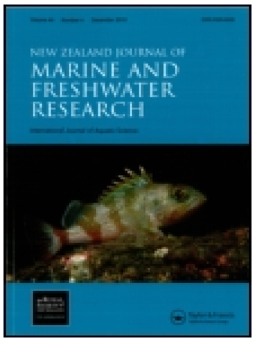

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Short communication

Distribution of meiobenthic copepods from various habitats in Pauatahanui Inlet, New Zealand

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Abstract The composition of meiobenthic copepod assemblages at two locations in Pauatahanui Inlet was determined for different substrata. In Ration Creek the density of copepods tended to increase from the creekside (which is covered with sea rush), to the bare mud of the creek bed. *Brianola* sp., though abundant, was restricted to the creek bed. On Mana Bank, which is an intertidal fine silty sand bank partially covered with eelgrass, *Zostera capricorni*, and the green alga *Enteromorpha* spp., there was little resemblance between the copepod assemblages at seven sites. The sediments of Mana Bank can apparently support a variety of copepod assemblages as a result of the increased spatial heterogeneity caused by vegetation and tidal exposure.

Keywords Pauatahanui Inlet; New Zealand; Copepoda; meiobenthos; estuary

INTRODUCTION

Meiobenthic copepod assemblages in estuaries have been shown to be affected by the nature of the substratum. For example, the high density of harpacticoid copepods in a low *Spartina* marsh in the eastern United States is supported by increased spatial heterogeneity, resulting from vegetation and the limited exposure to tidal action (Coull et al. 1979).

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The present study aimed to investigate if this principle applied also to the composition of the meiobenthic copepod communities of several different substrata in Pauatahanui Inlet, a shallow estuary on the west coast of the North Island, New Zealand. In Pauatahanui Inlet the meiobenthic copepods, especially *Parastenhelia megarostrum*, have been extensively studied (Hicks 1989). *P. megarostrum* plays a key role in the Inlet, because the density and production are very high and the species is extensively preyed upon by young flatfish.

MATERIALS AND METHODS

Pauatahanui Inlet is located 20 km north of Wellington, New Zealand (Fig. 1). Tidal flats and banks occupy about one quarter of the area of the Inlet (Healy 1980). Samples were collected from different substrata at Ration Point beach, Ration Creek, Mana beach, and Mana Bank (Table 1).

Ration Point beach (Stn 1) and Mana beach (Stn 10) are sandy beaches, the former containing more silt than the latter. Ration Creek flows across a saltmarsh at the eastern end of the Inlet. Clumps of sea rush, *Juncus maritimus*, form a dense cover in the marsh. Samples were taken along a transect across the creek from vegetated mud in the marsh on each side to bare mud in the creek bed. Mana Bank is an intertidal fine silty sand bank partially covered with eelgrass, *Zostera capricorni*, and the green alga *Enteromorpha* spp. Samples were collected from intertidal vegetated and bare sand and from subtidal sediments of the adjacent main drainage channel of the Inlet.

Sediment samples were collected to the depth of the redox layer (usually < 5–6 cm) by hand coring with a core tube of 23 mm internal diameter (4.15 cm^2). Single samples and duplicate samples were collected at Stns 1–14 and Stns 15–17, respectively. As a reference sample, copepods were collected from *Z. capricorni* by clipping blades at the base of the blade sheaths. Each sample was washed into a plastic bag with 10% formalin containing Rose Bengal stain. All sampling was at low tide in July 1989. In the

Table 1 Summary of single samples collected from Pauatahanui Inlet, New Zealand. Only at the last three sites were two samples collected (*).

Location	Station	Substrate
Ration Point	1	Sandy beach
Ration Creek (right bank)	2	Vegetated (*Juncus*) mud
	3	Bare mud between *Juncus* mud and creek
	4	Muddy creek bottom, 10 cm deep
	5	Muddy creek bottom, 50 cm deep
Ration Creek (left bank)	6	*Juncus* mud
	7	Bare mud between *Juncus* mud and creek
	8	Muddy creek bottom, 10 cm deep
	9	Muddy creek bottom, 50 cm deep
Mana beach	10	Sandy beach
Mana Bank	11	Intertidal bare sand by *Enteromorpha* bed
	12	Intertidal sand beneath *Enteromorpha*
	13	Intertidal bare sand by *Zostera* bed
	14	Intertidal sand beneath *Zostera*
	15	Intertidal sand beneath *Zostera* (dense *Zostera* bed)*
	16	Intertidal sand beneath *Zostera* (sparse *Zostera* bed)*
	17	Subtidal sandy bottom, 10 cm deep*

Table 2 Abundance (no. per 10 cm^2) and dominance (%) of meiofauna in Pauatahanui Inlet, New Zealand. The values at Stns 15, 16, and 17 are the average of two samples collected (*).

	Nematoda		Copepoda		Turbellaria		Kinorhyncha		Others		
Station	No.	%	No.	%	No.	%	No.	%	No.	%	Total
1	310.8	86.0	7.2	2.0	38.6	10.7			4.8	1.3	361.4
2	1156.5	97.8	9.6	0.8	2.4	0.2			14.5	1.2	1183.1
3	1122.9	89.8	19.3	1.5			21.7	1.7	86.7	6.9	1250.6
4	221.7	35.9	284.3	46.1	2.4	0.4	33.7	5.5	74.7	12.1	616.9
5	850.6	52.8	689.2	42.8	33.7	2.1			36.1	2.2	1609.6
6	1356.6	90.1	9.6	0.6	24.1	1.6	72.3	4.8	43.4	2.9	1506.0
7	303.6	71.6	55.4	13.1	7.2	1.7			57.8	13.6	424.1
8	612.0	71.1	178.3	20.7			19.3	2.2	50.6	5.9	860.2
9	547.0	57.2	339.8	35.5	4.8	0.5	36.1	3.8	28.9	3.0	956.6
10	901.2	97.1	19.3	2.1					7.2	0.8	927.7
11	1686.7	96.4	21.7	1.2	4.8	0.3	21.7	1.2	14.5	0.8	1749.4
12	214.5	68.5	50.6	16.2	14.5	4.6			33.7	10.8	313.3
13	219.3	70.0	53.0	16.9	14.5	4.6	4.8	1.5	21.7	6.9	313.3
14	272.3	92.6	7.2	2.4	9.6	3.3	2.4	0.8	2.4	0.8	294.0
15*	1401.2	95.9	21.7	1.5	14.5	1.0			24.1	1.6	1461.5
16*	2218.1	96.5	2.4	0.1	65.1	2.8			12.0	0.5	2297.6
17*	3134.9	94.3	131.4	4.0	19.3	0.6			37.3	1.1	3322.9

laboratory, each sample was filtered through a 63 μm sieve and the fauna in entire samples enumerated. Only Copepoda were identified to species level (although some species were new and remain as yet undescribed) based on Wells (1976) and Wells et al. (1982).

The data from each station were subjected to cluster analysis using the group-average method with Whittaker's percentage similarity (Whittaker 1952) as the similarity measure. Species diversity, H', and measurement of evenness, J', were calculated (Shannon & Weaver 1949; Pielou 1966).

RESULTS

Total meiofauna

The density of total meiofauna (expressed per 10 cm^2 surface: Table 2) ranged from 294 (Stn 14) to 3323 (Stn 17). Nematoda and Copepoda were the main constituents at all stations, accounting for 82–99% of the meiofauna. Nematoda was the most abundant group, at 35.9–97.8% of the total number. Copepoda accounted for 0.1–46.1% of the total number. Nematodes dominated at all stations except Stn 4, though their margin of dominance was small at Stn 5. Copepods dominated only at Stns 4–5 but comprised a significant proportion of the total fauna at Stns 7–9, 12, and 13.

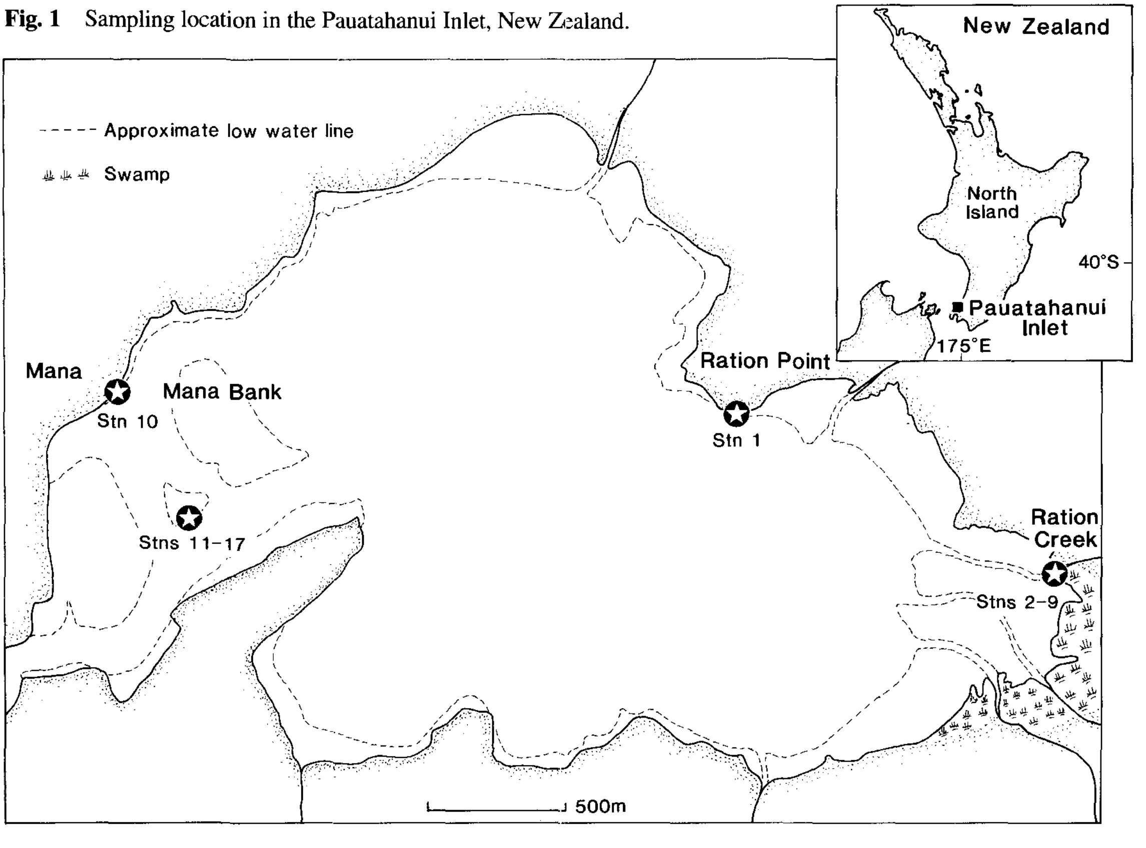
The density of Nematoda was very high at the edge and, particularly, on the bottom of the main drainage channel (Stns 16–17). Although Copepoda also were numerous at Stn 17, in general they were most dense at locations where Nematoda were less abundant.

Copepoda

A total of 899 specimens were captured. Of these, 877 were identified to 15 species in 13 genera, the remainder being unidentifiable copepodites. All species expect *Halicyclops* sp. belonged to the order Harpacticoida. The most abundant species are listed in Tables 3 and 4.

In Ration Point, Stn 1, only two species, *Brianola* sp. and *Halectinosoma hydrofuge*, occurred and the density of copepods was 7.2 per 10 cm^2 (Table 2 and 3). On the Ration Creek transect, Stns 2–9, the density of copepods ranged from 9.6 to 689.2 per 10 cm^2, with a tendency to increase from the bank to the bed of the creek (Table 2). Eight species were identified from this area (Table 3). The distribution patterns for the three abundant species, which together comprised 95.3% of the copepods from the transect, are shown in Fig. 2. The two most abundant species, *Brianola* sp. and *Miscegenus heretaunga*, were present only in the bed of the creek. *Stenhelia* sp. was the sole species on the creek banks. As few species were

Fig. 1 Sampling location in the Pauatahanui Inlet, New Zealand.



found in the banks of the creek, the values of H' were low (average 0.20 ± 0.35); they were moderately high in the creek bed stations (average 0.91 ± 0.20), but values of J' were below 0.54 as *Brianola* sp. comprised 71.0–90.2% of the copepod fauna.

In the Mana samples, Stns 10–17, the density of copepods ranged from 2.4 to 131.3 per 10 cm^2 (Table 2), being highest in the subtidal (Stn 17), and intermediate in the *Enteromorpha* bed (Stn 12) and in sand adjacent to *Zostera* (Stn 13). Eleven species were identified from this area (Table 4). The distribution patterns for the three most abundant species, which together comprised 82.0% of the copepods, are given in Fig. 3. The pattern for each

Table 3 Abundance (no. per 10 cm^2), number of species (S) and values of H' and J' of meiofaunal copepods at Ration Point beach and Ration Creek, Pauatahanui Inlet, New Zealand.

	1	2	3	4	5	6	7	8	9
	Ration Point beach	Right bank				Left bank			
		Juncus mud	Bare mud	10 cm depth	50 cm depth	*Juncus* mud	Bare mud	10 cm depth	50 cm depth
Brianola sp.	4.8			200.0	616.9			147.0	267.5
Miscegenus heretaunga				69.9	33.7			24.1	31.3
Stenhelia sp.			19.3		19.3		55.4	7.2	9.6
Halectinosoma hydrofuge	2.4	7.2							24.1
Halicyclops sp.				4.8	4.8				7.2
Enhydrosoma variabile				7.2		4.8			
Halectinosoma otakoua					9.6				
Robertsonia propinqua		2.4							
Total	7.2	9.6	19.3	281.9	684.3	4.8	55.4	178.3	339.7
S	2	2	1	4	5	1	1	3	5
H'	0.92	0.81	0	1.09	0.63	0	0	0.81	1.12
J'	0.92	0.81	–	0.54	0.27	–	–	0.51	0.48

Table 4 Abundance (no. per 10 cm^2), number of species (S) and values of H' and J' of meiofaunal copepods at Mana beach and Mana Bank, Pauatahanui Inlet, New Zealand. These values at Stns 15, 16 and 17 are the average of two samples collected (*).

	10	11	12	13	14	15*	16*	17*
	Beach	Bare sand	*Ent.* bed	Bare sand	*Zostera* bed			Subtidal bottom
						Dense	Sparse	
Parastenhelia megarostrum				2.4		6.0		114.5
Miscegenus heretaunga			21.7	24.1		3.6		
Robertsonia propinqua	2.4		24.1	4.8		2.4	1.2	
Halectinosoma hydrofuge		14.5	2.4	4.8	4.8	2.4		
Stenhelia sp.	7.2	7.2				1.2		
Paralaophonte sp.	2.4		2.4	7.2		1.2		
Quinquelaophonte candelabrum	7.2			2.4				
Halicyclops sp.				2.4	2.4			3.6
Enhydrosoma variabile						1.2		1.2
Halectinosoma otakoua						1.2		
Paralaophante aenigmaticum						1.2		
Total	19.3	21.7	50.6	48.2	7.2	20.5	1.2	119.3
S	4	2	4	7	2	5.5	0.5	2.5
H'	1.81	0.97	1.45	2.22	0.92	2.08	0.00	0.25
J'	0.91	0.97	0.73	0.79	0.92	0.92	–	0.19

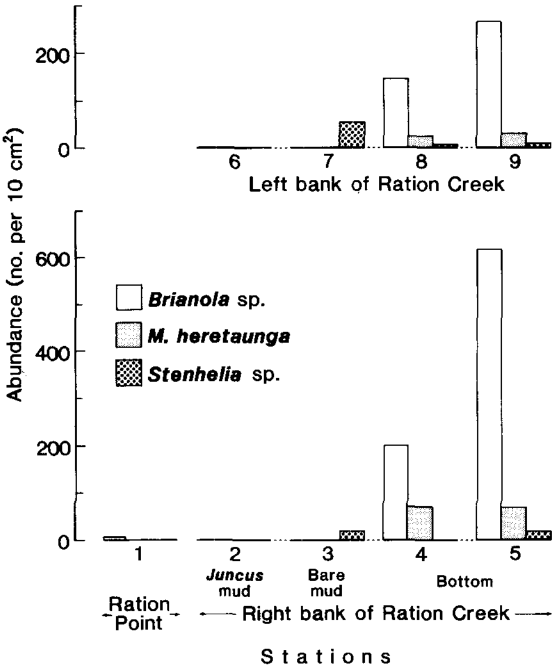


Fig. 2 Abundance of dominant copepod species at Ration Point beach and Ration Creek, Pauatahanui Inlet, New Zealand.

station was different except for Stns 11 and 14, where only two species occurred and *H. hydrofuge* dominated. The most abundant species, *P. megarostrum*, was present in large numbers in the bed of the drainage channel (Stn 17) but relatively rare elsewhere. The three species that dominated the intertidal, *M. heretaunga*, *Robertsonia propinqua*, and *H. hydrofuge*, were not present in the subtidal. The largest H' was found in the bare sand by the *Zostera* bed (Stn 13); the smallest H' in the samples from sand poorly colonised by *Zostera* (Stn 16).

Apart from one individual of *M. heretaunga*, the copepod fauna of the *Zostera* blades comprised species not present in the sediment samples. This sparse fauna was dominated by *Harpacticus* sp., with a few individuals of *Porcellidium* sp. and *Mesochra* sp.

The overall distribution observed throughout the sample array can be characterised as follows.

1. The most abundant species, *Brianola* sp. and *P. megarostrum*, were common in subtidal mud of Ration Creek and sand of Mana Bank, respectively.
2. *M. heretaunga*, *H. hydrofuge*, and *Stenhelia* sp. were widely distributed and relatively abundant on several substrata.
3. *R. propinqua* was primarily associated with vegetated sediments.

The result from cluster analysis is shown in Fig. 4. Only two clusters are apparent at similarity index level 80. The first comprises creek bed stations (Stns 4, 5, 8, 9) and is brought about by the dominance of *Brianola* sp. and *M. heretaunga* which make up 87% of the copepod fauna. The second cluster is a homogenous group clustering at the 100 level and composed of two stations (Stns 3, 7) in bare mud on the banks of Ration Creek where the sole copepod was *Stenhelia* sp.

DISCUSSION

The density of copepods in Mana Bank is significantly higher in subtidal than intertidal sediments (Table 5). This extends the observation by Hicks (1984) that the highest densities of *P. megarostrum* occurred in intertidal sediments on Mana Bank. Hicks also found that the species was more abundant in the troughs of the sediment ripples, compared to the crest, and postulated that this resulted from selective accumulation of organic detritus in the troughs. Thus

Table 5 Comparison of mean densities between difference substrata using which t-test and Kruskal-Willis analysis of variance of ranks. *, $P < 0.05$; NS, no significant differences.

	Density per 10 cm^2	No. of samples	
Mana Bank			
Intertidal *vs* subtidal			*
Intertidal site	22.6 ± 20.9	8	
Subtidal site	131.4 ± 49.4	2	
Vegetated *vs* bare			NS
Vegetated site	17.7 ± 20.0	6	
Bare site	37.4 ± 22.1	2	
Dense *vs* sparse			NS
Dense *Zostera* bed	21.7 ± 17.0	2	
Sparse *Zostera* bed	2.4 ± 3.4	2	
Ration Creek			
Vegetated *vs* bare *vs* bottom			*
Juncus mud	9.6 ± 0	2	
Bare mud	37.4 ± 25.5	2	
Creek bottom	372.9 ±221.3	4	
Between vegetated sites			NS
Enteromorpha bed	50.6	1	
Zostera bed	11.1 ± 13.1	5	
Juncus mud	9.6 ± 0	2	

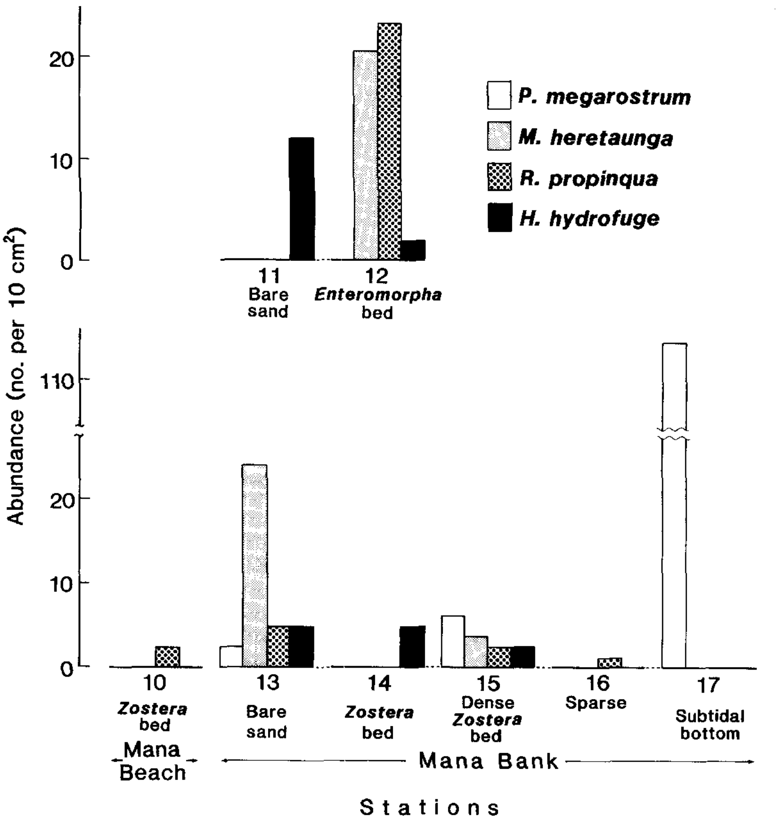


Fig. 3 Abundance of dominant copepod species at Mana beach and Mana Bank, Pauatahanui Inlet, New Zealand.

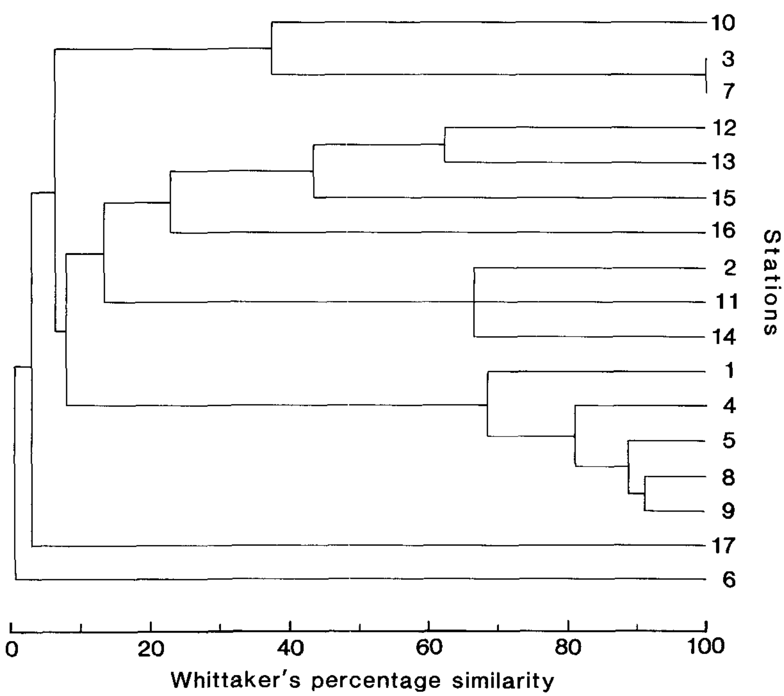


Fig. 4 Cluster dendrogram of similarity of species composition between stations in Pauatahanui Inlet, New Zealand.

the presence of ripples considerably enhanced the spatial heterogeneity of the habitat, in this instance subtidal sand. The presence of vegetation and the ebb and flow of the tide similarly increase spatial heterogeneity of the estuarine intertidal by supplying increased habitable space and refuges (Bell et al. 1978; Coull et al. 1979; Hicks 1986) and thus allow an increased density of meiobenthic copepods.

It was anticipated that copepod densities would be higher in vegetated than bare sediments and higher in the dense *Zostera* bed than in the sparse *Zostera* bed. This study shows, however, no significant differences between vegetated and bare sediments nor between dense and sparse *Zostera* beds (Table 5). Although the small number of samples prohibits conclusive statements, the study does show a significant difference between intertidal and subtidal sites. Further, the raw data show the highest densities to be in the seemingly unstructured mud of Ration Creek. So, simple observations of differences in surface structure cannot always be correlated with copepod distribution patterns.

By contrast, the cluster analysis indicates that although the stations on Mana Bank were only a few metres apart, there was little resemblance between their copepod assemblages. This suggests that the vegetation and tidal exposure pattern of Mana Bank radically influences spatial heterogeneity, and thus copepod distribution, abundance, and community diversity, on a relatively small scale of distance. Moreover, there were marked differences in copepod assemblages at Mana Bank and Ration Creek, with *P. megarostrum* and *Brianola* sp. dominating, respectively.

Five species—*Brianola* sp., *M. heretaunga*, *P. megarostrum*, *Halicyclops* sp., and *Halectinosoma otakoua*—show an apparent preference for submerged sediments or for sites with limited tidal exposure. *R. propinqua* is associated with vegetated sediments in this study. This is similar to its distribution in low *Spartina* marsh in the eastern United States (Coull et al. 1979). It seems that the preferences for grain size of two dominant species, *Brianola* sp. and *P. megarostrum*, were different; the former preferring mud, the later preferring fine sand.

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REFERENCES

Bell, S. S.; Watzin, M. C.; Coull, B. C. 1978: Biogenic structure and its effect on the spatial heterogeneity of meiofauna in a salt marsh. *Journal of experimental marine biology and ecology 35*: 99–107.

Coull, B. C.; Bell, S. S.; Savory, A. M.; Dudley, B. W. 1979: Zonation of meiobenthic copepods in a southeastern United States salt marsh. *Estuarine and coastal marine science 9*: 181–188.

Healy, W. B. 1980: Pauatahanui Inlet—an environmental study. *DSIR information series 141*, 197 p.

Hicks, G. R. F. 1984: Spatio-temporal dynamics of a meiobenthic copepod and the impact of predation-disturbance. *Journal of experimental marine biology and ecology 81*: 47–72.

Hicks, G. R. F. 1986: Distribution and behavior of meiofaunal copepods inside and outside seagrass beds. *Marine ecology progress series 31*: 159–170.

Hicks, G. R. F. 1989: Meiofauna of Mana Bank, Pauatahanui Inlet: a review. *In*: Water resource impact assessments, pp. 20–32. Wellington Regional Council, *Technical report 8*.

Pielou, E. C. 1966: The measurement of diversity in different types of biological collection. *Journal of theoretical biology 13*: 131–144.

Shannon, C. E.; Weaver, W. 1949: The mathematical theory of communication. University of Illinois Press, Urbana, 125 p.

Whittaker, R. H. 1952: A study of summer foliage insect communities in the Great Smoky Mountains. *Ecological monographs 22*: 1–44.

Wells, J. B. J. 1976: Key to aid in the identification of marine harpacticoid copepods. Department of Zoology, University of Aberdeen. 215 p.

Wells, J. B. J.; Hicks, G. R. F.; Coull, B. C. 1982: Common harpacticoid copepods from New Zealand harbours and estuaries. *New Zealand journal of zoology 9*: 151–184.