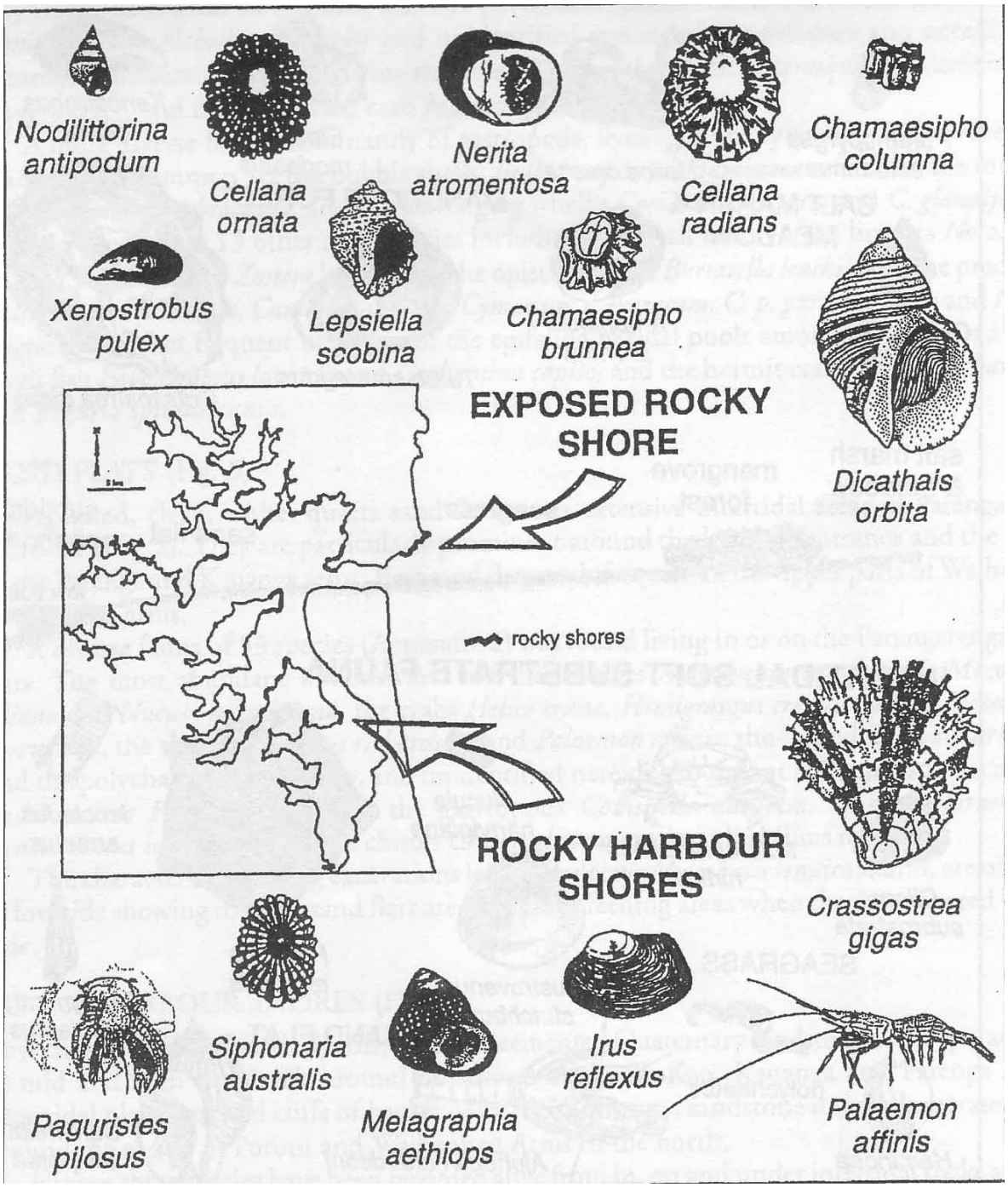


Fig. 6. Common organisms inhabiting rocky substrates in sheltered harbour and exposed open coast situations, Parengarenga. Illustrations by MSM, ABS and from Morton & Miller (1968).

EXPOSED BEACH

The exposed quartz sand beach on either side of the harbour entrance has few intertidal inhabitants apart from occasional tuatua *Paphies subtriangulata* and rarer low tidal to shallow subtidal *Dosinia subrosea,* toheroa P. *ventricosa,* and triangle shell *Spisula aequilateris.* Abundant specimens of the small wheel shell *Zethalia zelandica* live in the shallow subtidal sands on the north side of the harbour entrance. Washed up on the beach are the shells of many, mostly open coast molluscs (Appendix 2). including abundant shells of the the morning star shell

Tawera spissa and coiled internal shell of the pelagic *Spirula spirula.* Also washed up was a shell of the limpet *Cellana denticulata. This* species has a disjunct distribution centred on central New Zealand and the Three Kings Islands. It is common in prehistoric middens around northernmost Aupouri Peninsula but extremely rare alive in this region today.

EXPOSED ROCKY SHORES (Fig. 6)

Sixteen species were recorded living (Appendix 2) on the hard volcanic conglomerate forming the rocky shoreline on the north side of the outer entrance to Parengarenga Harbour (Fig. 1). The faunal abundance and composition differs considerably from that of the sheltered rocky shores inside the harbour. Here the dominant organisms at high tide are the grazing gastropods *Nerita atramentosa* and *Nodilittorina antipodum,* and at mid tide levels the encrusting barnacles *Chamaesipho brunnea* and *C. columna,* flea mussel *Xenostrobus pulex,* limpets *Cellana ornata* and *C. radians,* and predatory gastropods *Dicathais orbita* and *Lepsiella scobina.*

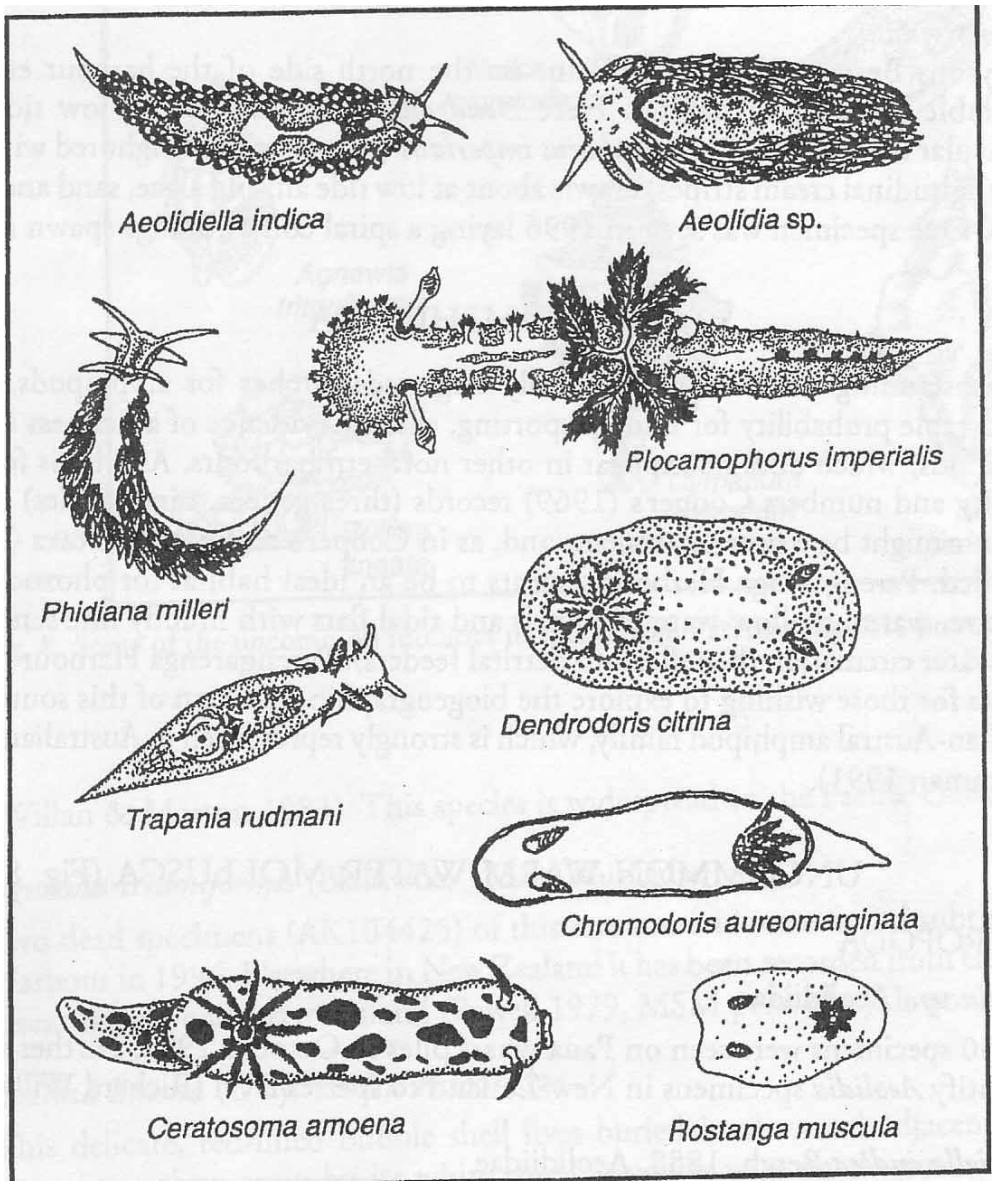


Fig. 7. Selection of nudibranchs from Parengarenga Harbour. All drawings by MSM.

NUDIBRANCHS (Fig. 7)

An unusually large number of colourful nudibranchs have been recorded from Parengarenga Harbour over the last few decades, many while snorkelling. Paua wharf area, on the edge of one of the main subtidal channels, is one of the prime sites. Here the white-bodied *Chromodoris aureomarginata* with a single gold line around the margin was seen in large numbers in November 1987 and October 1992 by MSM, approximately 10/m2 crawling on the dark muddy sand. White spiral coils of spawn were laid nearby. Numerous specimens of the lemon-yellow *Dendrodoris citrina* are sometimes present on and under rocks near Paua wharf, and the clown nudibranch *Ceratosoma amoena* (white to yellowish body with orange blotches and purple rhinopores and gills) crawls exposed on rocks. *Aeolidiella indica* has been seen under low tidal rocks at Dog Island.

Nudibranchs periodically seen living on the Paua wharf piles are *Phidiana milleri, Aeolidia* sp., the small dorid *Trapania rudmani* (white body with two bright yellow stripes) and the small red *Rostanga muscula* on red sponges.

Nudibranchs seen in good numbers subtidally on sponges growing on soft sandstone cliffs at Te Hapua in October 1992 include *Ceratosoma amoena, Dendrodoris citrina* and *Chromodoris aureomarginata.*

Dysons Beach and Ngatehe Point on the north side of the. harbour entrance, is also a favourable nudibranch habitat. Here *Dendrodoris citrina* lives on low tide rocks and the spectacular nudibranch *Plocamophorus imperialis* (pale peach to bright red with dark spots and two longitudinal cream stripes) crawls about at low tide among algae, sand and *Zostera* (Morley 1996). One specimen was seen in 1996 laying a spiral coil of orange spawn mass on a stone.

AMPHIPODA

Notwithstanding the lack of specifically targetted searches for amphipods, and therefore a considerable probability for under-reporting, there is evidence of a richness in phoxocephalid amphipods, which does not appear in other northern harbours. As a basis for comparison in diversity and numbers Cooper's (1969) records (three genera, nine species) from Wellington Harbour might be a near equivalent, and, as in Cooper's study, several taxa (3+) could not be identified. Parengarenga Harbour appears to be an ideal habitat for phoxocephalids with its extensive, warm, shallow-water channels and tidal flats with muddy fine sand substrates with good water circulation (beneficial to detrital feeders). Parengarenga Harbour must rank highly as a site for those wishing to explore the biogeographic radiation of this southern hemisphere Magellan-Austral amphipod family, which is strongly represented in Australian faunas (Barnard & Karaman 1991).

UNCOMMON WARM-WATER MOLLUSCA (Fig. 8)

GASTROPODA

Aeolidia sp., Aeolidiidae

Over 30 specimens were seen on Paua wharf piles in October 1992, Further study is required to identify *Aeolidia* specimens in New Zealand to species level (Richard Willan pers. comm.).

Aeolidiella indica Bergh, 1888, Aeolidiidae

One specimen of this rare nudibranch was found during our 1996 survey under a low tidal rock at Dog Island. Elsewhere in New Zealand it is recorded from the east coast of Northland

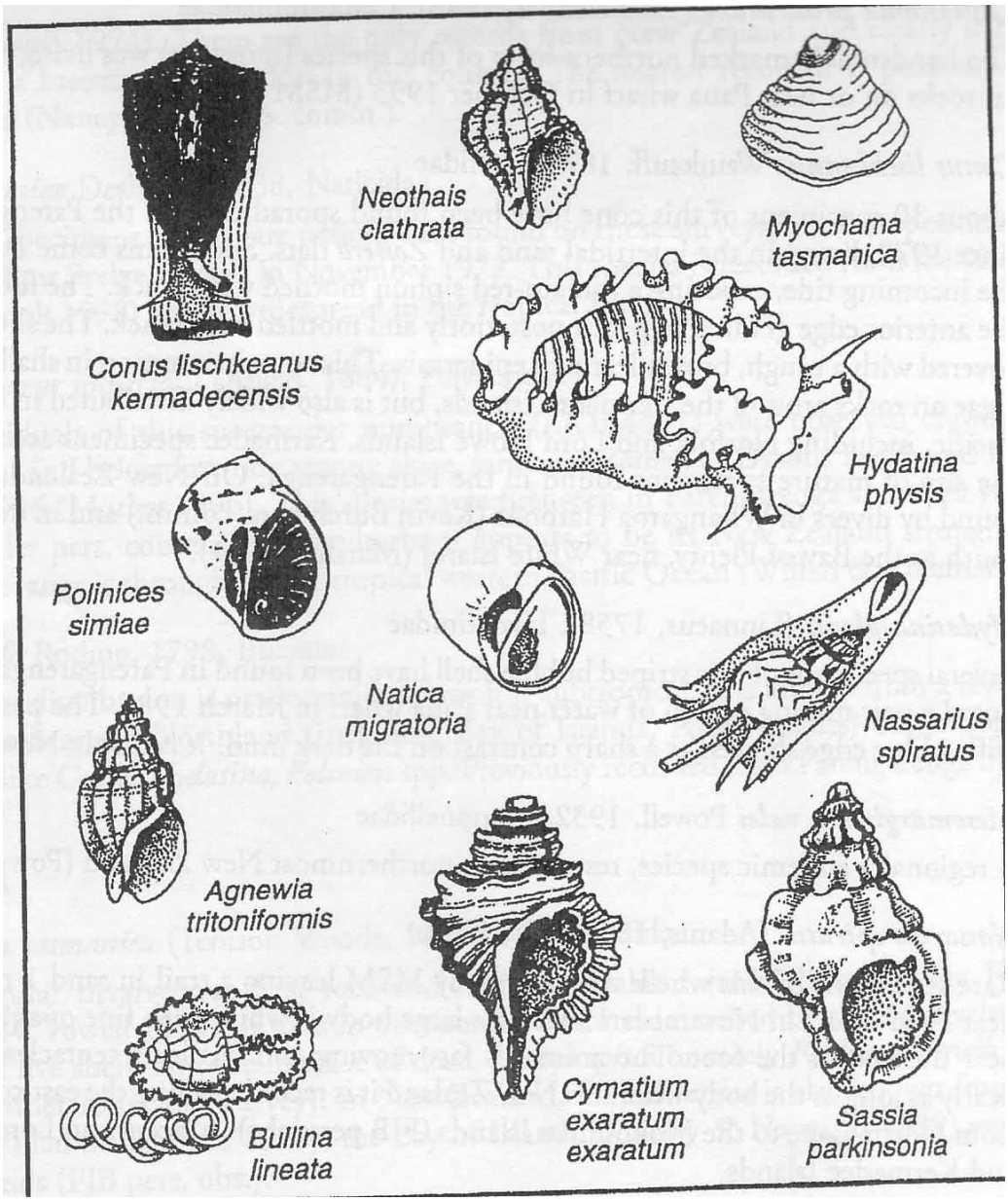


Fig. 8. Some of the uncommon molluscs recorded from Parengarenga Harbour. All drawings by MSM.

(Willan & Morton 1983). This species is widespread in the Pacific Ocean.

Agnewia tritoniformis (Blainville, 1833), Muricidae

Two dead specimens (AK104425) of this rare muricid were found subtidally in Parengarenga Harbour in 1996. Elsewhere in New Zealand it has been recorded from east coast of Northland, Great Barrier and Mayor Island (Powell 1979, MSM pers. obs.). It occurs on Norfolk Island.

Bullina lineata *(Gray, 1825),* Acteonidae

This delicate, red-lined bubble shell lives buried in the mud adjacent to Paua wharf. It is sometimes given away by its white spiral spawn masses on the surface. The animal has an iridescent blue border on a pale blue-grey mantle and is luminous at night (Richard Wilson pers. comm.).

Calliostoma pellucidum (Valenciennes, 1846), Calliostomatidae
The handsomely marked northern form of this species (spiratum) was living at a depth of 1 m on rocks on or near Paua wharf in October *1993 (MSM* pers. obs.).

Conus lischkeanus Wainkauff, 1875, Conidae
About 30 specimens of this cone have been found sporadically in the Parengarenga Harbour since 1972, living in the intertidal sand and *Zostera* flats. Specimens come out of the sand on the incoming tide, exposing a tomato-red siphon mottled with black. The foot is bright red at the anterior edge grading to peach posteriorly and mottled with black. The shell of live cones is covered with a tough, brown leathery epidermis. This cone is common in shallow water among algae on rocks around the Kermadec Islands, but is also widely distributed in the tropical West Pacific, including Norfolk and Lord Howe Islands. Kermadec specimens are about two-thirds the size of mature specimens found in the Parengarenga. Off New Zealand, it has also been found by divers in Whangaroa Harbour (Kevin Burch pers. comm.) and in deeper water as far south as the Bay of Plenty, near White Island (Marshall *19 8 1).*

Hydatina physis (Linnaeus, 1758), Hydatinidae
Several specimens of this striped bubble shell have been found in Parengarenga Harbour. MSM noted a pair mating in 2 m of water near Paua wharf in March *1986.* The peachy pink mantle with a blue edge showed as a sharp contrast on the dark mud. It is rare in New Zealand waters.

Mesomarginella valei Powell, 1932, Marginellidae
A regionally endemic species, restricted to northernmost New Zealand (Powell 1979*).*

Nassarius spiratus (Adams, 1852), Buccinidae
Rare specimens of this whelk were noted by MSM leaving a trail in sand 1 m below low tide near Paua wharf in November 1987. The large body is white with fine opaque white speckles near the end of the foot. The animal is fast moving and has long tentacles and a proboscis nearly as long as the body whorl. In New Zealand it is recorded along the east coast of Northland from North Cape to the Mokohinau Islands (FJB pers. obs). It occurs on Lord Howe, Norfolk and Kermadec Islands.

Natica migratoria (Powell, 1927*)*, Naticidae
Occasional specimens of this rare naticid have been seen alive in *Zostera* meadows and as sand trails off Paua in 1-3 m depths. It was first recorded and described from Te Hapua by Powell *(1927).*

Neothais clathrata (Adams, 1854), Muricidae
A live specimen of the small white whelk *Neothais clathrata* (AKI 38400) was found (by FT) in .1996 under a low tidal rock at Dog Island. This is the first recorded specimen en of this Indo-west Pacific species in New Zealand (Willan 1998), although there is no evidence that it has established a breeding population here. The estimated larval life of this species is about a month or possibly slightly longer (Robertson 1980) and the nearest recorded populations are around Vanuatu (Willan 1998*).*

Polinices melanostomoides Quoy & Gaimard, 1833, Naticidae

In 1972, two dead specimens of this naticid were found in Parengarenga Harbour and one at

Rarawa (Powell 1974). These are the only records from New Zealand and clearly it has not established a breeding population in this country. The nearest recorded populations are in Queensland (Nancy Smith pers. comm.).

Polinices simiae Deshayes, 1838, Naticidae
Only dead specimens of this rare naticid were found on these surveys, but live specimens were found by Hunt Seelye at Paua in November 1972. This species is recorded from the Kermadec Islands (Brook 1998) and is widespread in the tropical Pacific.

Plocamophortu imperialis (Angas, 1864), Polyceridae
Four individuals of this spectacular nudibranch (AK104471) were observed crawling and spawning at and below low tide among algae, sand and Zostera at Dysons Beach and Ngatehe Point in 1996 (Morley 1996). This species was first seen in Parengarenga about 30 years ago (M.C. Miller pers. comm.) and the harbour appears to be its New Zealand stronghold. Its geographic range is throughout the tropical western Pacific Ocean (Willan & Coleman 1984).

Tutufa bufo Roding, 1798, Bursidae
This species distribution is predominantly tropical-subtropical. It is known from a few coastal sites in northeastern Northland (including Bay of Islands, Poor Knights) but is apparently transitory like *Conus, Hydatina, Polinices spp.* Previously recorded from Parengarenga by Powell (1979).

BIVALVIA

Myochama tasmanica (Tenison Woods, 1877), Myochamidae
This irregular bivalve was first recorded in New Zealand from Parengarenga Harbour (AK131434, Powell 1974). It lives in the subtidal channels attached by the right valve to the exterior of live shells and the interior of dead *Tawera spissa* or rarely *Paphies australis* (Powell 1974, Gardner 1976, this survey). In New Zealand, *M. tasmanica is* also known from Matai Bay (R. Willan in Gardner 1978), the Bay of Islands (Morley & Hayward 1999) and Three Kings Islands (FJB pers. obs.).

DISCUSSION

DIVERSITY

In this study we record 452 species, including 266 molluscs, 33 crabs and shrimps, 22 amphipods, 16 isopods, 50 polychaetes and eight echinoderms. The number of mollusc species at Parengarenga is less than half the 551 recorded from the larger and more diverse habitats of the Bay of Islands (Morley & Hayward 1999), 130 krn south of Parengarenga, and considerably, more than the 179 species recorded from the similar, but considerably larger area of the middle and upper Waitemata Harbour, Auckland (Hayward et al. 1999). However the Parengarenga biota is less rich than the Waitemata (number of species in brackets) in its diversity of crabs and shrimps (43), amphipods (57), isopods (30), polychaetes (106) and echinoderms (16). These diversity differences probably relate to many factors, such as greater nutrient concentration, greater mud, greater turbidity and greater diversity of soft and hard substrate habitats in the Waitemata compared to the Parengarenga Harbour.
Parengarenga's low diversity in many phyla probably reflects the lack of diverse rocky shore

habitats around the harbour. For example there are very few boulders or cobbles to provide, shade and shelter for a wide range of animals like the black 'slug ‘*Scutus breviculus,* the golden oyster *Anomia trigonopsis,* the gastropods *Amphithalamus spp.* and *Herpetopoma spp.,* the seastars *Coscinasterias calamaria* and *Allostichaster jpolyplax,* the tunicates *Asterocarpa coerulea, Cnemidocarpa bicornuata* and *Pyura spp.,* the sea anemones *Isactinia olivacea, Diadumene neozelanica,* and *Paractisftrox,* and intertidal sponges like *Aaptos aaptos* and *Tethya aurantium.* Some other unexpected absences from Parengarenga Harbour include the common harbour channel-dwelling bivalves *Corbula zelandica* and *Dosina zelandica,* and the heart urchin *Echinocardium cordatum.*

Despite Parengarenga's low diversity, we record 50 molluscan species that have not been found in the diverse Bay of Islands fauna (Morley & Hayward 1999). A probable explanation for many of these additional records is the presence of extensive, shallow, warm-water *Zostera* and quartz sand flats in Parengarenga and the proximity of the harbour entrance to eddies of the warm East Auckland Current-a situation not repeated further south. These conditions may help facilitate the introduction and establishment of species with long larval phases from subtropical shores outside New Zealand.

Parengarenga Harbour is the type locality for at least three marine species-the naticid snail *Natica migratoria,* the gastropod *Chelidonura aureopunctula* (now a junior synonym of *Philinopsis taronga)* and bivalve *Lasaeaparengaensis.*

PARENGARENGA’S QUARTZ SAND AND *ZOSTERA* FLATS

The vast intertidal quartz sand and *Zostera* flats around Paua and Te Hapua are an unusual habitat for New Zealand. The soft, knee-deep sand is stabilised by the *Zostera* and never dries out between tides. It is the permanent or periodic home to sparse specimens of several uncommon gastropods seldom seen intertidally elsewhere in New Zealand.

These gastropods include large carnivorous species, such as the trumpet shell *Charonia lampas* which preys on the cushion seastar *Patiriella regularis,* the ranellids *Cymatium* e. *exaratum., Cymatium p. parthenopeum, Sassia parkinsonia* and *Ranella a. australasia* which feed on molluscs, and the trumpet shell *Cabestana spengleri* that feeds on ascidians. Some of the *Cymatium e. exaratum* specimens have an unusually long up-turned anterior canal, perhaps as a reponse to living in soft mud. Elsewhere in New Zealand, the usual habitat of these predators is the rocky shore at and below low tide.

Another unusual carnivore that lived and bred in this intertidal habitat, at least in the 1970s and 1980s, was *Conus lischkeanus*. We know of no live specimens being found in the 1990s.

Three relatively uncommon naticids, *Polinices simiae* (November 1972, Hunt Seelye pers. comm.), *Natica migratoria* and *Tanea zelandica,* have been found in the surface sand and *Zostera* flats off Paua.

Four bubble shells inhabit this unusual habitat. Occasionally found partly buried in shallow depressions in the sand or muddy sand are the rare species *Bullina lineata* and *Hydatinaphysis.* The common brown bubble shell *Bulla quoyii* appears as a bump in sand among *Zostera,* and the common smaller white bubble *Haminoea zelandiae* crawls exposed in sandy pools.

INTRODUCED SPECIES

The only species recorded in Parengarenga Harbour that have been introduced to New Zealand as a result of human activities are the Pacific oyster, the cord grass *Spartina* and the Asian mussel *Musculista senhousia.* Of these, the Asian mussel is known only from two dead shells

(AK98910) collected in 1991 from Paua. This is its northernmost record in New Zealand and it has not yet spread to the West Coast. No specimens were observed in Parengarenga in our mid 1990s surveys. The Pacific oyster, Crassostrea gigas, is largely restricted to the few areas of hard substrate (e.g. abandoned oyster farms) and mangrove forest trunks and has not yet invaded the extensive intertidal flats and subtidal channels as it has done in some other northern harbours (Hayward & Hollis 1993, Hayward et al. 1999). Perhaps the most threatening of the exotic species is the introduced cord grass that was mapped in six patches up the Waiheuheu and Parenga Arms and appeared to be spreading. Harbours on the east coast of Northland and Auckland have been invaded by several other introduced species in the last few decades (e.g. Hayward 1997). These include two exotic bivalves that have the potential to thrive in Parengarenga, the thin-shelled *Theora 1uhrica* and *Limaria orientalis,* but neither was recorded in this study.

CHANGES SINCE 1970s

Fifteen of the 72 mollusc species dredged from the main Parengarenga Harbour channel in the 1970s (Gardner 1978) were not found in the 1990s (Appendix 2). Most notable were the large clumps of the vermetid *Novastoa lamellosa.* Other species in the Auckland War Memorial Museum collections collected by Dr Powell at Te Hapua, Parengarenga, from shore washing in October 1971, but not found in this study, are the pyramidellid *Odostomia haurakiens,* rissoid *Rissoina chathamensis* and small bivalve *Mysella larochei.* Data on the state of the harbour biota before the 1990s is insufficient to document any major natural or human-induced changes that may have occurred. Taxa recorded as present in the 1970s but not found in our 1990s survey are largely small, dead shells that are probably mostly still present but in low numbers.

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