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SURVEY OF GASTROPOD POPULATIONS AT DIANI AND AT MALINDI MARINE NATIONAL PARK, KENYA

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INTRODUCTION

Shell collecting by dealers and tourists on the Kenya coast seriously threatens gastropods and the natural communities in which they live. Ray (1969) stated that shelling is the greatest reef-destroying factor, depleting the rich resources of the Kenya coast at an accelerated rate. He found that three to five tons of shells were being removed from Shimoni every two weeks. Jones (1969) found the mollusc population in a poor state at Watamu. Knowles (1970) maintained that the shell population in Kenya faces a potentially dangerous situation as a result of collecting pressure.

Ecological surveys of the marine national parks and unprotected areas are urgently needed to provide data necessary for management. This study compares gastropod populations of commercial value at protected and unprotected areas on the Kenya coast. The former are the fringing and North Reef areas in Malindi Marine National Park; the latter is at Diani.

METHODS

The species studied were primarily those that Knowles (1970) listed as commonly on sale at Mombasa and other resorts. Gastropods with smooth, glossy shells (Cowries: Cypracidae) or those with noticeably large shells (5 cm or more) were counted, both living and dead individuals. The sources used to identify species were Verdcourt (1954, 1959, 1960), Robson (1966), Macnae and Kalk (1958) and Spry (1968). A list of species found is given in the appendix.

Observations were made while walking or gogging along measured transects during daylight. The survey was conducted from 17 November to 31 December 1974.

At Diani (Figs. 1A and 1B), adjacent zones of the inner reef, each 150 m × 800 m, were gogged in transects parallel to the shore (Fig. 1C); transects were approximately 30-50 m apart. The outer reef was surveyed on foot by making similar transects during extreme low water of spring tides (ELWS). One-hour time intervals were recorded while surveying. At Malindi a similar procedure was followed in surveying seven zones along the fringing reef (Figs. 2A and 2B).

A detailed survey of all gastropods larger than 1.5 cm was made on the Malindi fringing reef from Chanoni Point to Casuarina Point (Fig. 2C). Sampling areas were 30 m × 60 m, the 30 m side being parallel to the shore. In alternate areas, complete counts were made along 10 random transects, each 2 m wide, running parallel to the shore. Transects in a sample area thus covered 600 m². Seven such areas were studied, sampling an area of 4200 m² out of a total of 12600 m².

Gastropods on the surface and under large rocks were counted; no attempt was made to include individuals that might have been buried under sand or hidden in crevices.

On Malindi North Reef counts were made on foot at ELWS. Transects were parallel with the edge of the reef, beginning near the outer edge and moving inwards towards the centre of the reef (Fig. 2A). These transects formed concentric lines approximately 10 m apart.

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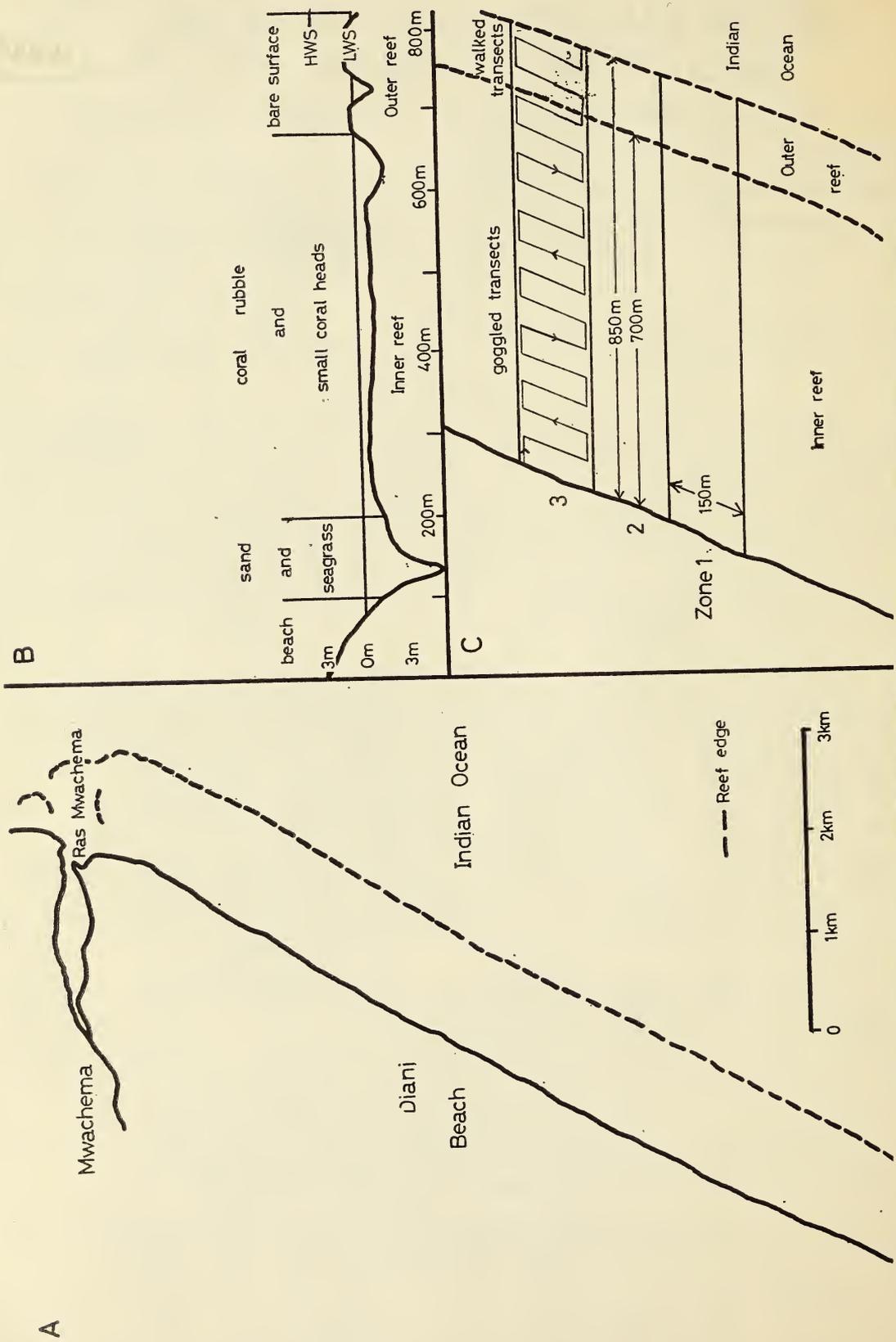


Fig. 1. (A) Diani beach (B) cross-sectional areas of the inner and outer reef (C) zonation studied along the reef.

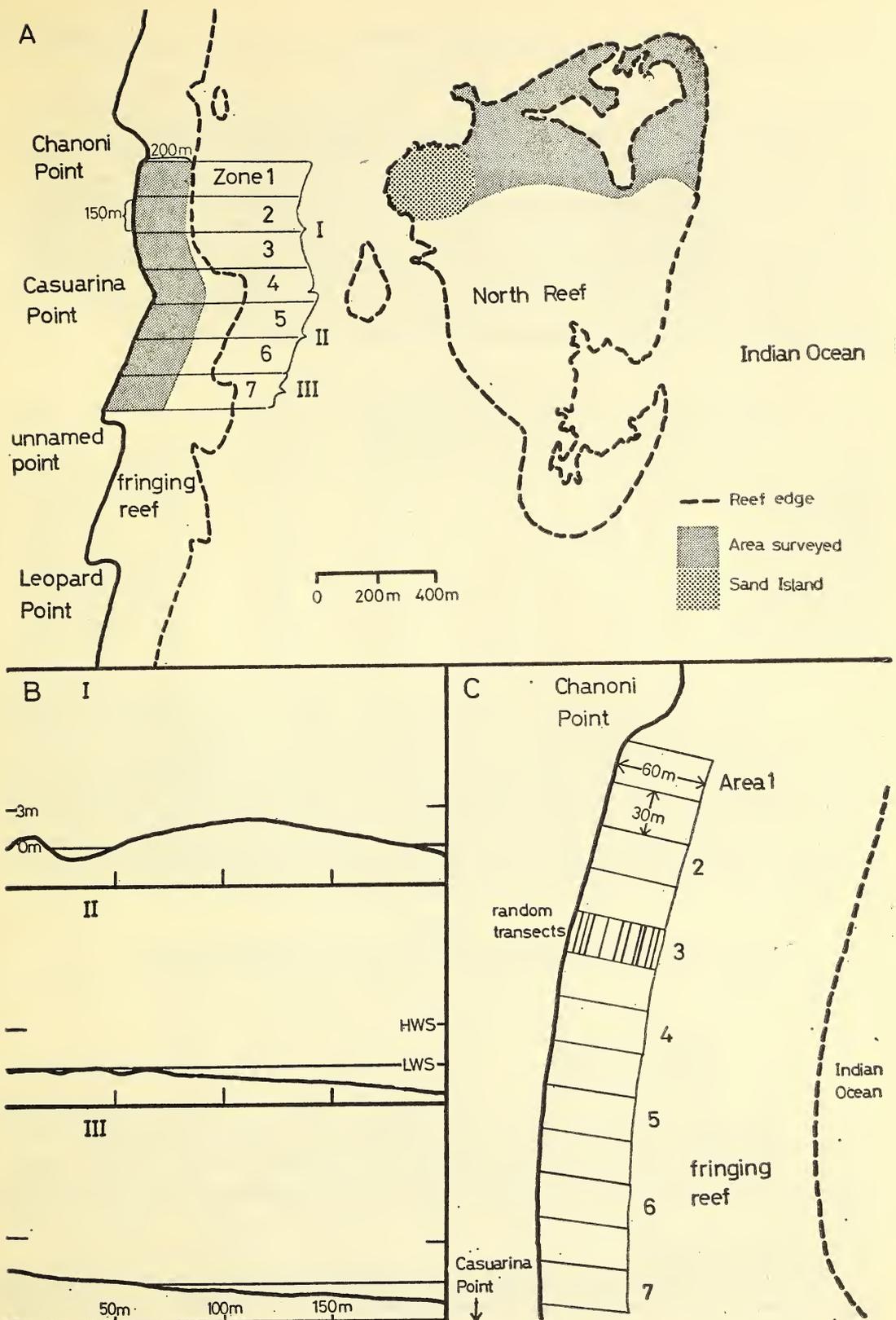


Fig. 2. (A) Malindi Marine National Park (B) cross-sections of the fringing reef at I, II and III (C) sample areas surveyed in detail along the reef.

RESULTS

Diani

At Diani an outer reef 700-800 m offshore encloses an old eroded inner reef and channels with sandy bottoms (Fig. 1B). Near the shore the beach drops off into a channel, then rises into interspersed flats of *Thalassodendron* (seagrass) and sand patches, with occasional beds of coral rubble. Toward the middle of the inner reef are larger areas of coral rubble supporting populations of sea urchins and a few small live coral heads. Farther out, live coral heads grow more abundantly, the largest measuring 1-2 m in diameter. Sand and *Thalassodendron* are again found in small patches before reaching another sand channel situated about 350 m from shore. Near the outer reef live coral heads are found in pools formed in the dead coral platform. The outer reef is an uneven platform that extends 150 m in width before sloping downward to the open sea; it was not exposed during a 1.3 m low tide. Observations were made while walking on the reef.

TABLE 1
Distribution of gastropod species at Diani

Species	Metres from shore					Total
	0-160	161-320	321-480	481-640	641-800	
<i>Cerithium nodulosum</i>	3	12	15	3	—	33
<i>Vasum rhinoceros</i>	4	5	8	6	5	28
<i>Lambis lambis</i>	1	1	3	3	3	11
<i>Chicoreus ramosus</i>	4	2	1	1	—	8
<i>Pleuroploca trapezium</i>	4	2	2	—	—	8
<i>Cypraea isabella</i>	—	—	—	—	2	2
<i>Cypraeassis rufa</i>	—	1	—	1	—	2
<i>Strombus lentiginosus</i>	—	1	—	—	—	1
<i>Terebra maculata</i>	—	1	—	—	—	1
<i>Phalium vibex</i>	—	—	—	1	—	1

In 12.5 hours of observation, 10 gastropod species, totalling 95 individuals, were found. Table 1 summarises their abundance and distribution. *Pleuroploca trapezium* was the only species confined to *Thalassodendron* flats close to shore. *Chicoreus ramosus* was found with *P. trapezium*, but also occurred on sandy patches between *Thalassodendron* flats throughout the entire inner reef. *Vasum rhinoceros* was distributed throughout the *Thalassodendron* flats and sand patches in the inner and outer reef. *Cerithium nodulosum* was found in rocky patches among *Thalassodendron* and in beds of coral rubble; it was the only species which lived among sea urchins. No live Cypraeidae was found at Diani. This confirms the observation of Spry (1968) that few gastropods are found on flat, bare, dead coral or in the presence of dense sea urchin populations.

TABLE 2
Numbers of individuals observed and hours of observation at Diani

	Zone 1	Zone 2	Zone 3	Total
Numbers observed	33.0	41.0	21.0	95.0
Hours of observation	5.0	4.0	3.5	12.5
Numbers per hour	6.7	10.25	6.0	7.6

The numbers of individuals, periods of observation, and numbers observed per hour are given for each zone in Table 2. The overall figure for Diani is 7.6 individuals per hour.

Five species represented 93% of all individuals observed: *Cerithium nodulosum* (35%), *Vasum rhinoceros* (29%), *Lambis lambis* (12%) and *Chicoreus ramosus* and *Pleuroploca trapezium* (8% each).

Malindi: fringing reef

The area of fringing reef studied, 1050 m along the shore by 200 m wide, lies between Chanoni Point and an unnamed point south of Casuarina Point (Fig. 2A). At Chanoni Point the reef is a

flat plateau running parallel to the beach until it approaches Casuarina Point, where it extends seaward about 150 m in a finger-like projection. This portion of the reef is rich in vegetation. Here large pools are found near the shore; the reef rises to a central ridge running parallel to the shore, with small rocky pools situated on the outer edge of the reef. Farther south, the reef slopes downward 0.5–1 m to give an uneven surface covered with *Thalassodendron*, dead coral and sand. Within 150 m of the unnamed point there is a plateau more level than that at the northern end of the reef. The reef at the southern end of the study area is covered with sand and is exposed during the mean low water level of spring tides (MLWS). From Casuarina Point to within 150 m of the unnamed point, the reef is submerged at all times except for a few areas at ELWS.

TABLE 3
Distribution of gastropod species at Malindi fringing reef

Species	Metres from shore						Total
	0-35	36-70	71-105	106-140	141-175	176-210	
<i>Vasum rhinoceros</i>	1	7	1	8	11	—	28
<i>Cypraea annulus</i>	—	5	7	3	—	9	24
<i>Pleuroploca trapezium</i>	2	5	4	4	4	3	22
<i>Cypraea tigris</i>	—	—	4	1	—	—	5
<i>Lambis lambis</i>	—	—	—	1	1	1	3
<i>Cypraea clandestina</i>	—	—	2	—	—	—	2
<i>Bulla ampulla</i>	—	1	—	—	—	—	1
<i>Cypraecassis rufa</i>	—	1	—	—	—	—	1
<i>Strigatella litterata</i>	—	1	—	—	—	—	1
<i>Turbo coronatus</i>	—	1	—	—	—	—	1
<i>Cypraea felina</i>	—	—	—	1	—	—	1
<i>C. helvola</i>	—	—	—	1	—	—	1
<i>Bursa bufo</i>	—	—	—	—	1	—	1
<i>Polinices zanzibarica</i>	—	—	—	—	1	—	1
<i>Bursa rosa</i>	—	—	—	—	—	1	1

In the 10-hour observation period, 93 individuals of 15 species were counted. Table 3 lists these species and their distribution along the length of the reef; most were found between Casuarina Point and the unnamed point. Mean numbers observed per hour for zones 1, 2 and 3 compared with zones 5, 6 and 7 (zone 4 is a transitional area, see Fig. 2A) were 5.8 and 9.5 respectively, indicating a general preference for less exposed sections of the fringing reef. Numbers of individuals observed per hour are given for each zone in Table 4.

TABLE 4
Numbers of individuals observed and hours of observation at Malindi fringing reef

	Zones							Total
	1	2	3	4	5	6	7	
Number observed	6.0	2.0	8.0	27.0	10.0	11.0	29.0	93.0
Hours of observation	1.0	0.75	1.0	2.0	1.5	1.75	2.0	10.0
Number per hour	6.0	2.6	8.0	13.5	6.6	6.28	14.5	9.3
Number per hour (cumulative)		5.82				9.52		

Only three of the 15 species were common, totalling 80% of all individuals seen. *Vasum rhinoceros*, *Cypraea annulus* and *Pleuroploca trapezium* were each observed more than 20 times; of the remaining 12 species, three were seen only a few times each, and nine only once.

Table 5 indicates habitat preferences of the three most abundant species. *Vasum rhinoceros* was found most frequently near the unnamed point, preferring a sandy substrate to the rocky, richly vegetated reef platform of Chanoni Point. *Pleuroploca trapezium* was found in the submerged

section of the reef on *Thalassodendron* platforms, while *Cypraea annulus* occurred where a combination of sand and algae was present.

TABLE 5
Distribution of the 3 most abundant species along the fringing reef at Malindi

Species	Zones							Total
	1	2	3	4	5	6	7	
<i>Vasum rhinoceros</i>	2	—	—	5	1	2	18	28
<i>Pleuroploca trapezium</i>	—	—	1	8	5	7	1	22
<i>Cypraea annulus</i>	2	2	7	9	—	—	4	24

Detailed survey of gastropods

A total of 816 individuals in 24 species were recorded on the fringing reef between Chanoni Point and Casuarina Point in an area of 4,200 m² (Fig. 2c). Only one or two individuals were recorded in 10 of the 24 species. Three species accounted for 88% of all individuals: *Pyrene flava* (53%), *Cerithium caeruleum* (25%) and *P. ligula* (10%). Population densities of species are given in Table 6.

TABLE 6
Distribution of gastropods on the fringing reef at Malindi between Chanoni Point and Casuarina Point

Species	Metres from shore						Total	No. per 1000 m ²
	0-10	11-20	21-30	31-40	41-50	51-60		
<i>Pyrene flava</i>	43	242	92	36	4	15	432	102.9
<i>Cerithium caeruleum</i>	7	120	59	7	4	4	201	47.9
<i>Pyrene ligula</i>	6	30	13	21	11	3	84	20.0
<i>Strombus floridus</i>	1	5	1	3	8	—	18	4.3
<i>Cypraea annulus</i>	—	5	—	5	5	1	16	3.8
<i>Conus ebraeus</i>	8	1	—	3	1	1	14	3.3
<i>Morula granulata</i>	—	4	—	1	4	—	9	2.1
<i>Conus lividus</i>	2	—	—	3	2	—	7	1.7
<i>Thais bitubercularis</i>	—	1	—	2	1	1	5	1.2
<i>Engina mendicaria</i>	3	1	—	—	—	—	4	1.0
<i>Vasum rhinoceros</i>	—	—	1	2	1	—	4	1.0
<i>Strombus gibberulus</i>	2	1	—	—	—	—	3	0.7
<i>Melongena pyrum</i>	—	—	—	3	—	—	3	0.7
<i>Nassarius crematus</i>	—	—	—	3	—	—	3	0.7
<i>Bursa rugosa</i>	—	—	1	—	—	1	2	0.5
<i>Conus coronatus</i>	—	—	1	1	—	—	2	0.5
<i>Nassarius pullus</i>	—	—	—	—	—	2	2	0.5
<i>Nerita</i> sp.	—	1	—	—	—	—	1	0.2
<i>Cymatium gemmatum</i>	—	—	1	—	—	—	1	0.2
<i>Nerita albicilla</i>	—	—	1	—	—	—	1	0.2
<i>Oliva</i> sp.	—	—	—	1	—	—	1	0.2
<i>Ranularia muricina</i>	—	—	—	—	1	—	1	0.2
<i>Cypraea moneta</i>	—	—	—	—	—	1	1	0.2
<i>Strombus mauritianus</i>	—	—	—	—	—	1	1	0.2
Total	72	411	170	91	42	30	816	

Most of the specimens observed were under cover of rocks or vegetation, but individuals of *Conus* sp. and *Strombus* sp. were often found on sandy substrates in pools or partially covered in water-saturated sand. *Pyrene flava* and *P. ligula* were found in association in water-saturated sand and under rocks in gregarious groups. *Cerithium caeruleum* occurred in similar habitats, but was also observed in more vegetated areas; individuals were usually distinctly spaced from one another. Table 6 also gives the distribution of all species along the transects. It shows that the three most common species, *P. flava*, *C. caeruleum* and *P. ligula*, preferred the inner raised sandy substrate over the outer rocky vegetated edge of the reef.

Malindi: North Reef

North Reef, located 1 km offshore from Casuarina Point, is approximately 600 m × 1750 m with its long axis parallel to the shore (Fig. 2A). The northern third of the reef was surveyed, including a sandbank which is exposed except during average high tide level (AHTL). This section of North Reef was exposed at ELWS. The vegetated western half of the reef is joined to the sandy eastern half by a central transition area. The outer edge of the reef has a rocky margin, but toward the centre the surface is flat.

In six hours, 169 individuals representing 22 species were observed. The two most abundant species, *Cypraea tigris* and *Vasum rhinoceros*, accounted for 26% and 18% of all individuals respectively. Seventeen species were represented by more than one individual (Table 7).

TABLE 7
Species observed at Malindi North Reef

Species	Number of individuals
<i>Cypraea tigris</i>	43
<i>Vasum rhinoceros</i>	30
<i>Cypraea annulus</i>	14
<i>Vasum ceramicum</i>	14
<i>Pleuroploca trapezium</i>	10
<i>Latirus nassatula</i>	8
<i>Vasum turbinellus</i>	8
<i>Thais bitubercularis</i>	6
<i>Cypraea isabella</i>	5
<i>Latirus polygonus</i>	5
<i>Conus textile</i>	4
<i>Cypraea carneola</i>	4
<i>C. moneta</i>	4
<i>Haliotis pustulatus</i>	3
<i>Cypraea felina</i>	2
<i>C. helvola</i>	2
<i>Trivia oryza</i>	2
<i>Bursa rugosa</i>	1
<i>Cypraea caurica</i>	1
<i>C. staphylaea</i>	1
<i>Cypræacassis rufa</i>	1
<i>Lampusia</i> sp.	1
Total	169

Seven species of *Cypraea* sp. were found under rocks, protected from exposure to the sun. *C. tigris*, however, showed a greater tolerance and was found exposed to sunlight and air on the surface of the reef. *C. annulus* and *C. moneta* were observed under cover of rocks, vegetation and water-saturated sand. *C. carneola*, *C. felina* and *C. isabella* were found attached to the underside of rocks and in rock holes.

Vasum rhinoceros was the most tolerant of the three *Vasum* species, occurring in vegetation on rocky or sandy substrata in exposed and submerged areas. *V. ceramicum* and *V. turbinellus* occurred only in rocky, vegetated areas.

Pleuroploca trapezium was found on the flat *Thalassodendron* beds of the vegetated zone, though two specimens were observed under large rocks partially covered by sand.

The remaining species were all observed under cover of rocks or vegetation.

CONCLUSIONS

A direct comparison of data from the areas is difficult. Ecological differences due to configuration of reefs and distances between study areas are great. Diani has sandy channels running between the beach and the outer reef; there are large areas of coral rubble around the inner reef inhabited by sea urchins, with intervening patches of *Thalassodendron* and sand. Malindi fringing reef by contrast adjoins the sandy shore and is somewhat protected on the outer edge by a submerged barrier of large coral heads. North Reef resembles an island when it is exposed at ELWS.

Species common to the three sites were *Cypraeacassis rufa*, *Pleuroploca trapezium* and *Vasum rhinoceros*. Species common to the fringing and North Reef areas at Malindi were *Cypraea annulus*, *C. felina*, *C. helvola*, *C. isabella*, *C. tigris* and *Lambis lambis*. While *L. lambis* was common to Diani and Malindi fringing reef, *C. isabella* was common to Diani and Malindi North Reef. Presumably Malindi fringing reef and North Reef had more species in common because of their proximity.

TABLE 8
Comparative population densities of gastropods at Diani, Malindi fringing reef and Malindi North reef

Location	Number of species	Number of individuals	Hours of Searching	Species observed per hour	No. individuals observed per hour
Diani	10.0	95.0	12.5	0.8	7.6
Malindi fringing reef	15.0	93.0	10.0	1.5	9.3
Malindi North Reef	22.0	169.0	6.0	3.7	28.2

Table 8 compares population densities of gastropods at each site. Less than one species per hour was encountered at Diani while 1.5 and 3.7 species per hour were encountered at the fringing and North Reef areas at Malindi respectively. Table 8 also shows a sequential gradient in the number of species, their abundance, and number observed per hour between the three sites.

Although ecological factors probably contribute to the differences in abundance, the data suggest a positive correlation between the number of species, their abundance and protection. North Reef, the most isolated protected area studied, possesses the richest population. The Malindi fringing reef population, being adjacent to shore, may be recovering from a formerly great collecting pressure or it may be a population still subjected to this pressure. Diani is an unprotected, highly commercialized tourist area, subject to widespread collecting; it possesses a relatively poor gastropod population.

There have been few investigations into the behaviour and ecology of gastropods in the western Indo-Pacific region and almost none in East Africa. Further studies of this nature, especially over several seasons, are needed for a better understanding of reef-associated gastropods.

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APPENDIX

Species observed are listed alphabetically by family. Common names are as in Spry (1968) or Abbott (1962).

Buccinidae — WHELKS

Engina mendicaria (Linné)

Bullidae — BUBBLE SHELLS

Bulla ampulla (Linné) Pacific Bubble

Bursidae — FROG SHELLS

Bursa bufo (Linné)

B. rosa (Perry)

B. rugosa

Cassididae — HELMET SHELLS

Cypraeacassis rufa (Linné) Bull Mouth Helmet

Phalium vibex (Reeve) Bonett Shell

Cerithiidae — CERITHS

Cerithium caeruleum (Sowerby)

C. nodulosum (Bruguiere) Giant Knobbed Cerith

Conidae — CONES

Conus coronatus (Röding)

C. ebraeus (Linné) Hebrew Cone

C. lividus (Hwass)

C. textile (Hwass) Textile Cone

Columbellidae — DOVE SHELLS

Pyrene flava (Bruguiere)

P. ligula (Duclos)

Cymatiidae — TRITON SHELLS

Cymatium gemmatum (Reeve)

Lampusia sp.

Ranularia muricina (Röding) or *tuberosus* (Lamarck)

Cypraeidae — COWRIES

Cypraea annulus (Linné) Ringed cowrie

C. carneola (Linné) Flesh-coloured cowrie

C. caurica (Linné) Thick-edge cowrie

C. clandestina (Linné) False three-banded cowrie

C. felina (Gmelin) Cat cowrie

C. helvola (Linné) Star cowrie

C. isabella (Linné) Isabelline cowrie

C. moneta (Linné) Money cowrie

C. staphylaea (Linné) Grooved cowrie

C. tigris (Linné) Tiger cowrie

Eratoidae

Trivia oryza (Lamarck)

Fasciolaridae — TULIP SHELLS

Latirus nassatula (Lamarck)

L. polygonus (Gmelin)

Pleuroploca trapezium (Linné)

- Haliotis pustulatus* (Reeve) **Haliotidae — VENUS EAR SHELLS**
- Melongena pyrum* (Gmelin) **Melongenidae — CHANK SHELLS**
- Strigatella litterata* (Lamarck) **Mitridae — MITRE SHELLS**
- Chicoreus ramosus* (Linné) Ramose murex **Muricidae — MUREX SHELLS**
- Nassarius crematus* (Hinds)
N. pullus (Linné) **Nassaridae — DOG WHELKS**
- Nerita albicilla* (Linné)
N. sp. **Neritidae — NERITE SHELLS**
- Polinices zanzibarica* (Recluz) **Naticidae — MOON SHELLS**
- Oliva sp.* **Olividae — OLIVE SHELLS**
- Strombidae — CONCH and SCORPION or WING SHELLS**
- Lambis lambis* (Linné) Common spider conch
Strombus floridus (Lamarck) or *mutabilis* (Swainson) Mutable conch
S. gibberulus (Linné) Humped conch
S. mauritanus (Lamarck) or *decorus decorus* (Röding)
S. lentiginosus (Linné) Silver conch
- Terebra maculata* (Linné) Marlinspike **Terebridae — AUGER SHELLS**
- Morula granulata* (Duclos) or *tuberculata* (Blainville)
Thais bitubercularis **Thaisidae — ROCK and DRUPE SHELLS**
- Turbo coronatus* (Gmelin) **Turbinidae — TURBAN SHELLS**
- Vasum ceramicum* (Linné) Ceram vase
V. rhinoceros (Gmelin)
V. turbinellus (Linné) Pacific top vase **Vasidae — VASE SHELLS**

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