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DISTRIBUTION OF THE NEW ZEALAND COCKLE, *CHIONE STUTCHBURYI*, AT PAUATAHANUI INLET

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ABSTRACT

Sampling at one low tide from 515 stations at Pauatahanui Inlet showed that *Chione stutchburyi* occupies all available soft substrates at an average density of 577 m $^{-2}$. Densities and recruitment are patchy but significant differences in population density do exist. There are differences in the distribution of epibionts between two areas within the inlet.

INTRODUCTION

Chione stutchburyi dominates the mudflats of Pauatahanui Inlet (Estcourt and Grange 1976) and, as part of the Pauatahanui Environmental Programme, a census of the species was made at low water on one day, November 30, 1976. This census provided information on the distribution, density and population structure of *C. stutchburyi* and on the occurrence of epibionts. It also provided a framework and reference point for sampling in succeeding periods.

METHOD

The area sampled and the lettering and numbering system used to define sections and transects are shown in Fig. 1. Each transect ran from high water mark to the water's edge and one transect from sections B, C, D and E was extended subtidally. Subtidal samples were also taken from transects crossing offshore sand shoals within the inlet.

Intertidal samples were taken at 20 m intervals along transect lines using sampling shovels (*see* Fig. 2) to remove a layer of substrate, 7 cm in depth and 0.1 m^2 in area, which was retained in a labelled cheese cloth bag. A sediment profile to an approximate depth of 30 cm was also taken at each station to establish the presence of any layers of dead shells.

Subtidal samples were collected from extensions of the shore transects B5, C4, D7 and L1 (the latter being an extension from an area midway between the last intertidal stations sampled at E7 and E8). Transect L3 was also exclusively subtidal while L2 , L4 and L5 included some intertidal stations on the sand shoals which they intersected (L2) or from which they originated (L4, L5). The transects L1 and L2 differed from the extended transects of B, C and D because a channel deeper than 2 m separates the area designated E from offshore sand shoals. Divers used garden spades to take samples and the amount collected at each station only roughly approximated an area of 0.1 m^2.

Mean low for spring tides is calculated at a height of 0.5 feet (150 mm) above datum (Hydrographic Branch, Royal New Zealand Navy 1969). Tide height at low water on November 30, 1976 was 0.5 m; consequently stations at the lower end of the range were below water and are included in records of the subtidal transects extending from the last intertidal stations sampled at B5, C4 and D7 (Appendix 2). Divers took samples along these transects until at least three stations in succession were found without specimens of *C. stutchburyi.*

The labels from 52 of the 515 stations sampled were unidentifiable and these samples were discarded. All specimens of *C. stutchburyi* contained in identifiable samples were measured for maximum length (antero-posterior axis). The presence on the shell of the anemone *Anthopleura aureoradiata*, the spionid worm *Boccardia acus*, the barnacle *Elminius modestus*, the limpet *Notoacmea helmsi*, and the algae *Ulva lactuca* and *Gracilaria secundata* was noted. The presence of brood capsules of an unidentified turbellarian was also recorded.

The data obtained from intertidal collections were statistically analysed. Collections from transects incorporating subtidal samples were not included in the analyses because of the difficulty of removing precise segments of substrate subtidally in the time available.

DISTRIBUTION

The distribution of *C. stutchburyi* is recorded separately for the intertidal transects (Table 1 and Appendix 1), for the subtidal transects L1 and L3 and for the predominately subtidal transects L2, L4, L5 (Appendix 2).

Chione stutchburyi was almost invariably absent from the first and second stations of each transect with only 39 of the 73 high water mark stations containing

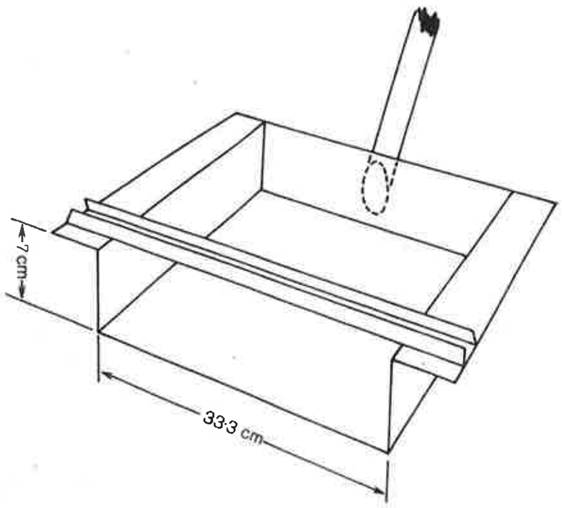


Fig. 2. The shovel used to remove layers of substrate of constant size.

specimens. The only other samples without specimens occurred along the transects A28, A29 and B5.

Thus, with the exception of 34 stations near high water and 8 stations from transects A28, A29 and B5, *C. stutchburyi* occupied all areas of the inlet sampled. Sediments occupied ranged from coarse sand to silt and only those areas composed of, or with a large component of, gravel were devoid of specimens. K.R. Grange (pers. comm.) has analysed the sediments derived from his sampling programme for all intertidal invertebrates in Pauatahanui Inlet and notes that these range from a mean grain size of 0.054 mm (coarse silt) to 0.5 mm (coarse sand) and that *C. stutchburyi* was found at all stations sampled by him.

The species was found to occur from high water mark to a distance of 340 m along transect B5, 700 m along transect C4 and 140 m along transect D7, the final samples being taken in depths of approximately 2 m.

DENSITY

Density was patchy in all areas of the inlet sampled. The maximum measured density of 280 specimens per 0.1 m² was at station C5-11, with stations either side containing 66 specimens (C5-10) and 34 specimens (C5-12) (Appendix 1).

A station was defined as being 0.1 m² in area and inhabited by *C. stutchburyi*; this definition excluded stations of different area (subtidal stations), and zero density (unsuitable substrate). Station and area data are summarised in Table 1. The mean density of *C. stutchburyi* in Pauatahanui Inlet was 58 per station (± 9 per station generates a 99% confidence interval for the mean).

Total numbers of *C. stutchburyi* for the inlet can be estimated by multiplying the average number per station by the area of the inlet inhabited by the species. The tidal flats occupy approximately 1 km², an area equivalent to 10 million stations. Therefore, the total mean estimate is 577 million, ignoring any error associated with calculating the inhabited area.

Densities were compared for areas A, B, C, and D, which are similar physiographically, having a gradual offshore slope. Area E was excluded because of its high slope variability as degree of slope and related time of submergence could influence density. However, the division of transects into groups with the same numbers of stations provided a measure of beach slope and of submergence time. Plots of mean density and associated 95% confidence intervals for groups of transects with 3, 4, 5, 6, and 7 stations are shown in Fig. 3. Analyses of variance on groups of transects with 3, 4, and 5 stations show areas A and D are significantly different from B and C indicating that one of the factors affecting density is area difference.

SIZE

A positive correlation between size and period of immersion has been shown for the European cockle *Cardium edule* (Hancock and Simpson 1962) and for *C. stutchburyi* in a number of localities from Whangateau Harbour to Otago Harbour (Larcombe 1971). The gradient in the mean size of specimens from high to low water is evident also in specimens from Pauatahanui Inlet. The average adult size of specimens from high water is 18 mm and that of specimens from the lowest intertidal station (C5-11) is 26 mm. Specimens with the

Table 1. Intertidal area and station summary.

Area	Number of transects	Total stations	Number missing	Number unsuitable substrate	Number with zero count	Total inhabited stations	Total Chione count
A	25	129	18	17	5	89	2,571
B	12	57	3	0	3	51	4,088
C	18	114	3	1	2	108	7,782
		22*	4	0	0	18	488
D	12	35	1	8	2	24	884
E	8	47	5	0	0	42	3,088
TOTAL	75	404	34	26	12	332	18,901

* Stations 0·05 m² in area

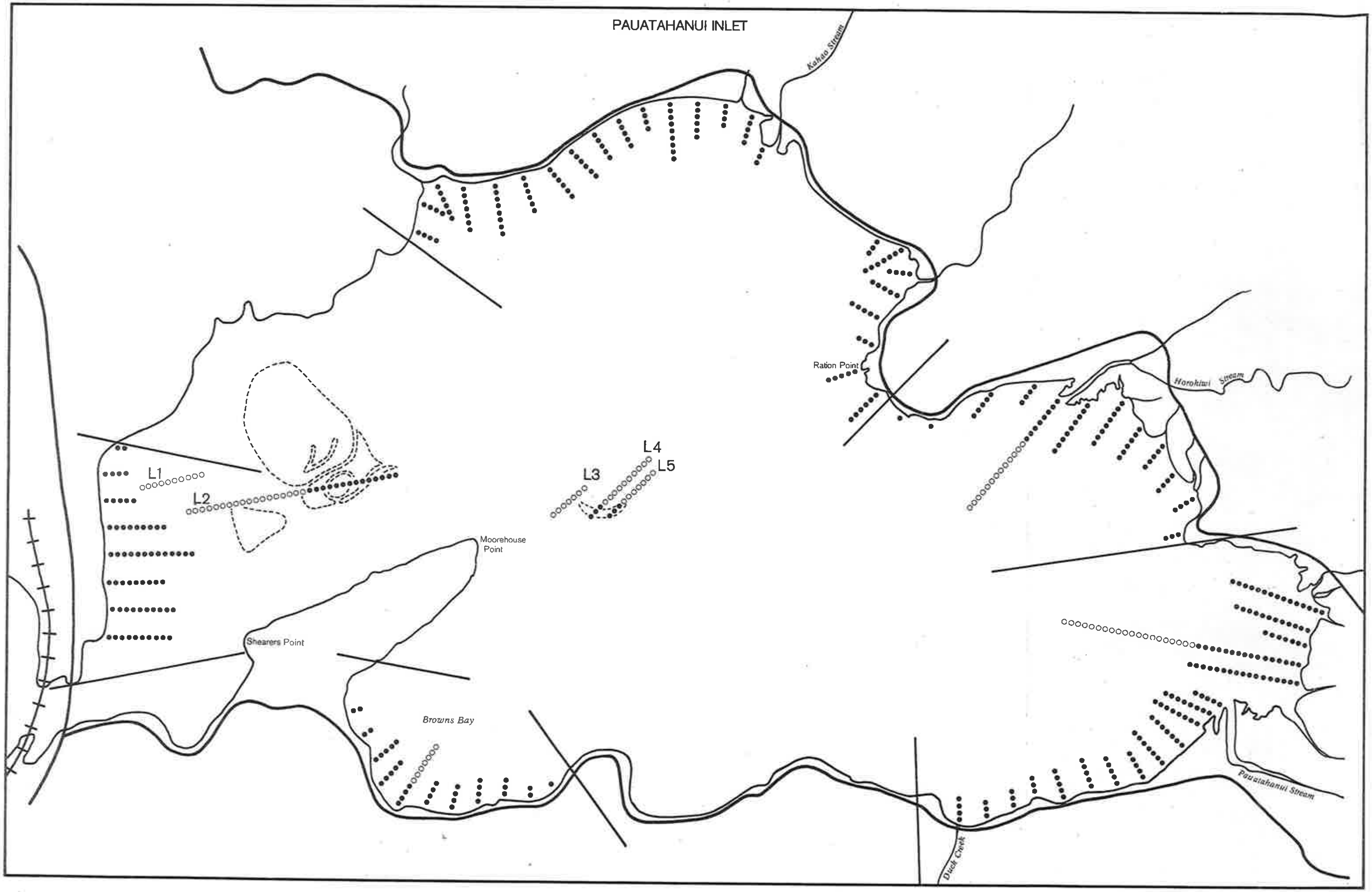


Fig. 1. Pauatahanui Inlet showing station positions. Solid circles indicate intertidal stations. Open circles indicate subtidal stations. The first station of each intertidal transect lies at high water mark.

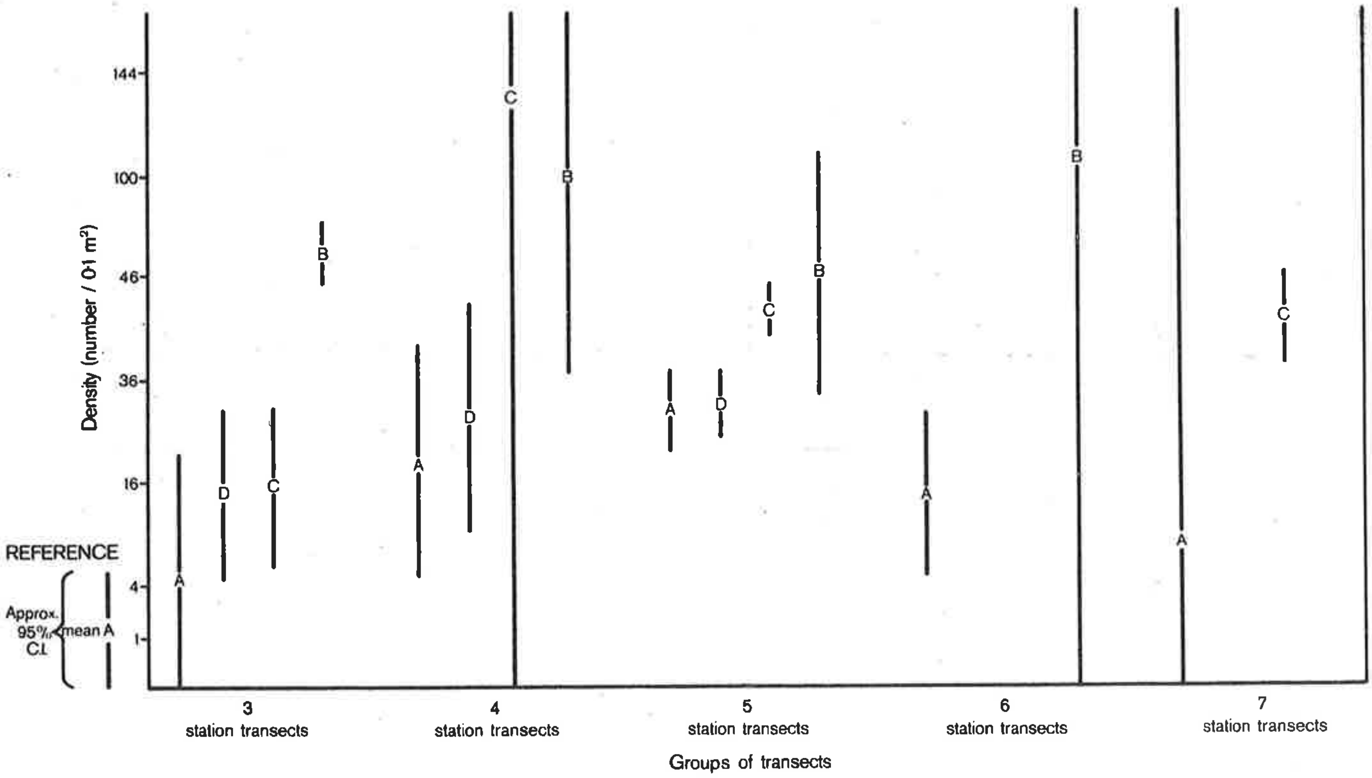


Fig. 3. Mean density of *Chione stutchburyi* by area and transect length.

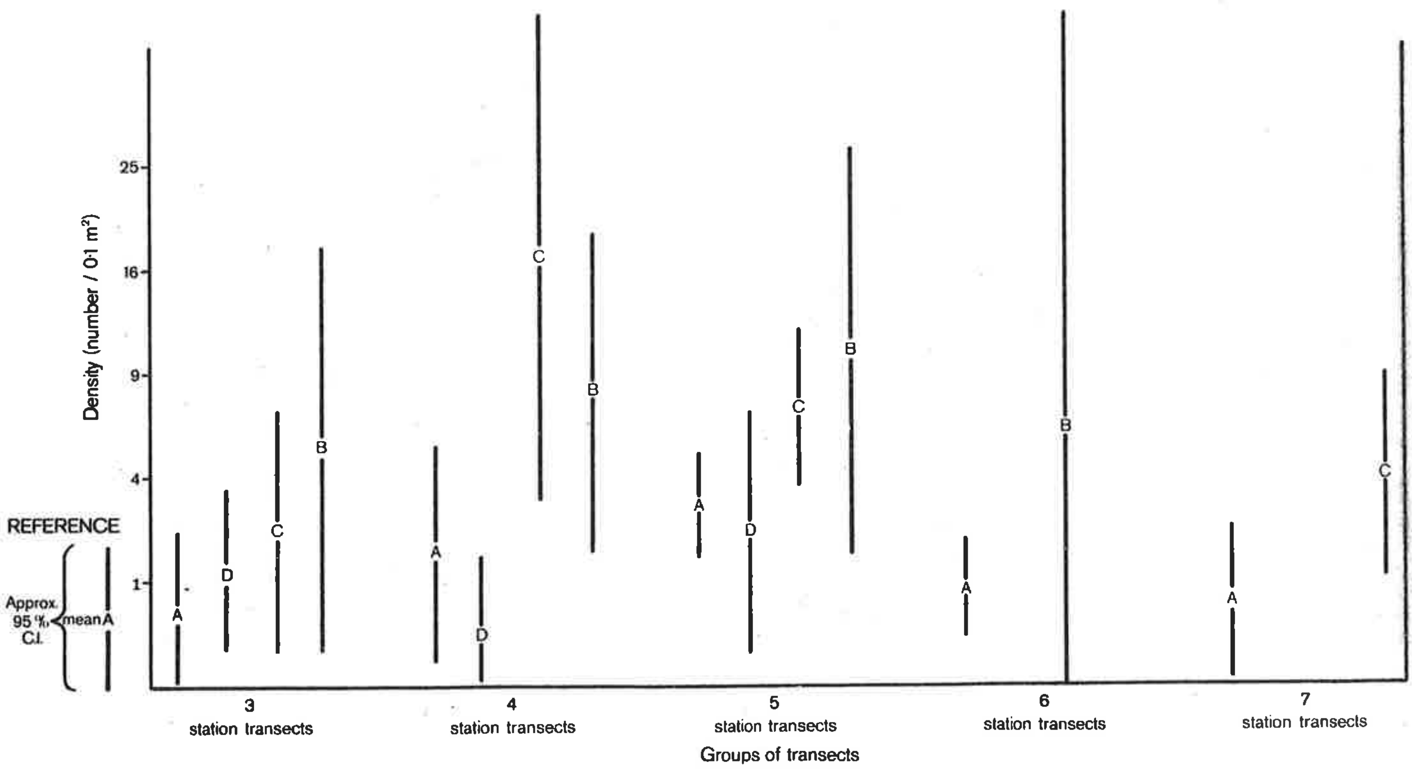


Fig. 4. Mean recruitment density by area for *Chione stutchburyi*.

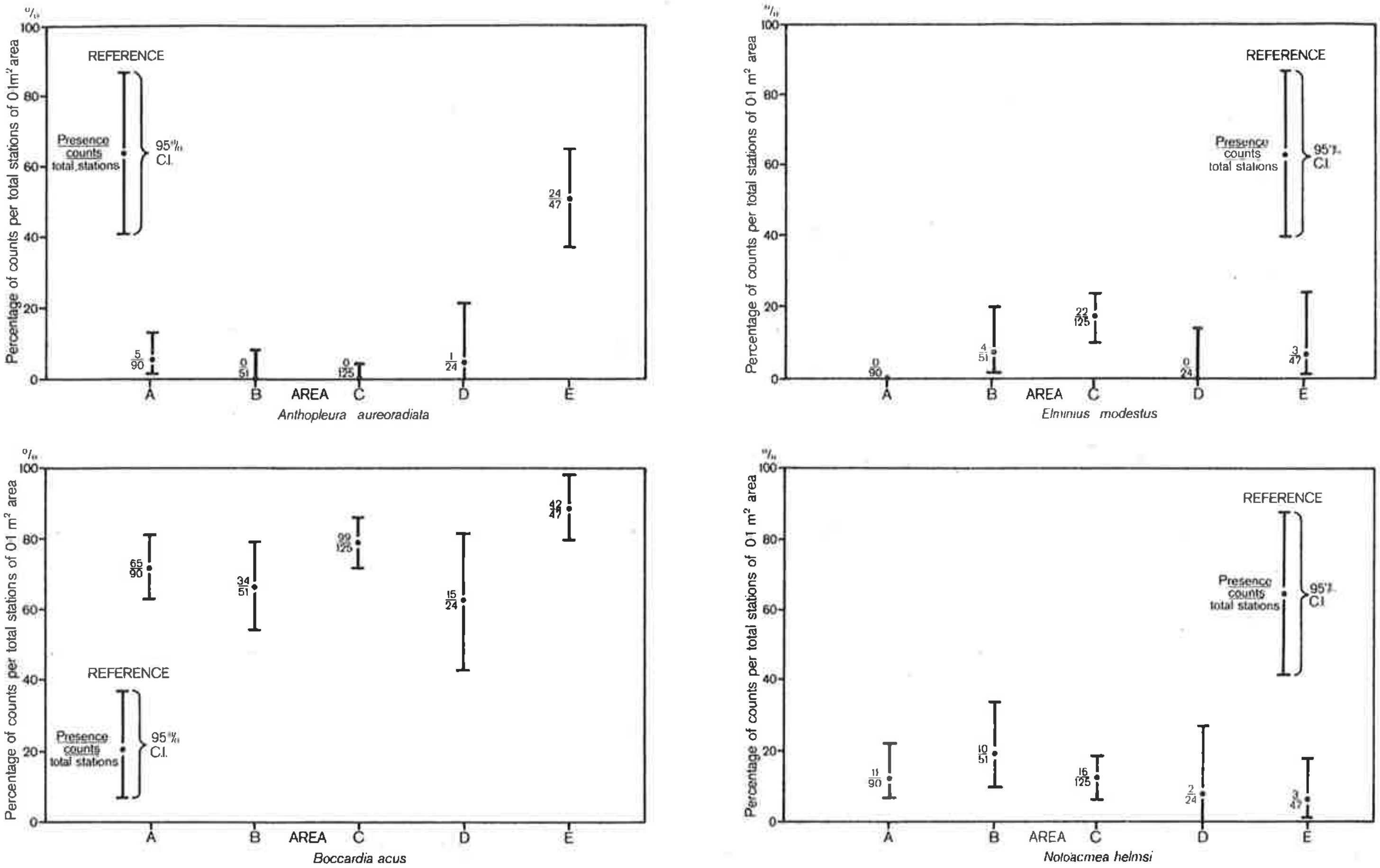
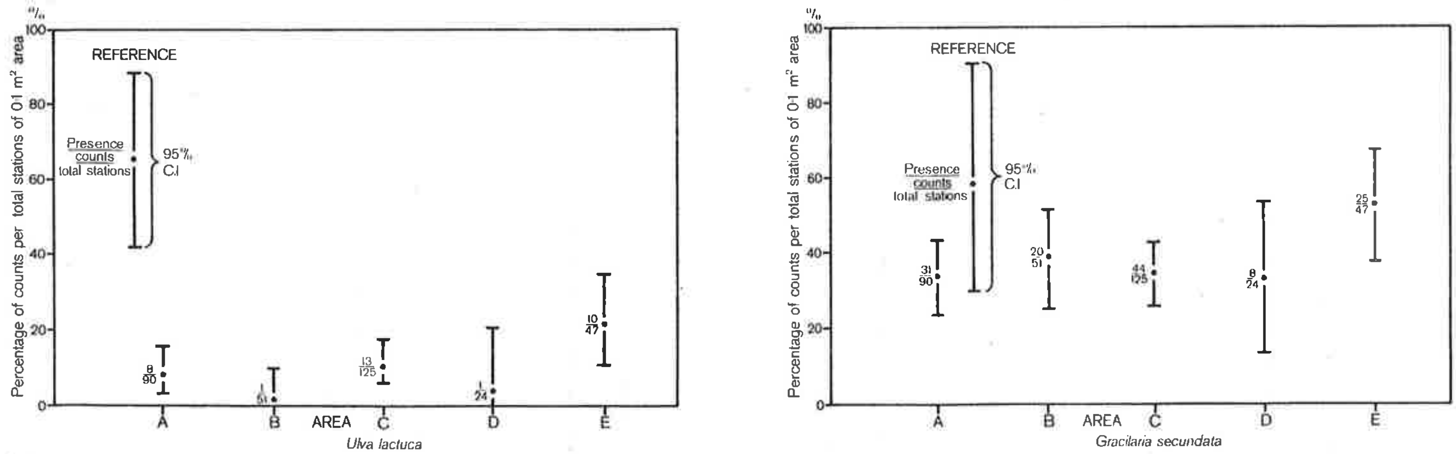


Fig. 5. Percentage occurrences of associated organisms in the five areas : Top left : *Anthopleura aureoradiata*; Top right : *Elminius modestus;* bottom left : *Boccardia acus*; bottom right : *Notoacmea helmsi.*



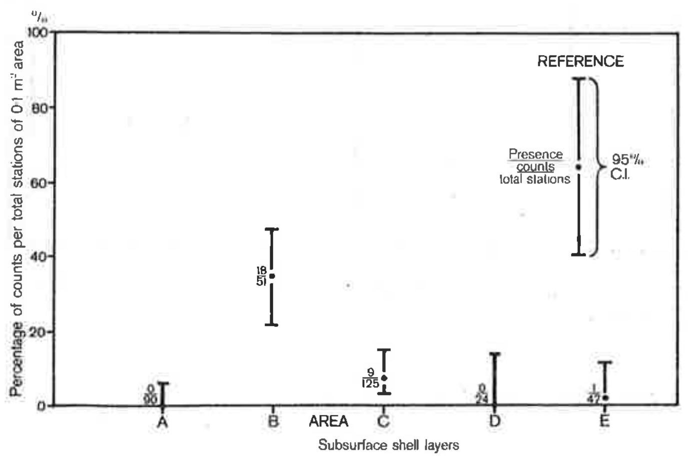


Fig. 6. Percentage occurrences of algae and subsurface shell layers in the five areas : Top left : *Ulva lactuca*; top right : *Gracilaria secundata*; bottom left : subsurface shell layers.

greatest average adult size (37 mm) were collected from subtidal stations on transects L2 and L3.

RECRUITMENT

Recruitment during the previous breeding season (summer of 1975–76) was estimated from the distribution of groups of specimens of 10 mm or less in length. From populations with comparable adult size ranges, Larcombe (1971) estimated growth rates in the first year to be 15 mm for fast-growing populations and 10 mm for slow-growing populations. Observations from July 1976 showed that gametes were not released until mid-December 1976 and therefore, we have assumed that individuals up to 10 mm long represent recruits of the previous breeding season.

The numbers of such recruits are given in Appendix 3. For transects with 4 and 5 stations, plots of mean recruitment density show that areas B and C contained more stations with recruits, and densities were higher at these stations than they were for areas A and D (Fig. 4). Analyses of variance show the results were significant at the 95% confidence level. There was no significant difference between areas A and D, or between areas B and C.

EPIBIONTS

Some shells of *C. stutchburyi* carry a variety of other organisms, some permanently attached, namely *Boccardia acus, Elminius modestus, Anthopleura aureoradiata, Ulva lactuca*, and *Gracilaria secundata.* Grazing molluscs, *Notoacmea helmsi* and *Amaurochiton glaucus* were also found on the valve surfaces, but *A. glaucus* was found only on specimens from subtidal stations. All epibionts except *A. glaucus* were recorded and the recorded presences were plotted as a percentage of total stations within each area. Associated 95% confidence intervals in which the percentage may lie have also been plotted (Figs 5 and 6).

Boccardia acus, N. helmsi, U. lactuca and *G. secundata* were recorded from each area. *Anthopleura aureoradiata* occurred in areas A, D and E, and *E. modestus* in areas B and E, and from transects 1 to 5 of area C.

BROOD CAPSULES

The shells of living specimens of *C. stutchburyi* carry minute stalked capsules of 0.1 mm in diameter. These unidentified structures were such consistent associates of *C. stutchburyi* that a record was made of their distribution. They have since been identified as brood capsules, probably of a turbellarian member of the interstitial fauna (Prof. J.B. Wells, pers. comm. 1978). One specimen of *C. stutchburyi* from each station was examined microscopically, and the capsules were present at all stations except those from the subtidal transects L1 and L3.

SHELL LAYERS

Sediment profiles showed layers of dead shells in area B (at 18 of the 51 stations sampled, area C (9 out of 125 stations) and area E (1 of 47 stations sampled). They consisted almost entirely of the shells of *C. stutchburyi* with only occasional valves of *Mactra ovata* and *Macomona liliana.*

The shell layers occurred at some stations along each transect of area B, but in area C they were present only along transects 1 to 5.

DISCUSSION

In a comprehensive study of populations of *C. stutchburyi* Larcombe (1971) observed the species over the greater part of its range on New Zealand's sheltered soft shores. He noted that populations show two size gradients – an increase in the mean size of individuals from high to low water and, in enclosed waters, a decrease in size with distance from the entrance. From these observations he concluded that longer exposure time to new supplies of plankton-rich water enhances growth. Populations from Otago Harbour did not follow the trend of greater mean size near the entrance, a fact attributed by Larcombe to differences in the circulation pattern of tidal water in a large area.

The data recorded here confirm the increase in average adult size from high to low water but differences in size according to position are not evident. At comparable tide levels, the mean size of specimens from intertidal flats nearest the inlet entrance (area E) is the same as that of specimens furthest from the entrance (area C).

However, there is a significant difference in two groups of areas. Areas A and D contain populations of lower density than do areas B and C, and they do not have layers of dead shells beneath the surface sediments. These areas differ in extent, but the fact that *Anthopleura aureoradiata* is not present on specimens from areas B and C and *Elminius modestus* does not occur on specimens from A and D suggests that factors other than physiography may be involved in density differences. A further differentiation may be made within area C in which transects 1 to 5 agree with area B transects in the presence of shell layers and *E. modestus.* The division into five areas was made in order to simplify collecting. It is now apparent that significant differences exist between two regions, one including areas A and D and that segment C south of the Pauatahanui Stream, the other area including B and that segment of C north of the Pauatahanui Stream.

ACKNOWLEDGMENTS

Almost every member of the staff of the N.Z. Oceanographic Institute was involved in collecting, cleaning, measuring and recording the large numbers of specimens required for this project and we are grateful for their help. B.J. Hunt, N.Z. Oceanographic Institute, designed and made the sampling shovels.

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Appendix 1. Intertidal station densities by length of transect.

R - substrate of rock or coarse gravel at station
M - label missing

Density (no./0.1 m^2)

Area	Transect	Station Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A	21	1																
B	1	44																
B	2	2																
D	1	R																
D	11	R																
D	2	R	49															
D	10	71	27															
D	12	R	44															
A	16	R	23	28														
A	22	R	1	4														
A	27	R	1	8														
B	11	15	64	156														
B	12	1	107	219														
C	16	31	35	3														
C	17	10	6	3														
C	18	67	33	1														
D	3	19	59	12														
D	5	6	R	R														
D	6	0	16	13														
A	1	R	22	M	8													
A	2	R	24	16	4													
A	11	R	32	86	33													
A	14	R	M	11	3													
A	24	R	4	85	41													
A	28	R	M	0	65													
B	4	19	42	67	83													
B	10	6	M	146	164													
C	19	M	203	127	80													
D	4	R	31	26	68													
D	7	1	0	68	20													
A	9	5	35	58	37	23												
A	10	R	17	M	31	149												
A	15	4	28	51	39	30												
A	25	10	M	14	26	8												
A	26	1	183	18	M	6												
B	3	1	55	110	96	36												
B	9	4	28	172	249	93												
C	12	32	41	131	62	59												
C	13	34	84	117	36	48												
C	14	63	70	53	M	13												
C	15	79	74	57	29	5												
D	8	R	R	25	47	43												
D	9	1	9	21	103	103												
A	6	R	30	32	16	12	18											
A	7	R	24	37	32	9	3											
A	8	6	M	65	26	M	11											
A	13	4	M	18	5	M	4											
A	23	R	M	1	53	48	46											
A	29	3	0	0	0	6	0											
B	8	21	51	154	M	84	147											
A	4	R	38	15	8	3	11	10										
C	3	66	53	26	33	36	37	31										
C	8	0	19	39	35	61	148	103										
C	10	10	29	52	66	128	168	33										
C	11	21	27	40	37	192	81	139										
C	7	R	M	12	114	128	108	125										
A	5	R	39	33	17	2	8	16	16									
B	5	2	0	0	2	25	35	0	1									
B	7	1	42	22	M	137	144	165	183									
C	9	0	16	18	42	35	172	161	199									
A	12	R	M	M	32	12	M	120	21	207								
B	6	2	2	22	30	63	131	152	257	234								
A	3	R	58	5	M	3	82	M	M	M	33							
C	2	19	60	69	54	33	54	96	27	69	102	97	86					
C	4	10	16	28	M	24	16	M	13	5	19	M	23					
C	1	68	33	44	87	155	115	81	40	34	6	30	21	125	182	207		
C	5	12	2	9	35	6	90	78	37	60	66	280	34	72	78	243	156	160

Appendix 2. Subtidal station densities.
M - label missing; D - water depth greater than 2 m.

Stn	Density (no./0.1 m^2)							
	Area / Transect							
No.	B5	C4	D7	L1	L2	L3	L4	L5
1	19	6	22	41	235	16	M	4
2	7	17	4	61	M	43	3	14
3	4	4	1	71	293	18	23	44
4	60	1	2	45	205	30	4	3
5	75	M	0	52	105	14	3	0
6	73	M	0	25	54	5	M	0
7	16	4		15	M	6	8	0
8	2	3		5	M	5	1	2
9	2	1		2	D		0	M
10	0	M		M	D		0	4
11	0	3			D		0	
12	0	M			D		0	
13	0	M			D		0	
14		2			D			
15		M			D			
16		M			D			
17		0			D			
18		0			50			
19		0			389			
20					138			
21					37			
22					15			
23					M			
24					M			
25					7			
26					26			
27					10			
28					44			
29					M			
30					20			
31					23			
32					4			

Appendix 3, Numbers of specimens with a length of less than 10 mm at intertidal stations.

R – substrate of rock or coarse gravel at station
M – label missing

Recruitment Totals (≤ 10 m.m)

Area	Transect	Station Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A	21	0																
B	1	19																
B	2	0																
D	1	R																
D	11	R																
D	2	R	0															
D	10	1	0															
D	12	R	5															
A	16	R	0	3														
A	22	R	1	2														
A	27	R	0	0														
B	11	0	6	43														
B	12	0	25	36														
C	15	3	4	0														
C	17	1	0	0														
C	18	22	0	0														
D	3	2	4	8														
D	5	0	R	R	R													
D	6	0	0	3														
A	1	R	0	M	1													
A	2	R	0	1	0													
A	11	R	8	22	5													
A	14	R	M	1	0													
A	24	R	0	4	1													
A	28	R	M	0	3													
B	4	1	9	8	6													
B	10	0	M	32	20													
C	19	M	43	11	7													
D	4	R	0	1	0													
D	7	0	0	3	2													
A	9	1	5	7	3	1												
A	10	R	1	M	1	36												
A	15	2	1	2	3	3												
A	25	1	M	8	2	0												
A	26	0	15	1	M	1												
B	3	0	16	20	7	6												
B	9	0	1	55	42	17												
C	12	1	5	26	11	15												
C	13	3	20	25	2	2												
C	14	4	14	9	M	3												
C	15	12	11	5	2	2												
D	8	M	R	2	12	7												
D	9	0	0	3	9	5												
A	6	R	1	5	2	0	2											
A	7	R	1	7	7	0	0											
A	8	0	M	8	3	M	1											
A	13	0	M	1	0	M	0											
A	23	R	M	0	6	2	1											
A	29	1	0	0	0	1	0											
B	8	1	0	22	M	10	15											
A	4	R	2	3	1	0	0	0										
C	3	1	0	4	0	2	2	2										
C	8	0	1	1	1	9	20	19										
C	10	0	0	15	5	28	53	0										
C	11	1	2	3	6	40	2	9										
C	7	R	M	1	4	11	14	10										
A	5	R	5	2	1	0	0	1	1									
B	5	0	0	0	0	1	4	0	0									
B	7	0	3	2	M	22	5	16	18									
C	9	0	0	0	5	5	18	40	46									
A	12	R	M	M	0	1	M	8	3	19								
B	6	0	0	0	2	25	17	61	42	16								
A	3	R	4	0	M	0	6	M	M	M	2							
C	2	0	8	16	5	2	7	8	0	5	8	3	3					
C	4	0	2	7	M	0	0	M	0	0	0	0	1	0	2			
C	1	1	1	3	1	20	7	16	0	0	1	0	0	1	4	17		
C	5	0	0	0	2	0	1	2	1	2	3	11	0	15	1	18	15	2