"OPTIMUM CORAL REEF RESOURCE USE: CASE STUDY OF A MARINE PROTECTED AREA"

M.Sc. THESIS

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By

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Declaration.

I, Weru, Sam D. M., do hereby declare that this thesis is my original work and to the best of my knowledge has not been presented to any other university for any academic honours or otherwise.

12th Oct 94

....

Weru, Sam D. M.

I, Warui K. Karanja, would like to state here that this thesis has been submited for examination with my approval as a university supervisor.

.... 28/10/94

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17/10/1994

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Declaration.

I, Weru, Sam D. M., do hereby wish to declare that this thesis is my original work and to the best of my knowledge it has not been presented to any other university for any academic honours or otherwise. Further, that all citations quoted herein are fully acknowledged both in the main text and in the reference section.

.... Nov 1994

Weru, Sam D. M.

Dedication.

To Muthoni and Wanyeki for persevering the long periods of my absence.

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I would like to express my sincere appreciation to Drs. Tim McClanahan and Warui Karanja for their sound academic advice and references/reprints made available to me without which this work would have been impossible. Special mention goes to Richard Leakey and the Coral Reef Conservation Project team for introducing and incorporating me into this project respectively. Let me thank the institution of Kenya Wildlife Service and all sponsors of the Coral Reef Conservation Project for their financial and equipment support. I would also like to acknowledge my peers, and to name a few, Robert Chira, Martin Mulama, Peter Kibanya, Esther Fondo, Jackie Uku, Wilson Ayiemba, Pritipal Soorae and Hamisi Mutinda. Special thanks go to all the officers and rangers of Mombasa Marine Park and Reserve. I would also like to thank Mr. Mariara (technician, KMFRI) for his assistance in the field, Drs. Else, Ntiba and Martens for their comments on my proposal and Ms. Farida Ndunge for assisting me in fisheries data collection. To all those who in one way or another contributed to the success of this work, I salute you.

Abstract.

A protected area, Mombasa Marine Park and Reserve was established in 1986, in an area that was previously fished. Exclusion of fishermen was however not fully achieved until 1990. This study was conducted between 1992 and 1993 in an attempt to determine the conservation area design and management guidelines which maximise resource protection and optimise economic returns without adverse effects to the coral reef ecosystem. The study considered tourism, space needs for various fish guilds and fisheries yield.

Tourism in Mombasa Marine Park earned 36% of all revenue accruing from Marine Parks and Reserves in Kenya. Tourist activities in the sea were concentrated in an area estimated at 5 km². From the questionnaire survey, over 72% of the tourists indicated this area to be in either satisfactory or excellent condition.

There was no statistically significant difference between the park and the reserve in terms of predation (percentage of tethered sea urchin eaten). The difference in predation between the coral and sea grass zones was significant in the reserve. In the park, one site (across the channel) shows significant difference but the other (wreck) shows no difference. In terms of herbivory (percentage of sea grass blade eaten), both the park and the reserve show no significant difference in general. Similarly, the reserve does not show any difference in herbivory levels between the coral and sea grass zone, whereas the park shows a significant difference.

Marine parks enjoy total protection from any consumptive utilisation whereas marine reserves, allow artisanal fisheries using traditional gear. To determine changes in community structure in space and time, species turnover for damselfish and wrasse were assessed using underwater visual census techniques. For both the marine park and reserve, species turnover for the two families level off after approximately 100 days. Highest species turnover is achieved after 400 m² in the park and at 200 m² in the reserve. The species-area relationship becomes asymptotic at 600 m² for 14 species of damselfish and at 800 m² for 17 species of wrasses.

For the families sampled, the park shows a higher species density than the reserve. However, in terms of diversity, the two areas show a significant difference only for damselfish but not for wrasses. The similarity indices between the park and reserve are 80.7% and 88.24% for wrasses and damselfish respectively.

Artisanal fishermen have centralised landing points where a fisheries scout is deployed to collect catch data. From a sample of 25 fishing boats spread over a period of three months, it was noted that 21.3% of the total weight of fish landed at the Jomo Kenyatta Public Beach landing point was not recorded/declared to the fish scout. An analysis of effort and yield data suggests that for optimum gain, the number of fishermen per fishing boat working for six hours should be 2, that is 12 man-hours.

To increase protection of species diversity, revenue from tourism and support from fishermen, the size of the current park should be reduced by 3 km^2 and a smaller fully protected area of 1 Km^2 established at Ras Iwatine/Nyali coral gardens. This is also expected to increase fishing yield.

CHAPTER 1

1.00. Introduction

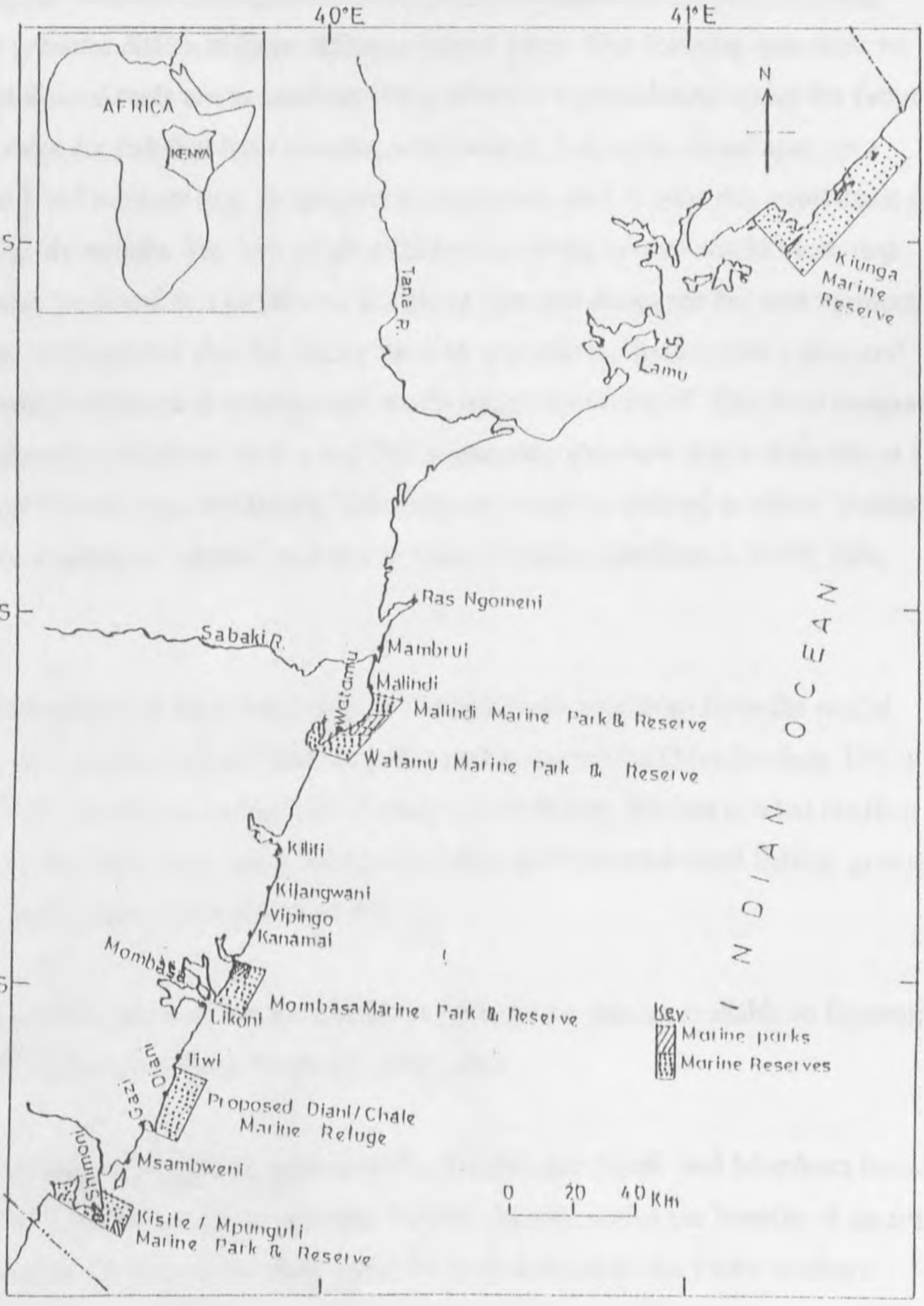
Kenya's coral reefs are the focus of many types of resource use ranging from artisanal fishing to jetskiing. Many of these are compatible, rarely creating conflicts in resource use, but others, such as fishing and tourism may result in conflicts and loss of ecological balance. Examples include over-utilization of fish, corals, and shellfish (Molluscs) resulting in decreased attractiveness of the reef and its potential use by tourists. The Kenya government wishes to increase both tourism and fishing yield. Since these two uses are not compatible in the same area, a policy has been developed which places reefs under three categories of management: See Fig. 1.

1) total protection (i.e. Malindi, Watamu, Mombasa and Kisite Marine National Parks),
2) partial protection (i.e. Malindi-Watamu, Kiunga, Mpunguti and Mombasa Marine National Reserves) and
3) no protection (i.e. all other reefs).

In areas with no protection previous research suggests that overfishing has occurred and is coincident with major changes in the reefs' community structure and ecological processes, while protected areas appear to support pristine coral reef ecosystems (McClanahan, 1992; McClanahan & Shafir, 1990). Overfishing in these unprotected areas has rendered many reefs to have low productivity as fisheries grounds while protected areas are also unproductive as fishing (not allowed) areas but maintain substantial incomes through tourism. In order to maximize the total economic yield of Kenya's reefs, an optimization and management plan needs to be established which considers not only species protection but also the economics and area requirements of fisheries and tourism. A microcosm of these problems exists in the newly created Mombasa Marine National Park and Reserve. (MNP&R) where a previously fished reef was converted into a marine park and reserve. The reef section from English Point to Mtwapa Creek is under total and partial protection with the northern section being under Park and the southern end under Reserve status. Tourists do not use the entire breadth and length of the protected area. Their activities are confined to certain areas of interest (coral gardens and the reef flat). The minimum area used is crucial in park zonation planning and management to avoid conflicts and damage to the resource.

Figure 1.

Map of the Kenyan coastline showing Marine Parks and Reserves.



Coral reef fish have a daily ranging pattern that takes them to foraging grounds and back to their hide-out within rock crevices. Benthic diurnal predators include wrasses (Labridae) whereas most grunts (Haemulidae) are nocturnal carnivores. Herbivores, including damselfish (Pomacentridae), surgeonfish (Acanthuridae) and parrotfish (Scaridae) are primarily diurnal feeders. The area utilized has different substrate types with seagrass beds and coral gardens being the most important. It is expected that foraging pressure differs in these different habitat types. This foraging area must be protected if coral reefs are to continue being effective replenishment zones for fished areas. Except for fish that have cleaning stations (e.g. *Labroides dimidiatus*) or a defended fixed territory (e.g. *Amphipirion akallopisos* and *A. allardii*), most coral reef fish are highly mobile. The lack of physical barriers in the system would mean that species may be found in a given area at a given time and disappear the next moment. However, it is expected that the higher the area one covers, there comes a time and scale at which different or new species are no longer encountered. This local emigration and immigration would result in a reef fish community structure that is definable at a given scale in both time and space. This turnover would be defined as either `constant and stable' (order) or `variable and due to chance' (chaos) (Bohnsack, 1983; Sale, 1991).

Since 1990 fishermen have been excluded (albeit some poaching) from the reef at Bamburi and studies indicate that the park's reef is recovering (McClanahan, 1992) in terms of fish abundance and species diversity. Nonetheless, this has created conflicts with fishermen who have lost a large part of their previous traditional fishing grounds. Two problems have arisen and these are:

1) Large areas in the northern section of the park are no longer available to fishermen who have used this resource for many years, and

2) Tourists from the southern section of the Reserve (i.e. Nyali and Mombasa Beach Hotels) are expected to pay an entrance fee but do not receive the benefits of an area protected from fishing unless they travel the long distance to the Park's northern section (this is rarely done due to the expense of a long boat trip).

Reef sections in the southern part of the reserve (Ras Iwatine) are heavily impacted by fishing activities and do not have the same aesthetic appeal as protected reefs. Among the alternatives (to the current policy) being considered by this study are:

(a) to designate another completely protected area (to end up with two parks) within the southern reserve for use by tourists while compensating fishermen through either

i) providing equipment for offshore fishing or,

ii) reducing the fishing effort through alternative sources of employment (e.g. involvement in aquaculture programs),

(b) to adjust the boundaries (reduce area) of the existing park to increase fishing grounds but maintain an effective conservation area.

Managing a conservation area requires manpower and equipment both of which cost money. An effective conservation area that allows resource utilization should maintain monetary returns that exceed running costs (should be profitable). Designating another completely protected area (two parks) is thus expected to increase costs. Tourists (at Nyali and Mombasa Beaches) who can not afford a long boat trip (to Bamburi) will enjoy the benefits of a completely protected area, thus increasing revenue. The efficacy of such a plan will thus be determined by net income accruing thereof.

1.10: Literature Review.

To have a single large or several small conservation areas is summarized by the `Single Large or Several Small' (SLOSS) debate. Though initially developed for tropical forests, the debate seeks to offer empirical evidence on whether one relatively large protected area will conserve more species (numbers only) than smaller archipelagos of equal total area. It was aimed at preventing possible extinction threats created by habitat fragmentation (MacArthur and Wilson, 1967; Simberloff, 1988). Prior research has focused on terrestrial environments with both sides (for small and for large) agreeing that the ideal strategy would be to have a lot of large conservation areas (Simberloff, 1988; Salm and Clark, 1984; Mann, 1991; Patterson, 1991). The problems are that;

1) several small areas are expected to support more species and may dampen the effects of competition better than a single large area, and

2) small archipelagos are more likely to suffer catastrophes that cause extinctions.

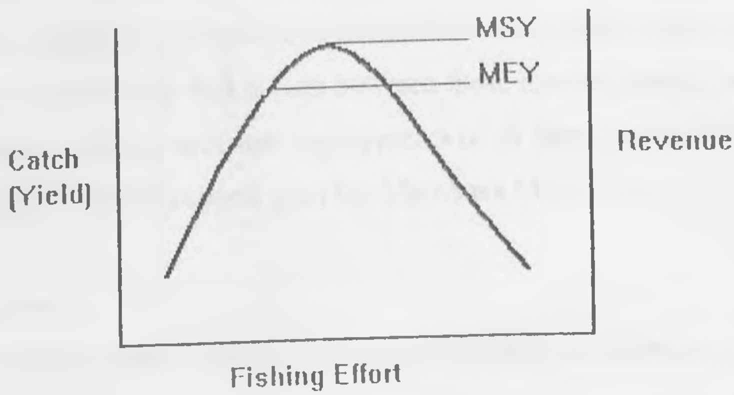
Most of these arguments are based on empirical findings (species- area relationship) rather than the identity and ecology of the species in question (MacArthur and Wilson, 1967; Simberloff, 1988). It would be preferable to base such conclusions on the ecology of the species concerned because any conservation area is bound to have a mosaic of species with different behavioral patterns, energetic and habitat requirements. A large area for a damselfish may be very small to a grouper. The situation becomes rather difficult in the very diverse tropical reefs. Other factors such as management problems (monitoring and law enforcement, etc) and economic implications are also vital in decision making. Although the SLOSS issue is not yet resolved, the debate supports the argument that the relationship between ecological pattern and scale is a central issue in conservation biology (see Levin, 1992).

The smallest reef size in which all (at least 95%) species of corals and coral reef fish in the general vicinity are found has been called "the critical minimum core area" and reported to be 300 ha (or 3 km^2) for the Chagos Archipelago corals and 3,470 ha for the Great Barrier Reef fish communities (Salm and Clark, 1984; Goeden, 1979 in Soule, 1986). The questions of what is the sufficient size and number of viable conservation areas that would balance the four primary processes of birth, death, emigration and immigration have not been successfully answered despite MacArthur and Wilson (1969) recognizing the importance of such natural reserves thus kicking off the debate. As early as 1920s analysts such as Arrhenius and Gleason studied the relationship between area and number of species in an attempt to develop models explaining biogeographic patterns (see Myers and Giller, 1988; Salm, 1980). Different places have different species abundance and diversity hence the critical minimum core area is expected to differ from place to place. Nevertheless, tropical marine habitats are not homogenous because, (a) surge channels, seagrass beds, sandy sea-beds and coral reef heads serve to create several discrete habitats analogous to ecological islands, (b) marine organisms have high dispersing ability so that archipelagos of different habitat types may be of little consequence as barriers (Salm and Clark, 1984) and (c) temporal changes in wind direction (monsoons), tides and current results in substrate mixing which in turn influences species distribution and local migrations.

Fishing is the major source of income for many coastal residents. When a fishery is profitable over-utilization may occur and may deplete stocks if not controlled. A profitable fishery should ideally be maintained at or near maximum economic yield (MEY) (Schaefer, 1957; Day *et. al.*, 1989) as depicted by Shaefer Curve shown in Figure 2. This model was developed for a single species fishery (for example tuna) in temperate countries where fishermen are better geared and educated. It was therefore easy to collect fisheries data (see Shaefer, 1957; Payne, 1986; Day *et. al.*, 1989). It is nevertheless a worthy alternative in the absence of reliable fisheries management plan.

Figure 2.

Schaefer Curve showing point at which a fishery is most profitable (after Schaefer, 1957).



MSY = Maximum Sustainable Yield

MEY = Maximum Economic Yield

Alternatively, zonation, control and management (Woodley, 1988; Kenchington, 1984) may increase opportunity costs and help avoid 'the tragedy of the commons' (Berkes, 1985) befalling this common resource. A casual observation of landed fish at the Bamburi landing site suggests ths some fish families such as rock cods (groupers), wrasses, surgeonfishes and parrots are caught more regularly than others or are preferred, hence the need closer attention.

Conservation, fishing and tourism are undertakings of major interest at the reef. Kenchington (1984) noted that whereas the fundamental conservationist would favour minimum human impacts on the reef, it is in the interest of the fisherman to maintain or increase the sustained use of species of mutual interest as edible and culturally valuable entities. Due to the overlap that occurs between these interest groups, any zonation plan must balance the resource use requirements of all three groups. This kind of plan was not considered in the original plan for Mombasa Marine Park.

1.20. Objectives.

To address the issues raised this study aimed at fulfilling the following objectives.

1.21: General objective:

Determine the conservation area design and management guidelines which maximize resource protection and optimize economic returns without adverse effects to the Mombasa Marine Park and Reserve coral reef community.

1.22: Specific objectives:

1. Determine the minimum area requirements for sustained ecological functioning of two fish families (Pomacentridae and Labridae) as well as herbivores and carnivores in general.

2: Undertake a historical analysis and future projections of the contributions of tourism and fishing to the coastal economy.

3: Develop a zonation plan which maximizes species diversity and abundance in the protected area, increases visitor access to a protected zone and reduces conflicts with fishermen.

1.30: Research Hypotheses:

1: Reef fish utilize a certain area adjoining the coral reef with the coral gardens acting as the core area.

2: Immigrations and emigrations (turnover) balance out after some time and space.

3: Due to different levels of protection and utilization, the park and the reserve differ in species diversity, abundance and absolute turnover.

1.40: Justification

There is need to harmonize conservation and utilization. This can be done through drawing effective management plans after management-oriented research. Mombasa MNP&R was established after a verbal political directive and later (1986) gazetted legally. No feasibility study or biological inventory was conducted. The boundary plan was consequently drawn without adequate biological knowledge of the ecosystem and economic well-being of the fishermen (who have anyway been fishing in this area since time-immemorial). The result is conflict between the park authorities and many other parties interested in this area. There is need, therefore, to evaluate the effectiveness of this conservation area *per se*, for the purposes of formulating an effective management plan. These plans will rely on knowing what the effective area for conservation of coral reefs and associated marine biota. This area of conservation biology touches on many of the current debates summarized by the SLOSS argument which has largely focused on terrestrial environments. This study intends to provide data and arguments pertinent to this debate in a marine environment.

CHAPTER 2

2.00. Methodology.

2.10: Study Area.

This study was carried out within Mombasa Marine Park and Reserve, see Figure 3 (situated along the Kenyan Coast from the entrance to the port, English Point, northwards to the entrance to Mtwapa Creek, Cannon Point, with the reserve spreading 13.5 km into the sea). The gazetted park lies between longitudes 39 40' and 39 54' east and latitudes 3 58' and 4 04' south covering an area of 10 Km^2 (about 2 km width and 5 Km length) (Wildlife Planning Unit, 1989). The park is encompassed by the reserve which covers an area of 200 Km^2 (13.5 Km width and 15 Km length). This conservation area was established under Act 376 of Laws of Kenya and gazetted in the legal notice number 315 and 316 of 9th December 1986 (Wildlife Planning Unit, 1989). Fishing is allowed in the reserve but not in the park. Two sites were of particular interest, the coral gardens in the park and at Ras Iwatine in the reserve. Both areas are protected from wave action by the fringing reef flat.

2.20: Tourism.

To estimate the area used for tourist activities, tourist activity densities were plotted on a map of the park and reserve based on the sitings of tourist boats while engaged in business. The reef flat was taken as the outer limit seawards whereas the lowest spring mark was the starting point from the beach-line.

Through a questionnaire (see table 1 a & b), tourists were asked to consider boat charges, condition of the park, the best park among those visited, other parks they visited while booked at these Mombasa hotels and to make other general comments. A boat trip costs money and whether a tourist visits a reef depends on the cost, willingness to see the fauna therein and experience from previous visit(s). To asses how much and how far tourists were willing to pay and travel to see pristine reefs (in parks) and how satisfied they were, 150 questionnaires in English (100) and French (50) were distributed to 6 hotels located to the north, middle and south of the park (two hotels at each site). These were Intercontinental, Serena, Severin, Bamburi, Mombasa and Nyali Beach Hotels. The receptionist, sales manager or guests relations manager in each hotel would distribute the questionnaires to the tourists who would fill and drop them at a collection point.

Figure 3.
Map of Mombasa Marine Park and Reserve showing areas where sampling was conducted.

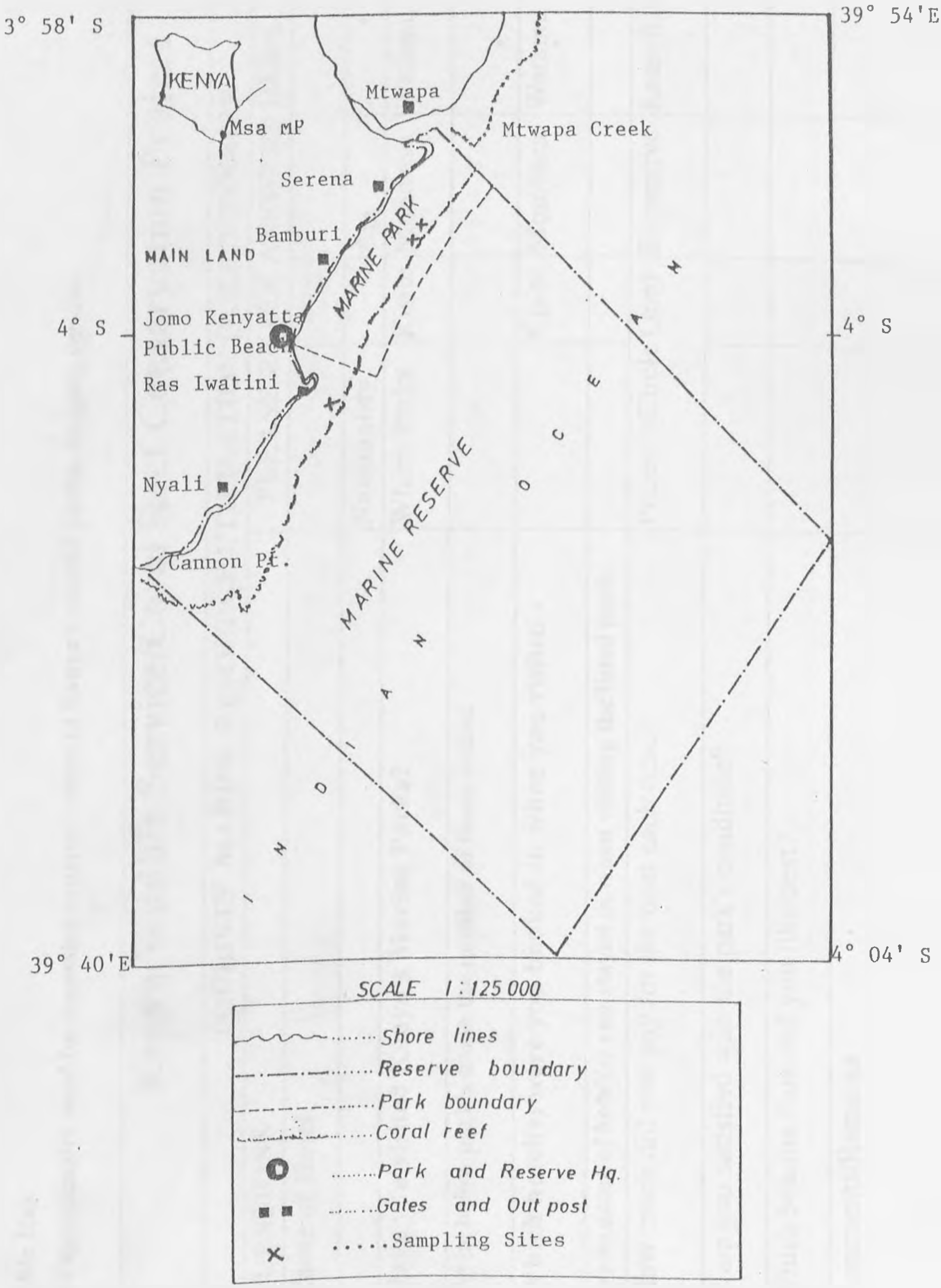


Table 1(a).

The questionaire used for assessing tourists' views of Kenya's marine parks, English version.

Kenya Wildlife Service/Coral Reef Conservation Project					
TOURISTS' MARINE RESOURCE UTILISATION QUESTIONNAIRE					
QUESTIONS	PLEASE ENTER ANSWERS HERE				
Name of Hotel					
	Nationality		Age		
Have you visited Kenya's Marine Parks?	Which Parks	Kisite	Mombasa	Watamu	Malindi
Write below park's name the number of times visited					
Which hotel(s) were you booked in when you visited -		Kisite	Mombasa	Watamu	Malindi
Write name of hotel(s) you stayed in when visiting the listed parks					
How much did you pay for the boat each time?	Prices? (Circle One)		Expensive	Reasonable	Cheap
Were you satisfied with the park's condition?					
Which Marine Park did you like best?					
Comments/Remarks					

Table 1(b).

The questionaire used for assessing tourists' views of Kenya's marine parks, French version.

Kenya Wildlife Service/Coral Reef Conservation Project				
UTILIZATION DE RESOURCES MARINS TOURISTIQUES				
QUESTIONS	ÉCRIVEZ VOS RÉPONSES CE-DESSOUS			
Nom d'hotel				
Nationalité				
Avez-vous visiter un parc marin au Kenya? Lesquel?	Kisite	Mombasa	Watamu	Malindi
Combien de visite? (indiquer sous le nom du park)				
Dans quels hotels étiez-vous à chaque endroit?	Kisite	Mombasa	Watamu	Malindi
Combien coûtez le bateau chaque fois?				
Étiez-vous safisfaits avec le condition de(s) parc(s)?				
Quel parc aimez-vous le plus? Pourquoi?				
Remarques				

2.30: Migratory and ranging patterns of coral reef fish.

Assuming that fish have a routine whereby they move out from their hideouts in the reef crevices, forage in the surrounding areas including sea grass beds and return to their hideouts, foraging patterns for predatory as well as herbivorous fish were assayed in April 1993. Three sites were chosen for this study; two in the park (Channel and Wreck) and one in the reserve (Ras Iwatine). Their profile is shown in Figure 4. The number of tethered sea-urchins eaten and the length of seagrass clipped off along a transect were recorded and expressed as a function of area.

Predator ranges were determined from the number of tethered rock-boring sea urchins (*Echinometra mathaei*) eaten along the transect (McClanahan and Shafir, 1990). Six sea urchins were tethered at 2 m intervals along a 10 m long twine. Several of these twines were laid at 20 m intervals across the substrata starting from the middle of coral reef lagoons and extended towards the seagrass beds in the deep channel (up to 250 m). The number taken at each line were counted (percentage) and subjected to arcsine transformation (Sokal and Rohlf, 1981; Zar, 1984) such that $p' = \arcsin \sqrt{p}$, where p is the proportion eaten. The percentage values were plotted against distance from the coral reef substratum. Predation rates were compared between;

i) the park and reserve,

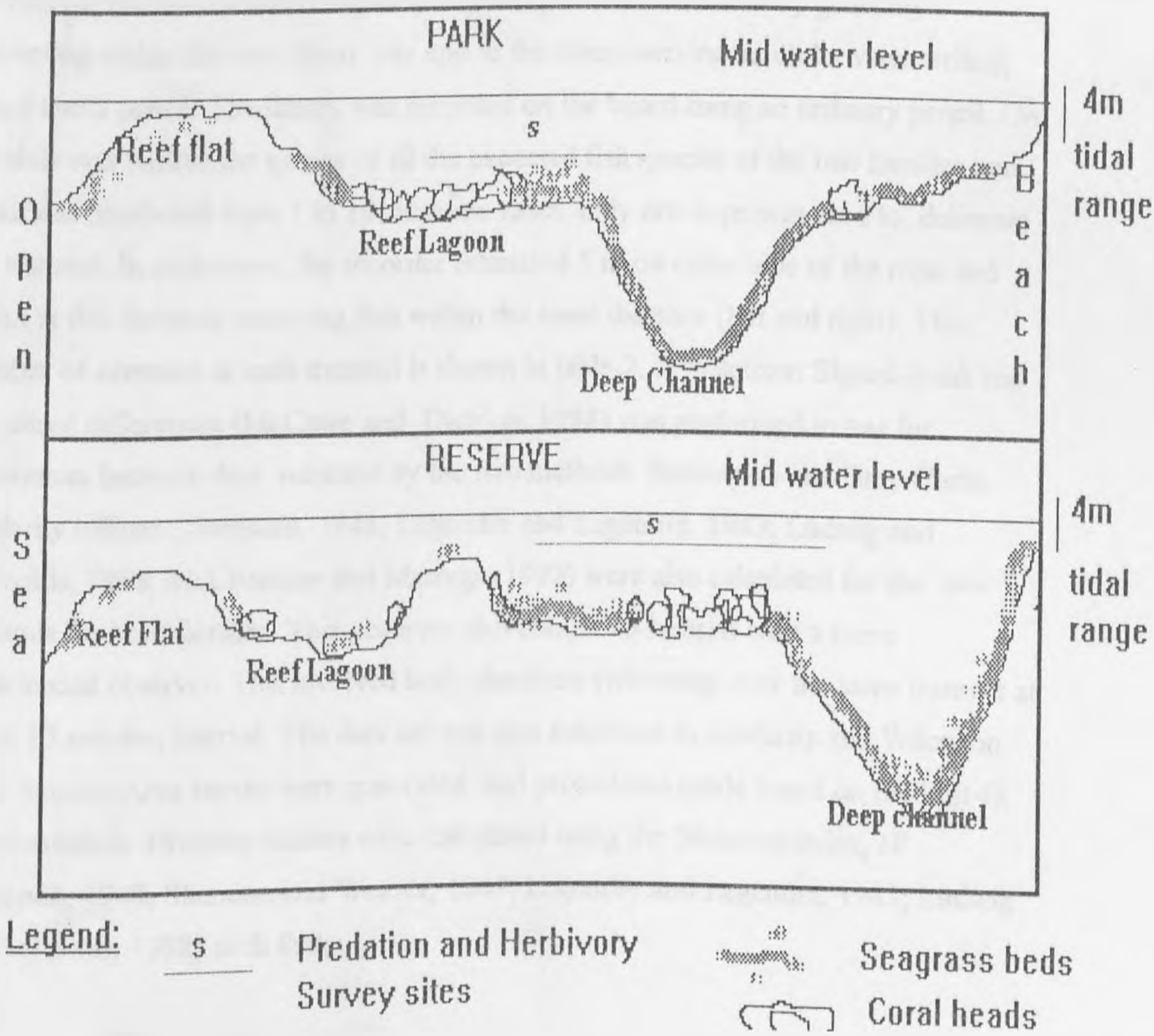
ii) coral and sea grass zones, and

To assess herbivory trends, turtle grass (*Thalassia hemprichii*) blades of known length (5 cm) were pegged using clothespins (plastic pegs) in place of the sea urchin as described earlier. The proportion of the blade eaten was assessed as a measure of herbivory rates (Hay, 1984). This grass species was used because it is readily eaten and develops nibbling marks distinct for herbivorous fish and sea urchins (Hay, 1984,). Fish nibbling marks are crescent shaped whereas sea urchins' marks are ragged (Hay *et al.*, 1983). Admittedly, *Thalassia* grazing bioassay is only a measure of herbivory on large macrophytes (Hay, 1984).

2.40: Fish Transect

Visual transect were used for censusing the two fish families (Labridae and Pomacentridae) by using the discrete group sampling technique. Four permanent sampling sites were established (two in the park and two in the reserve).

Figure 4.
Profile diagram (cross-sectional) of Mombasa Marine Park and Reserve showing sites where predation and herbivory were assayed for in April and May 1993.



Note: Diagram not to scale.

This involved cementing PVC pipes on the sea floor which was accomplished by compacting a previously prepared mixture of cement, sand and water around the pipe.This was done at the four corners of the transect. In some cases, the cement mixture was placed in a tin with the pipe standing in the middle. Once hard and dry, the sinkers were placed at the four corners of the permanent sampling sites. The transect were delineated by two 100 m nylon ropes divided by metallic swivels at 10 m intervals. The ropes were laid 10m apart thus, making ten $100m^2$ quadrats covering a total area of 1000 m^2. The ropes were tied at both ends to either underwater markers or coral heads. All fish (of the two families) within the two ropes were censused by generally swimming within this area from one end to the other carrying an underwater writing board and a pencil. The datum was recorded on the board using an ordinary pencil. On the slate was written the names of all the expected fish species of the two families and quadrates numbered from 1 to 10. In some cases, only one rope was used to delineate the transect. In such cases, the recorder estimated 5 m on either side of the rope and swam at this distance censusing fish within the same distance (left and right). The number of censuses at each transect is shown in table 2. A Wilcoxon Signed-Rank test for paired differences (McClave and Dietrich, 1988) was performed to test for differences between data returned by the two methods. Sorensen's and Bray-Curtis similarity indices (Sorensen, 1948; Legendre and Legendre, 1983; Ludwig and Reynolds, 1988; McClanahan and Muthiga, 1992) were also calculated for the two methods for both families. This observer also compared himself with a more experienced observer. This involved both observers swimming over the same transect at about 15 minutes interval. The data set was also subjected to similarity and Wilcoxon tests. Species-Area curves were generated and projections made based on the best-fit transformation. Diversity indices were calculated using the Shannon index, H' (Shannon, 1948; Shannon and Weaver, 1949; Legendre and Legendre, 1983; Ludwig and Reynolds, 1988) such that;

$$H' = -\sum_{i=1}^{s^*} (pi \ln pi)$$

where H' is average uncertainty per species in an infinite community made up of S* species with known proportional abundances p1, p2, p3,.......ps*.

Table 2.

Number of censuses and average time interval between censuses for the sites sampled between November 1992 and September 1993.

	PARK		RESERVE	
	TRANSECT 1	TRANSECT 2	TRANSECT 1	TRANSECT 2
Number of censuses	10	10	8	7
Mean Interval (Weeks)	3	3	4	4

Differences in diversity indices for the two different areas were tested for by Student's t-test (Zar, 1984; McClave and Dietrich, 1988). Absolute species turnover between any two censuses (MacArthur and Wilson, 1967; Bohnsack, 1983) was also calculated and plotted against time interval between census such that,

Absolute turnover = (I + E) / 2

whereby,

I = the number of species appearing on the second/consecutive census and not the first/previous census (immigrations, recruitment etc)

E = the number of species appearing on the first/previous and not the second/consecutive census (emigrations, extinctions etc). The assumption here is that the population is at equilibrium thus the division by two.

2.50: Fisheries

A score-card was developed aimed at assessing effort, catch per effort and how much of the fishermen's catch was not weighed and therefore not declared to the Fisheries Department's fish-scout (see Table 3). The recording was done in conjunction with the local fish scout who was well acquainted with the fishermen. A sample of five boats was identified. On 5 different dates within a period of two months, their total catch on board (real) and after weigh-in (landed weight), number of fishermen in the boat, fishing time and the dominant genera caught were recorded. The order of dominance was scored on a scale of 1 (10%) to 10 (100%). The differences between real and landed weight were tested for using a one-sample t-test for paired differences.

Using a sketch map of the park, fishermen from the Kenyatta Beach landing point were followed to their fishing grounds and their movements plotted to estimate how much sea area was utilized.

Liaising with the Mombasa MNP&R authority and Kenya Wildlife Service headquarters, revenue, visitor and expenditure statistics were obtained for the year 1992. These data were used to compare revenue accruing form tourism in the park in relationship to fishing.

Table 3.

Fisheries data score card.

FISHERIES DATA SCORE CARD													
DATE:						RECORDER(S) :							
Boat No.	Number f/men	Time in Landing	Time of Depart.	Observed Wt. Kgs	Declared Wt. Kgs	DOMINANT SPECIES CAUGHT: Score out of 10							
						R/fish	Snapper	P/fish	Octopus	Squids	Scavenger	Other	Scale
													1= 10%
													2= 20%
													3= 30%
													4= 40%
													5= 50%
													6= 60%
													7= 70%
													8= 80%
													9= 90%
													10= 100%

CHAPTER 3.

3.00. Results.

3.10. Tourism.

Of the 150 questionnaires distributed to the six hotels, 54 were returned with answers representing 36% of the total. One hotel did not return any. Analysis of the questionnaires indicate that the boat charges per person varied between KShs. 400/= to 600/= from which the boat operator would pay the park entry fee of KShs. 180/=, at the 1992/93 rate. The answers are summarised in Table 4. The total area used for tourist activities in the sea was estimated at 5 km² (10 km length X 0.5 km width) based on tourist boats concentration within the sea area between Ras Iwatini in the reserve and the reef off Serena beach, slightly to the north of the central mooring point in the park. Of all the marine parks, Mombasa earns 36% of all revenue from park entry fees (Figure 6).

3.20: Predation

Within the marine park, the number of tethered sea urchins eaten reach maximum at 100 m in the coral zone where sea urchin mortality due to predation reaches a maximum of 66%, (Figure 7). Once in the seagrass zone, the proportion eaten drops within 40 m to 30% where it oscillates for the next 60 m. The two substrate types return different mean predation levels at both sites sampled (across the channel and at the wreck), but one site (across the channel) shows a statistically significant difference ($t = 3.178$, $df = 7$, $p < 0.05$) between the two habitat types whereas the other (wreck) does not ($t = 0.458$, $df = 6$, $p > 0.05$), see table 5. The mean predation level in the park was 46.6%.

In the marine reserve predation peaked at 60% after 60 m of coral whereas in the sea grass area, the proportion eaten droped from a peak value of 50% to about 20% within a distance of 40 m. The two substrate types show significant differences ($t = 4.477$, $df = 5$, $p < 0.05$). When plotted in relation to dominant substrate cover, predation within coral areas show higher levels than sea grass areas, (Figure 8). The amount of sea urchin eaten in the coral zone averages 54.7% whereas in the sea grass zone, it averages 35.4%. The difference was statistically significant ($p < 0.05$), see Tables 5 & 6. Comparing the marine park with marine reserve in general, there was no statistically significant difference in predation, 46.6% and 41.3% respectively, ($t = 1.474$, $df = 13$, $p > 0.05$), see Table 7.

Table 4

Summary of answers given by tourists interviewed vide the 54 questionnaires returned from 5 hotels located along the Mombasa Marine Park and Reserve beach-line (1993).

ITEM	PROPORTION %	NATIONALITY/COMPOSITION.
1. Boat charges		
a. cheap	25	USA/Greece 1:1
b. reasonable	50	USA/Germany 3:1
c. expensive	25	USA/Italy 1:1
2. Condition of park (Mombasa MP)		
a. excellent	16.7	Britain/France 2:1
b. satisfied	55.6	Germany/USA/Canada/Switzerland/Italy/France 1:4:1:1:1
c. Not satisfied	5.6	Italy
d. No comment	22.2	Greece/Switzerland/Germany 1:2:1
3. Parks visited		
a. Mombasa	100	All interviewed
b. Kisite	22.2	Switzerland/Italy 3:1
c. Malindi/Watam	33.3	Germany/Italy/Switzerland/British 2:2:1:1:1
4. The best park*		
a. Kisite	33.3	Switzerland/Italy 1:1
b. Mombasa	50	Germany/Greece/Britain 1:1:1
c. Malindi	16.7	Italy

* Not all questions in the questionnaire were answered by tourists. Like in this case only 18 out of the returned 54 questionnaires had this question answered.

Fig. 6.
Comparative analysis of revenue accruing from Kenya's Marine Parks and Reserves, 1989 to 1993 (source: KWS revenue section)

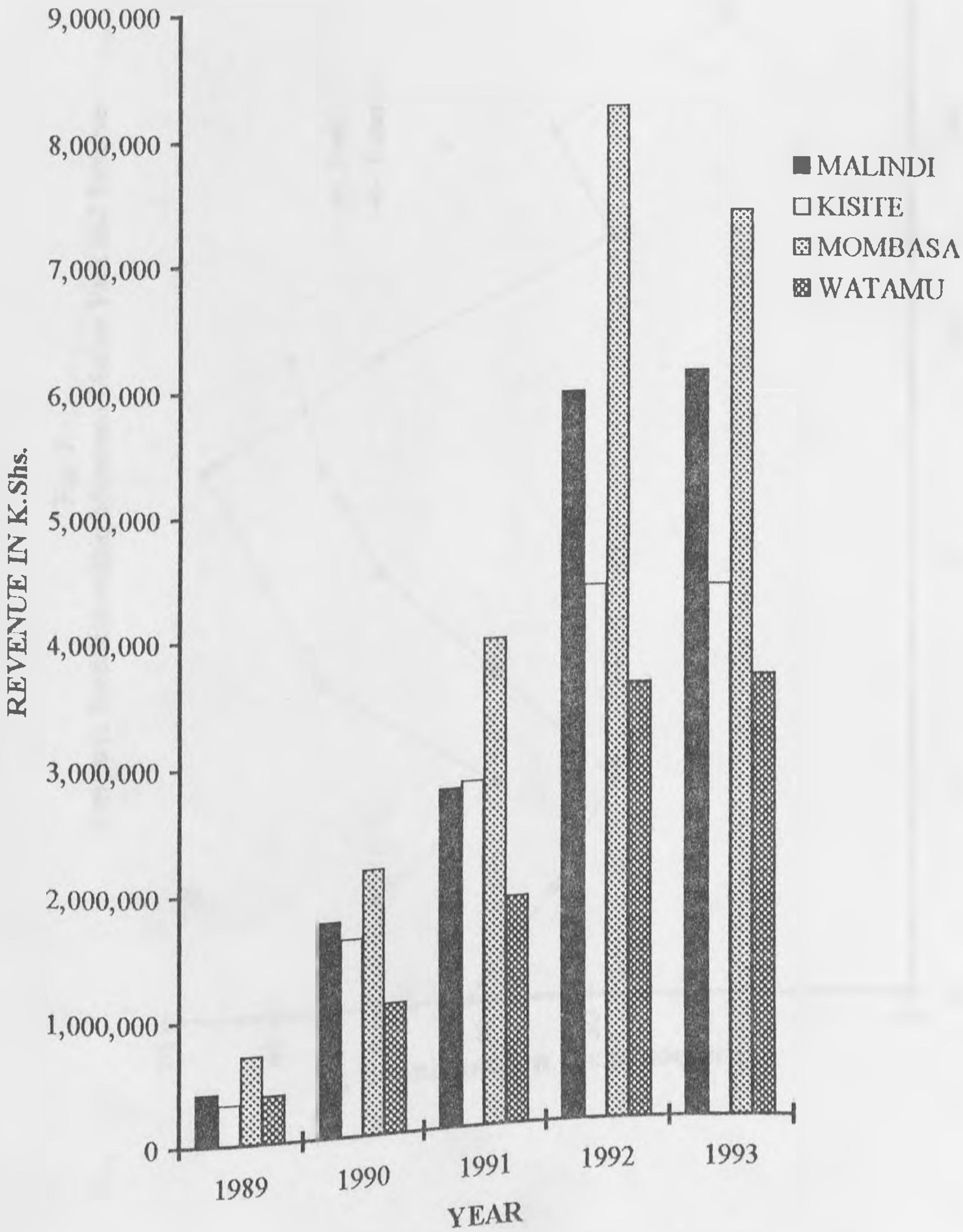


Fig. 7.
Trends in Predation within Mombasa Marine Park and Reserve

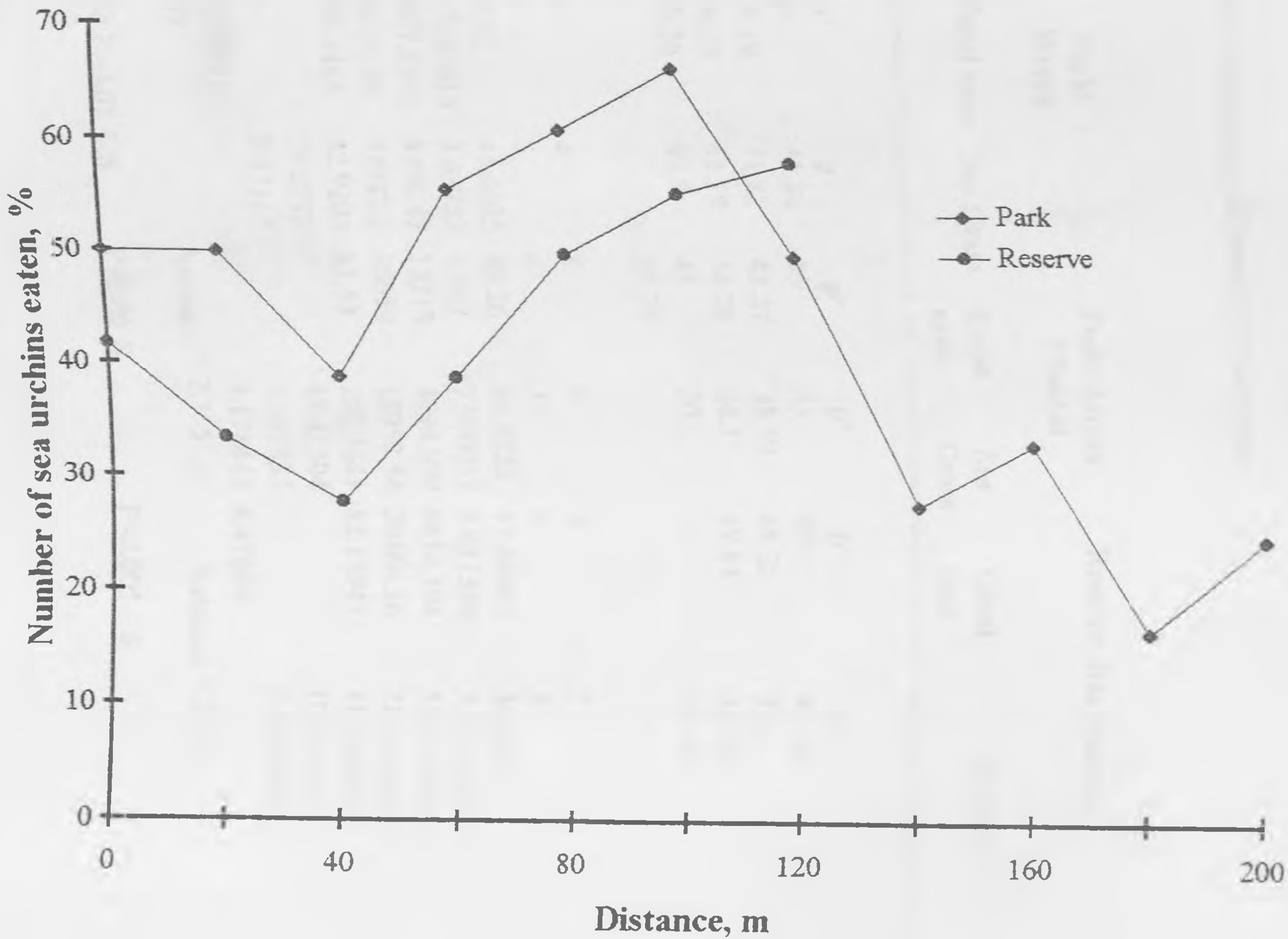


Table 5.

A two-sample (2) t-test for differences in predation among substrate types at various sites. Data subjected to arcsine transformation, p'(after Zar, 1984).

Ho: predation in coral zone same as in sea grass zone
Ha: predation in coral zone different from sea grass zone
$\alpha = 0.05$

	Park: Wreck		**Park: Across Channel**		**Reserve: Ras Iwatine**	
	Coral zone	**Sea Grass**	**Coral zone**	**Sea Grass**	**Coral zone**	**Seagrass**
	p'	p'	p'	p'	p'	p'
	60	41.81	45	45	45	40.22
	48.19	41.81	48.27	38.59	48.22	35.3
	48.19	48.19	54.76	24.1	49.84	31.82
	35.26	49.8	45	30		38.59
			53.26			
n	4	4	5	4	3	2
v	3	3	4	3	2	3
Mean	47.91	45.4025	49.26	34.4225	47.68667	36.4825
STD	8.7513913	3.63732	4.087	7.990057	2.011589	3.2228743
Sum p'^2	9487.8192	8298.47	12215	4994.998	6834.194	5365.4389
$(\text{Sum } p')^2$	36725.89	32982.2	60659	18958.54	20466.16	21295.565
SS	306.3465	52.9205	83.53	255.3641	12.13947	41.547675
Pooled var		59.8778		48.41304		10.73743
SE mean		5.47165		4.667533		2.5025986
t	0.4582715			3.178445	4.47684	

$t_{0.05(2)(n=6)} = 2.447$ $\quad$ $t_{0.05(2)(n=7)} = 2.365$ $\quad$ $t_{0.05(2)(n=5)} = 2.571$

CONCLUSION: $P>0.05$ NS $\quad$ $P<0.05$ S $\quad$ $P<0.005$ S

Figure 8.

Predation analysis by dominant substrate cover for Mombasa Marine Park and Reserve.

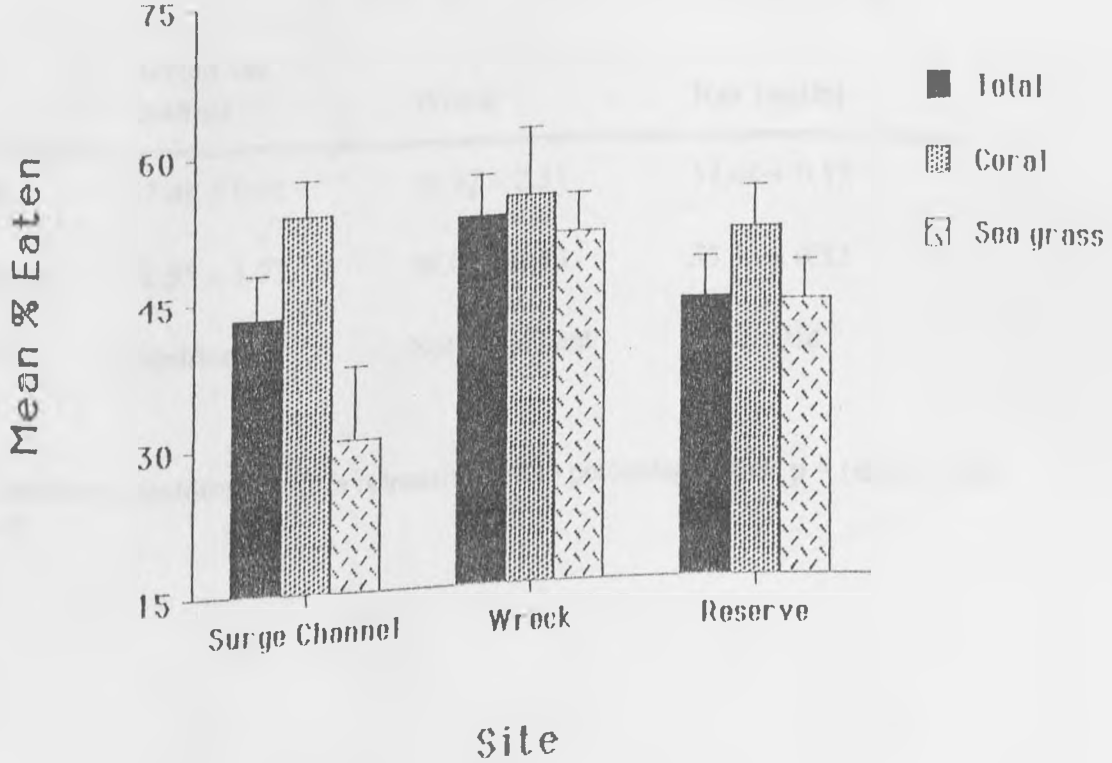


Table 6.

Table showing summary of statistical test (t-test) on predation among different substrate types in Mombasa Marine Park and Reserve.

	PARK		RESERVE
	Across the channel	**Wreck**	**Ras Iwatini**
Coral	57.40 ± 0.51	55.07 ± 2.31	54.68 ± 0.12
Seagrass	31.95 ± 1.93	50.07 ± 0.40	35.35 ± 0.32
t-test	Significant	Not Significant	Significant

Note: Arcsine transformed values retransformed to percentages, thus $p = (\sin p')^2$, see Table 5.

Table 7:

A two-sample two-tailed (2) t-test for differences between mean levels of predation for mombasa marine park and reserve.

{Percentage predation datum, p, subjected to arcsine transformation, p' such that p' = arcsin ($\sqrt{p}$) }

Ho: predation in park same as in reserve
Ha: predation in park different from reserve
α= 0.05

	PARK			RESERVE		
	p	p'	p'^2	p	p'	p'^2
	75	60	3600	41.7	40.22	1617.648
	55.56	48.19	2322.276	33.4	35.3	1246.09
	55.56	48.19	2322.276	27.8	31.82	1012.512
	33.33	35.24	1241.858	38.9	38.59	1489.188
	44.44	41.78	1745.568	50	45	2025
	44.44	41.78	1745.568	55.6	48.22	2325.168
	55.56	48.19	2322.276	58.4	49.84	2484.026
	58.34	49.78	2478.048			
v	7			6		
Mean	46.64375			41.28429		
SS	372.75			268.88		
(Sum p')²	139240.9			83515.22		
Sum (p'²)	17777.87			12199.63		
Pooled var	49.356					
SE mean	3.636					
t	1.474					

$t_{0.05(2)(13)}$=2.160 NS

CONCLUSION 0.05<P(|t| >or= 1.474)<0.20 Do not reject Ho:

3.30: Herbivory

In the park, the proportion of seagrass clipped off by herbivorous fish peaked at 22% within the first 60 m of coral dominated area, whereas it remained stable at below 10% for the next 40m which was sea grass dominated, (Figure 9). The total percent herbivory was also compared to mean percent herbivory levels within the respective dominant habitat types, (Figure 10). In the reserve, herbivory reached a peak value of 20% after the first coral dominated 60m zone, the amount of *Thalasia hemprichii* taken reached a peak value of 10% after the next 40m of sea grass. On the average, there was no statistically significant difference between herbivory levels in the park, 16.8% and the reserve, 20.3% ($t = |1.2605|$, $df = 15$, $p > 0.05$), see Tables 8 and 9. The park shows no significant difference in both coral and seagrass zones ($p > 0.05$) whereas the reserve shows a significant difference ($p < 0.05$), see Table 10.

3.40: Species Similarity.

The Sorensen's species similarity index between the park and the reserve returned 80.7% for wrasses and 88.2% for damselfish. The overall (both families considered) similarity was 83.5%. When this observer compared himself with a more experienced observer, similarity index between the two levelled at 500m² for damselfish and at 400m² for wrasses, Figure 11.

3.50: Species Turnover.

Spcies turnover, as described in the methodology section is a measure of the level of change in terms of incoming and out-going species based on a comparative analysis on consecutive census dates. The analysis, in both space and time perspectives, indicates scale and patterns for localised fish movements or migrations which in turn tell us how often and how big an area to sample in order to detect meaningful change in fish species compositions. In the park, absolute turnover for both damselfish and wrasses combined as a function of area reaches a peak at 400 m² (5.05), then falls to 3.7 at 1000 m² (Figure 12). In the reserve, absolute turnover rises sharply to peak at 200 m² then drops as sharply within 600 m² after which the slopes flattens and reaches zero at 1000 m². When absolute species turnover was plotted against the time interval between sampling period at a spatial scale of 1000 m² the trend is suggestive of chaos initailly but orderlines is established around 100 (approximately three months) days for both families, Figure 13.

Figure 9.
Herbivory trends within Mombasa Marine Park and Reserve

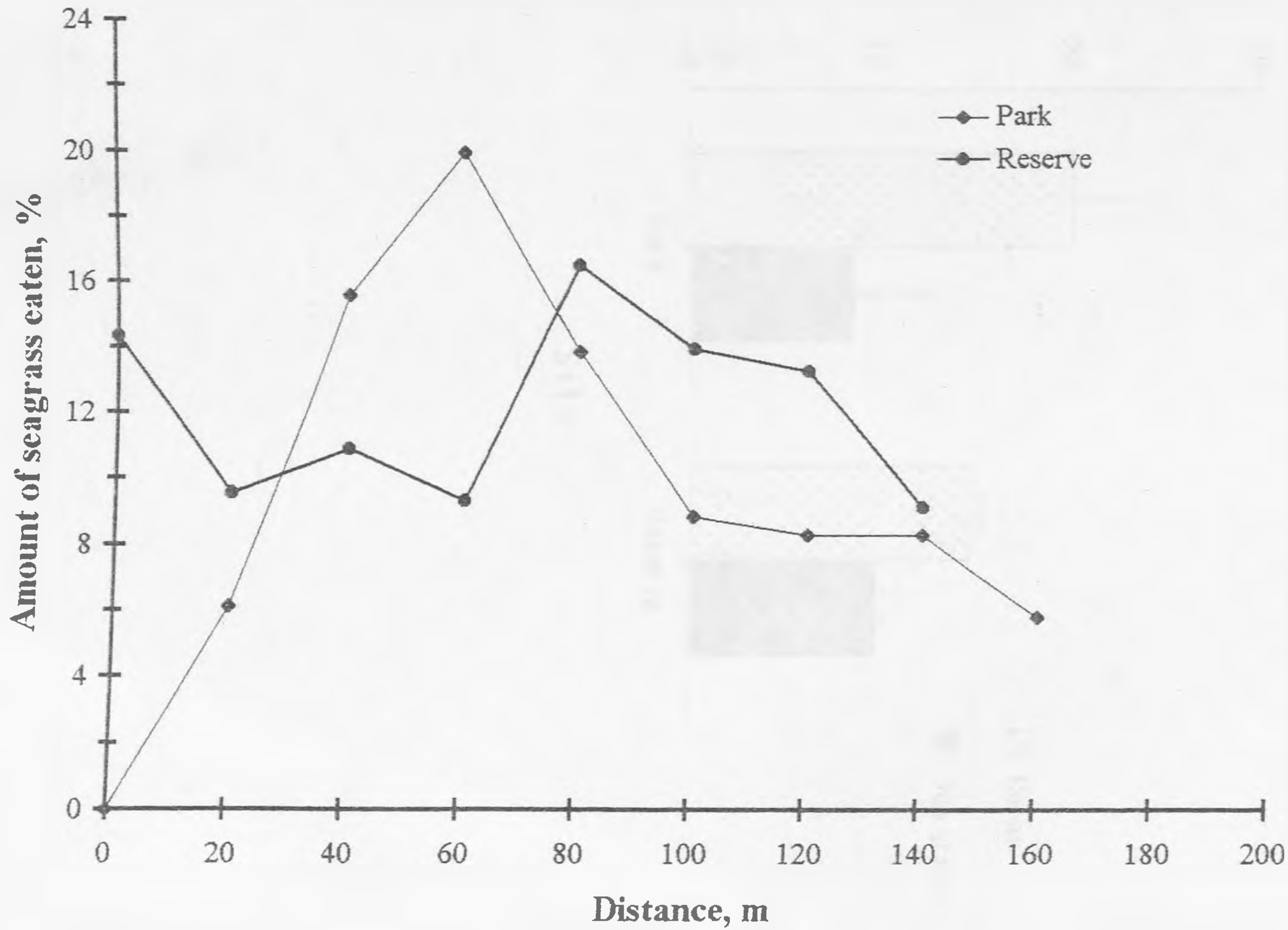


Figure 10.

Comparative analysis of herbivory by dominant substrate cover for Mombasa Marine Park and Reserve

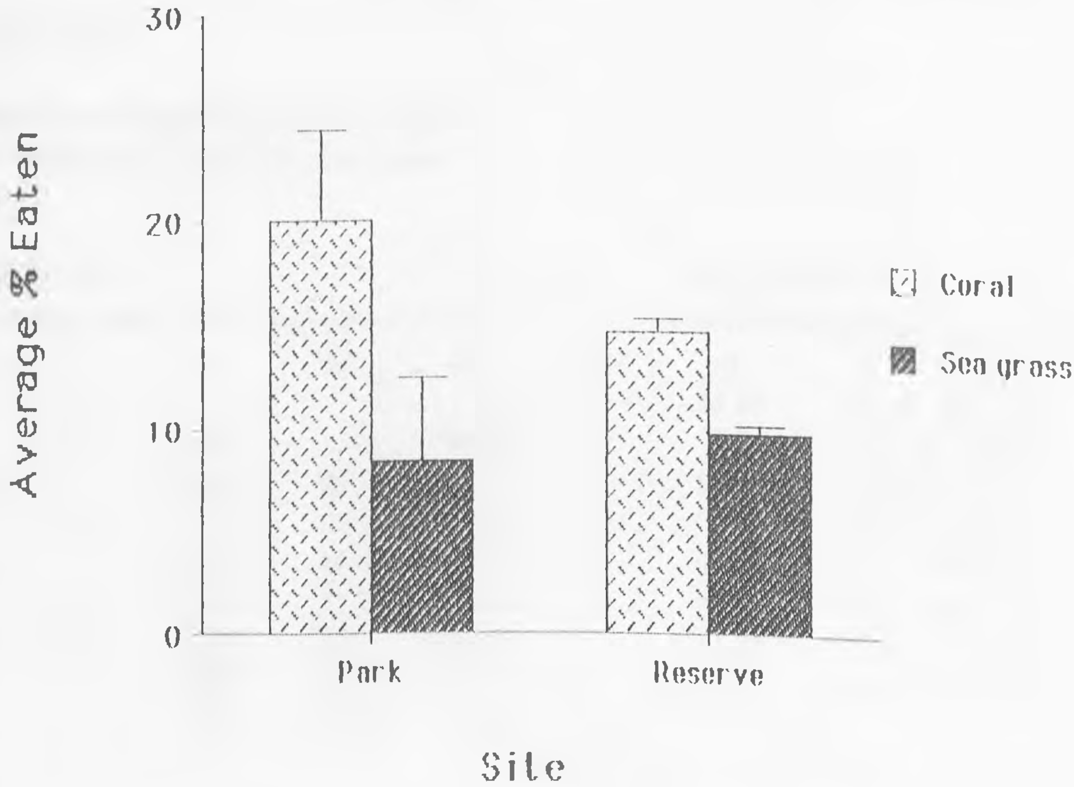


Table 8:

A two-sample two-tailed (2) t-test for differences in mean herbivory levels for mombasa marine park and reserve.

Note: Percentage herbivory datum, p, subjected to arcsine transformation, p' , such that p' = arcsine ($\sqrt{p}$).

Ho: herbivory is same in park as in reserve
Ha: herbivory in park is different from reserve

	PARK			RESERVE		
	p	p'	p'²	p	p'	p'²
	0	0	0	14.33	22.22	493.73
	6.11	14.3	204.49	9.56	18.05	325.8
	15.56	23.26	541.03	10.89	19.28	371.72
	20	26.57	705.96	9.33	17.76	315.42
	13.89	21.89	479.17	16.56	24.04	577.92
	8.89	17.36	301.37	14.01	21.97	482.68
	8.33	16.74	280.23	13.34	21.39	457.53
	8.33	16.74	280.23	9.17	17.66	311.88
	5.83	13.94	194.32			
v	8			7		
Mean	16.7556			20.2963		
(Sum p')²	22740.6			26364		
Sum p'²	2986.8			3336.68		
SS	460.065			41.1745		
Pooled var	33.416					
SE of mean	2.80889					
t	|1.2605285|	$t_{0.05(2)(15)} = 2.131$ NS				

CONCLUSION 0.20<P(|t|>or=1.261)<0.50, Do not reject Ho:

Table 9.

A two-sample two-tailed (2) t-test for differences in herbivory among substrate types in the park and reserve. Data subjected to arcsine transformation, p'(after Zar, 1984)

Ho: herbivory in coral zone same as in sea grass zone
Ha: herbivory in coral zone different from sea grass zone
$\alpha = 0.05$

	Park: Wreck		Reserve: Ras Iwatine	
	Coral zone	Sea Grass	Coral zone	Sea Grass
	p'	p'	p'	p'
	14.311	16.775	22.248	18.008
	23.264	16.775	24.018	19.269
	26.565	13.972	21.981	17.788
	21.89		21.425	17.622
n	4	3	4	4
v	3	2	3	3
Mean	21.5075	15.84067	22.418	18.17175
STD	4.488862	1.321347	0.970299	0.648124
Sum p'^2	1930.89	758.018	2014.033	1322.53
$(\text{Sum } p')^2$	7401.161	2258.341	8041.068	5283.4
SS	80.59952	5.237873	3.765918	1.680261
Pooled variance		17.16748		0.9076964
SE mean		3.164548		0.673683
t		1.791		6.303043

Park: $t_{0.05(2)(5)} = 2.571$ NS
CONCLUSION: $0.05 < P(|t| \geq 1.791) < 0.20$
Do not reject Ho

Reserve: $t_{0.05(2)(5)} = 2.447$ S ***
$P(|t| \geq 6.303) < 0.001$
Reject Ho

Table 10

Summary of statistical test on herbivory among different substrate cover types for both Mombasa Marine Park Reserve.

	Park (Wreck)	Reserve (Ras Iwatine)
Coral zone	13.4 ± 0.61	14.5 ± 0.03
Sea Grass zone	7.5 ± 0.05	9.7 ± 0.01
t-test	Not significant	Significant

Note:

Values are retransformed to % thus, $p = (\sin p')^2$, (Zar, 1984; Sokal and Rolf,1981) see Table 9.

Figure 11.
Species similarity index between an experienced observer (supervisor) and a student (author) as a function of area for damselfish and wrasse of Mombasa Marine Park

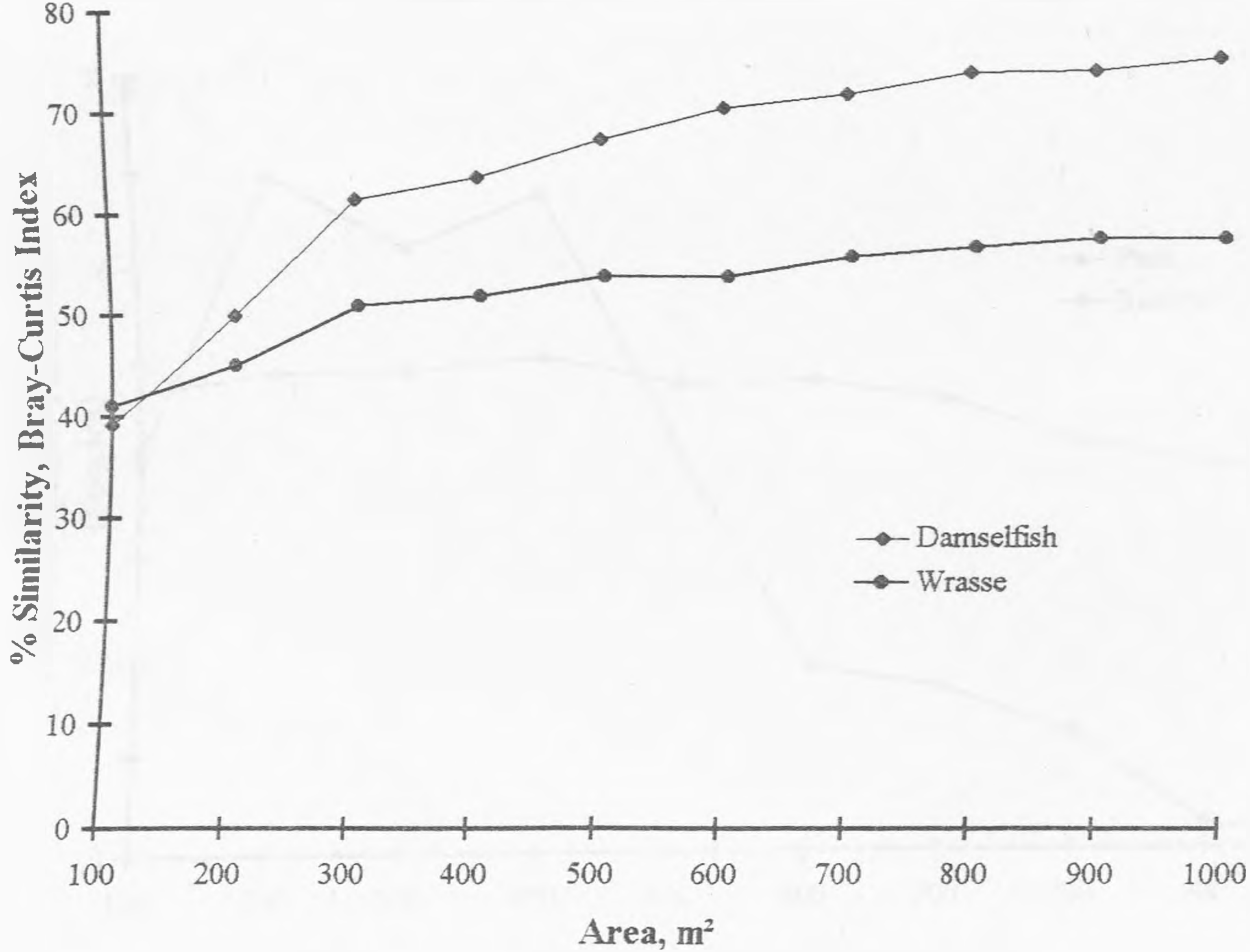


Figure 12.
Absolute species turnover as a function of area for damselfish and wrasse of Mombasa Marine Park and Reserve.

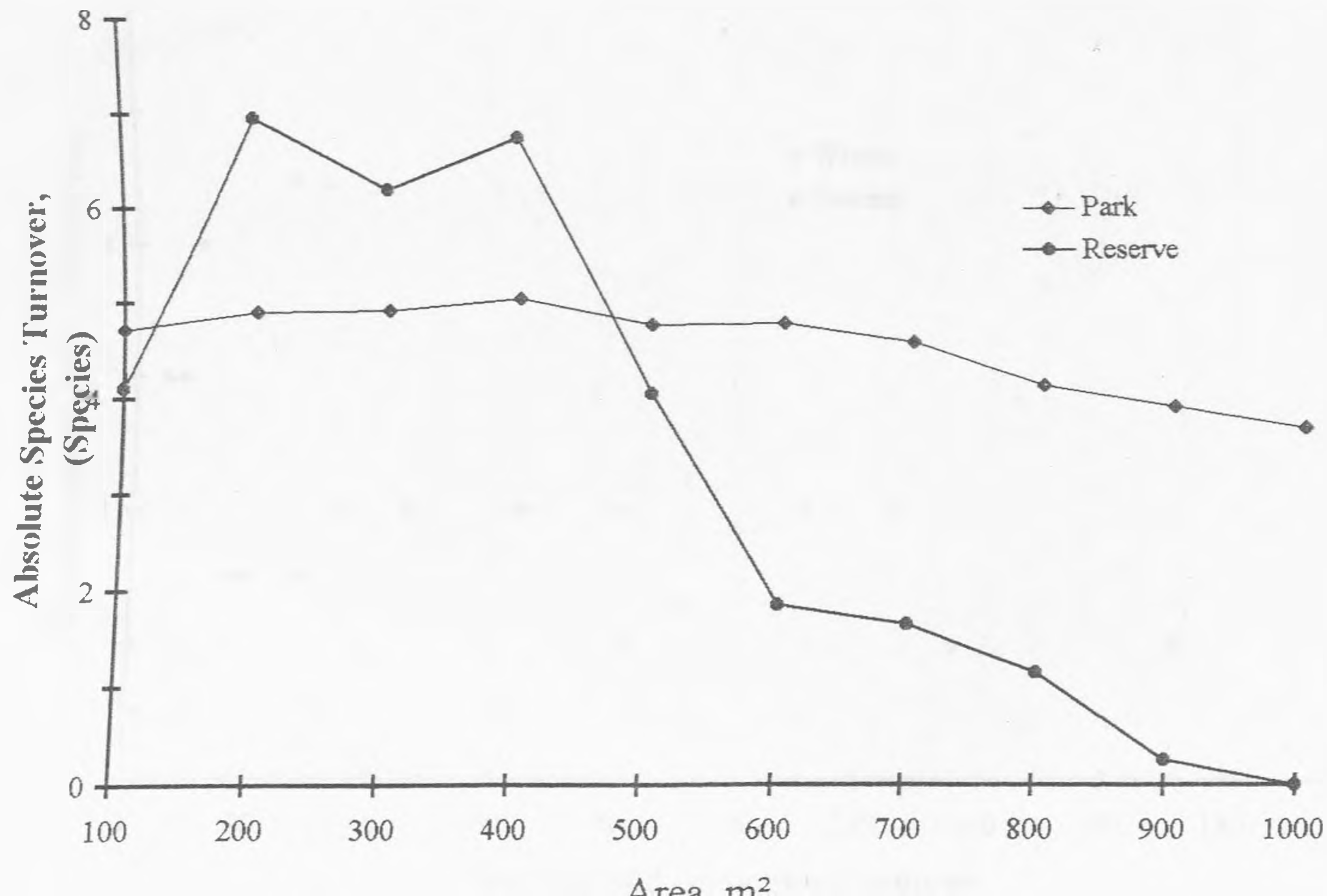
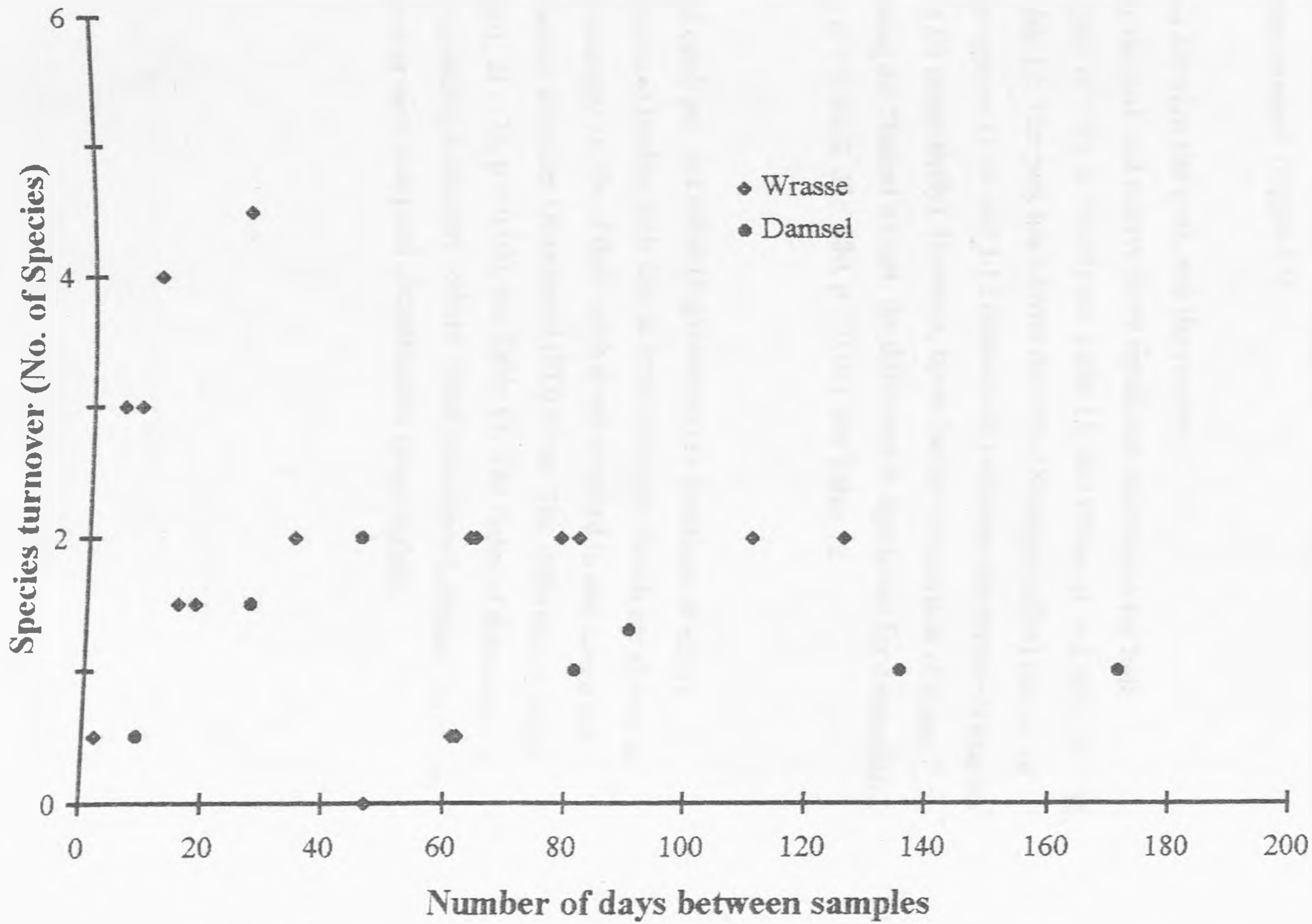


Figure 13.
Absolute species turnover as a function of time interval between sampling period at a spatial scale of 1000m² for damselfish and wrasse of Mombasa marine Park and Reserve.



3.60: Species-Area Relationship.

The number of species of damselfish and wrasse recorded within Mombasa Marine Park was plotted against area. Damselfish curve levels off after 600 m^2 at 14 species (Figure 14) whereas that one for wrasse attains highest peak at 17 species and at an area of 800 m^2. When this data is transformed to Log_{10} and plotted again, the curves do not show much variation in shape (Figure 15).

3.70: Comparison between the park and the reserve

In terms of density the park and reserve show significant differences for both damselfish ($t = 2.246$, $df = 35$, $p < 0.05$) see Table 11, and wrasse ($t = 6.494$, $df = 35$, $p < 0.05$), see Table 12. The park has a lower diversity (Shannon index) *per se*, of damselfish than the reserve (1.04 and 1.12 respectively) whereas the reverse is true for wrasse (1.10 and 1.08 respectively). However, upon further comparison of these diversity indices using the Student's t-test, the difference is significant for damselfish, but not for wrasse ($t = 0.3068$, $df = 180$, $p > 0.05$) see Table 12.

3.80: Fisheries

The catch (kg) and catch per unit effort (Kg/manhour) as functions of effort (manhours) for fishermen landing their fish at Jomo Kenyatta Beach are shown in Figure 15. On the average, 21.3% of their catch is not weighed in and hence not recorded by the resident Fisheries Department (FD) scout. The difference is highly significant ($t = 2.661$, $df = 24$, $p < 0.05$), see Table 13. The order of dominance is shown by table 14 including a category 'others' which comprises Labridae (wrasses), Serranidae (groupers or rock cods) and Acanthuridae (surgeonfish).

Figure 14.
Species-Area curve for damselfish and wrasse of Mombasa Marine Park

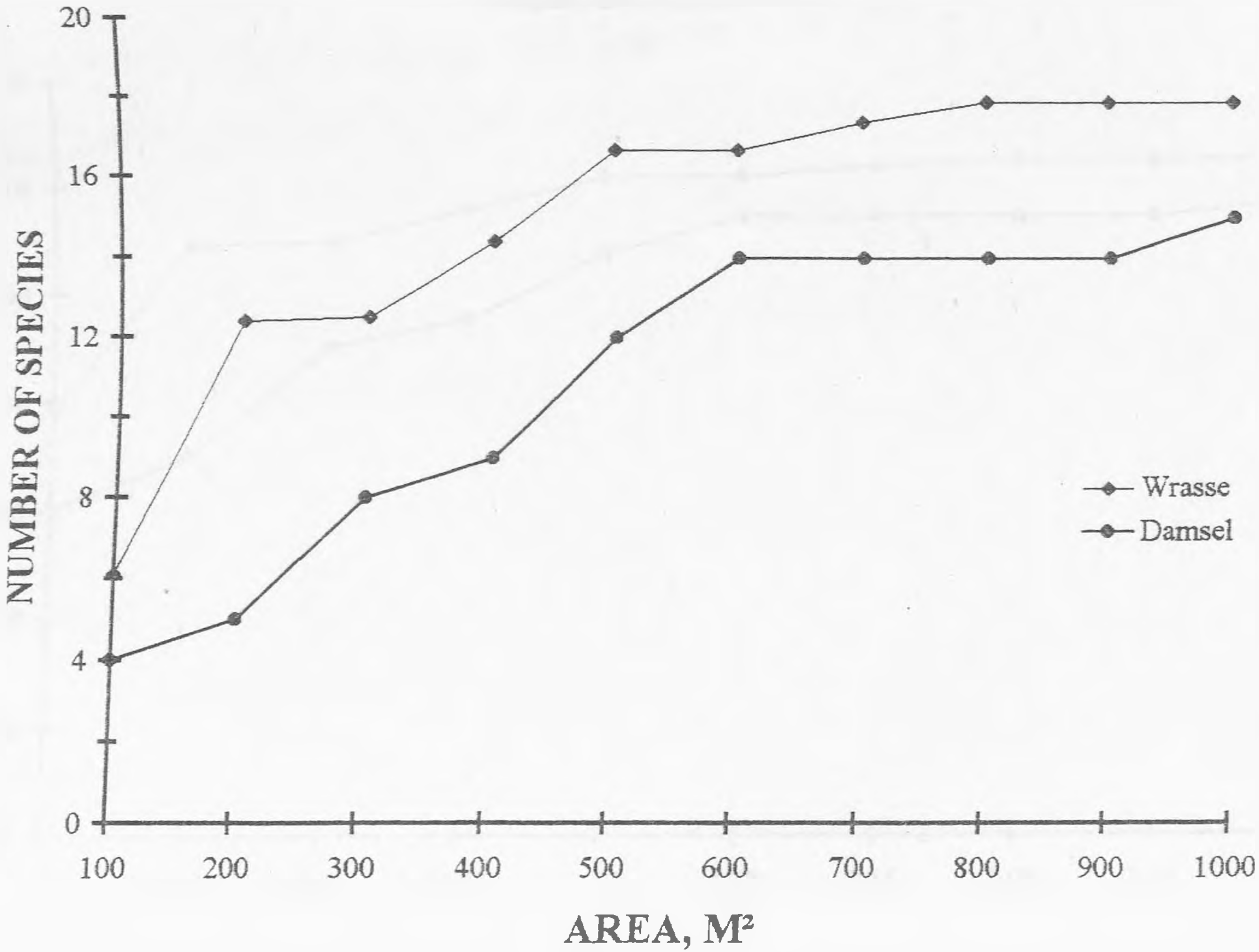


Figure 15.
Logarithmic (base 10) transformation of the species-area relationship for wrasse and damselfish of Mombasa Marine Park

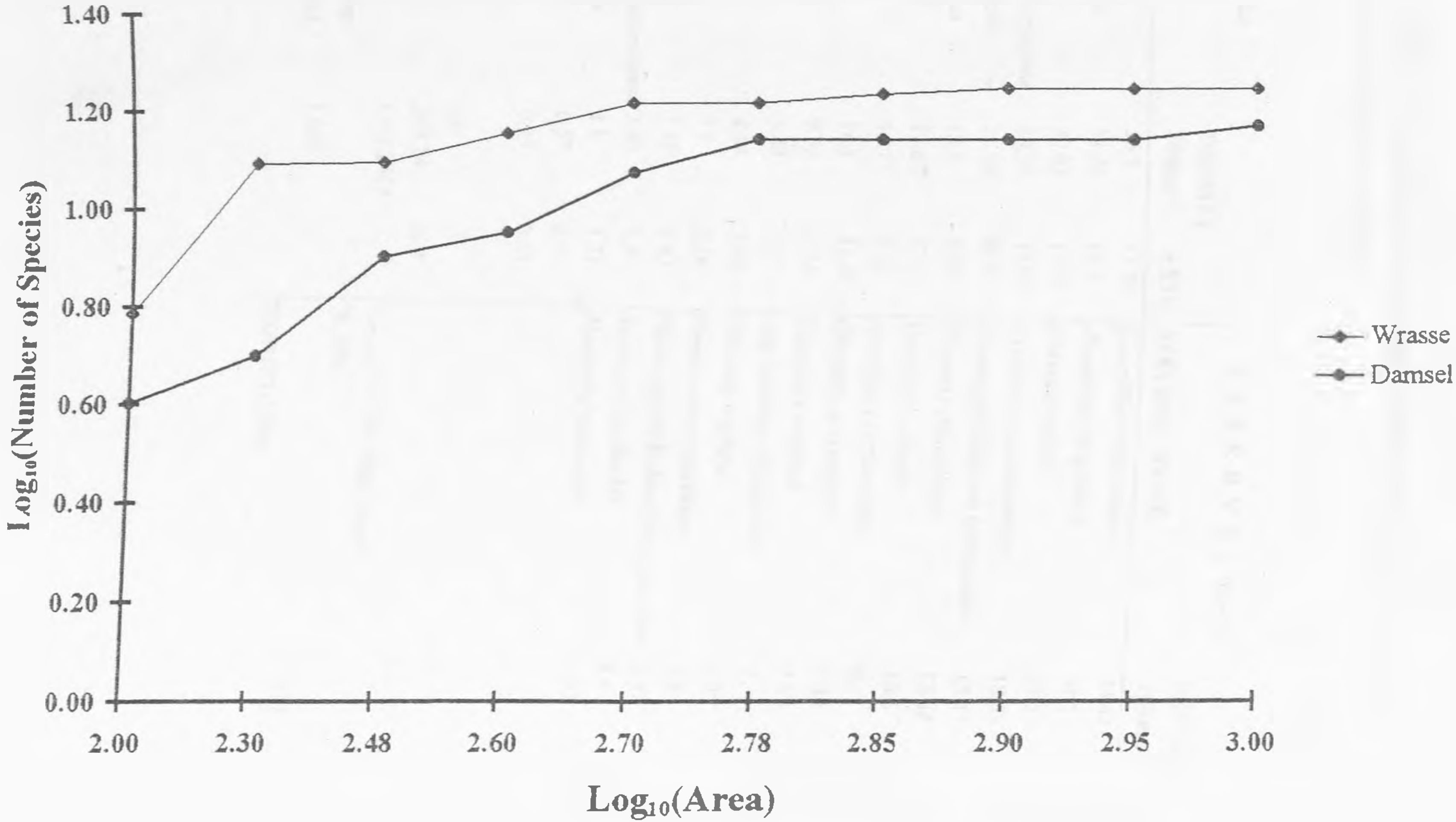


Table 11

A comparative analysis of damselfish of Mombasa Marine Park and Reserve in terms of density, diversity and similarlity.

P A R K; n = 21			**R E S E R V E; n = 15**		
SPECIES NAME	**DENSITY 1000m²**	**± STD**	**SPECIES NAME**	**DENSITY 1000m²**	**±STD**
Abudefduf vaigiensis	55.9	17.45	*Dascyllus trimaculatus*	44.47	14.95
Abudefduf sexfasciatus	51.43	18.3	*Abudefduf vaigiensis*	31.73	23.09
Chromis dimidiatus	30.05	11.58	*Chromis weberi*	27.33	11.25
Plectroglyphidodon lacrymatus	28.33	13.67	*Crysiptera unimacullata*	18.53	9.15
Plectroglyphidodon dickii	22.38	9.77	*Plectroglyphidodon lacrymatus*	15.47	13.5
Crysiptera unimacullata	18.9	0.08	*Chromis dimidiatus*	13.87	15.05
Dascyllus trimaculatus	17.67	13.12	*Dascyllus carneus*	10.6	10.78
Chromis opercularis	14.77	7.32	*Abudefduf sexfasciatus*	9	6.68
Chromis weberi	14.1	12.68	*Chromis opercularis*	7.33	7.74
Pomacentrus caeruleas	9.57	6.24	*Dascyllus aruanus*	7.07	6.42
Stegastes fasciolatus	5.48	3.57	*Amphipirion akallopisos*	7	7.47
Abudefduf sparoides	4.57	3.98	*Chromis nigrura*	6.93	8.76
Amphipirion clarkii	3.9	2.16	*Pomacentrus caeruleas*	5.8	6.27
Pomacentrus sulfurues	3.19	1.43	*Plectroglyphidodon johnstonianus*	2.47	3.69
Plectroglyphidodon johnstonianus	3.05	2.9	*Amphipirion clarkii*	2.4	1.99
Amphipirion akallopisos	1.1	1.31	*Abudefduf sparoides*	2.27	2.72
Dascyllus aruanus	0.57	0.9			
Dascyllus carneus	0.29	0.63			
Number of species	18			16	
TOTAL DENSITY	285.24	56.2		220.27	115.1
t test (Density)	t = 2.2464		$t_{0.05\,(35)} = 1.696$ Significant		
Sorensen similarity Index			88.24%		
Diversity index (shannon)	1.042			1.1215	
t-test for diversity			**SIGNIFICANT**		

Table 12

A comparative analysis of wrasses of Mombasa Marine Park and Reserve in terms of density, diversity and similarlity

PARK: n=22

SPECIES NAME	DENSITY #/1000m²	± STD
Thalasomma hebraicum	51.68	12.27
Diproctacanthus xanthurus	24.77	10.34
Labroides dimidiatus	23.23	9.48
Gomphosus coeruleus	22.09	11.72
Halichoeres hortulanis	18.91	10.97
Halichoeres scapularis	11.68	6.26
Thalasomma hardwickei	9.91	5.63
Coris caudimacula	6.55	3.76
Pseudocheilinus hexataenia	5.95	3.43
Stethojulis albovittatus	5.59	3.52
Anampses caerulopunctatus	5.18	4.72
Coris formosa	4	2.07
Bodianus axillaris	3.41	2.77
Cheilio inermis	3.27	2.2
Coris aygula	3.09	3.73
Anampses twisti	2.59	2.93
Stethojulis strigiventer	2	1.68
Anampses lineatus	1.45	1.16
Halichoeres marginatus	0.91	1.7
Cheilinus chlorurus	0.64	1.11
Labroides bicolor	0.64	0.57
Cheilinus bimaculatus	0.591	1.15
Halichoeres biocellata	0.45	0.78
Cheilinus diagramus	0.41	1.15
Thalasomma lunare	0.23	0.73
Epibulus insidiator	0.23	0.73
Novaculichthys taeniurus	0.23	0.6
Cheilinus trilobatus	0.18	0.65
Cheilinus lunulatus	0.09	0.42
Coris gaimard africana	0.05	0.21
Hemigymnus fasciatus	0.05	0.21

RESERVE: n=14

SPECIES NAME	DENSITY #/1000m²	± STD
Thalasomma hebraicum	30.29	8.27
Halichoeres hortulanis	11.07	5.02
Labroides dimidiatus	10.14	3.46
Halichoeres scapularis	9.07	4.862
Cheilio inermis	5.07	2.19
Gomphosus coeruleus	4.5	2.92
Coris caudimacula	3.93	2.87
Thalasomma hardwickei	3.5	3.11
Stethojulis albovittatus	3.5	3.29
Diproctacanthus xanthurus	2.29	3.51
Novaculichthys taeniurus	2.07	1.53
Coris formosa	2	1.65
Stethojulis strigiventer	1.86	2.67
Pseudocheilinus hexataenia	1.77	2.43
Coris aygula	1.29	1.44
Cheilinus trilobatus	1.21	1.32
Anampses twisti	1.07	1.62
Cheilinus fasciatus	1.07	1.53
Cheilinus bimaculatus	0.86	0.83
Cheilinus chlorurus	0.79	2.57
Thalasomma lunare	0.5	0.63
Bodianus bilunulatus	0.43	0.73
Epibulus insidiator	0.36	0.48
Cheilinus lunulatus	0.14	0.52
Bodianus axillaris	0.07	0.26
Cheilinus diagramus	0.07	0.26

	Park		Reserve	
Number of Species	31		26	
Total density	210.05	60.42	98.92	25.32
t-test (Density)	t = 6.49392		$t_{\alpha 0.05 (35)} = 1.696$	SIGNIFICANT
Diversity index (Shannon)	H = 1.1003		1.0824	
t- test (Diversity)	t = 0.3068		$t_{\alpha 0.05 (180)} = 1.645$	NOT SIGNIFICANT
Similarity index	80.7%			

Figure 16.
Fishing yield as a function of fishing effort for artisanal fishermen landing their fish at Jomo Kenyatta Public Beach. (Note: Each fishing trip lasts for about six hours)

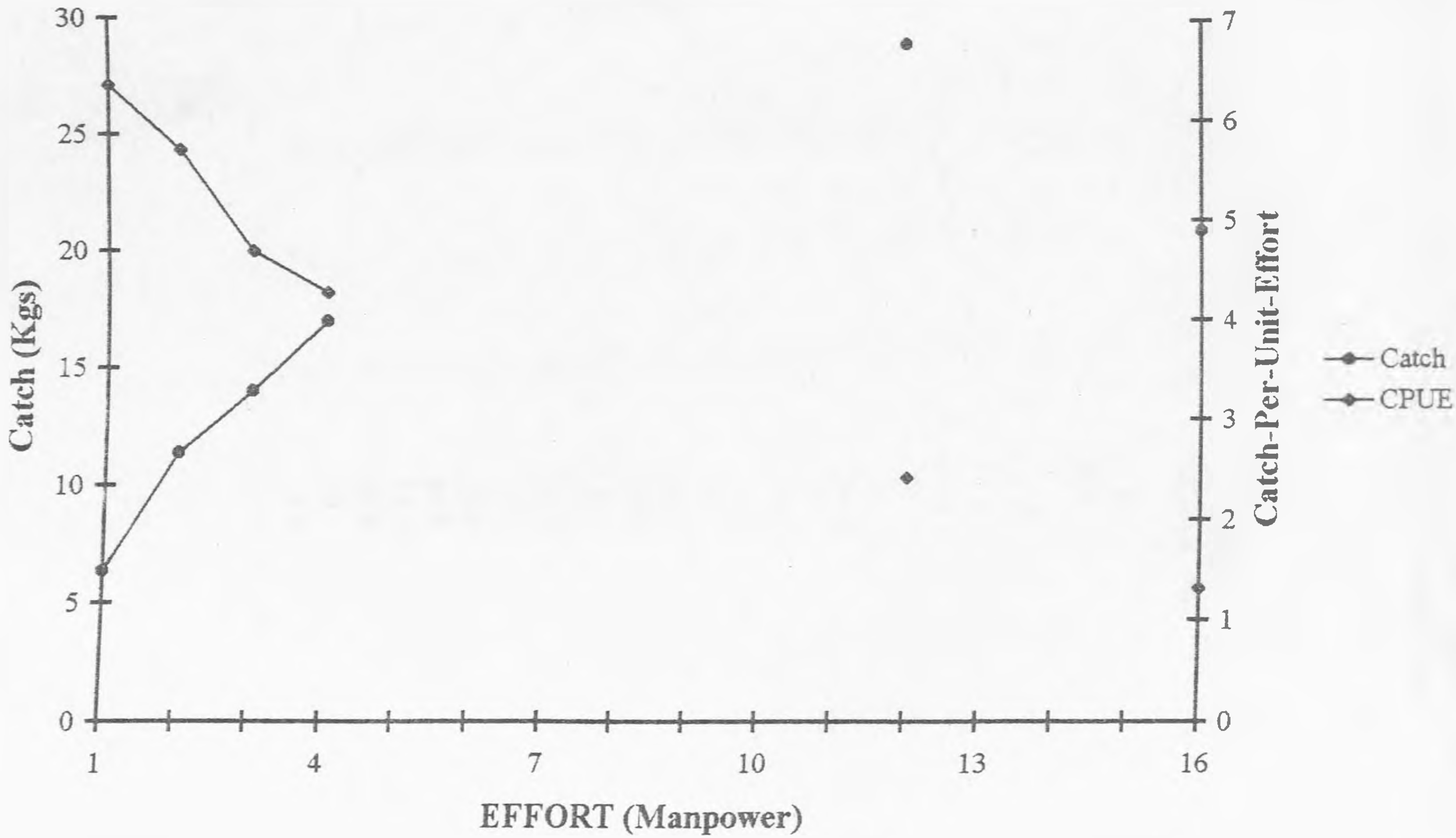


Table 13
One-sample t-test for paired difference between catch (real) weight and declared (sale) weight of fish weighed-in by fishermen at Jomo Kenyatta Beach, Mombasa.

Ho: $\mu_d = 0$
Ha: $\mu_d > 0$
$\alpha = 0.05$

Boat #	Real catch in Kg.	Declared Wt. (sale) kg	Difference d (real-sale)	Percentage difference %d
1	21	8	13	61.9
2	35	6	29	82.9
3	2	1.5	0.5	25
4	7	6	1	14.3
5	23	17	6	26.1
6	8	1	7	87.5
7	15	15	0	0
8	12	12	0	0
9	5	5	0	0
10	27	27	0	0
11	45	43	2	4.4
12	45	44	1	2.2
13	2	2	0	0
14	7	6	1	14.3
15	10	8	2	20.0
16	9	9	0	0
17	8	6	2	25.0
18	8	6	2	25.0
19	9	7	2	22.2
20	15	12	3	20.0
21	5	3	2	40.0
22	15	13	2	13.3
23	7	4	3	42.9
24	2	2	0	0
25	20	19	1	5.0

mean %d	21.3	
Mean d	3.18	
s_d	5.975	
n_d	25	
v	24	
t	2.661	
$t_{0.05\,(24)}$	1.711	Significant

Table 14

The most abundant fish families landed at Jomo Kenyatta Beach

FAMILY	ABUNDANCE SCORE	RANK *
Lethrinidae (scavengers)	64	1
Octopodidae (octopuses)	50	2
Siganidae (rabbitfishes)	49	3
Teuthoidea (squids)	31	4
Lutjanidae (snappers)	22	5
Scaridae (parrotfishes)	20	6
Others	14	7

Note:

* = Abundance score refers to total proportion (1-10) of respective fish familes per fishing trip based on th 25 boats sampled.

CHAPTER 4

4.00 Discussion.

4.10 Tourism.

Questionnaire surveys unless conducted solely and directly by the investigator concerned usually have low return rates. Most tourists don't like to be bothered when on holiday. Even those who were tolerant enough did not respond to all the questions or never gave concise information. For the questionnaire to get to the hotel guest and back to the investigator it had to pass through several individuals (guest relations officer, boatman, room attendant and sometimes the hotel general manager) some of whom were not known to the investigator hence never understood the importance of the survey. Another problem was the language barrier for the questionnaire was only in English and French. Future surveys must include German and Italian translations. Therefore a return rate of 36% in this survey is as good as any other under circumstances comparable to these. Although the questionnaire was intended for random circulation to any resident in each hotel sampled, this point was misunderstood by agents meant to distribute it. Only those who went out on a boat trip got the questionnaire. The question on the number of times an individual visited any named park was not answered adequately. Other observations included; the fish were 'friendly', the snorkelling site was too crowded with boats, the guides should know more about fish and coral and that security against shell collection should be improved.

Considering that most tourists save money purposely for a holiday in Kenya, it is not surprising that 75% of those surveyed indicated that boat charges were either cheap or reasonable. Another contributory factor to this response could be the weakness of the local currency compared to the United States dollar and the German Mark based on the nationalities of those who gave this response. With the coral gardens averaging 800m from the shoreline, long boat trips become expensive hence, boatmen try to keep their charges affordable. Some hotels own tourist boats and a trip to the coral gardens could be part of client's entertainment package with the guest paying park entry fees only. However for tourists booked in hotels to the south of the park (Mombasa and Nyali) a long boat trip is inevitable. To keep their charges affordable, boatmen operating in this area take their clients to a tour of the coral gardens in the reserve which are heavily impacted by fishing rendering them unattractive. It would be interesting to survey how many tourists actually prefer hotels near the park in order to be close to the higher quality reef areas thus avoiding expensive boat trips. Those would probably have taken a trip there previously.

The most frequented reefs are at Serena, Bamburi, Ras Iwatini and Nyali. This is because they still have some coral development and the reef flat is exposed at low tide. The effective tourist area of $5Km^2$ would cover these areas if the area of the current park is reduced and a small fully protected site is established at Ras Iwatini/Nyali. This would close the latter site to fishermen but new fishing grounds would be established at Bamburi and to the north of Serena Beach. If such a plan were to be effected, current conflicts with fishermen would be reduced. The park's operational costs would also decline because of the reduced administrative area.

4.20: Predator foraging pattern.

That the two sites in the same protected area can show different predation levels between habitat types can be explained by the fact that at one site (wreck) a sea-urchin removal experiment was in progress during the period of assaying, 1992/93. The experiment involved the removal of all sea urchins from the site to study the recovery process. Sea urchins are a major food item for predatory fish. It can be expected that due to the removal of this important food item, food for carnivores was therefore a limited resource at this site during the experiment. Consequently, predatory fish would therefore have to move further in search of food, hence the higher foraging pattern for carnivores at this site as shown in the results section. Coral covered areas show higher predation levels than sea grass zones. With reference to these sites, could be attributed to;

(a) better visibility and

(b) abundant predators.

The wider foraging pattern in the park than in the reserve could be attributed to;

(a) no disturbance from fishing in the park so fish move about freely as compared to the reserve where they are quite timid and hide under coral crevices with the slightest disturbance and

(b) higher fish abundances and density in the park (see Tables 11 & 12), suggesting that food is limited, forcing fish to forage further.

Coral cover in the reserve has been destroyed through fishing activity rendering the habitat inadequate for fish shelter (see McClanahan 1989; 1992). Fish replenishment in the reserve is quite slow because fishermen use fishing nets with a small mesh size which indiscriminately catch fish at all stages of development. Fishermen who use nets tend to avoid coral dominated areas. The few remaining coral heads therefore offer the only refuge for fish in the reserve. That fishermen still catch fish in this area is owed to these coral heads and replenishment from the park. If some of these coral heads were fully protected to exclude fishing, there would be faster recruitment of both coral and fish species allowing a higher fishing yield in the adjacent fishing grounds.

The sharp decline in predation at the coral-seagrass transition zone occurs within 40m. This suggests that any zonation plan aimed at fully protecting coral reef fish should have a 40m buffer zone between the edge of the coral gardens towards the seagrass bed end and the park boundary. In the reserve, this buffer zone would be a high fishing yield area as it would be quickly replenished by the fully protected coral gardens. The reserve would also act as a multiple use area where fishermen, researchers and resource managers would interact, exchange information and offer suggestions on possible management options.

4.30: Herbivore ranging pattern.

Herbivore food is superabundant within sea grass beds but scarce within coral overgrown areas. For the herbivores that shelter in the sea grass, their movements are therefore expected to be limited. For those that shelter in coral crevices and rocky hideouts, their foraging patterns takes them to the sea grass areas and back to their hideouts. The chance of an experimental sea grass blade being clipped off by a predator is therefore low in sea grass beds as compared to coral dominated areas where the experimental blade is very conspicuous. Herbivores, as shown in the graphs, would therefore move longer distances in coral zones than in sea grass zones. In the reserve, fishing is allowed and a variety of fishing gear including fishing baskets (*malema*), hook-and-line (*mshipi*), fishing nets (*nyavu*) and beach seines (*juya*). These methods, except the fishing baskets (*malema*), are not suitable in coral domonated substrata for they get entangled and easily broken. The gear is expensive and difficult to replace, so fishermen using them deliberately keep off coral dominated areas. Fish therefore confine themselves to the less disturbed coral areas. We could ask the question here whether this is an evolutionally race to avoid being fished. This would form an interesting study. If this were so, we would expect that local horizontal fish migrations to sea grass beds and back to the coral zones to be shortlived and/or taken only when food has become a limiting factor. This is what sustains the fishery in the reserve as these fish are caught whilr foraging. However in the park, the absence of fishing activity means low disturbance hence fish move more freely. Low disturbance in the park would also indicate high fish abundance as indicated in the results. Ecological theories postulate that when there is a high abundance of individuals in a natural ecosystem, food becomes limiting with time. This would lead to the wider ranging pattern in search of food as indicated in the results section.

Within seagrass areas, herbivory trend is constant. From this constant value to the pick value within coral dominated areas is a distance of 40m. This is a transition between coral and seagrass. This concurs with predation trends.

4.40: Species turnover.

Visual censuses although validated and still the best underwater quick and non-destructive fish sampling techniques available to ecologists so far (Samoilys and Carlos, 1992) have some some drawbacks;

i) are weak at sampling cryptic species. Some of the considered species are cryptic (e.g. *Plectroglyphidodon johnstonianus, P. dickii, Pseudocheilinus hexataenia, Stegastes fasciolatus, Anampses sp.*) and tend to hide upon approach of the swimmer. In the reserve where fishing is intensive, fish especially wrasses are very timid and detect human presence very quickly upon which they rush to hide under rock crevices or swim away. This leads to under-sampling.

ii) are only useful in sampling diurnal species. Nocturnal species when sampled during the day may not be detected at all. However the two families considered in this survey are primarily diurnal.

iii) some damsel species e.g. *Abudefduf sexfasciatus* and *A. vaigiensis* are gregarious and follow a swimmer for a distance and unless careful, one might count them severally. On the other hand, one may get used to the common and abundant species such that one ignores them unconsciously.

iv) fisheries scientist have been reluctant to adopt the techniques for providing stock estimates.

The absolute turnover as a function of time between sampling period curve levels off after 100 days at spartial scale of 1000 m². This observation suggests that for meaningful sampling analysis, the period between samples should about three months (or 100 days). Changes in the community structure will be more noticeable then. In both the park and reserve, this constancy is achieved at a high absolute turnover. Between 200 m² and 400 m², turnover peaks in the reserve and drops 3.7 at 1000 m² but never levels. In the park, turnover levels after 600 m^2 and drops to 0 at 1000 m^2. Species turnover is usually described as either chaotic or orderly (stochastic or deterministic theories, see Bohnsack, 1983). The high turnover in the reserve shows how unpredictable the community is therein. This could be attributed to fishing which removes some individuals thus creating space. According to Sale, 1991 and Bohnsack, 1983, this space will be colonized through a chance process; referred to as `reef lottery'. The reserve would therefore fall under the chaotic school of thought because the higher the turnover the lower the constancy (predictability). But turnover as a function of time shows instability in the first 100 days and levels after that albeit at a high level in both the park and the reserve. This would agree with island biogeographic theory.

4.50: Species-area relationship.

Damselfish are not migratory. Several of them e.g. anemonefish, three-spot damsels, Dick's damsel etc defend small territories. Larger species e.g. scissor-tail damsel and the sergeant major have foraging strategies that make them range wider especially in the park where they occur in great abundance. Thus the damselfish species-area curve develops an asymptote at a small spatial scale (600 m^2) beyond which new species are rarely encountered. Wrasses have larger bodies and therefore forage within a wider area (asymptote at 800 m^2). Any conservation area zonation plan should therefore include coral reef cross-sectional area larger than this for effective conservation of these families.

4.60: Fisheries

Fishermen practising their trade in this area do not use equipment whose tangible value can be easily quantified neither is their catch monospecific. All their boats are either wind- or muscle-power propelled. Only a handful use nets whereas a majority use fishing baskets (*malema*), traps (*uzio*) or home-made spear guns all of whose monetary value is unquantifiable for effective cost/benefit analysis. All of them take part of their catch home for food (`*mboga*') and is therefore not weighed before offering it for sale. Other fishermen do not land at the designated landing/weighing point. Some old men go fishing more as a hobby rather than for monetary gains. Although these old men are considered as fishermen, their catch is almost always negligible (1 kg or less). This makes it difficult to assess catch per unit effort. Some fishermen just swim in and out of the sea. The latter's gear includes goggles, flippers, home-made spear gun/metallic poke and a nylon basket. Majority of the fishermen are illiterate and look at any kind of research or government agent with suspicion. The difficulty of evaluating this kind of a fishery using current models is enormous.

Fisheries is subject to politics. Due to political interfereance and issuing of "directives" during political public meetings fishermen in this region have been made to adopt attitude that they should not necessarily record their catch with the Fisheries Department's fish scouts on site. However, a mutual agreement between the scout at the Jomo Kenyatta landing point and the fishermen allows for weighing and recording. It is not an air-tight agreement because some fishermen sell their fish at sea, others refuse to land at the designated point and some declare only part of their catch. The resultant default rate of 21.3% is quite high but not surprising given the circumstances. This proportion is removed before weigh-in for sale at sea or taken home for the needs of the fisherman's family.

On man-power basis, the catch versus catch-per-unit-effort curve declines in the same way as a typical comparison of the two variables in single species fishery with better quantification of effort. Although there is inadequate data to complete the graph, the curve if extrapolated indicates a fishery that is overexploited, one of the reasons being a very small fishing net mesh size. For maximum gains while fishing in the same area, each fishing vessel should ideally have a maximum of two fishermen fishing for six hours. Currently, fishermen are increasing effort in terms of manpower for a very small catch.

4.70: One versus two parks.

The sites sampled in both the park and the reserve do not show a significant difference in both predation and herbivory. In terms of diversity, they are not significantly different for wrasses but are different for damselfish species with the reserve being more diverse. In terms of density, both damselfish and wrasses show significant differences in both the park and reserve. These outcomes could be attributed to the removal oflarge predators through fishing. When turnover is plotted as a function of area and pooled for both the park and reserve, the curve develops a second but lower peak. This would mean more constancy in the reserve than in the park. For the unfished damselfish, the similarity index between the park and reserve is higher (88.24%) than for the fished wrasses (80.7%). The difference could be explained as a result of disturbance, fishing and habitat destruction in the reserve. Considering that the site sampled in the reserve was targeted for protection, these results are positive towards such a plan. Full protection would lead to recovery of corals and associated coral reef fauna. However to reduce operational costs in terms of patrols, the size of the current park should be reduced and the area proposed protected site in the reserve kept small. Some species were found in the reserve and not in the park and vice versa. Therefore two fully protected areas will conserve more species than one area because of habitat heterogeneity. Two parks will also dampen the effects of tourist damage by dispersing their attraction.

CHAPTER 5

5.00: Conclusions and Recommendations.

Total protection as offered by park status successfully maintains habitat diversity which is a potential factor for the maintenance of a higher species diversity and density than partial or no protection (see also McClanahan, 1992; McClanahan and Shafir, 1990; Simberloff, 1988; Salm 1984; Bohnsack, 1983) as well as ensuring high production of 'new' (incomig) species and/or a low rate of local 'extinction' (exit from an area). Although only two fish families and two fish guilds (predators and carnivores) were sampled for space requirements, the protected area has diverse species and guilds with different space requirements. Based on predator and herbivore foraging patterns and species turnover in relation to area, the coral is the most important resource for coral reef community conservation. All marine conservation efforts therefore should be concentrated more on the coral reef as the core area. But how big should such an area be? This is a difficult question to answer without comprehensive ecological studies of all the guilds and keystone species, which for a tropical coral reef ecosystem, would take a much longer period than this study. It would be easier if the situation dictated that conservation efforts focus on a single species or guild. Until such a study is done, resource managers and planners will continue to base their decisions on incomplete ecological information, intuition, common sense and guess work.

Protected areas also sustain fisheries through replenishment, thus justifying the fact that this marine resource management policy should be maintained. The fishery in Mombasa Marine Reserve is already overexploited and unproductive (see also McClanahan, 1989; 1992). Further, the catch versus effort and catch versus catch-per-unit-effort curves indicate a fishery beyond the break-even point (see Payne, 1986). However, because the effort is basically man-power based and fishermen do not consider this as a cost (it is also difficult to quantify for artisanal fishermen), the fishery is still being utilised albeit at low benefit. To increase fishing yield per fisherman, fishing effort should be reduced through,

a) limiting gear and manpower by

(i) effectively keeping out beach seines (*juya*),

(ii) effectively enforcing the 2.5 inches mesh size regulation for net fishing and restricting it to sea grass areas,

(iii) reducing the number of fishermen in the reserve by helping some of them acquire versatile fishing vessels and equipment for open water fishery,

b) increasing the fishing area by reducing the area of the park (see below),

c) exploring the possibilities of sea weed farming as an alternative to fishing.

The size of the Mombasa Marine Park *per se* (10 Km^2 or 1000 ha) should be reduced while adding a smaller protected area within the reserve. Currently, conflicts between fishermen and resource managers over fishing grounds are frequent. This could be resolved by adjusting the Mombasa Marine Park and Reserve boundary plan as follows;

i) the park boundary should be adjusted to start at the lowest spring tide water mark, approximately 300m from the beach,

ii) the Jomo Kenyatta Beach park boundary should be moved 1km northwards to Bamburi Beach,

iii) establish a small fully protected area in the reserve at Ras Iwatine/Nyali coral gardens with a total area of approximately 1Km^2 (0.5Km length by 1.8 km width),

iv) other boundaries to remain as previously established. .

There are two fish landing points along the park and reserve boundary (Jomo Kenyatta and Nyali Beaches). Nyali Beach landings were not assessed. This needs to be done for a comprehensive assessment of economic returns from fishing in the reserve.

In this fishery, like all others in Kenyan marine waters, the community as a whole is being exploited rather than just a single species. The effects of fishing mortality on a multi-specific community should be assessed more exhaustively and models developed for the same. Current fisheries models are based on single species fisheries especially where fishermen conduct their own cost-benefit analysis before engaging in the trade. These models should also consider manpower as an effort and wind propelled fishing craft.

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