Bandaramulla Reef of Southern Sri-Lanka: Present Status and Impacts of Coral Mining

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ABSTRACT

Bandaramulla Reef is an isolated reef on the southern coast of Sri Lanka where the activities of tourists, fishermen and coral miners are completely unregulated. As a result, the overall health of the reef is gradually becoming degraded. This paper describes the present status of the reef and highlights the impacts of mining activities. At present, the coral community is dominated by *Pocillopora, Goniopora* and *Podabacia*, which are known to thrive in highly turbid waters, while the reef fish community is comprised primarily of herbivores. Questionnaires and direct interviews determined that 81% of coral miners were between 15 and 25 years old and that each miner earns Rs. 375 per hour. In total, these miners remove approximately 60 tons of coral each month, averaging 50 coral bags per day. In order to find sustainable solutions to the degradation of Bandaramulla Reef, recommendations for awareness programs, alternative livelihood options, alternatives for coral lime production and improvements in law enforcement are proposed.

INTRODUCTION

Sri Lanka is a tropical island situated between 5° 55' and 9° 55' N latitude and 72° 42' and 81° 52' E longitude and south of the Indian sub-continent (figure 1). Sri Lanka

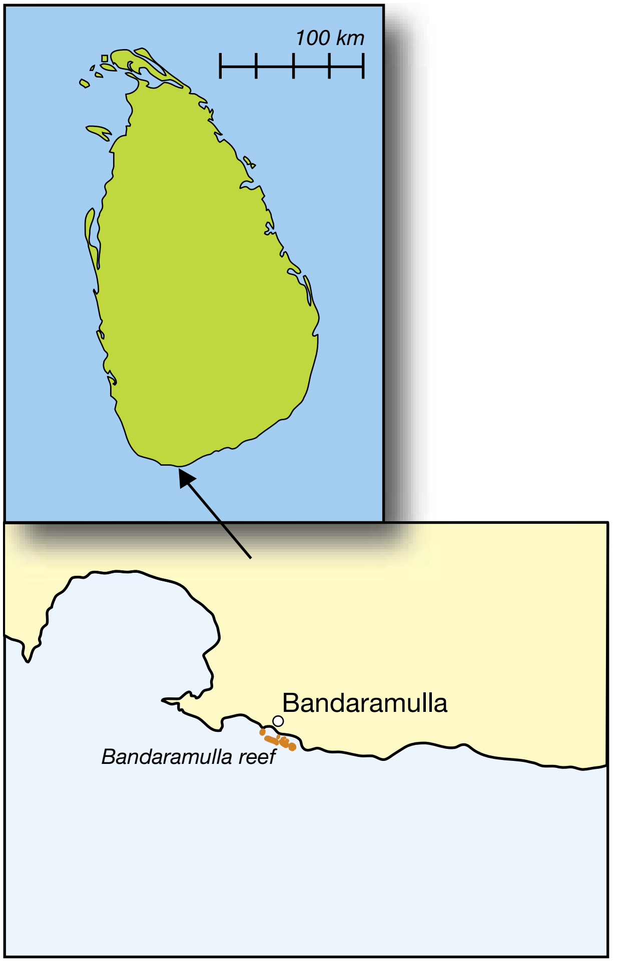

Figure 1. Map of Sri Lanka showing the location of Bandaramulla Reef.

has 1 740 km of coastline and a relatively narrow continental shelf, particularly along the southern coast. Fringing reefs that have formed on rock or limestone substrate abound in the coastal waters off the western, south-western and southern coast of Sri Lanka. In addition, there are a few true coral reefs which tend to be small and isolated fringing reefs (Rajasuriya & De Silva, 1988). During the 1998 El Niño event, corals on about 90% of the reefs in Sri Lanka bleached (Wilkinson *et al.,* 1999) causing considerable mortality. Recovery since the 1998 El Niño has been very slow, moderate or patchy and has been retarded by destructive anthropogenic activities such as dynamite fishing, coral mining, pollution, human settlement, mineral mining, shipping activities and intensive fish collection for the live fish and the aquarium trade. Although coral mining is illegal in Sri Lanka, mining of corals for building materials (Souter & Lindén, 2000) and to produce lime for agriculture and industry still occurs and the resulting degradation of Bandaramulla Reef from intense coral mining is alarming to local fishers.

Coral reefs around the world are incredibly diverse hosting a large proportion of known marine animals and plants. In 1998, it was estimated that the minimum economic value of coral reefs in Sri Lanka was approximately USD 140 000–7 500 000 per km^2 over a 20 year period (Berg *et al.*, 1998). The economic value of coral reefs can be divided into two major components, namely the extractive value and the non-extractive value. The extractive value is derived from the sale of resources harvested from coral reefs such as corals from coral mining, ornamental and food fish and sea cucumbers. Although these extractive activities can cause irreversible damage to coral reefs when conducted in an uncontrolled and unsustainable manner, they provide a short-term profitable source of income for the people involved.The non-extractive value includes the aesthetic qualities of the reef and the white coralline sand beaches that attract thousands of tourists annually and also their essential role in protecting coastlines from erosion by waves (Souter & Lindén, 2000).

Coral mining of living reef is an age-old activity in Sri Lanka, particularly along the southern coast. For centuries, these mined corals have been used for building houses, temples, tombstones and parapet walls to demarcate boundaries. However, these traditional uses have been forgotten and, during the last 20 years, corals have been mined solely for the production of lime for the building and agricultural sectors. In addition to the illegal coral mining conducted on shallow reefs, mining is also carried out on fossil reefs located inland, which supplies most inland areas with lime for building cement. This type of coral mining is legal and is regulated through the issuance of permits.

STUDY SITE

Bandaramulla Reef is located 6 km west of Matara and supports one of the oldest artisanal fishing communities in Sri Lanka. It is a fringing reef which extends for about 500 m across Bandaramulla Bay forming a shallow reef lagoon (figure 2). The depth of the lagoon ranges up to 3 m. The lagoon is occupied mostly by large dead *Millepora* boulders and mounds of *Acropora* rubble. The eastern part of the reef has been completely mined producing considerable quantities of coral rubble and exposing the sand bed during the last four years. Until recently, the central and the western part had not been mined because of the pressure from the fishermen and some of concerned villagers. Unfortunately however, in July 2003, a group of people supported by local gangsters started mining the central part of the reef, especially the reef top (figure 3).

Resources extracted from Bandaramulla Reef lagoon include finfish e.g. jacks (Carangidae), emperors (Lethrinidae), snappers (Lutjanidae), groupers (Serranidae), spiny lobsters (*Panulirus* spp), sea cucumbers (Holothuroidea) and also variety of fish, molluscs, crustaceans for ornamental purposes. Other important fish caught within the lagoon are *Selar crumenophthalmus* (Scads) *Sardinella brachysoma* (Sardinella) and other herring species. In particular, the scad fishery is very important for fishermen as it provides high profits even though fishermen use only traditional fishing gears such as pole and line and hook and line. This fishery is seasonal and exists

Figure 2. Eastern side of the lagoon formed behind Bandaramulla Reef.

Figure 3. Western side of the lagoon formed behind Bandaramulla Reef. Recently mined patches of reef are visible in the foreground as pale areas.

only during particular months of the year. In addition, seaweed culture has been established in the reef lagoon as an experimental trial and is carried out with great enthusiasm by the villagers.

PRESENT THREATS TO THE REEF

Bandaramulla Reef lagoon is an ideal place for traditional fishermen to fish. Unfortunately however, they use large granite boulders to anchor their boats, which crush and destroy everything on the bottom. In addition, the use of gill nets and the trampling corals when casting nets cause severe damage to the reef, especially to delicate corals such as *Montipora* and other newly settled corals. Usage of moxy nets and spear guns, and breakage of corals using crowbars further worsen the situation. Therefore, the low coral cover and diversity in the lagoon is a direct result of such unsustainable destructive fishing practices.

Off site developments cause serious threats to coral reefs because of their sensitivity and the interrelated nature of these ecosystems (Spurgeon, 1992). In addition, the rate of reef recovery from a disturbance will be largely dependent on the anthropogenic impacts and the environmental conditions encountered by newly settled coral recruits. On Bandaramulla Reef, high sediment influx from a nearby part of the shoreline which has been eroded causes severe impacts on coral larval settlement. As a consequence, the recovery rate of is very low while other reefs along the southern coast show promising signs, with large numbers of new coral recruits in many places.

METHODOLOGY

Coral mining activities at Bandaramulla Reef were monitored between July and September 2004. The numbers of bags collected and the number of people involved in mining and transporting mined corals were recorded secretly. In addition, on-site personal interviews were held with coral miners and selected villagers to collect data on the number of trips transported per week, the date of transport, the transportation time, number of bags loaded on the lorry and income levels. On each visit to the reef, the contents of ten randomly selected coral bags were examined. All dead corals within the bags were identified to the highest level possible and the number of live corals in the sample were identified and counted.

The benthic community was recorded using five line intercept transects 20 m in length. Transects were laid parallel to the reef crest and the linear extent of all coral colonies bisected by the line was recorded (English *et al.*, 1994). The cover of each substrate type was calculated as a percentage cover of the total coral cover and then categorized into percent cover classes (see table 2 for details). Fish communities were surveyed along the same 20 m transects. All fish within a 2 m wide band along the transect were counted. Time taken to record each transect was approximately 15 minutes.

RESULTS

Mining Activities

The commencement of mining activities each day varied in order to avoid the attention of police and local villagers and also as a response to tidal variation. Most commonly, mining was conducted very early in the morning around 5 am, and early afternoon around 1 pm or 5 pm. Initially, miners collect robust branching and massive corals from the shallow reef top. Then they break up other larger coral boulders into manageably sized pieces using iron bars. The broken pieces were then placed into polythene bags and lifted onto air filled tyre tubes, which are used to transport the corals ashore. The coral bags are then stored in the shallow water (<1 m) in order to conceal them from villagers and police until they can be loaded for transportation to kilns.

Age Distribution of Coral Miners

Almost all miners are early school leavers within the age group from 15 to 30 years (figure 4). During the non-monsoon season (November to April), they are ornamental fish collectors, hook and line fishermen or are engaged in other shallow water fishing activities. In the Bandaramulla area, some of young fishermen switch to coral mining activities only during the monsoon period (May to October) when the sea is rough and turbid enough to restrict all other fishing activities.

In each ten bag sample examined, dead massive corals predominated, namely *Goniastrea, Porites, Leptoria, Favia, Favites*, *Pavona* and *Platygyra*. The most common live corals found in bags were *Pocillopora, Podabacia, Leptoria, Favia, Favites, Goniopora, Hydnophora, Montipora* and *Galaxea* (table 1). The average number of live colonies in each ten bag sample was 19.44 (±7.29 S.D.). However, these live colonies were relatively small and were usually attached to the large dead boulder corals.

The number of coral bags mined per day is a function of the number of people involved and the time during which mining is permitted by the tidal cycle. The average extraction rate is 55.33 bags per day and the mean weight of each bag is 40.15 kg (±28.55 S.D.) giving an estimated total weight of coral mined within the month surveyed of 66 645 kg. Assuming similar amounts of coral are mined throughout the year, this translates into an estimated annual coral extraction rate of 799 metric tons.

Lorries, trucks and sometimes bicycles are used to transport corals. Loading, unloading and all transportation activities are only done early in the morning be-

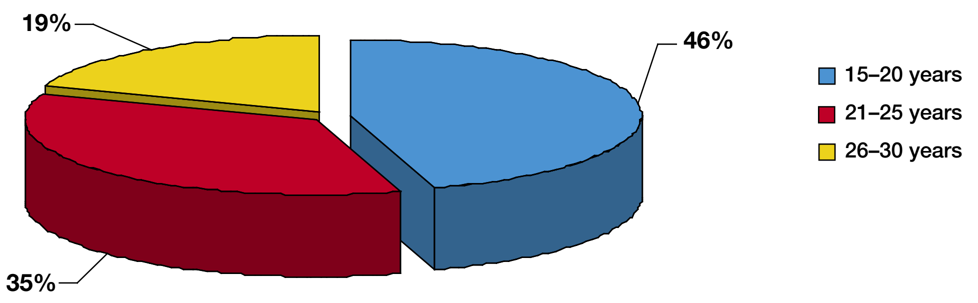

Figure 4. Age distribution of coral miners.

Table 1. Numbers of bags containing live corals transported to lime kilns per month

Date	Number of bags transported	Number of live corals counted in each 10 bag sample	The most common live corals contained in bags of mined coral
03/08/2004	170	24	*Pocillopora, Podabacia, Leptoria*
06/08/2004	155	11	*Pocillopora, Hydnophora*
10/08/2004	180	23	*Podabacia, Porites, Favites, Platygyra*
13/08/2004	140	-	
15/08/2004	140	13	*Galaxea, Montipora*
21/08/2004	190	26	*Pocillopora, Podabacia, Favia, Leptoria*
23/08/2004	160	17	*Pocillopora, Podabacia, Porites*
27/08/2004	175	8	*Goniopora, Podabacia*
01/09/2004	185	26	*Pocillopora, Pavona, Leptoria*
03/09/2004	165	27	*Leptoria, Favia*

tween 0300 and 0530. The middlemen engaged in transportation buy mined coral at the mining site for Rs. 45 per bag and then sell it to the lime kiln for Rs. 75 per bag, thus earning Rs. 30 per bag. The average number of coral bags transported per trip is 166 (±17.44 S.D.) with a value of about Rs. 12 450. The truck owner earns 40% of the total value and the remainder is shared between the miners and those involved in transportation. One single miner earns approximately Rs. 750 per day, which is only about two hours work.

The most abundant live coral species are *Pocillopora damicornis, Podabacia crustacia* and *Goniopora* spp. (table 2). Live coral abundance and cover is extremely low on Bandaramulla Reef primarily because the reef was severely affected during 1998 El Niño event and the recovery since has been very low. Large colonies of *Acropora formosa, A. hyacinthus* and *Millepora* sp. were completely bleached and died. Most remaining corals are less than 15 cm in diameter except colonies of *Goniopora, Porites, Platygyra* and *Leptoria.* Even though baseline data describing the pre-bleaching coral diversity are not available, it is clearly evident that there is a shift in the coral community composition when the existing community is compared with the composition of remaining dead coral colonies. The time needed for the 'original' species composition to be reestablished is extremely unpredictable and will depend

Table 2. Categorised percent live cover of each coral species recorded during surveys of Bandaramulla Reef

Family	Species	Percent cover
Pocilloporidae	*Pocillopora damicornis*	***
	Pocillopora verrucosa	*
Fungiidae	*Podabacia crustacia*	***
	Podabacia spp.	*
Agariciidae	*Pavona* spp.	*
Merulinidae	*Hydnophora minuta*	*
Acroporidae	Acropora hyacinthus	*
	Montipora aequituberculosa	*
	Montipora spp.	*
Poritidae	*Porites* spp.	**
	Goniopora spp.	***
	Alveopora spp.	*
Faviidae	*Favites pentagona*	*
	Favites spp.	**
	Goniastrea spp.	*
	Favia spp.	*
	Platygyra spp.	*
	Leptoria phrygia	**
Oculinidae	*Galaxea fascicularis*	**

* 1– 5%
** 5–10%
***10–15%

Figure 5. Barren substrate caused by mining activities.

on the extent of the damage and the capacity of surviving species to recover (Tamelander, 2002). In addition, unsustainable and destructive fishing practices used in the lagoon, such as moxy nets, spear fishing, and most importantly coral mining have also reduced the coral cover and diversity in the lagoon (figure 5).

The relationship between reef fish diversity and habitat is likely to be a complex phenomenon. The total number and diversity of reef fish were relatively low in shallow waters when compared with the deeper sites of the reef (table 3). The diversity of fish is relatively high along the reef slopes of mined areas compared with the reef top and bottom substrate. It is well known that there is a positive correlation between reef fish communities and live coral cover (Bell & Galzin, 1984). Reductions in coral cover on Bandaramulla Reef caused mainly by mining activities and destructive fishing methods has also caused concomitant declines in the reef's fish diversity. The absence of butterfly fish (Chaetodontidae) during surveys suggests that these fishes could be used as sensitive indicators of the health of coral reefs (Reese, 1981). Detritivorous and carnivorous fish diversity and abundance were greater at the newly mined sites whereas herbivore diversity was the highest at sites that had been subjected to intense mining activities some time ago. Herbivorous pomacentrids and acanthurids dominate the counts.

Table 3. Abundance of each fish species recorded during surveys of Bandaramulla Reef

Family	Species	Abundance
Muraenidae	*Gymnothorax javanicus*	*
	G. undulatus	*
	Echidna nebulosa	*
Serranidae	*Cephalopholus argus*	*
	Epinephelus merra	**
Scorpaenidae	*Pterois volitans*	*
Syngnathiformes	*Fistularia commersonii*	**
Balistidae	*Rhinecanthus* sp.	*
Pomacanthidae	*Pomacanthus annularis*	*
Diodontidae	*Diodon hystrix*	*
Ostraciidae	*Arothron meleagris*	**
Tetraodontidae	*Canthigaster solandri*	*
Pomacentridae	*Stegastes fasciolatus*	***
	Plectroglyphidodon dickii	***
	Plectroglyphidodon lacrymatus	****
	Abudefduf sexfasciatus	**
Pempheridae	*Pempheris* sp.	*****
Acanthuridae	*Zanclus cornutus*	*
	Acanthurus striatus	***
	Acanthurus triostegus	*
	Acanthurus lineatus	**

Number of fish:
* 1– 5
** 6–10
*** 11–15
**** 16–20
***** >20

CONSEQUENCES

While the Bandaramulla area is blessed with the rapid increase of coastal tourism in the southern region, coral mining and other destructive fishing activities hinder this development. Net economic losses in potential tourism and the coastal erosion caused by coral mining, has been extremely high over the past few years. Both ornamental fish collection and the reef food fish industry are in danger of imminent collapse. As a result, tourist visits would gradually decrease due to the reduced aesthetic value of

Figure 6. Small coral fragments resulting from mining activities and the disintegration of coral skeletons after bleaching are highly mobile and have a high potential to abrade and damage almost all bottom dwelling organisms.

the reef caused by coral destruction and ornamental fish removal. In addition, loss of coral reefs in the southern parts of Sri Lanka would drastically affect the people who directly depend on the coral reefs for their income.

Sedimentation, increased beach erosion and pollution caused by mining activities along the coast might result in an array of environmental problems. For example, coral mining has increased beach erosion along the west coast, south of Colombo and along the south coast of Sri Lanka (Wilhelmsson, 2002). The dead coral branches and rubble produced by coral mining are very mobile and their movements cause severe damage to sessile organisms such as sponges, octocorals, anemones, hard corals and all other soft bodied organisms dwelling on the bottom (figure 6).

More than 42% of the bottom surface of the lagoon was covered with sand and silt. There is a large probability that the increased mining activities will expand this sand and silt area. As a result, newly settled corals and other remaining live coral colonies may be subjected to mechanical abrasion and even smothering due to high suspended particle content and vigorous water movement across the damaged reef.

Permanent damage to the reef, the low availability of larval influx, the effect of environmental conditions such as increased current velocity, sediment level and competition with fast growing algae, caused as a result of mining activities would further impede the recovery rate of the reef. In addition, sedimentation and high water currents in the lagoon reduce the abundance of appropriate habitats for targeted fish species restricting artisanal fishing activities which have been practiced for centuries. The abundance of reef fish and all other reef dwelling organisms is dwindling threatening the livelihood of ornamental fish, lobster and sea cucumber collectors.

SOLUTIONS

There is an awareness of the extensive damage caused to the coral reefs from coral mining and other destructive activities. However, miners are poor and not in a position to stop their activities unless there is an acceptable alternative source of income. Therefore, it is a prime target of the government to provide suitable and satisfactory income sources to coral miners. Expansion of present seaweed culture, provision of alternative livelihood options in various sections of the growing tourist industry would be well-accepted solutions.

It is recommended that enforcement of the existing ban on coral mining be improved with better capacity and tools. Corrupt enforcement officers, including police, lack of arrests, delays in bringing cases to court and lack of or improper sentencing are major problems in controlling coral mining. The establishment of a task force with full potential and power to monitor and control all coastal destructive activities around the island, including coral mining, would help in controlling the situation. In addition, finding alternatives for coral lime through surveys for inland lime deposits is needed. Although inland mining activities are practiced, there are number of problems associated with it, such as the pale colour of the lime extracted, the inadequate quantities in the deposits to make the industry economically feasible and low demand. Research for finding new formulations

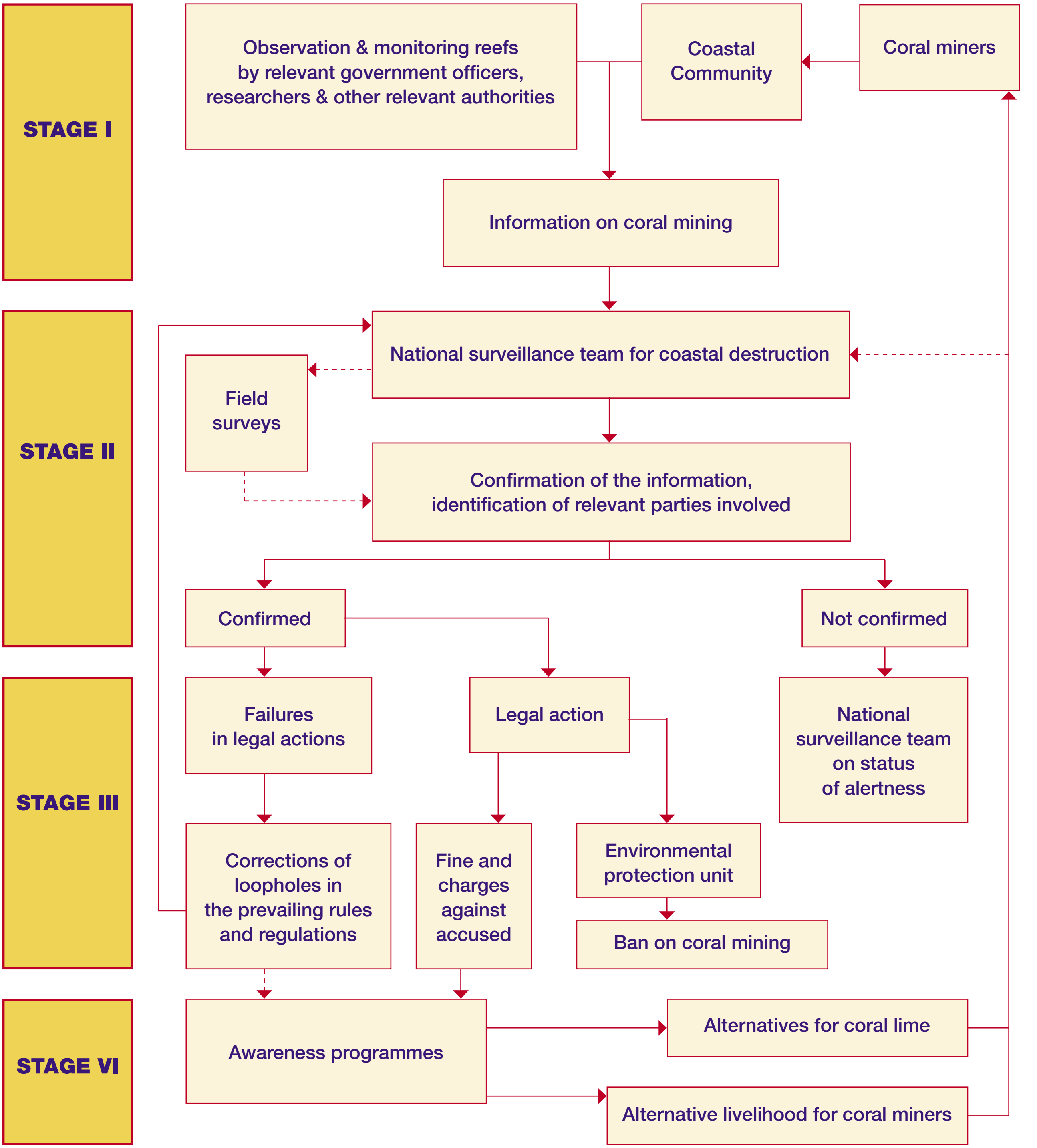

Figure 7. Action plan in the case of coral mining (Adapted from De Silva, 1998).

as a substitute for coral lime provides reasonable solutions to the problem (figure 7).

Mining activities have decreased in some places due to the increased law enforcement efforts and the vigilance of some stakeholders. However, the fines for such destructive activities are relatively low when compared to their income. On the other hand, there are a number of loopholes in existing regulations which make it difficult for law enforcing authorities to bring the accused to the court. Whatever the situation, the government is responsible for strengthening the existing legislations with higher fines, formulating sound regulations and improving enforcement. Various institutes, such as universities, governmental departments, and non-governmental organizations, coral miners, lime kiln owners, inland coral miners and community representatives, should be encouraged to participate in a multi-disciplinary, multi-stakeholder process to formulate a well constructed national policy to solve the coral mining problem.

Finally, there are a number of isolated reefs located around the country that have escaped the attention of scientists, the government, universities, non-governmental organizations or other relevant parties. The biodiversity of those reefs is very high and provide an excellent calm lagoon environment both for animals to live and human to conduct various activities. There should be a programme to identify these places of importance and manage them by legally gazetting them as a natural reserves or marine parks. Bandaramulla Reef is such an unidentified reef but it has been exposed to various threats over the last centuries.

CONCLUSION

Bandaramulla Reef supports a considerable number of fishermen and, during the last two years, has seen an expansion in the tourism industry. However, the reef itself is in great danger due to the low recovery rate after the degradation resulting from elevated sea temperatures caused by the 1998 El Niño event and anthropogenic activities, particularly vigorous coral mining activities that have started during the last couple of months. In order to control the situation, an awareness raising programme organized for the coastal communities on the importance of corals and the implications resulting from their destruction would be beneficial. In addition, alternative livelihoods such as seaweed culture; career opportunities in the tourist industry for coral miners and alternatives for coral lime are some of the possible solutions to the current situation. Strengthening and enforcing existing legislations assuring proper implementation, Sound and strict rules and regulations with high fines for all persons engaged in mining activities and other coastal destructive activities are also necessary. In order to implement the law, necessary facilities, power and acceptable wages for all coastal governing and enforcement officers are essential. Finally, formulation of a permanent national policy to terminate all destructive coastal practices is the final goal for a sustainable usage of non-recoverable natural resources including those extracted from coral reefs.

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