Changes in the Shallow Reef Fishery Associated With Implementation of a System of Fishing Priority and Marine Reserve Areas in Soufriere, St. Lucia

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ABSTRACT

Conceptually, Marine Protected Areas (MPAs) are a good fishery management tool, since they are known to help protect reef habitat; allow for recovery of fish population abundance, increases in individual fish size and thus fecundity; and allow for restoration of a climax community structure, within the boundaries of the MPA. However, there are few documented cases, to date, where MPAs have been shown to actually benefit surrounding reef fisheries.

The Soufriere Marine Management Area (SMMA), spanning an 11 km stretch of the central west coast of St. Lucia, opened on August 1, 1995, and comprises a series of zoned fishing priority and marine reserve areas. It is the first example in the Caribbean of a serious attempt at complex co-management of nearshore marine resources, striving to integrate management of these resources for the benefit of several (often conflicting) users. Monitoring the effects of the SMMA zoning not only on the resources themselves, but also on the resource users is therefore all the more important.

This paper reports on the effects of the SMMA zoning on the shallow reef fishery in Soufriere by documenting changes in catch rates and in fisher behavior, including the areas fished, the types of fishing gears used, and the distribution of fishing effort, which have occurred with the implementation of the SMMA.

KEY WORDS: Catch rates, coral reef fishery, marine protected areas, St. Lucia

INTRODUCTION

Caribbean coral reef fisheries employ a large number of part-time and full-time fishers, provide coastal communities with an accessible and affordable source of fish protein (Chakalall, 1992; Sary *et al.*, 1995), and are generally considered to be the most economically important fisheries in the region (Mahon, 1990).

Most Caribbean coral reefs have depressed yields, primarily as a result of over-exploitation (Munro, 1983; Bohnsack, 1993) and degradation of reef habitats by exposure to anthropogenic stresses (Rogers, 1985). The current state of degradation and over-exploitation of Caribbean reefs has resulted in part from a lack of informed and effective management of these reef fisheries (Sale *et al.*, 1994; Roberts and Hawkins, 1995). Effective management of reef fisheries is very difficult since they are typically multi-species, multi-gear, artisanal and decentralized (Medley *et al.*, 1993; Roberts and Polunin, 1993), and in the Caribbean have a long tradition of free access (FAO, 1993; Roberts and Hawkins, 1995). Reef fisheries have long been managed at the habitat or ecosystem levels through multiple use zoning of reefs and coastal environments (Alcala and White, 1984), which include zones protected from fishing mortality that serve as spatial refugia (sensu Beverton and Holt, 1957). Marine Protected Areas (MPAS, also called Marine Reserves: MRs) have become very popular in the Caribbean (Sobel, 1993; Stanley, 1995), although this is largely as a result of their value to tourism rather than as a fishery management tool (Roberts and Polunin, 1993; CANARI, 1995).

One good example in the region where MPAs are being used at community-level management of the nearshore marine resources is the Soufriere Marine Management Area (SMMA) initiative, covering 10 km of the central west coast of St. Lucia in the eastern Caribbean (Figure 1). The SMMA, which became operational in August 1995, was conceptualized in 1992 and created during a series of conflict resolution meetings at the community level, where agreement was reached on the use and management of the marine resources in the Soufriere area (Renard and Koester, 1995). These included local users of Soufriere's marine resources: fishers, dive operators and yachtsmen, as well as NGOs and Government. The SMMA currently consists of 23 zones (Figure 2), comprising five MRs, 10 Fishing Priority Areas (FPAs), four Multiple Use Areas (MUAs) and four Yacht Mooring Areas (YAs). It is co-managed under the auspices of the Soufriere Foundation through a Technical Advisory Committee (TAC) comprising representatives of the main resource user-groups from the Soufriere community, NGOs and Government management agencies with concurrent responsibility (Nichols and George, 1995). The objective of the SMMA is to integrate the management of the area's marine resources for several (often conflicting) users, and thus realize the goals of non-conflicting sustainable use of Soufriere's marine resources, while minimizing damage to the coral reef ecosystem (Van't Hof, 1994).

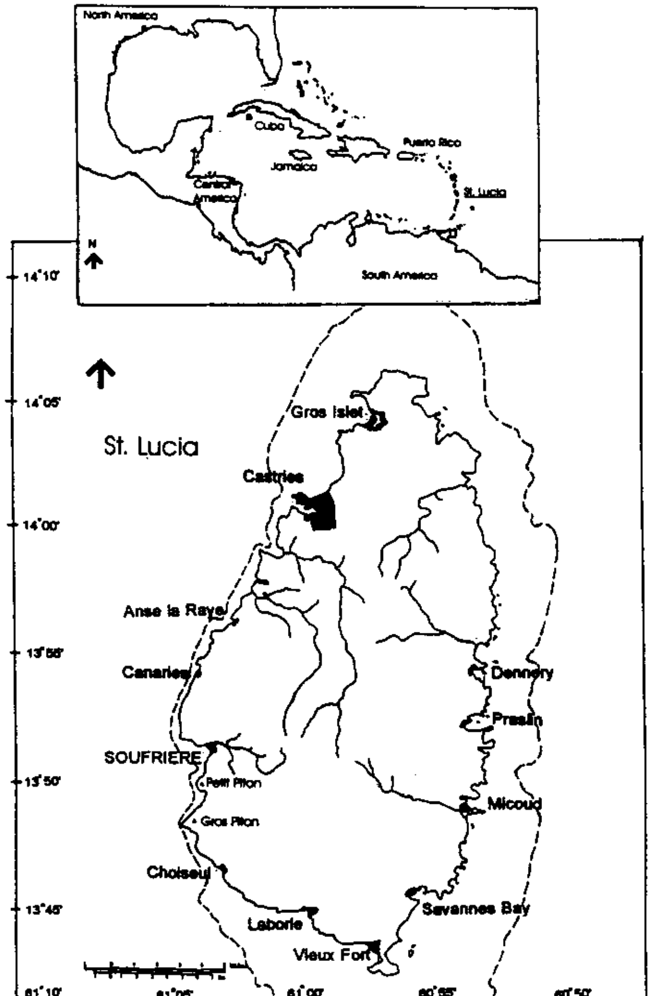

Figure 1. Map of St. Lucia showing the location of the study site, Soufriere; other main fish landing sites; and the 100 m isobath. Inset shows the location of St. Lucia within the Caribbean.

ZONE ALLOCATION

1	Anse Jambon/Mamin MUA	13	Malgretoute YA
2	Anse Mamin YA	14	S. Malgretoute FPA
3	Anse Chastanet FPA	15	Malgretoute Fish Pot FPA
4	Grand Caille MR	16	Petit Piton MR
5	Trou Diable FPA	17	Jalousie FPA
6	Trou Diable MUA	18	Jalousie YA
7	Ratchette Pt. MR	19	Beausejour MUA
8	N. Soufriere FPA	20	Coral Gardens MR
9	Soufriere Bay YA	21	Sabié FPA
10	S. Soufriere FPA	22	Gros Piton MR
11	La Point ti Bolo MUA	23	Anse L'Ivrogne FPA
12	N. Malgretoute FPA		SMMA zone boundaries

Lat. 13 50' N

HABITAT CODES

	sand plain or slope
	fringing reef
	patch reef on sandy bottom
	coral veneer on boulders
	wall reef

ZONE ALLOCATION

Fishing Priority Area (FPA)	Marine Reserve (MR)
Yacht Mooring Area (YA)	Multiple Use Area (MUA)

scale in metres

0 500 1000

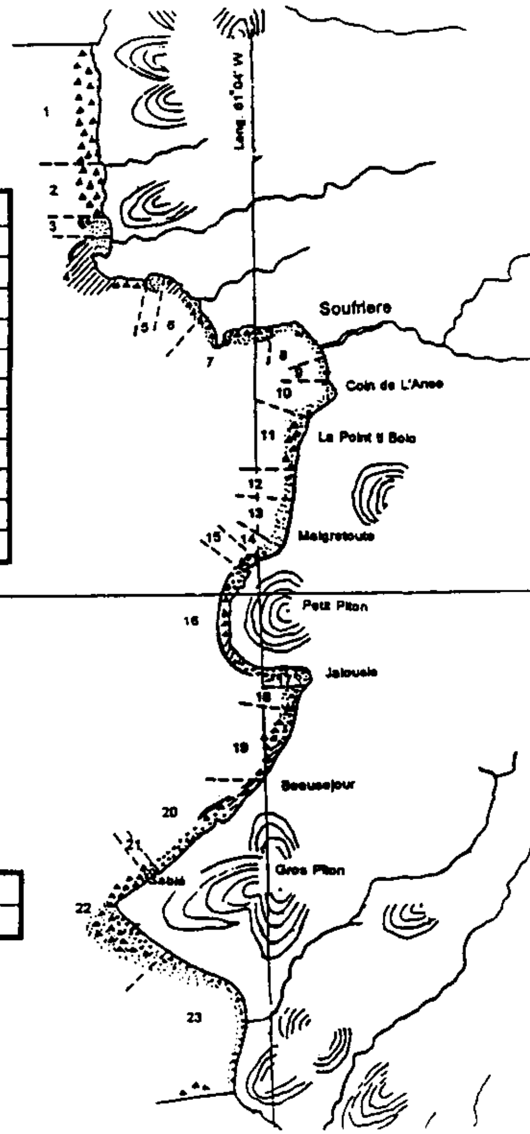

Figure 2. Chart of the Soufriere area showing the 23 management zones within the SMMA, and the shallow benthic habitat within these zones. Redrawn from Imray-Iolaire Chart B-1 (St. Lucia), 1991, and derived from unpublished St. Lucia Department of Fisheries data.

While it is known that MPAs/MRs help protect reef habitat and allow for recovery of reef fish stocks within their boundaries, the degree to which they actually benefit surrounding reef fisheries is virtually unknown (White, 1989; Roberts and Polunin, 1991), and their effect on displaced fishers undocumented in the Caribbean (Hatcher, 1995). Yet it is the promise of increased prosperity that is used to secure fishers' cooperation with zoning regulations, and many failed attempts at ecosystem-based reef resource management can be attributed to these people's inability to perceive, or achieve that benefit (Fiske, 1992; Russ and Alcala, 1994).

The Soufriere reef fishery is predominantly a pot fishery, with some bottom gill nets. Fishers normally go to sea in traditional wooden canoes or transom boats, and use one or more of three types of fish pots: traditional cane pots, small wire pots or large wire pots. Bottom-set gill nets also target the reef fishery.

The objective of this study within the Soufriere Experiment in Reef Fisheries Sustainability (SERFS, Hatcher *et al.*, 1995) was to determine the immediate costs and benefits to the coral reef fishery of the zoning of the SMMA. We concentrate on the coral reef fishers because they form an important component of the nearshore fishery in Soufriere (Jennings-Clark, 1992; Renard and Koester, 1995), but who were largely unrepresented during the conflict resolution meetings, and therefore not adequately considered when determining the location of FPAs within the SMMA (v'ant Hof, 1994; Nichols and George, 1995). Specifically we document the effects of the reduction in legally fishable area on fisher behavior (i.e persistence in the fishery, gear types used, location and intensity of fishing effort), and measure changes in catch rates during the year following the exclusion of fishing from the five MRs of the SMMA. We intend that these data will contribute to a realistic assessment of if, and how reef fishers are better off as a result of the formation of the SMMA. In the absence of detailed data on the reef fishery in the SMMA prior to zoning, we sought to establish an initial benchmark, against which future changes in the fishery could be assessed as the SMMA ecosystem and the management process evolve.

METHODS

Data were collected using four main methods: by examining the St. Lucia Department of Fisheries (DOF) catch and effort data collected in the year preceding zoning; by monitoring catch and effort at landing sites within the SMMA after zoning; by conducting regular surveys of fishing grounds; and through standard (formal) questionnaires administered to the shallow reef fishers. Valuable information was also gathered informally through casual observations and interactions with fishers, their families and other community members during a five month period of residence in the town of Soufriere.

Soufriere data (from 1/8/94 to 31/7/95) were extracted from the DOF Trip Interview Program (TIP) database to examine the status quo of the shallow reef fishery during the year prior to the opening of the SMMA.

A marine habitat survey conducted by the DOF in 1994 covered the SMMA environs, and recognized several distinct habitats, of which sand areas, fringing reefs, patch reefs, boulders with a coral veneer, and wall reefs are the most important. Using the DOF survey, personal visual observations and aerial photos, a basic (benthic) habitat map of the SMMA was constructed which allowed for estimates of reef area within the SMMA (Figure 2). The habitat map was also used to estimate the size of the designated zones within the SMMA (Table 1). As there is presently no seaward boundary on most of the zones, an offshore width of 100 m (approximating the seaward extent of reef habitat) was used to calculate their area, except in two cases where the narrow fringing reefs extend further offshore.

Although the SMMA is zoned into 23 areas of four management types (Figure 2), the shallow reef fishers who fish the SMMA waters recognize only about 16 fishing sites, which were used in this analysis (Table 2).

Between 1/11/95 and 31/7/96 the main Soufriere landing site (Coin de L'Anse; Figure 2) was monitored five to six days a week between 8:00 a.m. and 5:00 p.m. (there was virtually no fishing on Sundays). All reef fishers, their boat types, type and number of fishing gear, effort, and numbers of fish caught by species were recorded. Numbers of fish were subsequently converted to landed weight by using regression based on a subset of estimated weight data collected concurrently by the DOF.

Between 1/11/95 and 10/2/96, fishing activity in the SMMA was surveyed five to six days a week by boat, traversing one end of the zoned area to the other, between 7:00 a.m. and 9:00 a.m., and two to three times a week between 5:00 p.m. and 7:00 p.m. On each survey, the fisher, the location of fishing activity relative to zone boundaries within the SMMA, fisher identification, and the kind of gear being used was recorded.

A questionnaire was applied to a sample of the Soufriere reef fishers to compare fishing behaviors, gears, methods; and the fishers' perceptions of the reef fishery before the SMMA was zoned and immediately after the zoning was put into effect.

RESULTS

Reduction in Fishable Area

The present zoning of the SMMA has decreased the fishable area for the shallow reef fishery by approximately 50%. There is approximately 9200 m^2 of shallow habitat within the SMMA, comprising 30% sand, 30% patch reef, 22%

boulders with a coral veneer, 12% fringing reef, and 6% wall reef (Table 1, Figure 2). All of the habitat types, except the extensive areas of sand provide suitable reef habitat for coral reef fish, and are therefore potentially useful as fishing area for the coral within the SMMA (which covers 70% of the total area), has been designated as MR, and is therefore not available for fishing. The remaining area in which fishing is allowed comprises 26% MUA and 7% YA (Table 1), leaving 18% as FPA, in which fishing takes precedence over all other activities. This area is almost entirely sand (Figure 2).

Fishing Site Preferences

In the year following zoning of the SMMA (August 1995 to July 1996), 22 of the 23 zones within the SMMA were being used by the shallow reef fishers, including all five MRs, despite the fact that fishing in these was illegal (Table 2). The frequency with which zones are used varies, and it should be noted that fishers tend not to recognize all 23 zones as distinct, but refer to 16 "sites" (which include one or more of the 23 zones; Table 2).

The site most visited by pot fishers is Soufriere Bay (Site 7) comprising three zones: Soufriere Bay North and South FPAs and Soufriere YA, yet there is very , and there are rarely any strong currents, which means access by rowing, and setting and hauling traps there, is relatively easy. The second most popular site is the Point ti Bolo MUA (Site 8), which is mostly patch reef on sandy bottom. Fishers reported that this site is popular again as it can be reached easily by rowing, and does not tend to have strong currents. Two sites share the third most preferred rank: Site 9 (comprising the Malgretoute North and South FPAs, YA and Fish Pot FPA) and Site 12 (Beausejour MUA; Table 2). Malgretoute is relatively close to Soufriere, offers a diversity of habitats, and is next to the Petit Piton MR (Figure 2). The Beausejour MUA has good patch reef and fringing reef habitat, and shares a border with the Coral Gardens MR (Figure 2). The fishers report that they like these sites because they are as close as they can fish to the areas they previously fished.

Twenty-four percent of the pot fishing trips were made illegally in MRs (Table 2) and 12 (71%) of the 17 pot fishers were observed fishing in a MR. When questioned about fishing in the reserves, the fishers maintain that the reserves are the best places to catch fish, and they are not really prepared to give them up.

Bottom gill net fishers certainly prefer the MRs. Although only 9 bottom gill net sets were recorded after zoning, 4 (44%) were in the Grand Caille MR on Fairyland Reef (Figure 2). This reef is also one of the most popular dive sites in the Soufriere area. Another popular site for the bottom gill net fishers is within the Coral Gardens MR, west of what is locally known as "Wache Blanc" (Figure 2).

Table 1: Approximate area of the shallow benthic habitat types (m^2) for all named zones within the SMMA (areas calculated using a seaward limit of 100 m for all zones except areas where the edge of the reef extends beyond 100 m). Location of zones and code legend given in Figure 2.

SMMA Zone	Total Shallow Area (m^2)	Sand (m^2)	Fringing Reef (m^2)	Patch Reef (m^2)	Coral Veneer On Bldr (m^2)	Wall Reef (m^2)	Total Reef Area (m^2)
Grand Caille MR	550	18	312	120	25	75	532
Ratchette Pt. MR	370	130	40	200	0	0	240
Petit Piton MR	1000	40	150	160	275	375	960
Coral Gardens MR	730	25	150	130	400	25	705
Gros Piton MR	890	150	0	350	390	0	740
Anse Chastanet FPA	125	80	0	35	0	10	45
Trou Diable FPA	120	80	40	0	0	0	40
N. Soufriere FPA	426	395	15	0	6	10	31
S. Soufriere FPA	290	224	0	0	66	0	66
N. Malgretoute FPA	120	120	0	0	0	0	0
S. Malgretoute FPA	130	120	0	0	10	0	10
Malgretoute Fishpot FPA	170	0	0	0	70	100	170
Jalousie FPA	175	150	0	0	25	0	25
Sablé FPA	80	18	0	31	31	0	62
Anse L'Ivrogne FPA	1175	475	0	225	475	0	700

Table 1 (continued)

SMMA Zone	Total Shallow Area (m^2)	Sand (m^2)	Fringing Reef (m^2)	Patch Reef (m^2)	Coral Veneer On Bldr (m^2)	Wall Reef (m^2)	Total Reef Area (m^2)
Anse Mamin/ Jambon MUA	620	0	0	620	0	0	620
Trou Diable MUA	300	0	200	100	0	0	300
Point ti Bolo MUA	380	120	0	220	40	0	260
Beausejour MUA	600	90	225	260	25	0	510
Anse Chastanet YA	280	0	0	280	0	0	280
Soufriere YA	220	188	0	0	32	0	32
Malgretoute YA	220	220	0	0	0	0	0
Jalousie YA	225	110	0	0	115	0	115
TOTAL	9196	2753	1132	2731	1985	595	6443

Table 2: Frequency of use of sites by pot fishers during the year immediately following zoning of the SMMA (August 1995 to July 1996; number of trips sampled = 295).

SMMA zones	"Site" number	# times fished as a single site trip	# times fished as part of a multi-site trip	Total # times fished	% of total trips sampled
Anse Chastanet FPA & YA	2	12	0	12	4.1
Trou Diable FPA	4	8	10	18	6.1
Soufriere Bay North and South FPAs & YA	7	81	1	82	27.8
Malgretoute North and South FPAs, YA & Fishpot FPA	9	8	25	33	11.2
Jalousie FPA & YA	11	7	1	8	2.7
Sablé FPA	14	2	4	6	2.0
Anse L'Ivrogne FPA	16	1	0	1	0.3
Anse Mamin/Jambon MUA	1	0	0	0	0
Trou Diable MUA	5	17	12	29	9.8
Point ti Bolo MUA	8	25	26	51	17.3
Beausejour MUA	12	25	8	33	11.2
Grand Caille MR	3	8	0	8	2.7
Ratchette Pt MR	6	4	1	5	1.7
Petit Piton MR	10	8	18	26	8.8
Coral Gardens MR	13	10	3	13	4.4
Gros Piton MR	15	17	3	20	6.8

Changes in Fisher Behavior

Number of Fishers and Employment Status — The number of shallow reef fishers (i.e. those using fish pots and bottom gill nets) declined marginally from 21 (20 male and 1 female) in the year prior to zoning of the SMMA to 19 (18 male and 1 female) in the year immediately following. However, the total number of fishers using each type of gear is marginally larger than the real numbers since some fishers use more than one type of gear (Table 3). The proportion of part time fishers in the shallow reef fishery (38%) before zoning did not change in the year immediately after the area was zoned. Of the 13 full time fishers, 3 had alternative sources of income (both before and after zoning of the SMMA), but still considered themselves to be full time fishers.

Gear Preferences — In the year prior to SMMA zoning (August 1994 to July 1995), there were approximately 12 pot fishers and 10 bottom gill net fishers recorded fishing in the Soufriere area; after zoning, these numbers changed to 20 and 2 respectively, indicating a 40% increase in the number of pot fishers, and an 80% decrease in the number of bottom gill net fishers in the year after zoning of the SMMA (Table 3). There has also been a slight shift in the type of fish pot preferred, with cane pots now being used by 50% (10) of the pot fishers compared with 75% (9) before zoning; small wire pots now being used by 15% (3) compared with 8% (1) of the pot fishers; and large wire pots being used by 35% (7) compared with 16% (2) of the pot fishers (Table 3).

Fishing Effort

Fishing effort takes different forms in the shallow reef fishery, as it is dependent on the type of gear used. The traditional cane pots are fished in the tombé-levé method, in which multiple hauls of each pot are made during a fishing trip. Small wire pots are also usually hauled more than once during a trip, but large wire pots are hauled only once per fishing trip, as are bottom gill nets. Cane pots and bottom gill nets are usually set less than 20 m depth, while small wire pots may be set as deep as 30 m, and large wire pots are normally set in depths up to 50 m.

Fish pots — Although there were monthly fluctuations in the level of fishing effort by pot fishers, there does not appear to be a temporal pattern in fishing activity (Figure 3). There were large increases in the total number of pot fishers, total number of pots, and mean number of trips per day in the SMMA, which together comprise a significant increase in pot fishing effort in the reef areas since zoning.

The total number of fish pots being used in the fishery has increased by 28% from 63 in the year before the SMMA was zoned to 88 in the year after zoning, while the mean number owned per fisher did not decrease significantly (Mann-Whitney test: $U = -1.3400$, $n = 32$, $p = 0.1803$) from 5.25 to 4.40. Note however, that the significant change in the number of pots owned per fisher was not the same across all pot types (Table 3). The number of cane pots has increased marginally since the SMMA was zoned (43 to 45 pots). However, the mean number of cane pots owned per fisher (Mann-Whitney test: $U = -0.4549$, $n = 19$, $p = 0.6491$) and the mean number of cane pots fished per trip (Mann-

Table 3. Comparison of fishing methods used by the shallow reef fishers in Soufriere, shown separately by gear type for the year prior to zoning of the SMMA (August 1994 to July 1995) and for the year immediately following zoning (August 1995 to July 1996) by shallow reef fishers in Soufriere. Standard deviations are bracketed ( ); indicates no data available.

	pre-SMMA				post-SMMAp			
	Cane pots	Small Wire pots	Large wire pots	Bottom gill nets	Cane pots	Small wire pots	Large wire Pots	Bottom gill nets
number of fishers using gear	9	1	2	10	10	3	7	2
mean number of gear per fisher	4.78 (1.202)	4.00	8.00 (1.414)	1.00 (0)	4.50 (1.080)	3.00	4.85	1.50
mean soak time (hrs)	-	-	-	8.5 (1.254)	0.5 (2.256)	22.5 (16.556)	67.5 (27.126)	11.75 *** (1.669)
mean number of pots/nets per trip	4.0 (1.497)	2.9 (0.829)	5.5 (2.274)	1.0 (0)	3.7 (0.945)	2.1 ** (0.981)	3.8 *** (2.437)	1.3 *** (0.5)
mean number of hauls/trip	-	-	-	1.0 (0)	8.2 (3.694)	1.7 (1.601)	1.0 (0)	1.0 (0)
% set at night	0	0	0	53	0	0	0	88

note: for Mann-Whitney tests, * indicates significant difference, $p < 0.05$, ** indicates significant difference, $p < 0.005$, and *** indicates significant difference, $p < 0.001$.

Whitney test: U = -1.9400, n = 223, p = 0.0523) did not change significantly (Table 3). With zoning of the SMMA, the number of small wire pots increased 125%, from 4 pots (owned by 1 fisher) to 9 pots (owned by 3 fishers). The number of large wire pots increased 112.5% during the year after zoning from 16 to 34 pots, while the mean number of large wire pots fished per trip has decreased significantly (Mann-Whitney test: U = -3.8991, n = 148, p = 0.0001; Table 3).

The mean length of a pot fishing trip (about 4.0 hours) did not change significantly from the year after zoning (Mann-Whitney test:U = -1.0117, n = 443, p = 0.3117; Table 4). But there were significant decreases in trip length for certain pot types. Cane pot fishers significantly decreased the mean length of their fishing trips from 4.3 to 3.8 hours (Mann-Whitney test: U = -2.2162, n = 189, p = 0.0267), and large wire pot fishers significantly decreased the mean length of their fishing trips from 3.5 to 2.7 hours (Mann-Whitney test: U =-2.7792, n = 140, p = 0.0054; Table 4).

Consistent with the increase in the number of pot fishers, is a significant (102%) increase in the effort intensity of pot fishing in the SMMA from a mean of 1.16 trips per day prior to zoning, to a mean of 2.35 trips per day in the year after zoning (Mann-Whitney test: U = 7.2915, n = 264, p<0.0001). This increase in fishing intensity is significant for all individual pot types: cane pot fishers increased their mean daily number of trips by 48% (Mann-Whitney test: U = 2.8764, n = 264, p = 0.0040), small wire pot fishers increased their mean daily number of trips by 86% (Mann-Whitney test: U = 1.9781, n = 264, p = 0.0479), and large wire pot fishers increased their mean daily number of trips by 81% (Mann-Whitney test: U = 2.3304, n = 264, p = 0.0198; Table 5).

Bottom gill nets — The total number of bottom gill nets in the fishery decreased by 70% in the year after zoning, although the mean number owned per fisher has increased from 1.0 to 1.5 (Table 3). For the remaining nets, the way in which they are fished also appears to have changed, although sample sizes for post-SMMA operation are too small to test for differences. The mean soak time was 8.5 hours before the SMMA was zoned, and has now increased to 11.75 hours, and nets are now set at night more frequently (88%) of the time) than before SMMA zoning (53% of the time; Table 3).

The trip length for a bottom gill net fisher has significantly increased 31% in the year following zoning (Mann-Whitney test: U = 2.442, n = 139, p = 0,0248; Table 4).

Consistent with the decrease in the number of bottom gilll net fishers, is a significant decrease of 96% in the fishing intensity (as the daily mean number of trips conducted) in the year after the SMMA was zoned (Mann-Whitney test: U=-11.3586, N=264, P<0.001). Although there are monthly fluctuations in the level of fishing effort by bottom gill net fishers (mean daily number of trips), there are insufficient data to describe any temporal patterns since zoning of the SMMA (Figure 4).

Changes in Catch Rates

Fish Pots — In order to assess the current and past catch rates of fish pot landings in the shallow reef fishery in Soufriere, the catches from a total of 1,455 pots hauled in 392 pot fishing trips between August 1, 1995 to July 31, 1996, and catches from a total of 495 pots hauled in 113 pot fishing trips between August 1, 1994 to July 31, 1995 were sampled. Mean catch rates for all pots combined and individual pot types (as kg/gear type/fishing trip) are given in Table 5.

The mean catch rate for all pot types in the year following zoning of the SMMA is not significantly lower than in the year prior to SMMA zoning (Mann-Whitney test: U = -0.6110, n = 505, p = 0.5412; Table 5). However, there are significant changes in the mean catch rates of individual pot types from before and after the SMMA was zoned. The mean catch rate for cane pots decreased significantly by 28% in the year following zoning (Mann-Whitney test: U = -2.9025, n = 223, p = 0.0037; Table 5). The mean catch rate for small wire pots did not significantly change between the year prior to and the year immediately after zoning (Mann-Whitney test: U = -1.2885, n = 57, p = 0.1976; Table 5). In contrast the mean catch rate for large wire pots increased significantly by 24% in the year immediately following zoning (Mann-Whitney test: U = 1.9911, n = 148, p = 0.0465; Table 5).

Bottom gill nets — In order to assess the current and past catch rates of bottom gill net landings in the shallow reef fishery in Soufriere, catches from a total of 13 nets set in 9 fishing trips between August 1, 1995 to July 31, 1996, and catches from a total of 130 nets set in 130 bottom gill net fishing trips between August 1, 1994 to July 31, 1995 were sampled. Mean catch rates (as kg/gear type/fishing trip) are given in Table 5. The mean catch rate for bottom gill nets did not significantly change between the one year periods immediately prior to and after zoning (Mann-Whitney test: U = -0.6897, n = 139, p = 0.4903; Table 5).

Table 4: Mean length of fishing trip across all fishers and separately for fishers using single gear types for the year prior to zoning of the SMMA (August 1994 to July 1995) and for the year immediately following zoning (August 1995 to July 1996). P values are for comparison between years using Mann-Whitney tests, standard deviations are bracketed ( ).

Gear Type	Fishing Trip (hours) pre-SMMA length	pre-SMMA n	post-SMMA length	post-SMMA n	P value
all gears	2.6 (1.7239)	243	4.0 (1.9474)	339	0.0 ***
all pots	4.0 (1.4739)	113	3.7 (1.5141)	330	0.312
cane pots	4.3 (1.6126)	63	3.8 (1.0881)	117	0.027 *
small wire pots	3.6 (0.8273)	14	3.5 (1.5993)	32	0.143
large wire pots	3.5 (1.2471)	36	2.7 (1.0261)	104	0.005 **
bottom gill nets	1.3 (0.6651)	130	1.7 (0.3632)	9	0.0 ***

note: for Mann-Whitney tests, * indicates significant difference, $p < 0.05$, ** indicates significant difference, $p < 0.005$, and *** indicates significant difference, $p < 0.001$.

Table 5: Mean daily number of trips and mean catch rates (as kg/gear type/fishing trip) for all gears and for individual gear types for the year prior to zoning of the SMMA (August 1994 to July 1995) and for the year immediately following zoning (August 1995 to July 1996). ------ indicates that gear mean catch rates are not significantly different from one another within each time frame (i.e. pre- or post-SMMA). Standard deviations and n for each gear type are also shown.

	pre-SMMA					post-SMMAA				
	All pots	Cane pots	Small wire pots	Large wire pots	Bottom gill nets	All pots	Cane pots	Small wire pots	Large wire pots	Bottom gill nets
mean daily # trips	1.16	0.65	0.14	0.37	1.34	2.34 *	0.96 **	0.26 *	0.67 *	0.05 ***
std. dev'n	0.965	0.878	0.353	0.527	1.290	1.340	0.953	0.465	0.874	0.252
n			97					167		
Mean catch rate	4.32	4.27	4.40	4.39	31.12	4.26	3.08 **	3.90	5.81 *	33.56
std. dev'n	3.067	3.186	2.333	3.178	41.559	3.233	2.245	3.166	4.007	42.567
n	113	63	14	36	130	392	160	43	112	9

note: for Mann-Whitney tests, * indicates significant difference, $p < 0.05$, ** indicates significant difference, $p < 0.005$ and *** indicates significant difference, $p < 0.001$.

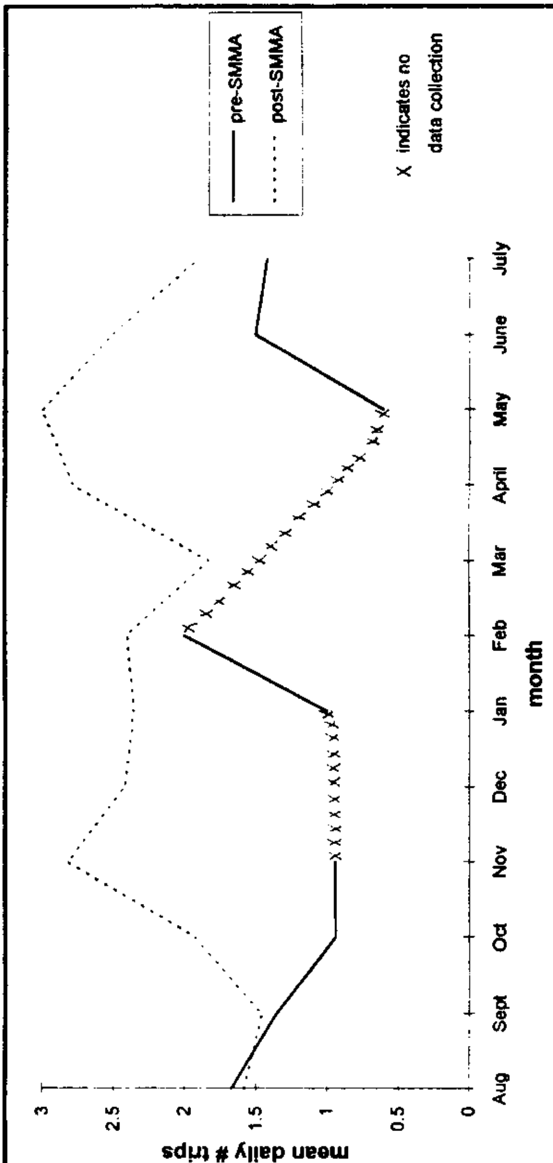

Figure 3. Monthly mean number of trips per day for all pot fishers for the year prior to SMMA zoning (1/8/94 - 1/7/95), and for the year immediately following zoning (1/8/95 - 31/7/96).

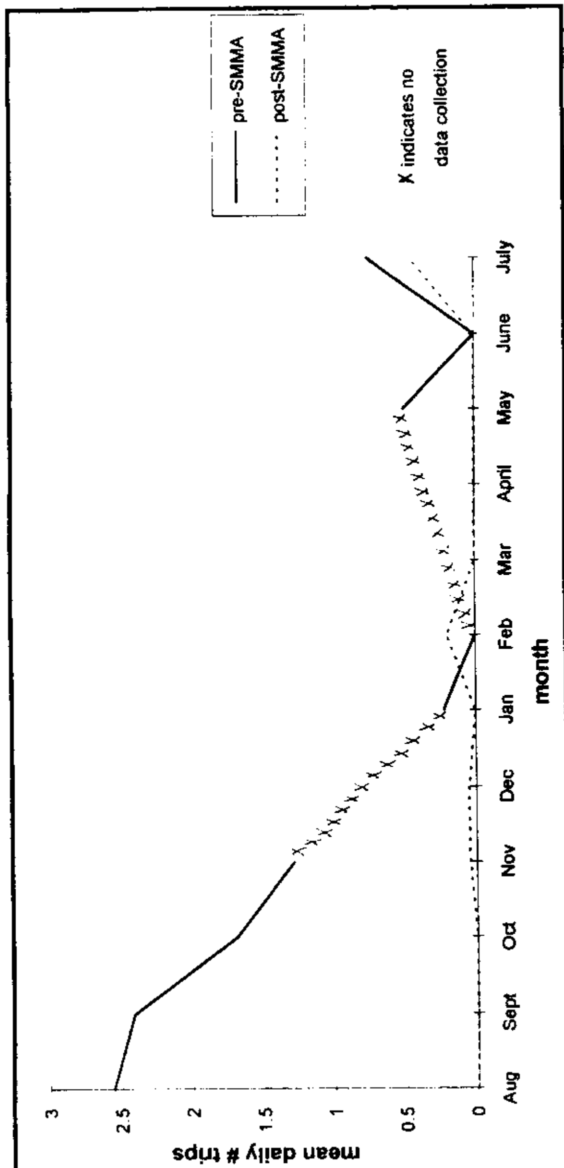

Figure 4. Monthly mean number of trips per day for all bottom gill net fishers for the year prior to SMMA zoning (1/8/94 - 1/7/95), and for the year immediately following zoning (1/8/95 - 31/7/96).

Comparison Between Gears

The different gear types used in the shallow reef fishery in Soufriere differed significantly in their mean catch rates both before and after zoning (Table 5). Pair-wise comparisons (Mann-Whitney tests) between gear types indicate that mean catch rates for all pot types are significantly lower than those for bottom gill nets during the years prior to and following SMMA zoning (Table 5). The mean catch rates of individual pot types did not differ significantly in the year prior to zoning. However, in the year following zoning, the catch rates of cane pots and small wire pots diverged significantly from that of large wire pots, but not from each other. The cane and small wire pots land about the same mean catch (in kg/pot/fishing trip), despite the different methods used to fish the pots (i.e. multi-hauls for cane pots and single hauls for small wire pots), while the large wire pots have a higher CPUE.

Comparison Between Zones

The sample sizes for small and large wire pots and bottom gill nets were too small to compare their catch rates between MRs and fishable sites on a per pot basis. However, adequate catch data from the two types of zone were available for cane pots. In the year following zoning, the mean catch rate for cane pots in MR areas was essentially the same in reserve and fishable areas (i.e. FPAs, MUAs and YAs) at about 3.6 kg/pot/trip (Mann-Whitney test: $U = 0.1461$, $n = 105$, $p = 0.8838$). The lack of any difference in catch rates by cane pots demonstrates that the reserve areas are no more valuable to fishers using this gear than are the fishable areas within the SMMA at this time.

DISCUSSION

The response of the reef fishing community of Soufriere to the loss of access to half their traditional fishing grounds has been both demographic and behavioral. But it has been relatively small and incremental to date, and not always in a predictable form. The regulatory and enforcement situation is highly dynamic, so this assessment can only be seen as a description of the initial response, not a post-zoning equilibrium. For example, in February 1996 the complete protection of fish in two of the five MRs was relaxed to allow fishing by licensed individuals using pots and nets in specified areas, and then the protection was re-instated in August 1996. It is too soon to see clearly what the effect on the fishery (or the reef fish community) of these changes will be. The need for ongoing monitoring of the socio-economics of the Soufriere fishing community is evident. Our interpretation of the first year's results is hampered by the absence of detailed behavioral profiles of the fishers, and the limited quantity and quality of fishery statistics from before zoning. The latter are based on interview samples of approximately 40% of the landings, often grouped above the species level (e.g. "mixed reef fish", "pot fish"), and usually lacking details of effort (e.g. number of pot hauls/trip) or area fished at the spatial scale of the zoning (i.e. we cannot determine what proportion of the reef fishing effort was deployed in the MRs prior to zoning). Coordinated efforts are being made to ensure that better fishery statistics will continue to be collected in Soufriere during the period of adjustment to the SMMA.

Despite these caveats, some clear patterns of response and effect are evident. The size of the reef fishery changed marginally from 21 to 19 fishers after zoning. But there was a turnover of at least 38% as eight of the bottom gill net fishers left the fishery, to be replaced by six fishers using pots. The resultant reduction from a total of 10 gill nets to 3 was accompanied by an increase in the total number of pots in the reef fishery from 63 to 88. A substantial change in the relative importance to fishers of the different pot types also took place after zoning (Table 3). Most of the new fishers chose to use the large wire pots, such that this gear type increased from 25 to 39% of the total number of pots used in the SMMA. From these results, and interviews it is clear that Soufriere fishers are reluctant to make major gear changes in response to zoning, and will leave the fishery rather than change from gill nets to pots (all of the gill net fishers who left the reef fishery now fish with surface seine nets).

Accepting that fishers are primarily motivated to maintain and even increase their catch, we (correctly) predicted that the fishers exploiting the reef resources of the SMMA would increase their effort in an attempt to offset the loss of access to much of their traditional fishing ground (a response observed in zoned reef fisheries elsewhere: e.g. McManus *et al.*, 1992). This could be achieved by increasing the amount of gear they deployed, by setting the gear more often, and by fishing for longer periods. Few fishers increased their total gear holdings during the year following zoning. In fact, per capita gear allocation stayed the same or decreased slightly (Table 3). The cost of new gear relative to the income of fishers coupled with normal attrition is the most parsimonious explanation for this result. Similarly, the amount of gear fishers used on each trip did not increase (probably due to limitations of vessel size). It is unfortunate that the before zoning data do not allow calculation of the pot soak times or number of pot hauls per trip, as these variables are the most likely indicators of an increase in fishing effort. Both measures increased by about 40% for the two gill net fishermen remaining in the fishery for the year after zoning (Table 3).

The mean duration of a fishing trip is a less obvious measure of fishing effort because it is affected by the distance to the fishing site, but we do have before and after zoning data (Table 4). There is no clear trend of trip length as it increases for gill nets and decreases slightly for two pot types. The overall value (all gears) after zoning increased by over 50% to 4 hours per trip, indicating that at least some fishers substantially increased the time they spent on a fishing trip after zoning. This fact was ascribed by interviewed fishers to the greater distance they had to travel to avoid no fishing areas. More significantly, because of the large increase in the number of pot fishers, significantly more fishing trips were made per day after the SMMA was zoned (Table 5). This is the strongest sign of a community effort response to zoning, showing increase in effort for all types of pot fishing, and an overall increase of over 100% in the mean number of pot fishing trips.

From the fisher's perspective, the bottom line is the catch rate they obtain from a certain type of effort. The substantial increases in fishing effort exerted by the reef fishers of Soufriere would be wasted if catch per unit effort (CPUE) fell by an equivalent amount. There is evidence that this has begun to happen for small fish pots (cane and small wire) in the first year following zoning of the SMMA (Table 5). But this effect was offset by a significant increase in the catch rate of large wire pots, such that the CPUE (kg/trip) of all pots showed no change. On this basis, we conclude that although they are working harder, as a group the reef fishers of Soufriere who use fish pots have been able to maintain their catches despite the loss of access to 50% of their fishing grounds. Individuals using cane and small wire pots appear to be at a disadvantage, however.

The zoning of the SMMA, which located all five MRs on coral reefs, appears to have disadvantaged fishers using bottom-set gill nets and the small types of fish pots in the short term. We speculate that this is because these gears must be set on reefs in depths of less than 20 m (i.e. on the tops of the fringing reefs, close to shore), and there is little of this habitat outside MRs (Table 1). The use of these gears is obvious due to the location and time spent setting and hauling them, so it is difficult to use them illegally within MRs without being apprehended. One bottom gill net fisher reported that it has become increasingly difficult to find adequate sites in which to set bottom gill nets, as all traditional sites have become MRs, and are, therefore, now out of bounds for fishers. Because of this, the bottom gill net fishers either fish illegally within the MRs mostly at night (in order to evade marine police), or prefer not to fish at all, as locating a new site to safely set nets is a long and difficult process. The bottom gill nets are particularly disliked by the sport diving community, and even when they are set in areas outside the MRs, net damage can still occur by non-fishers, and divers still complain about the nets being there.

The main problem reported by the shallow reef fishers with respect to the MR areas is that there are no outer boundaries on the MRs: the MRs ostensibly go "forever" in a seaward direction. This is a hard concept for the fishers to understand and visualize, and many will fish in the deeper waters of a MR, and believe they are fishing outside of the protected area. This fishing habitat favours the use of the large wire pots, which are less likely to be lost to the strong currents along the steep reef slopes, and which can hold more fish during longer soak times. These pots are often set below 30 m and tied discreetly to a subsurface line running almost to shore, rather than buoyed to the surface. They are thus less likely than small pots to be detected when set illegally.

The fact that almost a quarter of the total reef fishing effort during the year following zoning was deployed in the areas of the SMMA closed to fishing suggests that many (>70%) of the reef fishermen of Soufriere have not yet accepted either the logic or practice of the marine fishery reserve concept (Bohnsack, 1993). When fishers were questioned about their fishing sites, they did not deny it when told they had been observed fishing in a reserve. Yet only 26% of the fishers were willing to talk about their illegal fishing. These fishers defended their actions as the ones to take in order to feed their families and make a bit of money to pay bills. Sustained fishing in MRs will delay or negate the increase in reef fish biomass and fecundity expected on the basis of studies in more mature MPAs (Rowley, 1994), and will lead to further conflict between user groups in the SMMA. Continued education, communication and compromise will go some way to changing the fishers' behavior. (Renard and Koester, 1995).

Ultimately the catches from outside the reserves will have to support the reef fishery at a level acceptable to the community if they are to buy into the SMMA and respect the zoning regulations. Whether this is achieved in Soufriere will depend on the balance between the length of time that reef fishers can survive on the catches from the non-reserved areas, and the time it takes for the reserves to export catchable fish at a rate at least equal to 50% of the pre-zoning catch rate (Hatcher *et al.*, 1995). No measurable reserve effect on export rates was detected during the SMMA's first year of operation (Corless *et al..*, in press). Experience elsewhere suggests that it will be on the order of five years before a large-enough biomass accumulates within the reserves to support the putative spillover to adjacent fished areas (Rowley, 1994). Can the reef fishers of Soufriere wait that long?

LITERATURE CITED

Alcala, A.C. and A.T. White. 1984. Options for management. Pages 31 - 40 In: Kenchington, R.A. and Hudson, E.T. (eds.) *Coral reef management handbook.* UNESCO, Paris.

Beverton, R.J.H. and S.J. Holt. 1957. *On the dynamics of exploited fish populations*. Fishery Invest., London, Vol. 19. 533 p.

Bohnsack, J.A. 1993. Marine reserves: they enhance fisheries, reduce conflicts, and protect resources. *Oceanus* **36**(3).

CANARI 1995. Marine protected areas and fisheries management. *Caribbean Parks & Prot. Areas Bull.* **5**(2):1.

Chakalall, B. 1992. Fisheries management in the Lesser Antilles. *Proc. Gulf Carib. Fish. Instit.* **42**: 294 - 330.

FAO 1993. Marine fishery resources of the Antilles: Lesser Antilles, Puerto Rico and Hispaniola, Jamaica, Cuba. *FAO Fisheries Technical Paper* **326**: 235 p.

Fiske, S.J. 1992. Socio-economic aspects of establishing marine protected areas. *Ocean & Coastal Management* **18**:24 - 46.

Hatcher, B.G. 1995. How do marine protected areas benefit fisheries? *Caribbean Parks & Prot. Areas Bull.* **5**(2):9 - 11.

Hatcher, B.G., M. Corless, R. Goodridge, H.A. Oxenford and S. Scot. Testing mechanisms by which marine protected areas export fish to adjacent habitats: the Soufriere experiment in reef fisheries sustainability (SERFS). *Proc. Gulf Carib. Fish. Inst.* In Press.

Jennings-Clark, S. 1992. The status of coral reefs and reef management in St. Lucia. *St. Lucia Dept. of Fisheries Paper.* 8 p.

Mahon, R. 1990. Fishery management options for Lesser Antilles countries. *FAO Fisheries Technical Paper* **313**: 126 p.

Mahon, R. 1993. Lesser Antilles in: Marine fishery resources of the Antilles: Lesser Antilles, Puerto Rico and Hispaniola, Jamaica, Cuba. *FAO Fisheries Technical Paper* **326**: 5 - 98.

Medley, P.A., G. Gaudian and S. Wells. 1993. Coral reef fisheries stock assessment. *Reviews in Fish Biology and Fisheries.* **3**: 242 - 285.

Munro, J.L. 1983. *Caribbean coral reef fishery resources.* ICLARM, Manila, Philippines: 276 p.

Nichols, K. and S. George. 1995. A critical review of the implementation of the management for the Soufriere Marine Management Area: a case study. *Proc. Gulf Carib. Fish. Inst.* In Press.

Renard, Y. and S.K. Koester. 1995. Resolving conflicts for integrated coastal management: the case of Soufriere, St. Lucia. *Caribbean Parks & Prot. Areas Bull.* 5(2):5 - 7.

Roberts, C.M. and J.P. Hawkins. 1995. Marine fisheries reserves for the Caribbean. *Caribbean Parks & Prot. Areas Bull.* **5**(2):8.

Roberts, C.M. and N.V.C. Polunin. 1991. Are marine reserves effective in management of reef fisheries? *Reviews in Fish Biology and Fisheries* **1**:65 - 91.

Roberts, C.M. and N.V.C. Polunin. 1993. Marine reserves: simple solutions to managing complex fisheries? *Ambio* **22**(6):363 - 368.

Rogers, C.S. 1985. Degradation of Caribbean and western Atlantic coral reefs and decline of associated fisheries. *5th Int'l. Coral Reef Symp.* 491 - 496.

Russ, G.R. and A.C. Alcala. 1994. Sumilon Island reserve: 20 years of hopes and frustrations. *NAGA*. 8 - 12.

Sale, P.F., G.E. Forrester and P.S. Levin. 1994. Reef fish management. *National Geographic Research & Exploration* **10**(2):224 - 235.

Sary, Z., J.D. Woodley and H.A. Oxenford. Progress in the Fisheries Improvement Programme, Discovery Bay, Jamaica. In Prep.

Sobel, J. 1993. Conserving biological diversity through marine protected areas. *Oceanus* **36**(3):19 - 26.

Stanley, S. (ed) 1995. *A global representative system of marine protected areas, Volume II: Wider Caribbean, West Africa and South Atlantic.* IUCN. 93 p.

v'ant Hof, T. 1994. *Resolving common issues and problems of marine protected areas in the Caribbean.* Caribbean Conservation Association, Barbados. 58 p.

White, A.T. 1989. Two community-based marine reserves: lessons for coastal management. In: Chua, T-E. and Pauly, D. (eds.) *Coastal area management in Southeast Asia: policies, management strategies and case studies.* ICLARM (Manila) Conf. Proc. 19: 254 p.

APPENDIX 1

Zone Allocation

1	Anse Jambon/Mamin MUA	13	Malgretoute YA
2	Anse Mamin YA	14	S. Malgretoute FPA
3	Anse Chastanet FPA	15	Malgretoute Fish Pot FPA
4	Grand Caille MR	16	Petit Piton MR
5	Trou Diable FPA	17	Jalousie FPA
6	Trou Diable MUA	18	Jalousie YA
7	Ratchette Pt. MR	19	Beausejour MUA
8	N. Soufriere FPA	20	Coral Gardens MR
9	Soufriere Bay YA	21	Sablé FPA
10	S. Soufriere FPA	22	Gros Piton MR
11	La Point ti Bolo MUA	23	Anse L'Ivrogne FPA
12	N. Malgretoute FPA		SMMA zone boundaries

Habitat Codes

sand plain or slope
fringing reef
patch reef on sandy
coral veneer on
wall reef

Zone Allocation

Fishing Priority Area (FPA)	Marine Reserve (MR)
Yacht Mooring Area (YA)	Multiple Use Area (MUA)