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Effect of recreational fish feeding on reef fish community composition and behaviour

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Abstract—Feeding fish with bread or other food is widely used by tour operators to enhance human-animal interactions in coral reefs. Little is known, however, about the effects of recreational fish feeding on fish community structure and fish behaviour. These two issues were examined in this study within three marine protected areas of Kenya by comparing data from sites frequently used to feed fish and control sites not frequently visited by tour operator. The effects of feeding on community structure and fish behaviour were investigated through underwater visual surveys and fish feeding experiments, using bread. The numbers of individuals and species of fish at the feeding sites were higher than at control sites. This result suggests that the abundance of bread-feeding fish does not significantly negatively effect non-bread feeder population or total biodiversity. The main result of the fish behaviour study was that the reaction to bread at feeding sites was quicker than at control sites, which indicates that some species learn to feed on this novel source of food.

INTRODUCTION

The tourism industry is a growing sector, especially in tropical countries that provide exceptional biodiversity. Coral reefs provide opportunities for recreational activities that increase interactions between people and this biodiversity, but with potentially negative effects on the environment. A number of studies have focused on the physical damage of divers or snorkelers on coral (Talge, 1990; Hawkins & Roberts, 1992; Talge, 1992; Hawkins & Roberts, 1993; Rouphael & Inglis, 1995; Harriott *et al.*, 1997; Rouphael & Inglis, 1997; Hawkins *et al.*, 1999). Other researches have tried to determine the effects of recreational fishing (Craik, 1982; Tilmant, 1987). These studies highlight potential negative effects of recreational use of coral reefs, but there is also an increasing value being placed on visitor interactions with wildlife that will increase the attractiveness and income from tourism (Gauthier, 1993 in Reynolds & Braithwaite, 2001). This includes the marine environment, yet few studies have examined fish feeding, one of the most common human-wildlife interactions (Sweatman, 1996).

Fish feeding is usually forgotten from the list of possible tourism impacts (Harriott *et al.*, 1997). Nonetheless, as part of human-wildlife interactions, fish feeding has various potential negative influences such as an unhealthy diet, disease, habituation to humans and increased capture risk, dependency on humans, and human danger (Harriot, 2002). Many tourist-wildlife incidents, possibly caused by recreational fish

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feeding, have been recorded and there are some accounts of changes in fish behaviour, such as aggressiveness. For example, serious accidents can potentially occur at shark-feeding sites during feeding events (Perrine, 1989; Seaborn, 1990). Evidence for the direct link between the change in fish behaviour and fish feeding activities is usually not quantitative, but based on subjective evaluations by regular divers.

Many marine protected area (MPA) managers are ambivalent about allowing fish feeding, recognising the benefits of allowing visitors to see animals close up, but concerned about the possible negative consequences of feeding wild animals. In Kenya, the tourism industry has grown rapidly (Muthiga & McClanahan, 1997). Indeed, visitor frequency in three MPAs, Malindi, Watamu, and Mombasa, has increased from a few thousand in the 1970s to around 100,000 visitors per park per year until the late 1990s (Muthiga & McClanahan, 1997; McClanahan, 1999). Fish feeding is a widespread activity in these parks. Except for one study on tourist effects on corals (Muthiga & McClanahan, 1997), there has been little study of the other effects of tourists on these MPAs and none on the effects of fish feeding. This study is an initial attempt to increase knowledge on this issue and quantify potential ecological influences of fish-feeding activity.

The first aim of this study was to determine potential influences of recreational fish feeding activity on fish community structure. The parameters recorded for the community structure study were based on the survey of selected reef fish species that feed on human food (later called bread feeders) and others that do not feed on human food (later called non-bread feeders). Specific objectives were to determine if: (1) fish community composition depended on the daily time of the census, and (2) fish abundance, diversity, species composition, the proportion of bread and non-bread feeders differed between sites with and without feeding. The second aim of this study was to assess the effect of human food input on fish behaviour at feeding and control sites. The specific objectives were to compare: (1) fish abundance during feeding experiments, (2) the reaction time of selected species to experimental feedings, (3) the total duration of fish aggregation during feeding experiments, and (4) the order of appearance of each fish species.

MATERIALS AND METHODS

Study sites

The southeast coast of Kenya has four no-take marine parks and five gear-restricted reserves. Tourism is the main activity in the parks and fishing is only allowed in reserves. Fish feeding is not allowed in one park, Kisite Marine National Park, but this park could not be used as a control site because it is remote and seas were rough during the study period, making it difficult to undertake experiments. Only three marine national parks (MNP) were surveyed: Malindi, Watamu, and Mombasa (Fig.1). The study was carried out in May and June 2001 in the coral patches or "coral garden" areas visited by tourists. During these months of the low tourism season, there was an average of about 1,000 visitors, while there are 3,000 to 7,000 visitors per park per month during the high season from August to March. Mombasa is the most visited of the three mentioned parks (KWS, 2001). Each park possessed at least one site where fish were regularly (usually daily) fed bread, referred to as 'feeding sites'. Sites were selected in each park where there was no fish-feeding activity to act as 'control sites'. These sites were shallow (<3 m deep at low tide) reef lagoons with a benthos composed of a mix of coral rubble, living coral, seagrass and sand. Different sites were sampled in the three MNPs: 2 feeding sites and 1 control site in Malindi, 1 feeding site and 1 control site in Watamu, and 2 feeding sites and 2 control sites in Mombasa.

Fish community structure

Fish community composition was examined by underwater visual census technique undertaken while snorkelling. The list of fish species included in the census was determined by preliminary observations during feeding activities carried out by tour operators. Sixty-three species were surveyed within the 7 following families: Chaetodontidae, Pomacanthidae, Pomacentridae,

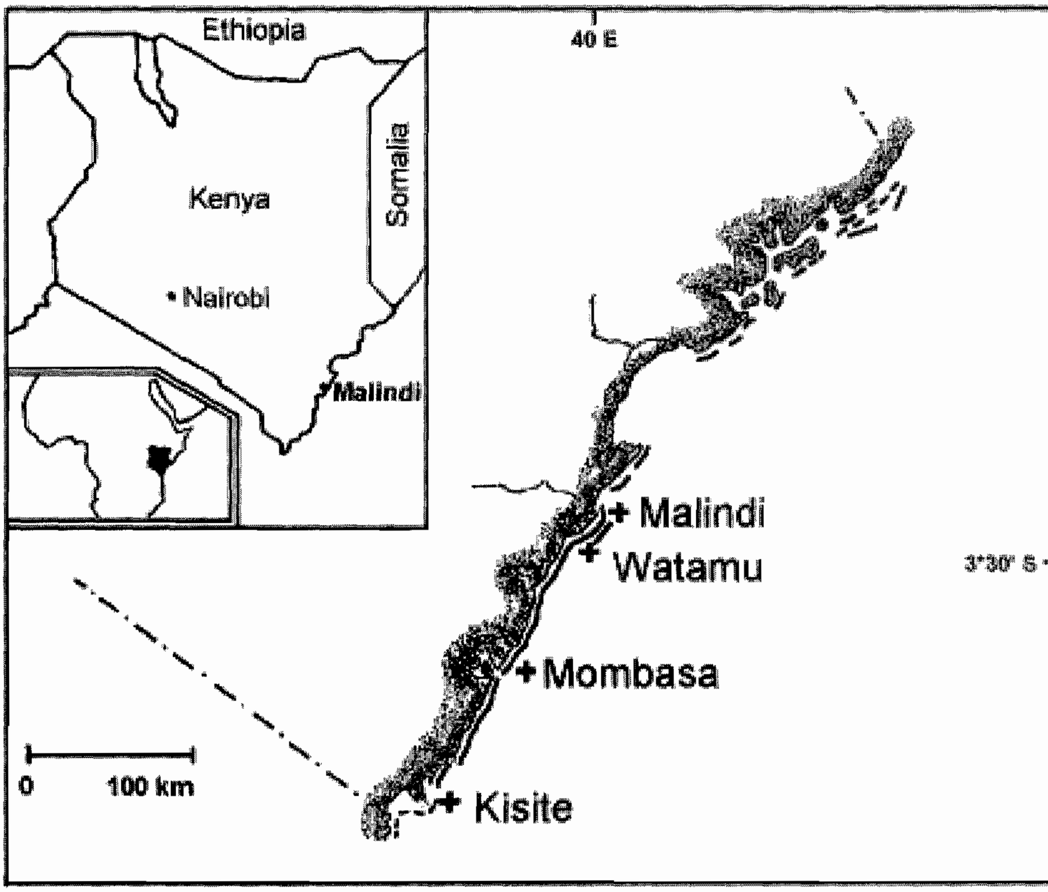

Fig. 1. Southeast coast of Kenya and its four marine national parks (+). Malindi, Watamu and Mombassa have been included in the study

Labridae, Acanthuridae, Balistidae and Kyphosidae. Chaetodontidae and Pomacanthidae were rarely observed feeding on bread and were, therefore, not included as bread-feeders in the analysis. They were recorded, however, as they were considered as ornamentals that tourists expect to see, and we therefore used the count data to test for possible competitive interactions between these ornamentals and the bread feeders. Species identification and nomenclature was based on Lieske and Myers (1994).

Within each site, 3 replicate quadrats of 5 x 5m, haphazardly chosen within the coral reef habitat, were surveyed at different hours of the day (3 in early morning, 3 in mid-morning, and 3 at midday) to test for daily variation of fish composition structure. Some extra sampling was made, and in total 39 control and 58 feeding sites quadrats were surveyed. Fish counts were started 3 minutes after setting up the quadrat and the census ran for 7 minutes. This length of time was based on preliminary observations where we determined that it takes about 7 minutes for fish attracted to arrive and after 7 minutes some fish begin to leave the site. Consequently, estimates of the shortest residence time of fish in the quadrat was about 7 minutes, and by limiting the counting period to 7 minutes, the possible error of double counting was reduced. Fish entering the 'virtual box' based on the quadrat and height of the water column to the surface were recorded. However, when individuals were clearly seen entering several times, they were counted only once. This method used a fixed area but not an instantaneous census because the objective was to include all fish and not just those that were territorial or site attached.

Indeed, with an instantaneous census, it would have been difficult to survey fish that fed on artificial food, as many are mobile.

Fish behaviour during food input experiments

Fish aggregation and behaviour around an artificial food source were observed during feeding experiments. As bread was the only food used by tour operators, it was used in the present feeding experiments. A perforated bag filled with bread was fastened to the substratum and allowed to float just below the water surface. Bread leaked out from the perforations, such that the floating bread around the bag resembled the feeding of bread by tourists but this method was used to avoid high bread dispersion by the current and thus concentrate the event around a fixed point, which facilitated observations. Direct observations during a recreational fish feeding event were not possible because bread and tourists were spread over a wider area than could be sampled. The bag floating just below the surface mimicked real fish feeding activity, where bread was thrown from a boat onto the water surface. Preliminary experiments were completed to determine the quantity of bread that would allow for sufficient observations. It was concluded that twenty-five grams of bread was an appropriate standard amount.

Snorkelling observations were started immediately after setting of the bag since fish reactions at feeding sites were fast. Observations were carried out from a stationary position at a minimum of 3 m from the bag of food. During the experiment, individuals eating the bread from the bag were identified to species and counted at one-minute intervals until all the bread was eaten. Fish were identified and counted in a virtual cylinder of 2 m diameter centred around the bread bag and water column high.

Statistical analysis

Fish community structure

Multivariate analysis was used to compare the overall fish community composition between feeding and control sites, between marine protected areas, and with daily variation. The quantitative methods used included multidimensional scaling (MDS), which is a technique for assessing similarities between ecological samples that can be viewed in a two-dimensional plot. The output was tested for differences between communities by a two-way crossed ANOSIM (PRIMER program of Plymouth Marine Laboratory). When data were not normally distributed or of unequal variances, Kruskal-Wallis tests were used to test for differences of the total number of individuals of each species between feeding and control sites. When data were normally distributed and had equal variances, a one-way ANOVA General Linear Model was built using a crossed and nested design to relate the different factors: site, treatment, and park to the fish feeding and community responses. The model was used to test for differences in the total fish abundance, the total number of species, the bread feeder and non-bread feeder abundance, and the species dominance between feeding and control sites and between marine protected areas. Dominance was calculated by the Simpson's dominance index (D), which emphasises the relative abundance of the commonest species in the sample.

Fish behaviour during food input experiment

Rare or single feeding observations of species (such as by Chaetodon spp., *Halichoeres hortulanus* and *Sufflamen chrysopterus*) were not included in the statistical analyses because of the low replication of these observations. Kruskal-Wallis tests were used to compare the parameters studied: maximum number of fish aggregated during feeding experiments, the time of reaction of fish, the total time of aggregation, and the total number of individuals between feeding and control sites. The difference between sites in the order of species appearance was also tested by two-way crossed ANOSIM.

RESULTS

Fish Community structure

Daily variation

Difference in the total number of fish surveyed at different time of the day for both experimental and control sites were significant but not as strong as the other variables (Two-way crossed ANOSIM for all control sites, R = 1.0, p = 0.013; all feeding sites, R = 1.0, p = 0.024, Fig. 2). Therefore, the parameter 'time' was not considered as a strong variable and data from the different times were pooled for the subsequent analyses.

Fish composition structure

Overall there were differences in community composition between control and feeding sites. The multidimensional scaling (MDS) of fish community structure indicated distinct groups for both sites and parks (Fig. 2). The stress value for the ordination of 0.21 was, however marginal, suggesting that differences were not large. The variation in composition between marine protected areas (ANOSIM R = 0.76, p < 0.001) was greater than the variation between feeding and control sites (R = 0.60, p < 0.001), but both were statistically significant. There was an indication in the MDS plot that the feeding sites were more similar to each other than control sites.

The total number of individuals did not vary significantly between feeding and control sites (ANOVA F = 1.72, p = 0.20), although a difference between MNP was observed (ANOVA F = 6.10, p = 0.007). The number of non-bread feeder individuals was higher than the number of bread feeders in all sites except at the Watamu feeding

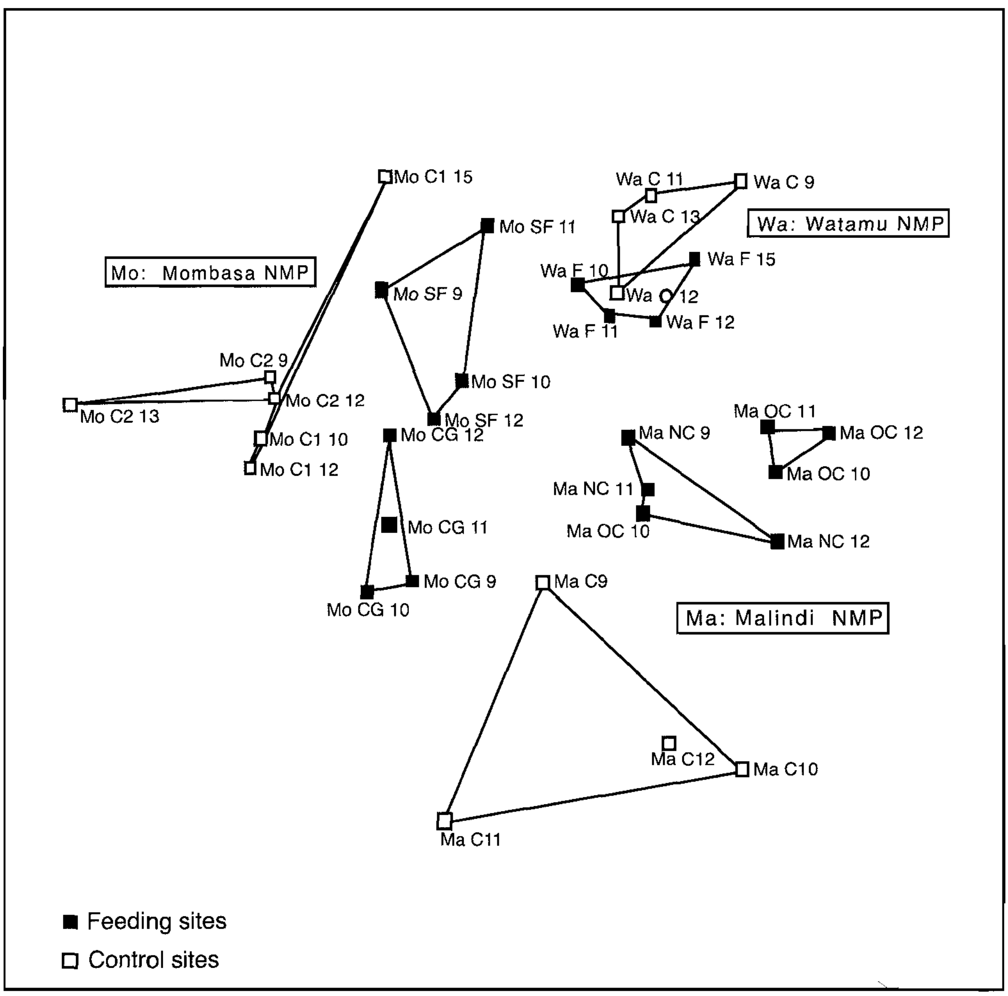

Fig. 2. MDS plot for the overall fish community structure at feeding and control sites. Sites symbols distinguished by the first two letters of the site, Mo = Mombasa, and controls and experiments by open and closed symbols respectively

site, where they were approximately the same between control and feeding sites (ANOVA F = 2.68, p = 0.114, Fig.3). However, there were significantly more bread feeders at feeding sites than control sites (ANOVA F = 9.98, p = 0.004).

Out of the total number of surveyed species, 14 out of 63 were found to be bread-feeder fish (Table 1). Species of the families Pomacentridae and Acanthuridae were mainly non-feeders. All observed Labridae, except *Halichoeres hortulanus*, fed on bread. *Abudefduf* sexfasciatus and *Abudefduf sparoides* were the only species

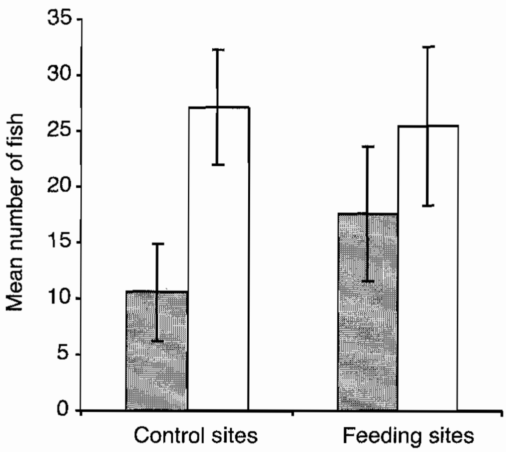

Fig. 3. Total number of bread feeders (■) and non-bread feeders (❑) at control and feeding sites

significantly more abundant at feeding than at control sites (Kruskal-Wallis p < 0.05). *Ctenochaetus striatus* and *Zebrasoma scopas* were the only non-bread feeder species to have a higher number of individuals per count at control sites (Kruskal-Wallis H = 7.07, p = 0.008). Finally, the abundance of Chaetodontidae and Pomacanthidae was not different between feeding and control sites (Kruskal-Wallis H = 0.34, p = 0.56 and H = 0.51, p = 0.47 respectively).

There was no significant difference in the total number of species present from lists generated from the MNPs (ANOVA F = 0.92, p = 0.40), but fewer species were recorded at control than feeding sites (F = 9.83, p = 0.002). Simpson's dominance index was significantly different between parks (ANOVA F = 5.53, p = 0.005) and between feeding and control sites (F = 4.97, p = 0.03), control sites having a slightly higher dominance index (D = 0.17 (0.03) than feeding sites (D = 0.14 (0.01).

Fish feeding experiment

The observer presence had no apparent effect on fish behaviour at control sites, while at feeding sites the observer attracted fish presumably because they were accustomed to the presence of people in the water during feeding activities.

Table 1. Mean number of individuals by species in one quadrat and their proportion (%) of bread feeder species at control and feeding sites

Families	Bread-feeder species	Mean numbers of individuals per quadrat (=25 m²)		Mean proportion of species per quadrat (=25 m²)	
		Control sites	Feeding sites	Control sites	Feeding sites
Pomacentridae	*Abudefduf vaigienis*	8.2	8.7	28.6	17.0
	A. sexfasciatus	7.1	20.0	24.7	39.1
	A. sparoides	1.9	3.8	6.6	7.4
	Dascyllus trimaculatus	0.2	2.1	0.7	4.1
	Neoglyphidodon melas	0	0.4	0.0	0.8
Labridae	*Thalassoma hardwicke*	4.6	4.1	16.0	8.0
	T. hebraicum	1.8	2.1	6.3	4.1
	T. lunare	0.8	2.1	2.8	4.1
	T. hardwicke	2.3	4.0	8.0	7.8
Acanthuridae	*Acanthurus dussumieri*	0.4	0.4	1.4	0.8
	A. xanthopterus	0.7	0.4	2.4	0.8
Balistidae	*Balistapus undulatus*	0.6	1.4	2.1	2.7
Kyphosidae	*Kyphosus* sp.	0.1	1.6	0.3	3.1

Maximum number of individuals

The maximum number of individuals aggregating at food input experiments was higher at feeding sites (mean= 48.5 ind. ± 10.0) than at control sites (mean= 22.5 ind. ± 4.4) (Kruskal-Wallis H = 9.56, p = 0.002).

Time of reaction after food inputs

The reaction time of fish was quicker at feeding sites than control sites with the maximum abundance occurring at 10 minutes compared to 20 minutes for feeding versus control sites (Kruskal-Wallis H = 2.48, p = 0.12). Experiments at Mombasa control sites were conducted only until half the bread was eaten because of the slow fish response and rough environmental conditions. However the maximum number of fish observed was used in the analysis to make full use of the number of replicates.

Total time of aggregation

The time for the fish aggregation to finish the bread around the artificial food source was significantly shorter at feeding sites (22 min. ± 15) compared to control sites (62 min. ± 31) (Kruskal-Wallis H = 5.82, p = 0.012). The shortest fish aggregation duration was observed at Watamu feeding sites (2 min.) where the number of bread feeders was higher than the non-bread feeders. The longest time to finish the bread was recorded at a Malindi control site (84 min.). One experiment at a Mombasa control site was terminated early as only half the bread was eaten after 49 minutes. Moreover, three experiments at the Mombasa control site and one at the Malindi control site were aborted after 20 minutes, as no fish were attracted to the bread bag.

Species behaviour

At the experimental sites, several species arrived simultaneously once the bread was made available, whereas they came serially at control sites. In Watamu Marine National Park, Kyphosidae were attracted to bread inputs only at feeding site experiments, even if they were recorded as present during the visual census at control site. The rabbitfish *Siganus sutor* was observed only once at a control site in Watamu whilst they arrived during 7 of 18 experiments, and were among the three first species to arrive at feeding sites. The surgeonfish *Acanthurus dussumeri* and *A. xanthopterus* were only counted at feeding sites. A marginal difference in order of appearance between control and feeding sites was found between species (ANOSIM R = 0.61, p = 0.004). The damselfish *A. sexfasciatus* arrived first 4 times out of 5 at control sites, whilst *A. vaigiensis* never arrived among the first three species and fed only twice on bread. In contrast, at the feeding sites, *A. sexfasciatus* appeared first 7 times out of the 18 experiments, *A. vaigiensis* appeared 7 times and was in the first three 16 of the 18 times. Generally, the damselfish family had the quickest response to the introduction of artificial food.

During the feeding experiments, wrasses were recorded in both control and feeding sites but *Thalassoma hardwicke* was less frequent at feeding sites. Surgeonfish were the slowest family to arrive. The number of damselfish at the beginning of the experiment was higher than wrasses or surgeonfish. The variations in damselfish numbers with time over the course of the experiment were large, especially at feeding sites. In contrast, the wrasses and surgeonfish abundance were constant and relatively low throughout experiments (Fig. 4).

Time spent at feeding

Damselfish spent the greatest amount of time feeding during experiments. For example, *A. sexfasciatus* was present at the feeding and control sites for more than 85% of the total time of the feeding experiments. *A. sexfasciatus* and *A. vaigiensis* spent the longest time eating at feeding and at control sites. Wrasses spent more time feeding at control compared to feeding sites.

DISCUSSION AND CONCLUSION

Fish community structure

Daily variation was significant, but not strong for the total numbers of bread feeders in the fish census. Therefore, fish were largely permanent residents and were not arriving only during times when tourist boats visit the reefs. This finding lies in contrast to those of Sweatman (1996) who reported a strong significant correlation between

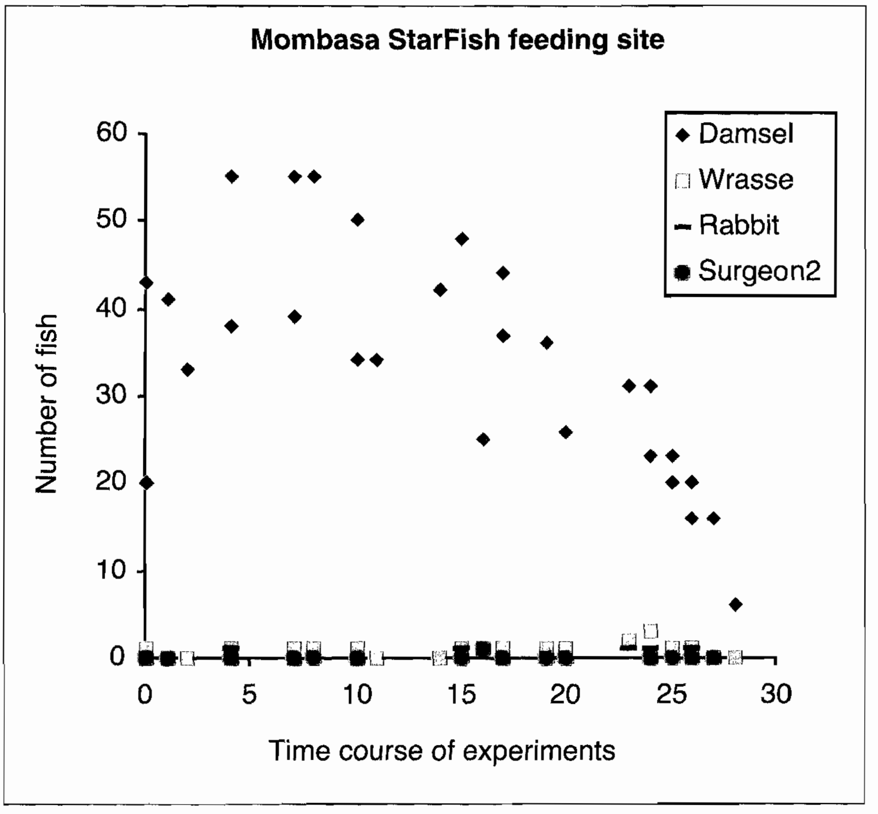

Fig. 4. Variations in the number of individual per family with time (in min.) over the course of the experiment. The example of Pomacentridae (Damsel), Labridae (Wrasse), Siganidae (Rabbit), and Acanthuridae (Surgeon) families at a Mombasa feeding site

the aggregation size of *Lethrinus nebulosus* and *Lutjanus bohar* around feeding sites and the hour of the day. These species were not seen in the present study and are probably not as site attached as the species recorded here. Despite similar environments, and the site-attached nature of the fish we studied, species composition at the sites differed between the MNPs, as has been found in a more thorough study of the fish fauna (see McClanahan, 1994). High spatial variation appears to be a common attribute of fish in unfished Kenyan reefs and may be due to differences in benthic cover and complexity between parks (McClanahan & Arthur, 2001). Feeding does, however, seem to homogenize the fauna as it increases the abundance of bread-feeding species and makes park feeding sites more similar to each other, but not obviously at the expense of other non-bread feeding species.

The number of bread versus non-bread feeders was higher at feeding than control sites. As suggested by Sweatman (1996), the increase in food supply could lead to an increase in survival rates of feeders, increasing the abundance of their populations. Sweatman (1996) also proposed that reproductive output could be raised by the subsidized diet. Although this study did not quantify reproduction, breeding individual of the two *Abudefduf* species were frequently observed near the feeding sites. The similarity in total number of non-bread feeder individuals and species at control and feeding sites indicate that the higher number of bread-feeding fish had not greatly influenced non-bread feeder populations. Although there was slightly higher dominance in the feeding sites, the differences were small and do not suggest that feeding leads to high dominance of bread feeders. Therefore, there is no evidence from this short-term study of an increase of resource competition or competitive exclusion of species between bread feeder and non-bread feeder species.

The frequency of fish-feeding activities is perhaps high enough to sustain the surplus of bread feeder population without causing competition and exclusion of non-bread feeder fish. Given that the present study was undertaken during the low tourist season, when bread feeding was relatively infrequent, inter-specific competition for bread might be expected to have reached its maximum. Since competition for this resource was not observed, neither was aggressive behaviour between species, or a diminished abundance of fish species, it seems unlikely that there were strong competitive effects created by this food subsidy.

Fish behaviour

During feeding experiments, the maximum number of fish in the aggregation and the abundance of bread feeders were higher at feeding than control sites. This result added to the findings of the fish composition study might support the hypothesis that bread is augmenting the diet of these species and leading to higher numbers of bread feeders at feeding sites. This may indicate that artificial food increases populations above those supported by natural conditions. If the food supply was permanently removed then mortality or emigration would be expected. As discussed for some marine birds dependent on discards from fishing boats (Furness, 1982; Blaber & Wassenberg, 1989), it is not known to what extent the population of fish, now possibly artificially enlarged by bread supply, will respond to future changes in tourist frequencies at current feeding sites.

The quick response of bread-feeder fish to the supply of artificial food at feeding sites indicates that fish learned to feed on bread. Even if no bread is given to the fish, they aggregate around boats and snorkelers. By contrast, at control sites, fish are slow or do not respond to bread in the water. The noise of engines and the presence of humans in the water would appear to be important factors influencing the response speed since it was observed that fish aggregate before the feeding activities start. Therefore, one of the detrimental aspects of bread feeding is a change in the behaviour of fish and increased attraction and aggression towards people. For example, damselfish, especially *A. sexfasciatus*, were observed nipping at people that entered the water, presumably because they associate them with bread and feeding. Although 'attacks' were commonly observed, no injuries were reported. This change of behaviour could, however, become a safety issue when feeding bigger predators such as sharks or large mammals. Aggressive behaviour towards humans is commonly observed as a consequence of the feeding of the Barbary macaques (*Macaca sylvanus*) at Queen's Gate, Gibraltar. This animal-human contact sometimes results in monkeys biting visitors (Fa, 1992; Oleary & Fa, 1993). Moreover, Orams *et al.* (1996) observed increased confidence among fed dolphins that led to increased forceful contacts with swimming guests.

CONCLUSION

Feeding of fish has had a significant effect on community structure, abundance, and diversity of fish by increasing the abundance of bread-feeder species. The amount of dependence of these bread feeders on this supplemental food supply could not be determined with this short-term study, although it is clear that they learn to feed on bread and associate it with people. A longer-term study on fish, including the elimination of bread-feeding activities, may be required to determine the consequences of the loss of this food surplus on species interactions and populations. Moreover, future work should compare high and low tourist seasons to determine the effect of the number of visitors on the population density and behaviour of bread-feeder fish. Finally, a study of the effects of the bread-feeding species on the feeding and success of their predators, such as groupers and jacks, may also help determine how predation might control the abundance of bread feeders.

The ethical aspect should also be considered when planning for fish feeding activities. Seaborn (1990) declared "fish feeding turns the sub-aquatic world into an aquarium without glass walls, a zoo without bars". The question of the kind of experience that visitors want needs to be assessed. However, for the moment, it appears that direct