Annex A2

R7668 Impact and amelioration of sediment pollution on coral reefs of St. Lucia, West Indies

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Abbreviations and acronyms

SMMA – Soufriere Marine Management Area (St. Lucia)

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1. Executive summary

St. Lucia's coral reefs are highly valuable resources. They support a fishing industry worth hundreds of thousands of EC dollars annually, and a tourism industry that nets tens of millions of EC dollars. Efforts to protect and manage reefs have been underway for a decade. Since 1995 the Soufriere Marine Management Area (SMMA) has facilitated a four-fold increase in fish stocks in marine reserves and a three-fold increase in fishing grounds. Fish catches have nearly doubled, and the profitability of the fishery has increased by a similar amount. The SMMA has become a model for successful management of coral reefs worldwide, and expansion of this approach to manage other nearshore resources and fisheries around the island is now warranted.

Improvements in fish stocks and the fishery have been made against a background of severe reef degradation. 55% of the coral that was present at the establishment of the SMMA has since died. The causes of coral decline include storms, sediment pollution, coral disease and tourism. To date, storms have been responsible for the greatest losses, followed by sedimentation impacts, then disease. However, sediment pollution is one of the most serious threats to St. Lucia's reefs because it inhibits recovery from other disturbances. Reefs affected by sediment pollution can thus undergo a 'ratchet' of decline, with coral cover falling at each new disturbance, such as a storm, and not recovering before the next disturbance reduces cover to a new low. Reducing rates of soil loss from land and sediment inputs to the sea represents a national priority if St. Lucia is to maintain and further enhance the quality of its reef resources.

Reducing pollution inputs and facilitating reef recovery is also an economic imperative. Tourism depends on a high quality reef environment, and tourists prefer sites with abundant fish, large fish, healthy corals and good underwater visibility. While reserves enhance fish stocks, increasing reef amenity value, sediment pollution increases coral mortality and reduces underwater visibility. Already, use of several dive sites has been abandoned due to reef degradation from sediment and rubbish, and further losses can be expected if sediment pollution inputs are not reduced. In future, losses of dive sites from sediment pollution could cost the St. Lucian economy between EC$430,000 and EC$750,000 per site per year. We describe a series of measures that will help reduce rates of sediment input and facilitate reef recovery.

Tourist pressure on reefs has been growing rapidly and use of some sites now far exceeds levels considered sustainable by scientists. Tourists damage reefs, although inadvertently. There is now a need to pro-actively manage tourism to improve sustainability and protect reefs. Spreading tourist pressure more equitably among sites is an important step. However, closer management of tourists in the water by tour leaders will increase the capacity of sites for tourism, and the revenues that can be generated by reefs. Management of reefs costs money, and it is clear that user fees paid to the SMMA can be increased with little effect on demand.

Without resolute action to curb sediment pollution and manage tourism growth, St. Lucia's reefs will continue to decline, jeopardising recent improvements to the fishery and fishers' livelihoods. Degrading environmental quality also risks a shift from low-volume, high-value tourism, to high-volume, low value, high environmental impact tourism. If this were to occur, the quality of life and opportunities for St. Lucians would also decline. Measures to protect and sustain the quality of reef resources deserve to rank high among national priorities.

2. Background

Caribbean coral reefs are among the most threatened in the world from human activities (Bryant et al. 1998, Gardner et al. 2003). In many parts of the region fisheries have intensified over the last few decades and fish stocks are now seriously overexploited. There have been large-scale losses of coral cover from disease outbreaks. The die off of the herbivorous sea urchin, *Diadema antillarum*, in the early 1980s has led to a gradual shift towards algal dominance at the expense of corals (Lessios 1988). Coupled with these impacts, pollution from land-based sources has been increasing and is further stressing coral reef ecosystems. Against this background, use of reefs by tourists has been on the increase, and in many places thousands of visitors now swim, snorkel or dive on reefs.

The above stresses may be much more serious in combination than if each were applied in isolation. Reduced herbivory by sea urchins is exacerbated by overexploitation of fish herbivores. Damage to corals by tourists may increase their susceptibility to disease (Hawkins et al. 1999). Natural disturbances like storms may initiate large-scale shifts from coral to algal dominance that are hard to reverse due to the interacting effects of other stresses like overfishing and sediment pollution. There is an urgent need for research on the interaction of human and natural stresses on coral reefs, and on management options to reduce stresses and facilitate recovery.

This report describes the findings of a multidisciplinary research programme that was initiated in 1994. It features research done between 2000 and 2003 with support from the UK Department for International Development's Natural Resources Systems Programme. However, earlier monitoring data are presented where appropriate to show long-term trajectories in the status of reef resources in St. Lucia and the effects of management of those reefs.

3. Purpose

This study is intended to improve understanding of the impacts of sediment pollution on coral reefs of St. Lucia West Indies. We examine the direct impacts of sediment pollution on reef organisms and look at interactions with other stresses, particularly storms and fishing. We also look at the options for improved management of sediment pollution and other human activities that impact St. Lucia's reefs.

4. State of the reefs in St. Lucia

4.1 Fish assemblages

We studied fish assemblages on reefs using visual census. Fish were censused annually at four sites around Anse La Raye/Anse Cochon and 21 sites in the SMMA. At each site we counted fish at two depths, 5m and 15m, making six counts at each depth every year from 1994/5 to 2002, with the exception of 1999. For each count, a 10m tape measure was placed on the reef to denote the diameter of a cylinder that extended 5m above the reef. All fish inside or passing through this cylinder were counted for a period of 15 minutes and their lengths estimated to the nearest centimetre. Length estimates were later converted to biomass using length-weight relationships.

The Soufriere Marine Management Area has been zoned for different uses since 1995. Around 35% of coral reefs lie within a series of four marine reserve zones that are protected from fishing. Figure 1 shows trajectories of change in fish biomass for marine reserves compared to fishing grounds over the period 1995-2002. Protection from fishing has been highly successful in rehabilitating what were severely overexploited fish stocks. Stocks of commercially important fish in marine reserve zones have increased four fold since the instigation of protection. They have increased three-fold in adjacent fishing areas, due to spillover of fish from marine reserve zones and augmentation of recruitment by reproduction of enhanced fish stocks in marine reserves (Roberts et al. 2001, Annex C1.1, C1.2).

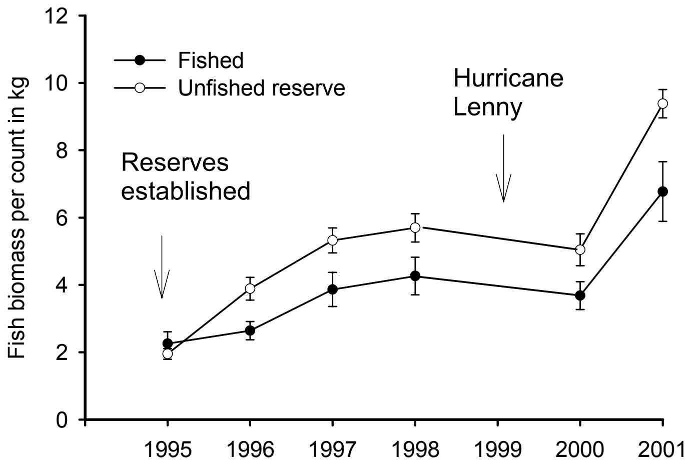

Figure 1: Change in biomass of five families of commercially important fishes in marine reserve zones and fishing grounds of the SMMA.

Although not all fish species have responded to protection from fishing, there have been particularly strong increases among snappers, groupers and parrotfishes (see Annex B2.9). All are key species within catches, and grazing parrotfishes are also very important in controlling algal growth on coral reefs.

4.2 Coral assemblages

We censused coral assemblages annually (except 1999), at 4 sites at Anse La Raye/Anse Cochon and 19 sites in the SMMA. Every year, between 12 and 18 1m^2 quadrats were sampled at each of 5m and 15m deep. Quadrats were placed at random intervals along these depth contours. Percentage cover of hard corals and other major benthic components were visually estimated within each quadrat.

Hard coral cover has declined steeply on St. Lucia's reefs since 1995, falling from an average of 40% cover in 1995 to 18% in 2001 (Annex B2.2). This represents a relative loss of 55% of the coral that was present at the establishment of the SMMA. There has been a reciprocal increase in cover of algae, rising from 42 to 55% cover from 1995 to 2001.

Each year we also estimated coral cover at a larger scale, within the areas of all fish counts, at all of the sites and depths that fish counts were undertaken at (see above). The results confirm the pattern of decline revealed by small-scale sampling. Figure 2 shows trajectories of decline of coral cover inside and outside marine reserve areas in the SMMA from 1995 to 2002.

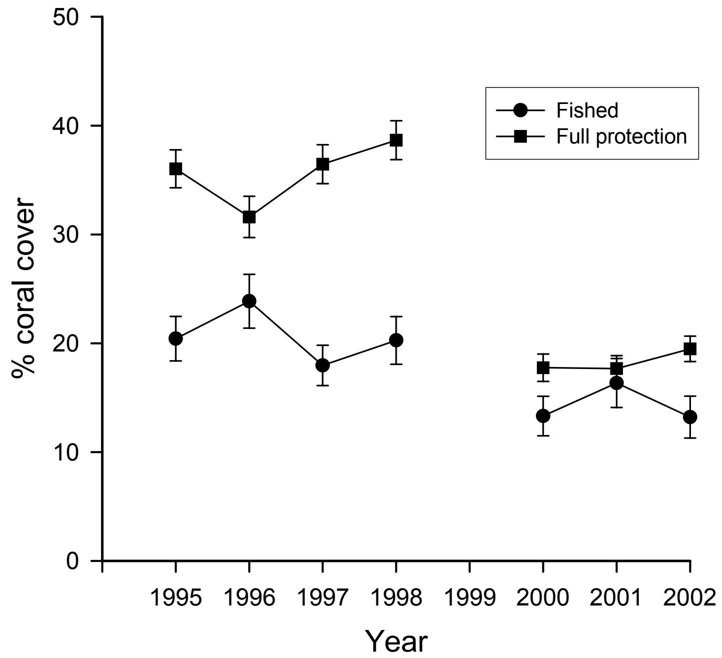

Figure 2: Trajectories of change in hard coral cover inside and outside marine reserves in the SMMA.

4.3 Causes of coral decline

There have been several agents of serious coral decline in St. Lucia: storms, coral disease outbreaks and sediment pollution. These agents have not acted in isolation. They interact in ways that can increase overall impact and reduce recovery rates. We describe the effects of these stresses below.

4.3.1 Storms

Storm impacts affected St. Lucian reefs in 1994 (Tropical Storm Debbie), 1995 (Hurricanes Luis, Iris and Marilyn), and 1999 (Hurricane Lenny). Tropical Storm Debbie in 1994 was one of the wettest storms on record and caused major landslides on the island. Enormous quantities of sediment were flushed into the sea and onto the reefs, burying reefs in mud in areas close to river mouths. Up to 50% of corals were killed in the worst affected areas (Sladek Nowlis et al. 1997) and thick sediment deposits remained on the reefs causing chronic stress in subsequent years.

In 1995, storm waves associated with Hurricanes Marilyn and Luis caused coral losses, mainly of branching corals in shallow water in exposed sites (Annex B2.2). However, Hurricane Lenny in 1999 caused severe damage to corals and associated reef organisms, especially in exposed headlands such as around the Pitons. Between monitoring work in 1998 and 2000, overall coral cover fell by 44% in shallow water (5m) and 29% deeper down (15m). In the most severely impacted places, such as the flanks of Petit Piton, the reef was reduced to rubble for the first 10m below the surface.

4.3.2 Coral disease

There have been serious outbreaks of coral disease at several locations in the SMMA (Nugues 2002). *Montastrea faveolata* and *Colpophyllia natans* were the two most affected species, and are important reef building corals on St. Lucia reefs. During surveys in 1998, 19% of *M. faveolata* colonies and 13% of *C. natans* colonies were infected. In 8 months from July 1997, these species lost 6.6% of living cover at the survey sites. Qualitative observations made since then at the same sites indicate that similar rates of loss have been sustained. The worst affected sites, Anse Chastanet and Turtle Reef, suffered overall losses of coral cover of 57% and 36% from 1995-2001.

4.3.3 Impacts of sediment pollution

Sediment pollution has been a growing problem for St. Lucia's reefs over the last two decades. The main sources of sediment pollution are land clearance for agriculture and development, and coastal construction works and dredging (Annex B2.2). Sediment is introduced to the sea with rainwater runoff. We monitored sediment pollution levels at 11 sites throughout the SMMA and 3 sites at Anse La Raye. Sediment traps were set at depths of 5m and 15m on the reef, and at each depth there were two traps at 25cm above the reef and two at 65cm. 65cm traps were designed to measure mainly new inputs of sediment, while those at 25cm would capture new inputs and sediment resuspended by waves. Bottom living corals and other organisms are exposed to both new inputs and resuspended sediments and so we mainly used data from 25cm traps to examine the impacts of sediment pollution. Traps were sampled at two week intervals, with 25 samples taken over 7 periods of two to six months spanning the years 1997-2001.

Sediment inputs were greatest close to river mouths, and declined from the heads of bays around rivers to headlands (Annex B2.2). Inputs of sediment to traps at 15m deep were positively correlated with rainfall, confirming a terrestrial origin for much of the sediment pollution. At 5m deep, sedimentation levels were also affected by wave action resuspending previous deposits. Furthermore, a previous study of the SMMA showed the fraction of terrestrially derived sediment to be substantial and to increase with proximity to rivers, increase with the size of the river, and increase from 5 to 15m depth (Sladek Nowlis et al. 1997).

4.3.3.1 Effects of sediment on adult corals

In a previous study, we examined the impacts of sediment on adult corals (Nugues and Roberts 2003). We examined rates of partial mortality of coral colonies (extent of recent loss of coral tissue) in relation to levels of sediment pollution. We looked at four coral species that are common on St. Lucian reefs: *Colpophyllia natans*, *Montastrea annularis, Siderastrea siderea* and *Porites astreoides*. Three of them, *C. natans, S. siderea* and *M. annularis*, are large species that are among the most important reef-building species around the island.

Rates of partial mortality were positively correlated with levels of sediment pollution input for two of the species, *S. siderea* and *M. annularis*. We chose to look at partial mortality because it is not possible to survey total mortality without tagging coral colonies and following their fate over long periods. However, rates of partial mortality were positively correlated with the rate of overall decline in coral cover at sites, showing that partial mortality is a good indicator of total mortality too. In short, sediment pollution increases mortality of some of the most important reef building corals in St. Lucia, and has contributed to a serious decline in these species from 1995-2002.

4.3.3.2 Effects of sediment on coral replenishment

Corals have a two-phase life history. Adults and juveniles live attached to the reef, and adults produce eggs and/or larvae that disperse with water currents before settling onto the reef. We established artificial coral settlement arrays at 11 sites in the SMMA and 3 sites at Anse La Raye to sample rates of settlement by coral larvae (Annex B2.4). Arrays consisted of a series of ceramic tiles attached to the reef at 25 and 65cm above the bottom. Two arrays were installed at 15m deep at each site and two pairs of tiles were attached to each array at each height. Tiles were removed and replaced after six months and two periods of settlement were sampled in this way. Tiles were examined under a microscope to record numbers and species of corals settling.

Overall rates of coral settlement were not correlated with level of sediment pollution. However, the species composition of settling corals differed between areas with high and low rates of sediment input. Sediment pollution may have influenced settlement behaviour in subtle ways though. More settling corals were found on the lower tiles in areas where sediment pollution was low, whereas more larvae settled on higher tiles in areas with high sediment input. It may be that corals in areas with greater sediment pollution are avoiding sites close to the reef where sediment levels will be higher due to resuspension of sediment deposits.

We also studied the effects of sediment pollution on juvenile corals that had settled naturally onto the reef (Annex B2.5). At each of the 14 locations with sediment traps, we established 9 permanent 20 x 30cm photoquadrats between 12 and 18m deep. Each quadrat was set up in a place with at least three juvenile corals (<4cm diameter). Each quadrat was sampled 3 times over a 14 month period and the corals present were identified, measured, their health status noted, and any new settlers recorded and measured. Contrary to our finding with artificial settlement arrays, rates of settlement to the reef were significantly lower in areas with high sediment input. Sediment pollution also significantly reduced coral growth rates. However, mortality rates did not differ significantly between areas with high or low sediment input.

We also conducted a more extensive survey of juvenile coral assemblages in relation to sediment pollution (Annex B2.3). At 15m deep, we sampled a minimum of 12 randomly placed quadrats of 60 x 80cm (8 times the area of permanent photoquadrats) at each of the 14 sites with sediment traps. In each quadrat, we recorded the number, size, species and health status of all the juvenile corals present. Densities of juvenile corals were significantly negatively correlated with rates of sediment input, i.e the more sediment, the fewer corals. The percentage of healthy corals (no overgrowth or partial mortality) decreased as sediment pollution levels increased. Average size of juvenile corals decreased with rising levels of sediment.

To summarise, sediment pollution negatively affects the replenishment of coral populations on reefs. It reduces rates of settlement and growth on natural substrata, and increases frequencies of partial mortality of juvenile corals.

4.3.4 Effects of tourism on reefs

St. Lucia's coral reefs have been subject to growing levels of use by tourists over the last 20 years. We studied the impacts of scuba divers and snorkellers by following tourists and recording all contacts they made with the reef and the outcomes of those contacts.

4.3.4.1 Diver impacts

We observed 353 divers (Annex B2.11). Contacts with the reef were common, with 74% of divers contacting the reef at least once on the dive with some part of their body or equipment. Certain diver, dive and site characteristics were correlated with higher levels of damage to the reef. Divers using a camera had significantly more contacts with the reef than those not using a camera (average 0.4 versus 0.2 contacts per minute), as did shore versus boat dives (average 0.5 versus 0.2 contacts per minute), and night versus day dives (average 1.0 versus 0.4 contacts per minute). Contact rates by divers were highest at the beginning of the dive (average of 0.6 contacts per minute) and reduced as the dive progressed (average of 0.04 contacts per minute).

Most diver contacts were caused by fin kicks causing minor damage (a touch or a scrape), with almost half of all contacts resulting in the re-suspension of sediment (sediment kicked up by fins or hand movement). Very few divers broke corals (4%), but scrapes and sediment damage cause cumulative stress to reefs at dive sites.

4.3.4.2 Snorkeller impacts

180 snorkellers were observed (Annex B2.12). Few snorkellers contacted the reef (20.6%), averaging 0.05 contacts per minute. The highest rates of contact (up to 1.10 contacts per minute) occurred at the beginning of the snorkel. Snorkellers using a camera caused more damage and had more than twice as many contacts as non camera users (average of 0.12 versus 0.04 contacts per minute). Although rates of snorkeller contact with the reef were lower than by divers, there may be more intensive use of some sites by snorkellers compared to divers. This means the overall rate of touching the reef by snorkellers can equal or exceed the rate of contact by divers.

4.3.4 Interacting stresses: storms, sediment pollution, fishing, coral disease and tourism

Each of the above stresses affects the reef in different ways, but they also interact (Annex B2.1, B2.2). Storms, sediment pollution and coral disease reduce coral cover. Much of the space opened up in this way has been taken over by algae. While overall coral cover fell from 40% to 18%, algal cover increased from 42 to 55%. Algal cover rose rapidly in fishing grounds but not in marine reserves between storms in 1994 and 1995 and Hurricane Lenny in 1999. It may be that increases in algal cover in marine reserves were being prevented by higher levels of herbivory from the larger fish stocks in reserves. However, major coral damage by Hurricane Lenny brought levels of algae in marine reserves close to values in fishing grounds.

Tourism has less impact on reefs than storms or sediment pollution. Contacts by divers and snorkellers cause increased rates of coral damage through scrapes and breakage. While these effects may not in themselves cause significant coral mortality, they may increase susceptibility of coral colonies to diseases that can kill them. Since the early 1980s the Caribbean has experienced successive widespread outbreaks of several coral diseases (Harvell et al. 1999). Diseases first wiped out branching corals of the genus *Acropora* in the mid-1980s, and since then there have been outbreaks of several different diseases. The disease outbreak in St. Lucia in 1997 was of a variety called White Plague Type II which affects large reef building corals of the genera *Montastrea* and *Colpophyllia*. The outbreak was centred around Anse Chastanet and Turtle Reefs. Anse Chastanet is the most intensively dived site in St. Lucia. In the Caribbean island of Bonaire, Hawkins et al. (1999) found that corals of these genera were disappearing from dive sites but not from undived control sites, suggesting that diving was increasing mortality rates. Since divers do not break corals, they suggested that tissue lesions from diver contacts had raised vulnerability to lethal diseases.

Sediment pollution causes both direct and indirect problems (Annex B2.1, B2.2). By killing corals, it reduces cover. By stressing corals, it reduces their resilience to other forms of disturbance or stress, such as lesions from diver and snorkeller contacts, or diseases. Effects of sediment on the early life stages of corals are of great concern. Natural disturbances such as storms are recurrent impacts on reefs. Large storms like Hurricane Lenny can cause mass coral mortality. By interfering with recovery, sediment pollution can increase the impacts of storms or coral diseases, and may lead to a ratchet of reef degradation. If each new storm, for example, causes a reduction in coral cover that has not been replaced by the time of the next storm, then the reef will degrade in steps. There is some evidence for this degradation ratchet in data on change in coral cover obtained from monitoring of $1m^2$ quadrats (Annex B2.2, Figure 3).

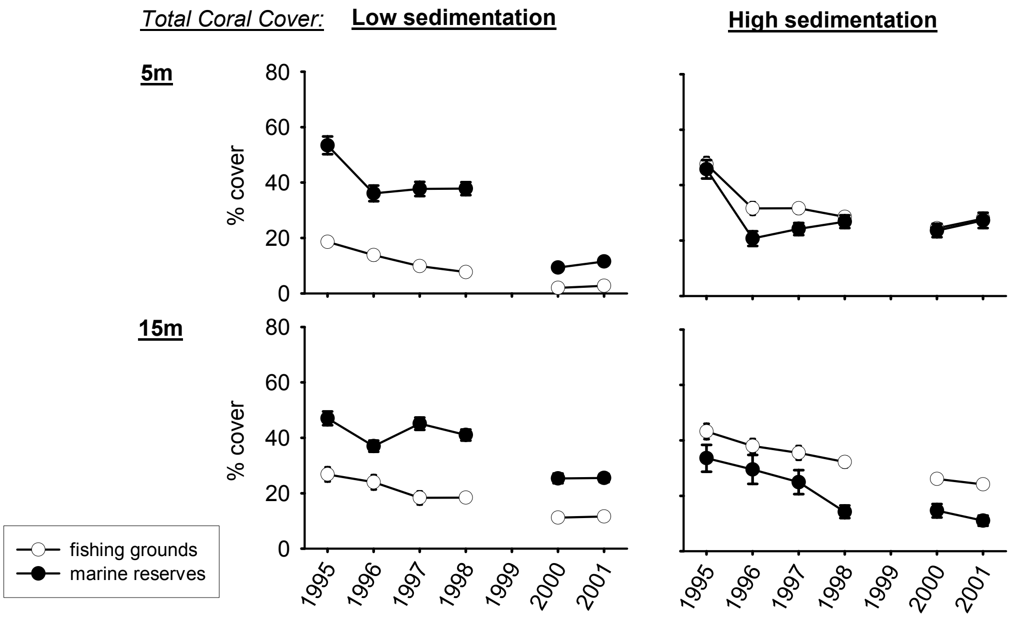

Figure 3: Trajectories of change in coral cover on St. Lucian reefs in relation to sediment pollution inputs and protection from fishing.

In some sites shown in Figure 3, there is an initial abrupt decline in coral cover following storms in 1994 and 1995 that is not replaced before there is a second abrupt decline in cover following Hurricane Lenny in 1999. Breaking this cycle of decline will require more pro-active management to mitigate impacts such as sediment pollution and tourism damage. We discuss options for management of these stresses below.

5. Economic values of St. Lucian coral reefs

5.1 Fisheries

In order to estimate the value of coral reefs for fisheries, it is necessary to calculate the value of landings per unit area of reef, and the costs of fishing (Annex B2.7). We interviewed Soufriere reef fishers in 2000/1 to estimate the value of catches landed and the costs of fishing. Two different estimation methods were used to calculate the value of landings from fishing grounds in the SMMA. To estimate the value of the fishery we derived figures for average catch per trip, number of trips per week and number of fishing weeks per year from fishery surveys. The price of fish per pound was taken as EC$11 for 2000/1, based on interview data.

For our lower bound (low) estimate of total annual value of the reef fishery we used our estimate of number of fishers active per day (derived from daily observations of fishing effort in the SMMA), the estimated average catch per trip in kilograms (derived from catch surveys), the number of days fished per year and the average cost of a kilogram of fish. We calculated this for four main fishing categories: pot fishing with pots left overnight (big pots), pot fishing with pots baited with fish and soaked for around one hour and reset a number of times on each trip (small pots), line fishing from boats and line fishing from the shore.

For our upper bound (high) estimates of the total annual value of the reef fishery, we used the total number of active reef fishers (in full-time fisher units to take account of part time fishers), the average number of trips per week, the average catch per trip, the market price of fish and the number of fishing weeks per year. We did this for the same four fishing method categories.

For 2000/1 estimated catch values lay between EC$233,000 and EC$356,000. These landings were derived from reefs within the SMMA only, 11km of coastline. The costs of fishing include gear, bait, boat fuel, boat maintenance and the capital costs of buying boats and engines. The total estimated cost of the reef fishery was EC$125,000 in 2000/1. The net value of the reef fishery therefore lies between EC$108,000 and EC$231,000.

5.2 Tourism

In order to calculate the revenues generated by reef-associated tourism, we investigated vacation choice and spending patterns of visitors to the Soufriere Marine Management Area (Annex B2.13, B2.14). We interviewed 459 tourists visiting beaches at Anse Chastanet and Jalousie.

On average, each visitor spent 7days on the island and EC$6145 on their trip to St. Lucia. Visitors staying on the island spent more on their trip (median of EC$464 per day) than cruiseship visitors (median of EC$186 per day). Coral reefs are an extremely valuable asset to the St. Lucian economy. Visitors spent EC$19.7 million on diving and snorkeling tours alone, nearly half of which (EC$9.45 million) was attributable to tours taken within the SMMA. We did not calculate the costs of providing scuba diving and snorkeling services, so the profits from reefs in the SMMA will be reduced when these are taken into account.

Visitors not only contribute revenue towards the SMMA in fees, but also benefit businesses. In St. Lucia, most dive and snorkel businesses are St. Lucian owned and collectively employ a workforce of over a hundred people. In addition, the hotel and restaurant industry that caters to visitors employs some 17,400 people, or 11% of the population (St. Lucia Government statistics, 2001). Central government also derives revenues from hotel occupancy (EC$23 million) and travel taxes (EC$2.53 million) as well as reporting an annual visitor expenditure of EC$292 million. The overall economic benefits of coral reef-associated tourism thus reach beyond revenues for the SMMA, and include wider benefits from other services provided for tourists. The extent of these extra revenues can be judged to some extent from overall visitor spending. On average, visitors we interviewed spent EC$6145 on their trip. Visitors coming primarily to scuba dive spent more than those coming for a general holiday or business (median of EC$6826 versus EC$5119 for general holiday and EC$4388 for business) whether they stayed on the island (median trip length of 7 days) or were cruiseship visitors (median trip length of <24hrs).

Not all of the above tourist spending remains on the island. Much of the cost of airfares, for example, is spent abroad. Excluding the cost of airfares, the average spending by stayover visitors was EC$494 per day. More than half of respondents (68%) interviewed bought their holiday as a package. Although the total holiday cost, whether package or not, was similar across respondents, it is likely that non-package holidays resulted in greater financial benefits to the St. Lucian economy. Package holidays are renowned for problems associated with ‘leakage’, i.e. money ‘leaking’ back out of the country. Significant proportions, sometimes up to 80%, of revenue is expatriated due to expenditures on tourism-related imports and services, foreign ownership of businesses, or overseas credit loans. Estimates of the leakage rate in St. Lucia range from 45% in 1978, to 61% for 1986. The increase in cruiseship activity and development of all-inclusive resorts, where all or most guest services are included in one pre-paid holiday package price may aggravate the problem of leakage, both in St. Lucia and the Caribbean in general. In addition, there may be an increase in conflict between visitors and local communities, who often perceive that all-inclusive resorts exclude them from tourism benefits.

To summarise, coral reefs are highly valuable resources to the St. Lucian economy. Fishery revenues from reefs in the SMMA alone amount to hundreds of thousands of EC$ per year, while tourism revenues amount to tens of millions of EC dollars.

6. Tourist experiences and perceptions of coral reefs

Visitors to the SMMA were also asked about their motivations for visiting St. Lucia’s reefs, their perceptions of reef attributes including fish and coral life (Annex B2.13), underwater visibility, garbage and crowding, their best and worst experiences on their reef trip and what would have improved their reef visit. 789 tourists were interviewed using two separate questionnaires over two sample periods (Period 1: December 2000 to March 2001; Period 2:

July to October 2001). 85.0% of visitors rated viewing marine life as their number one motivation for diving or snorkeling in St. Lucia. 88% of divers in Period 1 cited marine life as providing the highlight of their trip and 52.4% of divers and snorkelers interviewed in Period 2 said that marine life had given them the most enjoyment.

The most frequently cited negative experiences in St. Lucia related to equipment problems or personal difficulties (33%). However, quality of the reef and underwater environment was very important. Poor underwater visibility was cited as a disappointment by 14% and seeing damaged coral by another 14%. Remaining factors included poor weather or water conditions and seeing other divers damaging the reef. Similarly negative factors most cited in Period 2 were dead or damaged coral (15.4%), garbage (13.3%), boat traffic noise and pollution (11.2%). Remaining factors, each representing less than 9% of answers, included a lack of fish and diversity of fish, poor underwater visibility and crowding. To improve matters, in general, tourists wanted more information on the marine life of the area (51.9%), better infrastructure (30.4%), better service (15.2%) and removal of garbage (2.5%). Problems of reef degradation might have ranked more highly if tourists had seen the most heavily damaged sites. However, tour operators avoid the worst affected places.

7. Marine protected areas add value to reef resources

7.1 Fishery effects of marine reserves in the SMMA

As this report shows, stocks of fish have made a strong recovery in both marine reserves and fishing grounds as a result of protective management (Annex B2.6, B2.8, B2.9, C1, C2). Therefore we can expect that catches have also changed over time. At the outset of protection, the University of the West Indies made a study of the Soufriere reef fishery. Over a six month period, catches were weighed, and recordings made of what species had been caught using what gear, where the catch had come from and how long it had taken fishers to catch it. After the marine reserves had been protected for 5 years we repeated the study under the present project (Annex C1, C2).

Compliance with reserve protection and enforcement by the SMMA were good. The amount of illegal fishing in marine reserves measured in 2000/1 was five times lower than fishing effort in designated fishing areas. After five years of reserve protection, catches per trap per trip increased by 90% for fishers using small traps and by 46% for those using big traps. As well as improving average weight of catches, good landings became more reliable. Between 1995/6 and 2000/1, the number of people fishing remained virtually unchanged, so overall landings are likely to have increased by similar amounts to the figures above.

Annual monitoring of reef fish catches by St Lucia’s Department of Fisheries shows that the most difficult period for Soufriere’s fishers is now over and that marine reserves will continue to bring benefits (Annex B2.6). Figure 1 shows how catches per trap per trip initially declined in the first two years after reserves were established. This is because it takes time for fish stocks to increase in reserves and then for benefits to spillover into the fishery. However, after 1997, catches rose rapidly to become more than double the size they were in 1995. In response to the initial fall in catches, the St. Lucia Government gave compensation to some of the most badly affected reef fishers. Many of these men had no engines on their boats, and so would have had to row extra distance when they couldn’t fish inside reserves. Such a prospect is very daunting when you are in your 60’s and 70’s, and these people needed financial help until the reserves could bring them benefits. Compensation strengthened fishers’ support for marine reserves at a critical time, and the investment has clearly paid off.

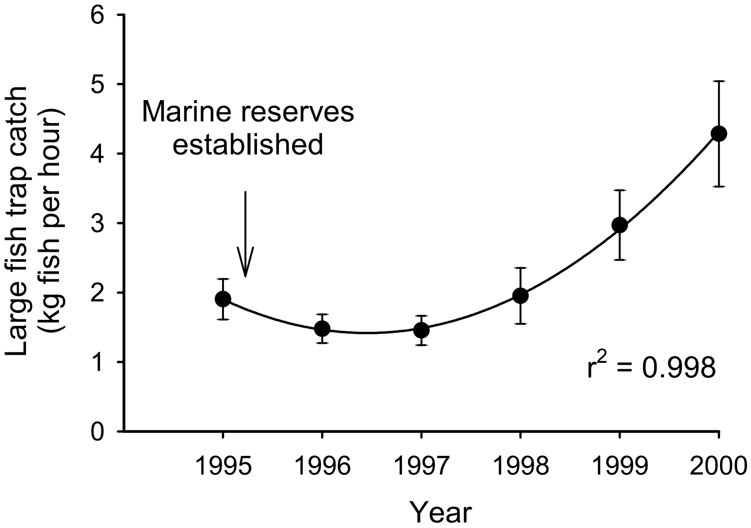

Figure 4: Change in catch-per-unit-effort in the Soufriere reef fishery from 1995 to 2000. Data collected and analysed by the St. Lucia Department of Fisheries.

We estimated the effects of management of the SMMA on fish catches by comparing the revenues generated by fishing between 1995/6 and 2000/1 (Annex B2.7). For 1995/6 estimates for the total value of the SMMA fishery varied from a lower bound estimate of EC$141,000 to an upper bound estimate of EC$270,000. For 2000/1 estimated values lay between EC$233,000 and EC$356,000. If we use the lower bound estimates for both years the value of the fishery has increased by EC$126,000, an increase of 91%. Using the upper bound estimates the value of the fishery has increased by EC$87,000, an increase of 32%. The upper bound estimate is in line with change in catch-per-unit-effort and may be the most reliable figure.

Depending on the method of estimation used, profitability of the fishery (catch value minus costs) increased between 28% and 189% from 1995/6 to 2000/1. Although this is very encouraging news, with annual incomes ranging between EC$3,922 and EC$8,412 in 2000/01, St Lucia's fishers still live well below the island's poverty line. If marine reserve protection continues, catches continue to improve at current rates, and rises in the cost of fishing remain at the current rate of 16% every 5 years, it will take another 15-20 years for the income of a family of four to rise above the poverty line.

In interviews, some fishers expressed the view that tourism was of no benefit to them (Annex B2.10). However, increases in fish catches and fishery profitability have arisen as a direct consequence of the protection of marine reserves in the SMMA. Users fees levied on scuba divers, snorkellers and yachts have paid for that management. Tourism has therefore paid for improvements in the reef fishery.

7.2 Effects of marine reserves on amenity value of reefs

Marine protected areas add value to the island's coral reef assets. Many visitors to St. Lucia that we interviewed were interested in environmental issues, with almost three-quarters surveyed either belonging to an environmental organisation or reading articles on marine life. Most visitors interviewed (86%) knew of the existence of the Soufriere Marine Management Area before their visit. Nearly half of those interviewed (44%) said that the existence of the SMMA had positively influenced their decision to visit St. Lucia (Annex B2.14). This demonstrates the value of marketing protected areas for economic gain.

Apart from the existence value of the SMMA, protection of fish stocks by marine reserves has also increased the amenity value of reefs for tourism. Our interviews revealed the importance of fish and coral life to visitors (Annex B2.13). Our annual fish censuses show that marine reserves have increased the variety, abundance and size of fish stocks. Large fish have also become more common. These effects have improved the attraction of reefs for tourists and so have increased the amenity value of reefs. A study in another part of the Caribbean, the Turks and Caicos Islands, showed that an increase in Nassau grouper abundance and/or mean size would add value to the dive experience because most divers held preferences for viewing more fish and larger fish (Rudd and Tupper 2002) and would be willing to pay more for more exclusive, small group dives when big fish were present. When big fish were not present, they would prefer larger group dives at lower cost.

7.3 Role of marine reserves in mitigating the impacts of disturbance and stress

So far, protection of reefs in marine reserves has mainly benefited the reef fishery. However, another effect of protecting fish stocks may be to increase reef resilience towards other forms of stress and disturbance. When major disturbances like storms hit reefs, they reduce coral cover and open up space for colonization by algae. As previously mentioned, this is what has happened in St. Lucia. The die off of the herbivorous sea urchin *Diadema antillarum* in 1983/4 (Lessios 1988) greatly reduced grazing pressure on Caribbean reefs. Low urchin densities leave reefs at risk of algal overgrowth unless herbivorous fish are sufficiently abundant to keep algae in check. In previous studies of St. Lucian reefs, we found that algae increased mortality and overgrowth of juvenile corals (Nugues 2000). By preventing expansion of algae after storm disturbances, large populations of herbivorous fish in and around marine reserves could facilitate more rapid recovery. We have suggestive evidence for this effect prior to Hurricane Lenny (Annex B2.2), but it is too early to say whether reefs in marine reserves are recovering faster than in fishing grounds following Hurricane Lenny.

8. Towards improved reef management

8.1 Management of fishing

Protection of the network of marine reserve zones within the SMMA has been highly successful in rehabilitating the reef fishery and promoting the development of large populations of fish that are attractive to tourists. Hence, management options suggested here focus on maintaining and improving the effectiveness of this management tool.

Maintain strong protection of marine reserves: To sustain benefits to the reef fishery, it is essential that reserves continue to be protected from fishing over the long-term. Reopening reserves to fishing will lead to a short-lived boom and then to a long-term bust in the fishery.

Maintain the area of marine reserves: At the time of this research, reserve zones protected 35% of reef habitat in the SMMA. Theoretical research indicates that the maximum fishery benefits from reserves will come when between 20 and 40% of fishing grounds are protected in marine reserves, the exact value depending on fishing pressure. A separate study has determined that the optimal area of protection for Soufriere's reef fishery is 36% (Pezzey et al. 2000). Reducing the area under protection can be expected to reduce fishery benefits.

Increase compliance with marine reserves: Although compliance is generally high, poaching remains a persistent problem. The best way to prevent poaching is to make people not want to do it. This can be achieved by educating people about why reserves exist and the benefits that they will bring if everybody in the community refrains from fishing in them. Compliance may increase if rangers inform offenders about the law and provide them with an opportunity to meet with the SMMA manager to learn more about the reserves.

Expand education efforts: Education about marine reserves is so vital it needs to be undertaken at every opportunity. Hiring a full time education and outreach officer would strengthen the success of the SMMA. Efforts to inform people about marine reserves need to be targeted widely. People may travel a long way to fish. In the past, most education effort has focussed on Soufriere. There is a need to expand outreach to other coastal communities and to people who come from inland areas to fish, as well as people from all walks of life and income brackets, since some fish for necessity while others do it for pleasure.

Strengthen enforcement of marine reserves: In addition to education, the threat of punishment is also necessary to stop illegal fishing, and the law must be properly enforced if people are to take it seriously. Enforcement could be improved if SMMA rangers patrol marine reserves at unpredictable times during both day and night, and always challenge illegal fishing. If patrols are predictable, fishers avoid fishing in reserves only when they expect a patrol to pass. Fining or confiscating the gear of repeat offenders, or both, will encourage compliance by others. Not applying these punishments will encourage others to offend. Offenders could also be required to attend a class informing them about the objectives of the SMMA and the importance of marine reserves in achieving this.

Monitor performance of marine resource management and regularly report results to stakeholders: It is very important that fishers and other stakeholders receive regular updates about how well marine reserves are performing. There is a continued need for collection, analysis and reporting of catch statistics by the Department of Fisheries. This is part of the ongoing educational process. While fishers know how good their own catches are, information about the fishery in general helps maintain their interest and commitment to reserves.

Expand SMMA style management to other areas and fishing communities around St. Lucia: Benefits from marine reserves and the zoning scheme of the SMMA are gained most by locals. Fishery benefits are delivered close to reserves, and those directly using the area experience the advantages of zoning to separate competing or conflicting activities. The demonstrated success of the SMMA now warrants expansion of marine reserves and management areas to other parts of St. Lucia so that all coastal communities can benefit.

Consider compensation for inshore fishers in the initial stages of implementation of new management areas: A year after reserves were set up in Soufriere, compensation for loss of fishing grounds was given to Soufriere's oldest fishers and helped them through a difficult period. Compensation was popular, helped gain support for reserves, and was important in reducing levels of poaching. If new reserves are set up elsewhere in St Lucia, paying fishers compensation for a short period of 1-3 years, perhaps with reducing levels over time, is a strategy that will help reserves become effective quickly.

Introduce and enforce a legal minimum mesh size for fish traps, and require escape gaps and biodegradable panels: Fish traps are such unselective gears that they have been completely banned in some countries (e.g. Bermuda). Ongoing research under a separate project in St. Lucia (Hawkins et al. in prep.) shows that fish traps in use capture many immature fish due to their small (2.5-3cm) mesh size. Research in Jamaica has shown that increasing mesh sizes will increase yields in the fishery (Sary et al. 1997). Furthermore, introducing vertical escape gaps will also reduce rates of capture of immature fish, and biodegradable panels will reduce rates of ghost fishing by lost traps. These measures will continue the rehabilitation of the reef fishery that has been initiated by marine reserves in the SMMA.

8.2 Mitigating sediment pollution

Gains in the size and value of fish catches have been made against a background of serious reef degradation in St. Lucia. Half of the coral that was present at the establishment of the SMMA has died. If land-based sources of sediment pollution are not reduced, improvements in fish stocks and fisheries are in jeopardy. Furthermore, sediment directly impacts on the amenity value of reefs for tourism. Divers and snorkellers frequently cited seeing dead corals, and poor underwater visibility as reducing their enjoyment of the reef. Reducing sediment pollution is a high priority if the quality and value of St. Lucia's reef resources are to be maintained and further enhanced. The solutions to sediment pollution are not difficult and will not be particularly expensive or involve great sacrifices. But implementing them will take great commitment. Strategies necessary to tackle sediment pollution include:

1. Increase public awareness of the problem and show ways in which individuals can help reduce soil loss. These include:

Avoid cutting back vegetation to ground level: At present most gardeners, householders and landowners are in the habitat of cutting back vegetation to expose bare soil. Bare soil is eroding soil, whereas vegetation binds the soil and prevents it washing away. A simple change in practice could significantly reduce soil loss.

Ensure access roads are sealed with tarmac, concrete, or rock: Roads represent a major source of sediment pollution. When new developments are undertaken or houses built, access roads are cut and are often left bare. Road cutting greatly increases sediment loss to the sea, even if roads are a long way inland. Sealing roads benefits both home or business owners and coral reefs. Less erosion from roads means a smoother ride, less mud, and secure foundations for construction.

Avoid repeated filling of potholes on unsealed roads with loose soil: Where roads are left unsealed, they quickly develop potholes. Landowners often fill potholes with loose soil or rock, repeating the process at regular intervals as soil washes away. This seriously increases soil loss and downstream sedimentation problems. It is necessary to treat the cause, not the symptoms of erosion. Roads need to be sealed if soil loss is to be controlled.

Minimize areas of bare soil in gardens: Planting gardens to minimize areas of bare soil will reduce erosion.

2. Enact policy changes within agencies and departments. Key actions include:

When clearing road verges, cut vegetation to above ground level rather than exposing soil: At present, road verges around St. Lucia are regularly cut back to soil level by men using cutlasses. This increases soil erosion, undermines road foundations and increases risks of landslides. Vegetation binds the soil and is a valuable asset. Changing policies and practice so that teams cut back to above ground level will leave the root systems intact and will greatly reduce erosion. The use of powered weed whackers facilitates effective cutting to above ground level. Weed whackers are already coming into use on the island and increasing usage to 100% by road teams will help effect a change to more sustainable practices. But training road teams using cutlasses to leave the bases of plants intact will also be important.

Implement vegetated buffer zones around storm drains, ditches: The West coast road project represents an excellent example of best practice to control soil erosion around roads. Vegetated buffer zones have been planted along the road verges to capture soil washed from the road before it enters drains and ditches. The West Coast Road project employed vetiver grass. This species is particularly good at reducing soil erosion and preventing water run-off. Vetiver grass produces long vertical roots that bind soil and stop it washing away, but does not spread and become a weed (OIA 1993). Such buffer zones decrease soil loss, reduce maintenance costs and protect coral reefs. Expanding the approach to other roads in St. Lucia would make a very significant contribution to sediment reduction.

3. Develop new national legislation. Key steps include:

Require environmental impact assessments that explicitly address sediment pollution for all new land-based and coastal developments, land changing activities, coastal protection measures and dredging.

Require sediment control measures to be an integral component of all of the above activities (models of such legislation can be found elsewhere in the Caribbean such as the U.S.Virgin Islands). Simple sediment control measures include setting up fabric fences around areas of soil exposed by development. These trap loose soil on site. Similar fabric curtains of a much larger size are used to screen off areas being dredged in the sea. Other measures include keeping the area of soil exposed to a minimum, sealing roads and planting vegetation on exposed soil at the end of the construction.

Implement vegetated buffer zones around rivers and streams: Much soil erosion occurs from the banks of rivers and streams, especially during storms with high rainfall. Vegetation protects river banks, reduces soil loss and protects productive land. In many countries, vegetated buffer zones are protected by law along the backs of rivers and streams. Adopting this policy in St. Lucia would make a large contribution to reducing sediment pollution levels.

4. Reduce soil loss from farms. Measures could include:

Continue and support development of soil and slope vulnerability maps in St. Lucia to identify places that should not be farmed. At present, many small-scale farms are being established on very steep slopes. Exposing and tilling soil in these areas leads to rapid erosion and a high risk of landslides. Indeed, it is possible to find crops planted on areas of soil exposed by recent landslides in the Soufriere valley. Farming steep slopes greatly increases soil loss to the sea, and exposes farmers and communities to the dangers of landslides. Legislation to prevent farming on unsuitably steep slopes and vulnerable soils is important, but will not work without enforcement.

Develop riverine vegetated buffer zones, including agro-forestry: As noted above, protecting river banks will reduce soil loss and protect productive land. One way to create vegetative buffer zones around rivers is to encourage agro-forestry, planting tree crops along the sides of rivers. Additionally, it is important to keep livestock away from river banks as they significantly increase river bank erosion by trampling soil and grazing.

Work to improve soil conservation measures used on farms and small-holdings. Develop incentives for their use: Soil loss from erosion reduces soil fertility and restricts the area available for cropping. It can increase the need for expensive fertilizers, and fertilizer use can also contribute to reef degradation through nutrient enrichment and algal overgrowth. Protecting soils is of benefit to farmers, to the land and to the reef. There are many improvements which could be made to farming practice that will reduce soil erosion and increase fertility. For example, creating vegetated buffers around plots or fields, mulching of vegetation into soil, and reducing tillage and weeding will all protect soils. When vetiver grass is planted in rows along contours, it converts eroding hill slopes into stable terraces, thus preventing soil loss and promoting greater productivity for agriculture (OIA 1993). The Agricultural Extension Service in St. Lucia has been experimenting with soil conservation practices. They need to be widely adopted to help reduce sediment pollution but this will require active support and resourcing by Government, and the development of incentives to promote uptake by farmers.

5. Continue monitoring rates of sedimentation around coastal areas of St. Lucia. The SMMA are continuing sediment monitoring according to the protocol established in this project. Consideration could be given to expanding the scope of the monitoring to provide important additional information on the sources of sediment. In addition to monitoring present on-reef sedimentation rates, an expanded study could look at sediment composition (terrestrial versus marine origins), organic matter in sediment and levels of suspended particulate matter. Fluorescent tracers could be added to suspected sources of sediment on land to partition sediment loads from particular sources. In addition, studies of hydrology, marine circulation and water movement could link terrestrial sources to site of deposition.

8.3 Management of tourist pressure

Tourist pressure on St. Lucian reefs is on the increase. On the one hand this is good news since more tourists means greater revenue for the island's economy and greater income for management of the SMMA. However, with increased tourism comes a greater level of damage to reef resources and an increased need to manage tourist pressure proactively.

Estimates of sustainable scuba diver carrying capacities for reefs range from 4,000-7,000 dives per dive site per year (Table 1). These estimates are based on the premise that above those intensities of use, reefs would suffer high frequencies of coral colony damage significant loss of coral cover. However, the figures may be conservative as the reefs on which those carrying capacity estimates were based had little or no management of in-water impacts by divers and snorkellers.

TABLE 1: ESTIMATES OF SCUBA DIVER CARRYING CAPACITY FOR CORAL REEFS

No. dives per site per year	**Location where study was carried out**	**Reference**
4000 – 6000	Bonaire, Netherland Antilles	Dixon et al. 1993, 1994
UP TO 5,000	Eastern Australia	Harriott et al. 1997
5000 – 6000	Egypt, Bonaire and Saba	Hawkins & Roberts 1997, Hawkins et al. 1999
5000 – 6000	Eilat, Israel	Zakai & Chadwick-Furman, 2002
maximum of 7000	Sodwana Bay, South Africa	Schleyer & Tomalin, 2000

TABLE 2: DISTRIBUTION OF DIVE SITE USE IN ST. LUCIA (YEAR 2000) AND CORRESPONDING ESTIMATE OF NUMBER OF DIVES DONE AT EACH USING 2001 DATA. SITES IN BOLD ARE THOSE WITHIN THE SOUFRIERE MARINE MANAGEMENT AREA (SMMA)

	Site	**No. dives (to nearest hundred)****	**% dives***		**Site**	**No. dives (to nearest hundred)****	**% dives***
1	**Anse Chastanet**	**28,100**	**20.5**	23	Le Wash	600	0.4
2	Anse Cochon (n)	14,000	10.2	24	The Arch	500	0.4
3	Lesleen M	11,300	8.3	25	Other	500	0.4
4	**Coral Gardens**	**8,300**	**6.1**	26	Oceron Point	500	0.3
5	**Pinnacles**	**7,400**	**5.4**	27	Saline Point	300	0.2
6	**Trou Diable**	**7,100**	**5.2**	28	Petit Trou	200	0.2
7	**Piton Wall**	**6,000**	**4.4**	29	Bourget Rocks	200	0.2
8	**Malgretoute**	**5,900**	**4.3**	30	Rosmund's Trench	200	0.1
9	**Turtle Reef**	**5,600**	**4.1**	31	North Beach	200	0.1
10	Virgin Cove	5,200	3.8	32	Anse Galet	200	0.1
11	**Grand Caille**	**5,100**	**3.7**	33	Cariblue Bay	200	0.1
12	**Fairyland**	**4,500**	**3.3**	34	Secret Garden	100	0.1
13	**Superman's Flight**	**3,700**	**2.7**	35	Smuggler's Cove	100	0.1
14	La Toc beach	3,400	2.5	36	Blue Water	0	0.0
15	Anse la Raye Wall	3,200	2.4	37	Cutty Cove	0	0.0
16	**Jalousie**	**3,100**	**2.2**	38	Jambette Point	0	0.0
17	Virgin Point	3,000	2.2	39	Barrel O' Beef	0	0.0
18	Choc Reef	2,500	1.8	**40**	**Hummingbird Wall**	**0**	**0.0**
19	Pigeon Island	1,800	1.3	**41**	**Blue Hole**	**0**	**0.0**
20	Anse Cochon (south)	1,600	1.2	42	Wauwinet Wreck	0	0.0
21	Rust Cove	1,400	1.0	43	Fish Feeding Point	0	0.0
22	Daini Koyomaru	700	0.5	44	Fond Blanc	0	0.0

*Based on SMMA data (2000). **Estimates based on interview data, calculated by multiplying the average number of divers by the average number of dives done per trip.

Interviews with all existing dive companies in 2001 showed that there is a great disparity in dive site use. Certain sites, particularly those within the SMMA, received many more tourists than others (Table 2). In 2000, six sites supported more than half of all dives (50.3%) and one site in particular, Anse Chastanet, received 20.5%. Using the most recent data obtained from interviews with dive operators (2001), the total number of dives done in St. Lucia was estimated at 137,000 per year. If one assumes that site use followed the same distribution as in 2000 (Table 2), approximately 84,800 dives would have been within the SMMA, with 28,000 dives at Anse Chastanet alone. For the year 2000, the number of dives at most sites were below researchers' estimates of carrying capacity set at between 4,000 to 7000 dives per site per year (Table 1), but some sites greatly exceeded these values. Five sites had above the maximum of 7,000 dives per site per year suggested by Schleyer and Tomalin (2000) and the most popular site, Anse Chastanet, received four times the maximum recommended capacity.

Reducing contact rates of tourists with reefs could increase carrying capacity of reefs for tourism. We explored management options to reduce damage to reefs. Short briefings were given by dive staff prior to the dive explaining the vulnerability of the reef and asking tourists not to touch. We compared contact rates between divers given a briefing and those who were not. Briefings appeared to have no effect on reducing contact rates to the reef by divers. But when briefings were followed up by dive leader intervention underwater when a diver was seen to touch the reef, they reduced rates of contact with the reef from 0.3 to 0.1 contacts per minute.

Giving snorkellers a briefing prior to their swim did not significantly reduce their contact with the reef but wearing a life-vest reduced mean contact rates by 20 times, from

0.06 to 0.003 contacts per minute. Contact rates were similar whether snorkellers were being guided by a staff member of the watersports company or snorkeling on their own.

Based on the above findings, it is clear that management of tourism is necessary in St. Lucia, both above and below water. Options for management include:

Spread scuba diving pressure more equitably among sites: At present there are a sufficient number of sites to support all the divers visiting St. Lucia without exceeding recommended carrying capacity estimates. Redistributing diving pressure will reduce impacts on the most attractive and most heavily used sites around the island. Unless numbers of divers at the most intensively used sites are reduced, they will degrade and the appeal of St. Lucia as a diving destination will decline.

Limit scuba diving intensities to levels below recommended carrying capacities: Keeping numbers of dives per site per year below 7000 will greatly increase the sustainability of diving in St. Lucia and should safeguard reefs from serious damage by tourists. With additional in-water management of diving (see below) site capacities could be increased.

Implement in-water intervention by dive and snorkel leaders: Based on this research, it is clear that damage levels could be significantly reduced if all dive and snorkel businesses provide environmental briefings and in-water intervention by leaders to prevent divers and snorkellers from touching the reef. In water intervention when leaders see guests touching the reef is essential if environmental briefings are to be made effective.

Consider a tradeable permit system to control dive site use: To implement such a scheme, dive carrying capacity for each site must be determined. This could be set at the same figure for all sites, or lower figures could be set for sites considered more vulnerable or in need of restoration. The corresponding number of tradable permits would then be sold to dive operators. In total they would allow no more than the pre-determined dive levels at each site during the specified period for which permits are valid. As permits are in limited supply they obtain a scarcity value and any business can sell their excess permits to another business.

Establish designated snorkelling areas in low risk sites: Setting up snorkelling areas like those at Anse Chastanet and Jalousie could help contain damage by people snorkeling independently. Suitable areas of reef for snorkelling are those where the depth is great enough to be avoided by snorkellers' fins (i.e. 2.5 to 3m minimum). Buoys could be used to mark snorkelling areas. Adding floating platforms could provide a safe entry point and give snorkellers an area to rest instead of standing on the reef.

8.4 Paying for management

The Soufriere Marine Management Area protects and manages reefs in the Soufriere region. Costs of managing the SMMA need to be met, and much comes from tourist user fees levied on scuba divers, snorkellers and yachts. However, only approximately 50% of costs are met from fees paid by divers and snorkellers and income from year to year varies, and can be unpredictable. We examined the options for increasing revenues to the SMMA (Annex B2.14). We surveyed willingness to pay for access to the SMMA for 327 visitors interviewed using a questionnaire between July and October 2001. Interviews were conducted on the beaches at Anse Chastanet and Jalousie. Interviewees were given details on existing and planned programs of the SMMA before being asked what was the maximum amount they would pay for access to marine park sites. They were told that revenues would go to support improved management.

Over 90% of visitors questioned were willing to pay more than the fees at the time of US$12 per diver per year, US$4 per diver per day and US$1 per snorkeller per day. 75% of divers were willing to pay at least US$6 for a daily SMMA fee, and 50% US$7. 75% of divers were willing to pay at least US$20 for an annual SMMA fee, and 50% US$30. Over 90% of snorkellers were willing to pay at least US$2 per day, and 50% US$4. 40.5% of visitors said they would have liked the option of an annual snorkeller fee, and 75% were willing to pay at least US$10 for it, and 50% US$20.

Using the maximum amount that 75% or 50% of visitors were willing to pay would increase annual revenue by 62% or 128%. This would bring park revenues from diving and snorkelling fees to EC$112,200 and EC$157,900 respectively, representing 52% and 73% of the total management budget.

The most expensive fee at present, US$12 per diver per year represents less than 1% of the average cost of a holiday (mean holiday cost was US$2276). If annual diver fees were increased to levels that 50% of divers were willing to pay, i.e. US$30, this would still only represent 1.3% of total holiday costs. Divers' willingness to pay was unaffected by the following factors: their family income, weather, exposure to environmental issues, dive qualification, total dives done in whole dive history, gender, the rating they gave to St. Lucian reefs for the amount of fish present, corals, underwater visibility or overall satisfaction with their dive. With snorkellers however, those with larger incomes were willing to pay higher fees as were those who gave higher scores for fish life, underwater visibility and overall satisfaction with their reef experience.

Yachts are also charged a fee according to their size and length of stay, ranging from US$10 for vessels of 35ft or less for a stay of up to two days, to US$25 for vessels of over 65ft staying for up to seven days. The revenue that yacht mooring fees contribute to total park revenue, including diver fees and donations, fluctuates from year to year. Between 1995 and 2000, yearly revenue from yacht mooring fees represented between 35 and 66% of total revenue, and averaged 52%. Yacht fees in 2001 totalled EC$135,000, representing 62% of all SMMA revenue collected (SMMA data, 2001). Yacht fees in St. Lucia are low compared to the British Virgin Islands (BVI Port Authority, 2003) and Hawaii (Ko Olina Marina, 2003), where for a vessel of 35ft, fees would range from US$61 to 65 per day compared to US$10 in the SMMA.

Options for increasing revenues to the SMMA and associated community include:

Increase daily and annual dive fees: Increasing fees to the levels that 50%, or even the lower values that 75% of divers said they would be willing to pay would considerably enhance the financial viability of the SMMA.

Increase daily snorkel fee and add the option for an annual fee: As for dive fees, snorkel revenues should be increased by raising fees to levels 50% or 75% of snorkellers said they would be willing to pay.

Consider a tiered fee system in which island residents are charged a lower fee than tourists.

Convert 'annual' passes into a 'multiple dive/snorkel pass, valid one year': This would prevent dissatisfaction from visitors who are currently presented with an annual pass which they feel is unreasonable if they are only staying a few weeks and will not be returning within the year.

Explore the possibility of increasing yacht fees to comparable levels charged elsewhere in the Caribbean, taking into account other fees that yachts may already be required to pay to enter St. Lucian waters.

Increases in fees are unlikely to decrease demand as long as visitors can see where the money is being spent. Many asked for more information on the marine life of St. Lucia's reefs and on park programs and projects. Most people say they will pay such fees, and the rest are not likely to be put off given that water-related activities are so important to a St. Lucian vacation and the percentage of their spending that the fee increase represents is so small.

Invest a fraction of the additional revenues generated by increased SMMA user fees to create a management buffer: This would help the SMMA survive periodic downturns in tourist numbers.

Create a community trust fund from a fraction of the revenues generated by increased SMMA user fees: A community trust fund would enable fishers and other community members to more directly benefit from tourism. For example, such a fund might be used to provide and upgrade town facilities, pay for repairs after hurricanes, pay for re-training programs and offer low cost loans to help residents with career development and access to new livelihoods such as in the tourism industry.

9. Two visions for the future of St. Lucia's reef resources

9.1 Business as usual

At present, protected area management in Soufriere is concentrated upon protecting marine reserves and reducing conflicts between fishing and tourism. In those pursuits the SMMA has been a great success. There have been improvements in management of garbage in Soufriere, although some is still washed into the sea with every shower. However, the

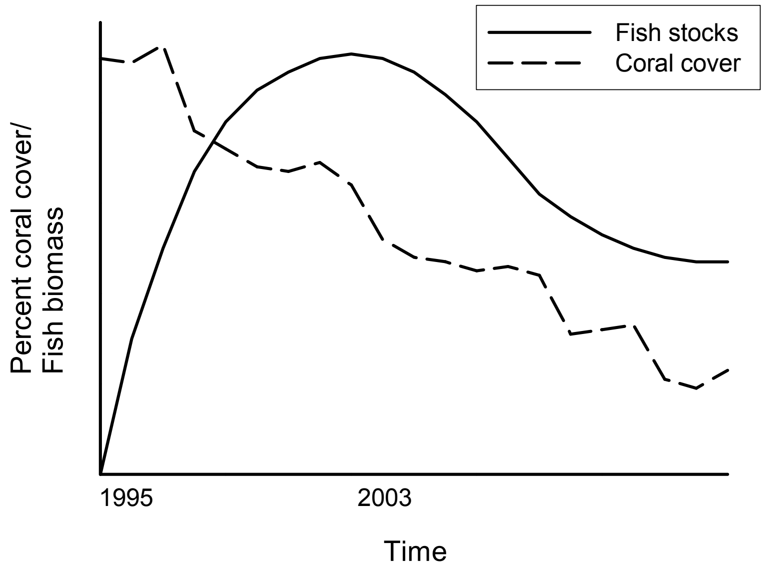

Figure 5: Past and possible future trajectories of change in fish and corals under a business-as-usual scenario of no change in reef management.

introduction of plastic drink bottles has significantly increased plastics pollution to the sea. At present, tourism pressure is not managed, nor are there programmes in place to combat sediment pollution either in Soufriere or nationally. What will be the future for coral reefs and reef-associated business if this level of management continues?

Fish stocks can be expected to continue to increase with maintenance of marine reserve protection, but only for a limited time. If rates of coral loss and reef degradation continue, as they will without action to reduce sediment pollution, then this will soon have a negative impact on fish stocks. Fish need structurally complex habitats to thrive, and reef degradation is reducing the complexity of St. Lucian reefs. Ultimately this will reduce the capacity of reefs to support fish and fish stocks will begin to decline. Figure 5 projects this likely scenario for fish and coral stocks if sediment pollution goes unchecked. The trend towards larger catches will reverse, the numbers of big fish in catches will fall, and the appeal of reefs for tourism would decline.

Without a national action plan to combat soil loss, sediment pollution will continue to grow over time. This will impose a growing cost on the St. Lucian economy. Sediment pollution and garbage problems have already resulted in several dive and snorkel sites within the SMMA being unusable for reef tours. Based on figures for revenues generated by the SMMA divided by the number of diving and snorkelling sites there are, it is possible to estimate the costs of losing sites to pollution or other negative impacts. They lie between EC$432,000 to EC$756,000 per site per year (Annex B2.15). These figures do not account for broader spending by tourists, which means that real losses could be much higher. Those losses will become more significant as tourism expands on the island. They will be further exacerbated if tourism goes downmarket as a result of declining environmental quality and overcrowding of reef sites.

Continuing losses of corals will reduce the appeal of reef for tourists, especially if there is also a downturn in fish stocks. If this occurs, the island would have to cater for greater numbers of lower spending visitors to sustain revenues. This would mean developing cheaper accommodation, and building up more coastal land. There would be a loss of traditional livelihoods like fishing, and there would likely be an increase in social disruption and problems from mass influx of visitors. The quality of life for St. Lucians would decline with the quality of the environment as land gets built up, towns become crowded with tourists, bars and nightclubs, and the sea becomes muddied and barren.

9.2 Management for sustainability

Imagine that, instead of the above scenario, policies were enacted to reduce sediment pollution, to manage and limit tourist pressure both above and below water, and to continue promoting fishery sustainability.

Managing dive sites so use is limited to below carrying capacity levels could bring large economic rewards. It would help maintain reef environmental quality and would increase the ability of reefs to withstand other stresses like storms. Take for example, the effect of one simple change in practice. If dive leaders consistently intervened when they saw their clients touching the reef, they could reduce contact rates significantly and sites within the SMMA may be able to withstand use greater than the maximum carrying capacity estimate of 7000 dives per site per year (Annex B2.15). If dive leader intervention reduces contact rates by a third or a half as our research suggests, carrying capacity could be increased to 9,000 and sites could possibly withstand use of up to 10,000 dives per site per year in well-regulated areas. These estimates do not include impacts to the reefs from other sources, and therefore a precautionary approach would be to use the lower carrying capacity estimate of 9,000 dives per site per year. Such numbers represent revenues of EC$972,000 per site per year in trip fees alone.

Implementing dive leader intervention would be virtually cost free. Yet if introduced it would mean that each site could potentially earn EC$216,000 more per year (Annex B2.15). As tourism on the island increases, more and more sites will reach their carrying capacity. If all sites were used to full capacity, with 44 dive sites this amounts to an extra EC$9.5 million per year in dive trip costs alone. Added to this would be all the additional spending of the additional divers the island could support. Close in-water management of divers could make a substantial contribution to the St. Lucian economy.

Reducing sediment pollution from land-based sources and preventing rubbish from being discharged to sea would promote recovery of places that are no longer used for tourism because they have become too degraded. As tourism expands, these degraded sites will impose a growing cost on the St. Lucian economy. At present day values (EC$108 per dive), and a carrying capacity of 7000 dives per site, the cost is up to EC$756,000 per site per year (again, a conservative estimate because it does not include other foregone income to businesses from providing transport, accommodation, food or other goods and services to visitors staying in St. Lucia). Recovery of sites damaged by sediment and clearing reefs affected by rubbish (and preventing new inputs) would expand the area available for tourism and would reduce pressure on sites being used now.

Table 3 contrasts differences in revenues from dive trip fees between two management regimes. Under Regime 1, only the number of dives made per site is limited to the sustainable capacity of 7000. However, pollution levels continue increasing which reduces sites available from 44 to 30. Furthermore, as sites degrade, dive charges fall from EC$108 per dive to EC$81 per dive due to reducing demand from higher spending tourists. Under Regime 2, pollution levels are reduced increasing the number of sites available from 44 to 50. In water intervention by dive leaders increases diver carrying capacity to 9000 dives per site per year, and high environmental quality attracts higher spending tourists and allows more to be charged per dive. Regime 1 would gross EC$17 million per year compared to Regime 2 which would gross EC48.6 million, nearly three times as much. Again, this does not consider broader spending by tourists.

TABLE 3: CONTRAST BETWEEN SCUBA DIVING TRIP REVENUES FROM TWO MANAGEMENT REGIMES.

Management	**No. of sites available for tourism**	**Dives made per site per year**	**Cost per dive**	**Total direct revenue from dive trips per year**
Regime 1: Site use by divers limited; pollution not controlled; marine reserves maintained.	30	7000	EC$81	EC$17.0 million
Regime 2: Pollution controlled; diving pressure and impacts managed; marine reserves maintained	50	9000	EC$108	EC$48.6 million

Maintaining strong marine reserve protection alongside reduced pollution input could reverse current trends of reef degradation. It would mean the continued expansion of reef fish stocks, and the gradual recovery of populations of large-bodied, high value fish species like groupers and snappers. Such improvements can be expected to continue for two to three decades before benefits peak (Annex C1). Expanding the area managed using marine reserves to other parts of the island will extend these benefits to other communities and will improve food security and income for coastal fishers and their families.

Under close management, St. Lucia's reefs could maintain high-value, low-volume tourism, with tourists paying a premium for diving in well-managed, high environmental quality sites. A study of two Red Sea diving resort areas (Medio 1996) found that regulating access and controlling development reduced damage and maintained quality of coral reefs. One resort allowed unlimited reef use for tourism and fishing as well as unrestricted coastline development, while the other imposed careful controls. Tourist businesses in one resort were able to charge almost double the prices in the other. The Seychelles has adopted the policy of promoting high-value, low-volume tourism. To attract wealthy visitors they have put their efforts into maintaining a high quality environment. Accordingly, they have put half of their land under protection and have closely regulated development on the rest (Gossling et al. 2002). The Maldives specifically target the up-market tourist (Inskeep 1992) and the government encourages resorts to upgrade to attract a higher-spending tourist clientele. The Mauritian government also promotes selective tourism, targeting affluent visitors, and resisting charter flight operations that cater to the masses of lower-spending tourists (Ramsamy 1992). But deliberate policies need to be adopted if St. Lucia is to avoid the slide into environmental degradation and high impact, low value tourism.

10. Conclusions

St. Lucia has made great progress in coral reef management over the last decade. The Soufriere Marine Management Area has been instrumental in turning around the fortunes of the fishery and improving the livelihoods of reef fishers. But gains in fish stocks have come against a background of reef decline. Sediment pollution levels have been rising and tourist pressure increasing. Sediment and tourist use are interacting with other stresses on reefs, including storms and coral diseases to cause long-term decline of reef resources. Reducing sediment pollution inputs island-wide and proactive management of tourist use of reefs are now necessary and urgent in order to maintain and further enhance the value of reef resources.

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12. Reports produced during the project

Annex A2

Annex A2. Roberts, C.M., Barker, N.L.H., Clarke, A.J., Gell, F.R.G., Hawkins, J.P., Nugues, M.M., Schelten, C.K. 2003. Impact and amelioration of sediment pollution on coral reefs of St. Lucia, West Indies. University of York, York.

Appendix A2.1. Policy and management brief 1: Impacts and mitigation of sediment pollution on coral reefs

Appendix A2.2. Policy and management brief 2: Value of the Soufriere reef fishery

Appendix A2.3. Policy and management brief 3: Value of coral reefs for tourism and costs of reef degradation

Appendix A2.4. Policy and management brief 4: Funding coral reef management

Appendix A2.5. Policy and management brief 5: Impacts of tourism on coral reefs and options for management

Annex B2

Report B2.1: Schelten, C.K. and C.M. Roberts. 2002. The effects of human-induced pollution on the replenishment of coral reefs. DFID NRSP Project R7668. University of York, UK.

Report B2.2: Schelten, C.K., Roberts, C.M., Nugues, M.M., Hawkins, J.P. 2002.The interacting effects of sedimentation, fishing and hurricanes on coral reefs: a long-term study in St. Lucia, West Indies. DFID NRSP Project R7668. University of York, UK.

Report B2.3: Schelten, C.K., Roberts, C.M., Wabnitz, C.C.C., Nugues, M.M. and Hawkins, J.P. 2002.The effects of human-induced sedimentation on juvenile coral assemblages. DFID NRSP Project R7668. University of York, UK.

Report B2.4: Schelten, C.K., Roberts, C.M,, Hawkins, J.P., and Nugues, M.M. 2003. The effects of sedimentation on coral larval settlement. DFID NRSP Project R7668. University of York, UK.

Report B2.5: Schelten, C.K., Roberts, C.M,, Hawkins, J.P., and Nugues, M.M. 2003. Impacts of sedimentation on juvenile coral settlement, mortality and growth. DFID NRSP Project R7668. University of York, UK

Report B2.6: P. Hubert. 2001. A study of the Soufriere Fisheries. DFID NRSP Project R7668. University of York, UK.

Report B2.7: Preliminary report on the economic effects of marine reserves on the reef fishery of Soufrière, Saint Lucia, West Indies. DFID NRSP Project R7668. University of York, UK.

Report B2.8: Gell, F.R., C.M. Roberts, P. Hubert, J.P. Hawkins, R. Goodridge, H.A. Oxenford, W. Joseph and S.N. George. 2003. The rate and trajectory of recovery of fisheries adjacent to marine reserves. DFID NRSP Project R7668. University of York, UK.

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Report B2.11: Barker, N.L.H. and C.M. Roberts. 2003. Scuba diver behaviour and the management of diving impacts on coral reefs. DFID NRSP Project R7668. University of York, UK.

Report B2.12: Barker, N.L.H. and C.M. Roberts. 2003. Snorkeler behaviour on coral reefs. DFID NRSP Project R7668. University of York, UK.

Report B2.13: Barker, N.L.H. and C.M. Roberts. 2003. Relationships between tourist perceptions and measured attributes of coral reefs. DFID NRSP Project R7668. University of York, UK.

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Report B2.15: Barker, N.L.H and C.M. Roberts. 2003. Management and development of coral reef tourism in St. Lucia. DFID NRSP Project R7668. University of York, UK.

Annex C

Annex C1.1: Roberts, C.M, J.A. Bohnsack, F.R. Gell, J.P. Hawkins and R. Goodridge. 2001. Effects of marine reserves on adjacent fisheries. Science, 294: 1920-1923.

Annex C1.2: Roberts, C.M, J.A. Bohnsack, F.R. Gell, J.P. Hawkins and R. Goodridge. 2002. Marine reserves and fisheries management. Science 295: 1233-1235.