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SEYCHELLES' MARINE PROTECTED AREAS: COMPARATIVE STRUCTURE AND STATUS OF REEF FISH COMMUNITIES

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Abstract

Effective management of Seychelles' reef resources is essential because the conflicting demands of fishing, tourism and conservation must be reconciled if sustainable development and the protection of natural resources is to be assured. Marine protected areas play a key role in the existing management strategy and yet there is little quantitative understanding of the benefits they may provide. We compare the biomass and species richness of fish assemblages on coral and granitic reef habitats in four areas which receive different levels of protection from fishing and other human activities. Species richness of the total fish community, biomass of the total fish community and species richness and biomass of many families were higher on both coralline and granitic reefs in two marine protected areas where protective regulations were effectively enforced. However, the biomass of the three principal families of fishes targeted by the fishery was significantly lower in one of these areas. This was attributed to illegal fishing and the fishing concessions offered to local people. We conclude that poaching and minor fishing concessions did not affect the aspects of the fish community which are important to most tourist visitors (biomass and overall species richness), but that they have a statistically significant effect on the structure of the fish community. Furthermore, whilst a small well-patrolled area will provide an effective refuge from fishing, it will often be stocked by larval fishes which are the progeny of adults living many kilometres away. As such, the protected area cannot operate in isolation to maintain biomass and diversity. A valid long-term aim of reserve management may be to assure the protection of a greater proportion of Seychelles' fishes throughout their life history. This may be achieved if current plans for the management of marine protected areas can be instituted.

Keywords: biomass, diversity, marine reserves, reef fishes, Seychelles.

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INTRODUCTION

The biological, socioeconomic, scientific and aesthetic values of coral reefs and their associated fauna are widely recognised (e.g. Smith, 1978; Salm & Kenchington, 1984; Munro & Williams, 1985; Clark *et al.*, 1989; Spurgeon, 1992) and there have been numerous attempts to conserve or manage coral reef resources through the establishment of marine protected areas (e.g. Bohnsack, 1990; Polunin, 1990; Roberts & Polunin, 1991; Rowley, 1994). Seychelles is almost exclusively reliant on fish exports and tourism for foreign revenue (Anon., 1990) and, as in other small island developing states, it is important that conflicts between conservation and exploitation are resolved if sustainable development and the protection of natural resources are to be assured (Stoddart, 1984; Jennings & Marshall, in press). The development of marine protected areas is considered to be a key approach to assuring the successful co-existence of activities which rely upon a shared resource base (Anon., 1990).

The Government of Seychelles implemented the 1969 National Parks and Nature Conservancy Ordinance in order to provide a framework for establishing protected areas. From 1973 to 1991, five areas in the Inner Seychelles group were designated as Marine National Parks and one as a Special Reserve which included protection for marine habitat (Marshall, 1994; Fig. 1). Whilst regulations which prohibit fishing and damage to reefs have been carefully described in statute (Anon., 1973, 1975*a*,*b*, 1979*a*,*b*,*c*, 1991), there are a number of practical constraints to their implementation (Anon., 1990). These include a lack of wardens and patrol boats, lack of boundary markers to delineate the parks, poor public awareness of the park regulations and a lack of visitor facilities (Anon., 1990). Of the Marine National Parks, only Sainte Anne has sufficient staff to ensure that park regulations are largely enforced. Cousin Island Special Reserve is a small independently managed reserve with a resident Seychellois warden and illegal fishing rarely occurs.

The Environmental Management Plan for the Seychelles (Anon., 1990) attaches the highest priority to improving management of Seychelles' Marine National

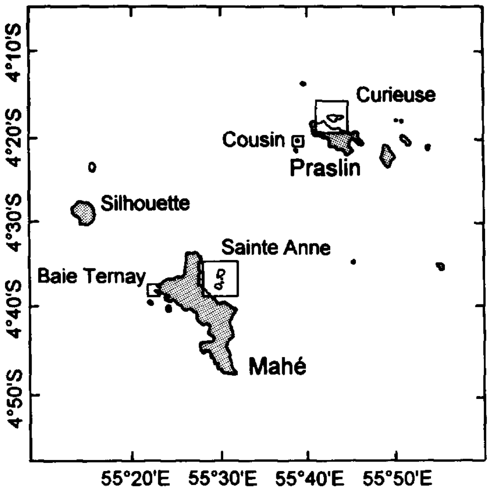

Fig. 1. General location of the Marine National Parks and Special Reserve selected for study (boxed). There are additional Marine National Parks at Port Launay (approximately 1 nautical mile southeast of Baie Ternay) and Silhouette Island. Boxes indicate coverage of maps in Fig. 2.

Parks. Whilst these parks have been established for at least 15 years and provide a number of roles, there is no quantitative information on the marine fishes which they protect (Polunin, 1984), and no clear demonstration of the ways the fish community may be affected by different management strategies. It is notable that the rate at which marine protected areas are proliferating far exceeds the rate at which we can quantify the benefits they may provide and determine optimal approaches for their design and management. In particular, given that most reef fishes have pelagic larval stages which may disperse over many kilometres (reviews Leis, 1991; Victor, 1991) and that the migrations of reef fishes may take them outside the boundaries of small reserves (reviews Parrish, 1989; Jennings & Lock, in press) there is a need for empirical studies describing how specific fish stocks respond to local protection and exploitation. No such studies have yet been conducted in Seychelles and evidence available from reef environments elsewhere (Russ, 1985; Alcala, 1988; Samoilys, 1988; Russ & Alcala, 1989; Alcala & Russ, 1990; Roberts & Polunin, 1992; Polunin & Roberts, 1993; McClanahan, 1994; Grigg, 1994; Watson & Ormond, 1994) cannot reliably be generalised to the diverse types of marine protected areas which now exist (e.g. McClanahan, 1994).

The aims of this study are (1) to provide a quantitative description of fish communities in the Seychelles' marine protected areas; (2) to compare the biomass, structure and species richness of the fish community in protected areas managed with differing degrees of efficiency; (3) to determine the extent to which the reserves protect different assemblages of reef fishes; and (4) to provide baseline information on the status of fish communities in two parks prior to the implementation of new management measures in 1995 (Anon., 1990), thereby providing a means by which to judge the value of these measures (Rowley, 1994).

METHODS

Study sites

Fish communities were censused in four marine protected areas in the Inner Seychelles Group (Fig. 1). These have been designated for at least 15 years (Table 1). The regulations which govern activities in these areas differ in detail, but all state that reef habitats must not be damaged and that fishes must not be captured (Anon., 1973, 1975*a*,*b*, 1979*a*,*b*,*c*, 1991). However, in practice, the regulations are difficult to enforce and the areas receive different degrees of protection (Anon., 1990). Cousin Island was developed as a bird and turtle reserve, but near total protection is provided for marine habitats up to 400 m from the shoreline of the island (Fig. 2). This includes the majority of the Cousin Island fringing reef. There is no tourist diving at Cousin, and poaching has been virtually eliminated in recent years (R. Bresson, pers. comm.). Sainte Anne Marine National Park (Fig. 2) is the most popular tourist site in Seychelles where 21,645 tourists, more

Table 1. Marine protected areas in the Inner Seychelles

Protected area	Established	Area (km^2)			Management	Enforcement[a]	References[b]
		Sea	Land	Total			
Cousin Island Nature Reserve	1968	1·2	0·3	1·5	BirdLife International[c]	Effective	1,2,3
Sainte Anne Marine National Park	1973[d]	10·0	4·2	14·2	Government of Seychelles	Effective[e]	4,5
Baie Ternay Marine National Park	1979	0·8	0·0	0·8	Government of Seychelles	Negligible	6
Curieuse Marine National Park	1979	10·8	2·9	13·7	Government of Seychelles	By day only	7,8

[a]The enforcement of park or reserve regulations relating to exploitation of fishes and damage to their habitat. Such activities are legally banned in all parks.
[b]1, Diamond (1975); 2, Anon. (1979*a*); 3, Diamond (1985); 4, Anon. (1973); 5 Anon. (1975*b*); 6, Anon. (1979*b*); 7, Anon. (1979*c*); 8, Anon. (1991).
[c]Cousin Island Nature Reserve was also gazetted as a Special Reserve by the Government of Seychelles in 1975. This provided legal protection for all the wildlife as described in the Cousin Island Special Reserve Regulations 1979 (Anon., 1979*a*). However, BirdLife International own the island and take responsibility for management.
[d]Enforcement of Park Regulations began in 1975 (Anon., 1975*b*).
[e]There are fishing concessions for residents of this park and some poaching occurs (see text).

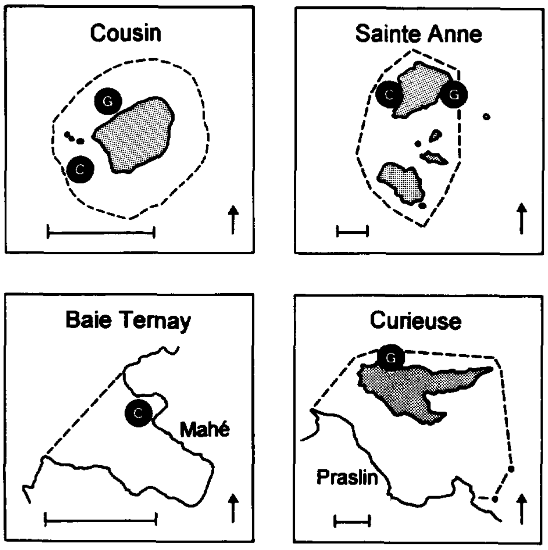

Fig. 2. The marine protected areas selected for study and the location of coralline (C) and granitic (G) reef sites. Arrows point true North, broken lines indicate reserve boundaries and scale bars represent 1 km.

than 25% of all those arriving in Seychelles, paid to snorkel, dive or view the reef from glass-bottom boats in 1993 (Anon., 1994). The reserve is actively patrolled, but its close proximity to the capital of Victoria means that poaching remains a problem. One hundred and thirty-seven illegal fish traps were removed from the park in 1993 (Anon., 1994). The Government also provides a concession which enables residents of the park to fish for their own consumption. As a result, approximately 10 fish traps and occasional hand-lines are used legally within the park (Anon., 1994). Baie Ternay Marine National Park (Fig. 2) is a protected area in name only. It is not widely used by tourists, although small numbers of recreational divers visit from diving centres in Beau Vallon, a coastal town approximately 4 nautical miles to the northeast. Little attempt is made to enforce park legislation and the reefs are fished. Curieuse was visited by 8964 tourists in 1993, but cannot be managed or patrolled on a full-time basis due to a lack of resources (Anon., 1994). Fish traps are often dropped after dark and collected before the arrival of park staff the following morning. The enforcement of regulations around Curieuse will be improved during 1995, with the introduction of demarcation buoys, increased ranger patrols and patrol equipment (Marshall, 1994).

Table 2. Families of reef-associated fishes included in the census

Acanthuridae	Surgeonfishes
Balistidae	Triggerfishes
Chaetodontidae	Butterflyfishes
Haemulidae	Grunts
Labridae	Wrasses
Lethrinidae	Emperors
Lutjanidae	Snappers
Monacanthidae	Filefishes
Mullidae	Goatfishes
Nemipteridae	Coral breams
Pomacanthidae	Angelfishes
Pomacentridae	Damselfishes
Scaridae	Parrotfishes
Serranidae	Groupers
Siganidae	Rabbitfishes
Zanclidae	Moorish idol

Fish communities

A visual census technique was used to estimate the numerical abundance and biomass of non-cryptic, diurnally active reef-associated fishes (Samoilys, 1992). Fishes from 16 families were censused (Table 2) on two types of reef habitat: fringing coral reef with a carbonate framework and granitic reef with corals growing on the rock (Jennings *et al.*, in press).

Sixteen randomly positioned point counts of 7 m radius were made at depths of 3·0–13·0 m by the same observer. The sizes and numerical abundances of target species estimated to be >7 cm length were determined by counting each individual and making an estimate of its length to the nearest 1 cm. The methods followed those of Samoilys (1992) and Samoilys and Carlos (1992) as modified by Jennings *et al.* (in press). Validation of the methodology and the benefits and disadvantages of the technique are discussed by Samoilys (1992), Samoilys and Carlos (1992) and Jennings and Polunin (in press *a*). In this study, the method offered a number of advantages when compared with traditional transect counts. In particular, the location of counts was easy to randomise, short count durations both reduced disturbance to the fishes present and allowed increased replication in a given time period and net movements of target species could not bias counts (Watson *et al.*, 1995). Fishes estimated to be <8 cm length were censused in a 2 m radius count after the 7 m count was complete. The methodology followed that for the 7 m count. Errors in length estimation were reduced by regular practice and assessed using the methods of Bell *et al.* (1985) and Polunin and Roberts (1993). Mean estimation error for lengths of 8–35 cm was 3·1% and no corrections were made.

Data analysis

Estimates of fish length were converted to mass using length–weight relationships from Bohnsack and Harper (1988), Kulbicki *et al.* (1993), Smith and Dalzell (1993) and unpublished sources. When a length–weight relationship for a given species was not available then one for a species with similar morphology was used. Fish biomass m^{-2} was calculated for 2 m and 7 m counts and summed to provide an estimate of total biomass. Several scarid juveniles could not be identified and their total biomass was apportioned within each census area in proportion to the distribution of adult biomass.

RESULTS

A total of 115 diurnally active reef-associated species were recorded during the census. Species richness of the total fish community was higher on both coralline and granitic reefs in those marine protected areas where park regulations were effectively enforced (Cousin and Sainte Anne) than in the areas where enforcement was less effective (Baie Ternay and Curieuse) (Figs 3 and 4). Relatively few species were unique to particular sites and the composition of assemblages was 64·3–81·5% similar at different pairs of sites (Table 3). As the area censused increased, the rate of increase in the number of species recorded was more rapid at coralline sites, both for all species and the five most speciose families examined (Fig. 3). At the granitic Curieuse site, the species richness of chaetodonts, pomacentrids, labrids and scarids was generally lower for a given area censused than at the granitic Cousin and Sainte Anne sites (Fig. 3). Such trends for these families were not apparent at the coralline sites (Fig. 3) although total species richness was lower (Figs 3 and 4).

The biomass of fish communities was lower at the Baie Ternay coralline and Curieuse granitic sites where protection was less effective (Fig. 4). Total biomass of the fish community at the coralline sites was 49·9 ± 3·73 (SE) g m^{-2} at Cousin, 68·7 ± 6·34g m^{-2} at Sainte Anne and 30·2 ± 2·46 g m^{-2} at Baie Ternay. Thus biomass at Baie Ternay was 40% lower than at Cousin and 60% lower than at Sainte Anne. Differences in biomass between these sites were all significant (ANOVA; F = 18·48, d.f. = 2,45; $p < 0·001$; Tukey's). Biomass of the total fish community at granitic sites was 54·0 ± 6·96 g m^{-2} at Cousin, 54·0 ± 7·45 g m^{-2} at Sainte Anne and 31·7 ± 2·87 g m^{-2} at Curieuse. Thus biomass was 41% lower at Curieuse than at the other sites and this difference was significant (ANOVA; F = 4·45; d.f. = 2,45; $p < 0·05$; Tukey's).

Despite the similarities between the overall biomass of the fish community at Cousin and Sainte Anne, the biomass of the fish community at Sainte Anne was dominated by relatively few families at both coralline (Fig. 5) and granitic (Fig. 6) sites. The biomass of serranids and lutjanids, two families which contain many of the primary target species for the Seychelles' reef fishery (Jennings *et al.*, in press), was significantly higher at the Cousin coralline site than at all others (Fig. 5, Table 4). Biomass of lethrinids, another family of primary target species, was significantly higher at Cousin and Sainte Anne coralline sites (Fig. 5, Table 4). Lethrinid and lutjanid biomass was significantly higher at the Cousin granitic site (Fig. 6, Table 4) although there were no significant differences in serranid biomass

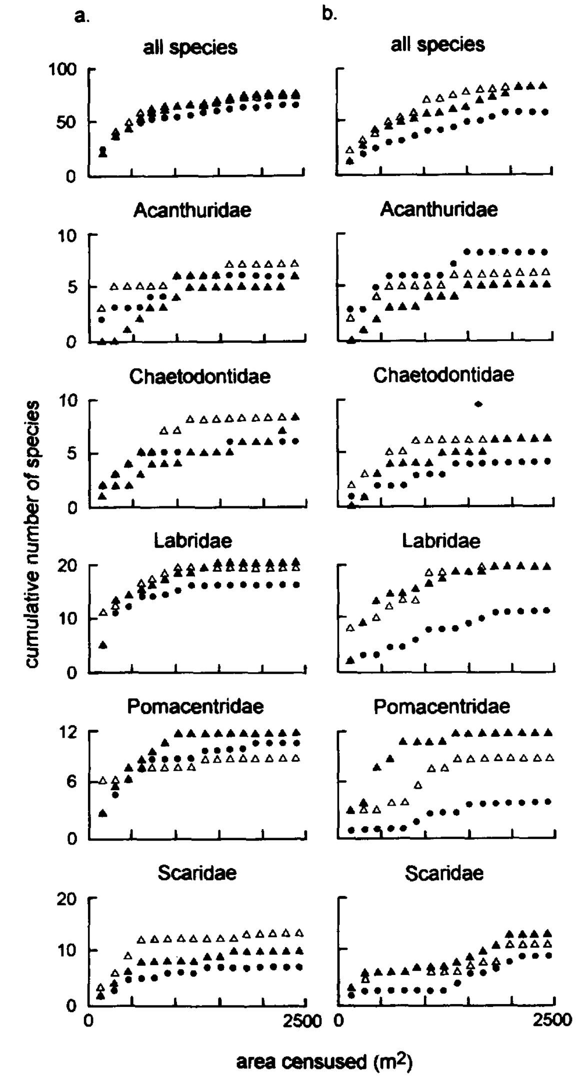

Fig. 3. Cumulative number of diurnally active reef-associated species recorded as a function of the area of coralline (a) or granitic (b) reef censused (7 m point counts only). △, Cousin; ▲, Sainte Anne; ●, Baie Ternay (coralline) or Curieuse (granitic).

Table 3. The proportion of diurnally active reef-associated species found at only one site or common to pairs of sites (expressed as a percentage of the total number of species recorded at a given site or pair of sites)

		Coralline reef			Granitic reef		
	Unique	Cousin	Sainte Anne	Baie Ternay	Cousin	Sainte Anne	Curieuse
Coralline reef							
Cousin	4.0%	—	—	—	—	—	—
Sainte Anne	7·7%	77·1%	—	—	—	—	—
Baie Ternay	4·4%	74·1%	78·1%	—	—	—	—
Granitic reef							
Cousin	5·1%	65·1%	64·7%	71·2%	—	—	—
Sainte Anne	3·8%	80·5%	79·0%	74·8%	81·5%	—	—
Curieuse	8·2%	70·6%	64·7%	65·1%	69·1%	64·3%	—

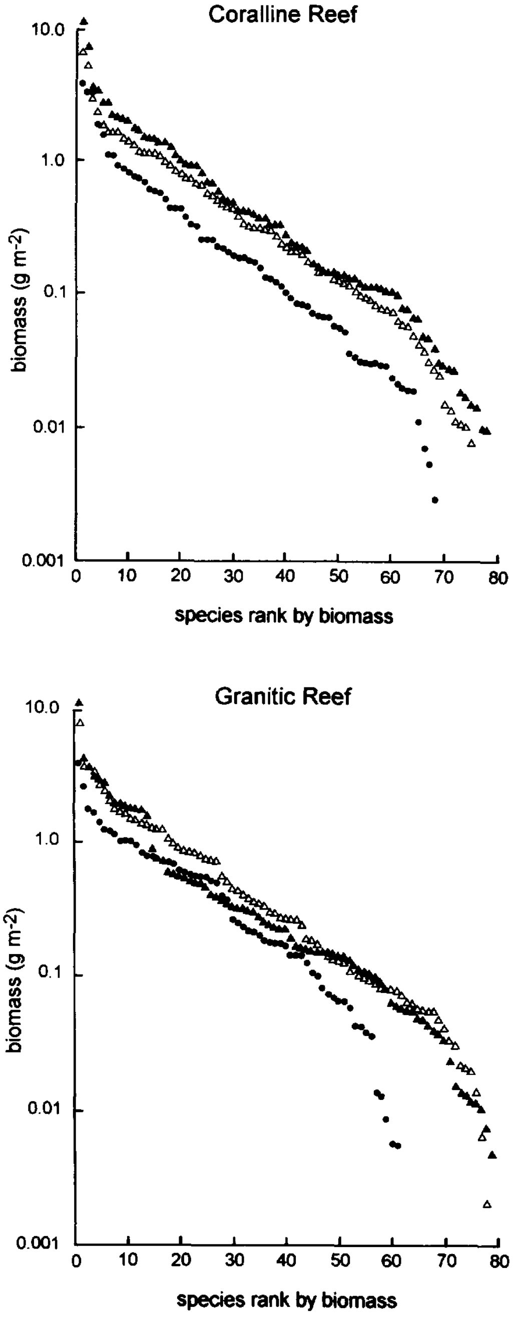

Fig. 4. Mean biomass of all diurnally active reef-associated species recorded at the census sites. △, Cousin; ▲, Sainte Anne; ●, Baie Ternay (coralline) or Curieuse (granitic).

between sites (Fig. 6, Table 4). These three families made a far smaller contribution to the overall biomass of the fish community at Sainte Anne, Baie Ternay and Curieuse (Fig. 6). This was reflected in the contribution of individual species to the total biomass of the fish community (Table 5). *Cephalopholis argus* (Serranidae), *Aprion virescens* (Lutjanidae) and *Lethrinus obsoletus* (Lethrinidae), three of the most important fished species in Seychelles, accounted for over 30% of community biomass at the Cousin coralline site (Table 5).

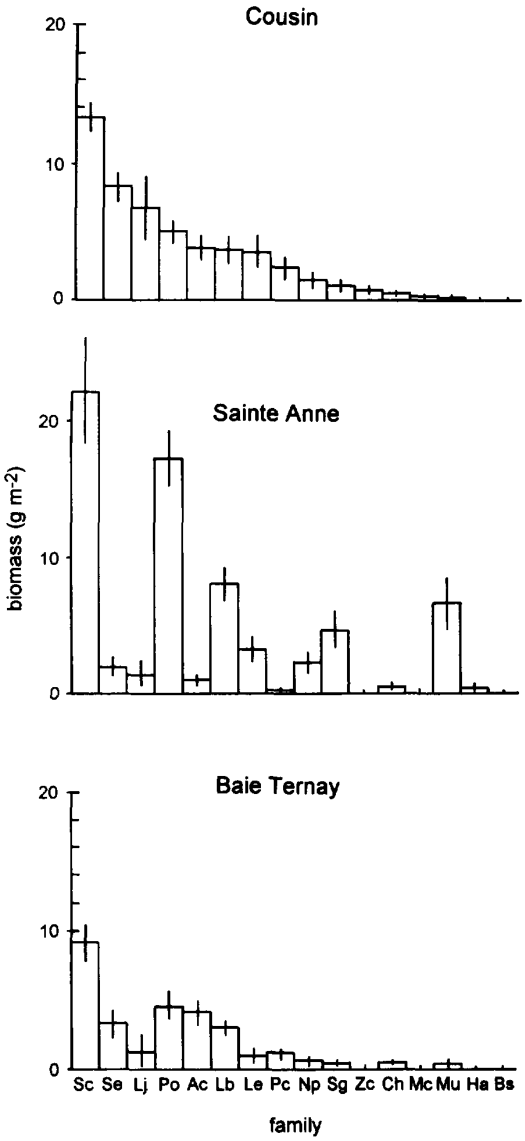

Fig. 5. Mean biomass (± SE) of 16 families of diurnally active reef-associated fishes at coralline census sites. Sc, Scaridae; Se, Serranidae; Lj, Lutjanidae; Po, Pomacentridae; Ac, Acanthuridae; Lb, Labridae; Le, Lethrinidae; Pc, Pomacanthidae; Np, Nemipteridae; Sg, Siganidae; Zc, Zanclidae; Ch, Chaetodontidae; Mc, Monocanthidae; Mu, Mullidae; Ha, Haemulidae; Bs, Balistidae.

No species of similar importance in the fishery were amongst the five species which contributed most to overall biomass at Sainte Anne and only *Cephalopholis argus* was included at Baie Ternay where it contributed to 6·1% of total biomass (Table 5). At the granitic sites, two lethrinids (*Lethrinus harak* and *Lethrinus obsoletus*) and a lutjanid (*Aprion virescens*) accounted for over 20% of total community biomass at Cousin, one lutjanid (*Aprion virescens*) accounted for 5.4% of total biomass at Sainte Anne and no species of primary commercial importance were amongst the five most abundant species at Curieuse (Table 5).

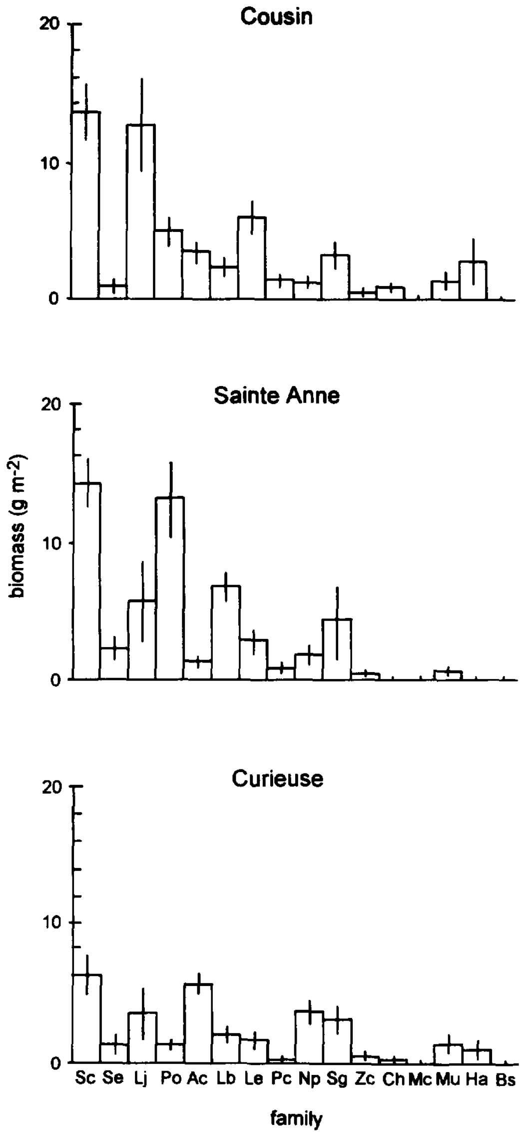

Fig. 6. Mean biomass (± SE) of 16 families of diurnally active reef-associated fishes at granitic census sites. Family codes follow Fig. 5.

DISCUSSION

Differences in the diversity and biomass of reef fish communities may be attributed to spatial and temporal variations in recruitment (Doherty, 1991), habitat effects (Williams, 1991) and other factors and may not be persistent in space or time (Hixon, 1991; Jones, 1991). However, there is a range of evidence to suggest that the relative effectiveness of management practices accounted for some of the significant differences observed. Analysis of habitat data from different regions of the Inner Seychelles' group has suggested that similarities between either coralline or granitic reef habitats in different regions were significantly greater than those similarities between coralline and granitic reefs in the same region (Jennings *et al.*, in press). Thus consistent differences between fish communities in the protected areas are unlikely to be attributable to habitat effects. Furthermore, the two areas which were effectively protected are closer to the poorly protected areas than to one another (Fig. 1, Table 1), suggesting that geographic trends in fish distribution or recruitment are unlikely to be solely responsible for the significant differences observed.

Small marine protected areas, such as those in the Inner Seychelles, offer a number of advantages for managers because they can be gazetted without depriving local people of all their fishing grounds and can be policed more readily. However, they will not harbour closed populations of fishes and are stocked by the episodic settlement of fishes from an external pool of larvae (Victor, 1991). A proportion of these larvae may be the progeny of adult fishes which spawned at sites tens or hundreds of kilometres away (Leis, 1991). As a result, the protected areas act as refuges for post-settlement fishes but do not operate independently to conserve biomass or biodiversity. Indeed, it is probable that the very small protected areas at Cousin and Baie Ternay are predominantly stocked with fishes originating in other areas. Thus the differences between fish assemblages in the protected areas are expected to indicate the responses of the resident post-settlement fish community to protective management.

A number of other studies have demonstrated that the abundance of the fish community is higher in protected areas (e.g. Alcala, 1988; Russ & Alcala, 1989; Alcala & Russ, 1990; Polunin & Roberts, 1993; Watson & Ormond, 1994) and that the abundance of those piscivores and carnivores which are the favoured target species are particularly sensitive indicators of fishing pressure (Russ, 1985, 1989; Watson & Ormond, 1994; Jennings & Polunin, in press *b,c*). Indeed, the biomass of lethrinids, lutjanids and serranids was significantly lower at Sainte Anne than at Cousin even though fishing pressure at Sainte Anne was minimal in comparison with the less effectively protected areas such as Baie Ternay and Curieuse. Fishing had a less marked effect on species richness than on biomass, as has been suggested by other empirical studies on small reserve sites (e.g. Alcala, 1988). McClanahan's (1994) study indicated that 52 of 110 species found on protected Kenyan reefs were absent when the same area was surveyed on fished reefs. However, these effects may have resulted from changes in habitat acting in conjunction with fishing effects because the release of sea-urchin populations in fished areas has resulted in bioerosion and loss of topographic complexity (McClanahan, 1994). In Seychelles, the habitats in fished and unfished areas are not significantly different (Jennings *et al.*, in press).

Effective protection of the fringing reef around Cousin has maintained a reef fish community of high diversity and biomass. This suggests that the regular migrations of species favoured in the fishery are not so extensive as to subject them to a risk of capture equivalent to that for the similar species in other areas. Cousin demonstrates that a very small refuge from

Table 4. Results of ANOVA and Tukey's test comparisons (Tukey's test *p* critical = 0·05) of the family-specific biomass of reef fishes in the four protected areas

Family	Coralline reef				Granitic reef			
	F	d.f.	*p*	Tukey[a]	F	d.f.	*p*	Tukey[a]
Scaridae	6·21	2,45	<0·01	An>(Co=Te)	4·16	2,45	<0·05	(An=Co)>Cu
Serranidae	12·52	2,45	<0·001	Co>(Te=An)	1·19	2,45	>0·1	NS
Lutjanidae	3·22	2,45	<0·05	Co>(An=Te)	3·81	2,45	<0·05	Co>(An=Cu)
Pomacentridae	25·53	2,45	<0·001	An>(Co=Te)	15·89	2,45	<0·001	An>(Co=Cu)
Acanthuridae	6·66	2,45	<0·01	(Te=Co)>An	10·85	2,45	<0·001	Cu>Co>An
Labridae	9·32	2,45	<0·001	An>(Co=Te)	12·24	2,45	<0·001	An>(Co=Cu)
Lethrinidae	3·64	2,45	<0·05	(Co=An)>Te	4·98	2,45	<0·05	Co>(An=Cu)
Pomacanthidae	4·89	2,45	<0·05	Co=Te=An	1·82	2,45	>0·1	NS
Nemipteridae	1·39	2,45	>0·1	NS	1·32	2,45	>0·1	NS
Siganidae	5·99	2,45	<0·01	An>(Co=Te)	0·09	2,45	>0·1	NS
Zanclidae	4·09	2,45	<0·05	Co>(An=Te)	0·56	2,45	>0·1	NS
Chaetodontidae	0·72	2,45	>0·1	NS	3·00	2,45	>0·05	NS
Monocanthidae	0·63	2,45	>0·1	NS	2·11	2,45	>0·1	NS
Mullidae	10·50	2,45	<0·001	An>(Te=Co)	0·79	2,45	>0·1	NS
Haemulidae	1·00	2,45	>0·1	NS	1·38	2,45	>0·1	NS
Balistidae	1·00	2,45	>0·1	NS	1·00	2,45	>0·1	NS

[a]Co, Cousin; An, Sainte Anne; Te, Baie Ternay; Cu, Curieuse.

Table 5. The contribution (%) of the five most abundant species to the total biomass of the reef fish community in the marine protected areas studied

Coralline reef		Granitic reef	
Species	%	Species	%
Cousin		Cousin	
Cephalopholis argus	13·6	*Aprion virescens*	13·6
Aprion virescens	10·8	*Plectroglyphidodon lacrymatus*	6·5
Lethrinus obsoletus	6·0	*Scarus sordidus*	6·3
Scarus sordidus	4·7	*Lethrinus harak*	5·9
Plectroglyphidodon lacrymatus	3·7	*Lethrinus obsoletus*	4·7
Sainte Anne		Sainte Anne	
Hipposcarus harid	16·5	*Plectrogyphidodon lacrymatus*	19·3
Plectroglyphidodon lacrymatus	10·6	*Siganus puelloides*	7·4
Parupeneus barberinus	5·3	*Scarus sordidus*	6·3
Chromis atripectoralis	5·0	*Aprion virescens*	5·4
Siganus puelloides	4·1	*Scarus niger*	5·3
Baie Ternay		Curieuse	
Scarus sordidus	12·7	*Scolopsis frenatus*	11·7
Ctenochaetus striatus	11·3	*Ctenochaetus striatus*	7·7
Scarus niger	11·2	*Acanthurus leucosternon*	5·3
Cephalopholis argus	6·1	*Siganus puelloides*	5·1
Pomacentrus caeruleus	5·3	*Scarus rubroviolaceus*	4·3

harvesting can provide good protection for primary target species. Small refugia have also been shown to operate effectively at other reef sites where exploitation in adjacent regions is not so intensive as to lead to collapses in spawning stock biomass (Russ, 1985, 1989; Russ & Alcala, 1989; Polunin & Roberts, 1993). Illegal fishing and the provision of minor fishing concessions at Sainte Anne did not lead to a reduction in the overall diversity or biomass of reef fishes but they did lead to significant reductions in the biomass of primary target species. Whilst the fish community at Sainte Anne may not represent a 'natural' post-settlement state, the numbers and range of fish types present are still likely to provide interest for tourists who visit the park to snorkel, dive or view the reef through glass-bottom boats. The dramatic reduction in biomass and diversity in the areas where protective legislation is not enforced would, however, reduce such aesthetic value.

The rationale for designating Seychelles' terrestrial parks has been clearly defined, and the success of management may be monitored on a continuous basis because the protected fauna and flora often spend their entire life histories within the park boundaries. Marine reserves have been established with a view to conserving biodiversity (Anon., 1994) but it is difficult to test how well they will fulfil this objective in the long term. Marine Parks provide safe areas for turtle nesting and the managed parks have undoubtedly helped to prevent the killing of turtles and the collection of their eggs. Furthermore, the marine protected areas which provide visitor facilities and interpretive information are a major source of tourist revenue (Jennings & Marshall, in press). If the intensive exploitation of Seychelles' reef fishes continues then marine protected areas may start to play an important role in protecting stocks of mature reef fishes and act as insurance against mismanagement of the fishery in adjacent areas (Bohnsack, 1990). It should be recognised, however, that the reserves may not maintain biomass and diversity so effectively if there were a complete collapse of fish populations in adjacent regions; since small reserves of this type are expected to be dependent on an externally spawned pool of pre-recruit fishes. Practical experience suggests that reserves which are sufficiently large to be self-sustaining would be impossible to manage effectively in a small island developing state such as Seychelles. If maximising the species richness and biomass of reef fishes are the reasonable aims of marine fish conservation, then the proposed improvement of enforcement in the marine protected areas (Anon., 1990; Marshall, 1994) should help to ensure that there will be an increased probability that the progeny of protected fishes can recruit to another protected area.

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