Macroinfauna of
Wainui Beach south of the Hamanatua Stream;
an assessment of changes associated with beach erosion

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1. INTRODUCTION

Wainui Beach, situated just to the east of Gisborne, is a 4.3 kilometre-long, broadly arcuate sandy shore which is fully exposed to the waves of the southern 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 $30^{0}/_{00}$. Sea surface temperatures in the region range from 14-19°C (Garner 1969) and the 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 southern headland hinge point has initiated retreat of the adjoining portion of Wainui Beach and the sea now threatens residential properties built on the primary dune. A resource consent is being sought for the construction of further protective structures along the worst affected portion of the shore and the Department of Conservation initiated the present study to assess the impact that modification of the natural processes occurring on the beach might be having on the beach habitats and their macroinfauna. Field studies relating to the assessment were carried out on 21-23 April 1993 during a period of spring tides.

This report describes the composition, distribution and abundance of the macroinfauna at two sites on Wainui Beach south of the Hamanatua Stream, one representing the 'stable' and the other the actively eroding portion of the beach; assesses the changes in the fauna that appear to have taken place as a result of the beach erosion; and examines the possible role existing beach protection measures may have played in these changes.

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2. DESCRIPTION OF STUDY AREA

Wainui Beach south of the Hamanatua Stream can be divided into two morphological units, a northern unit and a southern unit, separated by a relatively short transition zone. In the northern unit the intertidal area is relatively uniform in width and is backed by a developing primary dune partially covered with spinifex and marram (Fig. 1). The profile of the lower two-thirds of the beach is slightly convex and that of the upper one-third concave, with the drift line at the time of the study located several metres to seaward of the base of the developing primary dune. In contrast, the intertidal area of the southern unit varies in width, becoming progressively narrower from north to south and finally tapering out against a small promontory (Fig. 2). The beach profile is slightly concave and the drift line in most places is situated against or in amongst the railway irons, large boulders, sheet piling, gabions and timber variously used to form protective structures at the foot of a scarp cut into the seaward face of the primary dune. The scarp is several metres high and the dune is topped by urban development.

3. SURVEY METHODS

A single sampling site was selected in each of the morphological units identified and described above, these sites being taken to represent the 'stable' (Site A) and actively eroding (Site B) portions of the beach respectively.

Site A (Northern unit)

A transect was extended from the base of the developing primary dune to below the swash line at low tide and ten equally spaced sampling levels marked, the uppermost above the drift line, the second on the drift line, and the last in the swash zone. At each level the macroinfauna was sampled by taking two replicate 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 preserved in 5% formalin in seawater. In the laboratory the animals were hand-sorted under a binocular microscope, identified and counted. In addition to the quantitative sampling, a qualitative collection was made over the shore, especially along the drift line. Abundance per running metre of beach was obtained by linear interpolation between the sampling levels after calculating mean abundance per m^2 at each

Fig, l; View along a portion of the northern unit at Wainui Beach, looking south. The transect at Site A runs across the beach about 20 n from the camera position, Tuaheni Point (centre, far distanced marks the entrance to Poverty Bay,

Fig. 2; View along a portion of the southern unit at Wainui Beach, looking south, The transect at Site B runs across the beach a few metres in front of the steps, which lead to the end of Lloyd George Road, level. Species found only in the qualitative collection were assigned an arbitrary abundance of 10 m^{-1} (following McLachlan 1990).

The profile of the transect was surveyed using a builders level and graduated staff to obtain the slope. The positions of the drift line and the low tide effluent line were noted, and the depth to the water table 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), oven-dried at 60°C and dry sieved through a set of screens at 1 phi intervals to determine mean particle size and sorting parameters (Folk 1968).

Wave height and period values were obtained from Ministry of Works & Development waverider data collected off Tatapouri Point, 4 km north of Wainui Beach. From estimated modal significant breaker height, wave period, and sand fall velocity, Dean's dimensionless parameter (Short & Wright 1983) was calculated as a measure of modal morphodynamic state: $\Omega = H_b / W_s . T$, where H_b is breaker height in cm, W_s the sand fall velocity in cm.s^{-1} (Gibbs et al. 1971) and T the wave period in seconds.

Site B (Southern unit)

The sampling and analysis procedure was the same as that used for Site A 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 swash zone.

4. SURVEY RESULTS

Site A (Northern unit)

Site A was located opposite the primary school (Grid reference NZMS 260 Y18 515675). The beach measured 50-55 m from the lower limit of the low spring tide swash zone to the base of the developing primary dune, the lower two-thirds slightly convex with an average slope of 1 in 21, and the upper one-third concave with the slope rising steadily to reach 1 in 6 between the drift line and the base of the dune (Fig. 3). The mean slope across the full width of the beach was 1 in 18. The drift line was discontinuous 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 effluent line was 42 m from the base of the dune and the depth to the

Fig. 3: View of the transect at Site A, Wainui Beach, from the low tide swash zone, The distance to the base of the developing primary dune is 48 m, The pegs mark the sampling levels used to examine the macroinfauna,

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 ϕ, σ = 0.59 ϕ); of the middle beach moderately sorted slightly gravelly sand (Mz = 1.36 ϕ, σ = 0.77 ϕ) and of the lower beach poorly sorted gravelly sand (size distribution strongly bimodal, Mz = -0.37 ϕ, σ = 1.55 ϕ) The carbonate content was very high in all grades coarser than 2 ϕ across the full width of the beach. Dean's parameter, based on H_b = 1.1 m, T = 8.5 s, and the fall velocity of the estimated mean particle size across the beach, was calculated to be 1.8.

The macroinfauna at Site A was confined to samples from the upper intertidal, drift line and supralittoral zone (see Appendix 1); no animals were found in samples from the middle and lower beach. The tenebrionid beetle *Chaerodes trachyscelides* occurred in the supralittoral zone, the talitrid amphipod *Talorchestia quoyana* on the drift line, and the oniscoid isopod *Scyphax ornatus* in the upper intertidal. The qualitative collection showed that T. *quoyana* was locally abundant along the drift line under pieces of algal wrack, and was accompanied there by *Chaerodes trachyscelides.* An unidentified species of oligochaete was also present, but was rare. The total number of species recorded was four. The estimated abundance of the macroinfauna based on the transect and qualitative data was 480 m^{-1}.

Site B (Southern unit)

Site B was located just north of the end of Lloyd George Road (Grid reference NZMS 260 Y18 511664). The beach measured 35-40 m from the lower limit of the low spring tide swash zone to just inside the protection works at the top of the beach, these consisting of a row of railway irons behind which were large boulders piled up against a scarp (Fig. 4). The beach was slightly concave, the lower two-thirds with an average slope of 1 in 26 and the upper one-third 1 in 18. The mean slope across the full width of the beach was 1 in 23. Occasional flat cobbles were present on the sand over the lower two-thirds of the beach at this site but were more numerous and also present on the upper part of the beach in other places along the southern unit. The drift line was situated in amongst the boulders at the top of the beach. The low tide effluent line 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 both the upper and middle beach consisted of moderately well sorted sand (Mz = 2.20 and 2.07 ϕ, σ = 0.60 and 0.64 ϕ respectively); and of the lower beach moderately sorted slightly gravelly sand (Mz = 1.81 ϕ, σ = 0.81 ϕ). Carbonate was only conspicuous in the

Fig, 4; View of the transect at Site B, Wainui Beach, from the low tide swash zone, The distance to the row of railway irons at the base of the protection works is 40 m.

-1 ϕ and 0 ϕ grades from the lower beach. Dean's parameter, based on H_b = 0.8 m, T = 8.5 s, and the fall velocity of the mean particle size across the beach, was calculated to be 3.7.

No macroinfauna was present in any of the core samples taken at Site B. However, the qualitative collection showed that the amphipod *Talorchestia quoyana* was abundant under drift material within the protection works at the top of the beach, accompanied by smaller numbers of the oniscoid isopod *Ligia novaezealandiae.* The total number of species recorded was two. The estimated abundance of the macroinfauna based on the qualitative data was < 100 m^{-1}.

The macroinfauna

The species taken in the course of the survey are listed below along with notes on their biology.

Phylum Annelida
Class Oligochaeta
Genus and species not determined
Pilgrim (1969) notes the occurrence of *Pontodrilus matsushimensis* under logs in the supralittoral zone of sandy beaches in Canterbury. This species is widely distributed on islands in the Pacific Ocean, including Chatham Island (Lee 1959). The present specimen, which is incomplete, probably belongs to this species.

Phylum Arthropoda
Class Insecta
Order Coleoptera
Family Tenebrionidae
Chaerodes trachyscelides White
North Island: apparently generally distributed (Hudson 1934). A characteristic species of the drift line and supralittoral zone, *Chaerodes trachyscelides* adults feed principally on decaying algae, are active on the surface at night, and burrow into the sand during the day (Harris 1970a, b). Endemic.

Class Crustacea
Order Amphipoda
Family Talitridae
Talorchestia quoyana (Milne-Edwards)
North Island, South Island; sandy beaches throughout. Endemic.

Order Isopoda
Family Ligiidae
Ligia novaezealandiae Dana
Kermadec Islands, North Island, South Island, Stewart Island; under stones on rocky beaches (Hurley 1961). Endemic.

Family Scyphacidae
Scyphax ornatus Dana
North Island: sandy shores throughout. South Island: Westport (Hurley 1961). The species constructs a cylindrical vertical burrow of 20-30 centimetres depth and the adults are nocturnal scavengers (MacIntyre 1963). Endemic.

5. DISCUSSION

5.1 BEACH ENVIRONMENT

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 al.* 1985). Reflective beaches are produced by low waves, particularly in areas of coarse sand (mean grain 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 (e.g., the east coast of the South Island, McLean & Kirk 1969). Such beaches are relatively high, fronted by a steep beach face which grades into a coarse 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. Dean's parameter has a value < 1.

Combinations of high waves (> 2.5 m) and fine sand (mean grain 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. Dean's parameter has a value > 6.

Intermediate beaches require medium sands (mean grain size 0.25-0.50 mm) and moderately high waves (1-2.5 m) and can be subdivided into four beach states - bar-trough, rhythmic bar beach, transverse bar-rip, and ridge and runnel - representing a transition from dissipative to reflective. Short (1980) found that on medium grain 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 ridge and runnel when waves were approximately 1 m. Intermediate beaches are common along shores facing moderate energy east coast swell environments and have Dean's parameter values between 1 and 6.

Site A (Northern unit)

The elevation of the base of the developing primary dune above sea level at low water spring tide at Site A is approximately 3.5 m, which is considerably in excess of the maximum spring tidal range of 1.8 m. This suggests that in most circumstances the upper end of the dynamic swept prism is accomodated within the present subaerial beach. Also, a berm is present midway down the profile, consistent with onshore movement of sediment during the late summer/autumn period of low-energy conditions preceding the survey. Overall the beach morphology supports the assumption that Site A represents a relatively stable portion of the shore.

The sediment at Site A consists principally of medium sand (0.25-0.50 mm) across the upper and middle beach, then grades seawards to a mixture of coarser sands (0.50-2.00 mm) and small gravels (2.0-64.0 mm) in the low tide region. Significant wave heights offshore range from 0.5-2.0 m, with occasional storm waves of up to 6-7 m. Wave periods range from 7-12 seconds. A modal significant breaker height of 1.1 m and period of 8.5 s has been adopted here, and the Dean's parameter calculated for the site classifies it as an intermediate beach, consistent with the Short & Wright model. However, the steep upper beach profile suggests the site has a tendency to become reflective at high tide, especially in winter or during major storm events when the berm may be planed off and replaced by a broad concave profile extending across the full width of the beach.

Site B (Southern unit)

The beach morphology at Site B contrasts markedly with that of Site A. The profile is slightly concave across the entire width of the beach, with no mid-profile berm, steep upper beach face, or sandy supralittoral zone. The elevation of the foot of the scarp at the top of the beach above sea level at low water spring tide is about 1.7 m, which although greater than the mean spring tidal range, is still 0.1 m less than the maximum range. The present subaerial beach, therefore, provides little or no buffer against wave set-up or storm surge; the latter may elevate sea level by up to 0.6 m (Heath 1979). Consequently, both the existing protection structures and the primary dune lie within the dynamic swept prism.

Wave energy otherwise absorbed by the sand removed from the limits of the active prism by a protection structure must be dissipated elsewhere, either by the structure, by the prism seaward of the structure, or by reflection of wave energy. Wave reflection has been observed along the section of Wainui Beach including Site B during storm events (J. Gibb, pers. comm.). Since this leads to added turbulence it suggests that the upper intertidal at Site B is subject to greater disturbance than the equivalent zone at Site A.

The sediment at Site B is also different to that of Site A, consisting principally of fine sand (0.125-0.250 mm) on the upper and middle beach and grading to medium sand (0.25-0.50 mm) containing only occasional small pebbles on the lower beach. Waves arriving at the site from the south-east, which is the predominant wave direction, are influenced by an extensive submerged reef extending seaward from the adjacent headland, and as a consequence of the lower wave energy reaching the shore, the sediments at Site B will tend to contain a greater proportion of fine sand than those at Site A. This is confirmed by previous sediment analyses from the area, although the present situation appears to be extreme (J. Gibb, pers. comm.). Gravels derived from erosion of the headlands to the south have been, and still are, a conspicuous element of the littoral system along the southern portion of Wainui Beach (see p. 6). It therefore seems likely that the Dean's parameter calculated for the site does not represent its modal state, which historical data suggest would be closer to that calculated for Site A.

If modal beach state at Sites A and B is similar, as seems likely, and with Site A having been demonstrated to be relatively 'stable' and unmodified, it can be argued that any current differences in the habitats and macroinfauna between the sites are the result of beach erosion and/or human interference in beach processes at Site B.

5.2 MACROINFAUNA

General

Recent studies carried out on beaches in South Africa, Australia, the west coast of the U.S.A. and south-central Chile (McLachlan 1990; Jaramillo & McLachlan in prep.) have shown that beach type, as defined by Dean's dimensionless parameter, is a good predictor of 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.

The majority of the published studies on New Zealand's exposed sandy beaches are descriptive or autecological rather than synecological. Examples of general descriptive accounts can be found in Oliver (1923), MacIntyre (1963), Knox (1969), Morton (1973) and Morton & Miller (1968). Autecological studies have been directed mainly at economically important species of bivalve molluscs, namely, the toheroa and its relatives (Mestayer 1921; Cassie 1951, 1955; Rapson 1952, 1954; Greenaway 1969; Street 1971; Waugh & Greenaway 1967; *inter alia*), although Devine (1966) has studied *Callianassa* and Fincham (1974, 1977) the intertidal sand-dwelling peracarid fauna of Stewart Island and the North Island. Some autecological data on species from exposed sandy beaches can also be found in various taxonomic works (for example, Hurley 1956; Hurley & Murray 1968; Dawson 1959; Cooper & Fincham 1974; and Jansen 1978).

Quantitative synecological studies on New Zealand's sandy beach macrofauna are few (Fincham 1974, 1977; Wood 1963, 1968; Morgans 1967a, b; Morton & Miller 1968) and not all relate to fully exposed sites. Also, although all of the studies have used transects as the basis for sampling, other details of the methods have varied considerably. Thus there is no representative and consistent data set to provide a meaningful overview of the relationships between physical and biological parameters on New Zealand's exposed sandy beaches.

East coast North Island sandy beaches in particular have remained virtually unstudied: the only published work is that of Fincham (1977), who detailed the composition and abundance of the intertidal peracarid Crustacea at Westshore near Napier (39°29'S, 176°53'E) and at Castlepoint (40°54'S, 176°13'E). In both cases the section of beach examined was situated in the lee of a headland, had a north-westerly aspect, and the sediments were fine sands. Neither is directly comparable with Wainui Beach and it will be necessary to use overseas data to assess if the pattern of macroinfauna at Site A is consistent with the prevailing environmental conditions on Wainui Beach south of the Hamanatua Stream.

Site A (Northern unit)

A comparison of Site A at Wainui Beach with six other beaches from similar wave and tide environments elsewhere in the Southern Hemisphere (Table 1) shows that the species diver sity and abundance recorded for Site A also are consistent with those of the other beaches.

McLachlan (1990) and McLachlan *et al.* (1993) argue that it is not the beach state or type itself that is important for the macroinfauna, but the swash climate associated with it. There

TABLE 1

Environmental and macroinfaunal features of Site A, Wainui Beach, and six other Southern Hemisphere beaches. Slope = 1/mean gradient from above the drift line to the low tide swash zone. $H_b/W_s.T$ = Dean's dimensionless parameter for which < 1 = reflective, > 6 = dissipative, and 1-6 = intermediate beach types.

Beach location & coordinates (Source)	Tide type & maximum range (m)	Wave height H_b (m)	Wave period T (sec)	Sand Mz (μm)	Slope	$H_b/W_s.T$	No. Spp	Abundance (m^{-1})
Thompsons, South Africa 31°05'S, 30°10'E (Wooldridge *et al.* 1981)	semi-diurnal 2.1	1.3	8.5	362	1/10	2.9	3	105
Los Molinos, Chile 39°51'S, 73°23'W (McLachlan *et al.* 1993)	semi-diurnal 1.5	1.0	8.0	369	1/14	2.3	6	18925
Sodwana, South Africa 27°25'S, 32°44'E (Dye *et al.* 1981)	semi-diurnal 2.1	1.3	8.0	431	1/18	2.5	5	201
Site A, Wainui, N.Z. 38°40'S, 178°05'E (This study)	semi-diurnal 1.8	1.1	8.5	520	1/18	1.8	4	480
Codihue, Chile 39°51'S, 73°23'W (McLachlan *et al.* 1993)	semi-diurnal 1.5	1.0	9.0	674	1/13	1.0	1	80
Blythdale, South Africa 29°16'S, 31°16'E (Dye *et al.* 1981)	semi-diurnal 2.1	1.4	8.5	876	1/5	1.2	1	3
Kelso, South Africa 30°16'S, 30°40'E (Dye *et al.* 1981)	semi-diurnal 2.1	1.4	8.5	936	1/8	1.1	1	5

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 effluent line. Dissipative beaches display the opposite swash 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, ocypodid crabs, insects) which live 'outside' the swash climate remain.

This 'swash exclusion hypothesis', suggested by McLachlan *et al.* (1993), still needs to be tested experimentally. However, the zonation pattern exhibited by the macroinfauna at Site A, which has a talitrid amphipod, an oniscoid isopod, an insect and an oligochaete occupying the uppermost intertidal, drift line and supralittoral zone, is consistent both with the hypothesis and with the zonation pattern described for beaches of similar morphodynamic status at about the same latitude in south-central Chile (Jaramillo & McLachlan in prep.).

The evidence suggests that Site A can be taken as representing the natural pattern of the macroinfauna of Wainui Beach south of the Hamanatua Stream.

Site B (Southern unit)

The beach environment at Site B differs from that at Site A in a number of respects relevant to the macroinfauna. Beach width (i.e., the area of available habitat) is less, but more significantly, it is the steep upper intertidal and supralittoral zones, the levels occupied by the macroinfauna at Site A, which are modified and absent respectively. A drift line is present, but as it is entrapped within the protection structures at the top of the beach it is therefore subject to frequent submergence in the surf water. Such conditions can be tolerated by gill-bearing forms (such as amphipods and isopods) which can breathe in both water and damp air, but excludes tracheate forms (such as insects) which are adapted primarily for air-breathing. The appearance of *Ligia novaezealandiae,* which was not recorded at Site A, is probably related to the presence of the boulders, since stony beaches are the more typical habitat of this species.

Under conditions of beach retreat through a dune belt erosional events would be followed by rebuilding of the upper beach using, in part, material derived from the dunes. Inter polation of a protection structure within the normal limits of the swept prism prevents this from occurring, reducing the range, extent, and nature of the habitats available to the macroinfauna. This has happened at Site B on Wainui Beach and resulted in a decrease in species diversity and abundance, although the overall effect is small since general environmental conditions on Wainui Beach south of the Hamanatua Stream are such that the natural pattern is for there to be a macroinfauna of low species diversity and relatively low abundance.

6. SUMMARY AND CONCLUSIONS

Wainui Beach south of the Hamanatua Stream can be divided into two morphological units. The northern unit has a profile which in its upper third progressively steepens landwards to a developing primary dune partially covered by spinifex and marram. The macroinfauna has a low species diversity and relatively low abundance and is confined to the uppermost intertidal, drift line and supralittoral zone. This appears to be the natural pattern for the beach as its character is consistent with that recorded for beaches with similar environmental features elsewhere in the Southern Hemisphere.

In the southern unit erosion has cut a scarp in the seaward face of the primary dune and as a result protection works have been constructed in front of the dune. Since these structures interfere with natural beach processes, the upper intertidal beach slope has decreased, the sandy supralittoral zone has been eliminated, and the drift line confined to the base or interstices of the protection works. Relative to the northern unit species diversity and abundance is further reduced and the macroinfauna confined to the drift line.

To the extent that the protection works have contributed to the changes in the upper beach profile in the southern unit they have reduced the areas of, and/or modified, the habitats available for macroinfauna on Wainui Beach south of the Hamanatua Stream. Where this reduction and/or modification has occurred it has restricted the already limited macroinfauna of Wainui Beach to those species capable of surviving frequent submergence in surf water.

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APPENDIX 1:
Environmental and macroinfaunal data collected at Wainui Beach, April 1993

TABLE A1

Environmental and macroinfaunal data collected at Site A, Wainui Beach, April 1993. Abundance is based on two 0.03 m^2 cores (1 m apart) at each sampling level. + = present at this sampling level but only taken in the qualitative collection. Cha.t. = *Chaerodes trachyscelides,* Tal.q. _ *Talorchestia quoyana,* Scy.o. = *Scyphax ornatus.*

Sampling level		Distance from base of primary dune (m)	Sediment mean particle size (ϕ)	Depth to water table (mm)	Mean abundance (m^{-2})		
					Cha.t.	Tal.q.	Scy.o.
1		54	n.d.	0	-	-	-
2		48	-0.37	0	-	-	-
3	Effluent line	42	n.d.	0	-	-	-
4		36	n.d.	100	-	-	-
5		30	n.d.	290	-	-	-
6		24	1.36	320	-	-	-
7		18	n.d.	390	-	-	16
8		12	n.d.	470	-	-	-
9	Drift line	6	n.d.	890	+	16	-
10		0	1.78	n.d.	33	-	-

TABLE A2

Environmental and macroinfaunal data collected at Site B, Wainui Beach, April 1993. Abundance is based on two 0.03 m^2 cores (1 m apart) at each sampling level. + = present at this sampling level but only taken in the qualitative collection. Tal.q. = *Talorchestia quoyana,* Lig.n. = *Ligia novaezealandiae.*

Sampling level		Distance from centre of protection works (m)	Sediment mean particle size (ϕ)	Depth to water table (mm)	Mean abundance (m^{-2})	
					Tal.q.	Lig.n.
1		38	n.d.	0	-	-
	Effluent line	37				
		36	1.81	n.d.		
2		26	n.d.	100	-	-
		16	2.07	n.d.		
3		14	n.d.	210	-	-
4		2	2.20	570	-	-
	Railway irons	1				
	Drift line	0			+	+