THE ZOOPLANKTON OF MSIKABA ESTUARY

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ABSTRACT

Stratification is well developed in Msikaba estuary and has a major influence on the distribution of the zooplankton. The oligohaline zooplankton component does not become well established, while marine zooplankton organisms penetrate relatively far up the estuary in the high salinity bottom waters. The euryhaline component becomes relatively well established near the mouth and it would appear that these organisms maintain their position within the estuary by vertical migration between inflowing bottom and outflowing surface waters. Seasonal means of zooplankton biomass were similar and ranged between 16 mg/m^3 of water during winter and 15 mg/m^3 during summer.

INTRODUCTION

Msikaba Estuary is situated in the northern sub-tropical area of the Transkei coastal region, South Africa, at latitude 31°19′S. It is possibly the deepest South African estuary with a maximum recorded depth of 35 m. A recurved sand-bar is well-established at the mouth and the estuary is connected to the sea by a relatively narrow and shallow channel.

Preliminary investigations indicated that salinity stratification was well developed. This study is an investigation of the zooplankton and the effect of stratification on the distribution of the zooplankton in the estuary. The study was continued over a period of one year to include seasonal changes in the zooplankton.

This study forms part of an extensive programme of research on the plankton and productivity of South African estuaries being carried out under the auspices of the South African National Programme of Oceanographic Research (Grindley 1970).

METHODS

Fields methods

Zooplankton samples were taken eight times at each of four stations, at intervals of six weeks. The locations of the stations are shown in Figure 1. The project began in May 1972 and terminated in March 1973. Zooplankton samples were also taken in November 1970 and in February 1971.

The nets used during the survey were a conical net with a mouth diameter of 36 cm for qualitative samples and a Clarke-Bumpus Plankton sampler Model No. 012WA300 for quantitative samples. St Martin's nylon mesh with aperture size 124 microns was used for each net.

Four-minute plankton tows (qualitative and quantitative) were taken at each station from

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just below the water surface. Sampling commenced about half an hour after dark from a motorized boat at a speed which did not exceed three to four knots.

Stations were mainly occupied on an incoming tide and were always worked in the same order, beginning in the uppermost reaches of the estuary.

Hydrographic observations were made immediately before each zooplankton tow. Water samples were collected from the surface and near the bottom using a Van Doorn XRB 135 water sampler. Temperature and salinity were recorded. Salinity was determined by hydrometer to within 0,5‰.

Qualitative zooplankton samples were taken at different levels of the water column during February 1971. Vertical temperature and salinity distribution was also determined for each station during November 1972 and July 1973.

Laboratory methods

Qualitative samples were systematically examined under the microscope and relative abundance of species estimated according to the following method:

1–10: Total number of a species present if 10 or less in number. ; + : Present. ; ++ : Fairly common.; +++: Common.; ++++ : Abundant.; +++++ : Extremely abundant.

Settled volumes of zooplankton were also determined from qualitative samples. Organisms such as prawns and fish (which are not truly planktonic), were removed before settled volume determinations were made.

Biomass data were then calculated from settled volumes. Grindley & Wooldridge (1974) have shown that there is a significant correlation (at the 1 per cent level) between settled volume and biomass (dry weight) in zooplankton from South African estuaries where the relatively uniform size in the organisms gives a constant packing density of settled plankton ($y = 18{,}6 \times$).

The number per species of the various species present was determined from quantitative samples. The Clarke-Bumpus plankton samples were each made up to a known volume. A sample was thoroughly stirred and a subsample of known volume removed. The total number of each species present was counted and the number per m^3 of water calculated.

PHYSIOGRAPHY

The Msikaba River system drains an area of approximately 1 100 km^2, and over much of its length the river runs through deep gorges or between steep, forest-covered slopes.

The estuary is 3,3 km in length. The margins of the estuary are characterized by rocky cliffs and outcrops of rock which descend vertically into the depths of the estuary. The cliffs vary in height from over 100 m at Station 4, to 10 m and less in the lower reaches.

The depth in the upper region of the estuary varies between 1,5 and 5 m and increases to 8 m at Station 3 (Figure 1). Below Station 3 the estuary becomes shallow, but again rapidly increases in depth towards Station 2, where at its narrowest point (Figure 1) it is about 15 m wide. This is the deepest part of the estuary and reaches a depth of 35 m. The depth gradually decreases towards the mouth and reaches 5 m at Station 1.

The narrow mouth channel which connects the estuary to the sea is constantly changing in character and in July 1973 was 5 m in width. The depth in the lower region of the channel was 0,5 m at normal high tide. At the same locality during the summer of 1970 and 1971 the channel was considerably wider and approximately 2,5 m in depth.

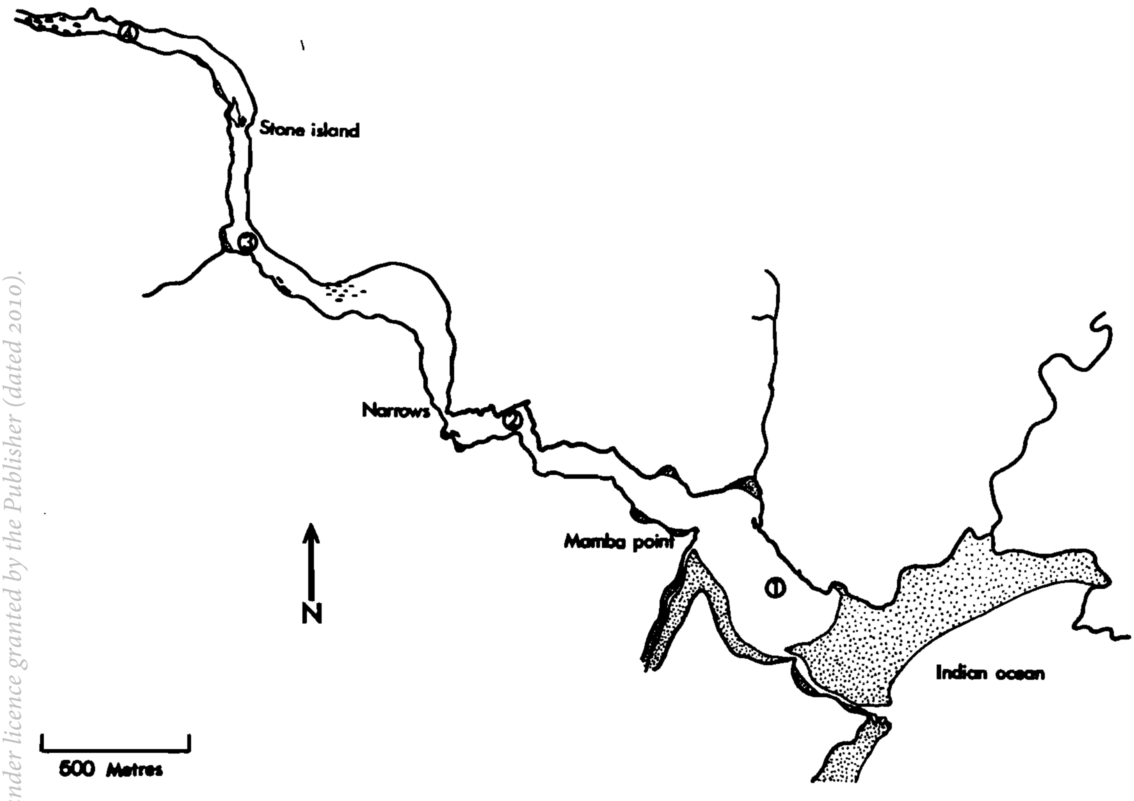

FIGURE 1

The position of the sampling stations on Msikaba Estuary.

RAINFALL

The average annual rainfall for the coastal region is about 1 445 mm. The rainfall decreases rapidly with increasing distance from the sea and in the upper reaches of the Msikaba catchment area, the average annual rainfall is only 864,5 mm. Maximum rainfall for the area falls during the months of October to April with a minimum during the winter months.

During the period of study, maximum rainfall in the catchment area was recorded in November (150 mm). During the winter months the rainfall was generally below 30 mm (Wooldridge 1974).

RESULTS

Salinity

A marked salinity stratification exists between surface and bottom waters (Figures 2–4). The stability of the bottom layers at the lower three stations is demonstrated in Figure 2 where the salinity does not drop below 33‰. Surface salinities recorded during the summer months (Figures 2, 3) are lower than those recorded from May to October (Figures 2, 4) and correspond to the higher rainfall recorded during that period. The maximum precipitation recorded in November is reflected in a sharp decrease in surface salinity throughout the estuary (Figure 2).

During August and October 1970, severe floods were experienced along part of the east coast of South Africa. In Msikaba Estuary, floodwaters had eroded a wide and deep channel through the normally well-established sand-bar at the mouth (Figure 1). High-salinity bottom waters were considerably affected by the flooding, and salinities of 23 and 23,5‰ were recorded at Stations 1 and 3 respectively, ten weeks after the August floods. The observed salinity distribution suggested that stratification had become established in the deep middle region. On 7 February 1971, the salinities of the bottom waters at Stations 1 and 3 had increased to 32,5 and 30‰ respectively, while the large vertical salinity difference recorded at Station 4 suggested that salinity stratification had become established throughout the estuary (Wooldridge 1974).

On 16 January 1973, vertical salinity and temperature observations were made at 13h00 at the lower two stations (Wooldridge 1974). Salinity stratification had broken down at Station 1 and this was due to the combined effect of high tide and a strong onshore wind blowing up the estuary. The effect was of short duration, and the stratified condition had returned when the station was again occupied at low tide the same night (Figure 2).

The evidence presented above suggests that salinity stratification is a normal characteristic of Msikaba Estuary, but may be broken down by extreme flood conditions. In the region of Station 1, salinity homogeneity may be attained for short periods due to the effects of high tidal inflow and favourable wind conditions.

Temperature

Temperature data show marked differences between surface and bottom temperatures (Figures 2, 3, 5). During the winter months, surface temperatures at all stations were lower than

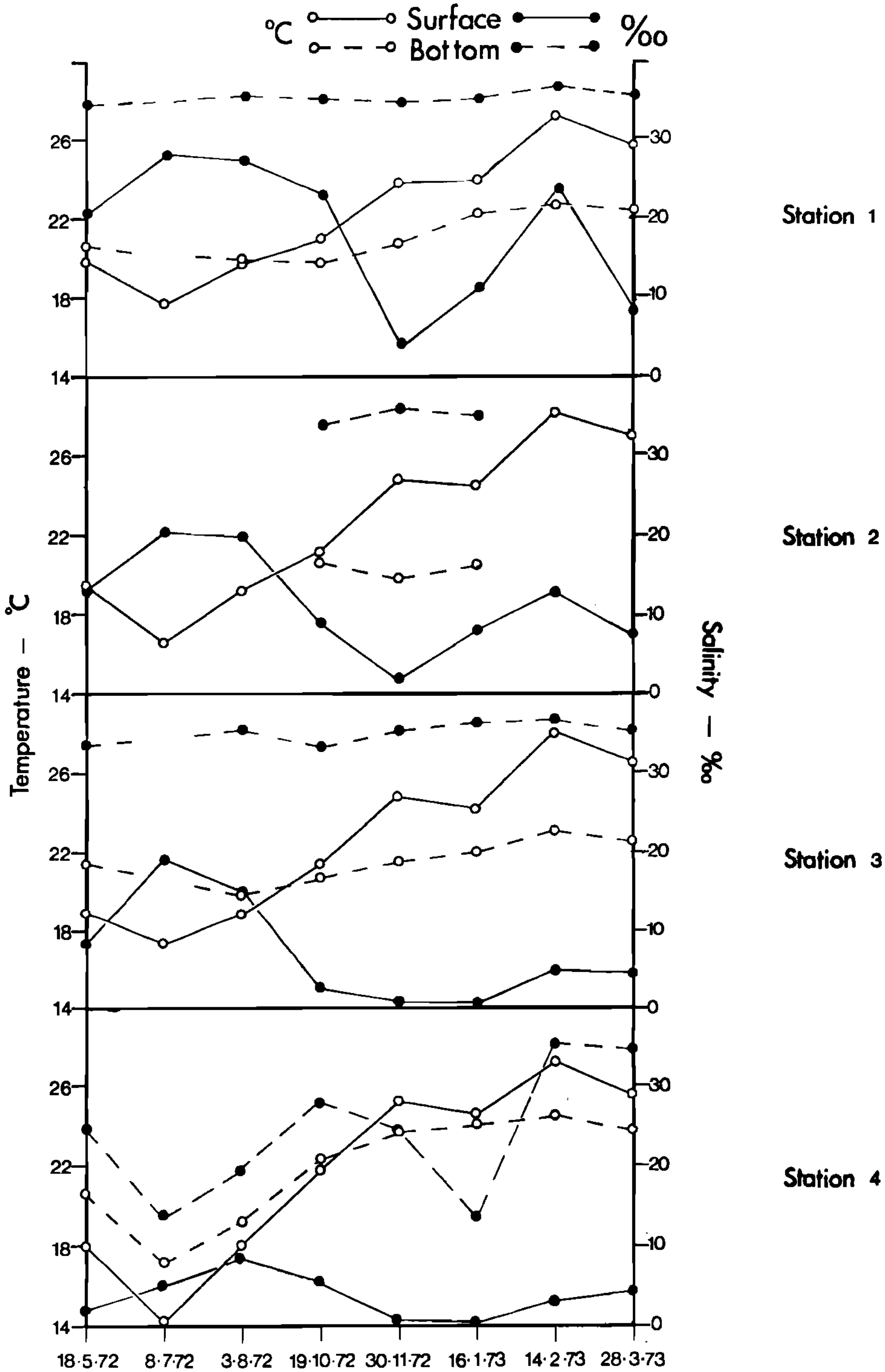

FIGURE 2
Surface and bottom salinity and temperature data, May 1972 to March 1973.

those recorded in the bottom waters. The low surface temperatures are associated with salinity stratification and cold fresh-water inflow. A temperature of 14,1°C was recorded in the surface waters at Station 4 in July 1972 (Figure 2), while in July 1973 a surface temperature of 13°C was recorded at the same station (Figure 5). This stratification is stable as at a surface temperature of 13°C and a surface salnity of 6‰ (Figures 4, 5), inversion would not occur unless

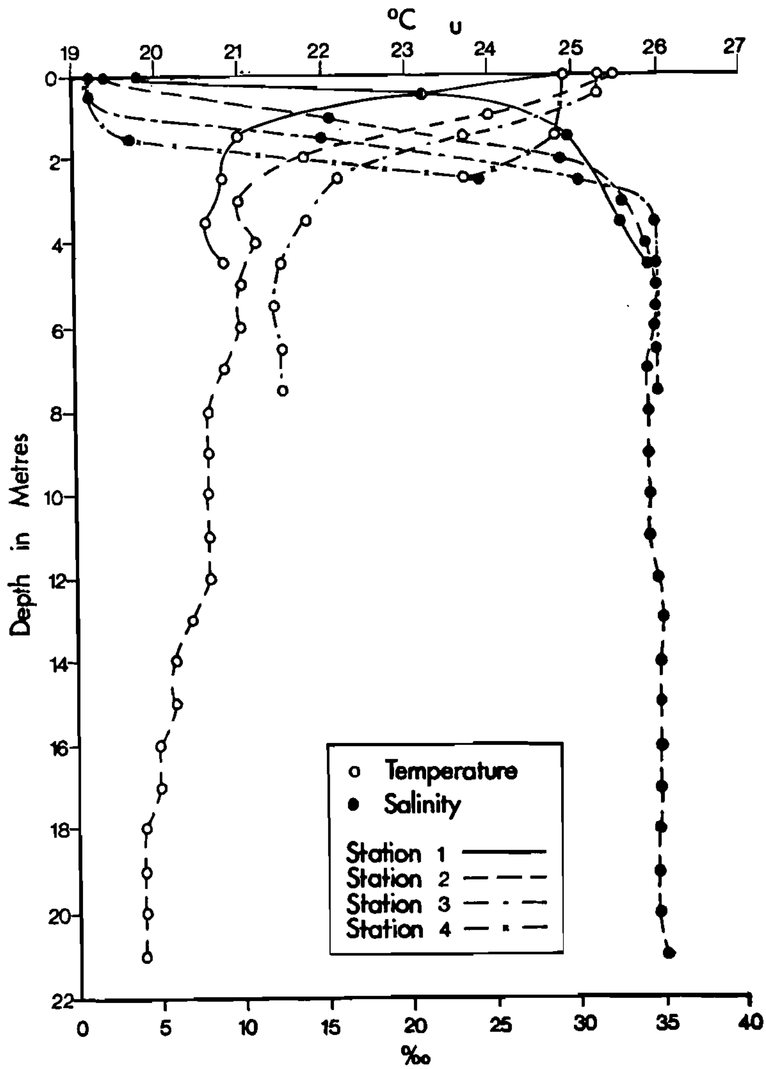

Figure 3

Vertical salinity and temperature distribution on 30 November 1972.

the salinity of the bottom water fell below 10‰ if the temperature reached 19°C. At this time the bottom water was at a temperature of 19,8°C and a salnity of 32,5‰ (Figures 4, 5: Station 4).

Figures 3 and 5 show the presence of a marked thermocline at the time of sampling in November 1972 and July 1973. In November temperatures averaged 4°C higher in the surface

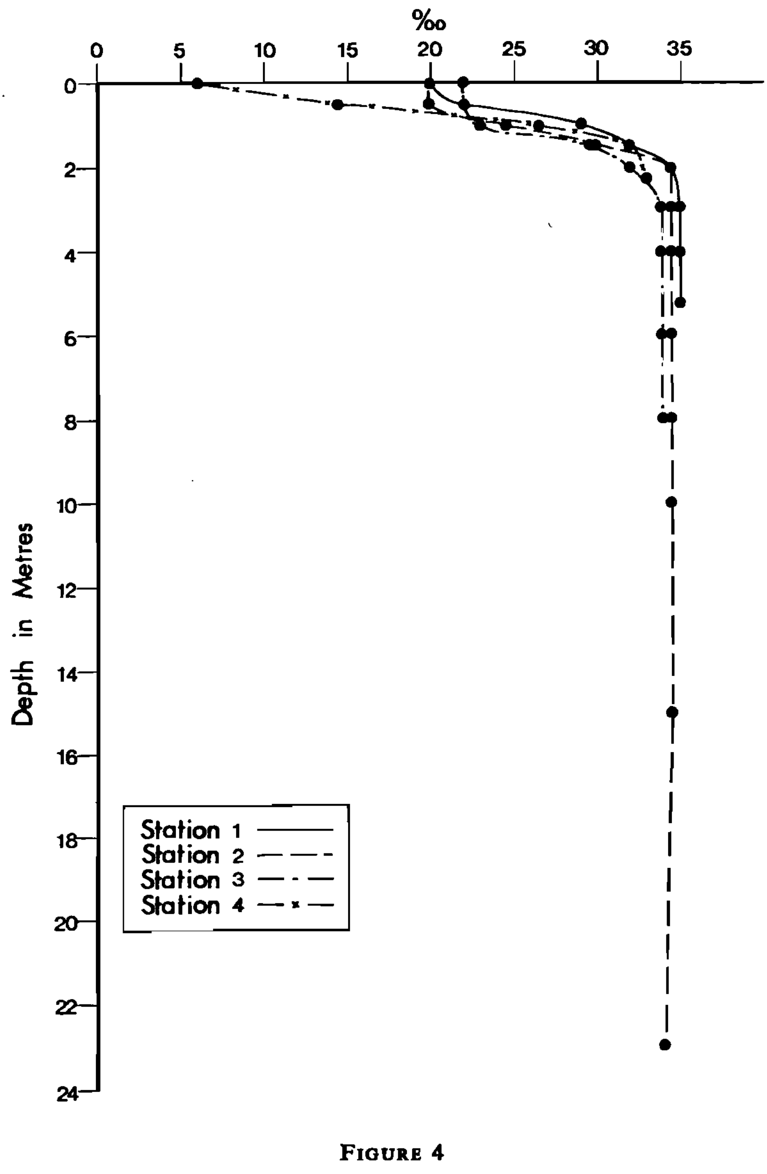

FIGURE 4

Vertical salinity distribution on 12 July 1973.

waters, while in July, the effect of the cold water inflow was well illustrated (Figure 5). Surface temperatures in the upper reaches of the estuary were almost 7°C lower than the temperatures in the bottom waters. At Station 1, a vertical difference of 3,4°C was present. The thermocline was also well established and corresponded to the depth of the salinity discontinuity layer (Figure 4).

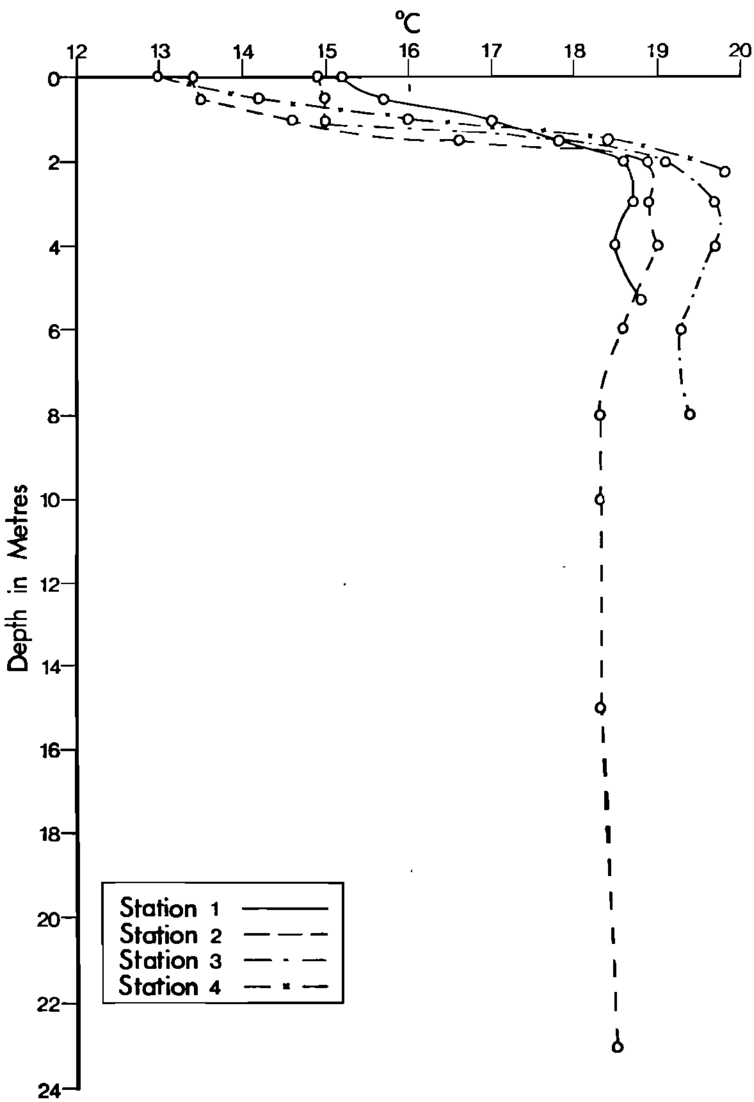

FIGURE 5

Vertical temperature distribution on 12 July 1973.

The distribution of the species

Zooplankton distribution data during the main period of study are given in Tables 1 and 2.

The zooplankton was dominated by crustacea with lesser numbers of coelenterates, annelids, insects, molluscs and other organisms. During the period of study a total of 75 species was recorded in the estuary, with a maximum number of 60 at Station 1. The number of species in the upper reaches was remarkably uniform, with 40 species at Station 2, 40 species at Station 3, and 39 species at the upper station. During the months July to October 67 zooplankton species were recorded in the estuary.

The diversity decreased in summer and did not exceed 50 species.

The most abundant zooplankton organism in the estuary was the copepod *Pseudodiaptomus hessei*. Table 1 shows *P. hessei* to be most abundant at Station 1 in August and at Station 2 in October. During the summer months *P. hessei* is less abundant, with maximum numbers in the lower reaches (3 083/m^3 at Station 2 in February: Table 2). No quantitative data are available for August, October and for Station 1 in February. Spatial distribution data show *P. hessei* to have a more variable distribution peak during the winter period. Low numbers were recorded above Station 2 during the summer and they did not exceed 178 organisms per m^3 of water.

The copepods, *Acartia natalensis* and *Oithona brevicornis* were most abundant during February at Station 2 (Table 1). The Clarke-Bumpus sampler did not function correctly at Station 1 and no reliable figures were obtained.

Mysidacea were represented by five species. *Mesopodopsis africana* was numerically the most abundant and reached maximum numbers during November at Station 1 (Table 1). Low numbers were recorded during the winter. No reliable quantitative data are available for the larger organisms such as the Mysidacea. This is probably due to avoidance action taken by organisms to the Clarke-Bumpus sampler. A single specimen of *M. slabberi* was collected in August, while a number of juveniles of an unidentified species of *Gastrosaccus* was collected in May and August. *G. brevifissura* was found throughout the estuary during the winter. During the summer it occurred in low numbers at Station 1 only.

Isopoda and Amphipoda were well represented (Table 1). *Cirolana fluviatilis, Corallana africana* and *Grandidierella* females and juveniles were common throughout the estuary, while species such as *Eurydice longicornis, Corophium triaenonyx, Melita zeylanica* and *Parorchestia rectipalma* were more abundant during the winter.

A number of species such as *Gnathia* sp., *Munna* sp., *Eriopisa chilkensis, Hyale grandicornis* and *Jassa fulcata* were encountered during the winter months in low numbers at Station 1 only.

Analysis of the 36 cm net zooplankton samples collected in November 1970 and in February 1971 are shown in Tables 3 and 4. A four-minute sub-surface zooplankton haul was also taken during normal night sampling (21h00–22h00) in February 1971. The sample was taken at a depth of 5 m at Station 1 with the 36 cm net. The results are shown in Table 4, column 1A. Three sub-surface plankton samples were also collected between 11h00 and 12h00 on the same day at Station 2 (Table 4). Column 2A is an analysis of a bottom sample collected at 23 m, column 2B is an analysis of a vertical sample from 23 m and column 2C is the analysis of a horizontal haul at about 20 m along the edge of the cliff face.

Station 1 was occupied at high neap tide in November 1970, and Table 3 shows predominantly marine plankton at this station. The marine plankton species include *Centropages*

Table 1

The distribution of the zooplankton fauna of Msikaba Estuary: July 1972–March 1973

(Numerals, actual numbers less than 11; p, present; f, fairly common; c, common; a, abundant; v, very abundant)

DATE	*18.5.72*				*8.7.72*				*31.8.72*				*19.10.72*				*30.11.72*				*16.1.73*				*14.2.73*				*28.3.73*			
STATION NUMBER	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
COELENTERATA																																
Hydroid medusae																									1	3						
ANNELIDA																																
Polychaete larvae	2	p							2																p							
Polychaete worms	2								p			p	1																			
CRUSTACEA																																
Ostracoda																																
Ostracod sp.		p				1					1		p		p	p	p		p	p		1	2		p							
Copepoda																																
Acartia longipatella									f	f	p		p	f											f				p	a		
Acartia natalensis	p	f	p	p	f	p	p	f							1			p	p		3	p	2	1	f	c	f	f	p	c	p	c
Calanoid juv.									p																							
Calanus sp.									p																							
Canthocalanus pauper					3																											
Corycaeus asiaticus																									6							
Cyclopoid sp.																									p							
Euterpina acutifrons	1				f	1							p	p											p							
Halicyclops sp. M2	p	p	p	p		p	p	p				p			1				p	p			10	p	p				p	p	p	
Halicyclops sp. M3		p			p		p			p			p	p	2		p		p	p	1				p							
Harpacticoid spp.	p	p	p	p		p	p	p		c	p	f	p	p	f	f		p	p	p	p		3		p		p	p	p		p	
Macrosetella gracilis																									p							
Microsetella norvegica	2																								p							
Microsetella rosea		1CB																														
Nauplii larvae	p	f				p	p	p	p	c	a	f		f	p	p					p	f	p	p	c	c				p		
Oithona brevicornis		p	p	p	1CB	c	f	p		p	p		p	p	p						p	p	1	p	a	v	p	p	a	v	p	p
Pseudodiaptomus hessei	p	c	c	c	p	c	c	a	v	c	c	a	a	v	c	f	f	a	f	p	c	f	c	f	c	c	p	f	f	f	f	f

DATE	18.5.72				8.7.72				31.8.72				19.10.72				30.11.72				16.1.73				14.2.73				28.3.73			
STATION NUMBER	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Mysidacea																																
Gastrosaccus brevifissura	p	9	2		1		3	1	f	2	2		5				1				1				5				10			
Gastrosaccus sp.	3								9																							
Mesopodopsis africana		2					1		p	3	4	6	5	p	4	3	a	f			3	3		1	4	p		p	c	f	p	6
Mesopodopsis slabberi									1																							
Rhopalophthalmus terranatalis		p	2						p	2							f	p			5	1	9		1	7		2	f	p	5	
Cumacea																																
Cumacean sp.									4																							
Iphinoe truncata	3				1				p				f				p												1			
Tanaidacea																																
Apseudes digitalis																			1	1				1				2				8
Tanais sp.									3																							
Isopoda																																
Anthurid sp.											1	1			1	1			6				1			1	2				p	
Cirolana fluviatilis	p	p	p	p	p	p	p		p	f	p	p		p	p	p	p	f	p	p	p	p	p	p	p	p	p	f	f	f	f	p
Corallana africana	1	p	p	p		p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	f	p	p	p	f	p	p	p	p
Eurydice longicornis	3				4				p																							
Gnathia sp.	6								3																							
Idoteid juv.	1																															
Munna sp.										p		p								2									1			
Sphaeromid juv.	2	1	3	3	2	7	2		p	p	p	p	p	p	p	p	p	p	4	1	p	5	2	1	p	p		1	p	p	3	
Amphipoda																																
Amphipod spp.									8																							
Afrochiltonia capensis		p	5	p	3	2	1	1		p	p	p			3	p	1CB		4	p				4				1		1	5	2
Corophium triaenonyx			2	p					3	2	5	p			2	p	p	2	1	p			1	p						1		
Corophium juv.							1						1																			
Eriopisa chilkensis juv.	1																															
Grandidierella bonnieri	1								p							1																
Grandidierella sp.	p	p	p	p		1			p		p	p		4		p	p	p	p	p	1		3	5				3	2		p	p
Hyale grandicornis													1																			
Jassa falcata									1																							
Melita zeylanica			3	5	2	p	p		p	f	p	p		1			1	4	1	1									3			
Parorchestia r ctipalma				1	1	1	1		2	2	p	p						2	1					1						2		
Penaeidea																																
Penaeid juv.									3	3	1	1																				
Penaeus canaliculatus						1																							1	4		

DATE	*18.5.72*				*8.7.72*				*31.8.72*				*19.10.72*				*30.11.72*				*16.1.73*				*14.2.73*				*28.3.73*			
STATION NUMBER	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Caridea																																
Alpheid larvae													p	p	3			p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
Carid juv.				1					1													1				1						
Caridina nilotica				1													1							3				1			3	4
Caridina larvae?			1CB	1												1	p	f	p	f	p	p	p	f	p	p	5	p	p	p	p	p
Palaemon juv.									1																							
Anomura																																
Upogebia larvae	7		2						6																							
Brachyura																																
Hymenosoma orbiculare						1CB			p	2	p	p	2	p	1		f	p	p		p	2	2			4			p	1CB	p	
Megalopa larvae	6	1			5	p	2	1	p	p	8	4	1				1				3	3						2			1	
Zoea larvae	p	f	f	c	f	f	f	f	p	f	f	p	p	p	f	p	p	c	p	p	p	p	5		p	p	2	3	p	p	p	
INSECTA																																
Coleoptera sp.												1																				
Diptera sp.	p		1CB		c	p	f	p	p	p	c	f			p	p			p	3												
Hemiptera sp.				p			1CB	p				f				p				3			2	5				3			1	2
Cast-off insect exoskeletons						f										f			f													
ARACHNIDA																																
Pycnogonida sp.			p		1																				2		1					
MOLLUSCA																																
Gastropoda sp.									p	p			c								p				f							
Lamellibranchia sp.												1															f	p			p	
CHAETOGNATHA																																
Sagitta sp.	4																															
PISCES																																
Fish eggs	p								1																		1					
Fish juv.											1	5					7			4	1		1						3	p		3
Fish larvae	p		f	1			f	f	4		1	p	p	p	1		2				3		2	2	p	p		3	3	p		p
Mugilidae juv.	1		1	3	1			2																								
Pellonulops madagascariensis							1																									
Therapon jarbua																							1					2				

furcatus, *Corycaeus africanus* and *Euterpina acutifrons*. Typical estuarine copepods such as *Acartia natalensis* were absent from Station 1, while *Pseudodiaptomus hessei* occurred in relatively low numbers.

TABLE 2

Msikaba Estuary: *Pseudodiaptomus hessei*, No. per m³, May 1972–March 1973

Date	*Station*	♂	*Ovig.* ♀	*Non-ovig.* ♀	*Juv.*	*Total number per m³*
18.5.72	1	11	4	14	14	43
	2	371	30	208	1008	1617
	3	324	112	279	475	1190
	4	28	113	198	498	837
8.7.72	1	4	0	2	16	22
	2	109	14	37	68	228
	3	2	4	9	14	29
	4	169	132	295	1272	1868
31.8.72	No C.B. sample					
19.10.72	No C.B. sample					
30.11.72	1	70	66	22	0	158
	2	209	40	43	29	321
	3	1	14	3	0	18
	4	0	1	1	0	2
16.1.73	1	104	91	22	671	888
	2	17	10	3	124	154
	3	49	14	30	54	147
	4	45	21	7	105	178
14.2.73	1	No. C. B. sample				
	2	1028	158	395	1502	3083
	3	32	14	18	0	64
	4	13	13	13	0	39
28.3.73	1	64	78	14	157	313
	2	57	9	9	30	105
	3	13	18	2	2	35
	4	6	21	13	6	46

TABLE 3

The distribution of the zooplankton fauna of Msikaba Estuary: 6 November 1970. For symbols see p. 24

Station No.	*1*	*2*	*3*	*4*
ANNELIDA				
Polychaete larvae	+			
CRUSTACEA				
Copepoda				
Acartia natalensis		+	+	+
Centropages furcatus	+			
Corycaeus africanus	+			
Corycaeus catus	+			
Clytemnestra scutellata	1			
Euterpina acutifrons	+			
Halicyclops spp.		+	+	
Harpacticoid spp.	+			
Harpacticus sp.	++			
Macrosetella gracilis	2			
Oithona brevicornis		1		
Oithona sp.	+			
Pseudodiaptomus hessei	++	++++	++++	+++
Cirripedia				
Cirripede nauplii	+			
Mysidacea				
Gastrosaccus brevifissura	++			
Cumacea				
Iphinoe truncata	2			
Tanaidacea				
Tanaid sp.			2	
Isopoda				
Cirolana fluviatilis	+	+	+	2
Corallana africana	++	++	++	+
Hemibranchiate sp. (juv)		1		
Amphipoda				
Corophium triaenonyx	1	2	3	2
Grandidierella sp (♀ and juv)		1	4	

Station No.	*1*	*2*	*3*	*4*
Penaeidea				
Leucifer penicillifer	1			
Anomura				
Upogebia larvae	+			
Brachyura				
Megalopa larvae		1	1	
Zoea larvae		3	1	
INSECTA				
Chironomid larvae		2		
Coleoptera sp.				3
Ephemeroptera nymphs				4
MOLLUSCA				
Gastropoda sp.	+			
Lamellibranchia sp.	+			

In February 1971, stratification was again well established at Station 1, and a predominantly estuarine zooplankton fauna was recorded in the surface waters. Of particular interest is the vertical distribution in the estuary. *Acartia longipatella* was present during the daylight hours and hours of darkness in the high salinity bottom waters. At no time was it recorded at the surface (Table 4). *Acartia natalensis* on the other hand, was also recorded in the surface waters during the hours of darkness.

Species of Isopoda and Amphipoda were absent from daylight sub-surface samples, but were present in samples collected during the hours of darkness.

The mysids, *Gastrosaccus brevifissura* and *Rhopalophthalmus terranatalis*, were collected in fairly large numbers during the hours of darkness from 5 m at Station 1. There was no evidence of their presence in the surface waters. A similar distribution was observed on a second occasion in October 1972. Although present at the surface, greater numbers of *G. brevifissura* and *Mesopodopsis africana* were present at 5 m (Wooldridge, unpublished data).

TABLE 4

The distribution of the zooplankton fauna of Msikaba Estuary: 7 February 1971. For symbols see p. 24.

Station No.	*1* Surface	*1A* Bottom 5m	*2* Surface	*3* Surface	*4* Surface	*2A* Bottom 23m	*2B* Vertical	*2C* 20 metres
COELENTERATA								
Ephyra larvae							1	+
Rhizostomid medusae						3		
CRUSTACEA								
Ostracoda								
Ostracod sp.		+				+		
Copepoda								
Acartia longipatella		+++				+++	++	++
Acartia natalensis	++	++	++	++	+	++	++	
Corycaeus catus?		1						
Euterpina acutifrons						1	1	
Halicyclops spp.	+	1	+	+	+			
Harpacticoid spp.	4(CB)		(4(CB)	+				
Oithona brevicornis	++		+++	+		+		+
Paracalanus crassirostris						+	+	
Pseudodiaptomus hessei	++	+++	+++	+++	+			+++
Pseudodiaptomus sp (juvs)						+	+	
Mysidacea								
Gastrosaccus brevifissura		++						
Mesopodopsis slabberi	1(CB)	1	1				1	
Mesopodopsis sp. (juv)						1		
Rhopalophthalmus terranatalis		++						
Isopoda								
Cirolana fluviatilis	++	++	++	++	+			2
Corallana africana	++	++	++	+	+			
Exosphaeroma hylecoetes	++	++	++	+				
Gnathia sp.				6				

Amphipoda								
Afrochiltonia capensis	2			+	1			
Ampithoidea sp (?)		2						++
Corophium triaenonyx		1	1	4	+			++
Grandidierella lignorum				1				
Grandidierella sp. (♀ and juv.)	4	+	+	+	+			
Melita zeylanica				1				
Penaeidea								
Penaeus indicus				1				
Penaeid juvs.		3	1					
Caridea								
Caridina nilotica					2			
Caridina larvae ?			2	2	++++			
Palaemon pacificus				1				
Brachyura								
Megalopa larvae		+	1	2		+	+	
Zoea larvae		1	8	1				
ARACHNIDA								
Pycnogonida sp.		1						
CHAETOGNATHA								
Sagitta sp.		1				1		
PISCES								
Fish eggs						+	++	++
Fish larvae		5						1

TABLE 5

Standing crop or biomass in mg/m³ for all stations on Msikaba Estuary.

Date	*Biomass in mg/m³*	*Seasonal average*
18.5.72	2,42	
8.7.72	8,37	
31.8.72	34,99	Winter: 15,81 mg/m³
19.10.72	17,48	
30.11.72	19,24	
16.1.73	3,53	
14.2.73	15,07	Summer: 14,96 mg/m³
28.3.73	21,99	

DISCUSSION

Estuarine plankton communities

Three major zooplankton groups may be distinguished in an estuary. The three groups were shown for the Columbia River estuary by Haertel & Osterburg (1967), and in an open, well-mixed estuary, may have the following distribution:

(a) A group tolerant of low salinities or freshwater which generally remains associated with the low salinity waters in the upper reaches of the estuary.
(b) A marine group entering the estuary from the oceans and associated with marine waters near the mouth.
(c) A third group tolerant of a wide range of salinities and endemic to an estuary.

The three groups may be distinguished in a stratified estuary, but a number of workers, including Hansen (1951), Lance (1962), Grindley (1964) and Harder (1968), have shown that the presence of a discontinuity layer has a marked effect on the distribution of the zooplankton organisms. Hansen (1951) noted the following vertical distribution of zooplankton in a stratified estuary:

(a) Migration from the discontinuity layer to the surface.
(b) Restriction to the discontinuity layer.
(c) Migration from the bottom up to the level of the discontinuity layer.
(d) Migration from the bottom through the discontinuity layer up to the surface.

Analysis of samples from Msikaba Estuary indicates the distribution of zooplankton organisms as shown by Hansen (1951), but the sampling procedure was inadequate to confirm their presence in the discontinuity layer.

Table 1 shows that marine zooplankton organisms were occasionally recorded in low numbers in surface 36 cm net tows. The marine organisms include *Canthocalanus pauper*, *Macrosetella gracilis* and *Microsetella* spp. These organisms were mainly recorded during the winter months at Station 1, when the difference in vertical salinity was minimal. In the upper reaches of the estuary, these organisms were absent in surface tows, although marine organisms were still recorded below the halocline at Station 3 (Wooldridge, unpublished data). In November 1970, salinity stratification was not well developed at Station 1, and marine zooplankton organisms were recorded in surface samples.

Fresh-water forms and organisms generally found in low salinity waters were collected below Station 4 and periodically in surface tows at Station 1. These forms include *Halicyclops* spp. and *Afrochiltonia capensis*. This component does not become well established and settled volumes in the upper reaches of the estuary were consistently low (Figure 6).

Maximum numbers of estuarine forms are found in the lower reaches at Stations 1 and 2. In open estuaries which are well mixed, maximum numbers of euryhaline forms are usually associated with the higher reaches of the estuary. Cronin *et al.* (1962) found that there is a strong layering in the Delaware River estuary during periods of high flow in winter and spring. In the Delaware River estuary the net outflow of water near the surface was complemented by a net inflow of oceanic water near the bottom. Cronin *et al.* (1962) stated that in such a two-layered system, diurnal vertical migration of planktonic organisms would successfully move organisms between inflowing and outflowing water and would therefore assist in maintaining their position in the estuary. During this period 'there was strong vertical movement with daylight concentration in deeper water and maximum night-time densities of most species near the surface'.

A mechanism similar to that described by Cronin *et al.* (1962) may be in operation in Msikaba Estuary. Organisms would maintain themselves within the estuary by a process of vertical migration through the halocline between inflowing and outflowing water. By such a process the estuarine population would be able to maintain itself in relatively high numbers near the mouth of the estuary.

Lance (1962) and Grindley (1964) have shown that the presence of a low salinity layer at the surface inhibited the vertical migration of certain species of estuarine zooplankton. Lance (1962), working on a number of estuarine species from Southampton waters, found that in an experimental water column with a single discontinuity layer, the percentage of individuals of each species which penetrated the discontinuity layer and entered the lower salinity surface waters decreased as the salinity differences between the two water layers increased. For example when the differences in salinity between the two layers was 50 per cent, between 19 and 29 per cent of two species of *Acartia* still penetrated the lower salinity water. No individuals were able to enter the zone of reduced salinity when a maximum dilution (5 per cent sea water) was used.

In the present study a similar vertical distribution of a number of euryhaline species was found. In February 1971, and again in October 1972, when a surface and bottom 36 cm net sample was taken at Station 1, greater numbers of *Pseudodiaptomus hessei* for example, were recorded in the bottom waters. In October 1972, the settled volume of the surface sample at

Station 1 was 5 ml. In the bottom sample a settled volume of 62 ml was recorded, although in addition to the euryhaline forms, marine species were also recorded. The vertical distribution of a number of other euryhaline organisms is further shown in Table 4 (column 1 and 1A). It is suggested therefore, that if the difference in vertical salinity is within the tolerance limits of a species, a certain number will migrate through the discontinuity layer, and that the number is dependent upon the difference in the vertical salinity. It is perhaps significant that the maximum numbers of euryhaline organisms are found in the lower reaches of the estuary where surface salinities are maximal. In addition, the greater species diversity recorded in the winter months could be partly due to relatively high surface salinities which fall within the tolerance range of a greater number of species.

Settled volumes and zooplankton biomass

Maximum settled volumes were recorded during the late winter and spring months (Figure 6). *Pseudodiaptomus hessei* was the dominant zooplankton organism at Station 1 in August and at Station 2 in October. The upper reaches of the estuary were characterized by low settled volumes, except during August, when large numbers of a dipteran species were recorded. During the spring and summer months the plankton was dominated by the copepod *Oithona brevicornis* and the *mysids, Mesopodopsis africana* and *Rhopalophthalmus terranatalis.*

Seasonal means of zooplankton biomass were similar and ranged between 16 mg/m^3 of water during the winter months and 15 mg/m^3 during the summer (Table 5). A maximum biomass of 35 mg/m^3 was measured in August. Comparative zooplankton biomass data are available for the Newport River estuary. Thayer *et al.* (1974) found that the average zooplankton biomass for the Newport River estuary in 1974 was 21 mg/m^3 while in 1970 it was only 14 mg/m^3. Their observations support the conclusions of Williams *et al.* (1968) who conclude that 'there is a general dearth of zooplankton in the Newport River estuary'. In South Africa zooplankton biomass data are available for Richards Bay (Grindley & Wooldridge 1974) and Mbotyi estuary (Wooldridge 1974). Seasonal means for different regions of Richard's Bay ranged from approximately 4 to 344 mg/m^3 of water. Seasonal means of 65 and 109 mg/m^3 were recorded from Mbotyi estuary (Wooldridge 1974). Zooplankton biomass data for the period of study suggests that secondary productivity was low in Msikaba estuary, with no seasonal maxima as large as those found for Mbotyi estuary and Richard's Bay.

CONCLUSIONS

Salinity stratification is well developed in Msikaba estuary. The relatively stable bottom waters are overlain by outflowing surface waters and this stratified condition is associated with the depth contour of the estuary and the narrow mouth channel over the shallow sill. Tidal velocities within the estuary are minimal and the mixing of marine and estuarine waters is slight.

Three major zooplankton groups occur, but stratification has a major influence on their distribution. Marine zooplankton organisms penetrate relatively far up the estuary in the high salinity bottom waters while organisms tolerant of low salinities do not become well established in the estuary. The euryhaline component becomes relatively well established at Stations 1 and 2,

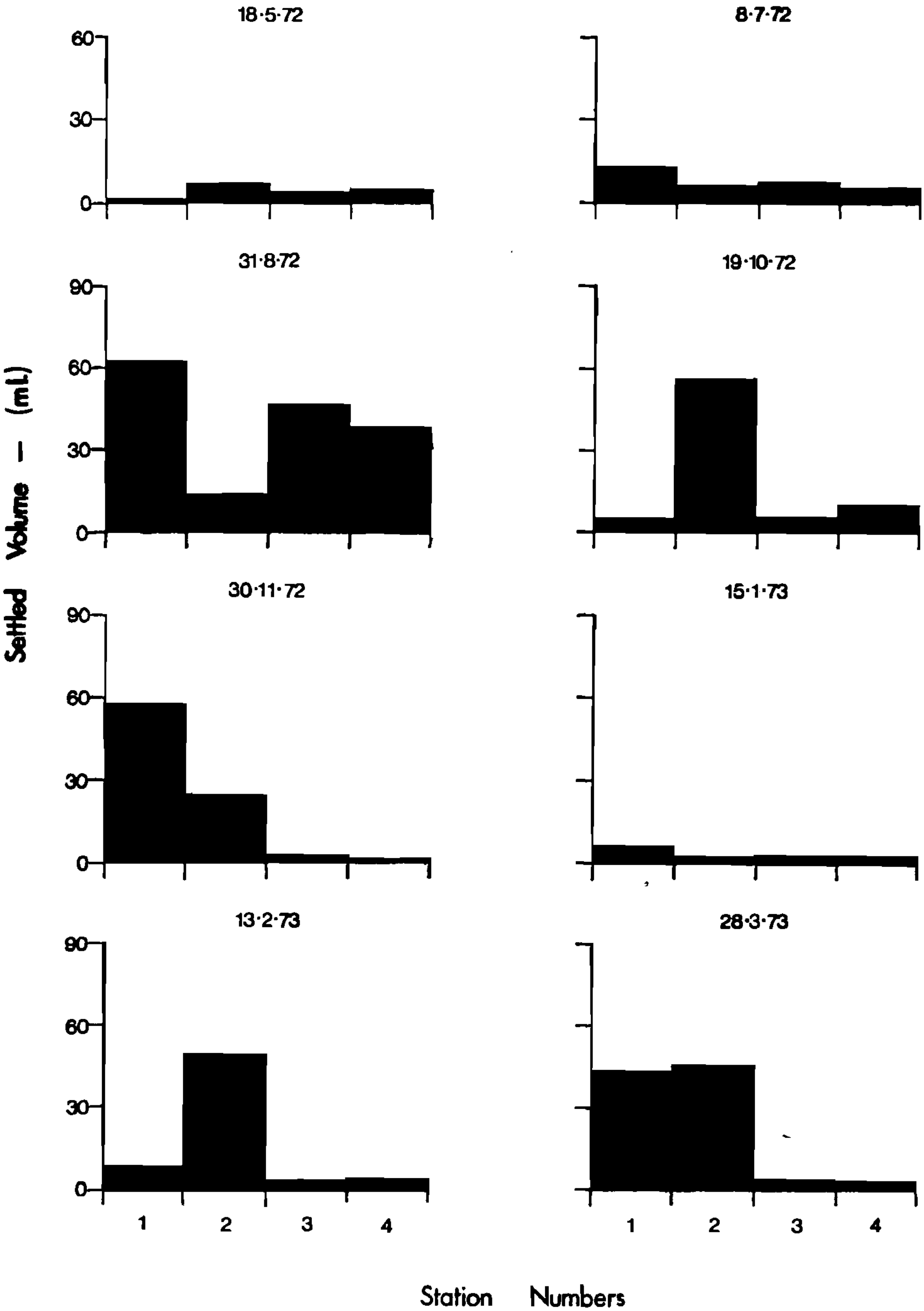

FIGURE 6

Settled volumes of zooplankton, May 1972 to March 1973.

and it would appear that these organisms maintain their position within the estuary by a process of vertical migration between inflowing bottom and outflowing surface waters. Maximum numbers of species are found during the winter months when vertical differences in salinity are minimal. The vertical differences in salinity could therefore be within the tolerance range of a greater number of species.

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