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BIOLOGICAL SURVEY OF MARINE COMMUNITIES AROUND TRIANGULAR ISLAN--ETC(U)

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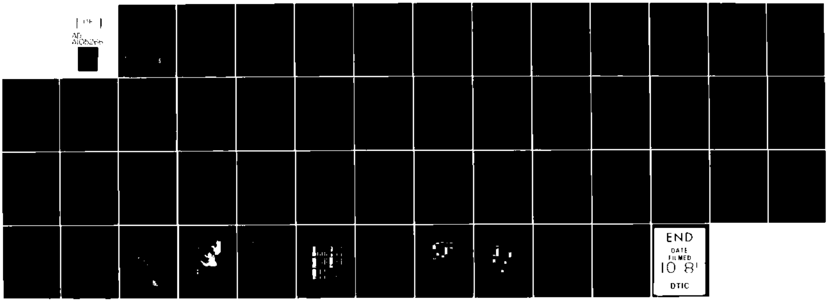

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DEPARTMENT OF DEFENCE

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REPORT

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BIOLOGICAL SURVEY OF MARINE COMMUNITIES AROUND TRIANGULAR ISLAND (SHOALWATER BAY, QUEENSLAND)

John A. Lewis, Ian C. Dunstan and John R. Forsyth

Approved for Public Release

APRIL, 1981

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Marine communities around Triangular Island in Shoalwater Bay, Queensland were surveyed to provide data from which the effects of Naval training activities in the area could be assessed. The abundance and taxonomic composition of fishes, zooplankton, benthic flora and benthic infauna were determined off three beaches around the island. The composition of benthic communities depended on the tidal height and particle size of the substrate and groups of species characteristic of the different beaches were recognised. Invertebrates were more numerous in fine sediments. The biomass and diversity of fishes were generally higher, and zooplankton concentrations lower, over the northern mudflat than off the other two beaches.

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Marine communities around Triangular Island in Shoalwater Bay, Queensland were surveyed to provide data from which the effects of Naval training activities in the area could be assessed. The abundance and taxonomic composition of fishes, zooplankton, benthic flora and benthic infauna were determined off three beaches around the island. The composition of benthic communities depended on the tidal height and particle size of the substrate and groups of species characteristic of the different beaches were recognised. Invertebrates were more numerous in fine sediments. The biomass and diversity of fishes were generally higher, and zooplankton concentrations lower, over the northern mudflat than off the other two beaches.

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BIOLOGICAL SURVEY OF MARINE COMMUNITIES AROUND TRIANGULAR ISLAND (SHOALWATER BAY, QUEENSLAND)

1. INTRODUCTION

Triangular Island, in Shoalwater Bay, Queensland (Figure 1), is used as a site for training RAN Clearance Divers in the techniques of mine disposal and underwater demolitions. In 1978, at the request of Defence Facilities Division, MRL undertook a literature review to determine the possible effects of underwater explosions on marine communities in the region [1,2]. No detailed information on the composition of marine communities in Shoalwater Bay was found. The area was surveyed by the CSIRO Division of Land Research in 1971 [3], but this survey was primarily on terrestrial communities with only scant reference to the marine biota. The only publication specifically on marine biota in Shoalwater Bay dealt with the ecology and behaviour of the dugong [4]. The biota of sheltered waters elsewhere along the Queensland coast have been surveyed [5,6,7], but little of this information could be related to Shoalwater Bay. A biological survey of the area was therefore recommended to enable the effects of Naval training activities on the marine biota to be assessed [1].

An initial visit to Triangular Island (24-31 July, 1978) permitted general observations on topography and marine community types in and around the training sites, and enabled the collection of some biological specimens. From these observations a programme was designed to sample the marine biological communities around the island. This sampling programme was implemented on a return visit to Triangular Island during 8-13 November, 1978.

The overall results of the biological survey of marine communities adjacent to Triangular Island are contained herein. Detailed quantitative data used in the formulation of this report are held by the authors. Further analyses on these data may be incorporated into future publications on specific groups of organisms or with results from proposed seasonal surveys.

General observations on the sites and the effects of training activities have been reported elsewhere [2,8].

2. METHODS

2.1 *Marine Plants*

General collections of marine plants in intertidal and shallow subtidal waters were made in July at Triangular Island and on the southern shore of Townshend Island. Plants on inner regions of the mudflats at Triangular Island were also collected in benthos core samples during the November survey.

2.2 *Benthos*

Two 200 m long transects were laid perpendicular to the shore during high tides on each of Big Bang Beach and Little Bang Beach, and one such transect laid on East Beach (Figures 2, 3). Samples were collected from ten sites on each transect; the first five at 10 m intervals from shore and the remainder at 30 m intervals. At each site, three sediment cores were taken by divers using sections of plastic tube (23 cm long x 5 cm diam.). Core samples were preserved in formaldehyde solution for return to the laboratory.

Depth was recorded at each sample site with capillary-type depth gauges and the approximate depth relative to chart datum estimated from tide tables.

In the laboratory, mud samples were rinsed through 2 mm and 1 mm mesh sieves and all biota set aside for identification and enumeration. Sediment size fractions were determined by weighing the whole sample and the residue retained on sieves after rinsing.

2.3 *Plankton*

Plankton hauls were attempted on day rising and falling tides off each of the three beaches. A 'General Oceanics' plankton net (153 µm mesh, 1 µm mouth diameter, 5 m long) was towed for 10 minutes behind a 5 m runabout powered by an outboard motor. The net was equipped with a 'General Oceanics' flowmeter to permit calculation of the volume of water filtered.

In the laboratory the larger (>10 mm) zooplankton, and those in conspicuous yet uncommon groups, were individually removed from each of the samples, identified and counted. The remaining zooplankton were too numerous for total counts and subsamples were therefore taken with a whirling apparatus. Samples were reduced to 1/100 or 1/500 of the original before the component zooplankton were counted.

2.4 Fishes

Fishes were collected over the inner mudflats with a 30 m beach seine net. Hauls were attempted on day rising and falling tides on each beach, and on night rising and falling tides on Little Bang Beach.

All small fishes were preserved in formaldehyde solution for return to the laboratory. Selected specimens of larger species were also retained and the remainder measured, weighed and their gut contents removed for later analysis. All specimens returned to the laboratory were identified, measured and weighed, and the gut contents of five specimens of each species examined.

Identification and systematic classification of the fishes follows Grant [9].

3. RESULTS AND DISCUSSION

3.1 Substrate Topography and Composition

The gradient, sediment composition and extent of the intertidal zone varies around Triangular Island. On the northern shore (Little Bang Beach), a sloping sandy beach abuts a mudflat at mid-tide level (Figure 3). The mud extends seaward for approximately 600 m (Figure 2) with little overall slope. Seagrass grows on the north-eastern region of this mudflat (Figure 2).

The intertidal zone on the eastern shore (East Beach) is approximately 250 m in width and has a gradual downward gradient (Figure 3). Mangroves grow at the upper tide levels and the mudflat is mostly covered by seagrass. The southern shore (Big Bang Beach) grades steeply near the beach but levels near the low water mark (Figure 3). Much of the upper shoreline is rocky and no seagrass grows on the intertidal substrata.

Sediments on the southern side of the island contain a higher proportion of coarse matter than those on the northern and eastern shores (Table 3.1.1). Sediment composition remains moderately uniform over most of the length of transects on Big Bang Beach (Figure 4). However, samples collected 20 and 30 m from the shore end of transect 1 had a much higher proportion of fine particulate matter.

Sediments on Little Bang Beach were also uniform in composition over most of the transects' lengths (Figure 4). The only evident variation was the higher proportion of coarse sediment at the inner 20 m of transect 3. On East Beach coarser sediments were present 80-170 m from shore than elsewhere along the transect (Figure 4).

TABLE 3.1.1

MEAN COMPOSITION OF SEDIMENTS OF EACH OF THE TRANSECTS

Transect No	% Particle Size Range (mean ± s.d.)		
	<1 mm	1 mm < p <2 mm	>2 mm
1	33.7 ± 27.18	32.0 ± 14.38	34.2 ± 19.00
2	31.7 ± 16.16	42.6 ± 12.67	25.6 ± 7.79
3	73.7 ± 16.85	14.6 ± 5.50	11.5 ± 13.33
4	60.1 ± 13.08	29.0 ± 7.51	10.7 ± 5.43
5	59.1 ± 13.08	26.4 ± 7.54	14.4 ± 9.83

The variation in sediment composition along transects 1 and 3 may be related to the effects of explosives detonated in these areas. The inshore segment of transect 1 traversed a channel blasted from the substratum to permit small-boat access to the island. The craters which form the channel are lined with fine silt and this explains the inshore variation in sediment composition observed on this transect. On transect 3, although the inner region was used for explosions, the variation in sediment composition is attributed to a band of coarser sediment observed to extend along the edge of the beach. Where explosives had been detonated, craters were again filled with fine silt. No core samples were taken within craters on this transect.

3.2 Benthic Marine Plants

Shallow embayments do not tend to support a high diversity of marine plants. Turbid water, which restricts the penetration of light, and lack of firm substrata combine to prevent the establishment of many species. Vegetation is present, however, as some plants are adapted to this type of environment. Notable amoung these are the seagrasses which can form dense meadows over sediments in shallow water.

Fifty-nine algal (Cyanophyta 4, Chlorophyta 11, Phaeophyta 11, Rhodophyta 33) and two seagrass species have been collected from around Triangular Island (Appendix A). Of these, the seagrass *Zostera capricorni* appears most abundant and covers large areas of the intertidal mudflats (Figure 2).

Twenty-seven of the plant species were collected in benthic samples on the transects. Most of these species were sparsely distributed with only twelve species collected in more than one sample on any transect (Table 3.2.1). Just three species, *Penicillus nodulosus, Enteromorpha clathrata* and *Zostera capricorni*, fulfilled this criterion on more than one transect.

P. nodulosus only occurred on the transects off Big Bang Beach whilst *E. clathrata* and *Z. capricorni* were widespread off the other two beaches. The overall composition of the plant communities off Big Bang Beach also differed to those off East Beach and Little Bang Beach (Table 3.2.2).

TABLE 3.2.1

PLANT SPECIES COLLECTED IN MORE THAN ONE SAMPLE ON TRANSECTS

Species	Transect				
	1	2	3	4	5
U. argentea	+				
Dasya sp.	+				
Polysiphonia sp.	+				
P. nodulosus	+	+			
E. clathrata			+	+	+
M. lyngbyaceus			+		
S. filamentosa				+	
Hypnea sp.				+	
H. ovalis				+	
C. clavulatum				+	
B. antillarum				+	
Z. capricorni				+	

Physical differences in the substrate composition and topography account for the observed dissimilarities. Unlike transects on Little Bang Beach and East Beach, the outer 100 m of transects 1 and 2 lay below the normal tidal range and benthic species would not be subject to lengthy periods of exposure to the atmosphere. The majority of plant species on these transects were collected in this region. In addition, the sediments on Big Bang Beach contained a high proportion of coarse particles (Table 3.1.1) which impart greater support to erect plants than do fine sediments. Most plants collected on Big Bang Beach were erect forms with defined holdfasts for attachment to stones or anchorage in the mud.

TABLE 3.2.2

SIMILARITY OF THE FLORA BETWEEN TRANSECTS USING THE SOERENSON COEFFICIENT OF SIMILARITY*

$* \frac{2a}{b + c}$, where 'a' = no. of species common to both transects
'b, c' = total no. of species on each transect [10].

Transects					
1	-				
2	0.43	-			
3	0.26	0.22	-		
4	0.33	0.32	0.63	-	
5	0.17	0.33	0.44	0.63	-
	1	2	3	4	5
			Transect		

Plants grew along the full lengths of transects 3, 4 and 5 with *Enteromorpha clathrata, Microcoleus lyngbyaceus, Zostera capricorni* and *Spyridia filamentosa* the most frequent. *E. clathrata* and *M. lyngbyaceus* have thread-like thalli which form extensive tangled mats on the mud surface whilst *Z. capricorni* has a well-developed creeping root system. *S. filamentosa*, and many of the other species on these transects, are diminutive plants which grew as epiphytes on the seagrass leaves or attached to shell fragments on the mud surface. Unlike transects 1 and 2, few erect plants were present.

3.3 Invertebrates - Benthic

One hundred and sixty invertebrate species were identified from benthic samples along the five transects (Appendix A). One hundred and twenty-nine of these species were each represented by less than 10 individuals. The predominant group, the annelid polychaetes, comprised 58% of the invertebrate species and 89% of the individuals collected.

Invertebrate numbers were not distributed uniformly along the transects (Table 3.3.1). On transect 1, 43% of the individuals were collected from the 20 and 30 m sample sites. These two sites were in a man-made channel where sediments were finer than elsewhere along the transect (see Section 3.1; Figure 4). This suggests that sediment size may influence the distribution of benthic infauna.

TABLE 3.3.1

DISTRIBUTION OF INVERTEBRATES ALONG THE TRANSECTS

TRANSECT		DISTANCE ALONG TRANSECT (m)										
		10	20	30	40	50	80	110	140	170	200	TOTAL
1	INDIVIDUALS	0	26	38	11	13	11	15	14	17	5	150
	SPECIES	0	10	8	9	11	8	14	13	13	4	50
2	INDIVIDUALS	-	-	26	13	10	13	15	13	24	30	144
	SPECIES	-	-	12	11	8	10	12	11	17	23	68
3	INDIVIDUALS	66	23	16	12	24	50	24	44	18	17	294
	SPECIES	14	8	7	5	16	16	11	20	10	8	63
4	INDIVIDUALS	18	20	41	21	19	25	12	32	51	17	256
	SPECIES	10	11	22	10	12	12	7	17	18	8	58
5	INDIVIDUALS	15	12	20	24	20	39	52	65	30	18	305
	SPECIES	10	8	12	7	10	17	22	26	16	14	65

Species were more numerous towards the seaward end of transect 5 than closer inshore (Table 3.3.1). In particular, relatively large numbers of individuals (55% of total) were taken from the 80, 110 and 140 m sample sites. The greater abundance of seagrass at these sites (Table 3.3.2) may have influenced invertebrate distribution. However, other sample sites where seagrass grew did not necessarily support high invertebrate numbers suggesting that additional parameters are also important. The variation in invertebrate abundance along transects 2, 3 and 4 could not be related to any physical or biological parameters measured in this survey.

TABLE 3.3.2

ABUNDANCE OF SEAGRASS *(ZOSTERA CAPRICORNI & HALOPHILA OVALIS)*

ALONG TRANSECTS 4 AND 5

(+ present in one core of sample site, ++ 2 cores, +++ 3 cores)

Transect	Distance along transect (m)									
	10	20	30	40	50	80	110	140	170	200
4	+++	+++	+++	+++	++					
5	+	+++			+	+++	+++	++		+

The composition of the benthic invertebrate communities showed greater similarity between transects on the same beach than between different beaches (Table 3.3.3). Communities on Little Bang Beach were more like East Beach than Big Bang Beach. Organisms were more abundant on the former two beaches although the numbers of species were similar for each transect (Table 3.3.1). In addition, although the majority of common species on Little Bang and East Beaches were also present on Big Bang Beach (Figure 5; group 2), a large number were not (Figure 5; group 3) whereas only one species occurred exclusively on Big Bang Beach (Figure 5; group 1).

The dissimilarities between beaches were also evident in the marine flora (Section 3.2) and can similarly be attributed to differences in substrate composition. Little Bang Beach and East Beach both had finer sediments and supported larger invertebrate populations than Big Bang Beach. In addition, the presence of seagrass on Little Bang Beach and East Beach may have affected population size as seagrass stands are known to be favourable habitats for invertebrates [1,2].

3.4 Invertebrates - Planktonic

Details of the successful plankton tows are presented in Table 3.4.1. Tow 6 was abandoned after the net caught in the mud.

TABLE 3.3.3

SIMILARITY OF INVERTEBRATE COMMUNITIES BETWEEN TRANSECTS USING THE BRAY-CURTIS COEFFICIENT*

Transects	1	-			
2	0.46	-			
3	0.22	0.27	-		
4	0.29	0.28	0.53	-	
5	0.33	0.28	0.41	0.51	-
	1	2	3	4	5

Transect

* $\frac{2x}{y + z}$, where 'x' = sum of smaller abundances for those species in common between the two transects.

'y, z' = total number of individuals from each transect [11].

TABLE 3.4.1

DETAILS OF PLANKTON HAULS

Haul No.	Date	Site	Time	Tide	Volume filtered (m^3)
1	8 Nov	Big Bang Beach	1550-1600	Rising	198.1
2	9 Nov	Little Bang Beach	1504-1514	Rising	159.1
3	11 Nov	East Beach	0914-0924	Falling	154.4
4	11 Nov	Big Bang Beach	0934-0944	Falling	176.4
5	12 Nov	Little Bang Beach	0843-0853	Falling	210.4
6	11 Nov	East Beach	Abandoned	Rising	-

The zooplankton communities of shallow marine embayments are neritic in composition in that they comprise both holoplankton (those organisms which are planktonic throughout their entire life-history) and a significant proportion of meroplankton (the larval stages of organisms whose adults dwell in or on the sea-bed and form part of the benthic community). Of the twenty-four taxonomic groups recognized from the Triangular Island zooplankton community, eight were holoplanktonic, twelve meroplanktonic, and four contained individuals of both types (Appendix B). The most abundant holoplanktonic organisms were the Copepoda which formed 80-90% of the total zooplankton composition in any haul (Figure 6). Important meroplanktonic groups included larval stages of the Gastropoda, Cirripedia (barnacles), Bivalvia and Brachyura (true crabs).

The plankton hauls collected off Little Bang Beach contain less zooplankton, both inclusive and exclusive of the Copepoda, than those hauls collected off either of the other two beaches (Table 3.4.2). Little Bang Beach faces onto Strong Tide Passage (Figure 2) and would be influenced to a greater extent by water entering Shoalwater Bay through Strong Tide Passage on the rising tide than would the other two beaches. The lower abundance figures for zooplankton in the waters off Little Bang Beach can be explained if the waters of 'outside' origin contained less zooplankton than the waters already present inside the bay. Shallow marine embayments tend to be highly productive ecosystems with extensive mangrove and seagrass areas. Large amounts of organic detritus are released into the water column which may be digested directly by zooplankton, or generate sufficient nutrients to support dense phytoplankton populations which, in turn, provide more food for the zooplankton. Evidence of the high primary productivity in Shoalwater Bay lies in the high abundance of the blue-green alga *Oscillatoria erythraea* (Ehrenberg) Kuetzing observed in the plankton hauls. The mesh size of the plankton net was too large to assess the abundance of smaller phytoplankton species.

Differences in the numerical abundance of the meroplanktonic forms occurred between rising and falling tides (Figure 7). With the exception of the large number of brachyuran zoea larvae in the rising tide haul collected off Big Bang Beach, greater numbers of each of the meroplanktonic groups were present in the falling tide hauls than in the rising tide hauls collected off the same beach. Many benthic organisms with planktonic larval stages inhabit the intertidal mudflats and rocky areas around Triangular Island. These organisms release their larvae at high tide to enable their dispersal by water movement, and the numbers of meroplanktonic forms would be expected to be greater in falling than in rising tides.

3.5 Fishes

Details of fish nettings are included in Table 3.5.1. The falling tide sample at East Beach was unsuccessful due to the tidal height at the planned time of netting, and the difficulties encountered in hauling the net onto shore near mangroves. To overcome these difficulties the rising tide sample at this beach was netted earlier in the tidal cycle than planned and sited off the seaward edge of the exposed mudflats.

TABLE 3.4.2

NUMERICAL ABUNDANCE (INDIVIDUALS/m^3) OF ZOOPLANKTON

	Haul				
	1 Big Bang Beach Rising Tide	4 Big Bang Beach Falling Tide	2 Little Bang Beach Rising Tide	5 Little Bang Beach Falling Tide	3 East Beach Falling Tide
Total zooplankton	4284	6471	3675	3156	7644
Total zooplankton excluding Copepoda	821	975	494	445	764

T A B L E 3.5.1

DETAILS OF FISH NETTINGS

Haul No.	Date	Site	Time	Tide	No. of hauls
1 (BDR)	8 Nov 78	Big Bang Beach	1415	Day-Rising	2
2 (BDF)	9 Nov 78	Big Bang Beach	0615	Day-Falling	2
3 (LDR)	9 Nov 78	Little Bang Beach	1530	Day-Rising	2
4 (LNF)	9 Nov 78	Little Bang Beach	2100	Nt.-Falling	2
5 (LNR)	10 Nov 78	Little Bang Beach	0430	Nt.-Falling	2
6 (EDF)	11 Nov 78	East Beach	0900	Day-Falling	-
7 (EDR)	11 Nov 78	East Beach	1745	Day-Rising	2
8 (LDF)	12 Nov 78	Little Bang Beach	0815	Day-Falling	2

Twenty-three fish and one prawn species were netted in the waters around Triangular Island (Appendix C). The most abundant species was the hardyhead, *Pranesus ogilbyi*. Other common species are listed in Table 3.5.2.

Nettings on Little Bang Beach contained a higher biomass of fish per haul than nettings on corresponding tides at the other two beaches (Table 3.5.3). The population diversity tended to be higher here and on East Beach than on Big Bang Beach and was also higher on rising than falling tides on each beach (Table 3.5.3).

On the basis of similarity coefficients (Table 3.5.4), two groupings are evident among the nettings:

1. day-rising tides on East and Big Bang Beaches, and

2. all hauls on East Beach and Little Bang Beach.

An exception to the latter group was the day-falling tide on Little Bang Beach which differed in containing large numbers of mature garfish (Table 3.5.2).

TABLE 3.5.2

NUMBER OF FISHES NETTED IN EACH OF THE HAULS

SPECIES	+LDR	LNR	LDF	LNF	EDR	BDR	BDF	TOTAL
P. ogilbyi	3	7	2	15	42	43	307	419
H. ardelio	3	4	67	-	3	9	2	88
juv. Mugilidae	5	60	3	13	-	3	-	84
G. argyreus	-	16	-	1	12	50	-	79
A. sclerolepsis	4	3	68	3	1	-	-	79
S. maculata	9	4	4	6	10	15	-	48
P. koelreuteri	11	16	-	-	12	-	-	39
P. plebejus	10	20	-	3	4	1	-	38
L. vaigiensis	7	17	1	4	-	-	-	29
A. australis	-	8	10	1	2	-	-	21
M. georgii	3	14	-	-	1	-	1	19
S. hamiltoni	-	-	-	3	7	1	-	11
Other	20	5	-	3	5	-	-	33

\+ See Table 3.5.1 for key to nettings.

TABLE 3.5.3

PARAMETERS OF FISH POPULATIONS NETTED OVER EACH BEACH AND ON DIFFERENT TIDES

Netting	No. of Hauls	Total Biomass (gm)	No. of Individuals	No. of Species	Diversity* (H')
+ LDF	2	10,080	155	7	0.50
LDR	2	3,660	75	16	1.09
LNR	2	2,250	174	14	0.93
BDF	2	1,210	310	3	0.03
LNF	3	1,170	52	12	0.88
EDR	2	600	99	14	0.83
BDR	2	220	122	7	0.59

*Shannon-Weaver diversity index = $-\sum_{i=1}^{i=n} P_i \log P_i$ where P_i is the proportion of the ith species in the population of n species [12].

+See Table 3.5.1 for key to nettings.

TABLE 3.5.4

SIMILARITY OF FISH POPULATIONS BETWEEN NETTINGS

USING BRAY-CURTIS COEFFICIENT [11]

Netting	BDF	BDR	EDR	LDR	LNR	LNF	LDF
+BDF	-						
BDR	0.21	-					
EDR	0.22	0.62	-				
LDR	0.03	0.19	0.40	-			
LNR	0.04	0.24	0.34	0.40	-		
LNF	0.05	0.25	0.30	0.35	0.27	-	
LDF	0.02	0.13	0.09	0.15	0.15	0.13	-

Netting

+ See Table 3.5.1 for key to nettings.

The similarity of hauls on rising tides at East Beach and Big Bang Beach is attributed to the presence of similar numbers of the common species *P. ogilbyi, Gerres argyreus* and *Sillago maculata*. Similarity between East Beach and Little Bang Beach hauls is attributed to the occurrence of a number of species on these beaches which did not occur on Big Bang Beach (Table 3.5.5).

Fish distribution may be related to the different substrate composition and its effects on food supply. Gut analyses of fish species showed a wide range of food preferences (Table 3.5.6), although the majority of species were dependent on benthic organisms. Only four species fed exclusively on plankton. The greater abundance of benthic invertebrates on Little Bang Beach and East Beach (Section 3.3) could account for the higher diversity of fish species there than on Big Bang Beach.

TABLE 3.5.5

DISTRIBUTION OF COMMON FISH SPECIES

I. Fish collected on all three beaches:

H. ardelio	*M. georgii*	*P. ogilbyi*	*G. argyreus*
S. maculata	*S. hamiltoni*	*P. plebejus*	

II. Fish collected on Little Bang and East Beaches only:

A. sclerolepsis	*A. australis*	*P. koelreuteri*	*T. jarbua*
L. vaigiensis	*S. multifasciata*	*S. pleurostictus*	*P. indicus*

TABLE 3.5.6

GUT CONTENTS OF FISH SPECIES COLLECTED IN NETTINGS

SPECIES	ALGAE	SEAGRASS	MOLLUSCS	POLYCHAETES	FISH	CRUSTACEA	
						BENTHIC	PLANKTONIC
A. sclerolepsis		+					
H. ardelio	+	+					
S. multifasciata		+					
L. vaigiensis	+	+	+			+	
A. australis	+	+	+			+	
M argenteus	+	+					+
P. koelreuteri	+			+			+
A. immaculatus	+		+	+		+	
T. blochi			+			+	
S. pleurostictus			+			+	
G. argyreus				+		+	+
P. indicus					+	+	
S. maculata						+	
S. hamiltoni						+	
T. angustifrons						+	
T. jarbua						+	+
S. carpentariae							+
H. koningsbergeri							+
juv. Mugilidae							+
P. ogilbyi							+

Two fish species, *Absalom radiatus* and *Gerres filamentosus*, were killed by explosions detonated during the July visit to the training area, but were not collected in the November survey. The apparent abundance of these species in July, and their absence in November, is indicative of the seasonal variation which may occur in biological populations. The composition and abundance of fish during the November survey can therefore be considered as representative of that time of year only. Surveys need to be conducted during other seasons to fully census the fishes that inhabit the training area.

4. CONCLUSIONS

The identification of 59 plant and 153 invertebrate species from benthic samples, together with 25 fishes and a rich zooplankton fauna from net hauls, shows that a diverse community of marine organisms occurs around Triangular Island.

The composition of the community varied off different beaches around the island and, for the benthic vegetation, benthic invertebrates and fishes, this variation is related mainly to differences in the substrate. The community composition off Little Bang Beach showed greater similarity to East Beach than to Big Bang Beach. The substrata off the former two beaches sloped more gently and contained a lower proportion of large particles than the substratum off Big Bang Beach. Lack of suitable anchorage points therefore prevented colonisation by many algal species and the vegetation off Little Bang and East Beaches was dominated by a few species, such as the seagrass *Zostera capricorni*, which are adapted to growth on fine sediments. Benthic invertebrates (predominantly annelid polychaetes) were more abundant in fine sediments and were therefore more numerous off Little Bang and East Beaches than off Big Bang Beach. The maximum biomass and diversity of fishes were collected off Little Bang Beach where their major food item, the benthic invertebrates, were most plentiful.

Variations in zooplankton concentrations around Triangular Island are attributed to the influence of water entering Shoalwater Bay along Strong Tide Passage.

Several fish species observed in July were absent from the November samples and this illustrates the need for additional surveys during other seasons of the year to comprehensively census community composition in the area.

5 ACKNOWLEDGEMENTS

We would like to thank divers from RAN Clearance Diving Team One for assistance in sample collection, the Commanding Officer and crew of HMAS BALILPAPAN for providing access and accommodation in Shoalwater Bay, and Mrs Gillian Phillips who sorted most of the samples.

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APPENDIX A

Systematic List of Benthic Species Collected in the Training Area

PLANT KINGDOM

DIVISION CYANOPHYTA (Blue-green algae)

ORDER CHROOCOCCALES

FAMILY OSCILLATORIACEAE

Microcoleus lyngbyaceus (Kuetzing) Crouan

FAMILY NOSTOCACEAE

Hormothamnion sp.

FAMILY RIVULARIACEAE

Calothrix sp.

FAMILY SCYTONEMATACEAE

Fremyella sp.

DIVISION CHLOROPHYTA (Green algae)

ORDER ULVALES

FAMILY ULVACEAE

Enteromorpha clathrata (Roth) Greville

ORDER CODIALES

FAMILY CODIACEAE

Halimeda macroloba Decaisne

Halimeda simulans Howe

Penicillus nodulosus (Lamouroux) Blainville

Udotea argentea Zanardini

Udotea orientalis Gepp & Gepp

ORDER CAULERPALES

FAMILY CAULERPACEAE

Caulerpa lentillifera J. Agardh

Caulerpa racemosa var. *laetevirens* (Montagne) Weber-van Bosse

Caulerpa sertularioides (Gmelin) Howe

ORDER SIPHONOCLADALES

FAMILY VALONIACEAE

Dictyosphaeria cavernosa (Forskål) Boergesen

ORDER DASYCLADALES

FAMILY DASYCLADACEAE

Neomeris annulata Dickie

DIVISION PHAEOPHYTA (Brown algae)

ORDER ECTOCARPALES

FAMILY ECTOCARPACEAE

Bachelotia antillarum (Grunow) Gerloff

Giffordia mitchellae (Harvey) Hamel

ORDER SPHACELARIALES

FAMILY CLADOSTEPHACEAE

Cladostephus verticillatus (Lightfoot) C. Agardh

ORDER DICTYOTALES

FAMILY DICTYOTACEAE

Pockockiella variegata (Lamouroux) Papenfuss

Padina australis Hauck

ORDER DICTYOSIPHONALES

FAMILY SCYTOSIPHONACEAE

Colpomenia peregrina (Sauvageau) Hamel

Hydroclathrus clathratus (C. Agardh) Howe

Rosenvingea intricata (J. Agardh) Boergesen

Scytosiphon lomentaria (Lyngbye) C. Agardh

ORDER FUCALES

FAMILY SARGASSACEAE

Sargassum flavicans (Mertens) C. Agardh

Sargassum sp.

DIVISION RHODOPHYTA (Red algae)

ORDER NEMALIALES

FAMILY ACROCHAETACEAE

Acrochaetium microscopica (Naegeli) Woelkerling

FAMILY HELMINTHOCLADIACEAE

Liagora valida Harvey

FAMILY CHAETANGIACEAE

Galaxaura robusta Kjellman

Galaxaura squalida Kjellman

FAMILY BONNEMAISONIACEAE

Asparagopsis taxiformis (Delile) Collins & Hervey

ORDER CRYPTONEMIALES

FAMILY SQUAMARIACEAE

Peyssonnelia sp.

ORDER GIGARTINALES

FAMILY GRACILARIACEAE

Ceratodictyon spongiosum Zanardini

Gracilaria edulis (Gmelin) Silva

FAMILY HYPNEACEAE

Hypnea cornuta (Lamouroux) J. Agardh

Hypnea valentiae Montagne

ORDER RHODYMENIALES

FAMILY LOMENTARIACEAE

Champia sp.

ORDER CERAMIALES

FAMILY CERAMIACEAE

Anotrichium tenue (C. Agardh) Naegeli

Centroceras clavulatum (C. Agardh) Montagne

Ceramium clarionense Setchell & Gardner

Ceramium flaccidum (Kuetzing) Ardissone

Crouania minutissima Yamada

Spyridia filamentosa (Wulfen) Harvey

Wrangelia plumosa Harvey

FAMILY DELESSARIACEAE

Martensia elegans Hering

FAMILY DASYACEAE

Dasya sp.

Heterosiphonia sp.

FAMILY RHODOMELACEAE

Chondria sp. 1

Chondria sp. 2

Dasyclonium flaccidum (Harvey) Kylin

Herposiphonia tenella (C. Agardh) Schmitz

Laurencia majuscula (Harvey) Lucas

Laurencia obtusa (Hudson) Lamouroux

Leveillea jungermannioides (Martens & Hering) Harvey

Polysiphonia flaccidissima Hollenberg

Polysiphonia sphaerocarpa Boergesen var. *distans* Hollenberg

Taenioma perpusillum (J. Agardh) J. Agardh

Tolypiocladia glomerulata (C. Agardh) Schmitz

DIVISION HELOBIAE (Seagrass)

FAMILY HYDROCHARITACEAE

Halophila ovalis (R. Brown) Hooker

FAMILY POTAMOGETONACEAE

Zostera capricorni Aschers

ANIMAL KINGDOM

PHYLUM COELENTERATA

CLASS HYDROZOA

ORDER THECATA

FAMILY AGLAOPHENIIDAE

Thecocarpus phyteuma (Kirchenpauer)

Lytocarpus pheoniceus (Busk)

CLASS ANTHOZOA

ORDER ACTINARIA

FAMILY ANTHENARIA

Athenaria 1

PHYLUM PLATYHELMINTHES

CLASS TURBELLARIA

ORDER POLYCLADIDA

Polycladida 1

Polycladida 2

PHYLUM NEMERTINEA

Nemertinea 1

Nemertinea 2

PHYLUM NEMOTODA

Nematoda 1

Nematoda 2

PHYLUM ANNELIDA

CLASS POLYCHAETA

ORDER ORBINIIDAE

FAMILY ORBINIIDAE

Haploscoloplos sp.

Scoloplos sp.

FAMILY PARAONIDAE

Aedicira sp. 1

Aedicira sp. 2

Cirrophorus branchiatus Ehlers

Paraonides sp.

Paraonis gracilis gracilis (Tauber)

ORDER COSSURIDA

FAMILY COSSURIDAE

Cossura sp.

ORDER SPIONIDA

FAMILY SPIONIDAE

Polydora sp.

Prionospio aucklandica Augener

Prionospio queenslandicus Blake & Kudenov

Pseudopolydora sp.

Scolelepis phyllobranchia Blake & Kudenov

Spio pacifica Blake & Kudenov

Spionidae 1

Spionidae 2

FAMILY MAGELONIDAE

Magelona capensis Day

FAMILY TROCHOCHAETIDAE

Poecilochaetus serpens Allen

FAMILY CIRRATULIDAE

Caulleriella sp. 1

Caulleriella sp. 2

Tharyx sp.

Cirratulidae 1

ORDER CAPITELLIDA

FAMILY CAPITELLIDAE

Bucherta sp.

Capitella capitata (Fabricius)

Mediomastus capensis Day

Mediomastus sp.

Scyphoproctus djiboutiensis Gravier

Capitellidae 1

FAMILY MALDANIDAE

Axiothella sp.

Nicomache sp.

Maldanidae 1

Maldanidae 2

Maldanidae 3

ORDER OPHELIIDA

FAMILY OPHELIIDAE

Armandia intermedia Fauvel

FAMILY SCALIBREGMIDAE

Scalibregma inflatum Rathke

ORDER PHYLLODICIDA

FAMILY PHYLLODOCIDAE

Eulalia sp. 1

Eulalia sp. 2

Phyllodoce sp.

FAMILY APHRODITIDAE

Harmothoe praeclara Haswell

FAMILY PALMYRIDAE

Paleonotus chrysolepis Schmarda

FAMILY PILARGIIDAE

Loandalia sp.

Sigambra sp.

FAMILY SYLLIDAE

Brania sp.

Exogone sp.

Odontosyllis sp.

Prionosyllis sp.

Sphaerosyllis sp.

Syllis cornuta Rathke

Syllis prolifera Krohn

Syllis sp. 1

Syllis sp. 2

Syllidae 1

Syllidae 2

FAMILY NEREIDAE

Ceratonereis erythraensis Fauvel

Ceratonereis mirabilis Kinberg

Ceratonereis sp.

Leonattes stephonsoni Rullier

Nereis caudata Delle Chiaje

Nereis vaalii (Kinberg)

Nereis sp.

Platynereis dumerilii (Auduoin & Milne Edwards)

FAMILY GONIADIDAE

Goniadidae 1

FAMILY GLYCERIDAE

Glycera sp.

Ophioglycera sp.

FAMILY LACYDONIDAE

Lacydonidae (?) 1

FAMILY NEPHTYIDAE

Nephtys mesobranchia Rainer & Hutchins

Nephtys sphaerocirrata (Wesenberg-Lund)

Nephtys sp.

ORDER EUNICIDA

FAMILY EUNICIDAE

Lysidice ninetta collaris Grube

Marphysa bifurcata Kott

Eunicidae 1

FAMILY LUMBRINERIDAE

Lumbrinereis aberrans Day

Lumbrinereis tetraura (Schmarda)

Lumbrinereis sp.

FAMILY ARABELLIDAE

Arabella sp. 1

Arabella sp. 2

Arabellidae 1

FAMILY DORVILLEIDAE

Dorvillea sp.

Protodorvillea egena Ehlers

Protodorvillea sp.

ORDER STERNASPIDA

FAMILY STERNASPIDAE

Sternaspis scutata (Renier)

ORDER TEREBELLIDA

FAMILY AMPHARETIDAE

Sabellides sp.

Ampharetidae 1

FAMILY TEREBELLIDAE

Amaeana trilobata (Sars)

Artacamella dibranchiata Knox & Cameron

Streblosoma gracile Caullery

FAMILY TRICHLBRANCHIDAE

Terebellides stroemii Sars

ORDER SABELLIDA

FAMILY SABELLIDAE

Jasmineira elegans Saint Joseph

Potamilla sp.

Unid. Polychaete 1

Unid. Polychaete 2

PHYLUM MOLLUSCA

CLASS GASTROPODA

ORDER NUDIBRANCHIA

Nudibranch 1

ORDER CEPHALOSPIDEA

FAMILY BULLARIDAE

Bullaridae 1

CLASS BIVALVIA

ORDER HETERODONTA

FAMILY VENERIDAE

Notocallista sp.

FAMILY CORBULIDAE

Corbulidae 1

Corbulidae 2

ORDER ANISOMYARIA

FAMILY MYTILIDAE

Mytilidae 1

FAMILY OSTREIDAE

Ostreidae 1

Unid. Bivalve 1

Unid. Bivalve 2

Unid. Bivalve 3

PHYLUM ARTHROPODA

CLASS CRUSTACEA

SUBCLASS COPEPODA

ORDER CALANOIDA

Calanoida 1

SUBCLASS MALACOSTRACA

ORDER MYSIDACEA

Mysidacea 1

Mysidacea 2

ORDER CUMACEA

Cumacea 1

Cumacea 2

ORDER TANAIDACEA

Tanaidacea 1

Tanaidacea 2

Tanaidacea 3

Tanaidacea 4

Tanaidacea 5

Tanaidacea 6

Tanaidacea 7

ORDER ISOPODA

FAMILY GNATHIIDAE

Anthuridae 1

Anthuridae 2

Anthuridae 3

Anthuridae 4

FAMILY EURYDICIDAE

Eurydicidae 1

ORDER AMPHIPODA

Yet to be identified

ORDER DELAPODA

FAMILY PALAEMONIDAE

Palaemonidae 1

FAMILY ALPHEIDAE

Alpheus sp.

FAMILY PAGURIDAE

Clibanarius sp.

Pagurinae 1

FAMILY MICTYRIDAE

Mictyris longicarpus (Latreille)

FAMILY OCYPODIDAE

Australoplax tridentata (A. Milne Edwards)

Macrophthalmus convexus Stimpson

Macrophthalmus punctulatus Miers

FAMILY PORTUNIDAE

Portunus pelagicus (Linnaeus)

Thalamita crenata H. Milne Edwards

FAMILY XANTHIDAE

Xanthidae 1

CLASS INSECTA

ORDER DIPTHERA

Dipteran larvae 1

Dipteran larvae 2

PHYLUM BRACHIOPODA

Brachiopoda 1

Brachiopoda 2

PHYLUM ECHINODERMATA

CLASS OPHIUROIDEA

Ophiuroidea 1

Ophiuroidea 2

Ophiuroidea 3

Ophiuroidea 4

Ophiuroidea 5

Ophiuroidea 6

Ophiuroidea 7

APPENDIX B

Systematic Composition of the Zooplankton from Waters Surrounding Triangular Island

Individuals classified to levels indicated by asterisks.

H = Holoplanktonic, M = Meroplanktonic

PHYLUM CEOLENTERATA

- CLASS HYDROZOA
  - ORDER HYDROIDA* (H,M)
  - ORDER SIPHONOPHORA* (H)

PHYLUM CTENOPHORA* (H)

PHYLUM ANNELIDA

- CLASS POLYCHAETA* (H,M)

PHYLUM MOLLUSCA

- CLASS GASTROPODA* (M)
- CLASS BIVALVIA* (M)
- CLASS CEPHALOPODA* (H)

PHYLUM ARTHROPODA

- CLASS CRUSTACEA
  - SUB-CLASS OSTRACODA* (H)
  - SUB-CLASS COPEPODA* (H)
  - SUB-CLASS CIRRIPEDIA* (M)

SUB-CLASS MALACOSTRACA

ORDER STOMATOPODA* (M)

ORDER CUMACEA* (M)

ORDER TANAIDACEA* (M)

ORDER ISOPODA* (H,M)

ORDER AMPHIPODA* (H,M)

ORDER DECAPODA

SUB-ORDER NATANTIA

SECTION PENAEIDEA

FAMILY SERGESTIDAE

Lucifer hanseni Nobili* (H)

SUB-ORDER REPTANTIA

SECTION MACRURA

SUPERFAMILY SCYLLARIDEA* (M)

SECTION ANOMURA

FAMILY PORCELLANIDAE* (M)

SECTION BRACHYURA* (M)

OTHER DECAPODA* (M)

PHYLUM CHAETOGNATHA* (H)

PHYLUM CHORDATA

SUB-PHYLUM UROCHORDATA

CLASS ASCIDIACEA* (M)

CLASS APPENDICULARIA* (H)

SUB-PHYLUM VERTEBRATA

CLASS TELEOSTOMI* (M)

APPENDIX C

Systematic List of the Fishes Collected in the Training Area

PHYLUM ARTHROPODA

CLASS CRUSTACEA

ORDER DECAPODA

FAMILY PENAEIDAE

Penaeus plebejus Hess	Eastern king prawn

PHYLUM CHORDATA

CLASS ELASMOBRANCHII

ORDER RHINOBATIFORMES

FAMILY RHINOBATIDAE

Rhinobatos batillum Whitley	Common shovel-nosed ray

CLASS TELEOSTOMI

ORDER CLUPEIFORMES

FAMILY DOROSOMIDAE

Stolephorus carpentariae (De Vis)	Gulf anchovy

FAMILY CLUPEIDAE

Harengula koningsbergeri (Weber & de Beaufort)	Spotted herring

ORDER BELONIFORMES

FAMILY HEMIRHAMPHIDAE

Arrhamphus sclerolepis Gunther	Snub-nose garfish
Hyporhamphus ardelio (Whitley)	River garfish

ORDER MUGILIFORMES

FAMILY MUGILIDAE

Liza vaigiensis (Quoy & Gaimard)	Diamond-scale mullet
Mugil georgii Ogilby	Fantail mullet

FAMILY ATHERINIDAE

Pranesus ogilbyi Whitley	Common hardyhead

ORDER PERCIFORMES

FAMILY CARANGIDAE

Absalom radiatus (Macleay)	Fringe-finned trevally
Trachinotus blochi (Lacepede)	Snub-nosed dart

FAMILY LATIDAE

Priopidicthys marianus (Gunther)	Yellow perchlet

FAMILY THERAPONIDAE

Therapon jarbua (Forskal)	Crescent bass

FAMILY SPARIDAE

Acanthopagrus australis (Gunther)	Bream

FAMILY GERRIDAE

Gerres argyreus (Bloch & Schneider)	Darney Island silverbelly
Gerres filamentosus Cuvier & Valenciennes	Spotted silver-biddy

FAMILY SILLAGINIDAE

Sillago maculata Quoy & Gaimard	Trumpeter whiting

FAMILY MONODACTYLIDAE

Monodactylus argenteus (Linnaeus)	Silver batfish

FAMILY SCATOPHAGIDAE

Selenotoca multifasciata (Richardson)	Butterfish

FAMILY SIGANIDAE	
Siganus sp.	Spinefoot
FAMILY PERIOPHTHALMIDAE	
Periophthalmodon koelreuteri (Pallas)	Mud-skipper
FAMILY PLATYCEPHALIDAE	
Platycephalus indicus (Linnaeus)	Bar-tailed flathead
ORDER TETRADONTIFORMES	
FAMILY TRIACANTHIDAE	
Tripodicthys angustifrons (Hollard)	Tripod fish
FAMILY LAGOCEPHALIDAE	
Spheroides hamiltoni (Gray & Richardson)	Common toado
Spheroides pleurostictus (Gunther)	Banded toado
FAMILY TETRODONTIDAE	
Arothron immaculatus (Bloch & Schneider)	Narrow-lined toadfish

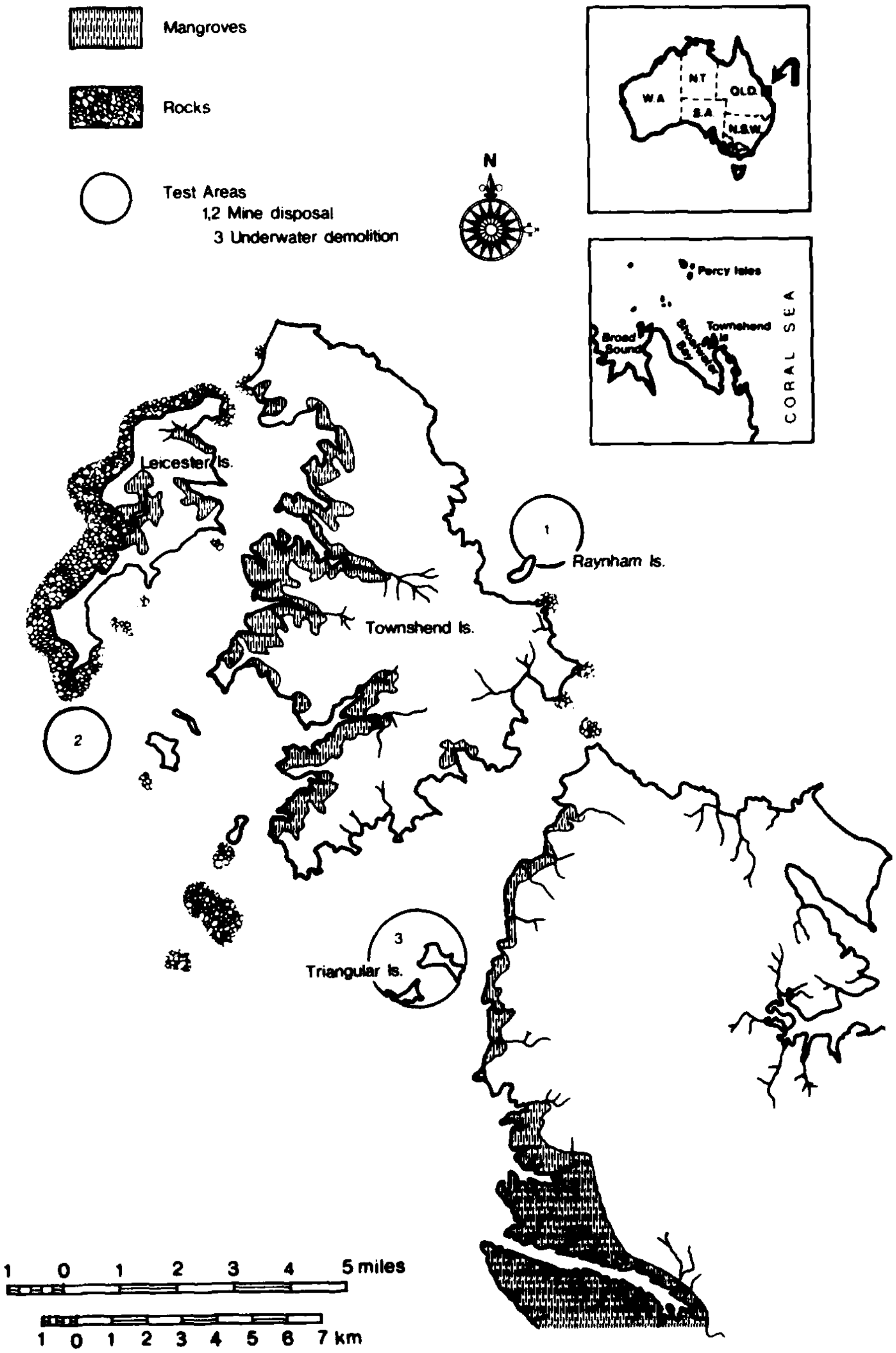

FIG. 1 - Location of the study area.

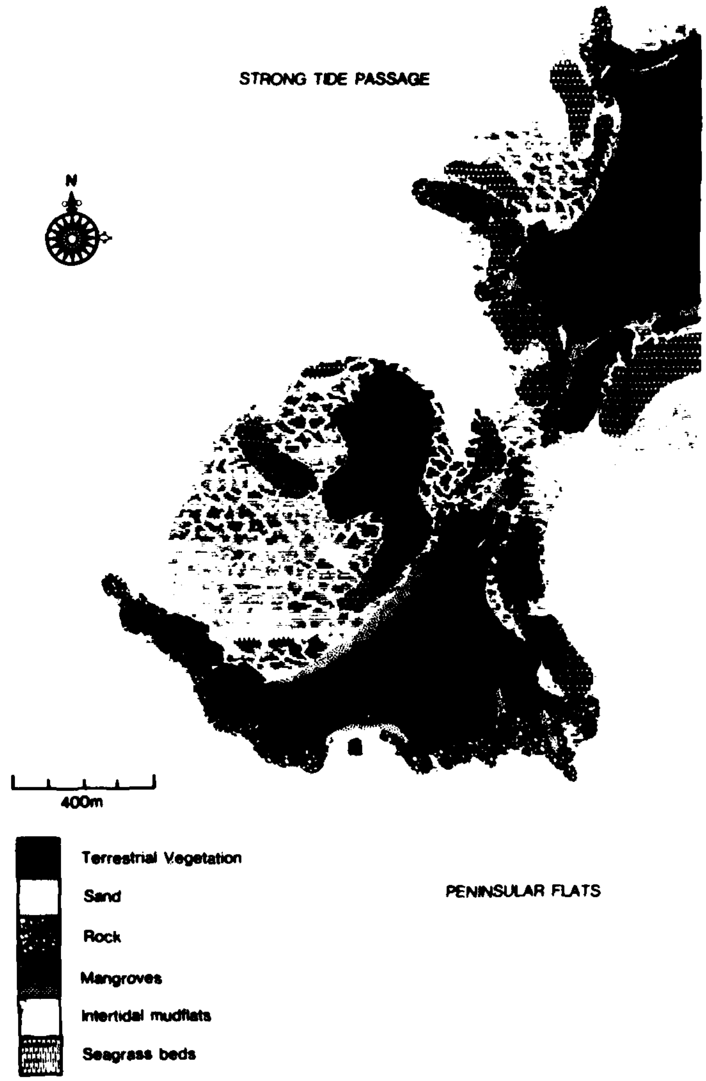

FIG. 2 - Map of Triangular Island showing the vegetation and types of substrata. (A, Little Bang Beach; B, Big Bang Beach; C, 'East Beach')

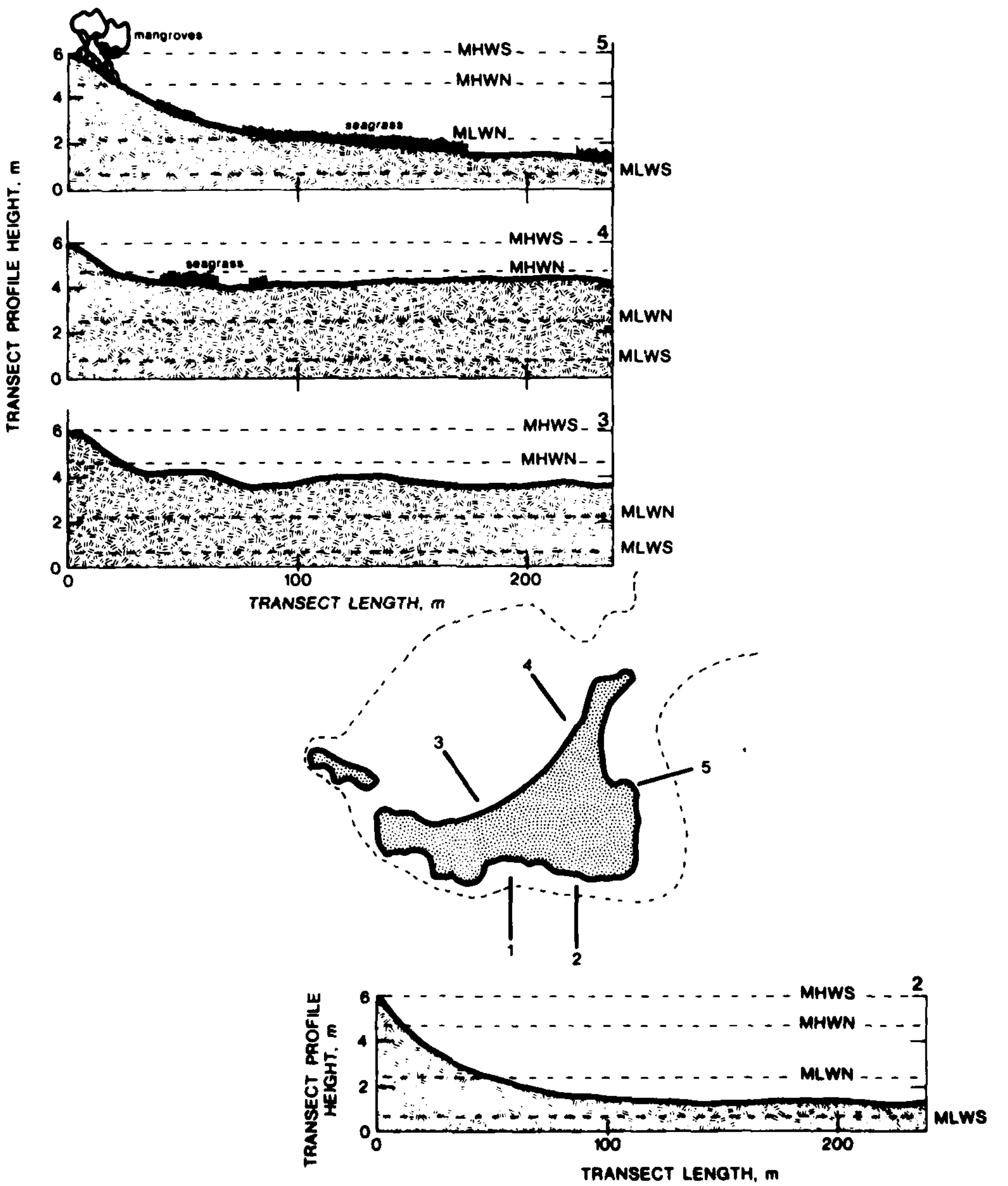

FIG. 3 - Location of transects and profiles of transects 2-5. (Transects 1, 2 Big Bang Beach; Transects 3, 4 Little Bang Beach, Transect 5, East Beach)

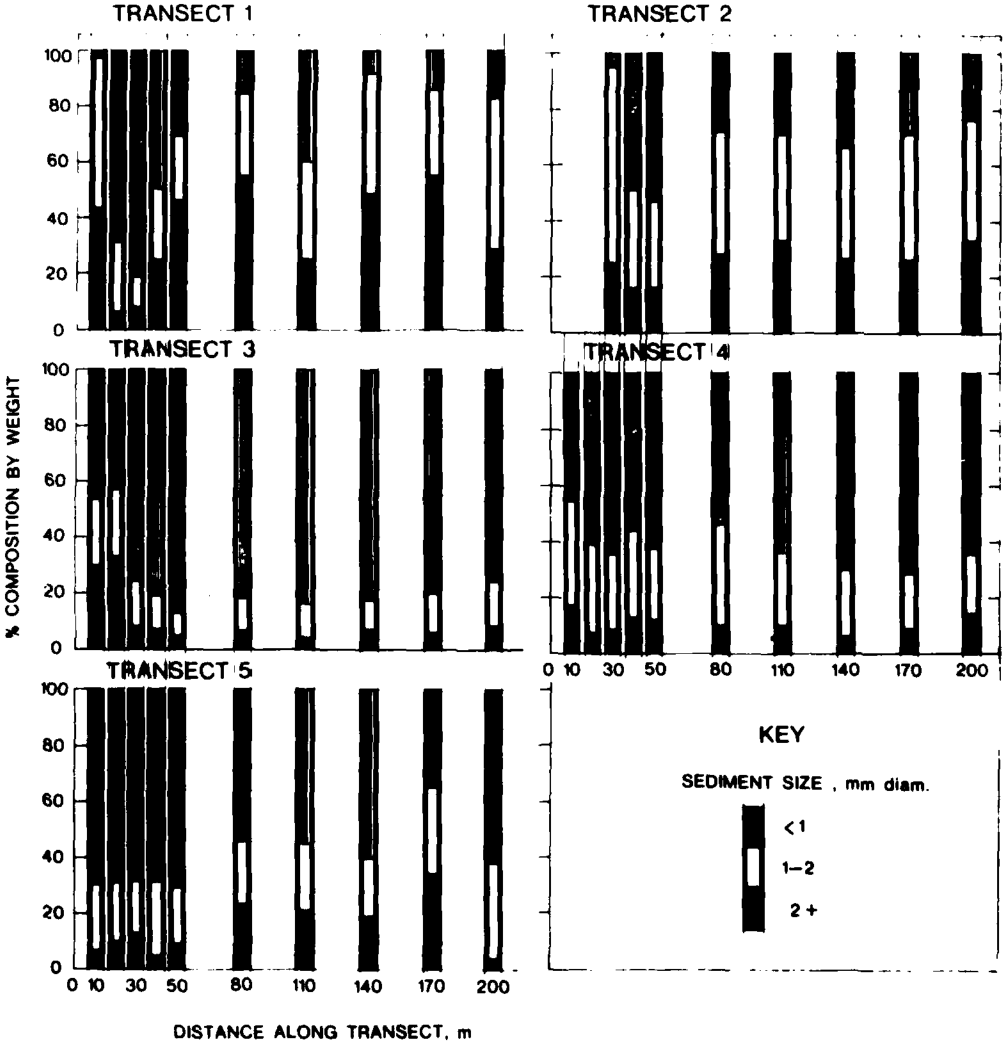

FIG. 4 - Sediment composition along transects.

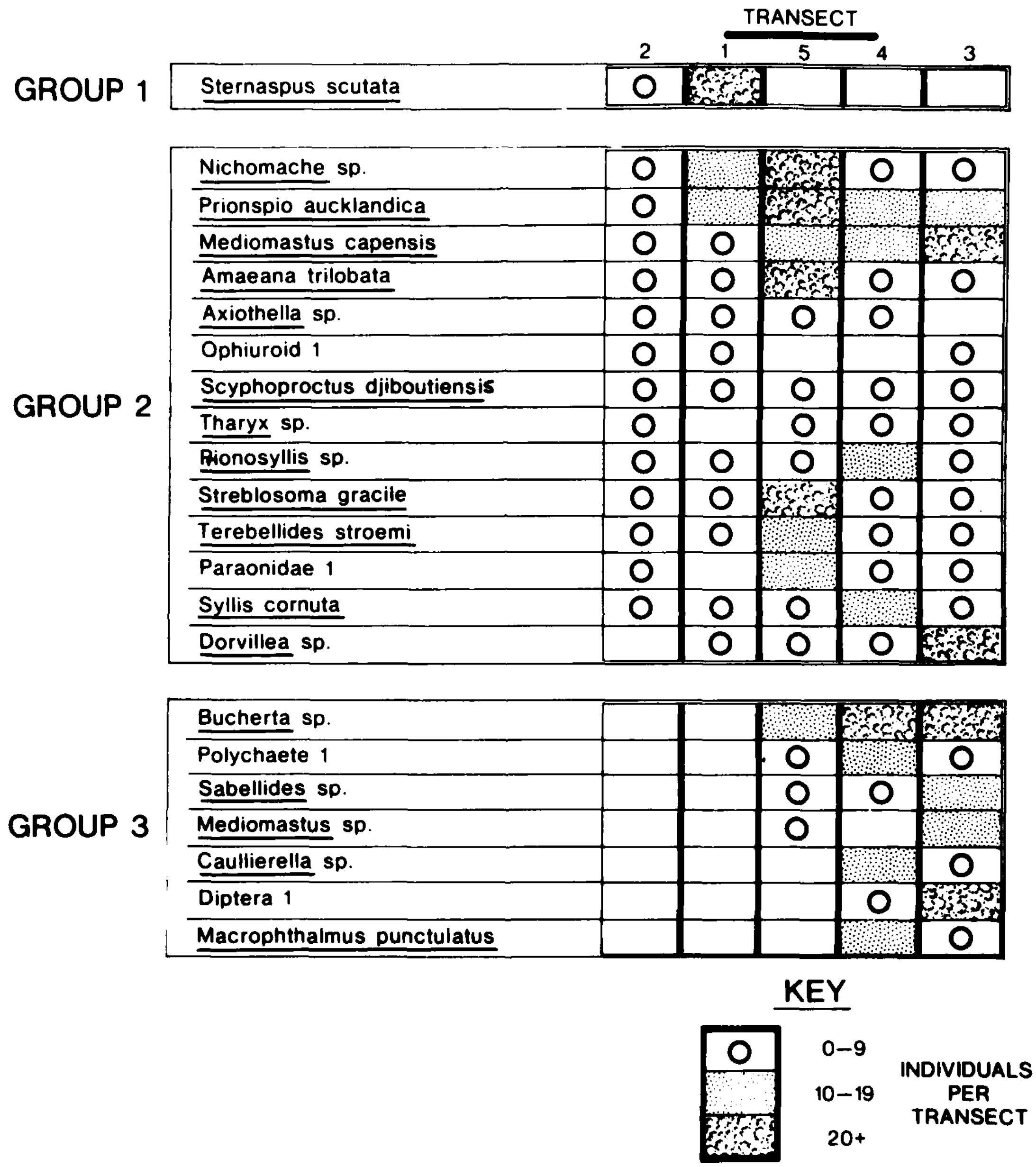

FIG. 5 – Distribution of the more common+ benthic invertebrate species around Triangular Island.

+ 15 or more individuals collected during study.

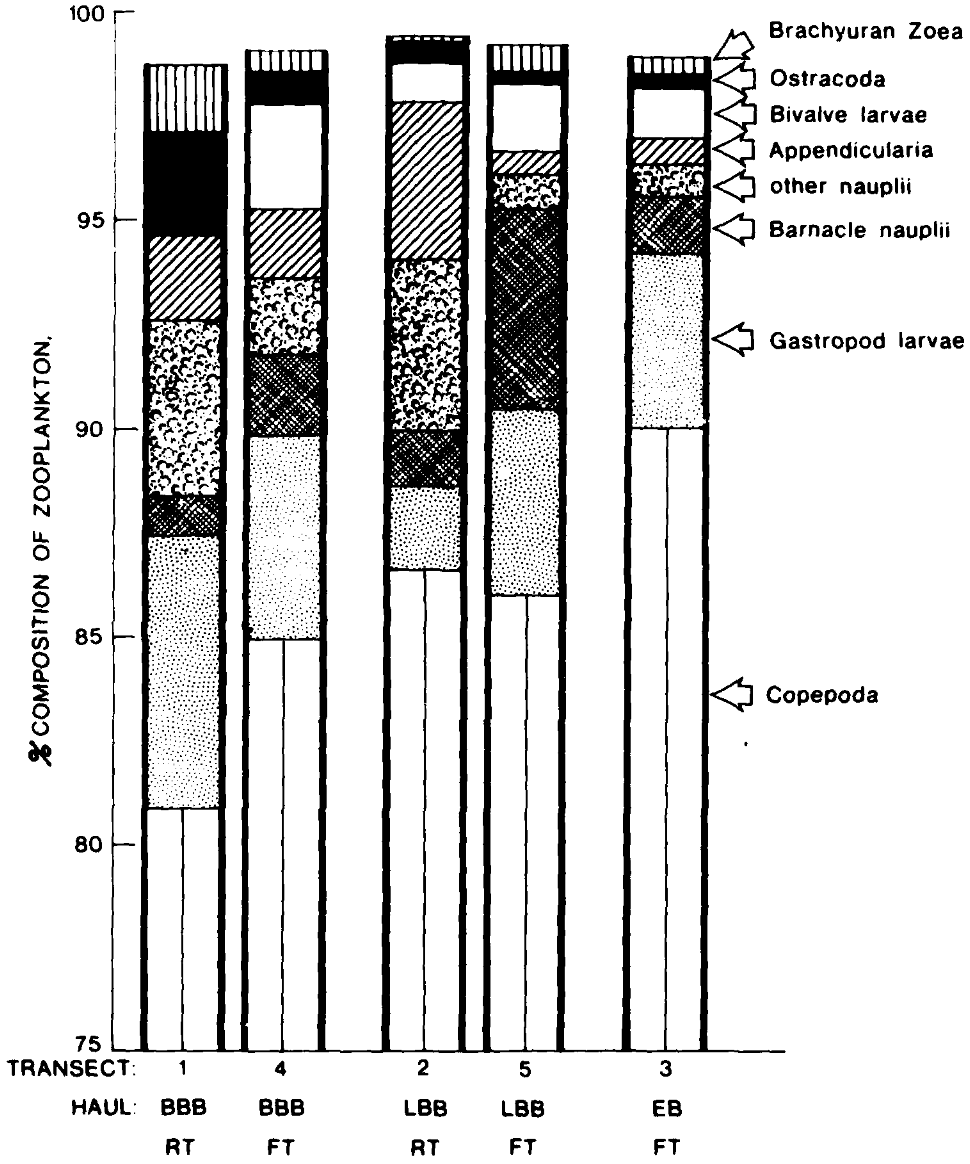

FIG. 6 - Composition of zooplankton in each of the hauls. (BBB, Big Bang Beach; LBB, Little Bang Beach; EB, East Beach; RT, Rising Tide; FT, Falling Tide).

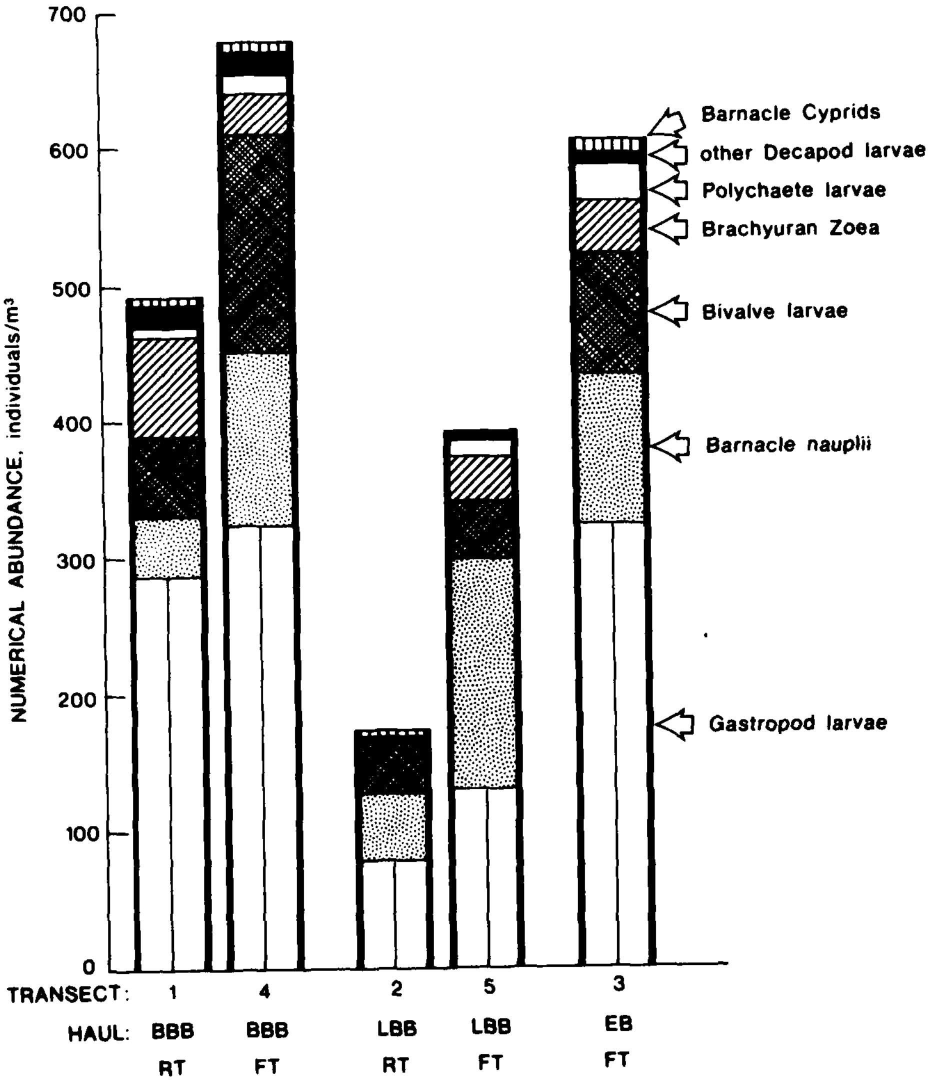

FIG. 7 - Abundance of meroplanktonic groups in each haul.

(MRL-R-810)

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