Macroinfauna of Wainui Beach, Gisborne - impact of beach protection structures

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1. Introduction

Wainui Beach, situated just to the east of Gisborne, is a 4.2 kilometre-long, broadly arcuate sandy shore which is fully exposed to the waves of the Pacific Ocean. The beach is limited by mudstone headlands at either end and bisected by the Hamanatua Stream, which drains a small catchment in the adjoining hills. The amount of sediment supplied to the beach from this source is negligible and even under conditions of heavy rainfall it is unlikely that salinities in the surf zone fall below 30%. Sea surface temperatures in the region range from 14 to 19°C (Garner 1969) and tides are semi-diurnal with a maximum range of 1.8 metres. The wave climate is mixed, with southerly swells originating in the westerlies south of New Zealand, and locally generated southerly and northerly storm waves (Pickrill & Mitchell 1979).

Erosion of the headlands has initiated retreat of Wainui Beach and the sea now threatens some of the residential properties which have been built on the main foredune along the 2.1 kilometre section of the shore south of the Hamanatua Stream. Resource consents are being sought for additional work on existing protection structures and the construction of new protection structures, and the Department of Conservation requested an assessment of the impact that modification of the natural processes occurring on the beach is having on the beach habitats and their macroinfauna[1]. Field studies used in the assessment were carried out at a site north of the Hamanatua Stream on 10-12 January 1995 (Stephenson unpublished data) and 11 December 1997, at two site south of the Hamanatua Stream on 21-23 April 1993 (Stephenson 1993), and at one of the latter sites, that adjacent to Lloyd George Road, on 10 and 12 December 1997. All of these studies took place during periods of spring tides.

2. Methods

SITE 1, JANUARY 1995

A transect was set up perpendicular to the shoreline, extending from the base of the foredune to below low water. A qualitative collection of the macroinfauna was made across the shore in the area adjacent to the transect by taking 16 samples of 0.1 m^2, these excavated to a depth of 30 cm and sieved using a 1 mm mesh bag. Two pitfall traps were set up on the backshore in the evening and operated for one night. At low water the beach profile was surveyed for the full length of the transect, using an automatic level, and the positions of the drift line and ground water table outcrop were noted.

[1] Infauna is a collective term applied to organisms that live principally in the sediment. These are further distinguished on the basis of size, macroinfauna being defined as those forms >1 mm in length.

Quantitative sampling of the macroinfauna involved establishing ten equally spaced sampling levels along the transect, the first above the drift line, the second on the drift line, and the last in the low-tide swash zone. At each level, ten 0.03 m^2 cores were taken to a depth of 30 cm, spaced at 0.5 m intervals along a line parallel to the shore and extending 2.25 m to either side of the transect. The contents of each core were sieved using a 1 mm mesh bag, and the material retained was fixed in 5% formalin in seawater. Three samples of sediment were collected at each sampling level using 3.5 cm diameter x 20 cm long metal cores inserted vertically into the sand. A hole was excavated at the intersection of the transect, and the sampling line at each level shortly after low tide and the depth of the water table was measured.

Animals were sorted from any residue, identified as far as practicable, and counted. Mean total abundance per m^2 at each sampling level was obtained by averaging data from the ten replicates, and total abundance per metre of beach was calculated by linear interpolation between the sampling levels. Species found only in the qualitative collection were assigned an arbitrary abundance of 10 m^{-1}. Sediment particle size was analysed by dry sieving at 1 phi intervals and mean sediment particle size and sorting calculated according to the moments method (McBride 1971). Mean sediment particle size at each sampling level was taken as the average of the three replicates.

SITE 1, DECEMBER 1997

A qualitative collection of the macroinfauna was made by taking 16 samples of 0.1 m^2, these spaced at 5 m intervals across the shore from the base of the foredune to the bottom of the low-tide swash zone. The samples were sieved using a 1 mm mesh bag and the animals identified and counted.

SITE 2, APRIL 1993

A transect was set up perpendicular to the shoreline, extending from the base of the foredune to below low water, and ten equally spaced sampling levels were marked, the uppermost above the drift line, the second on the drift line, and the last in the low-tide swash zone. At each level the macroinfauna was sampled by taking two 0.03 m^2 cores (1 metre apart) to a depth of 30 cm. Each core was washed through a 1 mm mesh sieve, and the residue retained on the sieve was preserved in 5% formalin in seawater. In addition to the quantitative sampling, a qualitative collection was made over the shore, especially along the drift line. The profile of the transect was surveyed using a builders level and a graduated staff. The positions of the drift line and the low tide groundwater table outcrop were noted, and the depth to the water table was measured at each sampling level above the latter point shortly after low tide. Sand samples for particle size analysis were taken at three levels on the shore (upper, mid, and lower beach).

In the laboratory the animals were hand-sorted under a binocular microscope, identified and counted. Abundance per metre of beach was obtained by linear interpolation between the sampling levels after calculating mean abundance per m^2 at each level. Species found only in the qualitative collection were assigned an arbitrary abundance of $10\ m^{-1}$. Sand samples were oven-dried at 60°C and dry sieved through a set of screens at 1 phi intervals to determine mean sediment particle size and sorting parameters.

SITE 3, APRIL 1993

The sampling and analysis procedure was the same as that used for Site 2 except that only four equally spaced sampling levels were used, the uppermost just outside the protection works at the top of the beach and the lowest in the low-tide swash zone.

SITE 3, DECEMBER 1997

The sampling and analysis procedure was the same as that used for Site 1 in January 1995 except that: (1) no pitfall traps were operated, (2) for quantitative sampling of the macroinfauna only five 0.03 m' cores were taken at each level, spaced at 1 m intervals along a line parallel to the shore and extending 2 m to either side of the transect, (3) replicate sediment samples were collected at only three levels, representing the upper, middle and lower beach, and (4) no water table measurements were made.

3. Results

The results of the investigations of the macroinfauna on Wainui Beach at the different sites and times are detailed below.

SITE 1, JANUARY 1995

Site 1 was located 1.5 km north of the mouth of the Hamanatua Stream (Grid reference NZMS 260Y18 531689). The beach measured 86 m from the lower limit of the low-tide swash zone to the base of the foredune, with a narrow berm at about 32 m and a low bar at about 80 m from the dune base. The mean slope of the intertidal beach was 1 in 29. Scattered plants of sea rocket *(Cakile* sp.*)* and clumps of spinifex *(Spinifex sericeus)* were present on the lower parts of the seaward face of the dune. The drift line was located 13 m from the base of the dune and the beach face to this level had numerous pieces of algal wrack, many of them partially buried in the sand. The low tide groundwater table outcrop was 57 m from the base of the dune and the depth of the water table at low tide increased steadily landwards to be 890 mm at the drift line and > 1340 mm at a point 5 m to seaward of the base of the dune. The sediment of the upper beach consisted of moderately well sorted sand ($Mz = 1.93\ ø$, $\sigma = 0.59\ ø$), and of the middle and lower beach moderately sorted slightly gravelly sand ($Mz = 1.46\ \phi$ and $1.01\ \phi$, $\sigma = 0.82\ \phi$ and $0.80\ \phi$ respectively).

The macroinfauna of the backshore was dominated by the beetle *Chaerodes trachyscelides* (6,641 m^{-1}). The beetle *Phycosecis atomaria* (432 m^{-1}), the amphipod *Talorchestia quoyana* (732 m^{-1}), and the isopod *Scyphax ornatus* (274 m^{-1}) were also common, with the latter two species found down to about the level of mean high-water neap tides. In the intertidal beach the dominant species was the isopod *Pseudaega tertia* (925 m^{-1}), accompanied above the low-tide groundwater table outcrop by the polychaete *Hemipodus simplex* (320 m^{-1}), and below the low-tide groundwater table outcrop by the polychaetes *Scoloplos* sp. (32 m^{-1}) and *Travisia* sp. (58 m^{-1}). Occasional *Paphies subtriangulata* (tuatua) were also present towards the bottom of the low-tide swash zone. The total number of species of macroinfauna recorded was 19, consisting of 9 marine species and 10 terrestrial species (Table 1). The estimated total abundance of the macroinfauna based on the qualitative and quantitative data was 9,675 m^{-1}.

SITE 1, DECEMBER 1997

The beach measured approximately 85 m from the lower limit of the low tide swash zone to the base of the foredune and the physical appearance of the beach was similar to that observed in January 1996. The beetle *Chaerodes trachyscelides* and the amphipod *Patuki breviuropodus* were the most abundant species in the samples from the backshore and intertidal beach, respectively. The total number of species of macroinfauna recorded was 17, consisting of 8 marine species and 9 terrestrial species (Table 1). Thirteen of these species were taken at the site in January 1995. Four species - the beetle *Carfius litoreus,* the isopod *Eurylana arcuata,* an unidentified dipteran, and an unidentified nemertean - were new records for the site.

SITE 2, APRIL 1993

Site 2 was located opposite the Wainui primary school (Grid reference NZMS 260Y18 515675). The beach measured 55 m from the lower limit of the low-tide swash zone to the base of a developing foredune. The dune was partially covered by spinifex and marram. The mean slope of the intertidal beach was 1 in 22. The drift line was discontinouous and diffuse, located 5.5-7 m from the base of the dune and consisting principally of small pieces of algal wrack partially buried in sand. The low-tide groundwater table outcrop was 42 m from the base of the dune and the depth to the water table at low tide increased steadily landwards to be 890 mm at a point 6 m to seaward of the base of the dune. The sediment of the upper beach consisted of moderately well sorted sand ($Mz - 1.78\ \phi$, $\sigma = 0.59\ \phi$); of the middle beach moderately sorted slightly gravelly sand ($Mz = 1.36\ \phi$, $\sigma = 0.77\ \phi$); and of the lower beach poorly sorted gravelly sand (size distribution strongly bimodal, $Mz = -0.37\ \phi$, $\sigma = 1.55\ \phi$).

The macroinfauna was confined to samples from the upper intertidal beach and backshore; no animals were found in the samples from the middle and lower intertidal beach. The beetle *Chaerodes trachyscelides* (115 m^{-1}) occurred on the backshore, and was accompanied along the drift line by the amphipod *Talorchestia quoyana* (96 m^{-1}). An unidentified species of oligochaete was also present, but was rare. The isopod *Scyphax ornatus* (96 m^{-1}) was the only species present in the upper intertidal beach. The total number of species of macroinfauna recorded was four, and all were terrestrial species (Table 1).The estimated total abundance of the macroinfauna based on the quantitative and qualitative data was 317 m^{-1}.

SITE 3, APRIL 1993

Site 3 was located a few metres north of the steps leading to the beach from the end of Lloyd George Road (Grid reference NZMS 260 Y18 511664). The beach measured 40 m from the lower limit of the low-tide swash zone to just inside the protection works at the top of the beach and was slightly concave. The mean slope of the intertidal beach was I in 24. The protection works consisted of a row of railway irons driven vertically into the underlying mudstone shore platform, and behind these a boulder revetment laid over debris at the base of a scarp cut into the main foredune. The drift line was situated amongst the boulders at the top of the beach. The low tide groundwater table outcrop was 36 m from the front of the protection works and the depth to the water table at low tide increased steadily landwards to be 570 mm at the front of the protection works. The sediment of the upper and middle beach consisted of moderately well sorted sand (Mz = 2.20 ø and 2.07 ø, σ = 0.60 ø and 0.64 ø respectively); and of the lower beach moderately sorted slightly gravelly sand (Mz = 1.81 ø, σ = 0.81 ø). Occasional flat cobbles were present on the sand over the lower two-thirds of the beach, these being the product of erosion of the headland to the south and at the time a conspicuous element of the littoral system on southern Wainui Beach.

No macroinfauna was present in any of the quantitative samples taken. However, the qualitative collection showed that the amphipod *Talorchestia guoyana* was common under drift material within the protection works at the top of the beach, accompanied by smaller numbers of the isopod *Ligia novaezealandiae*. The total number of species of macroinfauna recorded was two, both terrestrial species (Table 1). The estimated abundance of the macroinfauna based on the qualitative data was >100 m^{-1}.

SITE 3, DECEMBER 1997

The beach measured 72 m from the lower limit of the low-tide swash zone to the front of the protection works, and a ridge with a very steep seaward face was located about 27 m from the protection works. The mean slope of the intertidal beach was 1 in 24, but reached 1 in 8 in the section immediately seaward of the ridge. The drift line was located 7 m from the front of the protection works and the beach face down to this level had numerous pieces of algal wrack, many of them partially buried in the sand. The low-tide groundwater table outcrop was 50 m from the front of the protection works. The sediment of the upper beach consisted of moderately well sorted sand (Mz = 2.13 ø, σ = 0.52 ø); and of the middle and lower beach moderately sorted slightly gravelly sand (Mz = 1.58 ø and 1.18 ø, σ = 0.83 ø and 0.96 ø respectively).

The macroinfauna of the backshore was dominated by the amphipod *Talorchestia guoyana* (3,171 m^{-1}) and the beetle *Chaerodes trachyscelides* (697 m^{-1}). In the intertidal beach landward of the ridge the dominant species was the polychaete *Euzonus otagoensis* (6,208 m^{-1}), with the polychaete *Hemipodus simplex* (448 m^{-1}), the isopods Cirolanid n gen et sp. (112 m^{-1}) and *Scyphax ornatus* (168 m^{-1}) also common. Few animals were present in, or immediately to seaward of, the steep middle section of the beach. In the lower intertidal beach, below the low tide groundwater table outcrop, the amphipod *Patuki breviuropodus* (112 m^{-1}) was the most abundant species, accompanied by the polychaete *Scoloplos* sp. (101 m^{-1}). The total number of species of macroinfauna recorded was 17, consisting of 9 marine species and 8 terrestrial species (Table 1). The estimated total abundance of the macroinfauna based on the qualitative and quantitative data was 11,344 m^{-1}.

THE MACROINFAUNA

The species taken in the course of the surveys are listed below.

Phylum Nemertea
Genus and species not determined

Phylum Annelida
Class Oligochaeta
Genus and species not determined

Class Polychaeta
Order Opheliida
Family Opheliidae
Euzonus otagoensis Probert
Travisia sp.

Order Orbiniida
Family Orbiniidae
Scoloplos sp. cf. *S. ohlini* (Ehlers)

Order Phyllodocida
Family Glyceridae
Hemipodus simplex (Grube)

Family Nephtyidae
Aglaophamus macroura Schmarda

Phylum Mollusca
Class Bivalvia
Order Veneroida
Family Mesodesmatidae
Paphies subtriangulata (Wood)

Phylum Arthropoda
Class Chilopoda
Order Geophilomorpha
Scolioplanes sp.

Class Crustacea
Order Amphipoda
Family Oedicerotidae
Patuki breviuropodus Cooper & Fincham

Family Phoxocephalidae
Waitangi brevirostris Fincham

Family Talitridae
Talorchestia quoyana (Milne-Edwards)

Order Cumacea
Family Diastylidae
Colurostylis sp. cf. *C. longicauda* Jones

Order Isopoda
Family Cirolanidae
Eurylana arcuata (Hale)
New genus and species
Pseudaega tertia Jansen

Family Ligiidae
Ligia novaezealandiae Dana

Family Scyphacidae
Actaecia euchroa Dana
Scyphax ornatus Dana

Family Tylidae
Tylos neozelandicus Chilton

Family uncertain (Oniscoidea)
New genus and species

Class Insecta
Order Coleoptera
Family Carabidae
Genus and species not determined

Family Scarabaeidae
Pericoptus truncates Fabricius

Family Staphylinidae
Cafius litoreus Broun

Family Tenebrionidae
Chaerodes trachyscelides White

Family Trogositidae
Phycosecis atomaria Pascoe

Order Diptera
Family Therevidae
Genus and species not determined # 1

Family not determined
Genus and species not determined # 2

Family not determined
Genus and species not determined # 3

4. Discussion

4.1 SANDY BEACH ECOSYSTEMS

General

Sandy shores consist of three components - surf zones, beaches and dunes - which are linked by the interchange of material, particularly sand. Together they constitute a single geomorphic system, termed the littoral active zone (Tinley 1985). This is the part of the coast characterised by wave- and wind-driven sand transport and it lies between the outer limit of wave effects on bottom stability (usually between 5 and 15 m depth) and the landward limit of aeolian sand transport (i.e., the landward edge of the active dunes). Although this area constitutes a single geomorphic system, ecologically it consists of two distinct systems - a marine beach/surf zone ecosystem populated by marine biota and controlled by wave energy, and a terrestrial backshore/ dune system inhabited by terrestrial plants and animals and strongly influenced by wind energy. The most sensitive parts of these ecosystems to human impacts are the backshore and foredunes, but major engineering structures and other large- scale disturbances which interrupt sand movements and change wind and wave climates can have severe effects on all habitats in the littoral active zone.

Dune/beach exchanges

Besides climate and moisture, four materials are exchanged across the dune/ beach interface, these being sand, groundwater, salt spray, and living and dead organic material (McLachlan 1988). Virtually all coastal dunefields receive sand from and/or supply sand to beaches. Groundwater seeps from the land into the sea through confined or unconfined aquifers. This groundwater may be discharged in large volumes in some places and often contains very high nutrient levels, thereby adding significantly to the nutrient pool of the beach/surf zone ecosystem. Salt spray blown inland has an important effect on dune vegetation, and together with sand movement is a major factor structuring plant communities and landward gradients in coastal dunes. Four types of organic materials may be exchanged across the dune/beach interface: insects are often blown from land towards the sea; carrion and wrack cast ashore may provide a food source for dune animals which move down to the beach to feed; larger animals in the dunes, such as birds, are largely dependent on intertidal organisms for food; and litter from the dunes may be blown into the beach system.

Other than sand, which may be transported in huge volumes in high energy situations, the absolute quantities of the above materials transported across most dune/beach interfaces are fairly small. However, the impacts of these materials (groundwater nutrients, salt spray and organic materials) may be significant to both ecosystems. Thus although dunes and beaches are discrete, terrestrial and marine, wind-controlled and wave-controlled systems respectively, and although the interactions between them are quantitatively small, they are essentially interdependent and interacting.

The Resource Management Act 1991 defines the landward boundary of the Coastal Marine Area as the line of mean high water springs, except where that line crosses a river. On New Zealand sandy beaches this boundary coincides with the transition between the marine beach/surf zone ecosystem and the terrestrial back shore/dune ecosystem, but not with the landward boundary of the littoral active zone. The extent and nature of the physical and biological exchanges between these adjoining ecosystems and across the littoral active zone mean that beach protection structures built on or immediately to landward of mean high-water spring tide level have the capacity to impact on the habitats and biota of both the territorial coast and the Coastal Marine Area.

4.2 BEACH MORPHODYNAMICS

General

Exposed sandy beaches can be classified into three general morphodynamic types - reflective, intermediate and dissipative - based upon the interaction between wave energy, sand particle size and sediment abundance (Short 1979; Short & Wright 1983; Wright et at. 1985). Reflective beaches are produced by low waves, particularly in areas of coarse sand (mean particle size > 0.5 mm). They may also occur on moderate to high energy coasts where the sediments are composed of gravel, or sand and shingle. Such beaches are relatively high, fronted by a steep beach face which grades into a low-tide step. There are no surf zone or bar features, and waves surge and collapse close to the base of the beach face with much of the incident wave-energy being reflected.

Combinations of high waves (> 2.5 m) and fine sand (mean particle size < 0.25 mm) result in dissipative beaches characterised by a wide low-gradient beach face extending from the foot of the dunes to an even flatter lower beach face and surf zone. Waves break well to seaward of the shoreline and several subtle bars or breaker zones may be present across the surf zone, thus dissipating most of the wave-energy before it can reach the beach.

Intermediate beaches require medium sands (mean particle size 0.25 - 0.50 mm) and moderately high waves (1-2.5 m) and can be subdivided into four beach states - longshore bar-trough, rhythmic bar-beach, transverse bar-rip, and low-tide terrace - representing a transition from dissipative to reflective. Short (1980) found that, on medium particle size beaches, the higher energy bar-trough system persisted when modal waves exceeded 2 m, the rhythmic bar-beach when waves were 1.5-2 m, the transverse bar-rip when waves were 1-1 .5 m, and the low-tide terrace when waves were approximately 1 m. Intermediate beaches are common along shores facing moderate-energy east coast swell environments. They are characterised by high temporal variability, sediment constantly being shifted between the beach and surf zone, and bars and troughs in a surf zone displaying well-developed rip currents.

Relationship with beach macroinfauna

Recent studies carried out on beaches in South Africa, Australia, the west coast of the USA, south-central Chile, and northern New Zealand (McLachlan 1990; Jaramillo & McLachlan 1993; Stephenson & McLachlan in prep.) have shown that beach type is a good predictor of macrofaunal species diversity, the trend being for an increasing number of species towards dissipative conditions. This control appears to be a conservative feature of sandy beaches, differing little between zoogeographic provinces (McLachlan et al. 1993). Abundance and biomass follow a similar pattern, but are more variable as factors other than beach state also play a role in their determination.

McLachlan (1990) and McLachlan et al. (1993) have argued that it is not the beach state or type itself which is important for the macrofauna, but the swash climate associated with it. There is a consistent relationship between beach type and swash climate features (McArdle & McLachlan 1991, 1992). As reflective conditions are approached, swash periods shorten and approach wave period, swash speeds increase and tend to be high throughout the tidal cycle, and there is increasing swash activity above the groundwater table outcrop. Dissipative beaches display the opposite features. Physical stress in the swash zone thus increases from dissipative to reflective beaches and excludes more and more species until, in the fully reflective situation, only supralittoral forms (talitrid amphipods, insects), which live `outside' the swash climate, remain.

Stephenson & McLachlan (in prep.) have been able to demonstrate that on wave-exposed sandy beaches in the North Island, changes in beach face slope, sediment particle size and some aspects of swash climate correlate well with changes in beach state and with parallel trends in macroinfaunal community structure. Site 1 was one of the locations used for Stephenson and McLachlan's study, and the swash characteristics of the site, together with the diversity, abundance and biomass of the macroinfauna, were consistent with the classification of Wainui as an intermediate beach.

4.3 SANDY BEACH FOOD CHAINS

General

Sandy beaches are marine systems in which food chains mainly begin and end in the sea. Up to four biotic components may be present - primary producers, macrofauna, interstitial biota, and water column microbes. The presence of these various components and their relative importance in the system differ with beach type and particularly with the degree of coupling between beach and surf zones (Brown & McLachlan 1990). Two major types may be recognised - beaches with little or no surf zone, which are dependent on food inputs from the sea, and beaches with extensive surf zones sustaining sufficient primary production to be self-supporting. In the former, the system consists only of an intertidal sand body and there are only two food chains - interstitial and macrofaunal. In the latter, surf zone diatoms provide a rich source of primary production, well-developed circulation cells tend to retain this and other organic materials so the ecosystem is not dependent on marine inputs from beyond the surf, and all four biotic systems are present. Intermediate states occur between these two extremes.

Particulate organic matter is usually as common as, or more common than phytoplankton, as a food source and may dominate the sandy beach food chain, especially where there is a high input of macrophytes (large marine algae). Macrophytes are fed on directly by macroinfaunal scavengers associated with the drift line, such as talitrid amphipods, isopods, and insects. Following breakdown, much dissolved and particulate material may leach into the sand and become available to the interstitial fauna. Macrophyte detritus may also wash around in the surf zone and provide food for intertidal scavengers.

By feeding on primary food sources, making nutrients available to the interstitial fauna, and being prey for predators such as crabs, fish and birds, the macroinfauna occupies a key position in the centre of the food chain on sandy beaches. However, on beaches towards the reflective end of the morphodynamic spectrum, swish climate limits macroinfaunal abundance in the intertidal and this biotic component tends to become concentrated around the drift line where it is more vulnerable to the impact of human activities.

4.4 WAINUI BEACH

Site 1

Physical and biological observations made at this site in December 1997 indicate only minor differences from January 1995. On this basis, comparison of the 1995 data with that of the December 1997 investigation at Site 3 using the same methods is considered to be a valid option.

Site 2

This site is in a section of Wainui Beach south of the Hamanatua Stream which does not have beach protection structures. The species of macroinfauna found at this site in April 1993 have all been recorded elsewhere on Wainui Beach. The site was not re-examined in December 1997 and is not discussed further in this report.

Site 3

Although the sampling intensity of the April 1993 and December 1997 studies differed considerably, the basic sampling strategy was the same, and the 1993 data provide a temporal perspective on the macroinfauna at the site.

Macroinfauna

A total of 29 species of macroinfauna have now been recorded from Wainui Beach. Thirteen of these are marine forms which occur on the intertidal beach, 16 are terrestrial and inhabit the backshore. Overall, 23 (79%) of the species have been recorded at Site 1 (i.e., north of the Hamanatua Stream, adjoining "natural" dunes) and 18 (62%) at Site 3 (i.e., south of the Hamanatua Stream, adjoining protection structures). The corresponding numbers for the marine species are 11 and 9, and for the terrestrial species 12 and 9. However, the compositional difference between the faunas is much greater than these figures indicate, as the proportions of shared species for the backshore and intertidal are only 31% and 54%, respectively. This may indicate there are biologically important differences in the habitats between the two sites.

As far as the backshore is concerned, the most obvious difference is the lack of a landward connection to the dune system at Site 3, the result of the construction of shore protection structures along the beach immediately above mean high-water spring tide level. These structures constitute a barrier to migration and place the fauna at risk because, although terrestrial forms inhabiting the backshore can tolerate some submersion in sea water, they cannot risk being caught by the surf and swept out to sea. Most have a high degree of mobility and sophisticated responses to environmental cues, including diurnal or nocturnal, circatidal and/or circalunar rhythms of activity, and orientation responses to sun, moon, slope, or moisture content of the sand, but cannot fully utilise these to maximise their chances of survival when the landward extent of their habitat becomes limited in this way. The situation is further compounded by the protection structures preventing the transfer of sand to the beach, thus also limiting the habitat in the vertical sense during periods when sand is being removed from the backshore by storm waves. Protection structures can also affect the vertical extent of the backshore habitat by changing groundwater levels, flow rates and salinity, but no data are available on these for the present sites.

The impact of these limitations on the extent of the backshore habitat is illustrated by the results of the investigations at Site 3. In April 1993, not long after a period of erosion of the shoreface, the backshore was still subject to overwash at most high tides, and only one of the species usually associated with this habitat, a gill-breather, had returned to the site. In December 1997, with a beach now comparable in width to that at Site 1 and the backshore subject to overwash only at spring tides, more species were present but the relative number of gill-bearing species or species capable of cutaneous respiration as distinct from strictly air-breathing was greater than at Site 1. Coupled with this was a difference in the relative numbers of the two commonest species, the amphipod *Talorchestia quoyana* (a gill-breather) being dominant at Site 3 and the beetle *Chaerodes trachyscelides* (a tracheate form) at Site 1.

Whilst there is sufficient sand present on southern Wainui Beach to form a backshore, this effectively isolates the intertidal habitat from the protection structures, and the latter will only affect the intertidal macroinfauna where they interfere with the groundwater table. Current differences in the intertidal habitat and macroinfauna at Sites 1 and 3 therefore appear to be related to sediment particle size and wave exposure. The sediments at Site 3 are slightly finer than at Site 1 and waves arriving at Site 3 from the south-east, which is the predominant wave direction, are influenced by an extensive submerged reef extending seaward from the adjacent headland, producing more benign swash conditions. Site 1, on the other hand, is fully exposed to waves from this direction.

From a morphodynamic perspective,Wainui Beach is classified as an intermediate beach, and transfers of sand both along shore and onshore-offshore occur continuously depending on wave height and approach direction. In normal circumstances, during periods when substantial volumes of sand are being removed from the foreshore of a section of the beach, profile changes in the intertidal zone are mediated by transfer of sand stored in the backshore and/or dunes. Where this process is prevented from occurring, the beach face is lowered. Bores or breaking waves reach the upper beach and produce more rigorous swash conditions throughout the intertidal, this in turn leading to losses among the intertidal macroinfauna. Because Wainui Beach sits on a shore platform, in extreme events lowering of the beach face may lead to all of the sand being removed from the intertidal beach, resulting in the total destruction of the intertidal habitat and its macroinfauna. This is the probable cause of the absence of macroinfauna in the intertidal beach at Site 3 in April 1993, that survey following a series of major storms in 1992 which resulted in the mudstone shore platform at this site being exposed (Peacock 1992). It also indicates that the impact of these events on the intertidal macroinfauna may last for months, with recolonisation depending on wave climate, sediment supply and seasonal biological factors. To the extent that the beach protection structures are contributing to the frequency and duration of these events on southern Wainui Beach, they are impacting on the intertidal habitat and the survival of its macroinfauna.

5. Conclusions

The landward boundary of the Coastal Marine Area (CMA) on New Zealand sandy shores coincides with the transition between the marine beach/surf zone ecosystem and the terrestrial backshore/dune ecosystem, but not with the landward boundary of the littoral active zone. The extent and nature of the physical and biological exchanges between these adjoining ecosystems and across the littoral active zone mean that beach protection structures built on or immediately to landward of mean high-water spring tide level have the capacity to impact on the habitats and biota of both the territorial coast and the CMA.

Wainui Beach has a significant input of wrack, and the macroinfauna of its intertidal beach (a part of the CMA) and backshore (a part of the territorial coast) are the principal agents for the breakdown of this material, making the nutrients in it available to the interstitial biological system of the beach and to marine and terrestrial predators. The macroinfauna of these habitats thus form an integral part of the natural character of both the territorial coast and the CMA in the vicinity of Wainui Beach.

The available biological evidence indicates that the existing protection structures on southern Wainui Beach are influencing the composition (and perhaps abundance) of the macroinfauna of the backshore. At times the structures are also influencing the rate and/or degree of change in the swash climate and sediment volume of the foreshore, and hence the short-term (and perhaps ultimately the long-term) survival of the macroinfauna of the intertidal beach.

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7. Appendix 1. Macroinfauna on Wainui Beach

TABLE 1

List of the species of macroinfauna recorded on Wainui Beach, showing the sites and sampling dates on which they were taken. + = present at site; blank = not recorded.

Species	Site Number and Sampling Date				
	1 Jan. 1995	1 Dec. 1997	2 Apr. 1993	3 Apr. 1993	3 Dec. 1997
MARINE					
Aglaophamus macroura	+	+			+
Cirolanid n. gen. et sp.					+
Colurostylis sp.	+				
Eurylana arcuata		+			
Euzonus otagoensis	+	+			+
Hemipodus simplex	+	+			+
Nemertean sp. # 1		+			
Paphies subtriangulata	+				+
Patuki breviuropodus	+	+			+
Pseudaega tertia	+	+			+
Scoloplos sp.	+				+
Travisia sp.	+	+			
Waitangi brevirostris					+
Totals	**9**	**8**	**0**	**0**	**9**
TERRESTRIAL					
Actaecia euchroa	+	+			
Cafius litoreus		+			
Carabid sp. # 1					+
Chaerodes trachyscelides	+	+	+		+
Diptera sp. # 1	+				+
Diptera sp. # 2					+
Diptera sp. # 3		+			
Ligia novaezealandiae				+	
Oligochaete sp. # 1			+		+
Oniscoid n. gen. et sp.	+	+			
Pericoptus truncatus	+				
Phycosecis atomaria	+	+			
Scolioplanes sp.	+	+			+
Scyphax ornatus	+	+	+		+
Talorchestia quoyana	+	+	+	+	+
Tylos neozelanicus	+				
Totals	**10**	**9**	**4**	**2**	**8**

TABLE Al

Environmental and macroinfaunal data collected at Site 1, Wainui Beach, 10-12 January 1995. Abundance is based on ten 0.03 m2 cores at each sampling level. Three additional species - *Aglaophamus macroura*, *Colurostylis* sp., and *Paphies subtriangulata* - were present, but only taken in qualitative collections.

Sampling level		1	2	3	4	5	6	7	8	9	10
Distance from base of foredune (m)		77	69	61	53	45	37	29	21	13	5
Mean sediment particle size (ø)		1.04	0.98	1.53	1.54	1.22	1.54	1.81	2.11	2.09	1.71
(mm)		0	0	0	70	160	290	380	490	890	>1340
Mean abundance per square metre	*Actaecia euchroa*	0	0	0	0	0	0	0	0	0	4
	Chaerodes trachyscelides	0	0	0	0	0	0	0	0	25	991
	Diptera sp.# 1	0	0	0	0	0	0	0	0	0	4
	Euzonus otagoensis	0	0	0	0	0	0	4	0	0	0
	Hemipodus simplex	0	0	0	4	4	11	21	0	0	0
	Oniscoid n. gen. et sp.	0	0	0	0	0	0	0	0	0	4
	Patuki breviuropodus	0	7	0	0	0	4	0	0	0	0
	Pericoptus truncatus	0	0	0	0	0	0	0	0	0	4
	Phycosecis atomaria	0	0	0	0	0	0	4	0	7	53
	Pseudaega tertia	7	11	4	21	14	60	0	0	0	0
	Scolioplanes sp.	0	0	0	0	0	0	0	0	0	4
	Scoloplos sp.	0	4	0	0	0	0	0	0	0	0
	Scyphax ornatus	0	0	0	0	0	0	0	14	0	25
	Talorchestia quoyana	0	0	0	0	0	0	14	18	28	56
	Travisia sp.	4	0	4	0	0	0	0	0	0	0
	Tylos neozelanicus	0	0	0	0	0	0	0	0	4	0
	TOTAL	11	21	7	25	18	74	28	32	63	1143

TABLE A2

Environmental and macroinfaunal data collected at Site 2, Wainui Beach, 22 April 1993. Abundance is based on two 0.03 m2 cores at each sampling level. One additional species -- an unidentified oligochaete - was present, but only taken in qualitative collections. n.d. = no data.

Sampling level		1	2	3	4	5	6	7	8	9	10
Distance from base of foredune (m)		54	48	42	36	30	24	18	12	6	0
Mean sediment particle size (ø)		n.d.	-0.37	n.d.	n.d.	n.d.	1.36	n.d.	n.d.	n.d.	1.78
Depth to water table (mm)		0	0	0	100	290	320	390	470	890	n.d.
Mean abundance per square metre	*Chaerodes trachysclides*	0	0	0	0	0	0	0	0	0	33
	Scyphax ornatus	0	0	0	0	0	0	16	0	0	0
	Talorchestia quoyana	0	0	0	0	0	0	0	0	16	0
	TOTAL	0	0	0	0	0	0	16	0	16	33

TABLE A3

Environmental and macroinfaunal data collected at Site 3, Wainui Beach, 23 April 1993. Abundance is based on two 0.03 mz cores at each sampling level. Two species - *Ligia novaezealandiae* and *Talorchestia quoyana* - were present. but were taken only in qualitative collections. n.d. = no data.

Sampling level		1	2	3	4
Distance from base of protection works (m)		38	26	14	2
Mean sediment particle size (ø)		1.81	n.d.	2.07	2.20
Depth to water table (mm)		0	100	210	570
Mean abundance per square metre	TOTAL	0	0	0	0

TABLE A4

Environmental and macroinfaunal data collected at Site 3, Wainui Beach, 10 December 1997. Abundance is based on five 0.03 m2 cores at each sampling level. Three additional species - *Aglaophamus macroura,* Diptera sp. # 1, and *Pseudaego tertia* - were present, but only taken in qualitative collections. n.d. = no data.

Sampling level		1	2	3	4	5	6	7	8	9	10
Distance from base of protection works (m)		72	64	56	48	40	32	24	16	8	0
Mean sediment particle size (ø)		1.18	n.d.	n.d.	n.d.	1.58	n.d.	n.d.	n.d.	n.d.	2.13
Depth to water table (mm)		0	0	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Mean abundance per square metre	Carabid sp.# 1	0	0	0	0	0	0	0	0	7	14
	Chaerodes trachysclides	0	0	0	0	0	0	0	0	0	155
	Cirolanid n. gen. et sp.	0	0	0	0	0	7	0	7	0	0
	Diptera sp.# 3	0	0	0	0	0	0	0	0	0	7
	Euzonus otagoensis	0	0	0	0	0	0	0	769	7	0
	Hemipodus simplex	0	0	0	0	0	0	0	56	0	0
	Oligochaete sp.# 1	0	0	0	0	0	0	0	0	0	7
	Patuki breviuropodus	0	0	7	0	0	7	0	0	0	0
	Paphies subtriangulata	0	0	0	0	7	0	0	0	0	0
	Scolioplanes sp.	0	0	0	0	0	0	0	0	0	7
	Scoloplos sp.	7	7	0	0	0	0	0	0	0	0
	Scyphax ornatus	0	0	0	0	0	14	7	0	0	0
	Talorchestia quoyana	7	0	0	0	0	0	14	0	325	92
	Waitangi brevirostris	0	0	0	0	0	0	0	7	0	0
	TOTAL	14	7	7	0	7	28	21	839	339	282