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INTERTIDAL SAND-DWELLING PERACARID FAUNA OF NORTH ISLAND, NEW ZEALAND

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ABSTRACT

Substrate and infauna samples were taken at four tidal levels (mean high water springs, high mid beach, low mid beach, and mean low water neaps) with a $0.0625\,m^2$ quadrat at 14 North Island beaches in New Zealand. The distributions of Peracarida (Crustacea) were correlated with sediment type, tidal height, and degree of exposure; sampling began in March 1972 and was completed in November 1973.

Substrate samples were sieved and median diameter of the particles ranged from very coarse sand of -0.60ϕ to very fine sand of $+3.25\phi$. Substrates were variously sorted: ϕ quartile deviation ranged from 0.14ϕ to 0.66ϕ, skewness from -0.08ϕ to $+0.07\phi$.

Peracarid fauna was moderately abundant; the maximum value was 720 animals per square metre on a fully exposed beach. Highest average abundance (303 per square metre) for the 14 beaches was recorded from the mean low water neap station. Amphipoda was the dominant group (54% of all Peracarida recorded), followed by Isopoda (33%) and Cumacea (13%). Frequency of occurrence at the 56 stations was headed by Amphipoda (64%), followed by Isopoda (46%), and Cumacea (20%).

The results are compared with data from Stewart Island beaches, and the biogeographical distributions of recorded Peracarida are discussed. An unexpectedly high degree of endemism exists for a warm-temperate region, caused by the isolation of New Zealand, which has no direct shallow water contact with tropical or cold temperate regions.

INTRODUCTION

In his account of alga-living littoral Gammaridea, Barnard (1972) showed that, although there was no distinctive New Zealand warm-temperate amphipod fauna in the north of North Island, there was overall domination by species with warm-temperate Australian affinities. Also, about a quarter of the 113 species in 65 genera listed by Barnard have circum-subantarctic affinities. Collecting by Barnard was confined to east coasts and his exhortation for other workers to examine amphipod collections from the algal belt and "other neglected amphipodan biotopes" has been partially fulfilled in recent studies (Cooper 1974, Cooper & Fincham 1974, Fincham 1974a, b, 1977) on Stewart Island infauna, Wellington Harbour infauna and algal belt fauna, and North Island infauna.

The aims of the present study were to produce a quantitative list of infaunal Peracarida (including the orders Amphipoda, Cumacea, and Isopoda) for North Island beaches and to determine biogeographical patterns of distribution.

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METHODS

Four equally spaced stations – at mean high water springs (MHWS), high mid beach (HMB), low mid beach (LMB), and mean low water neaps (MLWN) – were sampled on 14 North Island beaches between March 1972 and November 1973. Sampling techniques employed were the same as in Fincham (1974a). No sediment sample was taken of the bank of broken shell at MHWS at Cheltenham Beach. Terminology used for sediment analysis is as in Creager (1963).

RESULTS

PHYSICAL CHARACTERISTICS OF THE BEACHES

Lyall Bay (41° 20′ S, 174° 48′ E) is deeply indented and exposed to the southeast with a fetch of over 2000 km from the Antarctic. The head of the bay was formed relatively recently, after the Wairapa Earthquake of 1855 uplifted the Miramar peninsula, thus severing the sea connection between Lyall Bay and Wellington Harbour.

The runway extension of concrete blocks to Wellington's Rongotai Airport has created an artificial breakwater in the NE corner of the bay. The short beach slopes through 49.5 m, with a marked berm about HMB. Above the berm crest the sand is dry and soft; below, the sand is firm. The sand consists mainly of quartz and mica derived from greywacke.

Median diameter of the beach substrate samples (Table 1, Fig 1) ranges from 2.83ϕ at MLWN to 2.96ϕ at MHWS, indicating great similarity of fine sand over the whole beach. The range of quartile deviation from 0.19ϕ at MHWS to 0.28ϕ at both LMB and MLWN is small and indicates good sorting on this exposed beach. Quartile skewness is very small, ranging from -0.02ϕ to $+0.03\phi$ at HMB, and indicating that both the smaller and the larger particles are equally well sorted.

Paraparaumu Beach (40° 54′ S, 174° 59′ E) is a WNW-facing beach partially protected by Kapiti Island, but otherwise exposed to the Tasman Sea. The beach slopes gently through 72.3 m and the firm sand consists of very fine quartz, mica, muscovite, and hornblende.

Median diameter of the substrate (Table 1, Fig. 2) ranges from $+2.79\phi$ at both MLWS and LMB to $+2.85\phi$ at MHWS indicating similar fine sand over the whole beach. The small range of quartile

OPPOSITE

FIGS 1–7—Cumulative curves of sand particles analysed from stations at MHWS (mean high water springs; solid square symbols), HMB (high mid beach; solid circle symbols), LMB (low mid beach; solid triangle symbols), and MLWN (mean low water neaps; open square symbols) on seven of the fourteen beaches sampled, North Island, New Zealand, March 1972–November 1973: 1–Lyall Bay; 2–Paraparaumu Beach; 3–Opunake Beach; 4–Onaero Beach; 5–Baylys Beach; 6–Ninety Mile Beach (Waipapakauri); 7–Ti Bay, Paihia.

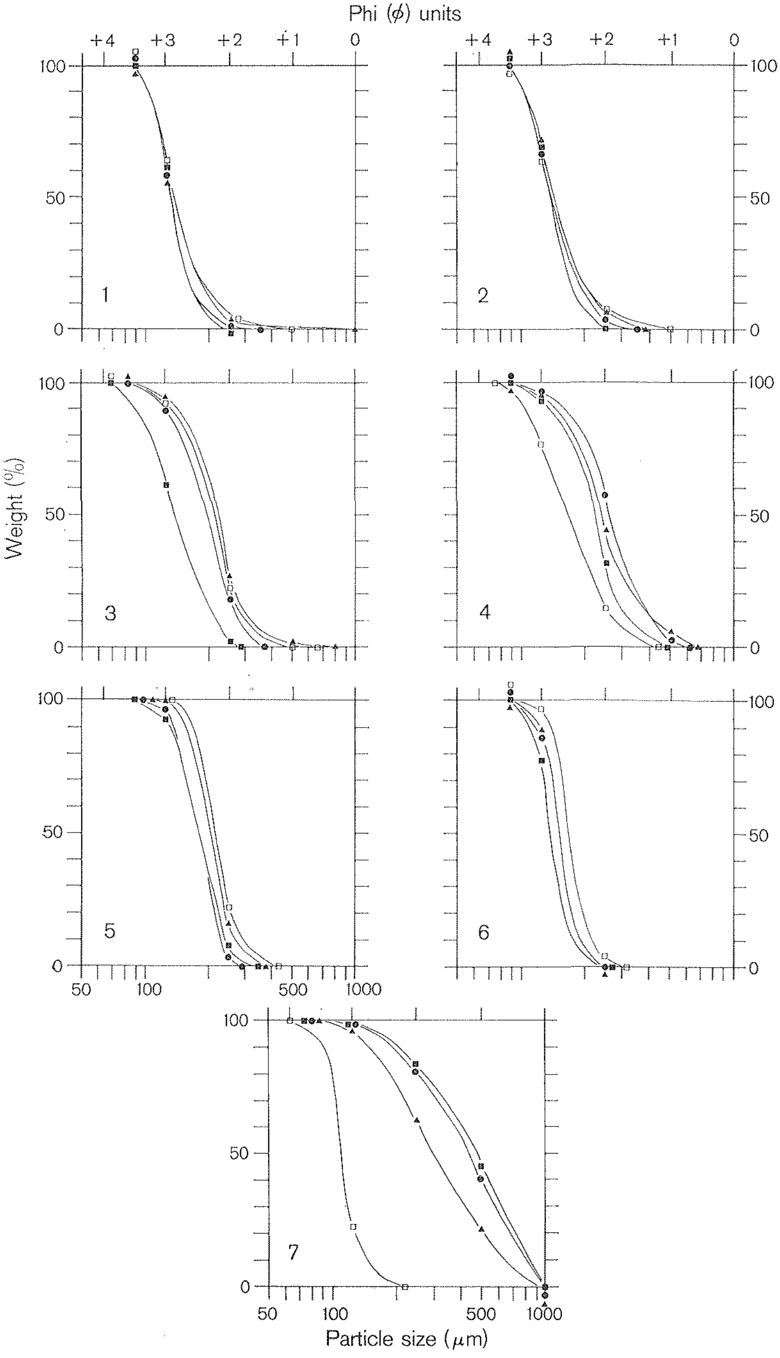

Phi (ϕ) units
+4
+3
+2
+1
0
100
50
0
1
2
3
4
5
6
7
Weight (%)
50
100
500
1000
Particle size (μm)

TABLE 1—Cumulative curve derivatives from the analysis of particle size (ϕ units) of sand from 14 North Island beaches sampled for intertidal peracarids, March 1972–November 1973 (MHWS = mean high water springs; HMB = high mid beach; LMB = low mid beach; MLWN = mean low water neaps)

STATION AND POSITION ON SHORE	ϕ MEDIAN DEVIATION	ϕ QUARTILE DEVIATION	ϕ QUARTILE SKEWNESS
LYALL BAY			
1 MHWS	+2.96	0.19	−0.02
2 HMB	+2.94	0.22	+0.03
3 LMB	+2.87	0.28	+0.01
4 MLWN	+2.83	0.28	−0.01
PARAPARAUMU BEACH			
1 MHWS	+2.85	0.22	−0.01
2 HMB	+2.83	0.31	−0.02
3 LMB	+2.79	0.34	−0.05
4 MLWN	+2.79	0.31	−0.06
OPUNAKE BEACH			
1 MHWS	+2.87	0.31	−0.04
2 HMB	+2.33	0.29	+0.04
3 LMB	+2.21	0.24	+0.01
4 MLWN	+2.27	0.24	+0.01
ONAERO BEACH			
1 MHWS	+2.15	0.18	−0.03
2 HMB	+1.96	0.31	−0.06
3 LMB	+2.06	0.33	−0.02
4 MLWN	+2.54	0.36	−0.01
BAYLYS BEACH			
1 MHWS	+2.46	0.27	+0.02
2 HMB	+2.50	0.25	0.00
3 LMB	+2.27	0.18	+0.01
4 MLWN	+2.23	0.20	−0.01
NINETY MILE BEACH (Waipapakauri)			
1 MHWS	+2.87	0.17	−0.04
2 HMB	+2.73	0.18	−0.01
3 LMB	+2.71	0.14	−0.01
4 MLWN	+2.52	0.16	−0.01
TI BAY, Paihia			
1 MHWS	+1.08	0.55	+0.07
2 HMB	+1.17	0.56	+0.06
3 LMB	+1.73	0.59	−0.03
4 MLWN	+3.25	0.14	−0.07
PAKIRI BEACH			
1 MHWS	+2.06	0.35	−0.08
2 HMB	+1.37	0.46	+0.04
3 LMB	+2.04	0.33	−0.08
4 MLWN	+1.98	0.32	−0.10

TABLE 1—(*Continued*)

STATION AND POSITION ON SHORE	ϕ MEDIAN DEVIATION	ϕ QUARTILE DEVIATION	ϕ QUARTILE SKEWNESS
LONG BAY			
1 MHWS	−2.87	0.29	0.00
2 HMB	+2.62	0.37	0.00
3 LMB	+2.37	0.37	+0.04
4 MLWN	+2.62	0.43	−0.03
CHELTENHAM BEACH			
2 HMB	−0.60	0.64	−0.03
3 LMB	+2.50	0.29	+0.04
4 MLWN	+2.69	0.25	−0.02
MOUNT MAUNGANUI BEACH			
1 MHWS	+2.46	0.29	+0.04
2 HMB	+1.87	0.66	−0.06
3 LMB	+2.23	0.29	−0.06
4 MLWN	+2.10	0.35	−0.04
OHOPE BEACH			
1 MHWS	+2.90	0.17	+0.02
2 HMB	+2.79	0.20	+0.01
3 LMB	+2.56	0.37	−0.06
4 MLWN	+2.46	0.33	0.00
WESTSHORE BEACH, Napier			
1 MHWS	+2.37	0.36	+0.01
2 HMB	+3.06	0.23	−0.05
3 LMB	+2.98	0.29	−0.02
4 MLWN	+2.92	0.27	−0.04
CASTLEPOINT			
1 MHWS	+2.10	0.26	+0.01
2 HMB	+2.62	0.30	−0.01
3 LMB	+2.46	0.35	+0.02
4 MLWN	+2.33	0.34	+0.07

deviation from 0.22ϕ at MHWS and 0.31ϕ at HMB indicates a good sorting, as would be expected on this mainly exposed coast. Quartile skewness is small and ranges from −0.01ϕ at MHWS to −0.06ϕ at MLWS, and indicates that particles of all sizes are equally well sorted.

Opunake Beach (39° 28′ S, 173° 51′ E) is enclosed by cliffy headlands typical of south Taranaki; it faces WSW and is completely exposed to the south-westerlies. The beach slopes gently and evenly through 198 m from the strand line of dry sand through firm mid beach sand to standing pools of water at MLWN; neighbouring beaches are boulder strewn. The sand consists of quartz, limestone fragments, and titanomagnetite, the typical component of ironsand beaches of North Island.

Median diameter of the substrate (Table 1, Fig. 3) ranges from 2.21ϕ at LMB to 2.87ϕ at MHWS, indicating a tendency for the coarser sediments to be deposited lower on the shore. The small range of quartile deviation of 0.24ϕ at both MLWN and LMB to 0.31ϕ at MHWS shows that within the first and third quartiles the sediments are well sorted. A small quartile skewness range from +0.04ϕ at HMB to −0.04ϕ at MHWS indicates little difference in sorting between coarse and fine sediments.

Onaero Beach (38° 59′ S, 174° 21′ E) on the north coast of Mt Egmont is a short, NW-facing ironsand beach sloping through 57.4 m, backed by sheer cliffs. The shore is littered with pebbles, and the sand consists largely of titanomagnetite and ilmenite.

Median diameter of the substrate (Table 1, Fig. 4) ranges from +1.96ϕ at HMB to +2.54ϕ at MLWN, indicating the coarser nature of the mid-shore sediment. The range of quartile deviation from 0.18ϕ at MHWS to 0.36ϕ at MLWN indicates moderately good sorting, becoming progressively worse towards low water. Quartile skewness is small, ranging from −0.06ϕ at HMB to −0.01ϕ at MLWN, and indicating that the coarser particles, especial at HMB, are slightly less well sorted than the finer particles.

Baylys Beach (35° 57′ S, 173° 45′ E) is an open, WSW-facing surf beach exposed to the Tasman Sea. The beach slopes evenly and gently through 180.2 m, and the firm golden sand consists mainly of quartz with some dark hornblende and augite and a little mica; the beach is backed by red cliffs.

Median diameter of the substrate (Table 1, Fig. 5) ranges from +2.23ϕ at MLWN to +2.50ϕ at HMB, indicating fine sand over the entire beach. The range of quartile deviation from 0.18ϕ at LMB to 0.27ϕ at MHWS is predictably small and indicates good sorting on this open beach. Quartile skewness is also very small, ranging from −0.01ϕ at MLWN to +0.02ϕ at MHWS.

Ninety Mile Beach at Waipapakauri (35° 03′ S, 173° 10′ E) is another open, WSW-facing surf beach exposed to the full fetch of the Tasman Sea. The beach slopes gently, with no obvious berm, through 163.8 m, and the fine golden sand consists of mainly quartz, and small amounts of hornblende, augite, and mica.

Median diameter of the substrate (Table 1, Fig. 6) ranges from +2.52ϕ at MLWN to 2.87ϕ at MHWS, indicating that finer wind-blown particles are deposited high on the beach. The range of quartile deviation from 0.14ϕ at LMB to 0.18ϕ at HMB is very small between the first and third quartiles, indicating almost perfect sorting of the fine sand over the whole beach. Quartile skewness is very small and much the same at all stations on the transect, ranging from −0.01ϕ at HMB, LMB, and MLWS to −0.04ϕ at MHWS.

Ti Bay at Paihia (35° 17′ S, 174° 05′ E) is a NE-facing protected beach with shelter provided by Russell Peninsula and the inshore islands, but exposed from the NNE to the Pacific. The short beach slopes steeply through 49.1 m, and the reddish sand consists of quartz discoloured with limonite.

Median diameter of the substrate (Table 1, Fig. 7) ranges from $+1.08\phi$ at MHWS to 3.25ϕ at MLWN, indicating coarse to medium sand high on the beach and very fine sand at low water. The range of quartile deviation, from 0.14ϕ at MLWN to 0.59ϕ at LMB, is high and the sediments on this sheltered beach are poorly worked from LMB to MHWS. Quartile skewness ranges from -0.07ϕ at MLWN to $+0.07\phi$ at MWHS indicating that the smaller particles are better sorted at low water, and the larger particles at high water.

Pakiri Beach (36° 20′ S, 174° 44′ E) is an open, NE-facing surf beach, fully exposed to the Pacific with minimal protection afforded by Great and Little Barrier Islands. The beach slopes through 77.2 m with a marked berm, and the white sand consists mainly of clear quartz, with small quantities of feldspar, magnetite, and red garnet.

Median diameter of the beach substrate samples (Table 1, Fig. 8) ranges from $+1.37\phi$ at HMB to $+2.06\phi$ at MHWS, indicating a small range of medium to fine sand. The range of quartile deviation, from 0.32ϕ at MLWN to 0.46ϕ at HMB, is quite small, but there is a moderate spread of particle size. Quartile skewness ranges from -0.01ϕ at MLWN to $+0.04\phi$ at HMB, indicating poor sorting of the smaller particles low and high on the beach, but better sorting of the larger particles near the berm.

Long Bay (36° 41′ S, 174° 45′ E) faces east into Hauraki Gulf; Great and Little Barrier Islands and Coromandel Peninsula afford limited protection. The beach slopes gently through 139.0 m from the beach head of pines, flanked by cliffs; the finest sand mixed with pine litter occurs at the top of the beach, with coarser sand and shell just below the surface at the other stations. The sand is mainly weathered sandstone fragments, with shell and some limestone.

Median diameter of the substrate (Table 1, Fig. 9) ranges from $+2.37\phi$ at LMB to $+2.87\phi$ at MHWS indicating fine sand over the whole beach. The range of quartile deviation from 0.29ϕ at MHWS to 0.43ϕ at MLWN indicates somewhat better sorting of particles at the top of the beach. Quartile skewness is very small and ranges from -0.03ϕ at MLWN to $+0.04\phi$ at LMB; perfectly equal sorting of fine and coarse particles occur at both MHWS and HMB.

Cheltenham Beach (36° 49′ S, 174° 49′ E) is a NE-facing beach completely sheltered from the Pacific by Rangitoto and other islands close inshore. The beach was the longest sampled, sloping very gently from HMB through 317.7 m, with much standing water. The sand is similar in composition to that at Long Bay.

Median diameter of the substrate (Table 1, Fig. 10) ranges from -0.60ϕ at HMB to $+2.69\phi$ at MLWN, indicating a wide range of sand from very coarse to fine. The range of quartile deviation from 0.25ϕ at HMB to 0.64ϕ at MLWN is high, with a wide range of particles at low water. Quartile skewness is moderate and ranges from -0.03ϕ at HMB to $+0.04\phi$ at LMB.

Mount Maunganui Beach (37° 38′ S, 176° 11′ E) faces NE and gains limited shelter from the Pacific by small islands in the western region of the Bay of Plenty. The beach slopes gently through 72.6 m, and the pale coloured sand consists of weathered pumice fragments, silica, and some magnetite. Live tuatuas *Paphies subtriangulata* (Gray) are much in evidence, as are broken gastropod shells, probably *Zethalia zelandica,* Hombron & Jacquinot.

Median diameter of the substrate (Table 1, Fig. 11) ranges from $+1.87\phi$ at HMB to $+2.46\phi$ at MHWS, indicating medium to fine sand over the whole beach. The range of quartile deviation from 0.29ϕ at MHWS and LMB to 0.66ϕ at HMB indicates reasonable sorting over most of the beach, with poorer sorting at LMB. Quartile skewness ranges from -0.60ϕ at HMB and LMB to $+0.04\phi$ at MHWS, indicating that smaller particles on the middle and lower beach and the larger particles high on the beach are better sorted.

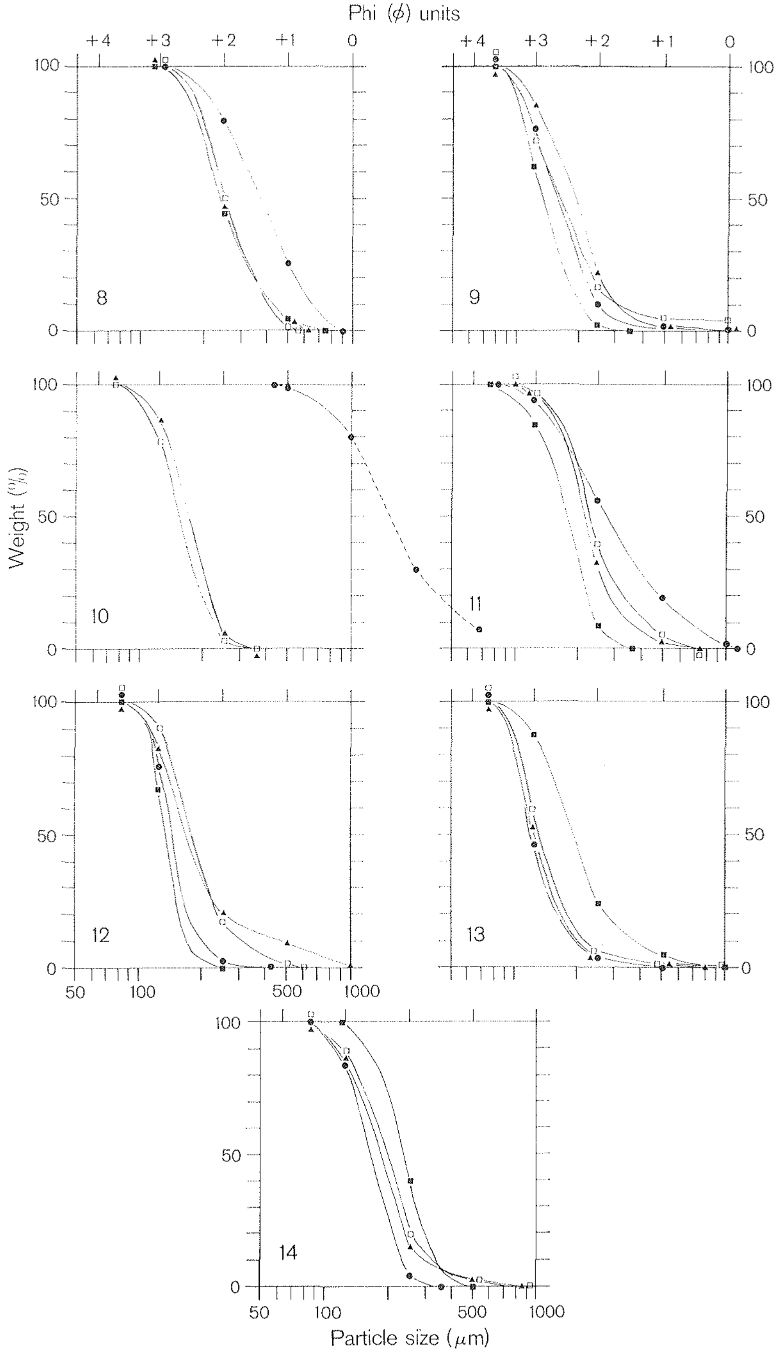
Ohope Beach (37° 58′ S, 177° 03′ E) faces NNE and is fully exposed. The beach slopes gently through 144.5 m, and the clear sand consists of fine quartz and a little mica.

Median diameter of the substrate (Table 1, Fig. 12) ranges from 2.46ϕ at MLWN to $+2.90\phi$ at MHWS, indicating fine sand over the whole beach, and a gradual decrease in particle size from low to high water. The range of quartile deviation from 0.17ϕ at MHWS to 0.37ϕ at LMB is small and, predictably, indicates reasonable sorting on this open beach. Quartile skewness is small and ranges from $+0.02\phi$ at MHWS to -0.60ϕ at LMB; perfectly equal sorting of fine and coarse particles occurs at MLWN.

Westshore Beach at Napier (39° 29′ S, 176° 53′ E) faces WNW and is relatively protected by Napier Bluff. The beach was the shortest sampled and slopes steeply through 39.6 m. The grey, well-drained sand consists of river sediment, weathered limestone, and small quantities of hornblende and epidote.

OPPOSITE

FIGS 8–14—Cumulative curves of sand particles analysed from stations at MHWS (mean high water springs; solid square symbols), HMB (high mid beach; solid circle symbols), LMB (low mid beach; solid triangle symbols), and MLWN (mean low water neaps; open square symbols) on seven of the fourteen beaches sampled, North Island, New Zealand, March 1972–November 1972: 8–Pakiri Beach; 9–Long Bay; 10–Cheltenham Beach; 11–Mount Maunganui Beach; 12–Ohope Beach; 13–Westshore Beach, Napier; 14–Castlepoint Beach.


Phi (ϕ) units
+4
+3
+2
+1
0
100
50
0
8
9
10
11
12
13
14
Weight (%)
50
100
500
1000
Particle size (μm)

Median diameter of the substrate (Table 1, Fig. 13) ranges from $+2.37\phi$ at MHWS to $+3.06\phi$ at HMB, indicating fine to very fine sand. The range of quartile deviation, from 0.23ϕ at HMB to 0.36ϕ at MHWS, is small, indicating moderately good sorting over the whole beach. Quartile skewness ranges from $+0.01\phi$ at MHWS to -0.05ϕ at HMB, showing a tendency for the smaller particles to be better sorted on the middle and low beach.

Castlepoint Beach (40° 54′ S, 176° 13′ E) faces NW, and the transect sampled was fully exposed. The beach slopes through 59.4 m and is backed by shifting sand dunes. The eastern arm of the beach is formed by a fossiliferous limestone bluff on which the lighthouse stands. The sand is derived mainly from limestone but also contains a small amount of mica.

Median diameter of the substrate (Table 1, Fig. 14) ranges from $+2.10\phi$ at MHWS to $+2.62\phi$ at HMB, indicating similar fine sand over the entire beach. The range of quartile deviation, from 0.26ϕ at MHWS to 0.35ϕ at LMB, is small, indicating moderate sorting over the whole transect. Quartile skewness ranges from -0.01ϕ at HMB to $+0.07\phi$ at MLWN and indicates that the larger particles are generally better sorted than the smaller ones.

PERACARID FAUNA

Abundance: Peracarida were recorded on all beaches sampled, but there was a wide range of abundance per square metre (Table 2), from an average of 8 at Onaero Beach to 484 at Baylys Beach (720 at HMB). Densities of over 200 per square metre are found on beaches ranging in exposure from fully exposed (Baylys Beach) to completely sheltered (Cheltenham Beach). In vertical distribution, highest average numbers per square metre for the 14 beaches were recorded from the lowest (MLWN) station (303); lowest average numbers were recorded at the MHWS station (75), with 114 at LMB, and 137 at HMB.

The beaches with the highest average numbers of amphipods per square metre were Lyall Bay (192), Paraparaumu Beach and Ti Bay, Paihia (both 168), and Long Bay (164); none were recorded on Onaero Beach. Amphipods were most abundant at the MLWN stations, with an average of 208 per square metre for the 14 beaches. There is a decline towards the top of the beach with 31 per square metre at MHWS. Highest numbers per square metre were recorded for the phoxocephalids *Waitangi chelatus* (Cooper, 1974) with 608 at MLWN on the protected beach at Ti Bay, Paihia, closely followed by *W. brevirostris* Fincham, 1977 with 528, again at MLWN, on Baylys Beach. Small numbers per square metre of two species of oedicerotid were found on four beaches: *Patuki breviuropodus* Cooper & Fincham 1974 on the exposed Ninety Mile Beach at Waipapakauri, on Pakiri Beach and on Ohope Beach, all at MLWN in numbers ranging from 64 to 80; and an undescribed new oedicerotid occurred on sheltered Cheltenham Beach at LMB and MLWN (16 and 32 respectively). The haustoriid *Urothöe elizae* Cooper

& Fincham, 1974 was found only at these same stations on Cheltenham Beach (at 80 and 320 per square metre respectively). *Talorchestia quoyana* (Milne Edwards) was present at the HMB and MHWS stations on most of the open beaches, with its greatest abundance per square metre in Lyall Bay at HMB (256).

The highest average numbers of isopods per square metre were on Baylys Beach (384) and in Lyall Bay (112). Greatest abundance per square metre was at HMB, with an average of 83 for the 14 beaches; the lowest density was at MLWN (21). Highest numbers per square metre were recorded on the open Baylys Beach with 720 and 656 *Pseudaega punctata* Thomson at HMB and LMB respectively. High numbers (304 per square metre) of *Isocladus armatus* (Milne Edwards) occurred at MHWS on sheltered Cheltenham Beach, and of the scyphacid *Actaecia euchroa* Dana (272 per square metre) at HMB in exposed Lyall Bay. *Scyphax ornatus* Dana reached its maximum density of 112 per square metre at MHWS at Long Bay, and *Macrochiridothea uncinata* Hurley & Murray was present on all west coast beaches sampled; its maximum density was 80 per square metre at LMB at Paraparaumu Beach.

Cumaceans were present on most east coast beaches sampled and occurred with a maximum density of 640 per square metre at MLWN on West Shore, Napier.

Dominance: The overall dominant group was Amphipoda, which formed 54% of the total Peracarida for the survey; Isopoda was the next most dominant group (33%), followed by Cumacea (13%).

The dominant species of amphipods were the phoxocephalids *Waitangi chelatus* and *W. brevirostris* comprising 39% and 24% respectively of the total Amphipoda. The two families Phoxocephalidae and Talitridae comprised over 85% of the amphipods, with the former dominating the middle and low shore and the single species of talitrid, *Talorchestia quoyana* (Milne Edwards), the upper shore.

The dominant isopod species was *Pseudaega punctata*, comprising 58% of the total Isopoda; this species was present from middle to low beach on shores of varying degrees of exposure (except in the extremely sheltered conditions of Cheltenham Beach). The next most dominant isopod, comprising only 14%, was *Actaecia euchroa*, found only in Lyall Bay.

Frequency: Frequency of occurrence on the 14 beaches and at all stations sampled was in the order amphipods (93% and 64% respectively), isopods (79%, 46%) and cumaceans (50%, 20%).

Of the most dominant amphipods, Phoxocephalidae was the most frequently occurring family, present on 79% of the beaches and at 48% of all stations sampled, with *Waitangi chelatus* on 50% and 30% respectively, and *W. brevirostris* on 36% and 16%. *Talorchestia quoyana* was

TABLE 2—Numbers of Peracarida per square metre from a 0.0625 m^2 quadrat at 4 stations on single transects of 14 North Island beaches, sampling begun March 1972 and completed November 1973 (Station 1 = MHWS, mean high water springs; 2 = HMB, high mid beach; 3 = LMB, low mid beach; 4 = MLWN, mean low water neaps; – = none recorded; figures in parentheses = lengths of transects in metres)

	LYALL BAY (49.5 m)				PARAPARAUMU BEACH (72.3 m)				OPUNAKE BEACH (198.0 m)				ONAERO BEACH (57.4 m)				BAYLYS BEACH (180.2 m)			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
AMPHIPODA																				
Patuki breviuropodus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Oedicerotid	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Metaphoxus littoralis	–	–	–	–	–	–	16	16	–	–	16	–	–	–	–	–	–	–	–	–
Waitangi brevirostris	–	–	–	–	–	192	160	112	–	–	–	–	–	–	–	–	–	–	–	528
Waitangi chelatus	16	16	80	368	–	–	–	160	–	–	–	–	–	–	–	–	–	–	–	–
Waitangi rakiura	–	–	–	–	–	–	–	–	–	–	96	112	–	–	–	–	–	–	–	–
Proharpinia sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Urothoe elizae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Talorchestia quoyana	32	256	–	–	16	–	–	–	–	–	–	–	–	–	–	–	16	–	–	–
Total	48	262	80	368	16	192	176	288	–	–	112	112	–	–	–	–	16	–	–	528
CUMACEA																				
Total	–	–	–	32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
ISOPODA																				
Actaecia euchroa	144	272	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pseudaega punctata	–	–	16	16	–	–	–	–	–	–	–	–	–	–	–	16	–	720	656	–
Macrochiridothea uncinata ..	–	–	–	–	–	–	–	80	–	–	–	64	–	–	–	16	–	–	–	16
Scyphax ornatus	–	–	–	–	16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cymodoce sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Exosphaeroma obtusum ..	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Isocladus armatus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	144	272	16	16	16	–	–	80	–	–	–	64	–	–	–	32	–	720	656	16
TOTAL	192	544	96	416	32	192	176	368	–	–	112	176	–	–	–	32	16	720	656	544
Average per transect	312				192				72				8				484			

	NINETY MILE BEACH Waipapakauri (163.8 m)				TI BAY, PAIHIA (49.1 m)				PAKIRI BEACH (77.2 m)				LONG BAY (139.0 m)				CHELTENHAM BEACH (317.7 m)			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
AMPHIPODA																				
Patuki breviuropodus	–	–	–	64	–	–	–	–	–	–	–	80	–	–	–	–	–	–	–	–
Oedicerotid	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16	32
Metaphoxus littoralis	–	–	–	–	–	–	–	–	–	–	16	32	–	–	–	–	–	–	–	–
Waitangi brevirostris	–	–	–	–	–	–	–	–	–	–	–	–	–	96	16	–	–	–	–	–
Waitangi chelatus	–	16	–	16	16	16	32	608	–	–	–	16	–	–	160	256	–	–	–	–
Waitangi rakiura	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Proharpinia sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Urothoe elizae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	80	320
Talorchestia quoyana	–	–	–	–	–	–	–	–	–	–	–	–	128	–	–	–	–	–	–	–
Total	–	16	–	80	16	16	32	608	–	–	16	128	128	96	176	256	–	–	112	352
CUMACEA																				
Total	–	–	–	–	–	16	48	32	–	–	–	–	–	–	16	48	–	48	–	160
ISOPODA																				
Actaecia euchroa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pseudaega punctata	–	64	–	–	–	–	–	16	–	–	16	–	–	96	–	–	–	–	–	–
Macrochiridothea uncinata ..	–	–	–	16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Scyphax ornatus	16	–	–	–	–	–	–	–	32	–	–	–	112	–	–	–	–	–	–	–
Cymodoce sp..	–	–	–	–	–	16	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Exosphaeroma obtusum ..	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16	–	–	–	16	–
Isocladus armatus	–	–	–	–	–	–	32	–	–	–	–	–	–	–	–	–	304	–	–	–
Total	16	64	–	16	–	16	22	16	32	–	16	–	112	96	16	–	304	–	16	–
TOTAL	16	80	–	96	16	48	112	656	32	–	32	128	240	192	208	304	304	48	128	512
Average per transect	48				208				48				236				248			

Table 2 continued on next page

TABLE 2—*continued*

	Mount Maunganui Beach (72.6 m) 1	2	3	4	Ohope Beach (144.5 m) 1	2	3	4	West Shore Beach Napier (29.6 m) 1	2	3	4	Castlepoint (59.4 m) 1	2	3	4
AMPHIPODA																
Patuki breviuropodus	–	–	–	–	–	–	–	80	–	–	–	–	–	–	–	–
Oediceroti̇d	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Metaphoxus littoralis	–	–	–	–	–	–	–	16	–	–	–	–	–	–	–	–
Waitangi brevirostris	–	16	–	16	–	–	16	–	–	–	–	–	–	–	–	–
Waitangi chelatus	–	–	–	–	–	–	–	22	–	–	16	48	–	–	–	–
Waitangi rakiura	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Proharpinia sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Urothoe elizae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Talorchestia quoyana	96	–	–	–	–	80	–	–	32	–	–	–	80	–	–	–
Total	96	16	–	16	–	80	16	128	22	–	16	48	80	–	–	–
CUMACEA																
Total	–	–	–	–	–	–	–	80	–	–	–	640	–	–	–	48
ISOPODA																
Actaecia euchroa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pseudaega punctata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	48	–
Macrochiridothea uncinata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	48
Scyphax ornatus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cymodoce sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Exosphaeroma obtusum	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Isocladus armatus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–	–	–	–	–	–	–	–	48	48
TOTAL	96	16	–	16	–	80	16	208	32	–	16	688	80	–	48	96
Average per transect	32				76				184				56			

also present on eight (57%) of the fourteen beaches sampled, at the top of the shore.

The dominant isopod *Pseudaega punctata* was present on 57% of beaches and in 18% of all stations sampled. The next most frequently occurring species was *Macrochiridothea uncinata*, present at MLWN on 43% of beaches and at 11% of all stations sampled.

DISCUSSION

INTERBEACH COMPARISONS

The beaches studied may be grouped into three main types:

1. Open surf beaches, fully exposed to either the Pacific Ocean or the Tasman Sea (Lyall Bay, Opunake Beach, Onaero Beach, Baylys Beach, Ninety Mile Beach, Pakiri Beach, Ohope Beach, and Castlepoint). Their sediments consist of fine, well-sorted sand (average median diameter $+2.44\phi$; quartile deviation 0.27ϕ) with a very slight tendency for the smaller particles to be better sorted (quartile skewness -0.01ϕ). In such unimodal sediments, median diameter relates directly to the energy conditions on the beach of deposition: the greater the exposure, the finer the sediments.

2. Beaches with some measure of protection from bluffs or islands which limit the fetch (Paraparaumu Beach, Long Bay, Mount Maunganui Beach and Westshore). Their sediments consist of fine, quite well-sorted sand (average median diameter $+2.61\phi$; quartile deviation 0.33ϕ) and with a slight tendency for the smaller particles to be better sorted (quartile skewness -0.02ϕ).

3. Sheltered beaches (Ti Bay and Cheltenham Beach). Their sediments consist of particles with a wide range of sizes, but with an average of medium sand (average median diameter $+1.68\phi$), tending towards only moderate sorting (quartile deviation 0.43ϕ) and with large and small particles equally well sorted (quartile skewness 0.0ϕ).

Calcium carbonate from the remains of animals such as molluscs and bryozoans forms an important part of the sediment on some beaches, particularly Cheltenham Beach. This calcarenite fraction tends to be coarse, thereby biassing median diameter, and it is relatively poorly sorted. In the finer, non-biogenic, detrital sands sorting is better than in the calcarenites.

Certain of the peracarid species showed definite preferences for one of these beach types (Table 3). Three species of amphipod (*Patuki breviuropodus*, *Metaphoxus littoralis*, and *Waitangi rakiura*) and the isopod *Actaecia euchroa* all show a preference for open beaches of fine sand, a reasonable degree of sorting, and with a slight negative quartile skewness (i.e., beaches where smaller particles are better sorted than the larger). Other amphipods such as *Proharpinia* sp., an oedicerotid, *Urothöe elizae*, and isopods *Cymodoce* sp. and *Isocladus armatus* definitely prefer sheltered beaches, again of fine sand, but tolerate more poorly sorted sediments. Amphipod species such as *Waitangi chelatus*,

TABLE 3—Species distribution of peracarids correlated with degree of exposure (O = Open; P = Protected; S = Sheltered) vertical range and sediment type (expressed in ϕ units); MHWS sample on Cheltenham beach not included in sediment analysis; – = not applicable)

SPECIES	EXPOSURE AND NO. OF BEACHES			VERTICAL RANGE	ϕ MEDIAN RANGE	DIAMETER AVERAGE	ϕ QUARTILE RANGE	DEVIATION AVERAGE	ϕ QUARTILE RANGE	SKEWNESS AVERAGE
AMPHIPODA										
Patuki breviuropodus	03	–	–	MLWN	+1.98 to +2.52	+2.32	0.16 to 0.33	0.27	−0.10 to 0.0	−0.04
Oedicerotid	–	–	S1	LMB–MLWN	+2.50 to +2·69	+2.59	0.25 to 0.29	0.27	−0.02 to +0.04	+0.01
Metaphoxus littoralis	03	P1	–	LMB–MLWN	+1.98 to +2.79	+2.38	0.24 to 0.34	0.31	−0.10 to 0.0	−0.05
Waitangi brevirostris	02	P3	–	HMB–MLWN	+1.87 to +2.83	+2.46	0.20 to 0.66	0.36	−0.06 to +0.04	−0.03
Waitangi chelatus	04	P3	S1	MHWS–MLWN	+1.08 to +3.25	+2.48	0.14 to 0.59	0.32	−0.10 to +0.07	−0.01
Waitangi rakiura	01	–	–	LMB–MLWN	+2.21 to +2.27	+2.24	0.24 to 0.24	0.24	+0.01 to +0.01	+0.01
Proharpinia sp.	–	–	S1	LMB	– –	+2.50	– –	0.29	– –	+0.04
Urothoe elizae	–	–	S1	LMB–MLWN	+2.50 to +2.69	+2.59	0.25 to 0.29	0.27	−0.02 to +0.04	+0.01
Talorchestia quoyana	04	P4	–	MHWS–HMB	+2.10 to +2.96	+2.64	0.19 to 0.36	0.25	−0.02 to +0.04	+0.01
CUMACEA	02	P3	S2	HMB–MLWN	−0.60 to +3.25	+2.16	0.14 to 0.64	0.38	−0.07 to +0.07	0.0
ISOPODA										
Actaecia euchroa	01	–	–	MHWS–HMB	+2.94 to +2.96	+2.95	0.19 to 0.22	0.20	−0.02 to +0.03	0.0
Pseudaega punctata	06	P1	S1	HMB–MLWN	+2.04 to +3.25	+2.61	0.14 to 0.37	0.27	−0.08 to +0.02	−0.01
Macrochiridothea uncinata	05	–	S1	MLWN	+2.23 to +2.79	+2.44	0.16 to 0.36	0.26	−0.06 to +0.07	0.0
Scyphax ornatus	02	P2	–	MHWS	+2.06 to +2.87	+2.66	0.17 to 0.35	0.25	−0.08 to 0.0	−0.03
Cymodoce sp.	–	–	S1	HMB	– –	+1.17	– –	0.56	– –	+0.06
Exosphaeroma obtusum	–	P1	S1	LMB	+2.37 to +2.50	+2.43	0.29 to 0.37	0.33	+0.04 to +0.04	+0.04
Isocladus armatus	–	–	S2	MHWS–LMB	– –	+2.27	– –	0.37	– –	+0.04

the cumaceans as a group, and the isopods *Pseudaega punctata* and *Macrochiridothea uncinata* all tolerate a wide range of exposure but, with the exception of the cumaceans, have a tendency to prefer open beaches. The amphipods *Waitangi brevirostris* and *Talorchesia quoyana* and the isopod *Scyphax ornatus* are almost equally divided in their distribution between both open and protected beaches.

COMPARISON WITH OTHER BEACH STUDIES

MacIntyre (1963) classified *Actaecia euchroa* as a sediment 'modifier', which constructs burrows in the sand, but he did not find the species in North Island. Morton & Miller (1968) record it from a transect at Muriwai Beach, Auckland west coast, and in the present survey it was recorded at Lyall Bay.

An interesting distribution is shown by the idotheid isopod *Macrochiridothea uncinata,* occurring on all west coast beaches sampled, but absent from all east coast beaches except Castlepoint. Although similar physical conditions of exposure and sediment occur in the north-east of North Island, this species may have been excluded on physiological grounds from these warmer waters of the Aupourian marine province, which is delineated by a boundary from East Cape on the east coast of North Island to a point between Ahipara and Kaipara Heads on the west coast (Powell 1961). The species may also have encountered a complex physical barrier at Cape Reinga. There are two currents off northernmost New Zealand, both of which stream south: the East Auckland Current off the east coast and the West Auckland Current off the west coast.

Summerhayes (1969) suggested, however, that the direction of longshore drift round northernmost New Zealand conflicts with the coastal current pattern. The southward streaming of the West Auckland Current is in fact well off shore and does not prevent the northward longshore drift which prevails on the west coast of North Island north of Mount Egmont. This movement of sediment northwards is supported by the distribution of heavy minerals (Summerhayes 1969). Here then is a possible means of extending the largely Forsterian and Cookian province distribution of *Macrochiridothea uncinata* into the Aupourian province, and yet successful colonisation does not occur. However, a similar counter-current drift exists off the north-east coast of New Zealand, and the meeting of these east and west coast drifts at Cape Reinga may prevent free movement from one coast to the other. Looking at the quantitative distribution of heavy minerals such as hornblende and pyroxine (Summerhayes 1969) it is possible to plot vectors representing transport directions. The concentration and movement of those minerals, away from the coast northwestwards from Cape Reinga and Cape Maria van Diemen, suggests that this is an effective, if highly localised, physical barrier to coastal migration.

Two more of MacIntyre's (1963) 'modifiers' are the talitrid amphipod *Talorchestia quoyana* and the oniscid isopod *Scyphax ornatus*. Both are nocturnal scavengers and are widely distributed on open and protected beaches around the MHWS tidal level. These species and *Actaecia euchroa* are used by Morton & Miller (1968) as representative species of crustaceans inhabiting the upper beach.

The mid beach is dominated by the aegiid isopod *Pseudaega punctata* and the phoxocephalid amphipods such as *Waitangi brevirostris* and *W. chelatus*. Morton & Miller (1968) state that compared with the Haustoriidae the Phoxocephalidae are "somewhat the more numerous on New Zealand beaches". In the light of the present survey this is wholly endorsed. Dominance in the equivalent niche in the northern hemisphere by the family Haustoriidae, with only a small number of species of Phoxocephalidae, is entirely reversed on New Zealand beaches. The morphological distinctions between these two closely related families is rather tenuous, however, and Fincham (1974a) suggested that the families should be merged.

Peracarids of the low beach include the phoxocephalid amphipods *Metaphoxus littoralis, Waitangi rakiura, Proharpinia* sp., and the haustoriid *Urothöe elizae,* and the idotheid isopod *Macrochiridothea uncinata* and the sphaeromatid isopods *Exosphaeroma obtusum* and *Isocladus armatus.*

When these results are compared with those of a similar survey of five Stewart Island beaches (Fincham 1974a), several important differences are apparent. Overall abundance is greater by a factor of 18 on the Stewart Island beaches than on North Island beaches. One can only speculate why this should be so. Although there was, not unexpectedly, a wider range of median diameter of sediment on the 14 North Island beaches, there was generally better sorting and a smaller range of skewness. The lowest average number of peracarids per transect for Stewart Island (272) was considerably higher than the lowest for the North Island beaches sampled (8 on Onaero Beach). The black ironsands containing titanomagnetite from the andesitic rocks of the Taranaki area (Buckenham 1965) support only very low to medium numbers of peracarids (average of 72 per transect on Opunake Beach). Only two species of amphipod and two species of isopod were found; *Macrochiridothea uncinata* was present on both Onaero and Opunake Beaches. The extreme heat of the surface layers on a sunny summer day at low tide would certainly exclude all but the most efficient burrowers from these beaches. In a short paper, Wood (1963) described the distribution of macrofauna on an ironsand beach at Marakopa, 32 km (20 miles) south of Kawhia on the west coast of North Island. He recorded two isopods *Scyphax ornatus* and *Pseudaega punctata,* and three amphipods: *Talorchestia* sp., and two un-named haustoriids 'A' and 'B'. On the basis of the present and a previous survey (Fincham 1974a), both these species are in fact probably phoxocephalids.

Amphipoda replaced Cumacea as the most abundant peracaridan group of North Island beaches compared with those of Stewart Island, and amphipods retained the position of the most frequently occurring group.

BIOGEOGRAPHY

In his study of the algae-dwelling littoral Gammaridea of New Zealand, Barnard (1972) emphasised the importance of the isolated biotopes of polar and tropical waters as centres of evolutionary diversity. As he pointed out, Amphipoda are unusual in lacking a larval dispersive phase; they also show a high degree of diversity in boreal regions.

Sandwiched between tropical and polar waters of known evolutionary potentiality, warm-temperate latitudes are subject to strong immigration pressures, especially in the Northern Hemisphere. When a warm-temperate region, such as part of New Zealand, does not have direct shallow water contact with tropical or cold-temperate zones, then a high degree of endemism may occur. This is apparent among the infaunal, sand-dwelling gammaridean amphipods. More than half the species recorded in two surveys (Fincham 1974a, and present study) are apparently endemic and include the oedicerotid *Patuki breviuropodus,* the phoxocephalids *Metaphoxous littoralis, Waitangi brevirostris, W. chelatus,* and *W. rakiura,* and the haustoriid *Urothöe elizae*. The genera *Patuki* and *Waitangi* are also endemic to New Zealand. Although there is no direct shallow water contact with a warm temperate zone either, the nearest being south-west Australia, there is nevertheless much evidence, from Barnard's work, of immigration across the Tasman Sea. Hence until the alpha taxonomy (diagnoses of species and genera) of Australian and New Zealand amphipods is more firmly established, the extent of New Zealand endemism remains speculative.

Barnard confined his study to the east coast of North and South Islands, as indeed has been the case historically. However, in this study, the west coast of North Island has certainly provided some informative distributions of species. Probably the west coast of South Island will prove equally instructive.

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