

## A preliminary account of two sandy beaches in South West India

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### Abstract

Observations were made on 2 beaches during the pre-monsoon period (January to March) when conditions were relatively stable. The beach below the berm at Cochin is 14 m wide with a slope of 1 in 8.5, and at Shertallai 40 m wide with a slope of 1 in 16. The well-sorted sand has a mean particle size of 275  $\mu$  at Cochin and 175  $\mu$  at Shertallai. The amount of chlorophyll attached to sand grains is very small. Chlorophyll in the water varies between 0.9 and 13.0  $\mu\text{g/l}$ . Carbon in the sand amounts to 210 to 630  $\mu\text{g/g}$ , and in the water to 355 to 3660  $\mu\text{g/l}$ . Throughout observations, the water temperature remained about 31 °C, but on the dry sand surface it reached 50 °C. Fauna zonation on the 2 beaches is similar to that of other tropical beaches; crabs of the genus *Ocyropsis* and the isopod *Eurydice* sp. occur at high water mark, the polychaetes of the genera *Glycera*, *Onuphis*, *Scoloplos* and *Lumbrineris* in the mid-intertidal region and below; the tidal migrants *Bullia melanoides* (Gastropoda), *Donax incarnatus* and *D. spiculum* (Bivalvia) and *Emerita holthuisi* (Crustacea) inhabit the wash zone of the surf. The average biomass is 0.73 g carbon/m<sup>2</sup> at Shertallai and 0.85 g C/m<sup>2</sup> at Cochin, where fewer species are present. This compares with a value of 0.63 g C/m<sup>2</sup> for a sandy beach on the west coast of Scotland.

### Introduction

Since 1965, the Marine Laboratory, Aberdeen, Scotland, has been carrying out an extensive study of the trophic ecology of a sandy beach situated within Loch Ewe, Wester Ross, Scotland. This study has included observations of seasonal fluctuations in phytoplankton biomass and production, primary production occurring in the sand (STEELE and BAIRD, 1968), meiobenthos and macrobenthos (ANSELL and TREVALLION, 1967; McINTYRE and ELEFThERIOU, 1968), epibenthic crustacean populations (MAUCHLINE, 1967, 1968), and juvenile and adult fish populations (EDWARDS and STEELE, 1968; EDWARDS et al., 1969; TREVALLION et al., 1970). As an extension of this programme, Dr. J. H. STEELE proposed, in 1966, that a study with similar aims, but centred on a sandy beach in tropical rather than north temperate latitudes would yield useful comparative data on production processes and community interrelationships in these contrasting geographical areas. With the support of the Inter-

national Biological Programme, such a study of sandy beaches on the south-west coast of India was begun in 1968 in collaboration with the Biological Oceanography Division of the National Institute of Oceanography of India; this paper presents a preliminary account of the physical conditions and the animal communities found in the 2 beaches selected for more extensive study.

### Methods

The results presented here are based on a series of visits made to the study area at 2-weekly intervals during the period January to March, 1968. Samples of the animals present were taken at stations along a transect extending at right angles to the wash zone, starting near high water mark at the seaward edge of the berm where there was usually a sharp change in the slope of the beach and in the condition of the sand. At each station a metal quadrant (area 1/10 m<sup>2</sup>) was forced into the sand, which was then dug out to a depth of 16 cm and washed through a sieve of 1 mm mesh. The material retained on the sieve was immediately preserved for later examination in the laboratory, when the total number of each species and the wet weight (formalin preserved) were determined. Where required, wet weights have later been converted for comparison to dry weights by use of conversion factors based on drying aliquots at 60 °C.

For particle size analysis, samples of sand from the top 10 cm of the sediment were collected from a number of stations. These samples were washed in fresh water, dried, and passed through a series of sieves ranging in aperture size from 63 to 3350  $\mu$ . Cumulative curves were drawn from each sample, and median diameters and sorting coefficients calculated (Table 2).

### Physical and chemical features of the study areas

The south-west coast of India, bordering the state of Kerala near Cochin, consists of an almost continuous

stretch of straight sand beach with no sheltered bays. The only interruptions are inlets into the extensive backwater system inland to the coast (Fig. 1). Much of the area is subject to seasonal beach erosion, and this has led the Indian government to establish breakwaters in an attempt to prevent massive transport of sand. Two areas were chosen for study: one, at Cochin, is situated just south of the entrance to the Cochin

affected by salinity changes arising from the great fresh-water outflow from the backwaters during the south-west monsoon season, extending from May into November (DARBYSHIRE, 1967).

The data collected from the physical and chemical measurements made during the period January to March, 1968 are summarised in Table 1. This period is one of relatively stable conditions both in relation to

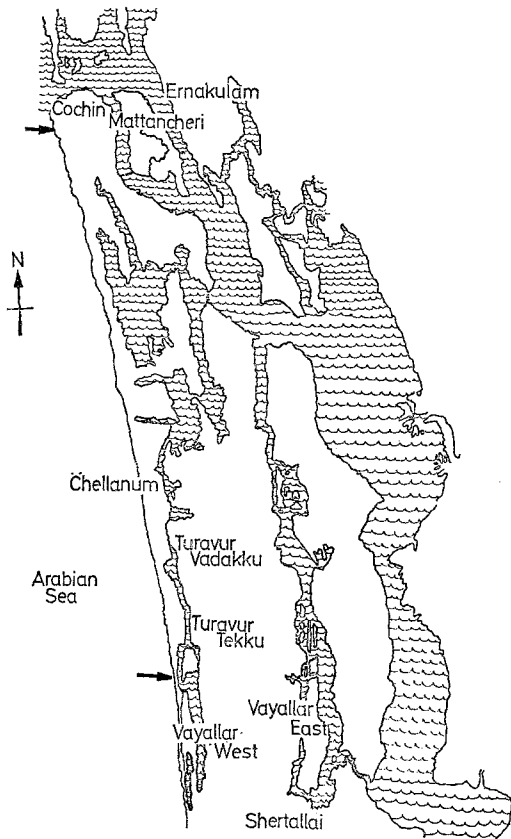


Fig. 1. Map of Cochin Backwaters and adjacent areas. The arrows show the location of the beaches referred to as Cochin and Shertallai. Scale:  $\frac{1}{2}'' = 1$  mile

backwaters; the other, near the town of Shertallai, is approximately 20 miles south of Cochin.

The tides in the region of Cochin are of a mixed type with a strong semi-diurnal influence; diurnal inequality is large (Fig. 2). The mean spring range is 64 cm (2.1 ft). During the period January to March, 1968, the maximum predicted spring tide amplitude was 90 cm; the minimum neap tide amplitude 46 cm. Wave action is continuous; waves result from ocean swell from the southern Arabian Sea. The currents along the Kerala coast flow northwards during November to January, and southwards from May to early September. Coastal areas are particularly

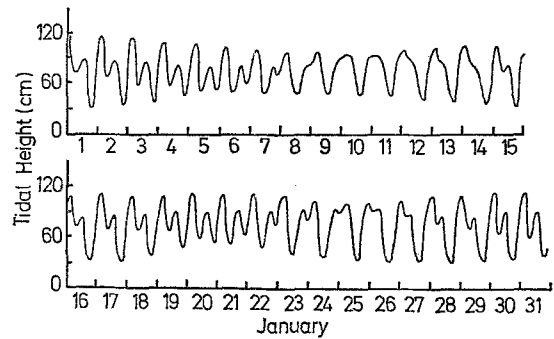


Fig. 2. Predicted tides for Cochin for the month of January, 1968, illustrating the range and form of the tidal cycle in the study areas

Table 1. Summary of physical and chemical measurements made on Shertallai and Cochin beaches, January to March, 1968

Measurements	Cochin	Shertallai
Width of berm	approximately 60 m	45 m
Width of beach (below berm)	14 m	40 m
Slope of beach	1 in 8.5	1 in 16
Mean sand particle size	275 $\mu$ (with patches 350 $\mu$ probably eroded from berm)	175 $\mu$
Temperature ( $^{\circ}$ C)		
at sand surface	30 - 40	32 - 50
at 5 cm	31 - 32	32 - 37
in water	31 - 34	31 - 34
Salinity ( $^{\circ}$ / $_{\infty}$ )	31.6 - 33.84	34.2 - 34.7
Chlorophyll		
in sand $\mu$ g/g	0.0 - 0.021	0.02 - 0.07
in water $\mu$ g/l	0.945 - 2.45	2.244 - 13.28
Carbon		
in sand $\mu$ g/g	210 - 630	255 - 525
in water $\mu$ g/l	355 - 1800	870-3660
Phosphate $\mu$ g at/l	1.21-2.82	0.823-2.7
Wave frequency	1 wave per 6-8 sec	1 wave per 6-8 sec

beach erosion and in the characteristics of the offshore waters DARBYSHIRE, (1967). Both beaches showed an extensive berm, with a steep scarp at the seaward end where the sand has been eroded by the tide at high water mark. Below the scarp, the intertidal region at Shertallai slopes seaward, with a gradient of 1 in 16,

Table 2. Particle size analysis of sand from Shertallai and Cochin beaches

Station	Metres below berm	Median particle size ( $\mu$ )	1st quartile ( $\mu$ )	3rd quartile ( $\mu$ )	Q d $\Phi$	So	% < 63 $\mu$	
Shertallai	1	3	180	150	210	0.23	1.17	0.15
	2	6	175	140	205	0.28	1.21	0.08
	3	9	160	130	200	0.31	1.24	0.13
	4	12	160	130	200	0.31	1.24	0.15
	5	15	180	133	235	0.40	1.33	0.85
Cochin	1	0	315	210	420	0.50	1.41	0.03
	2	2	290	157	370	0.60	1.53	0.02
	3	4	265	186	350	0.45	1.37	0.08
	4	6	290	200	380	0.45	1.38	0.03
	5	8	315	270	390	0.26	1.20	0.001
	6	10	315	210	420	0.50	1.41	0.05
	7	12	360	260	560	0.54	1.47	0.01

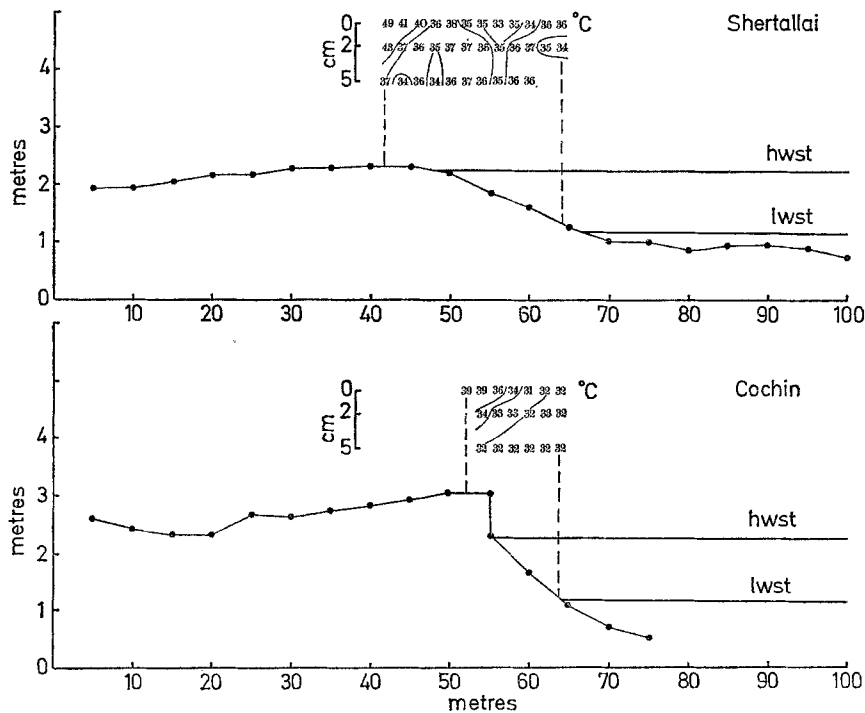


Fig. 3. Beach profiles for Shertallai and Cochin, with temperatures over the intertidal region taken at low water during the day. Temperature values rounded up to the nearest degree centigrade

while the beach at Cochin is much steeper with a slope of 1 in 8.5. Representative vertical profiles for the 2 beaches during this period are given in Fig. 3. Sand samples for granulometric analysis were taken near low water mark and at intermediate points along the transect, and the results are given in Table 2. Cumulative curves were plotted for each sample (Fig. 4), and median diameters and sorting coefficients calculated. Two sorting coefficients are given, one, defined as the

square root of the quotient of the first and third quartiles, for comparison with similar calculations made by McINTYRE (1968) and McINTYRE and ELEFThERIOU (1968) for various tropical and temperate beaches, and the other, Qd  $\Phi$ , defined as  $(\Phi_3 - \Phi_1)/2$  where  $\Phi_3$  is  $\log_2$  of the third quartile and  $\Phi_1$  is  $\log_2$  of the first quartile (KRUMBEIN, 1934). At Shertallai the fine, well-sorted sand of the type illustrated by these figures formed much of the berm, and also a layer of

varying depth over the intertidal region of the beach. Below this layer was a coarser sediment consisting largely of shell fragments, which is not represented in the granulometric analysis. At Shertallai, there was some indication during the observation period that beach erosion and build-up processes were alternating in similar fashion to those described by LA FOND and PRASADA RAO (1954), with material eroded from the berm during spring tides being deposited over the beach, thus increasing the thickness of the fine sand layer.

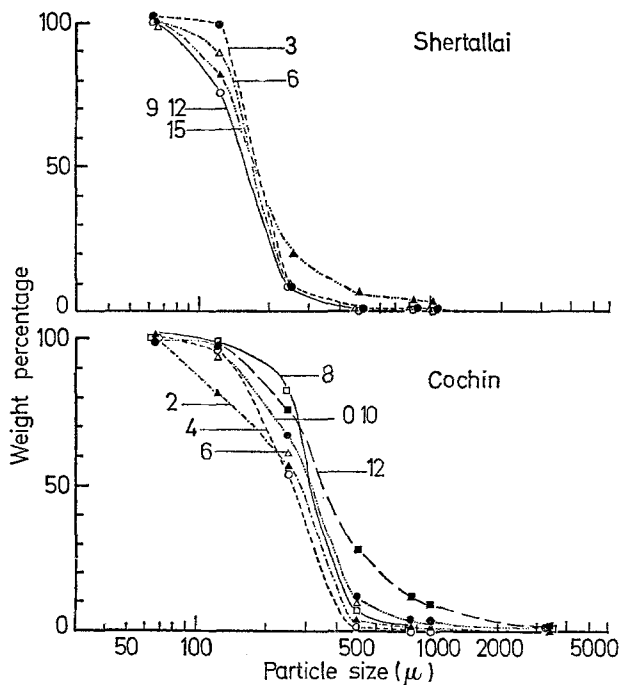


Fig. 4. Cumulative curves of particle size analysis of sand from Cochin and Shertallai beaches. The numbers refer to the distance, in metres seaward of the berm scarp at which each sample was collected; hwst: high water spring tide; lwst: low water spring tide

Temperatures along the line of the transect are shown in Fig. 3. Variable temperatures at the sand surface depend on several factors, including wind and length of exposure to the sun. Damp sand, and sand recently uncovered by the sea, tend to approach sea temperature, which was about 31 °C during the 3 months. Exposure to sun in the intertidal region raises the temperature at 5 cm as high as 37 °C while at the surface, and especially above high water level, much higher temperatures are recorded. A rapid change in sand temperature at all depths coincides with the scarp of the berm. In the shallow water of the incoming tide, the heat of the sand raises the water

temperature a few degrees. Sand temperatures at Shertallai are higher than those at Cochin, and this may be due to the difference in slope and exposure of the beaches. Shertallai beach, which is extensive and shallow-sloping, is dry for long periods, and never covered to such a depth as Cochin. At Cochin, the beach is so narrow that even at low tide the surf frequently washes almost to the top of the beach.

The lower salinity at Cochin is due to the proximity of the channel leading to the backwaters and the consequent mixing with brackish water. However, fresh-water runoff is minimal for the period between January and March, and much lower surface salinities at both beaches may be expected to occur during the time of the south-west monsoon rains during May to September. Chlorophyll and carbon measurements in the surf water suggest that the Shertallai area is the more productive, but phosphate and organic matter content of the sand is similar in the 2 areas.

#### Animal communities

The distribution of species at Shertallai, along a transect from high water mark to the level of the wash zone, is shown in Fig. 5. Above high water mark the berm slopes downward to a marshy hind-beach, in which the burrows of fiddler crabs are common. At around high water mark burrows of the ghost crab *Ocypode ceratophthalma* (PALLAS) are abundant, but these were not sampled quantitatively. The isopod *Eurydice* sp. occurs in a zone around mean high water and, at the time of these collections, the megalopa larvae of *Ocypode ceratophthalma* were common at about this tidal level, that is somewhat lower than the main centre of distribution of the adults.

The mid region of the intertidal zone is characterised by several species of polychaete worms whose distribution extends down into the surf zone. The most common of these are *Onuphis eremita* AUD. and MILNE EDW., *Scoloplos marsupialis* SOUTHERN, *Lumbriconereis latreilli* AUD. and MILNE EDW., and *Glycera alba* RATHKE. The wash zone of the surf is characterised at Shertallai by *Donax incarnatus* GMELIN, by the mole crab *Emerita holthuisi* SANKOLLI and by the Stenoglossan gastropod *Bullia melanoides* (DESHAYES). All 3 of these species are tidal migrants. *Donax incarnatus* was found at both Shertallai and Fort Cochin and, in both areas, numbers of individuals could be found in a zone near high water mark where they had been stranded at the time of the previous high tide. Also in the wash zone, and extending a little into the intertidal region, are found 2 other bivalve species: the mactrid, *Mactra olorina* PHILIPPI and the venerid *Timoclea imbricata* SOWERBY. A pagurid crab *Diogenes custos* is also fairly common in the wash zone.

The beach at Cochin produced fewer species, but the distribution of the dominants was similar to that at Shertallai. Scattered burrows of an ocypodid crab

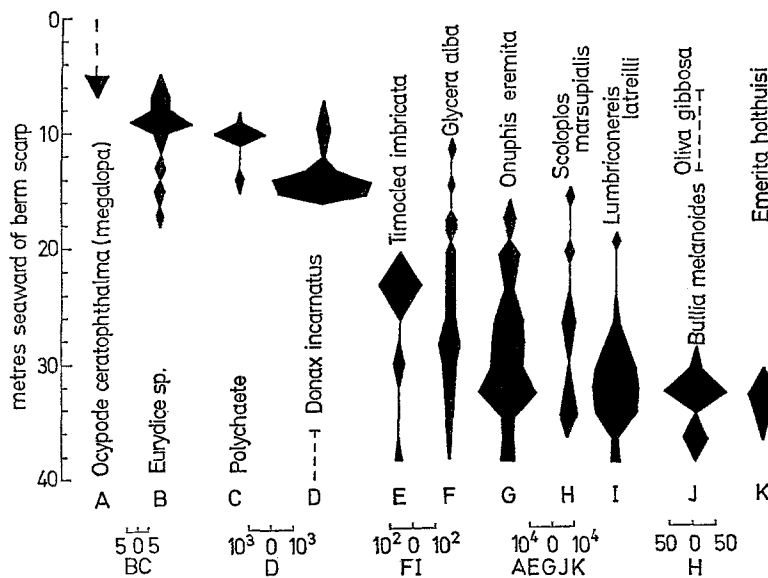


Fig. 5. The vertical distribution of the fauna on the beach at Shertallai, 29 January to 7 February, 1968. Scales are given as mg/wet weight organic matter (excluding shells) per  $1/10 \text{ m}^2$

occur around high water spring tide, but none were taken in the quantitative samples. *Eurydice* sp. was found just below this zone. On this steeply sloping beach the intertidal zone is narrow and extends little farther than the wash zone; the other species taken all extend into the area of the beach washed by surf at low water. The tidal migrants *Emerita holthuisi* and *Donax incarnatus* are characteristic inhabitants of this zone, together with another smaller *Donax* species *D. spiculum* REEVE. There were fewer species of polychaetes on this beach and the gastropod *Bullia* was not found.

### Biomass

Estimates of the biomass of the macrobenthos based on these preliminary surveys suggest a figure of 110 g/m traverse from high to low water, or 9.2 g/m<sup>2</sup> averaged over the beach for Cochin, and 250 g/m traverse or 7.4 g/m<sup>2</sup> for Shertallai. These figures are for the formalin-preserved wet weight. Corresponding dry weights calculated using the conversion factors of 0.2 for crustacea; 0.25 for bivalves, 0.3 for gastropods, and 0.1 for polychaetes are 1.7 g/m<sup>2</sup> averaged over the beach for Cochin, and 1.46 g/m<sup>2</sup> for Shertallai. These estimates are, at best, very approximate, based as they are on few samples; certain elements of the fauna are not included. The ocyppid crabs (which occur abundantly near high water mark) were not sampled quantitatively. The entrances to their burrows are obvious large holes which occur at a density of about 1/m<sup>2</sup>. The fiddler crabs at the landward side of the berm at Shertallai were also excluded from examination. Moreover, the estimated numbers of tidal

migrant species are probably lower than their true abundance, since the wash zone of the surf is difficult to sample quantitatively, and because the species involved tend to occur in large patches which move their position horizontally along the beach.

Another group of species which are not represented in the biomass figures, but may have some considerable importance in areas of the kind studied, are seasonal migrants. At Shertallai, the predaceous gastropod *Oliva gibbosa* (BORN) was found in moderate numbers near mean high water during January, its presence being apparent from small mounds left in the sand where it had burrowed under the surface. Despite searching, none were found subsequently in February or March. It is not clear whether the disappearance of this species was due to predation by the local fishing community, or to offshore migration, but a similar seasonal appearance of *O. gibbosa* at Madras for a short time during February was noted by CRICHTON (1942).

Few biomass data are available for other sandy intertidal areas. However, for one temperate beach,

Table 3. Comparison of macrobenthic biomass of Shertallai and Cochin beaches, India with that of Firemore Bay, Scotland

Station	Dry weight (g/m <sup>2</sup> )	Carbon (g/m <sup>2</sup> )	K (cal/m <sup>2</sup> )
Firemore Bay	1.27	0.63	5.7
Cochin	1.70	0.85	7.7
Shertallai	1.46	0.73	6.6

Firemore Bay in Loch Ewe, Scotland (McINTYRE and ELEFThERIOU, 1968), the average biomass is 1.27 g/m<sup>2</sup> dry weight (Table 3). For a sandy beach near Porto Novo on the east coast of India, McINTYRE (1968) found a macrofauna biomass ranging from 0.21 g/m<sup>2</sup> (wet weight) at high water to 3.53 g/m<sup>2</sup> at mid-tide. These values are similar to the range encountered in the present study, especially since McINTYRE's values do not include any tidal migrant forms present. For these tropical beaches production rates based on growth, reproduction and mortality, have still to be determined (an account of such studies at Shertallai is in preparation).

### Mortality and reproduction

During the short period covered by these observations, some other changes were observed in the fauna. At Cochin, through January and February, there was a rapid decline in numbers of *Donax incarnatus*, probably reflecting normal mortality at the end of a 1 or 2 year life span. At Shertallai, determination of body weight and observation of the gonads suggest that the gonad proliferates during January and February, and that some spawning may occur then: a few young specimens of this species were found in collections of 29th January and 7th February. A single male specimen of *Macra olarina* collected at Shertallai on 5th February, spawned in the laboratory on 6th February. On 21st February at Shertallai, 2 specimens of *Bullia melanoides* were collected which were carrying egg capsules attached to the foot (ANSELL and TREVALLION, 1970). Large numbers of ovigerous females of the crab *Emerita holthuisi* were present on both beaches for most of the 3 month period. Several releases of 1st stage zoea larvae occurred in the laboratory from such females, and numerous juvenile *Emerita* occurred in the collection from Shertallai on 13th March. The occurrence of the megalopa larva stage of *Ocyropsis* at Shertallai has already been mentioned (p. 271). Thus, there is apparently some reproduction of bivalves, gastropods and crustaceans throughout this pre-monsoon period.

### Discussion

Until recently, the literature on the fauna of sand beaches in tropical and sub-tropical waters has been limited. The studies of PEARSE et al. (1942) of beaches at Beaufort, North Carolina, USA, of GAULD and BUCHANAN (1956) of sand beaches in Ghana, and of MACNAE and KALK (1962) in Mozambique, provide the main comparisons, although there is some information on other areas in the works of DAHL (1952), KOEPKE and KOEPKE (1952), RODRIQUEZ (1959), and BROWN (1964). Recently, several studies have extended our knowledge of such faunas: in India (McINTYRE, 1968), in the West Indies (WADE, 1967),

and in Madagascar (PICHON, 1967), and these studies include observations on a wide range of beaches with different conditions, especially of exposure. PICHON (1967) has attempted a classification of communities associated with different conditions in Madagascar, which may serve as a useful basis for further comparisons with other areas.

PICHON (1967) recognises 3 main zones, each with certain characteristic faunal assemblages. An upper supralittoral zone is characterised by a biocoenosis comprising the amphipod *Talorchestia*, the isopod *Excirologana natalensis* and various species of Tenebrionidae. This assemblage was found on all the beaches examined, regardless of degree of exposure. Below this zone is a mid-littoral zone, characterised by a biocoenosis comprising various spionid polychaetes and the isopod *Excirologana orientalis*. Within this zone the species of spionid which becomes dominant, and the presence or absence of other species is determined by the degree of exposure and hence of disturbance and sorting of the sand by wave action. In general, a greater variety of species appears as the degree of exposure is reduced. Below this zone, PICHON delimits an infra-littoral zone whose characteristic faunal assemblage is determined by several features, mainly of the substratum; a community characterised by *Donax* species and by the polychaetes *Goniadopsis*, *Sigalion*, and *Spio*, occurs in exposed situations; in places where areas of coarser substratum occur this is replaced by a community characterised by *Terebra coerulea* and 2 species of the mole crab *Albunea*; in more sheltered areas PICHON recognised 5 further characteristic assemblages, whose appearance depend on tidal level, type of substratum, quantity of organic matter present in the sand, and salinity.

McINTYRE (1968) describes 4 beaches near the Marine Biological Station at Porto Novo on the south-east coast of India, 2 within the estuary of the river Velar with relatively muddy substrata, and 2 on the coasts of the Bay of Bengal, outside the estuary, with sand substrata. In the estuarine areas, ghost crabs *Ocyropsis* sp., and the talitrid amphipod *Talorchestia* occur at the upper levels, on dry sand above MHWS (mean high water spring tide), in a zone corresponding to PICHON's (1967) supralittoral zone. Below high water mark, the populations present on these beaches do not fit PICHON's classification and possibly represent a further type characteristic of estuarine situations with substrata rich in silt and organic material. In some respects these areas resemble the sheltered beaches on the west coast of Inhaca Island, Mozambique, studied by MACNAE and KALK (1962). The sand beaches of the more exposed areas, on the other hand, show many similarities to the more exposed beaches studied by PICHON.

In Table 4 we have attempted a comparison of the fauna recorded from the exposed beaches at Shertallai and Cochin with that of other exposed beaches in the

Table 4. Comparison of fauna recorded from

Beaufort N. Carolina, USA	Texas, USA	West Indies	Magarita Island, Venezuela	Peru
PEARSE et al., 1942	HEDGEPEPE, 1953; LOESCH, 1957	WADE, 1967	DAHL, 1952; RODRIGUEZ, 1959	KOEPKE and KOEPKE, 1952
34°43' N	27°50' N	18°50' N	11° N	—
<i>Ocypode albicans</i>	<i>Ocypode albicans</i>	<i>Ocypode albicans</i>	<i>Ocypode quadratus</i>	<i>Ocypode gaudi chaudi</i>
<i>Talorchestia megalophthalmia</i> <i>Orchestia grillus</i>	<i>Talorchestia longicomia</i> <i>Orchestia plantensis</i>  <i>Orchestia grillus</i>	<i>Talorchestia marcuzzi</i>	"Talitrids"	"Talitrids"
( <i>Donax variabilis</i> )		<i>Exciorolana brasiliensis</i>  ( <i>Donax denticulatus</i> )		
<i>Chiridotea caeca</i>		<i>Exciorolana brasiliensis</i>		<i>Exciorolana</i> sp.
(see below)	<i>Nerine agilis</i>	<i>Scolecopsis squamata</i>		
<i>Hauistorius</i> sp.		( <i>Hippa cubensis</i> ) ( <i>Albunea oxyophthalmia</i> )		
			( <i>Donax variabilis</i> )	
(Most polychaetes not identified)			<i>Tivela mactroides</i>	<i>Mesodesma</i> sp. <i>Tivela</i> sp.
<i>Oliva sayana</i> <sup>b</sup>	<i>Oliva sayana</i> <sup>b</sup>	<i>Terebra cinerea</i>		
<i>Arenius cribarius</i> <i>Callinectes sapidus</i> <i>Ovalipes ocellatus</i> <i>Callianassa major</i> <i>Lysiosquilla excavatrix</i> <i>Pagurus polycaris</i>	<i>Arenius</i> sp. <i>Callinectes</i> sp.  <i>Callianassa</i> sp.   <i>Albunea gibbsi</i>	<i>Arenius cribarius</i> <i>Callinectes exasperatus</i>		<i>Callianassa</i> sp.   <i>Coenobita</i> sp.
<i>Mellita quinquesperforata</i>	<i>Mellita quinquesperforata</i> <sup>c</sup>	<i>Mellita quinquesperforata</i> <sup>c</sup>	<i>Mellita quinquesperforata</i> <sup>c</sup>	

various beaches in tropical and sub-tropical areas

Ghana	Cape Peninsular	Madagascar	Mozambique	India, W. Coast	India, E. Coast
BUCHANAN, 1954; GAULD and BUCHANAN, 1956	BROWN, 1964	PICHON, 1967	MACNAE and KALK, 1962	This paper	McINTYRE, 1968
5—6° S	—	23°20' S	26° S	9°40' N	11°30' N
<i>(Ocypode africana)</i> <i>Ocypode cursor</i> <sup>a</sup>		Tenebrionidae <i>Ocypode</i> <i>ceratophthalmus</i> <i>O. cordimanus</i>	<i>Ocypode kuhli</i>	<i>Ocypode</i> <i>ceratophthalma</i>	<i>Ocypode</i> <i>platytarsus</i> <i>O. macrocera</i>
<i>(Talitrus saltator)</i>	<i>Talorchestia</i> <i>quadispinosa</i>	<i>Talorchestia</i> sp.			
		<i>Exciorolana</i> <i>natalansis</i>			
			<i>(Donax incarnata)</i>	<i>(Donax incarnatus)</i>	<i>Donax</i> sp.
<i>Exciorolana</i> <i>latipes</i>	<i>Eurydice</i> <i>longicornis</i>	<i>Exciorolana</i> <i>orientalis</i>		<i>Eurydice</i> sp.	
<i>Nerine cirratulus</i>		<i>(Nerine cirratulus)</i> <i>Nerinides?</i>		<i>Glycera alba</i> <i>Onuphis emerita</i> <i>Scoloplos</i> <i>marsupialis</i>	<i>Nerine cirratulus</i>
<i>Urothoë grimaldi</i> <i>Pantharpinia</i> <i>intermedia</i>	<i>Bathyporeia</i> sp.				<i>(Dotilla</i> <i>intermedia)</i>
<i>Donax pulchellus</i>	<i>Donax serra</i>	<i>Donax faba</i>			
<i>(Tivela tripla)</i>		<i>(Iacra petiti)</i>		<i>Mactra olorina</i> <i>Timoclea imbricata</i>	
<i>Lumbrineris</i> <i>impatiens</i>		<i>Goniadopsis</i> <i>incerta</i> <i>Sigalion</i> <i>mathildae</i> <i>(Lumbrineris</i> sp.) <i>(Spio magnus)</i>		<i>Lumbrineris</i> <i>latreilli</i>	
<i>Terebra africans</i> <i>Olivancillana</i> <i>hiatula</i>		<i>(Terebra</i> <i>coerulescens)</i>		<i>Oliva gibbosa</i> <sup>b</sup>	<i>Oliva</i> sp. <sup>b</sup>
<i>Callianassa</i> sp.	<i>Ovalipes</i> sp. <i>Callianassa</i> sp.			<i>Matuta lunaris</i> <i>Lysiosquilla</i> sp. ? <i>Diogenes custos</i>	
		<i>(Albuneazymista)</i> <i>(A. paretoi)</i>			
		<i>Echinodiscus</i> <i>bisperforatus</i> <sup>c</sup>			



Table 4.

Beaufort N. Carolina, USA	Texas, USA	West Indies	Magarita Island, Venezuela	Peru
PEARSE et al., 1942	HEDGEPEETH, 1953; LOESCH, 1957	WADE, 1967	DAHL, 1952; RODRIGUEZ, 1959	KOEPKE and KOEPKE, 1952
34°43' N	27°50' N	18°50' N	11° N	—
<i>Donax variabilis</i>	<i>Donax variabilis</i> <i>D. tumida</i>	<i>Donax denticulatus</i>		<i>Donax</i> sp.
	<i>Terebra saleana</i> <sup>a</sup>			
<i>Olivella</i> sp.				<i>Olivella</i> sp.
<i>Emerita talpoida</i>	<i>Emerita portoricensis</i>	<i>Emerita portoricensis</i>	<i>Emerita braziliensis</i>	<i>Emerita emerita</i> ( <i>E. analoga</i> )

<sup>a</sup> Reported as "*Ocypode hippeus*".

<sup>b</sup> Sublittoral species which migrate on to the shore at certain times of year.

<sup>c</sup> Found in the sublittoral region.

<sup>d</sup> See KORNIKER (1961).

tropical and subtropical areas. The entries for Mozambique and Cape Peninsula have been constructed from brief descriptions in the works of MACNAE and KALK (1962) and BROWN (1964), respectively. Although the former authors studied several beaches on the west coast of Inhaca Island in detail, these are not strictly comparable since they are sheltered from direct surf action. The beaches on the eastern shore, which are exposed to swell, are described only briefly. Although all the beaches included in Table 4 are surf beaches, some of the differences between areas may still be attributed to minor differences in exposure, an extreme case in this respect being that of the beach at Denu, in Ghana, described by GAULD and BUCHANAN (1956). Other differences probably arise from differences in sampling procedure, and particularly in the size of sieve used in sorting. In other cases the studies have been restricted to certain groups, for example DAHL (1952) was concerned mainly with Crustacea. Finally, certain of the groups represented, such as *Umbonium* and *Bullia*, are not distributed throughout the whole tropical region. With these qualifications in mind there is, nonetheless, a close similarity in the fauna of all the beaches studied.

The main faunal divisions might be summarised as follows:

(1) an upper zone (the supralittoral fringe of PICHON, 1967) which is characterised by the Talitridae

and Ocypodidae. These 2 groups are not mutually exclusive as suggested by DAHL (1952) but, on the contrary, appear together in most of the areas studied, although one or other may be absent in particular localities such as the Cape Peninsular beaches (BROWN, 1964). Certain species of cirrolanid isopods may also occur in this zone, for example *Excirrolana natalensis* in Madagascar (PICHON, 1967) and *Excirrolana latipes* in Ghana (GAULD and BUCHANAN, 1956), while terrestrial forms, such as beetles of the family Tenebrionidae, are also common. Within this zone, also, there may be found individuals of some *Donax* species, but most studies indicate that where *Donax* occurs in this way near high water mark, they represent only part of the population of a tidal migrant form which has been temporarily stranded during the previous high tide. Indeed, the occurrence of *Donax* in the upper region of a beach might be taken as an indication of the presence of a tidal migrant species of the genus.

(2) a middle zone (the midlittoral zone of PICHON, 1967) characterised normally by an isopod of the family Cirolanidae, and by one or more spionid polychaetes. Certain bivalve species may be found in the lower part of this zone, including apparently non-migratory species of *Donax*, such as *D. faba* in Madagascar (PICHON, 1967) and Mozambique (MACNAE and KALK, 1962) and possibly *D. pulchellus* at Labadi in

(continued)

Ghana	Cape Peninsular	Madagascar	Mozambique	India, W. Coast	India, E. Coast
BUCHANAN, 1954; GAULD and BUCHANAN, 1956	BROWN, 1964	PICHON, 1967	MACNAE and KALK, 1962	This paper	MCINTYRE, 1968
5—6° S	—	23°20' S	26° S	9°40' N	11°30' N
<i>Donax acutangulatus</i>		<i>Donax aemulus</i> <i>D. elegans</i> <i>D. madagascariensis</i>	<i>Donax incarnata</i>	<i>D. spiculum</i> <i>D. incarnatus</i>	<i>Donax</i> sp.
<i>Bullia granulosa</i>	<i>Bullia digitalis</i>		<i>Bullia natalensis</i> <i>B. rhodostoma</i>	<i>Bullia metanoides</i>	<i>Umbonium vestiarium</i>
<i>Gastrosaccus spinifers</i>	<i>Gastrosaccus psammodytes</i>				"Mysids"
<i>Hippa cubensis</i>			<i>Emerita austroafricana</i>	<i>Emerita holthuisa</i>	<i>Emerita asiatica</i>

Ghana; mactrids such as *Iacra* and *Mesodesma*, *Donacilla* (PICHON, 1967) and *Mactra*, and venerids such as *Timoclea* or *Tivela*.

(3) a lower zone (the infralittoral fringe of PICHON, 1967) which is less well characterised by resident species, and which shows the greatest variation in fauna both in relation to exposure and other physical features and in relation to geographical location. In north and south America and in the West Indies, the sand-dollar *Mellita* appears to be a characteristic form in this region, but this echinoderm is not represented on African and Indian beaches, although PICHON (1967) records that, after storms, the echinoderm *Echinodiscus bioperforatus* (LESKE) may be cast up on Madagascan beaches, indicating its presence in the shallow sublittoral. Burrowing prawns such as *Callinassa*, and stomatopod crustaceans like *Lysiosquilla*, which inhabit semi-permanent burrows, also appear commonly in this zone, as do gastropods of the genus *Terebra*. The fauna of this zone also includes some species which are distributed mainly in the sublittoral, but the shallow sublittoral of tropical beaches is a zone which has received almost no attention. On most of the beaches listed, characteristic forms for the sublittoral region are the portunid crabs, particularly species of *Arenius*, *Callinectes*, *Ovalipes* and *Matuta*. Indications from examination of the catches of beach seines operated by the local population at Shertallai,

and of trawled material at Porto Novo kindly made available by Professor SHESHAYA, would indicate that the immediate sublittoral region has a rich and varied fauna along Indian shores.

(4) In addition to those zones of the beach characterised by species which may be assigned to a particular area either as a permanent inhabitant (e.g. polychaetes) or because they return to semi-permanent burrows following feeding excursions (e.g. ocypodid crabs), a final group of species exists which are not confined to one level, but which migrate actively over the beach at each tidal cycle. These species are thus distributed relative to the line of the wash at all times, rather than to the substratum, and their position on the beach depends on the state of the tide at the time of collection. This mobile group may include bivalves of the family Donacidae, crustaceans of the family Hippidae, and gastropods such as *Bullia*, or some species of *Terebra*. Other types which may also show similar horizontal migrations up and down the beach are prosobranch gastropods of the family *Umbonium* in India and south-east Asia, mysids such as *Gastrosaccus* on African shores, and the small olivid gastropods such as *Olivaricella* or *Olivella*, although in none of these latter cases is there clear evidence of tidal migration occurring. Not all species which migrate do so throughout the whole of the tidal cycle; the gastropod *Bullia digitalis* for example, on South African

beaches, migrates only as high as half tide mark, where it burrows and remains until the falling tide induces further activity (BROWN, 1964), but all the species which exhibit this behaviour show characteristic adaptations of structure and behaviour which enable them to maintain their position relative to the surf zone and to exploit the energy of the breaking waves to accomplish their movements (ANSELL and TREVALLION, 1969). The trophic significance of the high incidence of active migratory species in the fauna of tropical beaches requires further study.

### Summary

1. Two Indian beaches, at Cochin and Shertallai, were sampled at fortnightly intervals between January and March, 1968.

2. The beach below the berm at Cochin is 14 m wide, with a slope of 1 in 8.5; at Shertallai, 40 m wide, with a slope of 1 in 16.

3. The sand is well sorted, with a mean particle size at Cochin of 275  $\mu$ , at Shertallai of 175  $\mu$ .

4. The salinity at Cochin, which is adjacent to the outlet from the Cochin backwaters, ranges between 31.6 and 33.8‰; at Shertallai between 34.2 and 34.7‰.

5. Values of phosphate in the water range between 0.8 and 2.8  $\mu\text{g at/l}$ .

6. Values for chlorophyll attached to sand grains are very low. Chlorophyll levels in the water range from 0.9 to 2.4 at Cochin, and from 2.2 to 13.3 at Shertallai.

7. Values for carbon in the sand range from 210 to 630  $\mu\text{g/g}$  at both beaches; carbon in the water from 355 to 1,800  $\mu\text{g/l}$  at Cochin, and from 870 to 3,660  $\mu\text{g/l}$  at Shertallai.

8. The macrobenthic fauna was sampled per  $\frac{1}{10}$  m<sup>2</sup> to a depth of 16 cm, at 2 m horizontal intervals. Distributions were similar on the two beaches. The ghost crab *Ocypode ceratophthalma* and the isopod *Eurydice* sp. occur in the zone around high water mark. The mid-intertidal zone is occupied by the polychaetes *Onuphis eremita*, *Glycera alba*, *Scoloplos marsupialis*, and *Lumbrinereis latreilli*. Four tidal migrant forms occur in the wash zone of the surf: the mole crab *Emerita holthuisi*, the gastropod *Bullia melanoides* and the bivalves *Donax incarnatus* and *D. spiculum*. The latter are absent at Shertallai; *B. melanoides* does not occur at Cochin. Cochin beach harbours fewer species of polychaetes.

9. The biomass of macrobenthos was estimated for a traverse of 1 m from high to low water. It amounts to 110 g (formalin weight) on Cochin beach, and to 250 g on Shertallai beach.

10. The formalin weights were converted to dry weights for the different groups of organisms, and the total weights averaged for the whole beach. This procedure gives 1.7 g/m<sup>2</sup> for Cochin and 1.46 g/m<sup>2</sup> for

Shertallai. These values compare with 1.27 g/m<sup>2</sup> for a sandy beach on the west coast of Scotland.

11. *Donax incarnatus* declines in numbers on Cochin beach in January and February.

12. At Shertallai, *D. incarnatus* spawns and yields a small recruitment.

13. In February, two specimens of *Bullia melanoides* were found carrying egg capsules.

14. Ovigerous females of *Emerita holthuisa* were present for most of the observation time, and juveniles appeared at Shertallai in March.

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