A LONG-TERM SAMPLING STUDY OF COPEPODS ACROSS A TROPICAL CREEK IN Mombasa, Kenya.

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Little attention has been given to the plankton in the inshore waters in the Western Indian Ocean along the Kenyan coast. The zooplankton changes in composition and abundance in Tudor creek near Mombasa have been discussed by Reay and Kimaro (1984).

Port Reitz is influenced by inland water influx and oceanic water, and offers nursery and feeding grounds for prawns post-larvae and fish (Groove *et al.*, 1986). Since many of the thousands of copepod taxa present in the sea may not be directly involved in prawns post-larva and larva fish food webs, the aim of this study is to identify those copepods which are the food of larval prawns and fish. As a complement to our previous investigations on the pelagic zone of Tudor Creek near Mombasa (Okemwa and Revis, 1986) we obtained six 24-h series of zooplankton samples from the Likoni Ferry. By sampling at 2-h intervals in each 24-h cycle and after every 2 months for a year, we assessed the influence of tidal cycles on the diel fluctuation of different copepod taxa. Detailed systematic analyses of copepod taxa were not performed.

MATERIALS AND METHODS

Study Area

Mombasa lies 450 km south of the equator, at latitude 4° S, longitude 40° E. Likoni Ferry is

the car ferry connecting Mombasa island with the south coast mainland across the mouth of Port Reitz Creek (Fig. 1), which has extensive areas of mangrove and open-water channels, mudflats and banks. Sampling from the ferry would enable mid-channel tows to be made at any time of day or night.

Generally, the study area experiences two wet seasons, April to June and November to December. North-easterly winds blow from November to March and south-easterly winds blow from April to October. The precise timing and extent of each season vary from year to year (Groove *et al.*, 1986). The perennial Rivers Mwachi, Mambone and Cha Shimba (Pembe) feed into the top of Port Creek, but have little influence on salinity.

The coast experiences mixed semi-diurnal tides, with a mean spring amplitude of 3.2 m and a neap range of 1.1 m (Brakel, 1982). Strong tidal currents may occur along breaks in the reef and at the opening of the creek. Sediments of Likoni Ferry are predominantly mud and some parts are covered with sand.

Sampling Procedure

Quantitative near-surface zooplankton samples were collected from the car ferry using a Cleark-Bumpus high speed sampler with a mouth area of 0.017 m². The sampler was equipped with 180 µm mesh net. The duration

Fig.1_Map of Kenya coast Mombasa showing position of study site at Likoni ferry .

of each tow was 4 min, and the speed of tow was approximately 1.6 m s^{-1} ; the speed was calculated by suspending a Braystoke current meter alongside the sampler from the car ferry. After each tow, before the contents were removed, the net was thoroughly washed with seawater. Every catch was preserved in 5% formalin. The volume of water filtered was estimated from a flow-meter fixed inside the sampler.

Samples were taken at 2-h intervals in each 24-h cycle starting from 08.30 to 06.30 hours the following day, once a month. This was repeated every 2 months from 24th April 1985 to 25th February 1986. April, June, August and October 1985 samples were taken between neap and spring tides while those of December 1985 and February 1986 were taken on neap and spring tides, respectively.

Surface water temperature was recorded using an electronic sampling oxygen meter and temperature probe (OX1 91) whenever sampling was done. Salinity was recorded using a simple refractometer, but this only recorded to the nearest percentage.

Laboratory Procedure

If a sample contained a noticeable conglomerate of detritus or phytoplankton, the zooplankton portion was separated from this material. Plankton samples were transferred to fresh water through a sieve of finer mesh (42 μm) than the original plankton netting before closer inspection. The residue was placed in petri dishes and the whole sample observed under a stereo microscope; copepods were separated from other zooplankton.

Each copepod was dissected with fine needles and parts were mounted in glycerine jelly for detailed microscopic examination. Copepods were identified by examining the antennae, antennules, mouth parts, thoracopods and furca, and using keys and reference books

(Frost and Fleminger, 1968; Bradford, 1972; and Fleminger, 1973). Copepods were usually subsampled volumetrically using a modified Stempel pipette. Five subsamples were taken from each tow; the volume of each subsample was generally being 1/10th that of the sample. In some cases samples were so sparse that the entire sample was examined. Analyses were made under a stereo microscope at $\times 10$ magnification for the bigger animals and $\times 40$ magnification for the smaller animals. The copepods in each sample were identified to approximate taxa and counted.

Data Processing

Statistical processing of copepod density taxa was effected on the 24-h series. Data covering 31 species of copepods collected by Clarke-Bumpus plankton net at Likoni Ferry, Mombasa, were used.

The variables were standardized to cater for large variations in data ranging from small fractions and zeros to hundreds. A transformation to $\sqrt{Y+1}$ was carried out according to Snedecor and Cochran (1967), and Sockal and Rohlf (1969). Cluster analyses were also used. A dendrogram was drawn by agglomeration method using squared Euclidian distance. Euclidian distances (not correlations) were used in matrices where number species was large enough.

RESULTS

Hydrological Features

Figures 2 and 3 show the distribution of surface temperature and surface salinity during the six 24-h cycles. The maximum sea-surface temperature of 28.9°C was attained in both December 1985 and February 1986. The minimum (24.0°C) occurred during August 1985 (Fig. 2).

Fig.2 Showing two hourly fluctuations in Salinity (x—x) and Temperature (—•—) on six dates, April 24, April 24/25, June 24/25, August 28/29 1985, October 30/31 1985, December 4/5 1985, February 25/26 1986, LW = Low water tide, HW = High water tide.

Fig. 3. Variation in abundance of copepods over three 24hr periods, April 24, June 24 and August 28 1985. (Total calanoid (.....), total poecilostomatoida (—○—), total cyclopoida (—●—) and total harpacticoida (—○—)). Abscissas show time of day (top hrs) and day regime bottom; stippled area indicate night tidal height (—). LW = Low water tide; HW = High water tide.

Maximum (36 ‰) and minimum (30 ‰) levels of salinity were recorded in February and June respectively. The range of salinity at the surface waters showed the maximum salinity at high tide and slightly low salinity at low tide (Fig. 2).

Biological Features

One hundred and forty-four tows were taken during the six 24-h series. Of this number, 96 hauls were taken between April and October 1985 (during the south-east monsoon). The remainder were taken in December 1985 and February 1986 (during the north-east monsoon).

The Species of Copepods

About one hundred species were identified in the samples. These are listed below in taxonomic order.

		<i>Eucalanus longiceps</i>	
		<i>Eucalanus monachus</i>	
		<i>Eucalanus subtenius</i>	
		<i>Eucalanus</i> sp.	
		<i>Rhincalanus cornutus</i>	Dana 1849
		Fam. Paracalanidae	Giesbre c h t 1892
		<i>Acrocalanus gibber</i>	Giesbre c h t 1888
		<i>Acrocalanus gracilis</i>	Giesbre c h t 1888
		<i>Acrocalanus longicornis</i>	Giesbre c h t 1888
		<i>Acrocalanus monachus</i>	Giesbre c h t 1888
		<i>Acrocalanus</i> sp.	
		<i>Bestiola</i> sp.	
		<i>Paracalanus aculeatis</i>	Giesbre c h t 1888
		<i>Paracalanus crassirostris</i>	Dahl 1894
		<i>Paracalanus indicus</i>	Wolfen den 1905
		<i>Paracalanus tropicus</i>	Andron o v 1977
		<i>Paracalanus</i> sp.	
		Fam. Calanidae	Dana 1953
		<i>Calanus darwini</i>	(Lubbo c k 1860)
		<i>Calanus minor</i>	(Claus 1863)
		<i>Canthocalanus pauper</i>	Giesbre c h t 1888
		<i>Undinula vulgaris</i>	(Dana 1849)
		Fam. Calocalanidae	Bernard 1958
		<i>Calocalanus</i> sp.	Giesbre c h t 1888
		<i>Ischnocalanus</i> sp.	Bernard 1963
		Fam. Eucalanidae	Giesbre c h t 1892
		Fam. Clausocalanidae	Giesbre c h t 1888
		<i>Clausocalanus arcuicornis</i>	(Dana 1849)
		<i>Clausocalanus farrani</i>	Sewell 1929
		<i>Clausocalanus furcatus</i>	(Brady 1883)
		<i>Clausocalanus minor</i>	Sewell

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1929		1849	
<i>Clausocalanus</i> sp. 1		<i>Centropages gracilis</i>	Dana
<i>Clausocalanus</i> sp. 2		1849	
		<i>Centropages orsinii</i>	
Fam. Euchaetidae	Sars	Giesbrecht 1892	
	1902		
<i>Euchaeta marina</i>	Prestan	Fam. Pseudodiaptomidae	Sars
	dr a	1902	
	1833	<i>Pseudodiaptomus stuhlmani</i>	
<i>Euchaeta pubera</i>	Sars	Poppe & Mrzek 1895	
	1907	<i>Pseudodiaptomus</i> sp.	
<i>Euchaeta tenuis</i>	Esterly		
	1906	Fam. Lucicutidae	
		<i>Lucicutia flavicornis</i>	(Claus 1863)
Fam. Scolecitricidae	Sars		
	1902		
<i>Scolecithrix danae</i>	(Lubbock	Fam. Aequiaptilidae	
	ck	<i>Haloptilus longicornis</i>	Claus
	1956)		
		Fam. Candaciidae	
Fam. Temoridae	Sars	Giesbrecht 1892	
	1902	<i>Candacia catula</i>	(Giesbrecht 1889)
<i>Temora discaudata</i>	Giesbrecht		(Claus
	1888	<i>Candacia longimana</i>	
		1863)	
<i>Temora stylifera</i>	Dana	<i>Candacia magna</i>	(Sewell
	1849	1912)	
<i>Temora turbinata</i>	Dana	<i>Candacia pachydactyla</i>	(Dana
	1849	1849)	
		<i>Candacia tenuimana</i>	
Fam. Metridinidae	Sars	(Giesbrecht 1889)	
1902		<i>Paracandacia bispinosa</i>	(Claus
<i>Pleuromamma indica</i>		1863)	
Wolfenden 1905		<i>Paracandacia simplex</i>	
<i>Pleuromamm piseki</i>	Farran	(Giesbrecht 1889)	
1929		<i>Paracandacia truncata</i>	Dana
		1849	
Fam. Centropagidae			
Giesbrecht 1892		Fam. Pontellidae	Sars
<i>Centropages brachiatus</i>	Dana	1902	
1849		<i>Calanopia elliptica</i>	(Dana
<i>Centropages calaninus</i>	Dana	1849)	
1849		<i>calanopia minor</i>	A. Scott
<i>Centropages elongatus</i>		1909	
Giesbrecht 1846		<i>Calanopia parathompsoni</i>	Gaudy
<i>Centropages furcatus</i>	Dana	1969	

<i>Labidocera acuta</i>	Giesbrecht 1892
<i>Labidocera kroyeri</i>	Brady 1883
<i>Labidocera laevidentata</i>	(Brady 1883)
<i>Labidocera madurae</i>	A. Scott 1909
<i>Labidocera minuta</i>	Giesbrecht 1892
<i>Labidocera orsinii</i>	
<i>Labidocera fera</i>	
<i>Pontellina morii</i>	Fleminger & Hulseman 1974
<i>Pontellina plumata</i>	Dana 1849
<i>Pontella princeps</i>	Sewel 1912
<i>Pontella</i> sp.	
<i>Pontellopsis herdmanni</i>	Thompson & Scott 1903
<i>Pontellopsis regalis</i>	Farran 1929
<i>Pontellopsis scotti</i>	
<i>Pontellopsis tenuicauda</i>	
<i>Pontellopsis</i> sp.	
Fam. Acartiidae	Sars 1903
<i>Acartia amboinensis</i>	Carl 1907
<i>Acartia bispinosa</i>	Carl 1907
<i>Acartia danae</i>	Giesbrecht 1889
<i>Acartia natalensis</i>	Connel & Grindley 1974
<i>Acartia negligens</i>	Dana 1849
<i>Acartia pietschmani</i>	Pesta 1912
<i>Acartia</i> sp.	
Fam. Tortanidae	Sars 1902
<i>Tortanus barbatus</i>	(Brady 1883)
<i>Tortanus gracilis</i>	(Brady 1883)
<i>Tortanus</i> sp.	
POECILOSTOMATOIDA	Thorell 1859
Fam. Corycaeidae	Claus 1853
<i>Corycaeus (O) agilis</i>	Dana 1849
<i>Corycaeus (D) asiaticus</i>	F. Dahl 1894
<i>Corycaeus catus</i>	F. Dahl 1894
<i>Corycaeus (C) crassiusculus</i>	Dana 1849
<i>Corycaeus (D) dubius</i>	Farran 1911
<i>Corycaeus (O) pacificus</i>	F. Dahl 1894
<i>Corycaeus (C) specius</i>	Dana 1849
<i>Corycaeus (D) subtilis</i>	M. Dahl 1812
<i>Corycaeus</i> sp.	
<i>Farranula gibbulus</i>	(Giesbrecht 1891)
Fam. Oncaeidae	Giesbrecht 1892
<i>Oncaea conifera</i>	Giesbrecht 1891

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<i>Oncaea mediterranea</i> 1863	Claus	<i>Oithona simplex</i> 1913	Farran
<i>Oncaea venusta</i> 1843	Philippi	<i>Oithona</i> sp.	
<i>Lubbockia squillimana</i> 1863	Claus	HARPACTICOIDA	Sars 1903
Fam. Sapphirinidae 1859	Thorell	Fam. Ectinosomatidae 1878	Moore
<i>Copilia mirabilis</i> 1849	Dana	<i>Microsetella rosea</i> 1849	Dana
<i>Copilia quadrata</i> 1849	Dana	Fam. Clytemnestridae	A. Scott
<i>Sapphirina auritens</i> 1863-sinuicauda Brady 1883	Claus	1909 <i>Clytemnestra</i> 1852	Dana
<i>Sapphirina lactens</i> Giesbrecht 1892			
<i>Sapphirina nigromaculata</i> 1863	Claus	Fam. Miracidae 1846	Dana
<i>Sapphirina opalina</i> 1849	Dana	<i>Macrosetella gracillis</i> 1849	Dana
<i>Sapphirina ovatolanceolata</i> Dana 1849-gemma Dana 1849		<i>Miracia efferata</i>	Dana
Fam. Clausidiidae Embleton 1901		Fam. Porcellidiidae <i>Porcellidium</i> sp.	
<i>Saphirella tropica</i> Wolfenden 1905		Fam. Tachidiidae 1909	Sars
<i>Saphirella</i> sp.		<i>Euterpina acutifrons</i> 1849)	(Dana
<i>Lichomolgidae</i> Kossmann 1877			
<i>Kelleria pectinata</i> 1909)	(A. Scott	Fam. Harpacticidae 1846	Dana
<i>Kelleria</i> sp.		<i>Harpacticella</i> sp. <i>Harpacticoida</i> sp.	
CYCLOPOIDA Burmeister 1834		Fam. Rataniidae <i>Ratania</i> Giesbrecht 1892	
Fam. Oithonidae 1913	Sars	MONSTRILLOIDA 1902	Sars
<i>Oithona attenuata</i>			
<i>Oithona decipiens</i>			
<i>Oithona (Dioithona) oculata</i>			
<i>Oithona plumifera</i> 1843	Baird	Fam. Monstrillidae 1911	Sars
<i>Oithona setigera</i> 1849	Dana		

Species Composition and Relative Abundance of Copepods

Throughout most of the six 24-h series, copepod populations formed a major portion of the zooplankton samples from Likoni Ferry. The zooplankton were diverse. Copepoda were dominant with over 100 species identified from Likoni Ferry samples. Of this total, 38 species were observed in the 24-h series of April, 50 in June, 41 in August, 44 in October, 34 in December and 42 in February. Temporal differences in species composition were also evident. Copepoda were always dominant relative to other members of the holoplankton, averaging 69% and ranging between 48 and 90%. Maximum abundance recorded in any haul was 1023 m⁻³, but the highest average of the six 24-h series was 206 m⁻³ in February, and the lowest was 60 m⁻³ in June.

Calanus darwini, *Paracalanus crassirostris*, *P. indicus*, *P. tropicus*, *Labidocera laevidentata*, and *Sapphirina lactens* are new records for the west Indian Ocean. *Oithona* spp. was always the most abundant copepod in Likoni Ferry, ranging from 5 to 21 m⁻³ in the six 24-h series. *Oncaea* spp. and *Corycaeus* spp. commonly formed the next most numerous species ranging from 4-15 m⁻³ each in the six 24-h series. In a small portion of these series, *Clausocalanus*, *Eucalanus*, *Acrocalanus*, *Acartia*, *Temora*, *Centropages*, *Paracalanus*, and *Pseudodiaptomus* spp., *Microsetella rosea*, and *Macrosetella gracilis* ranked among the ten most abundant species forming 46-77% of all copepod species and 33-55% of the total zooplankton. *Oithona*, *Acartia*, and *Temora* spp., *Harpacticoid* sp., *Macrosetella gracilis*, *Centropages orsinii* and *Pseudodiaptomus* were more abundant in the 24-h series of December and February during the north-east monsoon than during the southern monsoon in the other 24-h series.

Undinula vulgaris was present in all the sampling periods, mainly during the night at flood tide. In the 24-h series of August, *Calanopia elliptica* was found during flood tide while *C. minor* and *C. thompsoni* was found during ebb tide. *Euchaeta* spp. were found in April and June 24-h series, during flood tide on both occasions. *Candacia* spp. did not show any appreciable variation, being present most of the time at levels between 0 and 15 m in April, June, August, and October 24-h series. Their highest density coincided with flood tide in all cases.

Acartia spp. were present in all the six 24-h series. The highest density (11 m⁻³) was recorded in the 24-h series of February at 14.30 h before flood tide. Relatively low numbers were recorded in the 24-h series of June between low and high tide. *Pseudodiaptomus* spp. were found in all the six 24-h series except those in April. In August and February, numbers reaching 26 m⁻³ were recorded during ebb tide.

Eucalanus spp. were present in all the six 24-h series. The highest densities of *Eucalanus* spp. occurred at flood tide in the February series. *Pontella* spp. were present only in low numbers, which did not exceed 1 m⁻³ except on the 24-h series of October when 6 m⁻³ were caught at 06.30 h during flood tide. *Pontella princeps* occurred in the October series and was the largest copepod (6 mm) encountered. Poecilostomatoida averaged 12% of the copepod fauna (8% of the total zooplankton) in the six 24-h series. *Oncaea mediterranea* (Claus) were recorded at densities up to 45 m⁻³ in the 24-h series of April at 18.30 h during flood tide. Harpacticoida followed Poecilostomatoida and averaged 11% of the copepod fauna (8% of the total zooplankton). Harpacticoid copepods were most abundant during April and February series. *Macrosetella gracilis* (Dana) reached their maximum of 108 m⁻³ on the 24-h series of February at sunset (18.30 h) after flood.

The temperature range between October 1985 and February 1986 was 26.0 - 29.0°C. During this period, Likoni Ferry was dominated by *Acartia*, *Acrocalanus*, *Paracalanus*, *Clausocalanus*, *Temora*, *Oncaea*, *Oithona*, and *Corycaeus* spp., *Euterpina acutifrons*, and *Centropages orsinii* when sampling was carried out.

Centropages orsinii was the most abundant calanoid in the samples from the mouth of the creek (Likoni Ferry). *Acrocalanus* spp. was also significant numerically.

The samples collected during the 24-h series of April 24/25 occurred mid-way between spring and neap tides. Calanoid dominated all the samples; total calanoids showed a clear difference between day and night samples with a conspicuous peak after sunset, 2 h after flood tide (Fig. 3). The peak at 20.30 h involved high numbers of *Clausocalanus*, *Acartia*, and *acrocalanus* spp. Poecilostomatoids showed no difference between day and night, but the lowest catch was at mid-day. They showed four peaks all occurring during flood tide except one that occurred at ebb tide at 24.30 h (Fig. 3). The peaks were caused by high numbers of *Oncaea*, and *Corycaeus* spp. Harpacticoids showed two peaks at 16.30 and 02.30 h. *Macrosetella gracilis* contributed to the high density (Fig. 3). The cyclopoids showed a bimodal pattern of distribution; the peaks occurred at 20.30 and 04.30 h and were caused by *Oithona plumifera* (Fig. 3).

The samples collected during the 24-h series of June 24/25 also occurred mid-way between spring and neap tides. The pattern was determined by Calanoids, which were dominant (Fig. 3).

Poecilostomatoids showed a very clearly defined peak at sunrise and dropped quickly after 2 h. The other small peaks

occurred at 14.30 and 02.30 h during ebb tide. Harpacticoid occurred in small numbers and did not show a well defined pattern. Total cyclopoid showed only one peak at 14.30 h during ebb tide.

The samples collected during the 24-h series of August 28/29 occurred mid-way between spring and neap tides. There was no clear distinction between day and night values for calanoids (Fig. 3). The peak occurred at 08.30 h and decreased gradually, and cannot be related to the tidal cycle. Poecilostomatoids had peaks at mid-day and sunrise during flood tide. There was a small peak at ebb tide at 24.30 h followed by a great drop in density at 02.30 h and a rise as the high tide approached. Harpacticoids had a peak at 24.30 h which occurred 2 h after ebb tide. Cyclopoids showed no difference in distribution between day and night. During the day, the pattern followed the tide, becoming low at low tide and increasing with in-coming tide.

The samples collected during the 24-h series of October 30/31 occurred mid-way between neap and spring tides. This series to some extent was quite different from the previous ones, and showed no difference between day and night. Calanoids dominated the samples of copepods. The peaks at 10.30 and 24.30 h appeared during ebb tide and were due to calanoid copepodites (Fig. 4). Over the 24-h period, Poecilostomatoids showed a cyclic variation with four maxima. Harpacticoid showed a peak at 22.30 h, 2 h before ebb tide.

A conspicuous peak was recorded at 12.30 h for cyclopoids and was counter balanced by a small one at 24.30 h (Fig. 4).

The samples collected during the 24-h series of December 4/5 occurred during neap tide and showed more calanoid in the night period than during day time. The peaks coincided with ebbing tide (Fig. 4).

Poecilostomatoids showed a peak at

08.30 h with a decrease and an increase at 18.30 h, thereafter there was a fall and a rise, then another peak at 24.30 h, which coincided with ebb tide (Fig. 4). Harpacticoid showed a bimodal pattern at 18.30 and 04.30 h, 2 h after ebb tide.

A small peak of cyclopoid was recorded in the morning at 10.30 h but the maximum peak occurred at 16.30 h. These two peaks were counterbalanced by two others which occurred at around 24.30 and 04.30 h.

The samples collected during the 24-h series of February 25/26 occurred during spring tide and demonstrated very clear differences between day and night with an indication of a peak occurring around sunset and in the early part of the morning (Fig. 4). These peaks coincided with flow tide. The peaks at 18.30 and 04.30 h involved high numbers of calanoid copepodite, *Temora turbinata* and *Paracalanus* spp.

Isolated density peaks of poecilostomatoids were noted throughout the 24-h cycle; at 04.30 h, a major peak was recorded during flood tide.

Overall, much higher sample values of Harpacticoid were recorded; these showed two peaks, one at sunrise and the other at sunset, at flood tide (Fig. 4). The overall numbers of cyclopoids were low compared with other 24 h series in this study. The pattern didn't come out clearly to relate it to tidal cycle.

The Diel Cycle

A diel cycle in abundance was detected from the six 24-h series carried out. During the series, the copepods *Centropages*, *Pseudodiaptomus*, *Temora*, *Oncaea*, *Corycaeus*, and *Oithona* spp., contributed between 24 and 43% of the total abundance of the copepods. Their abundance varied between day and night. The overall abundance, and the degree of

difference between day and night samples differed between the series. Few copepod species were selected, it was found that in general, significantly more copepods were caught in the night than in the day, although there was some overlap. *Oncaea* spp. and *Eucalanus* spp. were more abundant in the night than in the day and was the opposite for *Acartia* spp. and *Centropages orsinii*. *Oithona plumifera*, *Temora turbinata*, *Pseudodiaptomus* spp. and *Corycaeus* spp. showed an overlap abundance; in certain series the day-time was more abundant than night-time while in others was the reverse.

Cluster Analysis

The dendrogram drawn from the 31 x 31 matrix (Fig. 5) enables identification of three distinct cluster samples which are homogeneous as to the relative abundance of the different species given some biotic and abiotic conditions. The results shown are consistent in that almost identical groupings of species were obtained in the separate analyses made for each of the six 24-h series. This consistency confirms the validity of the method used. The following copepod associations can be identified to sampling periods between 08.30 and 06.30h.

1. A dusk association of fourteen species: *Candacia* spp., *Pontellid nauplii*, *Sapphirina* sp., *Canthocalanus pauper*, *Pontellopsis* spp., *Euchaeta* spp., *Pontella* spp., *Euterpina acutifrons*, *Porcellidium* sp., *Pontellina* spp., *Lubbockia squillimana*, *Rhincalanus cornutus*, *Tortanus* spp., and *Copilia* spp.
2. A dawn association of ten species: *Paracalanus* spp., *Harpacticella* sp., *Eucalanus* spp., *Clausocalanus* spp., *Pseudodiaptomus* spp., *Acartia* spp., *Labidocera* spp., *Calanopia* spp., *Undinula vulgaris*, and *Microsetella rosea*.

Fig. 4. Variation in abundance of copepods over three 24hr periods October 30, December 4, 1985 and February 28, 1986. Total calanoida (+.....+), total poecilostomatoida (o.....o), total cyclopoida (x.....x), total harpacticoida (x.....x). Abscissas show time of the day (top; hrs) and day regime bottom. Stippled area indicate night. Tidal height (—) LW= Low water tide; HW= High water tide.

Fig. 5.—Dendrogram drawn from the 31x31 similarity matrix (31 is the number of Species collected by Clarke-Bumpus plankton net at Likoni Ferry)

3. A day-time association of six species: *Centropages* spp., *Temora* spp., *Macrosetella gracilis*, *Corycaeus* spp., *Oncaea* spp., and *Oithona* spp.

These species branch in various ways in the dendrogram but occur together consistently.

The rest of the species which showed lowest association or no association at all to any member of the association in Figure 5 were appearing in the samples inconsistently in the night and/or day.

Studies on the nocturnal distribution of estuarine zooplankton relative to tidal currents in the Sundays River estuary demonstrated that zooplankton was behaviourally active, rather than passive as generally conceived (Wooldridge and Bailey, 1982). During the six 24-h cycles, the copepod community samples from the Likoni Ferry included both inshore and offshore components. The occasional occurrence of *Euchaeta*, *Eucalanus*, and *Candacia* spp., and *Rhincalanus cornutus* which occur during flood tide, is indicative of a more Oceanic origin for the water mass, whereas *Pseudodiaptomus* spp., which occurred during ebb tide indicate a seaward incursion of Creek water. Similar work has been done elsewhere. Ferrari *et al.* (1985) analyzed a 24-h cycle of zooplankton samples collected at spring-tide in August 1981 in a lagoon of the Po River Delta, Sacca del Canarin and found out that density fluctuations of some taxa were greatly influenced by hydrodynamic factors, in particular by the tidal currents.

Cassie (1960) accounted for the distribution pattern of zooplankton in an area of mixing between oceanic and harbour water in terms of temperature and salinity preferences of the animals.

Cassie (1963) reviewed the literature dealing with correlation coefficients between

zooplankton species and concluded that no consistent pattern in the coefficients could be ascertained. He stated that when correlations did exist it was because the animals were reacting to one another or to environmental factors that they responded to in common. In this study the copepod population is constituted by a large number of species. Their relative abundance varies essentially as a function of oceanic water mass coming into the creek and creek water intrusion to the sea.

Specific diversity increases in the night. This implies that certain taxa migrate toward the surface during the day for *Centropages orsinii* and *Acartia* spp., and at night for *Macrosetella gracilis*.

Patriti *et al.* (1984), working at Marseilles' Vieux Port, observed over a 24-h period that *Euterpina acutifrons* was the most abundant in the late night hours and used it as reference in identifying typical port plankton. In this study, *Euterpina acutifrons* was found to increase in abundance at the surface during the night; this is a good indication of characteristic port Kilindini fauna.

SUMMARY

Surface copepod samples were taken across Port Kilindini (Likoni Ferry), Mombasa, during April, June, August, October, December 1985 and February 1986, including six 24-h series, and analysed for relative abundance. Changes were observed among abundant species of copepods, namely *Corycaeus*, *Acrocalanus*, *Oithona*, *Acartia*, *Oncaea*, *Centropages*, and *Temora* spp., and *Macrosetella gracilis*. A regular, predictable cycle caused by the spring-neap tidal and high-low tidal cycle was revealed. The night/day differences were a striking feature which was evident from the samples.

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