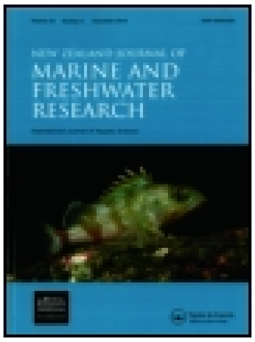

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INTERTIDAL SAND-DWELLING PERACARID FAUNA OF STEWART ISLAND

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ABSTRACT

The distributions of infaunal Peracarida (Crustacea) and their correlation with sediment type, tidal height, and degree of exposure were studied in winter (June) at five beaches on Stewart Island, New Zealand. The beaches were selected to cover a range of exposures to wind and wave action and substrate sorting. Substrate and infauna samples were taken at four tidal levels from each, with a 0.0625 m^2 quadrat.

Sieve separation and statistical analysis of the substrate samples indicated predominantly sand-sized particles from all beaches, with median diameters in the range +1.52 to +2.92 ϕ (phi) units. Substrates were well sorted throughout the size range: ϕ quartile deviation ranged from 0.26 to 0.71, skewness from −0.18 to +0.07 ϕ.

Peracarid fauna was generally abundant, with a maximum of 29 136 per m^2 sampled in a more sheltered beach. Cumacea was the most abundant group, followed by Amphipoda, Isopoda, and Tanaidacea; dominance followed a similar sequence, being 78%, 19%, 2% and 1% respectively. Frequency of occurrence at the 19 stations was headed by Amphipoda (100%), with Isopoda 53%, Cumacea 32% and Tanaidacea 11%.

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Horizontal distribution of the Peracarida is discussed in relation to Dahl's (1953) world-wide tripartite zonation of sandy shores. Results are compared with those of similar studies in New Zealand and Europe, and a similarity to South American faunas is noted.

Three amphipods (two Phoxocephalidae and one Oedicerotidae) and an isopod (*Paravireia* sp.) found in this study are new species and have been described recently. On both anatomical and ecological grounds, the merging of amphipod families Haustoriidae and Phoxocephalidae is suggested.

INTRODUCTION

A more congenial place than Stewart Island in which to study intertidal fauna would be difficult to imagine. The island is roughly triangular in shape, with the area to the north of Paterson Inlet fault line composed of granite. The coastline in this area is indented with bush-fringed bays, which have a variety of sand types derived from the intrusive rock ranging from a pure glassy quartz, through rust-coloured quartz, to dark mixtures of hornblende and quartz. Many of the bays are protected by offshore islets or even smaller nuggets, while others are open fully to the brunt of the prevailing westerlies. Foveaux Strait shares with Cook Strait the distinction of 28 gale days on average per year (Watts 1947), the wind being funnelled through both straits.

The hydrography of the area is influenced by two distinct water masses: Subtropical Water from the branch of the Tasman Current flowing through Foveaux Strait (Southland Current), and cool Subantarctic Water to the east of Stewart Island (Houtman 1966). The sandy shores of Stewart Island, for which no quantitative infaunal studies have been published, provide a rich and virtually undisturbed part of the Forsterian marine province. The strong subantarctic influence in the province has been noted by Powell (1961) for five genera of molluscs, and Brewin (1958) found that 16 species of ascidian were restricted to Stewart Island (10 of them were endemic and two had possibly circum-polar distributions).

The present limited study of five beaches (Fig. 1) was undertaken in order to determine the distribution of infaunal Peracarida and their correlation with sediment type, degree of exposure and tidal heights.

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 four of the five beaches during 3–5 June 1972; no MLWN station was sampled at Ringaringa Beach. A 0.0625 m^2 box quadrat (with sides of 25 cm) was pushed into the sand to a depth of 7.5 cm, and the contents removed and sieved using a 1-mm-mesh sieve. The residue on the sieve was preserved in 4% formalin, and

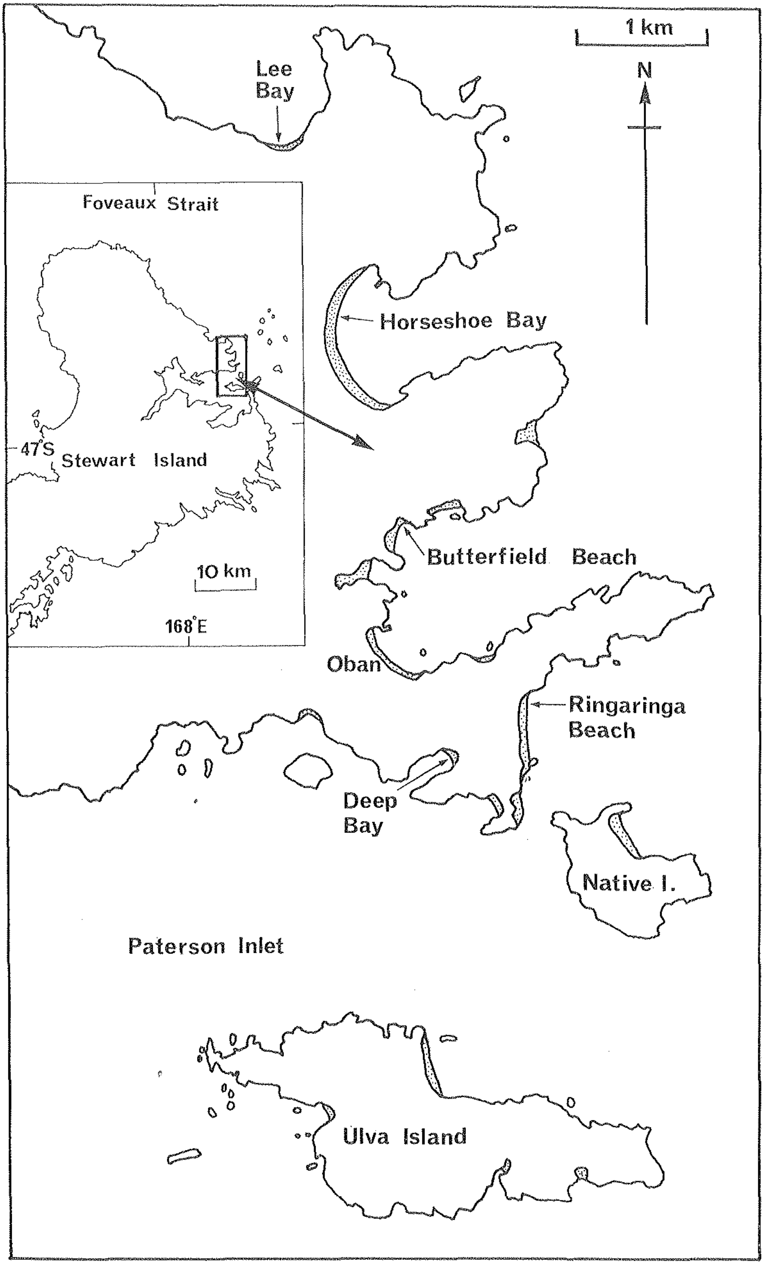

FIG. 1—Sketch map of the five beaches sampled, with arrows indicating the position of transects; stippling denotes sandy beaches. *Inset map* shows the area studied in relation to the rest of Stewart Island.

the amphipods and other small peracarids identified. A sand sample was also taken at each station. This sample was dried at 105°c for 24 h and passed through a series of sieves of 1000, 500, 355, 250, 178, 125, 88 and 63 μm diameter mesh; a mechanical shaker was used for 10 min on each sample. Median diameter, phi (ϕ) quartile deviation, and phi quartile skewness values were calculated for each of the beach stations (Morgans 1956). The tidal height was estimated, and also the degree of exposure of each beach—open, protected, or sheltered.

RESULTS

PHYSICAL CHARACTERISTICS OF THE BEACHES

Lee Bay is an open beach (*see* Morton & Miller 1968) facing north, and receives the full impact of the funnel effect of Foveaux Strait on the prevailing westerlies. The beach slopes gently through 38.7 m from the strand line to MLWN. The sand consists of a mixture of clear glassy and rust-coloured quartz with hornblende. There are no broken shell fragments; a freshwater stream bisects the beach.

Median diameter of the beach substrate samples (Table 1, Fig. 2) ranges from $+2.25\ \phi$ at MLWN to $2.35\ \phi$ at MHWS, indicating a general similarity over the whole beach. The range of quartile deviation from $0.26\ \phi$ at HMB to $0.30\ \phi$ at MLWN and LMB is small, and indicates good sorting on this open beach. Quartile skewness is very small ($-0.03\ \phi$ to $+0.02\phi$), indicating that both the smaller and the larger particles are equally well sorted.

Ringaringa Beach faces east and is protected by Native Island to the south and by Bench Island further offshore (off the map in Fig. 1). The beach is relatively steep, measuring 21.6 m from the strand line to LMB. The sand is a mixture of quartz, hornblende, feldspar, and muscovite; there are shell fragments of both molluscs and foraminiferans.

Substrate median diameter ranges from $+2.88\ \phi$ at LMB to $+1.54\ \phi$ at MHWS, indicating a wide range of sediments on the beach. This is probably a reflection of recent quarrying further to the south on the beach, giving rise to a disturbance in sediment sorting; the range of quartile deviation from $0.37\ \phi$ at MHWS to $0.66\ \phi$ at HMB does indicate poorer sorting than at Lee Bay. Quartile skewness is very small, ranging from $-0.03\ \phi$ at LMB and MHWS to $+0.01\ \phi$ at HMB.

Horseshoe Bay is deeply indented between rocky headlands, and these provide protection except to the east. The beach is quite steep at the north end, measuring 32.4 m from strand line to MLWN. The grey-coloured sand is a mixture of white and clear glassy quartz with a small amount of hornblende and epidote. There is a little broken shell at the low water station.

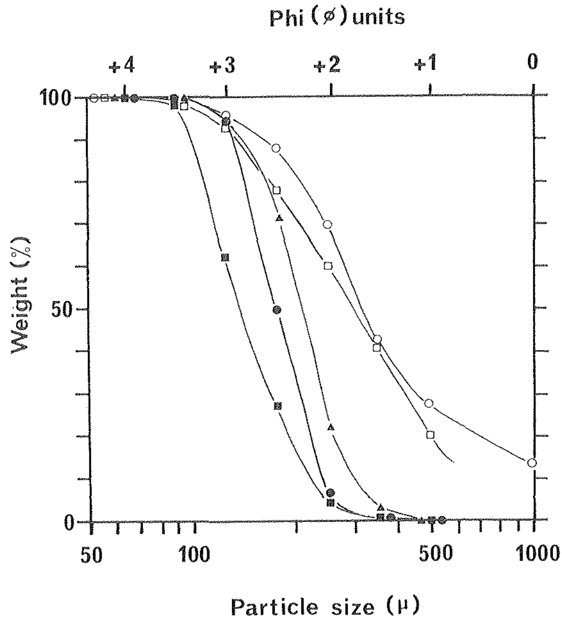

FIG. 2—Cumulative curves of sand particle analysis at the high mid-beach (HMB) station on each of the five beaches on Stewart Island. ■: Horseshoe Bay; ●: Butterfield Beach; ▲: Lee Bay; □: Ringaringa Beach; ○: Deep Bay. (Particle size: $1\mu = 1\mu$m.)

Substrate median diameter ranges from $+2.92\ \phi$ at LMB to $+2.52\ \phi$ at MHWS, indicating a fine sand type over the whole beach. The range of quartile deviation from $0.31\ \phi$ at MHWS to $0.43\ \phi$ at MLWN indicates generally good sorting. Quartile skewness is very small, and ranges from $0.00\ \phi$ at MHWS to $-0.09\ \phi$ at MLWN and LMB.

Butterfield Beach is a small protected inlet on the northern headland of Horseshoe Bay. The beach slopes gently through 40.5 m from the strand line to MLWN. The golden-coloured sand consists of a mixture of quartz coloured with limonite, some clear quartz, and a small amount of hornblende. Shell fragments are in evidence, particularly high on the beach.

Substrate median diameter ranges from $+2.35\ \phi$ at MHWS to $+2.50\ \phi$ at HMB, indicating a general similarity of sand type over the whole beach. The range of quartile deviation from $0.27\ \phi$ at HMB to $0.30\ \phi$ at MLWN is low, and indicative of good sorting. The range of quartile skewness from $+0.04\ \phi$ at MHWS to $-0.03\ \phi$ at MLWN is very small, showing that there was little difference in sorting between the smaller and larger particles.

TABLE 1—Cumulative curve derivatives for the analysis of particle size (phi units) of sand from five Stewart Island beaches (listed in order of decreasing exposure to wind and wave action)

Station (position on shore)	Median Diameter	Quartile Deviation	Quartile Skewness
Lee Bay			
1 MHWS	+2.35	0.27	+0.02
2 HMB	+2.27	0.26	+0.01
3 LMB	+2.27	0.30	−0.01
4 MLWN	+2.25	0.30	−0.03
Ringaringa Beach			
1 MHWS	+1.54	0.37	−0.03
2 HMB	+1.75	0.66	+0.01
3 LMB	+2.88	0.38	−0.03
Horseshoe Bay			
1 MHWS	+2.52	0.31	0.00
2 HMB	+2.85	0.34	−0.04
3 LMB	+2.92	0.38	−0.09
4 MLWN	+2.85	0.43	−0.09
Butterfield Beach			
1 MHWS	+2.35	0.26	+0.04
2 HMB	+2.50	0.27	0.00
3 LMB	+2.38	0.28	−0.01
4 MLWN	+2.42	0.30	−0.03
Deep Bay			
1 MHWS	+1.42	0.43	−0.08
2 HMB	+1.67	0.64	−0.18
3 LMB	+1.52	0.71	−0.17
4 MLWN	+2.42	0.45	+0.07

Deep Bay is a deeply indented, narrow inlet which is completely sheltered, facing south-west into Paterson Inlet. The beach slopes very gently but unevenly through 70.2 m from the strand line to MLWN. There are patches of *Zostera* on the low shore, indicating an admixture of mud. The sand consists mainly of coarse glassy quartz with some hornblende; there is a small amount of shell fragments.

Substrate median diameter ranges from $+2.42\ \phi$ at MLWN to $+1.42\ \phi$ at MHWS, indicating a wide range of sediments present on the beach. The range of quartile deviation from $0.43\ \phi$ at MHWS to $0.71\ \phi$ at LMB indicates a generally poorer sorting of sediments compared with the other beaches surveyed. This is a direct effect of the completely sheltered nature of the bay resulting in limited wave action. The bay also has the greatest range of quartile skewness, from $+0.07\ \phi$ at MLWN to $-0.18\ \phi$ at HMB, demonstrating that the larger particles are less well sorted than the smaller particles.

THE PERACARID FAUNA

ABUNDANCE

The most striking result of this study is the general abundance of Peracarida, and of Cumacea in particular. Butterfield Beach had the most abundant peracarid fauna, with 29 136 per m^2 (Table 2); the MLWN station on the Horseshoe Bay transect also was high at 20 720 per m^2.

Average abundance on the five beaches sampled varied from 7404 per m^2 on Butterfield Beach to 272 per m^2 at Lee Bay; the highest densities of Peracarida are thus present on the protected beaches, the lowest in more exposed situations. However, the very sheltered conditions in Deep Bay resulted in a lowering of numbers to an average of 548 per m^2. In vertical distribution, highest average numbers for the five beaches were recorded from the lowest (MLWN) station (12 792 per m^2); lowest average numbers were recorded at the LMB station (256 per m^2), with 394 per m^2 at MHWS and 355 per m^2 at HMB.

The beaches with the highest average numbers of amphipods per station were Butterfield and Horseshoe (876 and 844 per m^2 respectively), with the relatively exposed Lee Bay having the lowest of 216 per m^2 (Fig. 3). Amphipods were more abundant at either the MLWN or MHWS stations, with averages for the five beaches of MLWN 1868 per m^2 and MHWS 394 per m^2. Highest numbers were recorded for the oedicerotid *Patuki breviuropodus* Cooper & Fincham (1974) at MLWN on the protected beaches of Butterfield with 2992 per m^2 and Horseshoe with 2400 per m^2. The phoxocephalid *Paraphoxus chelatus* Cooper was the next most abundant amphipod. Again, greatest abundance was recorded at the MLWN stations, with the highest density of 864 per m^2 occurring on the sheltered Deep Bay beach, where there were no oedicerotids present.

High numbers of *Talorchestia quoyana* (Milne-Edwards) were recorded at MHWS (1216 per m^2 Ringaringa Beach; 304 per m^2 Lee Bay) on the more exposed locations. Relatively few were taken from the protected beaches, e.g., 32 per m^2 at MHWS in Horseshoe Bay.

The highest average numbers of isopods per station were in Horseshoe Bay (180 per m^2) and Deep Bay (128 per m^2). Greatest abundance was at HMB, with an average of 221 per m^2 for the five beaches; none were recorded above HMB. Highest numbers were recorded on the sheltered and protected beaches at HMB, with 432 per m^2 *Paravireia pistus* Jansen (1973) in Deep Bay and the same density of *Pseudaega punctata* Thomson in Horseshoe Bay. The unusual *Macrochiridothea uncinata* Hurley & Murray (1968) attains its maximum density of 96 per m^2 at MLWS in Horseshoe Bay, but is also found in smaller numbers on the low shore in the more exposed Lee Bay (Table 2).

The tanaidacean *Tanais novaezealandiae* Thomson occurred only in the sheltered conditions afforded by Deep Bay, reaching greatest abundance at LMB with 144 per m^2 (Table 2).

Cumaceans were present on only two beaches, but abundance recorded at the MLWN stations was the highest throughout the survey (25 808 per m^2 Butterfield Beach; 17 568 per m^2 Horseshoe Bay).

TABLE 2—Numbers of Peracarida per m² from a 0.0625 m² quadrat at each station sampled on single transects of five Stewart Island beaches, June 1972 (Station 1=MHWS, 2=HMB, 3=LMB, 4=MLWN; –=none recorded; figures in parentheses=lengths of transects in metres)

	Lee Bay (38.7)				Ringaringa Beach (21.6)			Horseshoe Bay (32.4)				Butterfield Beach (40.5)				Deep Bay (70.2)			
	1	2	3	4	1	2	3	1	2	3	4	1	2	3	4	1	2	3	4
AMPHIPODA																			
Platyischnopus neozelandicus	–	–	–	16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Parawaldeckia thomsoni	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16
Patuki breviuropodus	–	–	–	–	–	–	–	–	–	16	2400	–	–	32	2992	–	–	–	–
Metaphoxus littoralis	–	32	16	–	–	64	64	–	–	–	–	–	16	32	–	–	–	–	–
Paraphoxus australis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	48	176	16
Paraphoxus chelatus	–	–	–	80	–	–	–	16	192	96	624	–	–	–	272	–	–	–	864
Paraphoxus rakiura	–	288	16	112	–	–	16	–	–	–	–	–	–	–	–	–	–	–	–
Proharpina arenata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	80
Talorchestia quoyana	304	–	–	–	1216	–	–	32	–	–	–	160	–	–	–	240	–	–	–
Total	304	320	32	208	1216	64	80	48	192	112	3024	160	16	64	3264	240	48	176	976
CUMACEA																			
Total	–	–	–	–	–	–	–	–	16	176	17568	–	16	240	25808	–	–	–	–
ISOPODA																			
Macrochiridothea uncinata	–	–	16	32	–	–	–	–	–	–	96	–	–	–	–	–	–	–	–
Pseudaega punctata	–	144	16	–	–	–	64	–	432	80	32	–	–	–	64	–	–	–	–
Isocladus armatus	–	16	–	–	–	–	–	–	16	64	–	–	–	–	–	–	64	16	–
Paravireia pistus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	432	–	–
Total	–	160	32	32	–	–	64	–	448	144	128	–	–	–	64	–	496	16	–
TANAIDACEA																			
Tanais novaezealandiae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	144	96
Total	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	144	96
TOTAL	304	480	64	240	1216	64	144	48	656	432	20720	160	32	304	29136	240	544	336	1072
Average/transect	272				475			5464				7408				548			

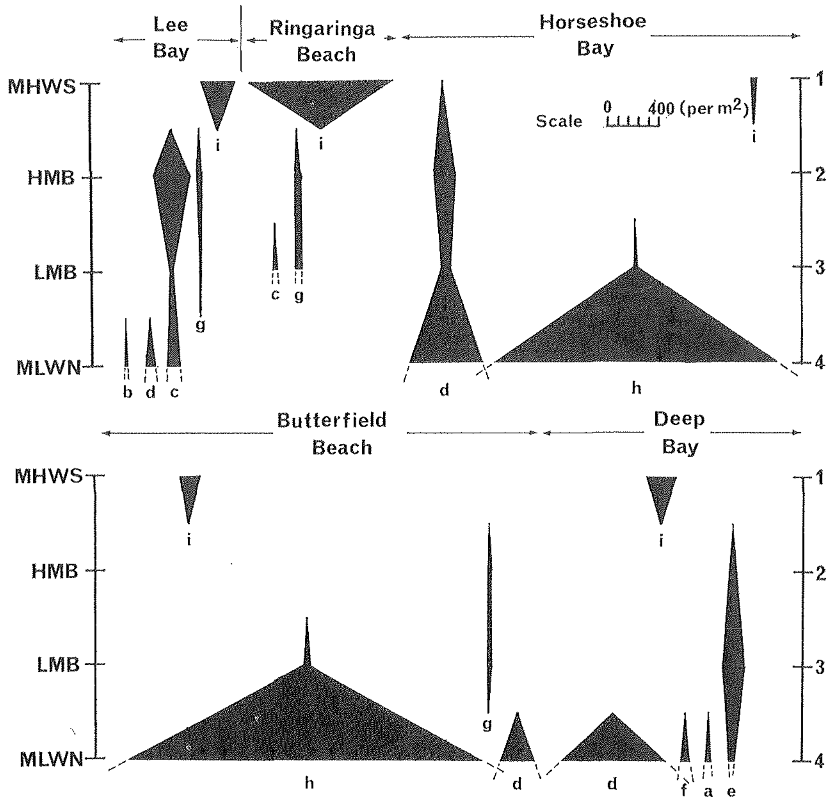

FIG. 3—Distribution of Amphipoda as numbers per m² for transects sampled on five Stewart Island beaches in June 1972. MHWS: mean high water springs; HMB: high mid-beach; LMB: low mid-beach; MLWN: mean low water neaps. a: *Parawaldeckia thomsoni*; b: *Platyischnopus neozelandicus*; c: *Paraphoxus rakiura*; d: *P. chelatus*; e: *P. australis*; f: *Proharpinia arenata*; g: *Metaphoxus littoralis*; h: *Patuki breviuropodus*; i: *Talorchestia quoyana*.

DOMINANCE

The overall dominant group was Cumacea, which formed 78% of the total Peracarida for the survey, in spite of being present on only two of the five beaches (Table 2). Amphipoda was the next most dominant group (19%), followed by Isopoda (2%), both being present on all beaches sampled. Tanaidacea formed only 0.4% of the total.

The dominant amphipod species was the oedicerotid *Patuki breviuropodus* comprising 41% of the total Amphipoda, followed by the phoxocephalid *Paraphoxus chelatus* (20%). The three families Oedicerotidae, Phoxocephalidae, and Talitridae comprised over 80% of the amphipods, with the first two families dominating the lower and middle shores and the last dominating the upper shore with the single species *Talorchestia quoyana*.

The dominant isopod species was *Pseudaega punctata* comprising 53% of the total Isopoda; this species predominated on all beaches except sheltered Deep Bay. The next most dominant isopod, comprising 27%, was the newly described species *Paravireia pistus*, which occurred only in the sheltered conditions of Deep Bay.

FREQUENCY

Frequency of occurrences at the stations sampled was in the order Amphipoda (100%), Isopoda (53%), Cumacea (32%) and Tanaidacea (11%).

Looking at the Amphipoda in more detail, *Talorchestia quoyana* was present at all the MHWS stations on the beaches surveyed. Phoxocephalidae was the next most frequently occurring family, with *Paraphoxus chelatus* present in 37%, *Paraphoxus rakiura* Cooper & Fincham (1974) in 21%, *P. australis* (K. H. Barnard) in 16% and *Metaphoxus littoralis* Cooper & Fincham (1974) in 32% of all stations. The oedicerotid *Patuki breviuropodus* occurred in 21% of all stations, and the remaining species were present at only one station.

The isopod *Pseudaega punctata* was present on four of the five beaches sampled, and occurred in 37% of all stations. *Isocladus armatus* (Milne-Edwards) was present in 26% of stations sampled.

DISCUSSION

The five beaches sampled on Stewart Island, all less than 5.25 km apart, showed a remarkable diversity in the fauna recorded. The abundance of the Peracarida, and of Cumacea in particular, on the protected beaches of Horseshoe Bay and Butterfield Beach contrasts with the relative paucity of the fauna on the more exposed Lee Bay. The success of the infauna undoubtedly depends on the physical characteristics of these beaches: protection from heavy seas by offshore islands, nuggets and prominent headlands, but with sufficient wave action to allow sorting of the sand particles.

Comparisons of the sand analyses for the MLWN stations of Horseshoe Bay and Butterfield Beach show a high degree of similarity. It is these sand characteristics, together with the low position on the shore and the protected nature of the beaches, that in combination have provided the physical framework in which the fauna has been able to attain densities approaching a biological 'limit' for the macrofauna in the intertidal zone; much higher densities are achieved in offshore grounds (J. K. Lowry, Canterbury University pers. comm.). The maximum figures obtained from Stewart Island compare favourably with the highest densities quoted by MacIntyre & Eleftheriou (1968), who attempted to correlate their findings from Loch Ewe on the west coast of Scotland with the results of previous workers: of Watkin (1942) in Kames Bay in the Clyde, a sheltered environment with a rich infauna; and of Colman & Segrove (1955) at Stoupe Beck Sands on the Yorkshire coast, an exposed environment with a relatively poor fauna. They found that Firemore Bay in Loch Ewe was intermediate both in abundance and diversity. Results from Port Erin, Isle of Man (Fincham 1971) were closely parallel to those for Firemore Bay, but certain indicator species showed closer affinities with the more sheltered faunal assemblage at Kames Bay.

Classifying shores by such comparisons has not proved easy within the confines of the British Isles; the task is made even more difficult when comparisons with faunas from the Southern Hemisphere are made. However, using Dahl's (1953) world-wide zonation pattern proposed for sandy shores, basic similarities begin to emerge. Caution has to be exercised when using Dahl's three horizontal zones: subterrestrial fringe (talitrid belt), midlittoral zone (*Cirolana* belt) and sublittoral zone (haustoriid, phoxocephalid, and oedicerotid belt). Dahl points out some variations to the midlittoral zone pattern in Western Europe, where haustoriids frequently co-occur with cirolanids (*see also* Colman & Segrove 1955, MacIntyre & Eleftheriou 1968, Fincham 1971). This co-occurrence is not unique to Western Europe; Wood (1963) reports that on Marakopa beach on the exposed west coast of North Island, New Zealand, an haustoriid was present in the midlittoral zone with the cirolanid *Pseudaega punctata*. This, also, was the situation on Stewart Island beaches (Table 2), with phoxocephalids co-occurring with *Pseudaega punctata*. The sublittoral fringe was dominated by the families Oedicerotidae (represented by a newly described genus, *Patuki*) and Phoxocephalidae (five species recorded, two of them new). These new species—*Patuki breviuropodus*, *Paraphoxus rakiura*, and *Metaphoxus littoralis*—have been described recently (Cooper & Fincham 1974).

Dahl found that the haustoriid amphipods, which predominate on the lower shore of European beaches, were replaced by oedicerotids and phoxocephalids in Chile. This would appear to be a widespread ecological replacement in the southern hemisphere; only one haustoriid, *Platyischnopus neozelandicus* Chilton, appeared at MLWN on the exposed beach at Lee Bay. Wood (1963) concluded from his comparison of open and estuarine beaches that "haustoriid amphipods are present in the sublittoral fringe on open beaches while phoxocephalids are present in this zone only in the more sheltered, muddy beaches". However, on many of the Stewart Island beaches studied phoxocephalids were present in non-muddy conditions.

The distinction between Haustoriidae and Phoxocephalidae is quite tenuous; the artificial taxonomic division on the size of the rostrum and shape of peraeopod 5 bears little relation to the situation on the shore. The species belonging to these two groups are too closely related to merit division into two families; it is apparent that a single family should be erected to contain both the Haustoriidae and Phoxocephalidae. Barnard (1969) ruefully states: "With some genera, one must flip a coin to choose the proper family."

The newly described isopod species *Paravireia pistus* was abundant in the sheltered conditions of Deep Bay, and this species fills the cirolanid niche of Dahl's midlittoral belt. *Pseudaega punctata* fills this niche on the other four beaches.

It is interesting to note that the isopod *Isocladus armatus* ranges from exposed (Lee Bay) to sheltered (Deep Bay) habitats, but with higher densities on the more sheltered beaches. This supports the conclusions by Jansen (1971) in his study of the Kaikoura peninsula, South Island, New Zealand. He found also that vertical distribution varied, and that "centres of concentration . . . rise with increasing exposure"; 64 per m^2 were recorded from the LMB station in sheltered Deep Bay, whereas the same density was recorded at the HMB station in the relatively more exposed Horseshoe Bay.

The chaetilinid *Macrochiridothea uncinata* was recorded on the exposed beach at Lee Bay (46° 61′ S) and the protected beach at Horseshoe Bay (46° 65′ S); these records extend both the previous known geographical range for New Zealand and the substrate type. Hurley & Murray (1968) recorded the species only from North Island, and determined that 60–70% of the sand particles were between 0.251 and 0.125 mm in diameter. In Lee Bay the figures were 66–67%, but on Horseshoe Beach only 47% of the sediment was in this range, although it was still the dominant fraction. The sub-family Chaetilinae is of biogeographical interest because of its distribution, which is limited to the southern hemisphere. The genus *Macrochiridothea* has been recorded only from the Falkland Islands, southern Chile (Magellan Straits and Tierra del Fuego), and in New Zealand.

Kite diagrams (Fig. 3) are used here to show the distribution of peracarids, but Fish (1970) has shown that this is a dangerous simplification when dealing with such mobile organisms. Her work on the intertidal cirolanid *Eurydice pulchra* showed that distribution varied on a seasonal, lunar, and even on a daily basis; similar variability in the distribution of isopods (Jansen 1971) and amphipods (Fincham 1970) has also been recorded.

Stewart Island, of which there is "still too little known" (Morton & Miller 1968), offers to the student of intertidal ecology a variety of fauna and unspoiled habitat that is unique, because it straddles both sub-antarctic and subtropical water masses. Our understanding of faunal abundance, diversity, and biogeography will undoubtedly be advanced by further studies there.

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