Rapid Marine Ecological Baseline Assessment of Islands of Baa Atoll

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Executive Summary

1. Baa Atoll consists of three distinct atolls located in the western chain of atolls in the central part of the Maldives, just north of the Kaashidhoo Kandu. It receives swell from the southeast and the west, which break on the atoll rim.
2. The Atoll contains 53 islands which cover a total land area of only 5.5 km^2 (Naseer & Hatcher 2004). Of these, thirteen are inhabited by locals, six are operating resort islands, two were attributed for aquaculture and agriculture purposes and four are planned resorts or under construction.
3. The Government of Maldives is undertaking the "Atoll Ecosystem Conservation" project in the atoll co-financed by the Global Environment Facility (GEF) and implemented through UNDP.
4. The natural endowment that is essential to maintaining the structure and function of atoll ecosystems, the viability of globally significant biological diversity, and the livelihoods and environmental security of the people is threatened by the overall economic development.
5. In Maldives social and economic change is altering consumptive behaviour and livelihood strategies, outpacing institutional capacity and sectoral programs to adequately manage it.
6. The effective management of Baa Atoll's marine ecosystems and biodiversity requires a good baseline understanding of the biodiversity that is present. This report provides the findings of the Rapid Assessment survey that was carried out in June 2008.
7. Twenty-six biological indicators included either in the IUCN Red list or in the protected marine species list of Maldives were selected, as well as other indicators of reef health.
8. The 100 reef systems of the atolls were surveyed using manta tows and photo transects.
9. The manta tow technique, where a snorkeler is towed behind a boat, was used to assess the abundance of the proposed biological indicators underwater, get a visual assessment of the various types of habitats and substrate cover, as well as larger benthic organisms over large areas. Photo transects were used to obtain quantitative substrate cover data at a given point. Boat observations were also carried out to record any marine mammals, seabirds or other large individuals observed.

10. These methods gives a good idea to compare the different reefs and get atoll scale patterns.
11. The data was treated to provide linear frequencies of sightings and the data mapped with MapInfo.
12. First, the distribution maps of the different indicators are shown along with a short description for the 17 indicators encountered during the survey. Substrate categories are then presented showing the subcategories proposed.
13. Very common biological indicators, which exhibited high mean densities throughout Baa Atoll, were peacock and vermillion groupers, lunar-tailed grouper, 'other' groupers, clams, sea cucumbers and sea stars. Regularly encountered species or group of species were hawksbill turtles and big groupers, while lobsters, black coral and napoleon wrasse were found locally abundant but not frequent.
14. Overall four species were never observed during this survey, these are the white tip shark, the humphead parrotfish, the triton shell and the whale shark. Other shark species, the green turtle and the winged pearl oyster were rarely encountered.
15. The hawksbill turtles occurred throughout the entire Atoll. This species was mostly found in the reefs located inside the Atoll or in the inner side of the reefs, particularly where the substrate is heavily colonized by zoanthids. Green turtles had a very limited distribution area, restricted to the south and the centre of the main Atoll.
16. Napoleon fish were only observed in the outer slopes of the reefs forming the border of the Baa Atoll with the open sea.
17. Very few sharks have been seen during the survey.
18. Among groupers, peacock groupers were the most abundant throughout the entire Baa Atoll, with lower densities in the reefs inside the main Atoll. The big groupers observed, were mainly composed of *Plectropomus* spp. (212 individuals) and *Epinephelus* spp. (28 individuals). Their distribution follows more or less a north-south decreasing gradient, with the exception of particular places in the centre, which exhibit very high densities. Other groupers observed were mainly composed of small *Epinephelus* spp. and *Cephalopholis* spp., with densities much higher in the north than in the south part of the Atoll.
19. Bait fish exhibited a clear pattern with schools found majorly in the north-eastern part of Baa Atoll with some exception for some reefs located inside the main Atoll.

20. Black corals and lobsters were locally abundant species (but not frequent). Highest densities of black coral were recorded near Reethi Beach, whereas medium to high densities were encountered in the northern Atoll and around the reef south of Fares. Lobster distribution was patchy. They were found predominantly in the reefs inside the west of the main Atoll and near Reethi Beach with overall low densities. Winged pearl oysters (*Pteria penguin*), usually associated with black corals were rarely seen during this survey.
21. Clams, sea cucumbers and sea stars were widely distributed throughout the Atoll. Clams yielded the highest densities of all indicator groups and were heterogeneously distributed, with in particular very few on the western side. Recorded sea stars were all cushion star (*Culcita schmedeliana*) except seven individuals of crown of thorns starfish (*Acanthaster planci*). Similarly, a vast majority of the sea cucumbers observed were of the species *Pearsonothuria graeffei*, followed in numbers by *Stichopus chloronotus*.
22. The benthic substrate was characterised by high percentage cover of abiotic substrate (pavement, rubble, sand and silt) followed by hard live corals, algae and other living organisms (sponges, ascidians, zoanthids and soft corals). Recently dead corals contribution to the total percentage cover was very limited. Important live coral cover was found in the reefs located in the centre of the main Atoll. Algae proportions were generally low but widespread in the main and northern Atolls.
23. The more widespread coral lifeforms were represented by massive (*Porites, Favia, Favites*) and encrusting corals (*Pavona, Goniastrea*) followed by submassive (*Pocillopora*, *P. rus*), tabulate (*A. clathrata, A. hyacinthus*), digitate (*A. digitifera, A. samoensis*) and branching (*A. microphtalma, A. aspera*) corals. Mushroom corals and even more foliose corals were scarce as compared to other coral forms. Massive and encrusting coral forms were widely distributed throughout the Atolls. Tabulate and submassive corals were mainly observed in the reefs inside the main Atoll and in Goidhoo Atoll. Important branching coral cover was always restricted to the lee side of the reefs and limited to a number of specific places. Few mushroom corals were detected in the central reefs inside the main Atoll.
24. Algae were mainly represented by coralline algae, such as *Mesophyllum* or *Sporolython,* which contributed significantly to the overall cover. Turf algae, such as *Microcoleus* or *Enteromorpha,* were fairly widespread. Macroalgae, such as *Halimeda*,

Padina, *Turbinaria* or *Tydemania*, were more scarce and with a limited cover and distribution.

25. The ‘other living organisms’ category was dominated by moderately widespread sponges. The sponge *Terpios* sp. is an invasive species that covered both biotic and abiotic substrates. This species was recorded in high proportions in the central inside reefs of the main Atoll, around Vakkaru and near Muthaafushi, but is a potential threat to the reef. Low presence levels were found for soft corals (*Sarcophyton, Lemnalia* or *Sinularia* or *Lobophyton*), and ascidians. Zoanthids distribution was really patchy and high abundances were restricted to a few places. However their contribution to the overall cover was not negligible. Very high proportion of the invasive corallimorphs (Discosoma) was recorded in four areas: Kudarikilu, Kendhoo and Funadhoo, Dhonfanu and Muthaafushi.
26. Globally, dead corals with algae and old dead corals yielded a low contribution to the overall cover. Very few recently dead corals were recorded during the survey, indicating an absence of rampant coral mortality.
27. Abiotic substrate composed most of the habitats surveyed. Pavement and rubble were recorded in a vast majority of the samples, yielding the highest cover percentages. Pavement forms the basis of Baa Atolls and is present almost everywhere. Rubble was also present in most of the Atoll, becoming the main substrate component in many places. This could be linked to a poor recover of the branching forms since the 1998 mass bleaching event. Sand and silt were less predominant component of the abiotic substrate in Baa Atoll.
28. Manta rays (*Manta birostris* and *Mobula mobular*) were observed on seven occasions, and each time a single individual was seen. Most manta ray sightings occurred in the north-eastern region, near the atoll rim.
29. Spinner dolphins (*Stenella longirostris*) were seen all around the main Atoll and in Goidhoo Atoll. Group size was typically around 20 individuals, but ranged from two individuals to 40 – 50 animals. Bottlenose dolphins (*Tursiops truncatus*) were mainly encountered in the east of the main Atoll, along with one sighting in Goidhoo Atoll. Group sizes ranged from a single individual to 15 animals. A total of six individuals of the genus *Stenella*, four in Goidhoo Atoll and two in the south of the main Atoll, were observed.

30. Seven species of nesting seabirds were observed, *Phaethon lepturus,* dhandifulhu dhooni , *Sterna sumatrana,* kirudhooni, *Anous tenuirostri,* kurangi *Sterna hirundo,* valhlha, *Sterna bengalensis,* ainmathee gaadhooni, *Anous stolidus,* maaranga, and *Puffinus lheminieri,* Dhivehi hoagula*.* They were generally encountered in isolated sand banks and islands, but some were also seen in inhabited islands. Development of islands seems to reduce the area of their available natural habitat, which needs protection.
31. Even though several flaws are highlighted with the methods used, they provide a good general view of the biodiversity of the atoll, especially for the substrate cover. For the more mobile species, they can provide a good site comparison criterion, but cannot be used for absolute stock assessment.
32. It appears that the recovery from the 1998 bleaching event, which is still the main event explaining low coral cover in this atoll, is not homogeneous. Different species other than corals, which seem to show expansionist evolutions, such as sponges, zoanthids and corallimorphs may be a threat. The sponge *Terpios*, which is largely present on the healthier reefs seem of particular importance, as it does cover and smother live corals.
33. From the study it would seem that some species such as clams, smaller groupers, napoleons and hawksbill turtles are exhibiting healthy stocks while others, usually targeted by fisheries and poaching, such as sharks, larger groupers, lobsters or green turtles show disturbingly low levels. Sea cucumbers show a severe imbalance, with one single species almost omnipresent.
34. Seagrasses habitat was surveyed around three uninhabited islands, Goidhoo, Thulhaadhoo and Hithaadhoo. The survey consisted of a visual assessment of the area, with some photographs of the most important features taken for the records. The sea grass beds around the islands appeared relatively recent and very healthy.
35. Four mangroves areas were surveyed in Baa Atoll. These mangroves were located in Goidhoo, in Maamaduvari, in Olhugiri, and in Keyodhoo. Due to the scattering distribution of mangroves in Maldives, this habitat needs protection to preserve the overall biodiversity of the Maldivian ecosystem.
36. To determine the areas of biological significance, the hotspots or spots of highest densities are given for each indicator. Four different indices are then calculated to

aggregate different indicators of importance for the tourism industry, fisheries and the biodiversity, based on IUCN endangered species and total diversity.

37. The activities around the Atoll are also mapped to provide a background of the anthropogenic pressure which is likely to be met as well as the opportunities offered for reef management.
38. A set of areas are then proposed for protection based on the pattern of the highest frequency indices present. The most interesting areas are located in mostly three areas, Goidhoo Atoll, the western central part of the main atoll, and the very north of the northern atoll.

1 Introduction

1.1. General Description

The Republic of Maldives lies in the Indian Ocean from 7°06’N to 0°42’S. There are approximately 1200 islands, about 200 of which are inhabited by the local people. The islands are geographically grouped into ring-shaped reefs called atolls. The islands are divided into 26 geographic atolls but only 19 administrative groups. The atolls vary in size and in the number of islands they contain.

Baa Atoll, also called South Maalhosmadulu Atoll is located in the west of the central part of the Maldives, just north of the Kashidhoo Kandhoo, the largest channel divinding the northern chain of atolls. It stretches 63,5 km from 5°22’N to 4°48’S and from 72°48’E to 73°11’E from east to west. The capital island of this atoll is Eydafushi. Goidhoo Atoll lies 12 km south of Baa Atoll but is under the same administrative area. The northern part of the atoll is also an atoll in its own right being separated by much deeper channels from the main atoll of Baa to the south and Raa atoll in the north.

The atoll receives the swell through the Kaashidhoo Kandu from the south east, but also from the west, especially during the southwest monsoon. These break on the outer rim of the atolls, which consists in a series of narrow islands on the eastern part of the atoll and a few large ones on the western side. The rim of the atoll is largely open with numerous passes. The atoll of Goidhoo, on the other hand is closed with a single natural pass, the Dhooru Kandu at the very south of Baa. The atoll has a number of patch reefs, thilas and giris in its central part, but these are rather in the central and southern part of the main atoll.

There are 53 islands on top of the reef flats, submitted to a usual monsoonal sediment transport pattern. The total land area is only 5.5 km^2 (Naseer & Hatcher 2004). Of these, thirteen are inhabited by locals and six are operating resort islands (Coco Palm Dhunikolhu, Soneva Fushi Resort & Spa, Royal Island, Valtur Kihaad, Reethi Beach Resort and Four Seasons Resort Maldives at Landaa Giraavaru), while four others are planned or under construction. They are mainly located in the north-east part of the atoll. The island of Maamaduvari is being rented for agriculture purposes and the island of Dhakandhoo with the large reef of Maafaru has been attributed for aquaculture purposes.

There is one existing marine reserve, Dhigali Haa, created in 1995 and located 5°08'N 73°02'E, where fishing and anchoring is not allowed. The island of Olhugiri is also a protected area, encompassing an island, which is a known nesting ground for frigate birds.

1.2 Baa AEC project

1.2.1 Overall aims of the project

The Government of the Maldives is undertaking a project on the conservation and sustainable use of globally significant biological diversity in the Maldives' Baa Atoll. The "Atoll Ecosystem Conservation" (AEC) project is co-financed by the Global Environment Facility (GEF) and implemented through UNDP. In the Maldives, atoll ecosystems literally provide the basis for the country's existence as well as life-supporting services such as shoreline protection and goods upon which the economy entirely depends such as fish and tourism. However, social and economic change is altering consumptive behavior and livelihood strategies, outpacing institutional capacity and sectoral programs to adequately manage it. This in turn is threatening the natural endowment that is essential to maintaining the structure and function of atoll ecosystems, the viability of globally significant biological diversity, and the livelihoods and environmental security of the people. Most important policy decisions affecting biodiversity are taken at the level of individual sectors, such as infrastructure, fisheries, and tourism. Government initiatives to manage change and mitigate the impacts caused by it are rooted in sector-by-sector approaches, resulting in narrow, sectoral institutions, policies, and interventions.

Recognising these challenges, the Government of Maldives established the AEC project with the purpose of establishing an effective management system for atoll ecosystem conservation and sustainable development on Baa Atoll, which could then be replicated throughout Maldives. The project's implementation strategy involves three strands: a) introducing the ecosystem conservation approach to policies and plans, both nationally and on Baa Atoll; b) designing and piloting a model system for ecosystem conservation on Baa Atoll; c) supporting sustainable livelihoods development on Baa Atoll.

1.2.2 Purpose of the present study

The effective management of Baa Atoll's marine ecosystems and biodiversity requires a good baseline understanding of the biodiversity that is present, current resource stock populations of a number of key indicator species and the identification of the most important marine biological features of the atoll. This information will then form an integral development component of the long term management of Baa Atolls marine ecosystems. Current information pertaining to the marine ecosystems of Baa Atoll is sparse and is a major constraint to effective conservation and management programmes. The purpose of this survey is to provide the AEC with a baseline marine ecological study and report to allow the successful management of the Baa Atolls marine biodiversity.

1.2.3 Objectives and terms of reference

The objective of the survey therefore is to undertake a rapid marine ecological assessment of Baa Atoll using international best practices and methodologies to provide an assessment and site specific locations of current resource stocks and biological habitats of key indicator species that demonstrate the status of globally significant biological diversity in Baa Atoll (and the Maldives) and to recommend priority biological sites for marine management. It is expected that the consultant will assess the majority of reefs associated with Baa atoll, including the reefs associated with Dhighaliha protected area, reef surrounding the island of Olhugiri and Goidhoo Atoll.

1.2.3.1 Indicator Species

The biological assessment should include all IUCN Red list marine species and all Maldivian marine protected marine life including but not limited to the following indicator species and biological parameters. Included; sea grasses, turtles, nesting sites for sea birds and turtles, sea cucumbers (species level), giant clams (species level), Triton shells, Black coral, crown of thorns starfish, crayfish (species level), dominant finfish groups [e.g. grouper species (Epinephelus sp), coral trout's (Plectropomus sp.), Napoleon wrasse (Cheilinus undulatus), Bumphead Parrot fish (Bolbometopon muricatum)], manta rays, sharks, whale sharks, cetaceans (Dolphins and whales), winged pearl oyster (Pteria penguin) percent live coral cover, reef conditions (arbitrary ranking), substrate, dominant benthic forms, dominant corals morphological forms (at least genus level), turf algae/macro algae.

1.2.3.2 Ecological Habitats

The rapid assessment should identify, map and document all marine biological habitats associated with the atoll (including mangroves), site specific habitats (e.g. sand beaches) associated with bird nesting and roosting including a physical description of each assessment site and provide provisions in the database to allow this information to be compatible with GIS programmes.

1.2.3.3 Methodologies

Internationally accepted coral reef assessment methodologies are to be employed to collect the information for the assessment.

1.2.3.4 Data Collection and Data Bases

Field data collection and data storage (raw and analyzed) will need to be compatible and directly convertible with GIS systems. The consultant will need to provide a GIS map that details all sites assessed and incorporates the recommended priority marine biological areas. The development of all other GIS layers and subsequent maps are not the responsibility of the consultant but the provision of the data in the GIS format.

1.2.3.5 Training of Government Staff

The consultant will need to include in its planning the requirement that one staff per week from one of the government line ministries (MEEW, ERC, MoFAMR and MRC) will be participating in the field assessments. It is expected that the consultant will integrate the staff member in all aspects of the field programmes to further develop their field skills. Specific training in assessment skills may be required and it is expected that this will be undertaken by the consultant team whilst undertaking the assessment. The cost associated with these staff will not be the responsibility of the consultant and will rest with the respective government agencies and the AEC project.

1.2.3.6 Identify Priority Biological Sites for Marine Biodiversity Management

The consultant will recommend a list of priority marine areas for consideration for biodiversity management and detail justification for these decisions. The priority areas should include recommended size including buffer zones. These sites should be identified on an atoll wide GIS generated map and provide specific GPS coordinates for each recommended site.

2 Coral reef survey

2.1 Methods

The rapid assessment survey presented here was conducted from June 9th until July 2nd 2008. Most of the peripheries of the Baa Atoll reefs were surveyed. In total 100 reef systems (islands house reefs, faroes, outer reefs and thilas) have been listed and surveyed (fig II.1).

Two methods, namely manta tows and photo transects, were used in order to assess the abundance of the provided biological indicators underwater. Opportunistic observations from the boat were also conducted to record surface sightings of cetaceans and nesting birds.

2.1.1 Indicator species

A list of key indicator species was provided to the consultant. Key indicator species have been chosen according either to their protection or their emblematic status, their fishing interest or their threat potential to the reefs, such as the crown-of-thorns starfish. All IUCN Red list and all Maldivian marine protected life were included. In total 26 species or group of species were chosen as key indicator species for this assessment (Table 2.1). In parallel, areas with high abundance of bait fish were recorded.

Table 2.1. List of the indicator species selected

Group	Genus / Species	Common name
Turtles	*Chelonia mydas*	Green turtle
	Eretmochelys imbricata	Hawksbill turtle
Sharks	*Carcharhinus melanopterus*	Black tip reef shark
	Triaenodon obesus	White tip reef shark
	Carcharhinus amblyrhynchos	Grey reef shark
		Other shark
Fish	*Plectropomus*	Coral grouper
	Cephalopholis(argus,	Rock Cod

	miniata)	
	Variola	Lunar-tailed grouper
	Epinephelus fuscoguttatus	Flower grouper
	Epinephelus sp., Other	Other groupers
	Cephalopholis sp., other genus	
	Bolbometopon muricatum	Humphead parrotfish
	Cheilinus undulatus	Napoleon fish
	Bait fish	Presence / Absence
Sea cucumber		All sea cucumbers observed
Clams	*Tridacna sp*	Clams
Sea star	*Acanthaster planci*	Crown-of-thorn sea star
	Culcita schmedeliana	Pin-cushion sea star
Other benthic organisms	*Panulirus versicolor*	Painted rock lobster
	Antipathes sp	Black coral
	Pteria penguin	Winged pearl oyster
	Charonia tritonis	Triton shell
Marine mammals	*Tursiops truncatus*	Bottlenose dolphin
	Stenella longirostris	Spinner dolphin
		Other marine mammals
Other emblematic species	*Manta birostris*	Manta rays
	Rhincodon typus	Whale shark

The list of indicators above is slightly different than the ones listed in the TOR. The groupers in particular were divided in function of the type of the fishery, fresh chilled or live. Due to practical constraints, and feasibility in the field, the clams were not discriminated at species level, nor were the sea cucumbers. A posteriori, this does not pose so much of a problem for this rapid assessment especially for the clams. For the sea cucumbers, one single species (not targeted by the poachers) was overwhelmingly present.

2.1.2 Sampling protocol

A dhoani and a Boston Wailer operated simultaneously around the different reefs of Baa atoll (Fig. 2.1). On each boat one person (the boat observer) was responsible to record

GPS coordinates, to direct the boat so as to be in the right place on the reef, to enter data on the monitoring sheet and to carry out and note down sea surface observations (Fig 2.3). The other person (the snorkeler) was towed behind the boat to count key indicator species and to conduct photo transect between each manta tows (Fig 2.2).

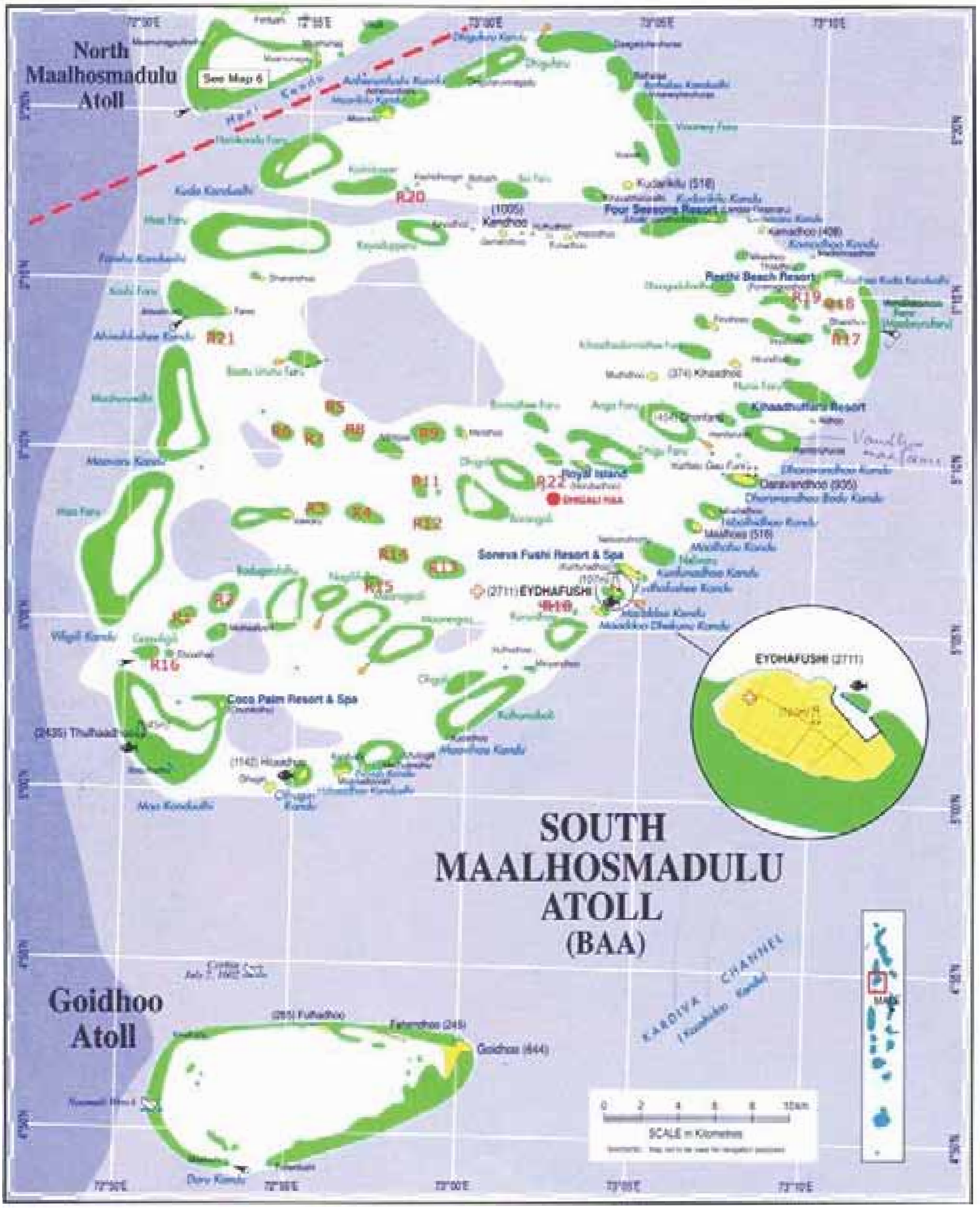

Figure 2.1. Reefs of Baa Atoll

2.1.2.1 Manta tows

The manta tow technique is widely used to get a visual assessment of the various types of habitats and substrate cover, as well as large obvious organisms present in an area (Uychiacco 2001). It is an appropriate method to cover large-scale areas within a short time and to detect either interesting high-biodiversity sites or large-scale disturbance such as outbreaks of crown-of-thorns starfish.

The manta board was attached at the back of the boat with an 18 m rope and the snorkeler was pulled behind. The boat followed the reef edge at a constant speed. Each manta tow lasted for 15 minutes and the process was repeated until the totality of the reef edge of the area was covered. During each tow, the snorkeler counted the number of key indicator species observed. After 15 minutes, the boat observer stopped the boat and some time was devoted to note down what have been observed by the snorkeler during the last tow.

At the beginning and at the end of each tow, GPS coordinates of the site, tow number and time were recorded.

Figure 2.2. Picture of the snorkeler with the manta board at the surface and underwater

2.1.2.2 Photo-transects

At each site (meaning at the beginning and at the end of each tow), a photo transect was conducted by the snorkeler in order to obtain data about coral cover and substrate habitats. A series of 5 pictures was taken at each point, perpendicularly to the substrate. While doing transect, the snorkeler followed the current to avoid overlap in the photos. At most sites, photos were also taken to illustrate the overall site landscape.

2.1.2.3 Boat observations

The boat observer was also responsible to record any marine mammals, seabirds or other large individuals that he could observe from the boat. Species name, the number of individuals (when possible) was recorded and the estimation of the position was recorded on the map.

Figure 2.3. Observer on board recording data from the snorkeler, GPS coordinates and boat observations

Concerning cetaceans and birds, their presence only will be presented in this report because systematic reliable estimates of abundance would have required specifically trained observers. However, group size was estimated when possible.

2.1.3 Data analysis

2.1.3.1 Species densities

In total, 480 manta tows covered all the reefs of Baa atoll, even though some sections of two reefs were not towed when conditions were too drastic. Data from the manta tow were transformed into densities to obtain a number of individuals per km for each of the key indicator species. To do so, observed counts of individuals were divided by the length of the manta tow (computed with the GIS, see below).

Some of the species have been grouped together in order to facilitate the lecture of the map: the ‘big groupers’ group combines *Plectropomus sp.* and the large *Epinephelus* species; the “little groupers” mainly comprise the *Cephalopholis argus* and *C. miniata*, and *Variola louti*. the ‘other groupers’ group gathers all other species of *Epinephelus* observed, the smaller *Cephalopholis* as well as other genus, such as *Aethaloperca*, *Anyperodon* and *Gracila*; sea stars combine the crown-of-thorn and the pin-cushion sea stars; finally, both the clam and the sea cucumber groups contains all the individuals, irrespective of species observed within the class or sub-class. One species of sea cucumber was very predominant, *Pearsonothuria graeffei*, while *Stichopus chloronotus* was the second most abundant. Anecdotic sightings of *Bohadschia marmorata, Actinopyga miliaris, A. mauritania, Holothuria nobilis, Thelenota anax* and *T. ananas* also occurred.

2.1.3.2 Substrate cover

In total 606 photo-transects were conducted. Each transect contains 5 pictures, except 11 transects which contain only 4 pictures and 14 transects which contain 6 pictures. Therefore, the substrate cover assessment is based on 3033 geo-referenced pictures.

Pictures from the photo-transect survey were then analysed with Coral Point Count with Excel extension (CPCe), a software developped by the National Coral Reef Institute (Kohler & Gill 2006). Photo transects analysed with CPCe are a reliable and efficient sampling method to obtain quantitative percent cover data and information about spatial pattern. Even if it might be difficult to standardise some of the lifeform categories, it can be practised by person with limited identification experience and still gives some useful information about coral reef benthic communities (English *et al*. 1997). Repeated over time, at the same sites, this method can provide information about temporal changes.

For this study, the CPCe software highlighted 25 random points on each picture that the observer had to identify according to different substrate classes. 6 classes were defined with different sub-categories within each of them (Table 2.2). The different lifeforms and classes were taken from the Survey Manual for Tropical Marine Resouces guide (English et al. 1997). This classification is useful to provide a morphological description of the reef community. The predominant genera were *Acropora*, *Porites*, *Pocillopora*, *Montipora*, *Pavona*, *Favia*, *Favites* and *Echinopora*.

Table 2.2. Classes and sub-categories of substrate

Class	Sub-Category	Abbreviation
Live coral	Coral foliose	CF
	Coral mushroom	CMR
	Coral encrusting	CE
	Coral branching	CB
	Coral digitate	CD
	Coral submassive	CS
	Coral massive	CM
	Coral tabular	CT
Dead coral	Recently dead coral	RDC
	Dead coral with algae	DCA
	Old dead coral	ODC
Others organisms	Soft coral	SC
	Sponge	S
	Zoanthid	ZO
	Ascidians	ASC
	Others	U
Algae	Coralline algae	CA
	Macroalgae	MA
	Turf algae	TA
Abiotic	Pavement	PV
	Rubble	RB
	Sand	SA

	Silt	SL
Unknown	Shadow	SHAD

Thus, 125 points (5 pictures x 25 points) were analysed for each site. The data were then integrated into an Excel statistical analysis to obtain a mean percentage cover of each class and each sub-category.

2.1.3.3 GIS mapping

Reef structure data for Baa Atoll was kindly provided by the Ministry of Environment, Energy and Water. By means of GPS coordinates, both photo-transect and manta tow data were mapped with the GIS MapInfo 9.0 (MapInfo Corporation©).

To obtain manta tow lengths, the distance was computed by following the outer slope line between the starting and ending points of each manta tow. The average manta tow length (± SD) was 1.25 km (± 0.37 km), with a minimum of 0.22 km and a maximum of 2.23 km.

2.2 Results

2.2.1 Distributions of indicator species

2.2.1.1 Overview

Table 2.3 gives the basic statistics associated with indicator species densities collected by manta tows over the whole Baa Atoll.

Table 2.3. Statistics associated with indicator species densities

Species	Presence (nb samples)	Presence (% samples)	Mean	Standard Deviation	1st quartile	Median	3rd quartile
Humphead parrotfish	0	0	0	0	0	0	0
Triton shell	0	0	0	0	0	0	0
White tip shark	0	0	0	0	0	0	0

Whale shark	0	0	0	0	0	0	0
Black tip shark	3	0.6	0.006	0.078	0	0	0
Grey reef shark	1	0.2	0.002	0.034	0	0	0
Other sharks	8	1.7	0.017	0.142	0	0	0
Winged pearl oyster	9	1.9	0.046	0.492	0	0	0
Green turtle	22	4.6	0.054	0.283	0	0	0
Black coral	38	7.9	0.407	2.793	0	0	0
Lobsters	47	9.8	0.17	0.785	0	0	0
Napoleon fish	51	10.6	0.17	0.669	0	0	0
Bait fish	49	10.2	x	x	x	x	x
Big groupers	141	29.4	0.429	0.928	0	0	0.69
Hawksbill turtle	179	37.3	0.571	1.125	0	0	0.77
Other groupers	294	61.3	1.938	2.515	0	1.1	2.69
Lunar-tailed grouper	327	68.1	2.203	2.95	0	1.31	3.08
Sea cucumbers	372	77.5	5.913	8.152	0.72	3.56	8.04
Sea stars	373	77.7	6.138	8.978	0.72	3.25	7.95
Clams	403	84	14.239	19.08	2.13	7.68	18.92
Peacok grouper	439	91.5	6.887	6.462	1.89	5.15	9.76

Four species, white tip shark, humphead parrotfish, triton shell and whale shark were never observed during this survey.

Some other six species were rarely encountered. These are all the sharks species observed at least once, the green turtle and the winged pearl oyster. since they were recorded in less than 5% of the samples (48 manta tows out of 480) and displayed very low densities (mean < 0.1 individual / km, or one individual every 10 km). This is the case

Three species can be classified as locally abundant, but not frequent: the lobsters, the black coral and the napoleon fish. They rarely occurred, ranging 7.9 – 10.6 % of the samples, but showed medium densities (1 individual / km > mean > 0.1 individual / km). This is typical of species having a distribution area restricted to specific areas, and though being quite numerous there, these conditions are not met everywhere (e.g: the napoleon fish are never found on the inner reefs). This is also applies to the bait fish.

Two species or groups of species were regularly encountered, appearing in 30-40 % of the samples and exhibiting medium densities (around 0.5 individual / km): the hawksbill turtle and the big groupers.

Finally, the remaining six species or groups of species were very common: the peacock and vermillion grouper, the lunar-tailed grouper, the other groupers, the clams, the sea cucumbers and the sea stars. They were present in more than 60 % of the samples, reaching up to 91.5 % of the samples for the peacock grouper. Mean densities were typically high (mean > 1 individual / km), and spanned from 1.9 to 14.2 individual / km.

2.2.1.2 Turtle distributions

Figure 2.4 illustrates the distributions of Green turtle in green and Hawksbill turtles in orange. Hawksbill turtles are much more numerous than Green turtle, and occur throughout the entire Atoll. They are mostly found in the reefs located inside the Atoll (around Nibiligaa) or in the inner side of the reefs (near Bathalaa). However, the high densities of Hawksbill turtles found in the outer slope of the eastern Goidhoo Atoll constitute a noticeable exception to this trend. Green turtles have a very limited distribution area, restricted to the south (Thulaadhoo and Hithaadhoo) and the centre (from Vakkaru to Dhonfanu) of the main Atoll. Even though the data is not conclusive, it would appear that hawksbill turtles are abundant where the substrate is heavily colonized by zoanthids, whereas green turtle seem to be attracted to sea grass beds. This would need to be further substantiated.

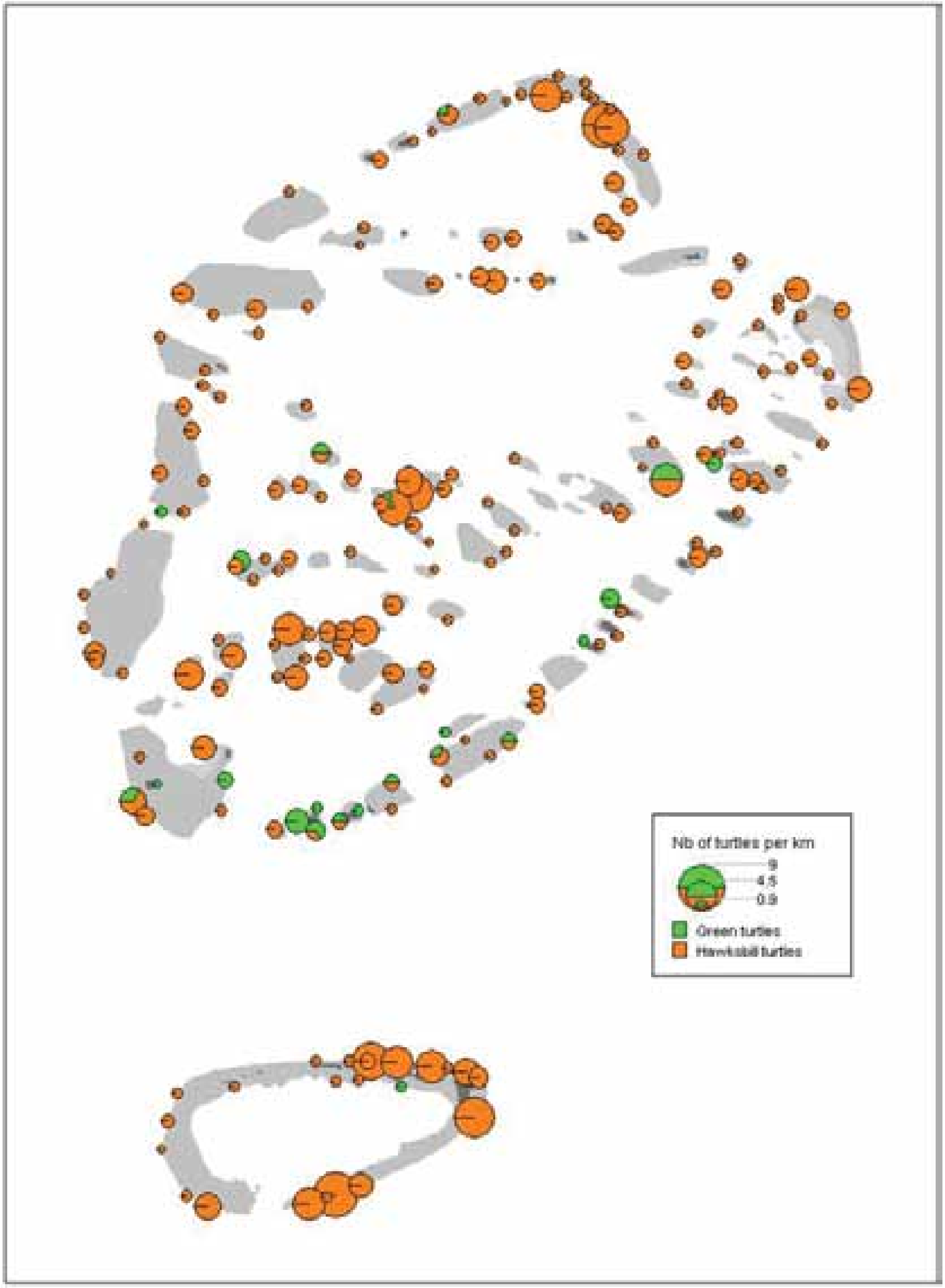

Figure 2.4. Turtle distributions in Baa Atoll. Circles are square rooted to densities for easier reading.

2.2.1.3 Shark and Napoleon fish distributions

Figure 2.5 illustrates the distributions of Napoleon fish (in orange), Black tip shark (in green), Grey reef shark (in red) and other sharks, mainly Nurse shark *Ginglymostoma cirratum* (in yellow).

Napoleon fish distribution exhibits a very clear trend: these fishes are only observed in the outer slopes of the reefs forming the boarder of the Baa Atoll with the open sea. Moreover, they are mainly present in the western side of the Atoll, with the exception of Reethi Beach where quite high densities have been recorded.

Very few sharks have been seen during this survey. Of these 14 individuals, only one Grey reef shark was observed near Hanikandu Faru. Four Black tip sharks were seen in the reefs inside of the Atoll, mainly near Vakkaru. Half of the Other sharks were recorded in the same place as well, while the second half of the Other sharks were sighted in the north-eastern part of Baa Atoll.

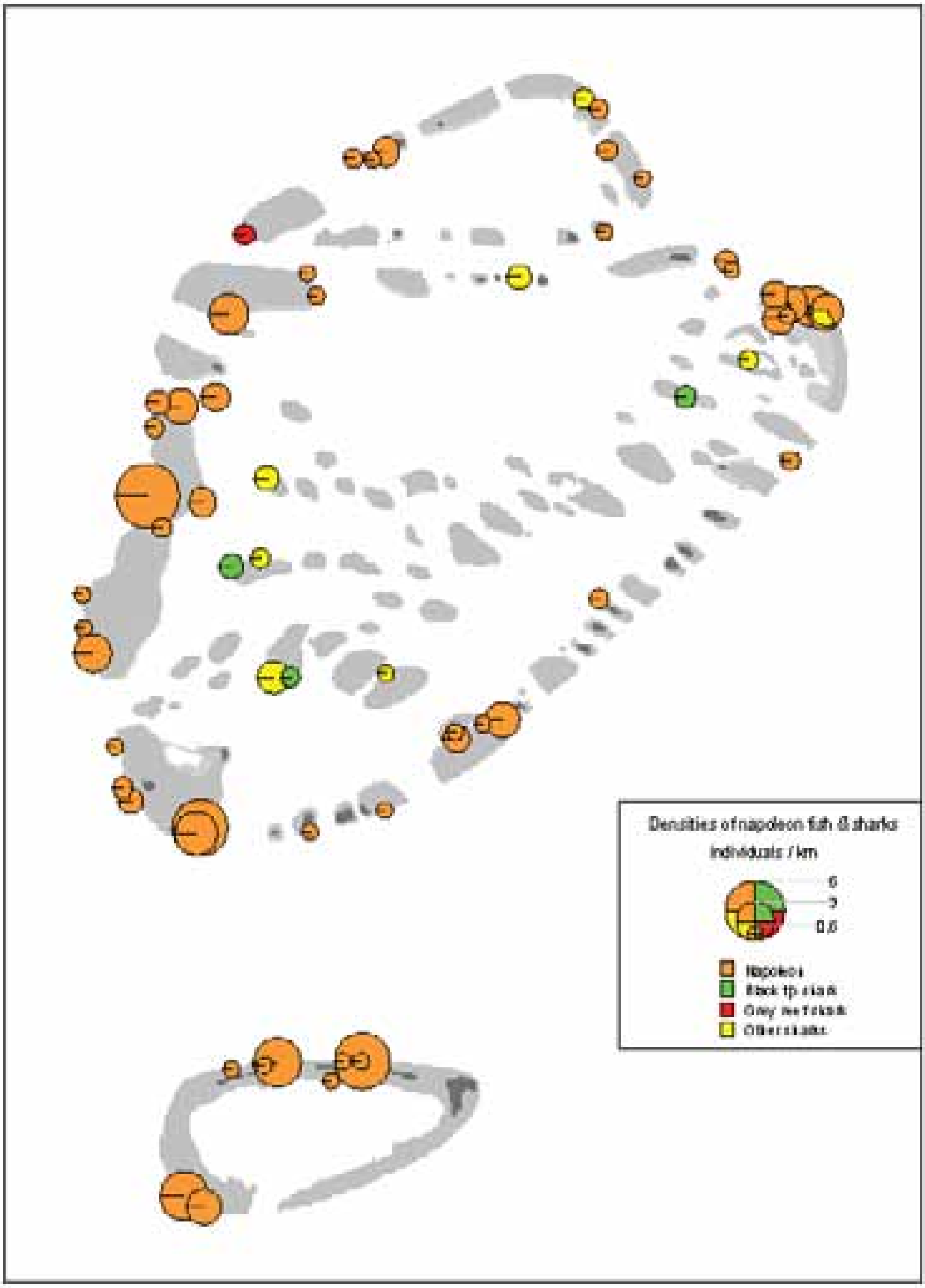

Figure 2.5. Napoleon fish and shark distributions in Baa Atoll. Circles are log-proportional to densities for easier reading.

2.2.1.4 Grouper distributions

The distribution of *C. argus*, *C. miniata* is shown in figure 2.6, *V. louti* distribution in figure 2.7, big grouper distribution in figure 2.8 and other grouper distribution in figure 2.9. The Peacock grouper is by far the most abundant of all the groupers we have recorded. Actually, *Cephalopholis miniata* have been also included in this category, but the number of individuals of this species that have been recorded is very low compared to *Cephalopholis argus*. Their mean density is three times that of Lunar-tailed groupers and that of other groupers, and twelve times that of big groupers. They were found throughout the entire Baa Atoll, though in very low densities in its south-western part, near South Maafaru, Thulaadhoo and in the west of Goidhoo. Peacock grouper densities are also lower in the reefs inside the main Atoll, although to a lesser extent.

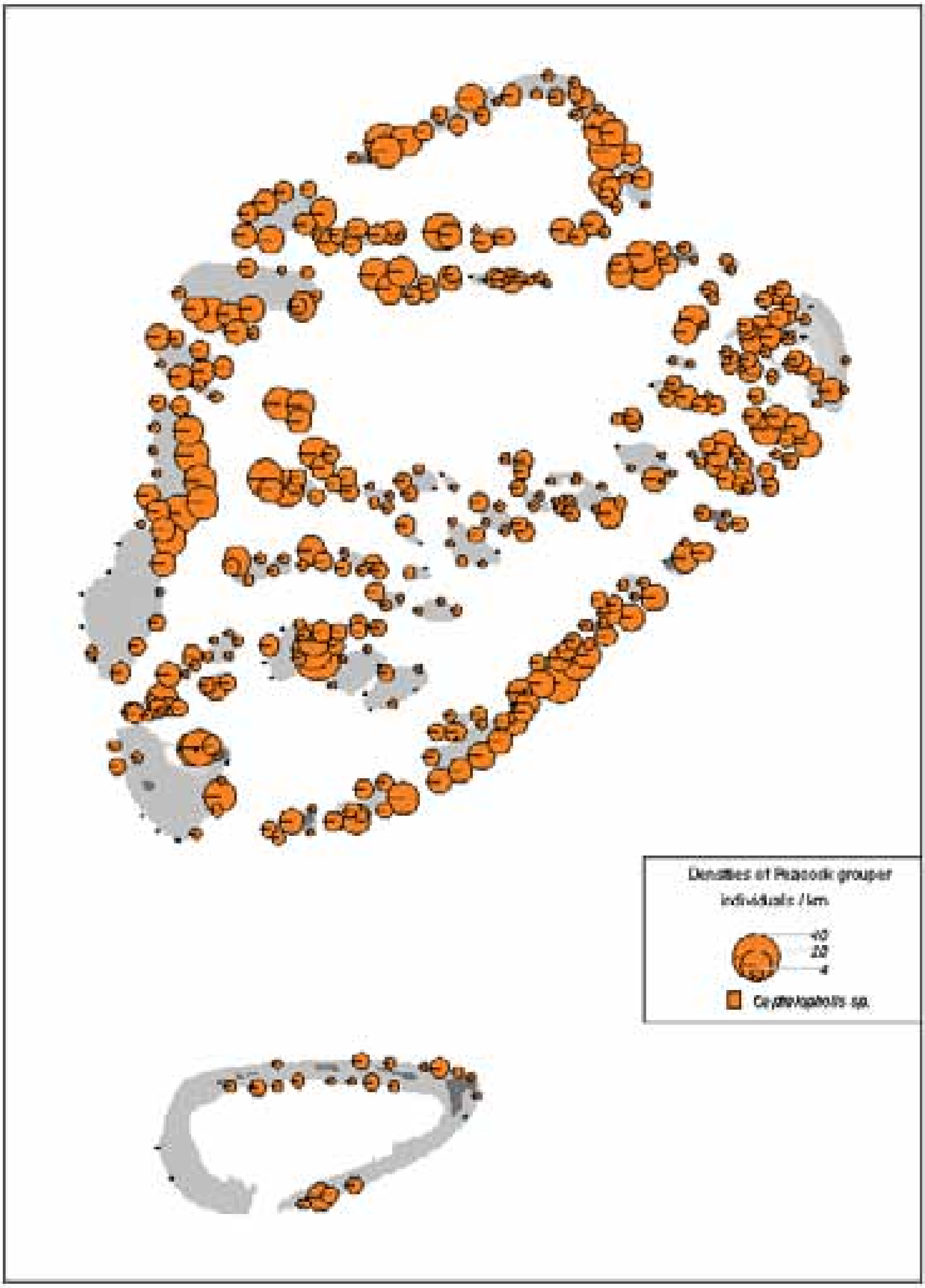

Figure 2.6. Distribution of the peacock grouper in Baa Atoll. Circles are log-proportional to densities for easier reading.

In general, Lunar-tailed grouper densities are higher in the northern part of Baa Atoll. Hovewer, there is no clear density gradient from north to south. Instead, higher densities are mostly found in the centre of the main Atoll, then in the northern Atoll, and finally they are lower in the south, except in Thulaadhoo and Maamaduvvari. Lunar-tailed groupers densities are very low in Goidhoo Atoll.

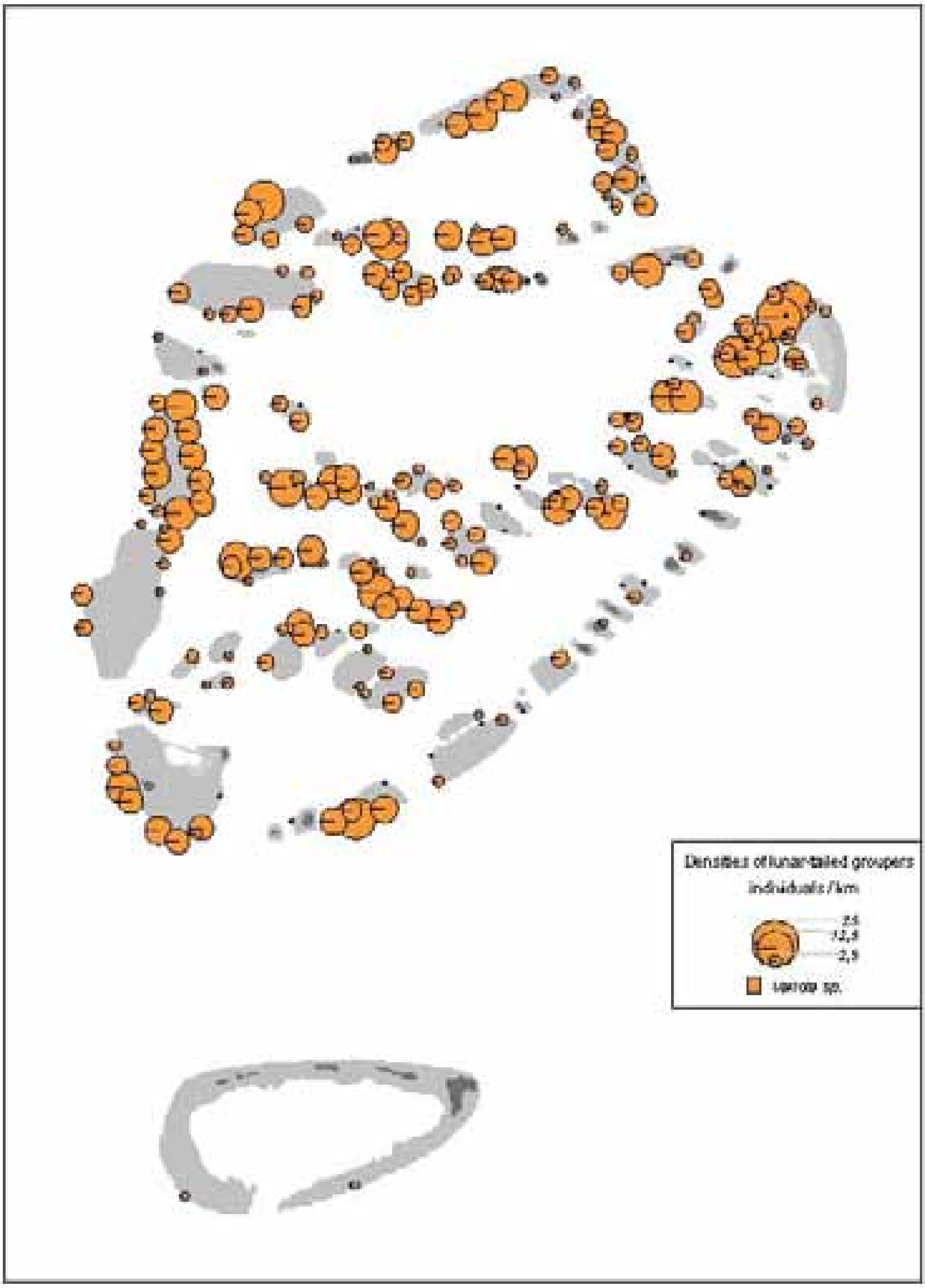

Figure 2.7. Distribution of the lunar-tailed grouper in Baa Atoll. Circles are log-proportional to densities for easier reading.

Big groupers observed were mainly composed of *Plectropomus* species (212 individuals), followed by few *Epinephelus* species (28 individuals), especially *E. fuscoguttatus* and *E. polyphekadion*. Their distribution follows more or less a north-south decreasing gradient, although it is patchy and erratic. Hence the mean densities are higher in the northern Atoll, but particular places in the centre exhibit very high densities (Vakkaru, Dhigu Faru and Reethi Beach).

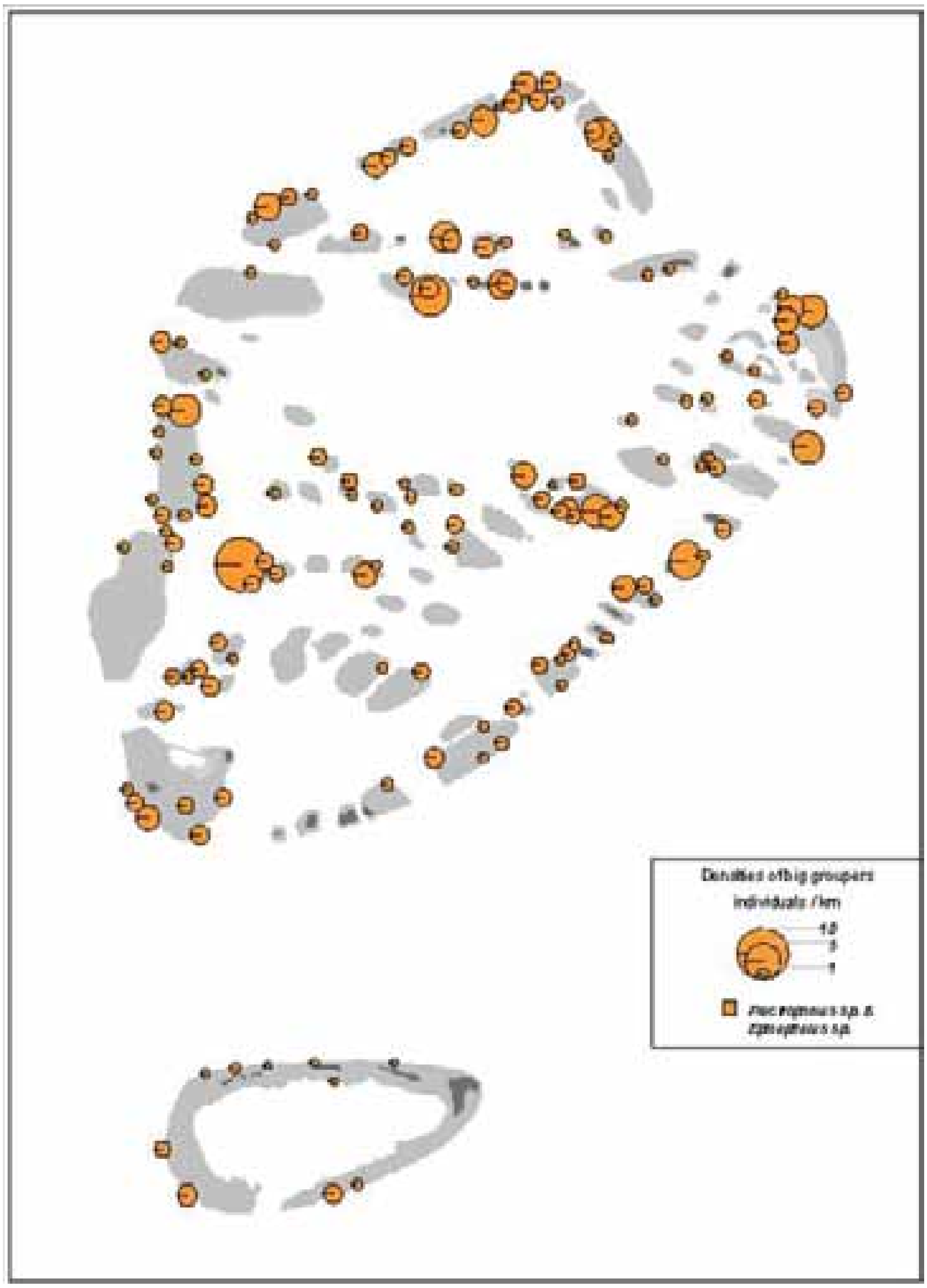

Figure 2.8. Distribution of the big groupers in Baa Atoll. Circles are log-proportional to densities for easier reading.

The other groupers observed were mainly composed of small *Epinephelus* species, such as *E. spilotoceps*, *E. melanostigma*, *E. macrospilos*, *E. merra*, *E. longispinis*, and *Cephalopholis* species, such as *C. leoparda*, *C. boenak* and *C. nigripinnis* but the red-flushed grouper (*Aethaloperca rogaa*) and the white-lined grouper (*Anyperodon leucogrammus*) were often observed as well, *Gracila* was only seen on Maahuruvalhi. The distribution of these groupers is clearly divided in two by a virtual line joining South Maafaru and Daravandhoo. The densities recorded are much higher in the north than in the south. Furthermore, densities are evenly distributed in the northern part of the Atoll. Their presence is more erratic in the south, with high densities recorded in the inner side of South Maafaru and Kani Fushi, and low densities elsewhere.

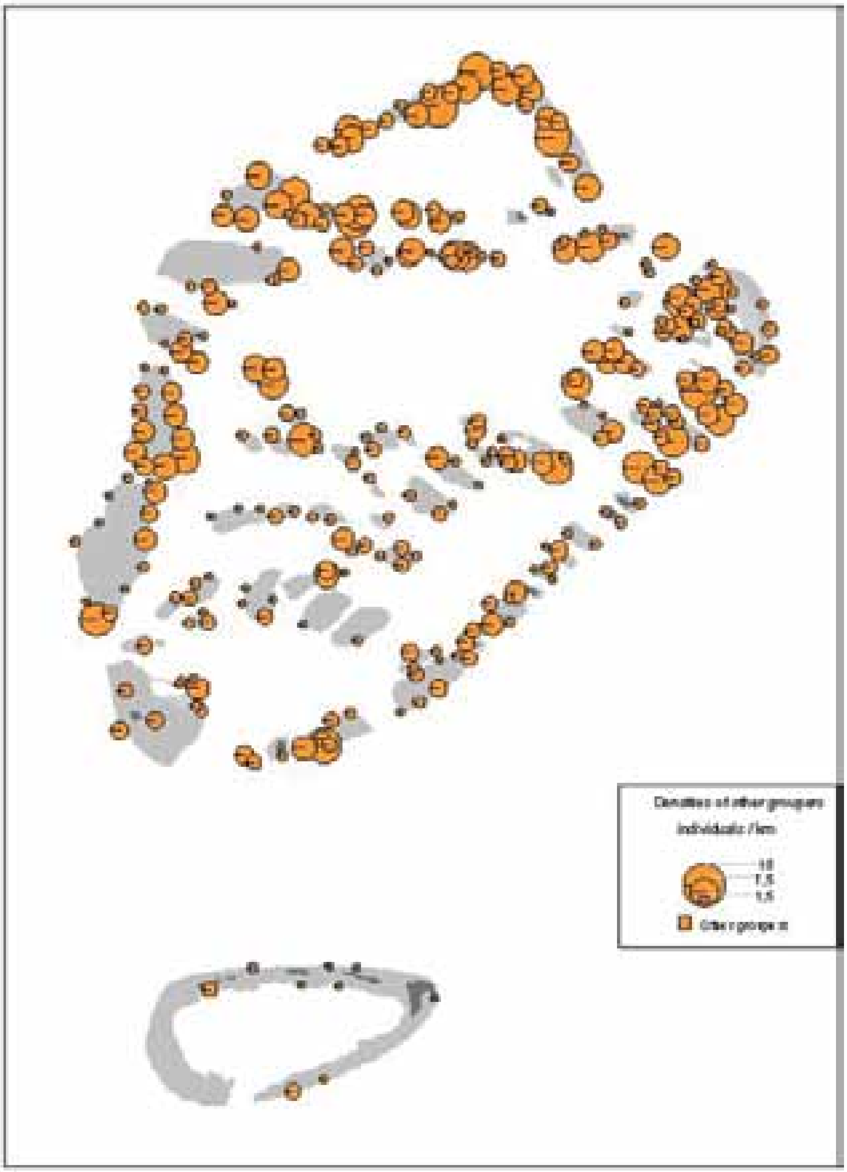

Figure 2.9. Distribution of other groupers in Baa Atoll. Circles are log-proportional to densities for easier reading.

2.2.1.5 Bait fish distribution

The distribution of the bait fish was not quantified and observations were focussed on *Spratelloides gracilis*, other bait species not belonging to the cupleidae, such as *Chromis viridis* were note taken into account. The presence with qualifying comments was recorded. In this context, “consequent” presence of schools of bait fish was coded as "1", and “very consequent” were coded as "2" (figure 2.10). Since this appreciation depends on the observer sensitivity, it should be considered with caution, also some bait fish can also be found in lower abundance on other reefs. However, the pattern of the bait fish presence is clear: schools are majorly found in the north-eastern part of Baa Atoll. Bait fish was also observed in some reefs located in the centre, inside the main Atoll.

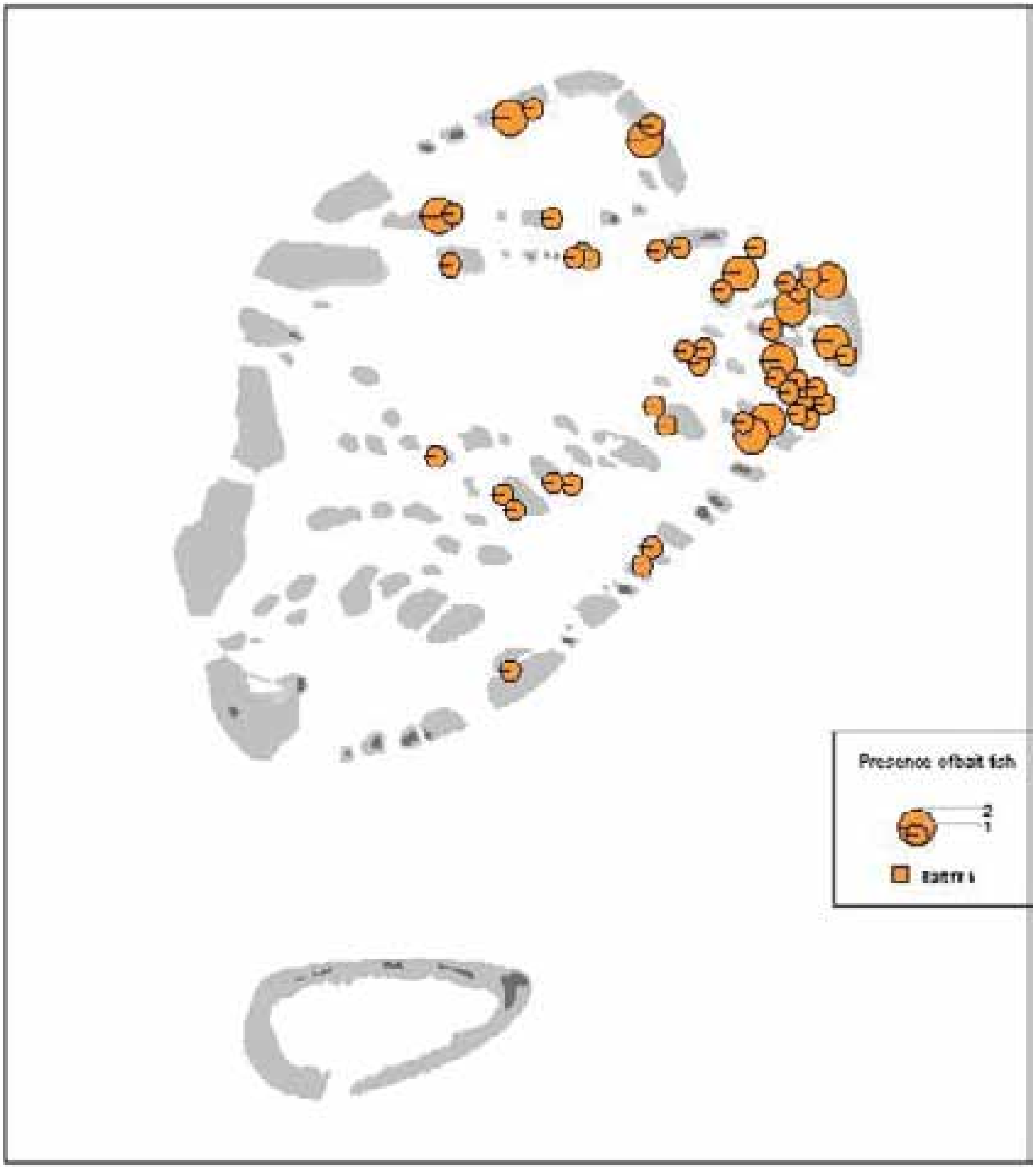

Figure 2.10. Bait fish presence in Baa Atoll. Circles are proportional to densities.

2.2.1.6 Invertebrate distributions

Lobsters, sea cucumbers, sea stars and clams were recorded without quantitative distinction of species. However, if it was impossible to distinguish clam species underwater, some qualitative information was gathered on other groups. Recorded sea stars were all *Culcita schmedeliana* except 7 individuals of *Acanthaster planci*. Among lobsters, *Panulirus versicolor* was the only one identified with certainty. Similarly, a vast majority (at least 90%) of the sea cucumbers observed belonged to *Pearsonothuria graeffei*, followed by *Stichopus chloronotus*. Anecdotic sightings of *Bohadschia marmorata*, *Actinopyga miliaris, A. mauritania*, *Holothuria nobilis*, *Thelenota anax* and *T. Ananas* also occurred.

The manta tow method is not very adapted to assess lobster and black coral quantities. The black coral are somewhat too deep, and lobsters are too cryptic especially species such as *Panulirus femorstriga* or *P. longipes*, which are best seen at night on the outside reefs. Black corals and lobsters were locally abundant species (but not frequent). Indeed, noticeable densities of black coral were only found north of a line joining Maahuruvalhi and Aidhoo (figure 2.11). Highest densities were recorded near Reethi Beach, whereas medium to high densities were encountered in the northern Atoll and around R21 in the west of the main Atoll. Pearl oysters were very rarely seen during this survey. The highest densities were recorded in Hibalhidhoo; in this site, winged pearl oysters (*Pteria penguin*) were observed on black corals, but the number of these black corals was not determined.

Although a little bit more widespread throughout Baa Atoll than black corals, lobster distribution (figure 2.12) is patchy and predominantly in the reefs inside the west of the main Atoll and near Reethi Beach, and, to a lesser extent, in the northern Atoll. The overall densities are low and the number of lobsters recorded seems amazingly low. If we are not to disregard the method altogether for assessing the health of the lobster community, it is clear that there is an alarming impact from the fishery.

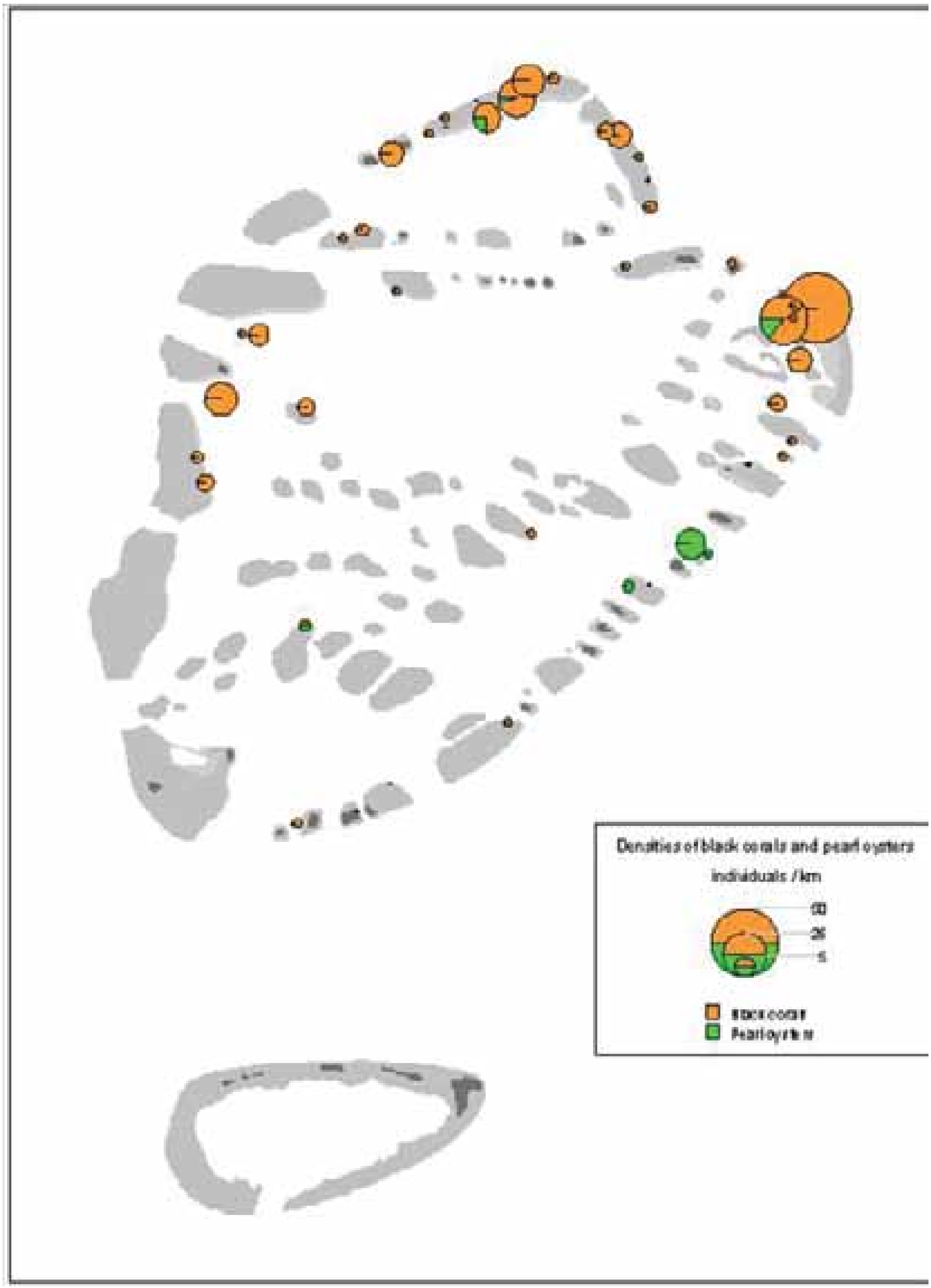

Figure 2.11. Black corals and pearl oysters distributions in Baa Atoll. Circles are log-proportional to densities for easier reading.

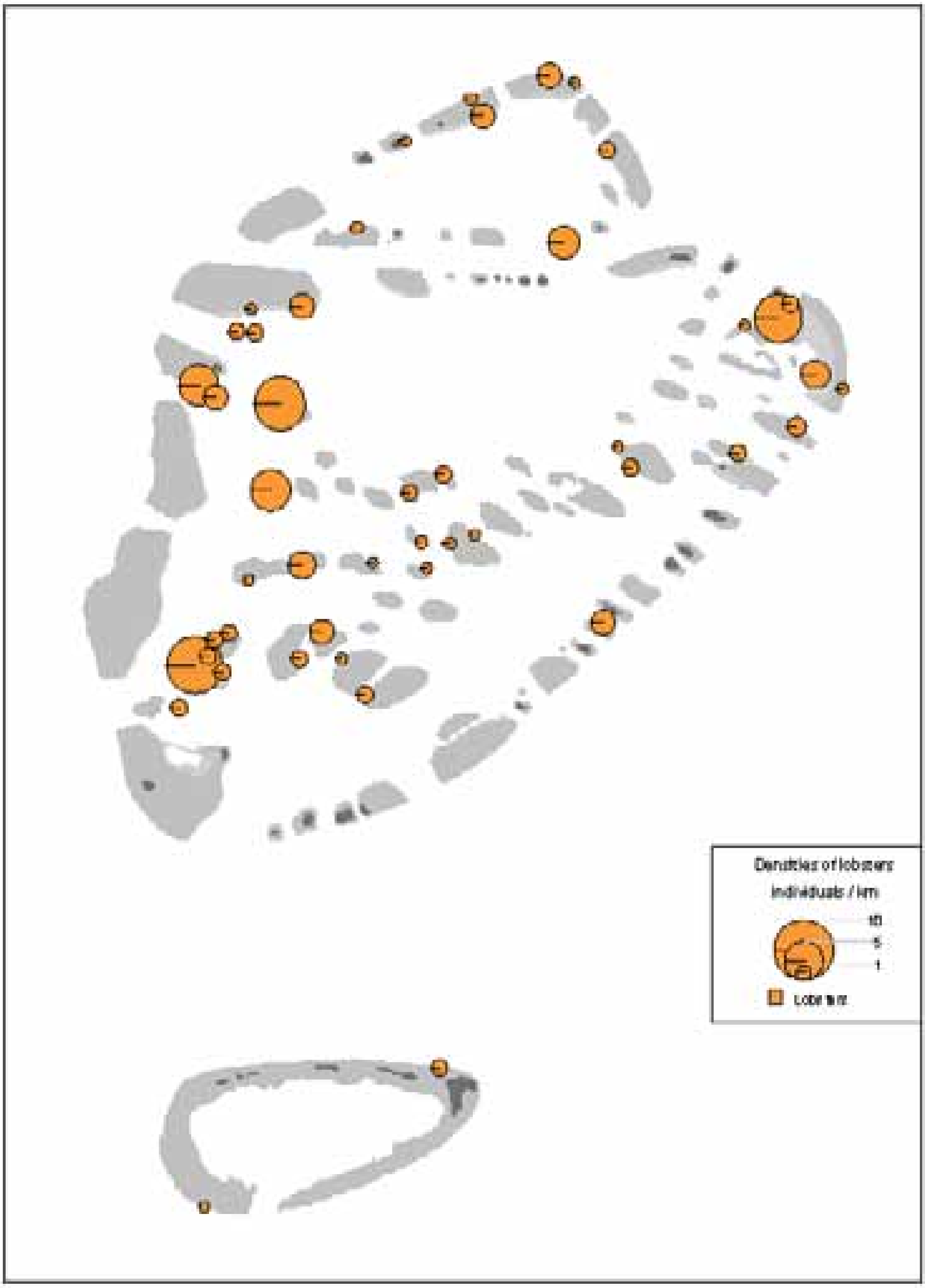

Figure 2.12. Distribution of lobsters in Baa Atoll. Circles are log-proportional to densities for easier reading.

In opposition, distributions of clams, sea cucumbers and sea stars are widespread throughout the atoll.

Clams (figure 2.13) yielded the highest densities of all indicator groups and were found throughout the entire main and northern Atolls; very few clams were recorded in Goidhoo Atoll. Although being widespread, clam distribution is also heterogeneous. Low densities were observed along the west side of the main Atoll and in the centre in general, while some reefs act as epicentres of high densities in several places: within the main Atoll, this is the case for Nagilifalhu and R15 in the centre and for Mudhdhoo in the east, and this is also the case for Boi Faru in the northern Atoll.

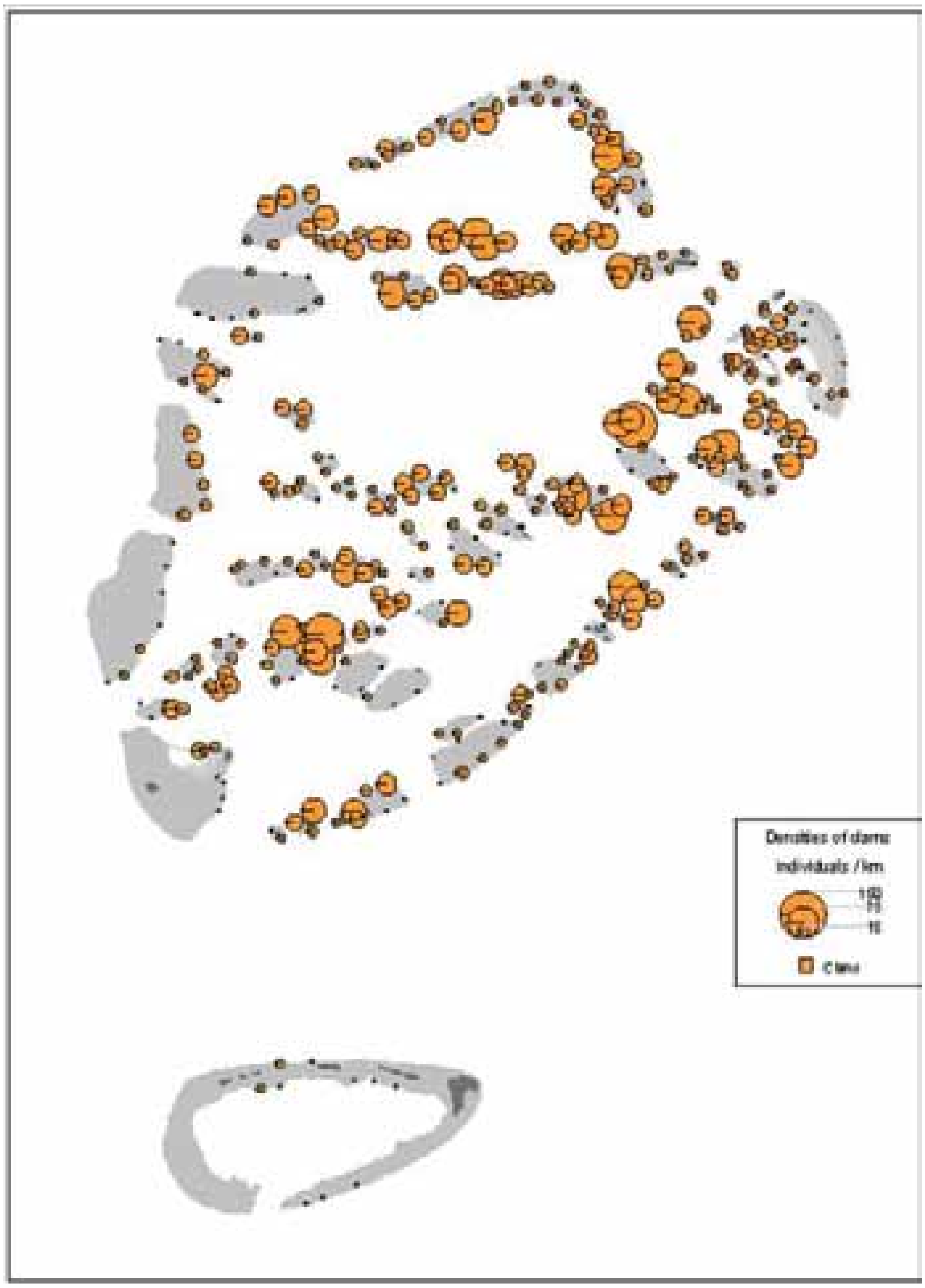

Figure 2.13. Clams distributions in Baa Atoll. Circles are log-proportional to densities for easier reading.

Sea cucumber distribution (figure 2.14) is quite similar to that of clams: low or null densities were recorded in Goidhoo Atoll and along the west side of the main Atoll (with the exception of the inner side of Maahuruvalhi), whereas high densities were found in several local places. However, sea cucumber seemed to be more randomly distributed than clams, with some hotspots in Maahuruvalhi, Hanikandu Faru, Binmathee Faru and around Dhonfanu. Sea stars are even more widespread than the two precedent species groups (figure 2.15). They are quite dense in Goidhoo Atoll, but only in its western side. The northern Atoll yielded the uphighest mean densities, followed by the north-east of the main Atoll. Some hotspots were encountered very locally in the centre (Vakkaru, Binmathee Faru and the south of Maaneigaa) or in the south of the main Atoll (around Hithaadhoo). Still within the main Atoll, some places in the centre exhibited null densities, and densities were generally low along the west side.

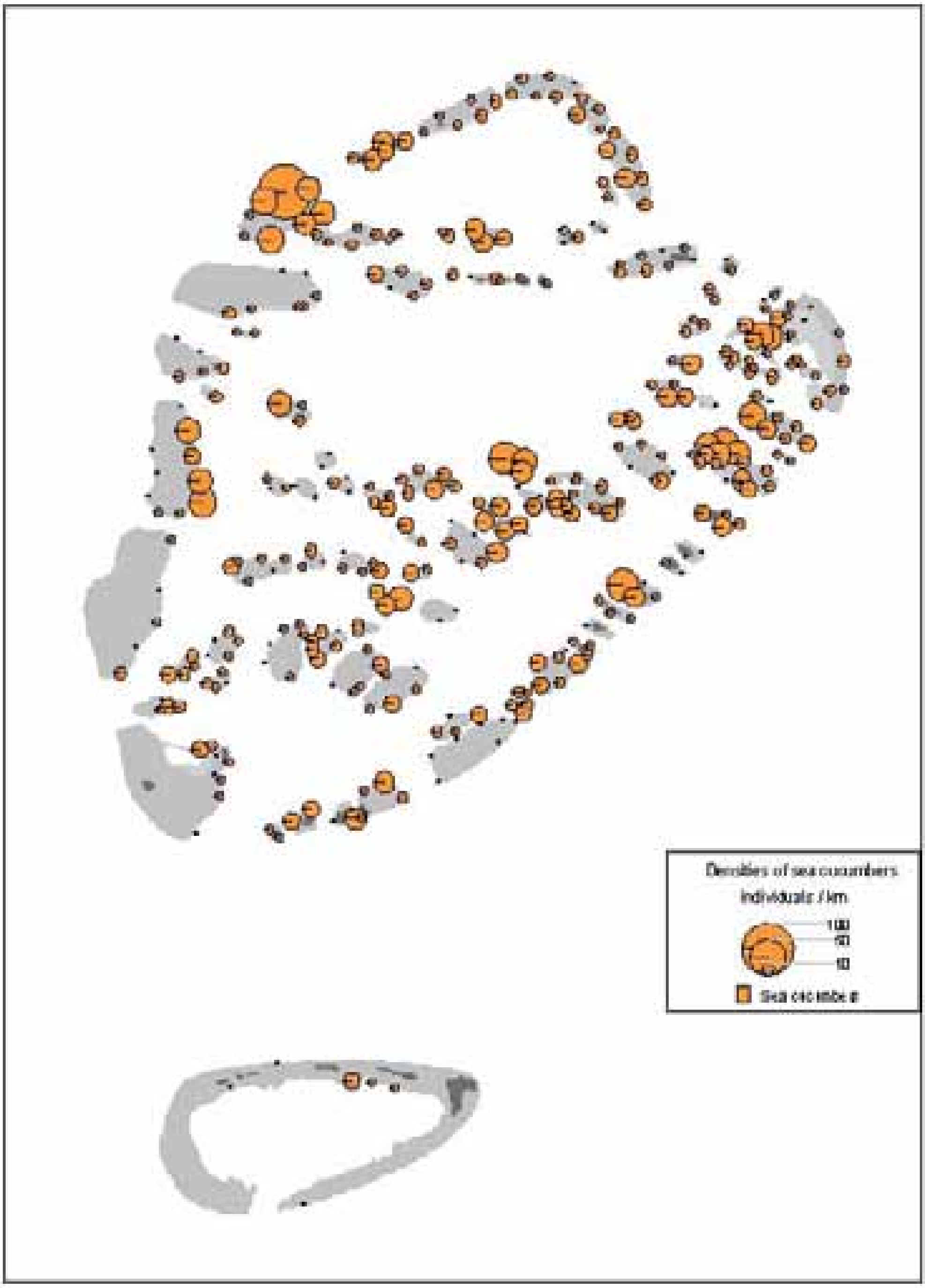

Figure 2.14. Sea cucumbers distributions in Baa Atoll. Circles are log-proportional to densities for easier reading.

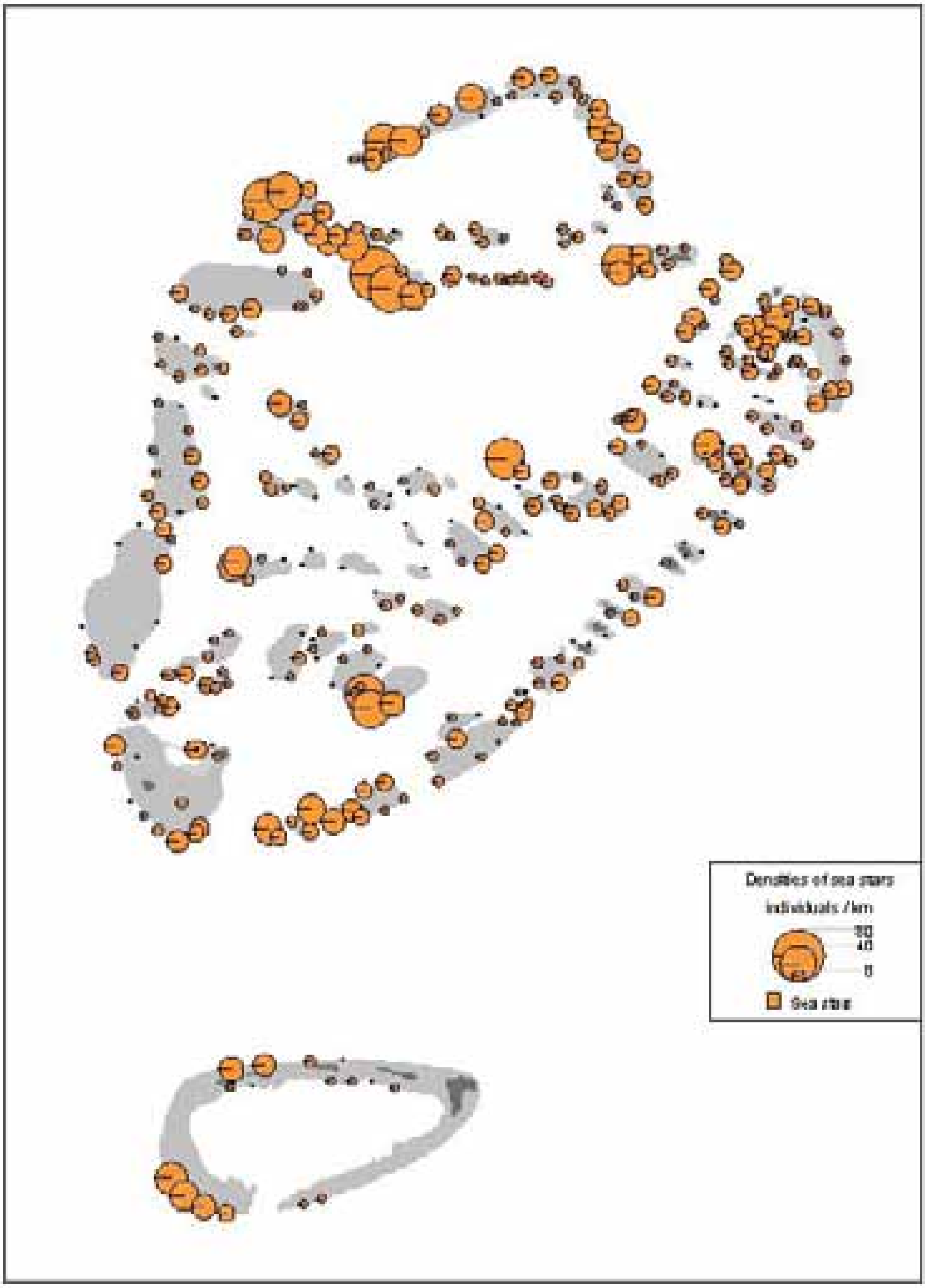

Figure 2.15. Sea stars distributions in Baa Atoll. Circles are log-proportional to densities for easier reading.

2.2.2 Substrate cover

2.2.2.1 Class overview and distributions

Table 2.4 shows the basic statistic associated to the substrate classes, while their distribution is illustrated in figure 2.16.

Abiotic substrates (pavement, rubble, sand and silt) were present in all photographic samples. Live corals and algae were recorded in a vast majority of the samples (96.5 % and 88.0 % respectively) as well. 56.4 % of the samples contained other living organisms such as sponges, ascidians, zoanthids and soft corals, and dead corals were observed in half of the photos.

In average proportions, abiotic substrates accounted for two thirds of the total substrate cover. The remaining third, corresponding to living organisms, is mainly composed of live coral (22.0 %) and algae (8.2 %). Other living organisms accounted for 2.8 % of the total cover and dead coral contribution to total cover was very limited (1.1 %).

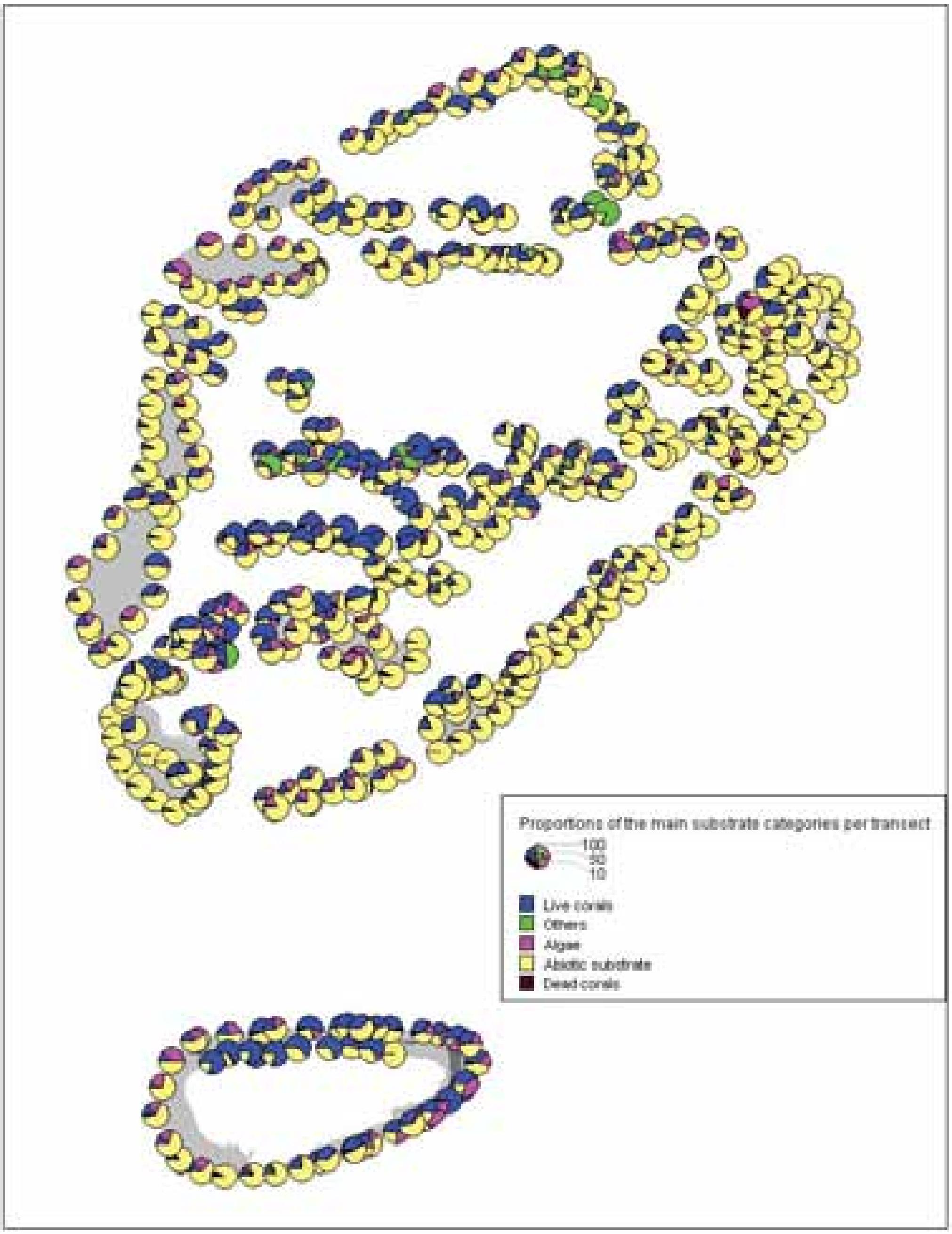

Figure 2.16. Proportions of the main substrate classes.

Table 2.4. Statistics associated with substrate classes

Class	Presence (nb samples)	Presence (% samples)	Mean	Standard Deviation	Minimum	Maximum
Coral cover	585	96.5	22	18.9	0	89.2
Algae	533	88	8.2	8.5	0	51.7
Other living organisms	342	56.4	2.8	8.2	0	81
Dead corals	295	48.7	1.1	1.8	0	17.7
Abiotic substrates	606	100	66	21.6	2.4	100
Shadow	486	80.2	3	3.1	0	15.2

The distribution of substrate relative composition shows quite clear trends in the main and northern atolls. In general, benthic life has poorly developed in the reefs forming the rim of the atolls with the open sea. Nevertheless, this trend becomes less obvious in the north, where some live coral and algae contribute significantly to the overall composition, the healthier outer reef slope being found at Vinaneyi faru. Goidhoo Atoll has quite a good live coral cover even on its outer rim. In the main Atoll, important live coral cover was found in the reefs located in the centre. At the reef scale, the difference between the inner reefs and the outer reefs is also quite important, with live coral barely present in the outer sides while they generally contributed to at least 20 % of the total cover on the lee sides of the reefs. Algae proportions were generally low but widespread in the main and northern Atolls. However, their contribution can increase to noticeable levels in particular places, such as in the inner reefs of the south (from Bodugaafalhu to Maaneigaa) or in both north and south Maafaru. Other biotic substrate development was very low but in few places where proportions can reach quite high levels: this was the case for the inner reefs in the centre of the main Atoll (from R6 to Mendhoo) or in the eastern region of the northern Atoll (from Gaagadufaruhuraa to Kudarikilu). When present, these organisms are often predominant, attaining sometime 81 % of the total cover. Finally, dead corals occurred in negligible proportions as a whole, although non-negligible percentages were very locally observed in few reefs of the north-eastern region of the main Atoll.

The case of Goidhoo Atoll appears to be very specific. Its outer slope is mainly composed of abiotic substrate in the south- west, while very important live coral cover was found in the south-east, and in the north-east to a lesser extent. Algae were mainly observed in the north. It could be that this atoll being in the middle of the Kaashidhoo Kandu was less affected by the coral bleaching event of 1998, but other hypothesis could be thought about.

2.2.2.2 Coral form overview and distributions

A statistical summary of live coral cover classified according to the lifeform categories is given in table 2.5 and their distribution map is illustrated in figure 2.17.

Table 2.5. Statistics associated with substrate sub-categories

Class	Subcategory	Presence (nb transects)	Presence (% transects)	Mean	Standard Deviation	Minimum	Maximum
Coral forms	Coral Branching	147	24.3	1.2	5	0.0	60.0
	Coral Digitate	272	44.9	2.7	5.8	0.0	70.1
	Coral Foliose	15	2.5	0	0.2	0.0	2.4
	Coral Massive	540	89.1	6	6.8	0.0	49.9
	Coral Mushroom	87	14.4	0.2	0.6	0.0	4.9
	Coral Submassive	432	71.3	3	3.8	0.0	35.5
	Coral Tabular	279	46	5.1	10.8	0.0	77.3
	Coral Encrusting	494	81.5	3.8	4.1	0.0	26.3
Algae	Coralline Algae	491	81	6.1	6.7	0.0	43.7
	Macroalgae	91	15	0.4	2.2	0.0	36.1
	Turf Algae	189	31.2	1.7	4.6	0.0	46.4
Other living organisms	Ascidians	85	14	0.3	1	0.0	11.2
	Soft Coral	95	15.7	0.3	1.2	0.0	19.2
	Sponges	171	28.2	1	4	0.0	56.0
	Others	90	14.9	0.7	5.4	0.0	81.0
	Zoanthids	23	3.8	0.6	4.7	0.0	60.0
Dead corals	Dead coral with	175	28.9	0.6	1.4	0.0	17.7

	Algae						
	Old Dead Coral	147	24.3	0.4	1	0.0	10.8
	Recently dead coral	45	7.4	0.1	0.4	0.0	5.7
Abiotic substrates	Pavement	597	98.5	43.4	19.8	0.0	100.0
	Rubble	549	90.6	16.2	15.1	0.0	88.0
	Sand	275	45.4	4.6	13.4	0.0	100.0
	Silt	234	38.6	2	5.8	0.0	68.8

The massive corals (*Porites, Favia, Favites*) and the encrusting corals (*Pavona, Goniastrea*) were the more widespread coral lifeforms, occurring in 89.1 % and 81.5 % of the samples respectively. Submassive corals (*Pocillopora, P. rus*) were present in more than two thirds of the samples, while tabular (*A. clathrata, A. hyacinthus*) and digitate corals (*A. digitifera, A. samoensis*) were observed in nearly half of them. Branching corals (*A. microphtalma, A. aspera*) were also quite common, since they were found in one quarter of the samples. In contrast, mushroom corals and even more foliose corals were scarce as compared to other coral forms, with a presence limited to 14.4 % and 2.5 % of the samples respectively.

The mean cover shows the contribution to the overall cover (i.e. of all categories) and generally follows the trend highlighted by the presence data. Thus, the mean contribution of massive coral was very significant (6.8 %), that of branching corals was medium (1.3 %) whereas those of mushroom and foliose corals were negligible (maximum 0.2 %). However, the mean contribution also reflects the size of the corals, which leads to substantial differences in the ranking of the intermediate coral forms. Indeed, due to their morphology and ecology (where present they are quite dominant), tabular corals which ranked only 4th in presence reached a very significant mean contribution (5.1 %). On the opposite, encrusting, submassive and digitate corals exhibited medium contributions (3.8 %, 3.0 % and 2.7 % respectively).

The distribution of the different coral forms shows that massive corals were widespread and accounted for most of the coral cover in all the reefs on the atoll rim. Tabular corals were mainly observed in the reefs inside the main Atoll and in Goidhoo Atoll. A similar pattern was displayed by submassive corals, which nonetheless extended more eastward than tabular corals. Like massive corals, encrusting corals were widely distributed throughout the Atolls, although high cover was mostly recorded in the central reefs inside the main Atoll and in the eastern side of Goidhoo Atoll. Digitate coral distribution seemed to be concentrated in the inner reefs of the western side of the main and northern Atolls, even if noticeable cover was found in the eastern side of Goidhoo Atoll. Important branching coral cover was always restricted to the lee side of the reefs and were limited to a number of specific places, such as the inner reefs of Goidhoo and Thulaadhoo, around Nibiligaa and on a few reefs in the northern Atoll. Finally, few mushroom corals can be detected in the central reefs inside the main Atoll.

Patterns of coral form distribution can somewhat be linked to patterns observed for the whole coral class. Concerning the main Atoll, it appeared that corals as a whole were more represented inside the main Atoll and in the lee side of the rim reefs. This result could be related to the high levels of the tabular coral cover, whose distribution in yellow in figure II.18 closely match high levels of the coral class cover (in blue in figure II.17). Similarly, high levels of coral cover in the northern Atoll might be better related to important levels of massive corals and, in the outer slope of Goidhoo Atoll, to important levels of submassive and encrusting corals. This picture can be explained by the 1998 bleaching event where massive and encrusting corals have survived better. Zahir (2005) even noticed that encrusting corals were major contributors to the overall coral recruitment. On the other hand, the faster growing tabular corals seem to be recruiting / surviving and growing more on the inner reefs and therefore account for most of the areas of high coral cover. It is not clear whether these species have a recruitment limitation on other parts of the atoll.

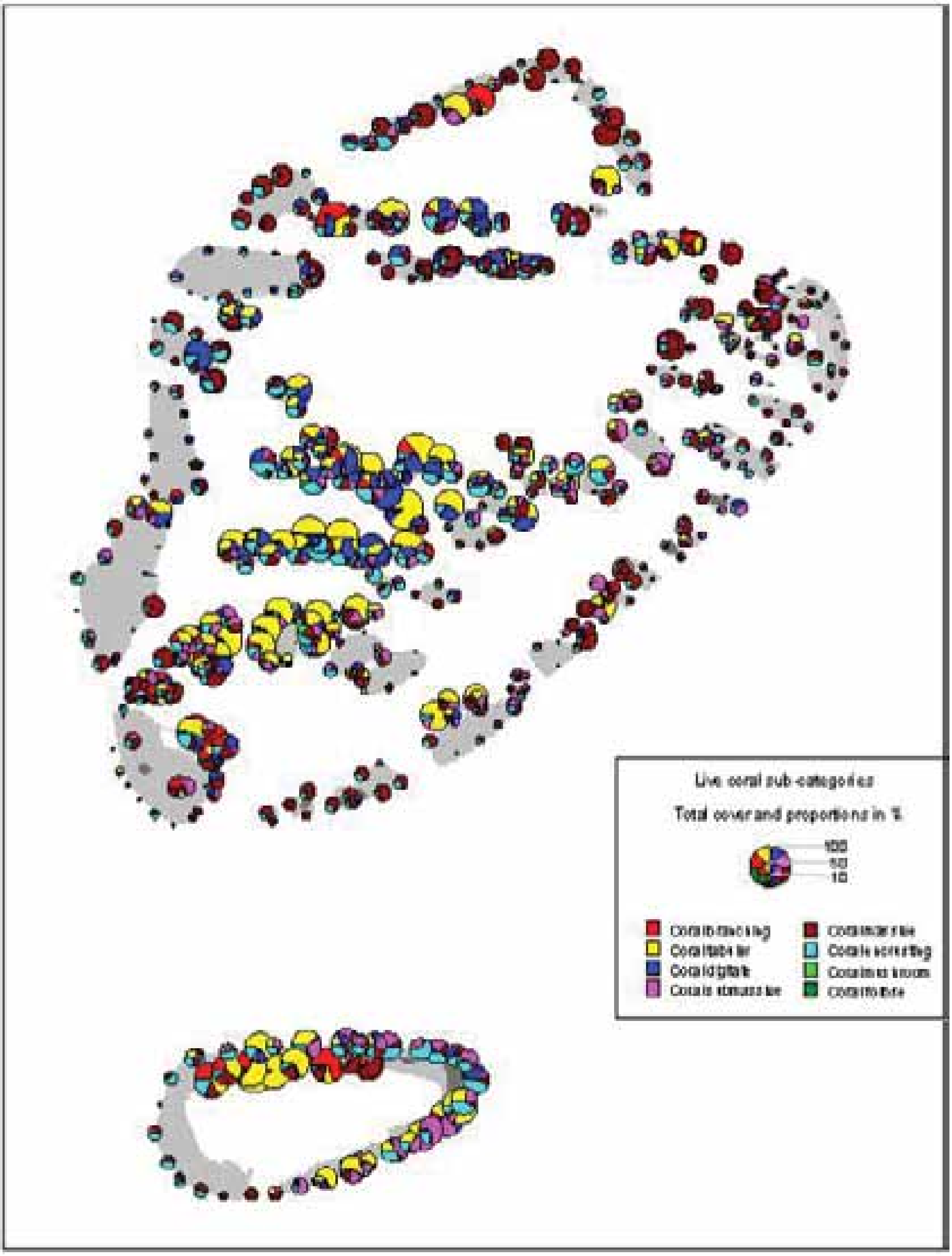

Figure 2.17. Subcategories of live coral. Circles are proportional to total cover.

2.2.2.3 Algae overview and distributions

A statistical summary of algae cover is given in table 2.5 and their distribution map is illustrated in figure 2.18.

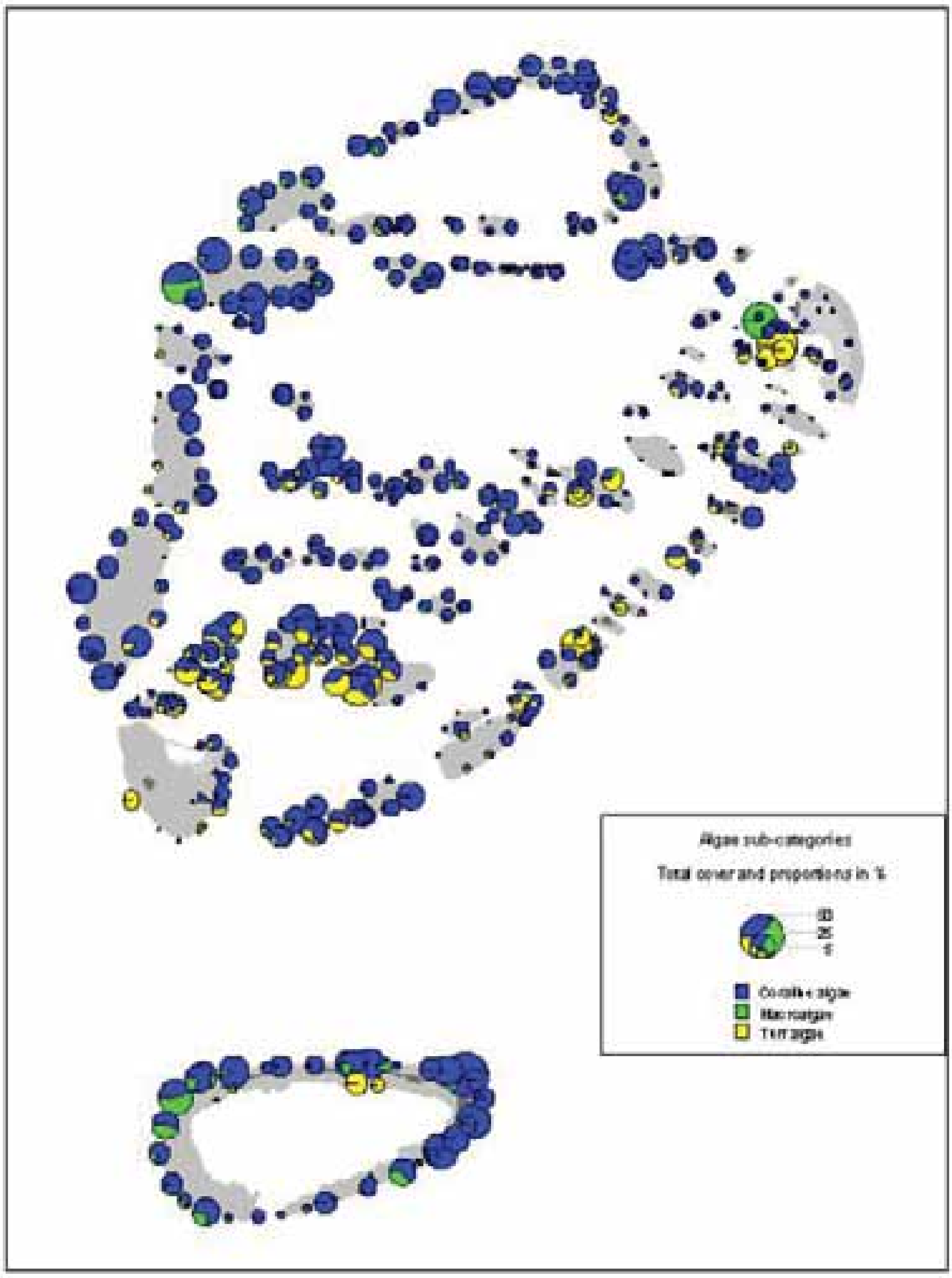

Figure 2.18. Subcategories of algae. Circles are proportional to total cover.

Algae were mainly represented by coralline algae, such as *Mesophyllum* or *Sporolython*, which occurred in more than 80 % of the samples and contributed very significantly to the overall cover (6.1 %). Turf algae, such as *Microcoleus* or *Enteromorpha*, were present in one third of the samples, and accounted for nearly 2 % of the total proportions. It has to be noted that very short turf algae covering the pavement was not counted as turf but as pavement. Macroalgae, such as *Halimeda*, *Padina*, *Turbinaria* or *Tydemania*, were more scarce (15.0 % of the samples) with a limited cover (0.4 %).

Coralline algae distribution covered all three Atolls, and accounted for an important proportion of the habitat in the north and in the east of Goidhoo Atoll, in the southern inner reefs of the main Atoll and in North Maafaru. Besides these high proportions, coralline algae distribution was fairly homogeneous.

Turf Algae was also fairly widespread. However, the areas where they composed most of the algae community were observed in very well defined places, such as the eastern rim reefs and the southern inside reefs of the main Atoll.

In contrast, macroalgae (principally *Halimeda* spp.) distribution was restricted to a few places. They were mostly recorded in Goidhoo Atoll, in particular in its western side. The two other places where lots of macroalgae were observed were North Maafaru and in the north of Veyofushi.

2.2.2.4 Other living organism overview and distributions

A statistical summary of other living organism cover is given in table 2.5 and their distribution map is illustrated in figure 2.19.

Sponges dominated the other living organisms and were observed in 28.2 % of the samples for a low but significant mean cover (1.0 %). Low presence levels were found for the soft coral, ascidians and other living forms (15.7 %, 14.0 % and 14.9 % respectively), with a similar trend concerning the cover (0.3 %, 0.3 % and 0.7 % respectively). Finally, zoanthids were only present in 3.8 % of the samples. However, their contribution to the overall cover was not negligible (0.6 %), suggesting a locally abundant living organism.

Sponge distribution was fairly widespread, and yet it can be divided into three general areas. In two of them, namely the north-eastern part of the main Atoll and the northern Atoll, mean proportions reached only low to medium levels and concerned various species of sponges, such as *Clathria*, *Carteriospongia*, *Stylotella*, *Pseudaxinella* or *Paratetilla*, . In contrast, very high proportions were recorded in the third area: in the central inside reefs of the main Atoll, around Vakkaru and near Muthaafushi. These records corresponded to *Terpios* sp., an invasive species that covered both biotic and abiotic substrates where it was found. *Terpios* sp. was observed as well in Anhenunfushi in the northern Atoll and Dhakandhoo, although in lower proportions.

Soft coral cover was always very limited. Soft coral, such as *Sarcophyton*, *Lemnalia* or *Sinularia* or *Lobophyton* were primarily found in the central inside reefs and in the north-eastern region, although the highest proportion was observed in the north of the northern Atoll, in the channel between Bathalaa and Gaagadufaruhuraa, and corresponded to *Litophyton*.

The same area was remarkable as well for the very high proportions of zoanthids recorded there. High proportions of zoanthids were also found in the central inside reefs near Nibiligaa and in the east near Kihaadhoo. Globally, zoanthid distribution was very patchy and restricted to a few places.

Ascidians were widely distributed except in Goidhoo Atoll, but their contribution to the overall cover was always very low.

In general, others living benthic organisms were rarely seen, and mostly concerned few individuals. However, some very high proportions (70-85 % of the cover), corresponding to invasive corallimorphs (*Discosoma*), were recorded in four areas: Kudarikilu, Kendhoo and Funadhoo, Dhonfanu, and Muthaafushi.

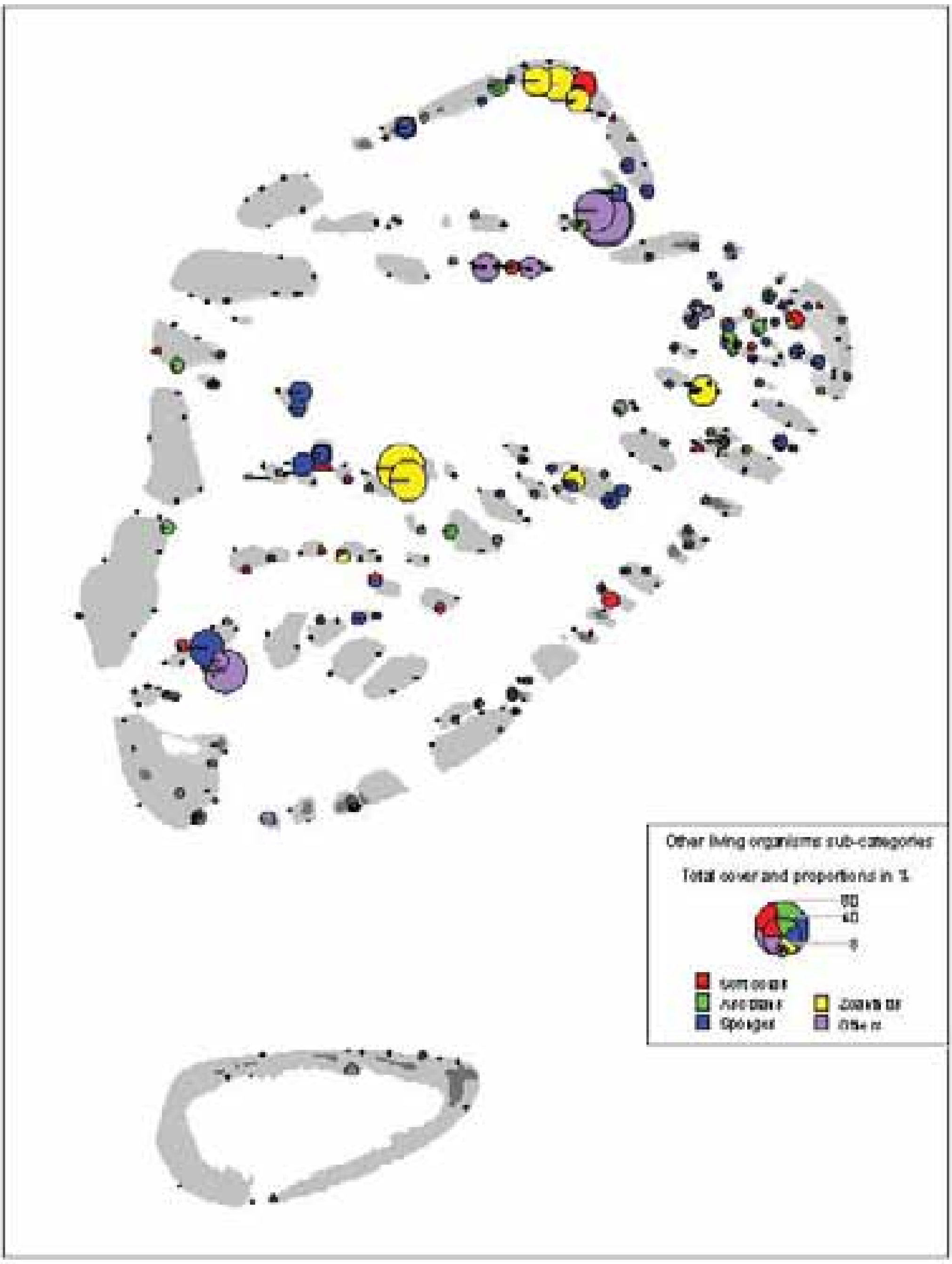

Figure 2.19. Subcategories of other living organisms. Circles are proportional to total cover.

2.2.2.5 Dead coral overview and distributions

A statistical summary of dead coral cover is given in table 2.5 and their distribution map is illustrated in figure 2.20.

Although present in an appreciable percentage of samples, dead corals with algae (28.4 %) and old dead corals (24.3 %) yielded a low contribution to the overall cover (0.6 % and 0.4 % respectively). In contrast, recently dead corals were rare (7.4 % of the samples), displaying negligible cover (0.1 %).

The most important information is that very few recently dead corals were recorded during the survey, indicating an absence of rampant coral mortality. The examination of the map shows that the few recently dead corals were mainly observed in Goidhoo Atoll.

The distribution of dead corals with algae closely followed that of the turf algae, whose highest proportions were also observed in the eastern reefs and in the southern inside reefs.

Finally, old dead corals were more abundant in areas of highest live coral cover, as in the central reefs and the eastern side of Goidhoo.

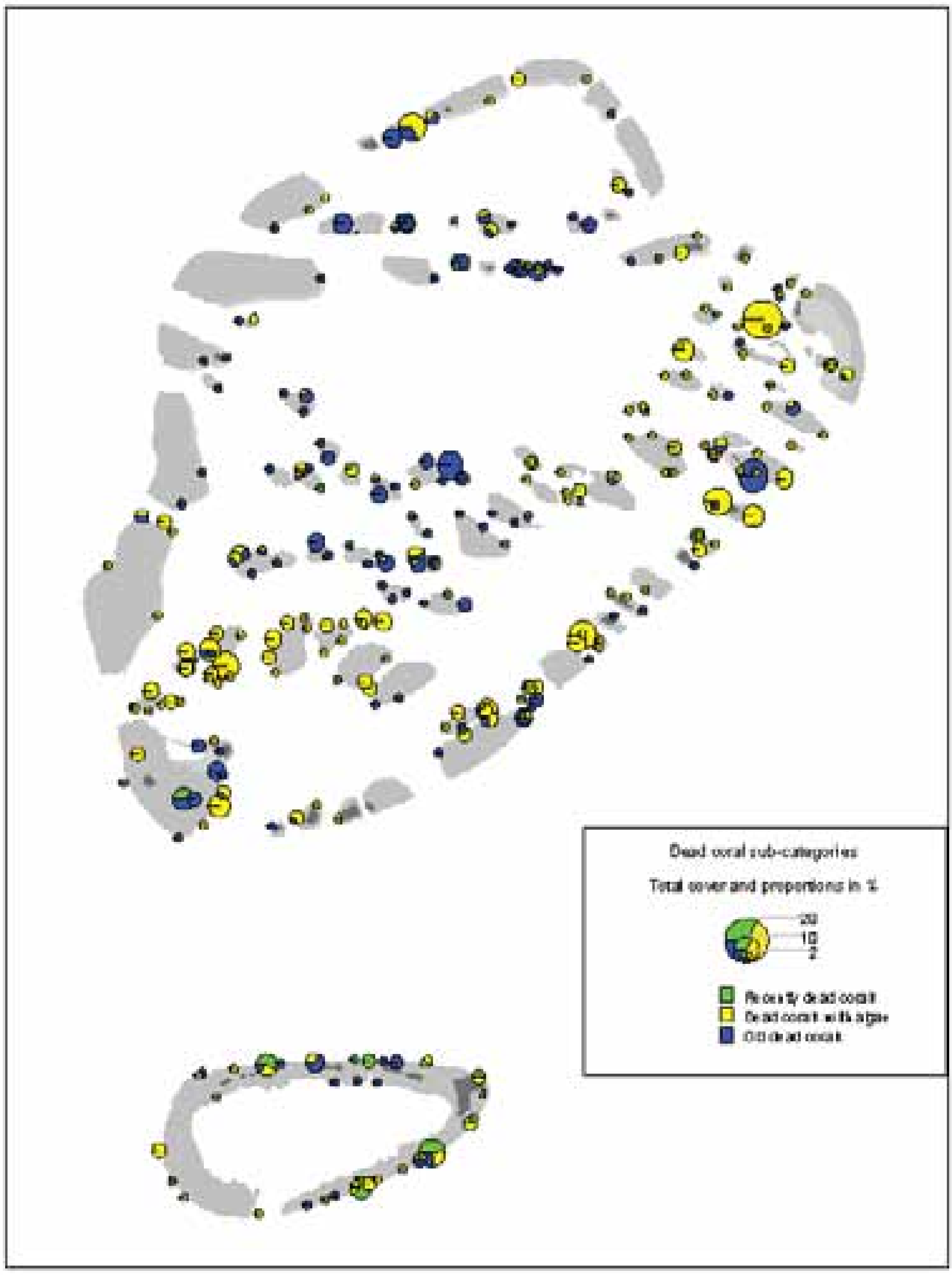

Figure 2.20. Subcategories of dead corals. Circles are proportional to total cover.

2.2.2.6 Abiotic substrate overview and distributions

A statistical summary of abiotic substrate cover is given in table 2.5 and their distribution map is illustrated in figure 2.21.

Abiotic substrate composed most of the habitats surveyed. Pavement and rubble were recorded in a vast majority of the samples (98.5 % and 90.6 % respectively), yielding very high cover percentages (43.4 % and 16.2 % respectively). Less predominant, sand and silt occurred in one third to half of the samples (45.4 % and 38.6 % respectively), resulting in medium to significant covers (4.6 % and 2.0 % respectively).

Pavement forms the basis of Baa Atolls and is present almost everywhere. Exceptions generally resided in inner reefs and are linked to particular sediment transport patterns with rubble or sand falling down the slope of the reef, as in Voavah where the sand of the island sometimes goes over the crest preventing coral growth. In silty areas, with little water movement, the silt can also father on the pavement.

Rubble was also present in most of the Baa Atolls, but it was the main substrate observed in the north-eastern region of the main Atoll, from Dhigu Faru and Eydafushi to Landaa Giraavaru and Kamadhoo. Similarly, rubble was the main component of the substrate in the inner side of Maahuruvalhi and in the central inside reefs around Nagilifalhu. This could be linked to areas where branching forms previously abundant died during the mass bleaching event of 1998 and have poorly recovered since.

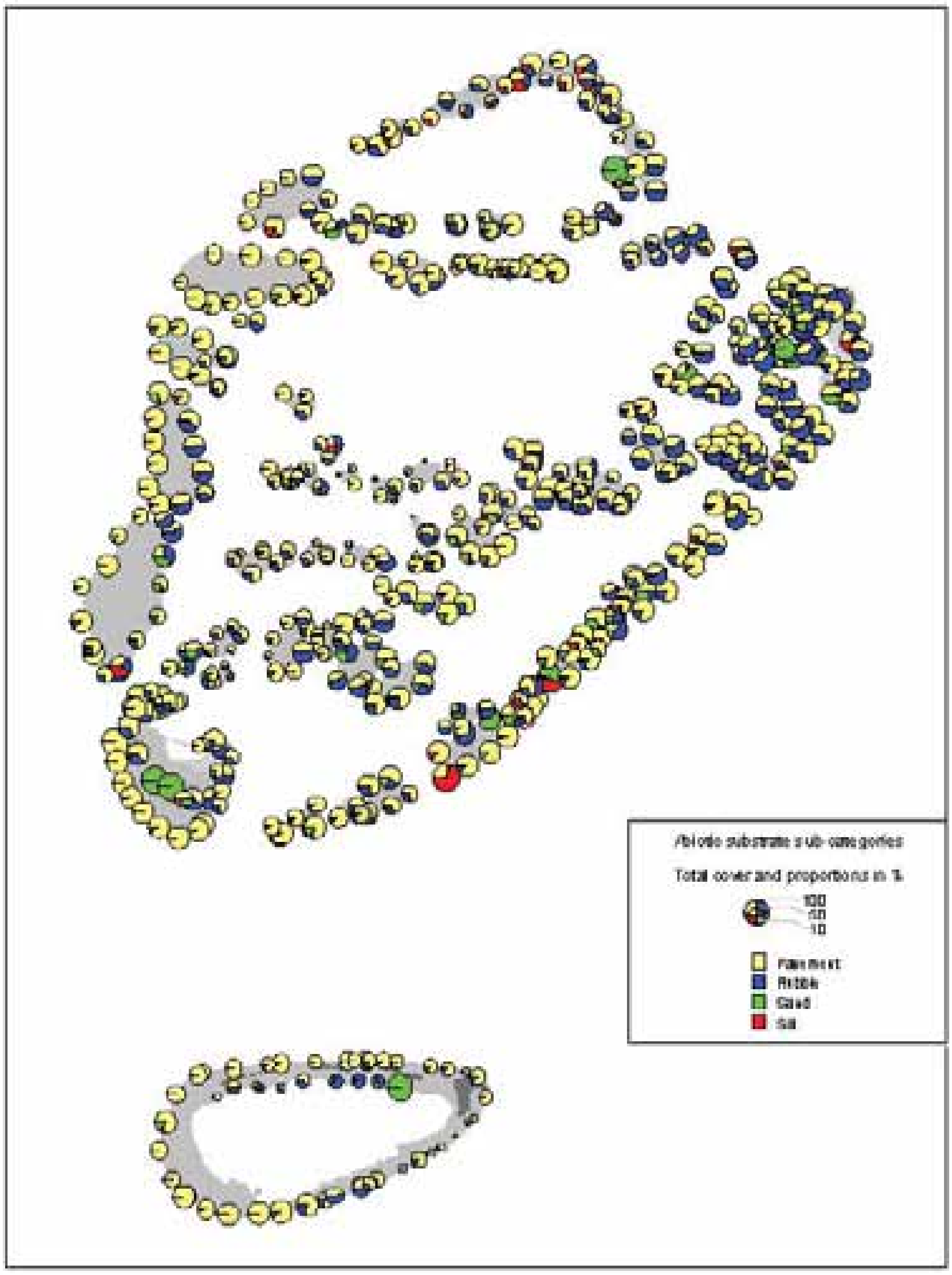

Figure 2.21. Subcategories of abiotic substrate. Circles are proportional to total cover.

2.2.2.7 Other observations

Figure 2.22 shows the presence of the largest animals, namely manta rays and cetaceans. No whale shark was recorded during this survey. In general, large animals were scattered throughout the three Atolls, almost always in the reefs bordering the open sea.

Manta rays (*Manta birostris* and *Mobula mobular*) were observed on seven occasions, and each time a single individual was seen. Most manta ray sightings occurred in the north-eastern region, near the atoll rim. One individual was observed in the south of the main Atoll, and another one in the northern Atoll.

Spinner dolphins (*Stenella longirostris*) were seen all around the main Atoll and in Goidhoo Atoll. Group size was typically around 20 individuals, but ranged from two individuals to 40 – 50 animals. Bottlenose dolphins (*Tursiops truncatus*) were mainly encountered in the east of the main Atoll, along with one sighting in Goidhoo Atoll and one sighting in the northern Atoll. Not surprisingly, group sizes were smaller than those of spinner dolphins, ranging from a single individual to 15 animals. Four sightings were noted down as unidentified cetaceans. The southernmost sighting, in Goidhoo Atoll, concerned 4 black animals, but it was not possible to reliably determine which species it was between short-finned pilot whale (*Globicephala macrorynchus*), false killer whale (*Pseudorca crassidens*), pigmy killer whale (*Feresa attenuata*) and melon-headed whale (*Penopocephala electra*), although the latter may be the most likely given the nearshore location of the sighting and the melon-shaped head of the animals. The other sighting in Goidhoo Atoll concerned four individuals of small dolphins belonging to the genus *Stenella*. Two individuals of the same genus *Stenella* were also recorded in the south of the main Atoll.

The last sighting in the north-east of the main Atoll is a record of a single individual, completely unidentified.

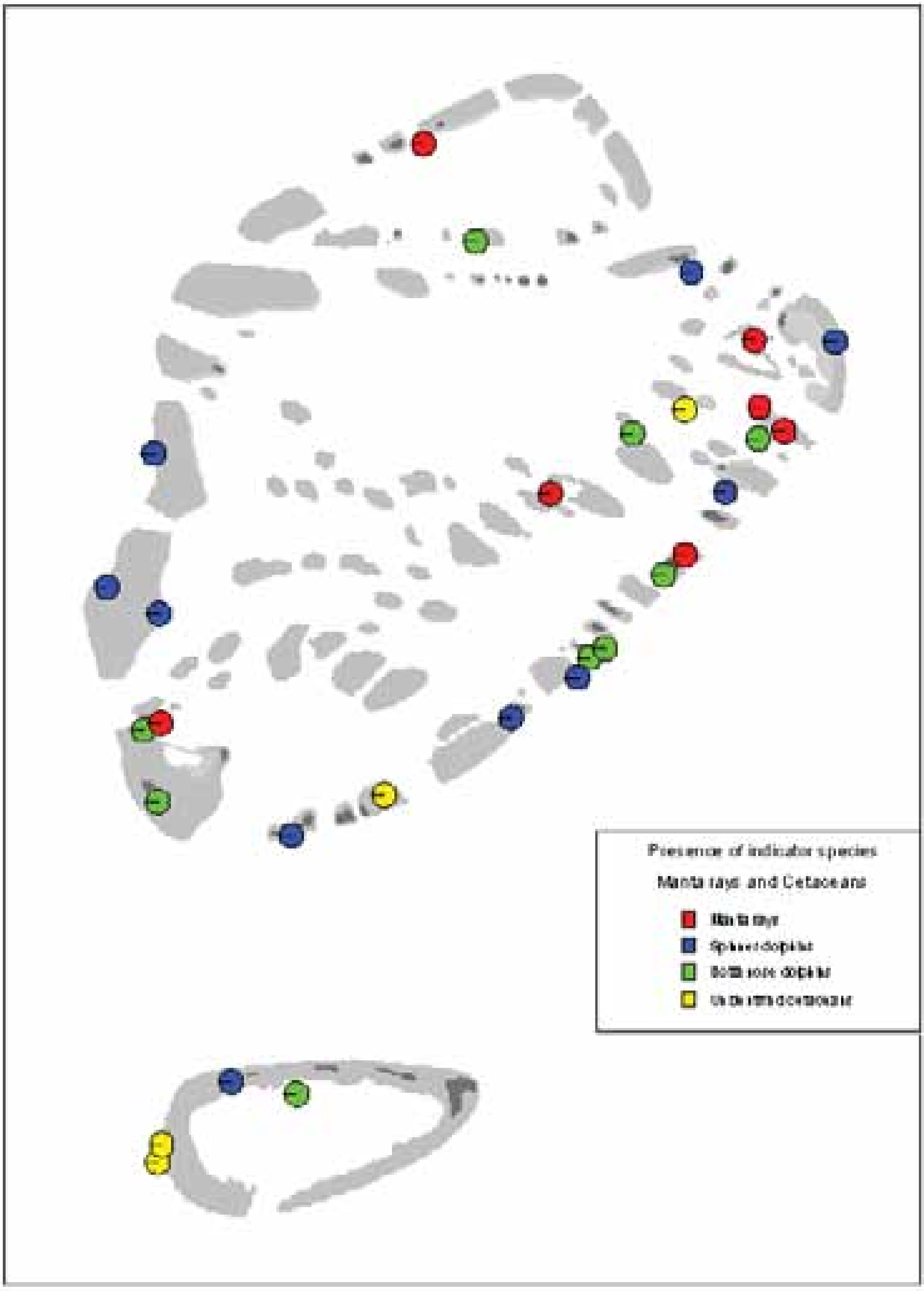

Figure 2.22. Presence of manta rays and cetaceans.

The map of the nesting seabird diversity is presented in figure 2.23. Seven species of nesting seabirds were observed, *Phaethon lepturus, Sterna sumatrana, Anous tenuirostri,* *Sterna hirundo, Sterna bengalensis, Anous stolidus* and *Puffinus lheminieri.* They were generally encountered in isolated sand banks, but some were also seen in inhabited islands. This was the case in particular for the white-tailed tropicbird (*Phaethon lepturus*), or dhandifulhu dhooni, which was observed in Mendhoo and Olhugiri. Species of both genus *Sterna* and *Anous* were the most abundant in our sightings. Specifically, Kurangi (*Anous tenuirostris* or lesser noddy) and kiru dhooni (*Sterna sumatrana* or Black-naped tern) were the most abundant of all nesting seabirds with 8 observations each and were seen throughout the whole Baa Atoll. Gaa dhooni (*Sterna hirundo* or *Sterna dougallii*, respectively common or roseate terns) and valla (*Sterna bengalensis* or lesser crested tern) were also encountered throughout the whole Baa Atoll, but less frequently (four observations). Finally, maaranga (*Anous stolidus* or brown noddy) and dhivehi hoagulaa (*Puffinus lheminieri* or Audubon shearwater) were sighted only twice and once respectively.

Simultaneous records of more than two seabird species were collected in two places only, in Dhandhoo and around Bathalaa Kanduolhi. The co-occurrence of two species was observed more frequently (4 observations in the main and Goidhoo Atolls), although still less than single species observations (10 observations).

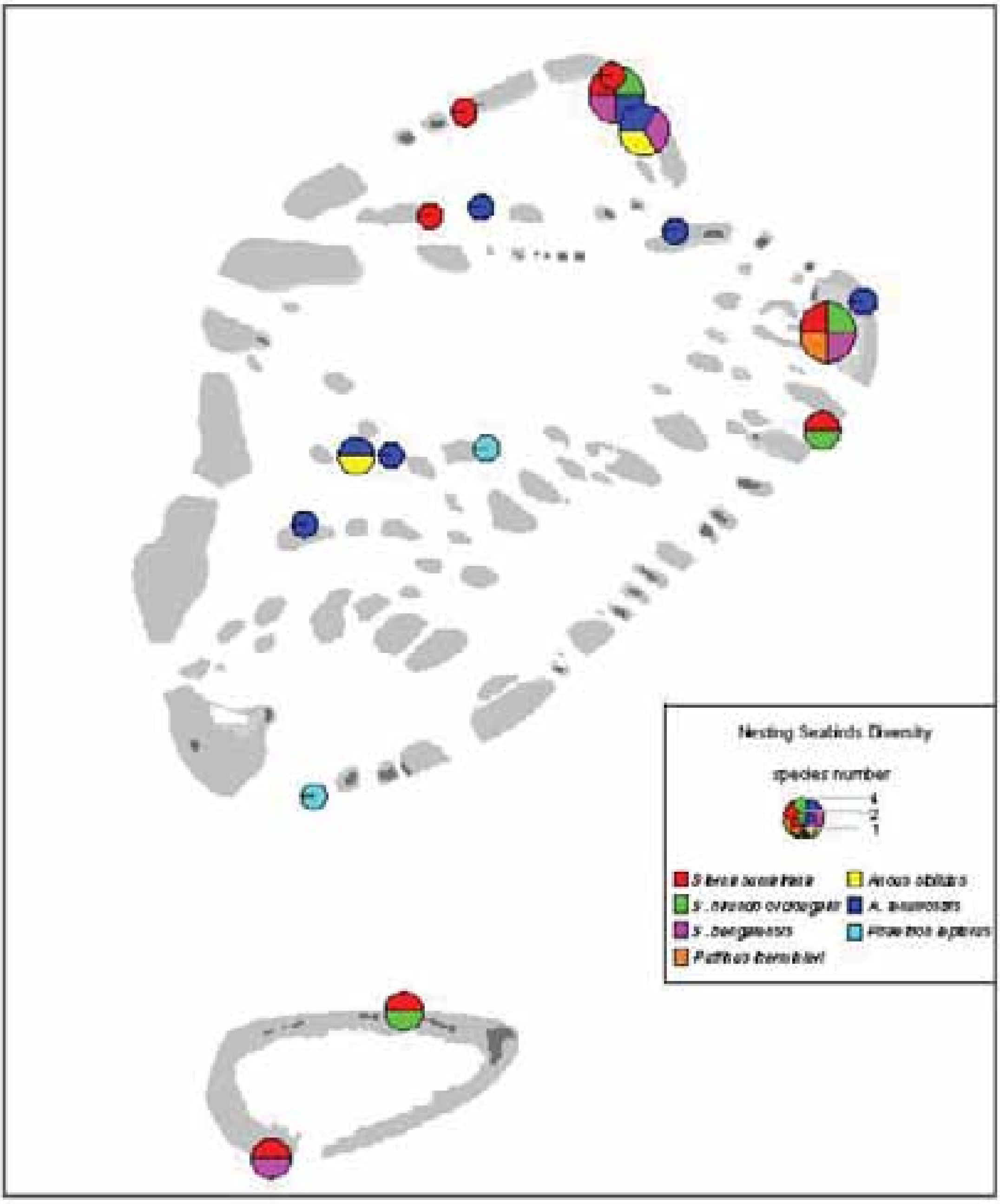

Figure 2.23. Nesting seabird diversity. Circles are proportional to the number of species.

2.3 Discussion and Conclusions

2.3.1 Methods limitations

2.3.1.1 Overall approach

The rapid assessment surveys enable a fairly good representation of the biodiversity of the atoll at a given time. It has to be noted that the ecosystem will probably have cyclic patterns of evolution governed by the tides, the lunar cycles and the monsoons. Some of these influences have been discussed for the groupers based on catch data (Sattar, 2005). It is therefore quite difficult to interpret the data further than the description. The time of the day the observation is carried out would also influence the sightings. If this remark is particularly true for the most mobile indicators, the substrate data is more reliable.

It also seems that some important sites go unaccounted for with the list of indicators chosen. In particular, two large aggregations of snappers on the western coast do not show on the maps.

2.3.1.2 Manta tow technique

This is a very useful method to provide a rapid assessment of large areas of reefs requiring relatively little material or equipment. Densities obtained from this technique are very likely to be under-estimated because some species may be frightened and hide. It is also sometimes difficult to appreciate sightings due to the speed and distances. During the survey, it was noticed that when carrying out the photo transects at the end of the manta tow, many more individuals could be seen during this closer inspection. All in all, it does seem realistic to consider the densities from the manta to as a good way to compare sites, but not as a way to have precise ideas of the stocks.

2.3.1.3 Photo transect

The photo transect method gives a good idea of the substrate at a given spot. Unfortunately, with a mean distance between transects of 1.25 km, transects are not always in a place representative of the entire reef. Even reefs usually have a number of transects on them, the pictures given can be inaccurate at the reef scale. This is why observations by the snorkelers as well as pictures of the area surrounding the transect points are also important.

At the atoll scale, it seems realistic to consider that the picture given depicts the broad scale pattern of the substrate and its cover.

2.3.2 General Discussion about coral reef survey

The rapid assessment survey yields a consequent amount of information and some patterns are emerging from the data collected. In particular, it seems that the recovery from the 1998 bleaching event, which is still the main event explaining low coral cover in this atoll is not homogeneous. Some reefs seem to have regained a pre-bleaching coral cover, while some still are in poor condition. This is especially true of the reefs located on the rim of the atoll. Goidhoo atoll seems to be in a healthier state than most other reefs submitted to higher wave energies. The inner reefs having poor coral cover constitute an enigma, and it is not sure whether these sites are limited in recruitment (especially of Acroporid species), or if the survival on these reefs is poor for different reasons and that these causes should be addressed. All in all, it does seem that the corals are slowly recovering. The Status of the coral reefs of the world of 1998 states that the live coral cover in the Maldives is excellent, often exceeding 75 % as a pre-bleaching baseline. With an average of 22 % of live coral cover on all the transects, the reefs of Baa atoll are still very different of what it was only a bit more than 10 years ago.

The different species other than corals, which seem to show expansionist evolutions, such as sponges (Rutzler & Muzik, 1993), zoanthids and corallimorphs (Moostleiner, 1989; Kuguru, 2004) are a further threat. The sponge *Terpios*, which is largely present on the healthier reefs seems of particular importance, as it does cover and smother live corals.

In the absence of other studies using the same technique, it is presumptuous to draw conclusions as to what a “healthy” stock of the different fish retained as indicators would be.

Nonetheless an attempt will be done here in light of the activities usually carried out by stakeholders on the reef.

It is difficult to tell whether the densities of the different invertebrate species are in balance and reflect a natural distribution of these species. The giant clam's fishery has been prohibited since 1992, and was only carried out in 1991 and 1992. There are also no accounts of illegal giant clams fishing or export, and therefore it is fair enough to assume that the population levels of these animals is satisfactory, with difference in distribution imputed to ecological factors rather than human pressure. This is also valid for the pin cushion sea star (*Culcita schmedeliana*), and given that this coral predator is not drastic, and that the dead coral with algae and recently dead corals do not correlate with the highest densities of these animals, it does not seem to pose a threat at the atoll scale. On the other hand, with only 7 crown of thorns (*Acanthaster planci*) noticed on the reef, it seems that we are far from any serious levels of infestations. Nonetheless, these all being present at a same site, it should be kept under scrutiny. On the other hand, the sea cucumber population seems to be in a severe imbalance, with very low diversity and very high abundance of one species. It is also well known that the sea cucumber fishery, carried out using scuba diving equipment, even though forbidden is depleting the Maldivian stocks of all the more valuable species and those of Baa atoll are no exception. The results from the present assessment emphasize the urgency to manage this fishery better.

The case of the lobster fishery is similar to that of the sea cucumber. From this study, it would seem that the lobster stocks are alarmingly low. As the manta tow can easily be dismissed as a good method to assess the health of the lobster stocks, it is urgent that more is done to understand this fishery better and try to manage it. This is all the more important and feasible that lobsters are almost entirely consumed in resorts so that stakeholders all have interests to manage this fishery well.

Humphead parrotfish are not a favourite in the Maldivian diet, and are usually not caught. They were not seen during the survey, but these fish are relatively rare in the Maldives. Therefore, the survey team is not surprised not to have seen any during the survey.

It seems that the number of napoleon fish encountered is quite satisfactory. Protected by law and export banned this fish is not a target to reef fishermen. In places rather large aggregations (up to 10 individuals) have been spotted. This species is quite indifferent to the boat and snorkeler intrusion and being quite distinct even from afar, the counts of napoleon fish are more reliable than many other species. They have been seen exclusively on rim reefs.

On the other hand, the shark sightings are very few. This could be due to the manta tow method, but has also been confirmed by the dive schools in the atoll, who rarely see sharks. It does look like the shark population is far below satisfactory levels. On the more positive note, a 4 foot tiger shark was caught and released near Vakaru, proving that this species, although rare is still present in the atoll.

The validity of the manta tow method for the groupers counts is open for discussion. Some species have been very seldom seen, and in the big groupers categories, most of the sightings are that of *P. laevis,* while *E. fuscoguttatus* was rarely seen. Still we are not sure how this can be interpreted, as *P. laevis* has a better market value than *E. fuscoguttatus*. This last species is more cryptic and stays in caves and rocks, while the *Plectropomus* are often seen swimming above the reef and therefore much more obvious. Often a few individuals are seen together and it seems important to conserve areas where large individuals would be left. Indeed, large individuals spawn a lot more than smaller individuals, and therefore leaving no-go zones seems to be a better option than have size regulations. Once again, specifics of larval dispersal around the atoll would be some interesting information to possess to maximize the recruitment. For the small groupers, it seems that the numbers seen are quite high and that the stocks are not dramatically depleted, despite *C. argus* and *V. louti* being some of the most fished grouper species. The grouper monitoring effort should further be strengthened to ascertain this.

The turtle distribution is lending itself to more possible explanations. The number of hawksill turtles (*Eretmochelys imbricata*) is so high compared to that of the green turtle (*Chelonia mydas*) that it seems reasonable to think that beside species discrepancies', the impact of poaching on the green turtle (*Chelonia mydas*) is not negligible. The Maldivians traditionally prefer the green turtle over the hawksbill, and therefore tend to catch them in larger numbers, even though this does not appear to have been reported so far. The difference in population is all the more unexpected that the hawksbill turtle has a more stringent protection status according to IUCN. As mentioned before, it also seems that the hawksbill would benefit from the areas heavily colonized by zoanthids, whereas the green turtles are found in areas closer to sea grass. It could be that Baa atoll is globally important for the hawksbill population and therefore protection measures should be further developed.

Sea birds are not judged to be over-abundant or diverse from the present survey. It is clear that a more specific studies focusing on them would be welcome. The growing number of islands being utilized around the atoll makes it quite important to preserve some of them to insure bird protection. Even though many sand banks are colonized by the birds it has been noticed that if this habitat was to disappear, a number of nesting sites would be lost. It was already observed that some birds were flocking on a small sand bank to eventually have to leave it altogether with the rising tide.

If the overall conditions of corals on the reefs around the atoll seem quite good, given the recent devastating 1998 bleaching event, some imbalances seem to be present. Whether these imbalances are responsible and to what extent for a slowed recovery of the reefs in terms of corals are not clear. A lot of uncertainties remain in the interpretation of the data, but a continued effort would probably yield a wealth of information useful to the management of the reefs. A number of questions would also need to be scrutinized to understand reef processes and in particular creeping threats such as expansionist species noticed on several reefs. On the negative sides and keeping in mind the flaws in the data mentioned before, it seems that some illegal activities or unmanaged fisheries have an impact on targeted animals stocks. This is true in particular for sea cucumbers, lobsters and sharks, while a lot of uncertainty remains as to the grouper fishery, especially when it comes to the larger species targeted by the most lucrative live trade market.

3 Associated habitat description

3.1 Seagrass beds

There are four sea grass beds present in Baa atoll, and their presence is quite recent. These are located near the inhabited islands of Goidhoo, Thulhaadhoo, Hithaadhoo and Dhonfanu. The first three sea grass beds were visited, while the Dhonfanu one was not. The survey consisted of a visual assessment of the area, with some photographs of the most important features taken for the records.

3.1.1 Thulhaadhoo seagrass bed

The seagrass in Thulhaadhoo was located on the eastern side of the harbour entrance, and was split in two parts by the channel on its left side (figure 3.1). The surface of both parts of the seagrass estimated from satellite photo mapped with GIS was 10.52 ha. Its shape was more or less triangular, with limits delineated by the sandy area of the reef flat. It was orientated approximately toward the north-east, and the current was fairly strong. Water depth was shallow near the island, but got deeper seaward, reaching 2.5-3 m depth.

Figure 3.1. Thulaadhoo and its seagrass in the east.

Following the same pattern, the seagrass was dense close to the island, and became less and less dense away from the island (figures 3.2 and 3.3). The seagrass flora community was largely dominated by *Cymodocea* sp., displaying a moderate plant height around 15-20 cm. Other seagrass phanerogames with long and thin leaves were observed, which probably belong to *Syringodium isoetifolium* or less likely to the genus *Halodule*. Green algae were present with small patches of turf algae (*Enteromorpha clathrata*) in sandy places, and small brushes of *Halimeda* sp. (possibly *H. opuntia*, Fig. 3.4) between seagrass rhizomes.

Figure 3.2. The seagrass near the island

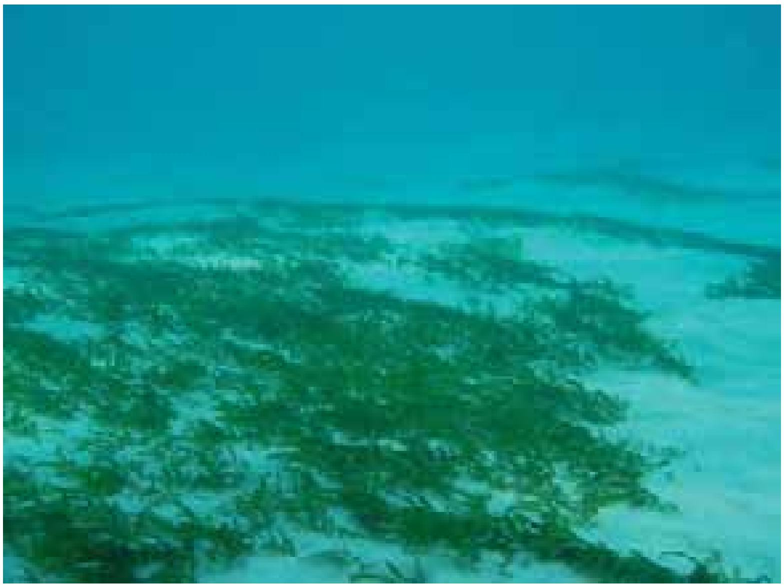

Figure 3.3. The seagrass far from the island

Sessile life was also represented by coral bommies scattered in the seagrass, either soft coral, like the blue coral *Heliopora coerulea*, or stony corals. Stony corals were fairly diverse, with four species recorded: *Acropora aspera*, *Pseudosiderastrea tayami*, *Pavona sp.* and a mushroom coral of the Fongiidae family, probably *Halomitra sp.*(Fig. 3.5)

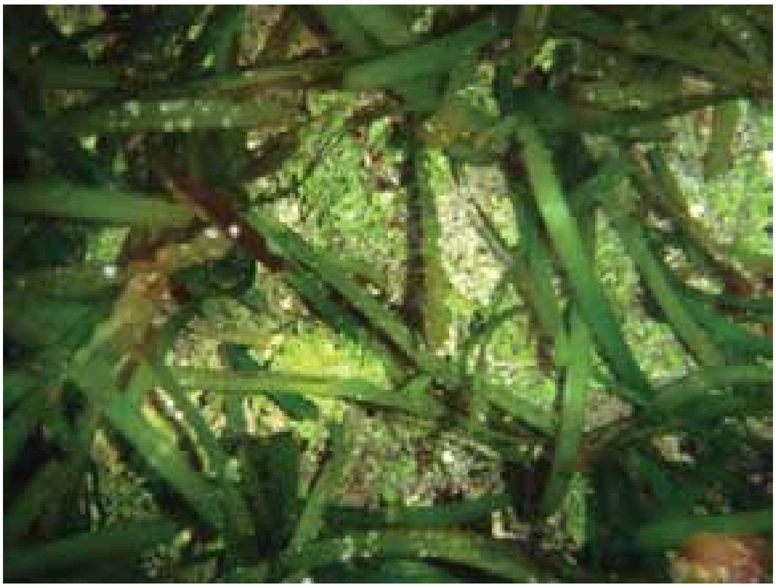

Figure 3.4. The algae *Halimeda* sp. between the *Cymodocea* rhizomes

Figure 3.5. *Acropora aspera* on the left and a mushroom coral on the right

The associated fauna observed appeared to be quite rich, especially concerning echinoderms and fishes. A shell and a crustacean were encountered as well. Among echinoderms, two sea urchins (the cake urchin *Tripneustes gratilla* (Figure 3.6), and another sea urchin *Heterocentrotus sp.*, probably *H. mammilatus*), one sea cucumber (either marmorate sea cucumber *Bohadschia marmorata*, or *B. subrubra*) and one sea star (the cushion sea star *Culcita schmedeliana*) were photographed. The shell observed belonged to the genus *Cyprea* and the crustacean was the hermit crab *Dardanus megistos* (Figure 3.7).

Figure 3.6. The cake urchin *Tripneustes gratilla*

Figure 3.7. The hermit crab *Dardanus megistos*

Six species of fishes were photographed: two wrasses, *Labroides dimidiatus* (Fig. 3.9) and *Halichoeres sp.*, one goatfish *Parupeneus macronema* (Fig. 3.8), one damselfish

Chrysiptera biocellata, one goby *Amblygobius semicinctus* and one surgeonfish of undetermined species.

Figure 3.8. Goatfishes and wrasses between the seagrass and the sand

Figure 3.9. Goatfishes and a cleaner wrasse in front of a blue coral

3.1.2 Hithaadhoo Seagrass

The seagrass was on the western side of Hithaadoo and spread from the shore to the reef crest, in a north-west direction (Figure 3.10). The surface of the seagrass, estimated from satellite photo mapped with GIS was 27.30 ha. It occupied most of the inner reef of the west part of Hithaadhoo, which was very flat and shallow (< 1.5 m depth) with a weak current.

Figure 3.10. Hithaadhoo and its seagrass on the west.

The phanerogames were quite dense and fairly uniform all over the seagrass, with clear limits near the reef crest. The plant heights were also uniformately short (height < 5-10 cm) in all surveyed parts of the seagrass. As in Thulaadhoo seagrass, plants of the genus *Cymodocea* were predominant in Hithaadhoo seagrass. However, quite large and mixed patches of equal proportions *of Cymodocea sp.* (Fig. 3.11) and another species likely to be *Syringodium isoetifolium* (Fig. 3.12) were observed. In these mixed patches, the density became very high.

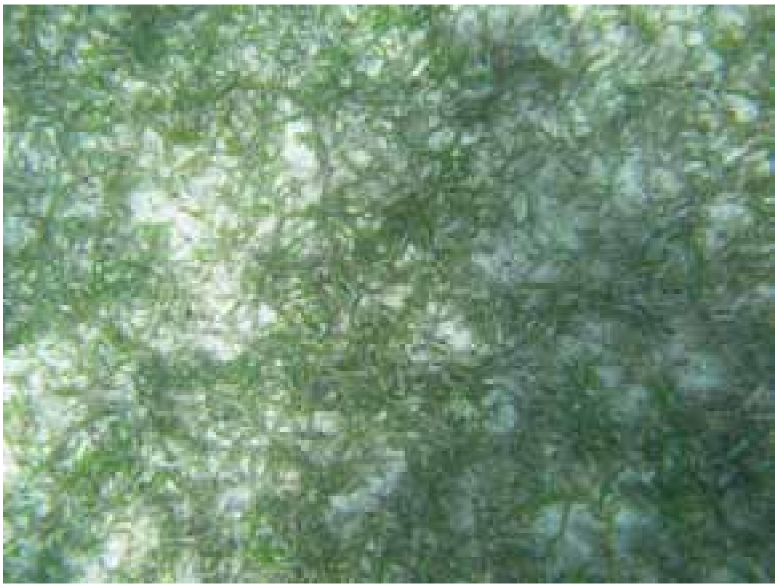

Figure 3.11. Short and moderately dense *Cymodocea* sp. seagrass

Figure 3.12: Very dense mixed patches of *Cymodocea sp*. and *Syringodium isoetifolium*.

Among *Cymodocea sp.*, we observed massive coral bommies (Fig 3.13), constituted by different species of *Porites*. On these massive coral bommies, coralline algae and bubble algae *Valonia sp.* were present, as well as other coral colonies of *Turbinaria stellulata* (Fig. 3.14) and several individuals of the clam *Tridacna sp.* had settled. In addition to the massive bommies, small coral colonies of *Porites rus*, *Porites cylindrical* (Fig. 3.15) and *Pavona sp.* were encountered from place to place.

Figure 3.13. Massive coral bommy of *Porites*.

Figure 3.14. *Turbinaria stellulata*, coralline algae and bubble algae *Valonia* sp. on a massive coral

On the sand between *Cymodocea* patches two echinoderms were observed, the cushion sea star *Culcita schmedeliana* and the arthritic spider shell *Lambis chiragra arthritica* (Fig 3.16)

Figure 3.15. Small colony of *Porites cylindrica*, with picasso triggerfish on top of it

Figure 3.16. Arthritic spider shell *Lambis chiragra arthritica*

Finally, six species of fishes were recorded. The cigar wrasse *Cheilio inermis* was the most abundant, swimming in small schools above the seagrass. Four other fishes were photographed around the coral colonies: the citron butterfly fish *Chaetodon citrinellus*, the threadfin butterfly fish *Chaetodon auriga*, the picasso triggerfish *Rhinecanthus aculeatus* and the convict surgeonfish *Acanthurus triostegus* (Fig. 3.17) One individual of four-saddle grouper *Epinephelus spilotoceps* (Fig. 3.18) was seen near a hole filled with detritus in a sandy patch.

Figure 3.17. Convict surgeonfishes and a young citron butterfly fish near coral bommies

Figure 3.18. The four-saddle grouper *Epinephelus spilotoceps* near a hole in the seagrass

3.1.3 Goidhoo Seagrasses

The seagrasses in Goidhoo were located in four places (Fig 3.19): one west of the harbour which was the most developed (estimated surface 10.26 ha), one in front of both the harbour and the mangrove (estimated surface 6.73 ha), and two small ones in front of the eastern beach (estimated surface 1.26 ha) and northern beach (estimated surface 0.68 ha) of the island which were not surveyed during the monitoring.

Figure 3.19. Seagrasses and Mangrove of Goidhoo.

The most developed seagrass extended westward on solid bottom covered by sand and vegetal debris. The westward extension of the seagrass was limited by the currents entering the atoll by the main northern channel. The limit of the seagrass toward the reef is then likely to evolve with sediment transport. Above the seagrass, currents were mild, the bottom was flat with the exception of some riddle marks and the water was shallow (< 1.5 m depth).

Phanerogame cover was fairly dense and the plant height was very short (max height of 5 cm). The seagrass was composed of only one species, belonging to the genus *Cymodocea* (Fig 3.20). In between the rhizomes, small but very frequent patches of *Halimeda sp*. and turf algae (*Enteromorpha clathrata*) had developed (Fig 3.21, 3.22).

Figure 3.20. Fairly dense and short seagrass of *Cymodocea* in west Goidhoo.

Figure 3.21. Patches of vegetal debris and algae between the rhizomes.

Not much fauna had been observed within this monospecific seagrass (*Cymodocea sp.)*, which was, from a diversity point of view, much poorer than the two previous seagrasses surveyed. We observed one mollusc, the giant frog shell *Bursa bulbo* (3.25), one nudibranch identified as Forskal pleurobranchus (*Pleurobranchus forskalii*, Fig. 3.24) and two fish species, one flutemouth (*Fistularia commersonii*, Fig. 3.23) and several schools of cigar wrasse (*Cheilio inermis*), again the most abundant fish.

Figure 3.22. Small patches of *Halimeda* and turf algae among *Cymodocea*.

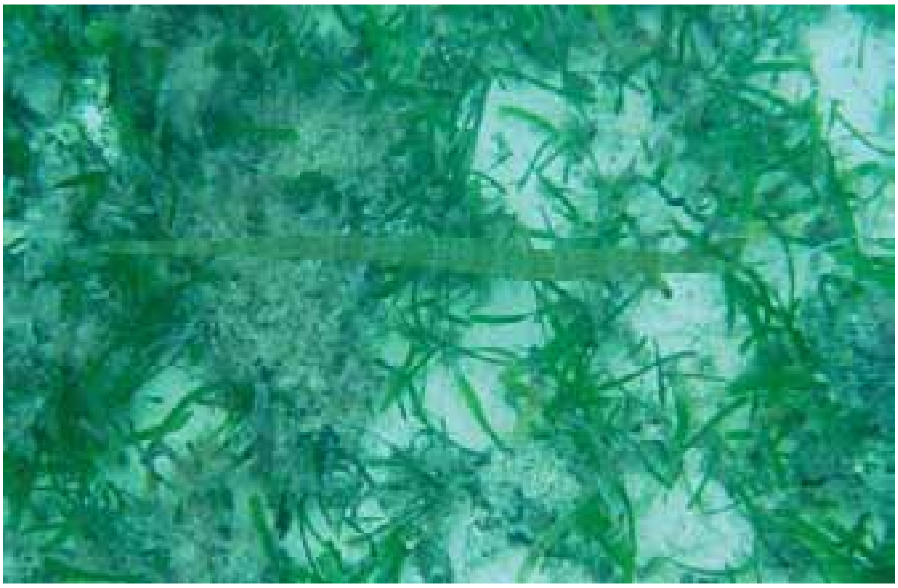

Figure 3.23. The flutemouth *Fistularia commersonii* above the seagrass

Figure 3.24. The nudibranch *Pleurobranchus forskalii.*

Figure 3.25. The giant frog shell *Bursa bulbo*.

The seagrass bed situated right in the north of the harbour was split in two parts by the harbour entrance. Its eastern part developed in front of the mangrove and was delineated in the north by the reef crest. The seagrass settled on the reef flat where important amounts of material were transported by the waves flowing above the crest. Wave currents were strong and the seagrass development was very irregular, being mixed with rubble, sandy and vegetal debris. This particular situation resulted in bad visibility, which, in combination to bad weather conditions, explained why only a few photographs were taken.

However, these photographs allowed us for the identification of the phanerogame genus *Cymodocea* Fig. 3.26, which was more patchy than in the western seagrass but also taller. The associated fauna were composed of the blue coral *Heliopora coerulea*, the foliate sponge *Carteriospongia foliascens* and the shell Giant mitre *Mitra mitra* (Fig. 3.27).

Figure 3.26. Tall patches of *Cymodocea* sp.

Figure 3.27. The shell Giant mitre *Mitra mitra*.

3.2 Mangroves

There are four mangroves in Baa Atoll, the largest one located in Goidhoo. The other two are located in Maamaduvari, in Olhugiri, and in Keyodhoo. Only the most significant of the unprotected mangroves were visited. It is located in the north of Goidhoo island, in an enclosed bay. It extends from the seagrass on its north-west to the reef crest on its northern side. The firm land of the island is present on its south and east sides. The mangrove surface was estimated by GIS to 7.16 ha. The mangrove front developed on the limit between the reef flat and the bay. This pioneering front (Fig 3.28) formed a straight line from the beach near the harbour (west) to the reef crest (east), only separated by two channels allowing for water exchange between the enclosed bay and the reef flat (Fig. 3.29).

Figure 3.28. Northern part of the pioneer front, near the reef crest.

Figure 3.29. The pioneer front with the channels, and the enclosed bay behind.

The front flora was made of well developed mangrove trees, belonging to two true mangrove species:

- *Rhizophora mucronata* (Ran'doo), which is a typical pioneer species with characteristic stilt roots and height above 15 meters. It is the most abundant tree of the front (Fig 3.31, 3.32).
- *Pemphis acidula (*kuredi*)*, with smaller height (5 meters), is less abundant and form sort of brushes, even if it is a tree (Fig 3.30).

The islanders had built some *Holuashi* houses on stilts near the island. In that area, abundant algae growth as well as numerous upside-down jelly fishes (*Cassiopea Andromeda*), which even though only noticed in that area in the atoll is widespread in the indo-pacifique and reaches the Mediterranean sea.

Figure 3.30. The enclosed bay seen from the southern channel. The front is on the left, with *Pemphis acidula* tree.

Figure 3.31. Entire view of a *Rhizophora mucronata* tree in the front

Figure 3.32. Leaves and stilt roots of *Rhizophora mucronata*.

Figure 3.33. Leaves, flower and fruit of *Pemphis acidula.*

3.3 Discussion

In general, seagrass beds are not very extensive in the Maldives and few studies have been carried out on these areas at ecosystem level. However, seagrass surfaces have increased importantly in recent years near inhabited islands, principally in islands where traditional fishing is the main resource (Miller & Sluka, 1999). The increase in sea grass is probably linked to the increased nutrient loads due to change in anthropogenic habits and increased population.

Three out of the four seagrasses that can be found in Baa Atoll (Bers, 2005) were surveyed in the present study. The remaining one, the seagrass of Dhonfanu, is much smaller than the seagrasses surveyed here. These have been found quite healthy, and are probably still in an expansion phase. It does not look like they need special type of protection, but their presence is probably beneficial as it transforms human excess nutriment into biomass.

There is a different concerning the species with the previous assessment (Clark, 2001), which is the unique information on seagrass composition of Baa Atoll. Clark (2001) identified *Thalassia hemprichii* as the main component of the seagrasses, while *Cymodocea* sp. was determined here. On the basis of the photographs, the main reason why the consultants indentified *Cymodocea sp.* rather than *Thalassia hemprichii* concerned the rhizomes, which were not covered by brown scales but were uniformly pale-coloured and displayed regularly spaced shoots (Richmond, 2002). In addition, the absence of old leaf sheaths forming a shaggy mass around base of shoots, typical of *Thalassia hemprichii*, also supports this identification. Moreover, *Cymodocea rotundata* has recently been reported in Vaavu Atoll, south of Male Atoll (Milchakova *et al.*, 2005).

These authors also reported the presence of *Halodule uninervis* in the same Atoll. Besides, neither has the other species of the seagrass been reliably identified between *Syringodium isoetifolium* and the genus *Halodule* sp.

Mangroves are present in four places in Baa Atoll: Olhugiri, Maamaduvvari, Keyodhoo and Goidhoo. The first three mangroves are rather small, and no extensive forest has developed (Bers, 2005), which is also confirmed by the present survey. Outside Baa Atoll, mangrove abundance is low and mangroves are scattered throughout the Maldives. Nevertheless, species richness is fairly high in the Maldives with twelve species. The two predominant species, *Rhizophora mucronata* and *Brughiera cylindrica*, show a clear pattern of distribution: *R. mucronata* is dominant in the south, while *B. cylindrica* is dominant in the north. Then, the dominance of *R. mucronata* in the mangrove of Goidhoo would suggest closer links with the southern atolls than with the northern ones, despite its location north of Male Atoll.

The mangrove in Goidhoo was previously used to dump the garbage, but some efforts were made in its rehabilitation. The islanders built two holuhashi, but it does not look like the effort is sustained at present. It therefore seems judicious to establish a management plan.

4 Existing protected areas

4.1 Dhigali Haa

4.1.1 Presentation

Dhigali Haa or Horubadhoo Thila is located two kilometres south west to Horubadhoo in the Eydhafushi region of Baa Atoll (N05°8.842' E073°2.2430). This site is currently the only gazetted (or use designated) marine protected area within Baa Atoll. The site was nominated for this protection status on 21rst October 1999, based on its importance as a dive site for the tourism industry and gazetted under the nation's 10 year Tourism Master Plan (1996-2005). The sites special dive features included; "grey reef sharks, white tip sharks, Barracudas, bait fish and sea turtles while sometimes dolphins are sited" (MRC, 1999). The following map depicts the area (fig 4.1):

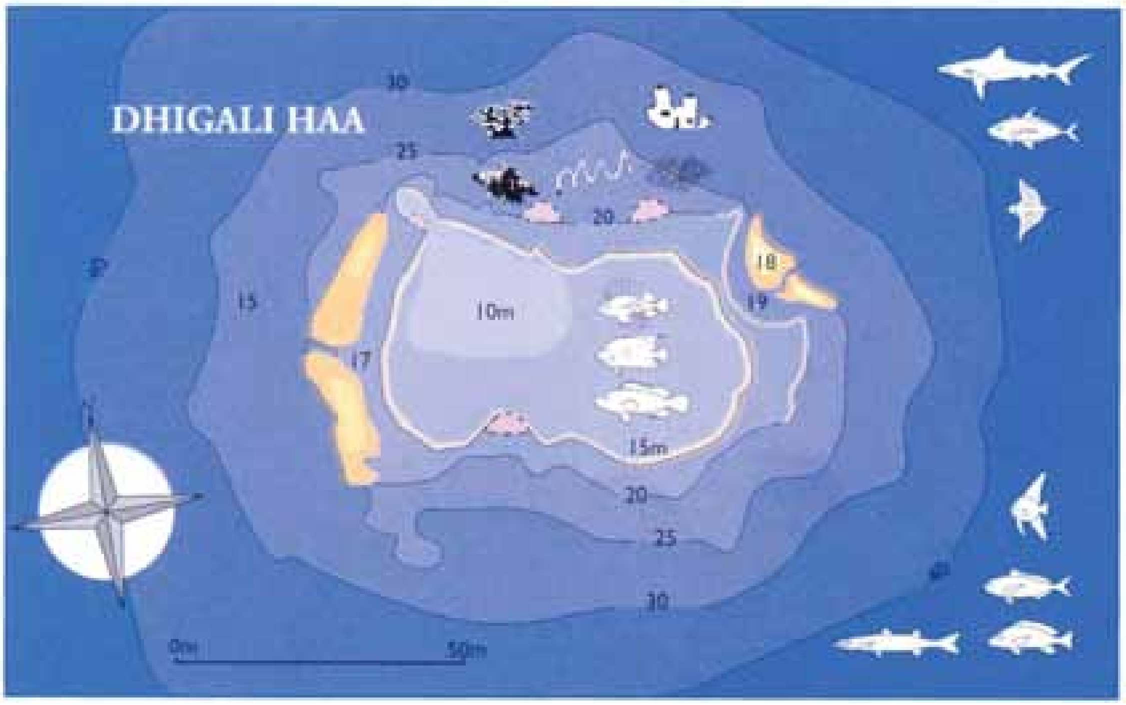

Figure 4.1: Dive map of Dhigali Haa (Godfrey, 2008)

4.1.2 Management

Within this designation the following activities were prohibited:

- Anchoring (except in an emergency),
- Coral and sand mining,
- Rubbish dumping,
- Removal of any living and non living resources,
- Fishing of any kind (with the exception of traditional live bait fishing),
- Any other activity which may cause damage to the area or its associated marine life.

Furthermore the Ministry of Tourism (now referred to the Ministry of Tourism, Arts and Culture) would manage the protected dive sites in association with the local dive companies and present an annual report to the Ministry of Home Affairs, Housing and Environment (now referred as the Ministry of Housing, Transport and Environment) (MRC, 1999).

4.1.3 Description

Dhigali Haa protected dive site is a patch reef surging from the floor of the atoll lagoon, at a depth of around 40 m and a flat top at a depth of 10 m (*thila*). It is characterized by a fragmented structure with massive fractured pieces of the reef top toppled over especially on the western and eastern side. These fractures are probably the result of heavy scouring of the harder reef top and many caves and overhangs are present on the steep walls of the thila. Caves represent the ideal habitat for sponges, black corals and gorgonians and add structural complexity increasing biological diversity at this site. This appears to be a “give-up” reef, where the coral growth has not been sufficient to keep up with the pace of sea level rise, and where due to reduced light conditions, it is unlikely that calcification rates will increase sufficiently for it to progress to the surface in a foreseeable geological future.

The thila is located well away from other reef formations and receives a relatively strong current despite being located inside the atoll. At times though, the water can be turbid and loaded with plankton and small organic debris. As such, the conditions are conducive for an abundant fish feeding aggregation with a wide array of species, from top predators to the smallest species and bait fish.

4.1.4 Method

This site was physically assessed by the consultant (snorkelling) and members of the Baa AEC team in March 2009 and included information derived from video footage of the site supplied by AEC project collected in late 2008.

4.1.5 Biodiversity

Dhigali Haa exhibits an abundant fish fauna. The numerous bait fish shoals (Cupleidae) populating the site, as well as small and larger fusiliers (*Pterocaesio sp.* and *Caesio sps*.), yellow sweepers (*Parapriancanthus ransonneti*) and cardinal fishes (Apogonidae) would supposedly sustained a more abundant population of pelagic or semi-pelagic predator species, as only one dog tooth tuna (*Gymnosarda unicolor)* and a few blue fin trevally (*Caranx melampygus*). The structural complexity of the substrate is an optimal refuge for juveniles and small fish species. A few bushes of black coral (*Anthipathes sp*.) and well developed colonies of the midnight coral (*Tubastrea micrantha*) contribute to this, especially on the fractured rocks.

Overall the hard coral cover and biodiversity is low at the site with few big tabulate (Acropora sp.) corals found on a reef top being otherwise very bare. As previously highlight the depth that characterised the site and the reef features are possible causes for this modest hard coral cover. Coralline algae are abundant, as well as lesser species of dendrophylliidae (non-zooxanthellate corals). An important patch of soft corals, probably *Sarcophyton sp.* is present on the top of the thila especially on the north-western part of the reef top. More of these can be found at the bottom of the slope and in between the fractured rocks. Scattered anemones with clown fishes are well distributed in the shallow part of the reef. In addition, two royal sea cucumbers (*Thelenota anax*) were seen at the site, as well as the two species of clams, *T. maxima* and *T. squamosa*. No crown of thorns sea star (*Acanthaster planci*), and relatively few pincushion sea star (*Culcita schmedeliana*) where spotted. During the visit carried out under this project by the Baa AEC team, manta rays (*Manta birostris*) were also encountered at the site, but no sharks were spotted on any occasions.

The past decade has seen a rapid increase in shark fishing within Baa atoll resulting in severely reduced shark populations. The high and consistent daily shark numbers reported at this site during the 1990's (on average 10-20 grey reef sharks) are no longer recorded (dive operators personnel communication). Godfrey (2008) reports that 5 or 6 grey reef sharks were seen circling over the reef however the assessment team did not locate any sharks during the assessment.

4.1.6 Conclusion

The reef is an interesting dive site, but the biodiversity at the site is more due to physical factors such as topography and currents than biological ones, as the substrate live cover is poor as compared to other reefs in the atoll. Fishing pressure does not seem to have stopped at the site, and is a possible explanation for the absence of a greater array of predator species. This is precisely this absence of predators which makes the site a haven for smaller species, which are present at the site in great abundance. This means that if the fishing stops, the pelagic fish should again find a good feeding site here and gather in higher numbers. This is especially valid for sharks.

4.2 Olhugiri

4.2.1 Description

The island of Olhugiri is located on the most southern island of the main part of Baa atoll. As such, it is on the side of the Kaashidhoo Kandu, facing Goidhoo Atoll. It has to be noted that this 7 nm wide channel, with depth over 400 m, is deeper than the larger part of the Kaashidhoo Kandu separating Goidhoo Atoll and Ari Atoll.

The island is only protected from the predominant swells by Goidhoo Atoll, and receives an important swell both from the southeast and from thesouthwest, which seems to be more energetic, not being refracted by the eastern chain of atolls. The reef exhibits a distinct spur and groove system on the southern side, on the shallower parts of the reef foreslope. This foreslope itself is large and flat, with very low coral cover, and in this resembles all the reefs bordering this section of the Kaashidhoo Kandu. The other two sides of the reef system, which is roughly triangular are less exposed to the swell and there is a better coral cover on the northern side, whereas the eastern side is very sandy, as the sandy tip tends to grow outwards and fall down the slope during the southwest monsoon.

The island has been protected since 2007 under the environment act (4/93), as one of the two known regular site of frigate bird roosting in the country, having many bird catcher trees (*lhos, Pisonia grandis*). The reef has not been designated any protection status. Resource extraction activities are periodically undertaken on the reef systems of this island which includes fishing and turtle egg collection.

4.2.2 Method

The reef was surveyed twice during this assessment, one during the general survey in June 2008, as well as more during a particular survey with the AEC project consultant on 27th March 2009. During this last survey, transect where carried out while snorkeling, and a subset of the biological indicators were counted along belt transects defined by different width and referenced by their geo-coordinates.
The transects details are given in the table below (Table 4.1):

Table 4.1: Transects details

Transect	Geocoordinates Start of transect	Geocoordinates Finish of transect	Wind knots	Sea Conditions	Length (m)
1	05^0 00.148N $072^0$54.500E	04^0 59.945N $072^0$54.565E	>5	Calm	420
2	04^0 59.914N $072^0$54.476E	04^0 59.887N $072^0$54.269E	>5	Calm	390
3	04^0 59.947N $072^0$54.150E	05^0 00.101N $072^0$54.149E	>5	Calm	300
4	05^0 00.198N $072^0$54.250E	05^0 00.101N $072^0$54.149E	>5	Calm	260

A map summarizing the two surveys is shown below (fig 4.2)

Figure 4.2: The mantas tows and survey point during the baseline survey, and the belt transects carried out by the project consultant

4.2.3 Results

Overall qualitative observations were made by the consultant to describe the substrate but also some of the indicators and these are presented in the following table (Table 4.2), while the indicator species recorded during the consultant's survey are presented in the next table (Table 4.3)

Table 4.2: Substrate description relating to consultant survey transects

Transect Number	Dominant Substrate Types	Dominant Benthic Forms	Dominant Hard Coral Morphological Form and Genius
T1	Sand & small coral rubble interspersed with medium to large coral rock.	Sand and small coral rubble dominate the reef flat and slope. Coral rock increases towards the open sea (exposed region) and is located on the reef edge and slope.	Small and medium size Porites sp, small branching *Pocilipora sp*. *Heliopora coerulea*, branching and small tables of *Acropora sp*. and soft coral *Sarcophyton sp.* dominated the reef edge and slope. High populations of the pin cushion

		Shoreline dominated with coral rubble.	starfish *Culcita schmedeliana*.
T2	Hard substrate dominates reef flat and edge. High wave area. Low number of coral heads.	Reef flat and edge flat, limited lose rubble and sand with spur and grooves close to shore. Shoreline dominated with coral rubble.	Very small numbers of coral colonies located on reef edge and flat. Dominated by Porites sp, branching *Pocilipora sp*. *Heliopora coerulea* and Acropora sp. branching and small tables and soft coral *Sarcophyton sp.* The pin cushion starfish *Culcita schmedeliana* present in low numbers. High wave energy region with high coverage of cropped turf algae.
T3	Hard substrate dominates reef flat. High wave area dominated by spur and grooves. Low number of coral heads	Reef flat dominated by spur and grooves, limited lose rubble and sand with spur and grooves close to shore. Shoreline dominated by coral rubble. Coral colonies (small) increase once reef edge located.	Very small numbers of small coral colonies located on sections of the spur and groves. Dominated by branching *Pocilipora sp*., Acropora sp. and *Heliopora coerulea*. . High wave energy region with high coverage of cropped turf algae and red and green coralline (*Halimeda sp.)* algae.
T4	Hard substrate dominates reef flat and edge. Reef edge undulating including some crevices with reef slope distinctive from 4 – 12 meters.	Coral colony coverage increasing on reef edge and slope. Sand dominates shore line.	Small and medium size Porites sp, small branching *Pocilipora sp*. *Heliopora coerulea*, branching and small tables of *Acropora sp*. and soft coral *Sarcophyton sp.* dominated the reef edge and slope. Low numbers of the pin cushion starfish *Culcita schmedeliana*.

Table 4.3: Indicators recorded during the consultant survey:

Location Site	Transect Number	Water Depth (m)	Transect Length (m)	Transect Width (m)	Hawksbill	Mollusc Clams, Oysters,	Sea Cucumber	Coral Cover	Finfish
Olhughiri	T1	2-10	420	6	0	1 Ts 22 Tm	3 Pg	5	A3, B9, C1, D1, 6 Others
Olhughiri	T2	4-8	390	10	1	2 Tm	3 Pg	>1	A1, B9, D3 12 Others
Olhughiri	T3	1-3	300	4	1	1 Ts 3 Tm 1 Lambis sp.	0 Pg	>2	B1, 3 Others
Olhughiri	T4	3-8	260	8	0	3 Tm	3 Pg	>5	B7, D2, 4 Others

A = Coral Trout (*Plectropomus laevis*).

B = Peacock (*Cephalopholus argus*).

C = Napoleon Wrasse (*Cheilinus undulatus*).

D = Coronation Trout (*Variola louti*).

Tm = *Tridacna maxima*.

Ts = *Tridacna squamosa*.

Pg = *Pearsonothuria graffei*

These results have been correlated with the results obtained during the baseline biological indicator survey and are presented in the following table (Table 4.4). To render the comparison meaningful, all the values have been calculated to represent the number of sightings per km.

Table 4.4: Comparative results of the two surveys; the baseline survey (BS) with references to provided data set and the consultant survey (CS).

Reference	Hawksbill	Clams	Sea Cucumber	Napoleon wrasse	Plectro pomus	Cephalo pholis	Variola	Other
MA1016DHO	1.15	3.44	2.29	0.00	0.00	6.88	1.15	3.44
MA1017DHO	0.00	7.70	3.08	0.00	0.00	4.62	0.77	2.31
T1	0.00	54.76	7.14	2.38	7.14	21.43	2.38	14.29
T2	2.56	5.13	7.69	0.00	2.56	23.08	7.69	30.77
T3	3.33	13.33	0.00	0.00	0.00	3.33	0.00	10.00
T4	0.00	11.54	11.54	0.00	0.00	26.92	7.69	15.38
Average BS	0.57	5.57	2.69	0.00	0.00	5.75	0.96	2.88
Average CS	1.47	21.19	6.59	0.60	2.43	18.69	4.44	17.61
BS/CS	0.39	0.26	0.41	0.00	0.00	0.31	0.22	0.16

It appears that the two methods are consistent in relative amplitude between indicators, but that the manta tow, effectuated at much higher speed under-evaluates the number of indicators present, and record about one third of the ones seen during a snorkel. Of course, many different factors such as weather, time or tide could also explain the discrepancies noted.

In addition, during the baseline survey, three photographic transects were carried out, and the first level details is given in the following table (Table 4):

Table 4.5: photographic transects results from baseline survey

Reference	Live_Coral	Others	Algae	Abiotic	Dead_coral	Shade
TA1015DHO	7.2	0	11.2	81.6	0	0
TA1016DHO	19.2	0	16.8	63.2	0.8	0
TA1017DHO	2.4	0	16.9	80.7	0	0.8

4.2.4 Discussion

The coral cover seems to agree on the southern side, which has a very low cover. The first transect closer to the reef crest records the slightly better coverage thanks to a number of small porites present when moving towards the reef edge, while the third transect, higher on the foreslope gives a lower cover, in keeping with the > 1 % of the consultant survey. On the other hand, the photographic transect on the northern side gives a better coral cover as compared to the consultant survey, 19.2 % against > 5 %, this value would be one of the lowest for a Baa atoll lee side reef.

Hawksbill turtles have been spotted on both occasions, whereas the coral trout (4 sightings) and the napoleon wrasse (1 sighting) have only been seen during the slower survey. The other groupers species where seen in similar proportion during both surveys. All these indicators are not in particular abundance compared to the rest of the atoll (fig 2.6-9).

The sea cucumber *P. graffei* was the only one present in quite low numbers (fig 2.14). The pincushion sea stars were quite abundant with one of the manta tow ranking 15th in density from around the atoll (2.15). Both species of clams are present but in rather low numbers (fig 2.13).

None of the other biological indicators, such as green turtles, sharks, humphead parrot fishes, lobsters, black corals, winged pearl oyster or bait fish was sighted.

Overall the reef does not exhibit tremendous biological interest. Even though some fishes are present, the low coral cover makes it not such an interesting on a conservation point of view, especially in comparison to other reefs in the atoll. Nonetheless, as the island is protected, it is probably better to include the reef in the protected area.

5 Areas of biological significance

5.1 Hotspot sites

5.1.1 Methods

The maps of hotspots were computed by determining sites yielding exceptionally high densities of different key indicator species. In these places, the densities are exceptional enough to suspect that some special processes are potentially occurring at the site.

Hotspots of key indicator species were grouped in thematic maps according to their potential interest for four categories: tourism, fisheries, other species important for biodiversity and species representing a potential threat for the reef or symptomatic of an imbalance (thereafter called ‘coldspots’). Similar groups will later be used in the section about diversity indices.

Four groups of species collected with manta tows were selected as being species of special interest to the tourism industry: the green turtle, the hawksbill turtle, the Napoleon fish and all sharks encountered, considered as one indicator without detailing species. In addition to the species collected with manta tows, live coral cover was also taken into account.

With respect to fishing industry, two groups of species were first selected as being species of special interest: the little groupers (*Cephalopholis argus* and *Variola louti*) and the big groupers (*Plectropomus laevis*, *Epinephelus fuscoguttatus* and other *Epinephelus* sp). Furthermore, the lobster *Panulirus versicolor* was also added, since this resource is sold by fishermen as resort food supply.

Four other invertebrate species were commonly observed and are of interest for assessing biodiversity: it was then important to show their hotspots. One of them is the black coral. The three other species are invertebrates, namely the sea cucumbers, the clams and the sea stars. The sea cucumbers encountered were at least 90 % *Pearsonoturia graeffei*, which is of no interest to fishermen, *Stichopus chloronotus* accounting for most of the remaining sightings. Given the very large number of pin-cushion sea stars encountered as compared to crown-of-thorn, this map actually reflects pin-cushion sea stars hotspots. A detail of crown-of-thorns sea star highest densities is provided further in ‘coldspots’ map.

The map of ‘coldspots’ was made in order to identify sites with high proportions of organisms potentially dangerous for reefs health and diversity. It can be discussed whether these variations from the predominant and expected ecosystem are pockets of a different biodiversity or symptoms of a problematic imbalance. In any case, some attention should be drawn towards these peculiarities. The list of the key indicators selected includes two direct predators of coral colonies: the crown-of-thorn sea star (*Acanthaster planci*) and the pin-cushion sea star (*Culcita schmedeliana*). Both these species are reported to feed on corals. Moreover, four other types of benthic organisms, observed on the substrate and showing inthe photo-transects, have the potential to become invasive species. The could outcompete corals or impair the recruitment of coral colonies, which could in turn result in problematic changes in reef ecology. These are the zoanthid, *Zoanthus mantoni,* the corallimorph *Discosoma* and the grey sponge *Terpios hoshinota*, as well as to a lesser extent ascidians. Therefore six species or class of species were identified and represented on the coldspots map.

5.1.2 Results

5.1.2.1 Hotspots of key indicator species of special interest for tourism

With respect to each species, hotspots are quite widely distributed over Baa atoll, even though the eastern part of the main atoll does not present the same interests (figure 5.1).
Seven hotspots have been selected for the live corals ranging from 79.2 to 89.1 % cover. Sites were concentrated in the centre of the atoll with the highest percentages at R9, R11, R4, R2 and Nibiligaa. Two other sites with respectively 85.5 and 79.2 % of live coral cover were situated in the inner reef in Goidhoo atoll, in front of Innafushi.

Three hotspots have been selected for the green turtle *Chelonia mydas*. Highest density was recorded at Hitaadhoo with 2.9 turtles per km. Two of the hotspots (Hitaadhoo and Angaafaru) may be associated with sea grass beds (in Dhonfaanu for Angaafaru). The third hotspot, situated in Vakkaru with 2.35 turtles per km, is not associated with sea grass. Another point is that no green turtle were sighted in the vicinity of the Goidhoo sea grass beds.

Seven hotspots were identified for the hawksbill turtle *Eretmochelys imbricata*, ranging from 8.9 to 5.2 individuals per km. From the seven hotspots, two were located in Bathalaa, in the north of Baa, with respectively 8.9 and 6.4 turtles per km and four were located on the outer western reefs of Goidhoo atoll. Last hotspot was in R9. There seems to be a relation in the northern site and in R9 with high density of Hawksbill turtle correlating with an important benthic coverage of the zoanthid *Zoanthus mantoni*. This observation does not hold for the periphery of Goidhoo atoll.

Five hotspots were identified for the napoleon fish *Cheilinus undulatus*. The two sites with the highest densities were located in the south-west of the main Atoll in Thulhaadhoo (5.4 indivuduals per km) and Maahuruvalhi (6.6 individuals per km). The three other sites were situated on the outer reefs of Goidhoo, in the north and the west, ranging from 5.3 to 3.9 individuals per km (ind.km^{-1}).

Sharks were quite rarely observed during the survey; therefore it is difficult to talk about 'hotspot' for only few observations. Nevertheless it seems important to indicate the sites where they were present during the monitoring. Three manta tows recorded the presence of black tip shark, in Bodugaa falhu (1 individual), Kihaadhoobinmatheefaru (1 individual) and Vakkaru (2 individuals), all situated inside the main atoll of Baa. Grey reef shark was only observed once at Hanikandu faru. Finally, from the nine other sharks observations, four have been identified as being nurse shark *Ginglymostoma cirratum*. Highest densities were recorded in Bodugaa falhu (2.1 ind.km^{-1}), R6 (1.2 ind.km^{-1}) and Funadhoo (1.05 ind.km^{-1}), all situated inside the main atoll of Baa.

A clear lack of conclusive data concerning manta rays and whale shark impedes a clear picture of the seasonal presence of these animals. Hanifaru is the most famous spot for the observation of these large plankton feeders, and already well visited by the guests of the different resorts. The Four Seasons already collects data through their manta ray and whale shark project and some reliable secondary data could be explored. What could be obtained from the resort has been included in paragraph 4.3.3.2.6 below. It is therefore mentioned here for inclusion in the final site choice for protection even though the site has little else to speak for itself with the chosen indicators.

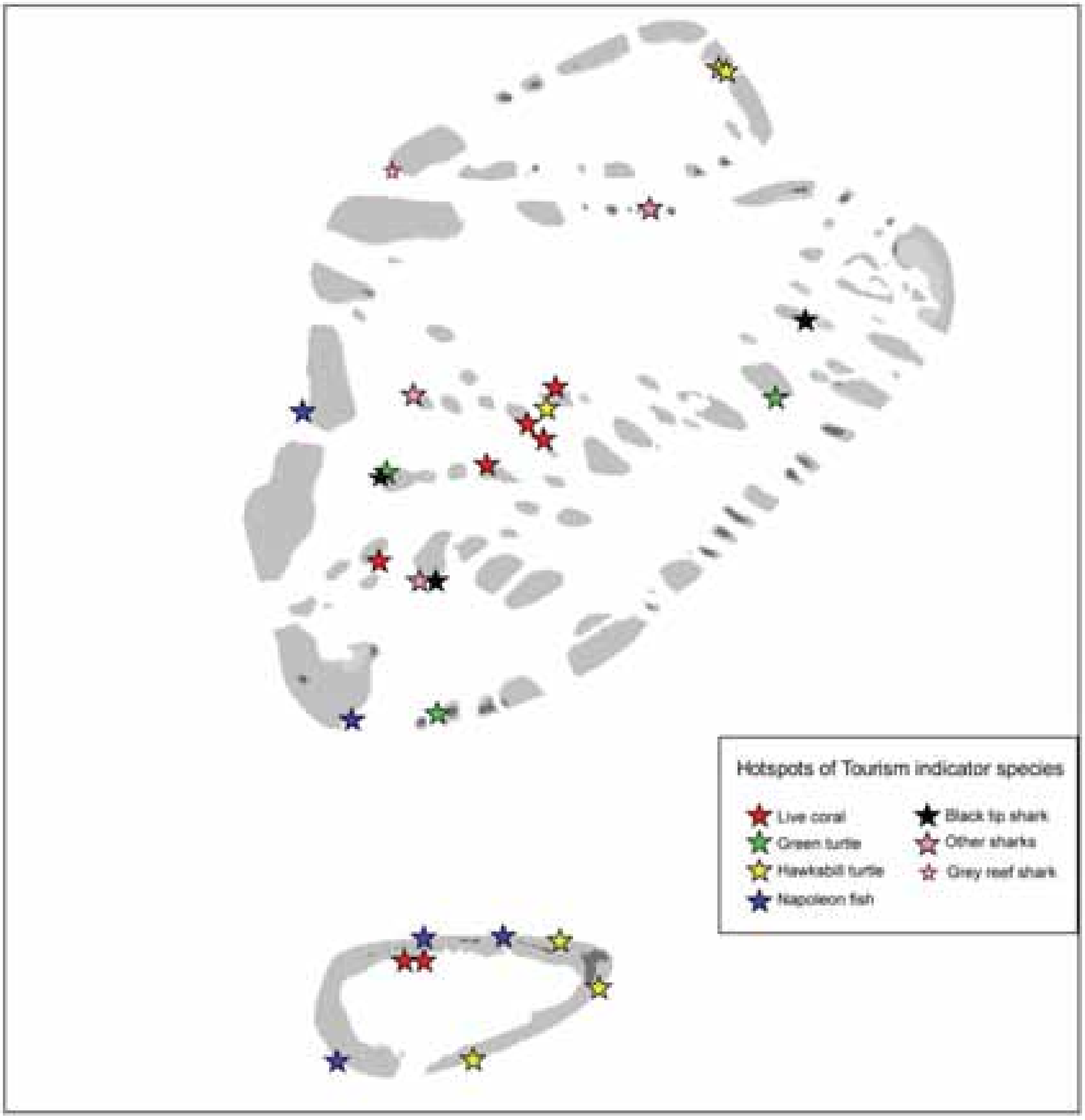

Figure 5.1. Hotspots of species of special interest for tourism

5.1.2.2 Hotspots of key indicator species with special interest for fisheries

The map of hotspots of fished species (figure 5.2) indicates that most of the hotspots were located on the south-western part of the main atoll, with few sites in the north-eastern part. No hotspots were situated in Goidhoo atoll.

Nine sites were identified as being hotspots for little groupers, ranging from 38.6 to 30.6 individuals per km. Three sites were located in the north at Vinaneiyfaruhuraa, Landaa

Giraavaru and Reethi Beach. The rest of the sites were all grouped in the south west of the main atoll, from Maahuruvalhi to Maamaduvvaree.

Three hotspots have been identified for the big groupers : Vakkaru (9.4 $ind.km^{-1}$), Keyodupperu (5.9 $ind.km^{-1}$) and Hibalhidhoo (4.9 $ind.km^{-1}$).

Five sites were identified for lobsters hotspots. One was located in Reethi Beach in the north east part , all the other sites were gathered on the west reefs inside the main atoll. Densities ranged from 8.7 individuals per km (R1) to 5.02 individuals per km (R6).

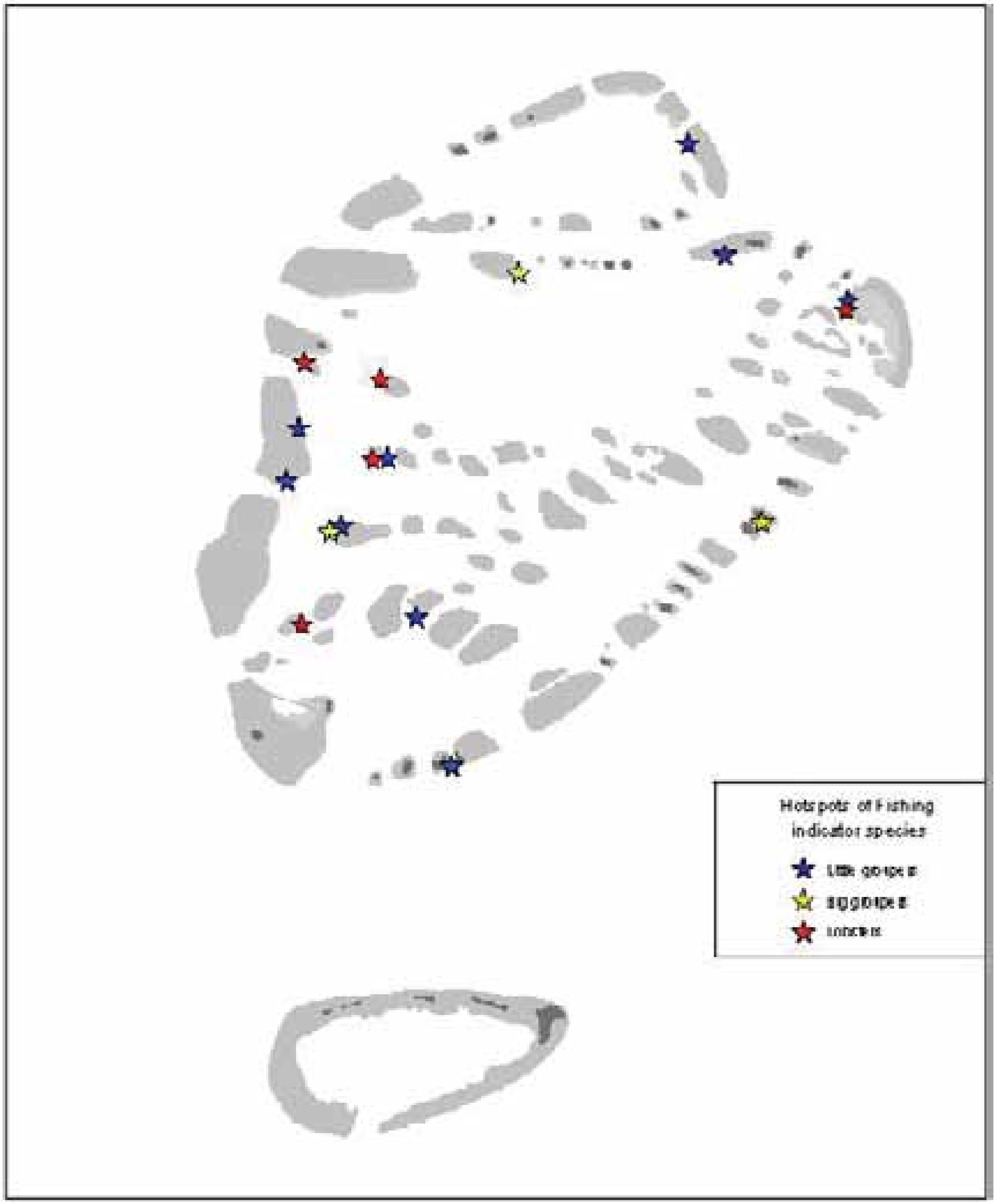

Figure 5.2. Hotspots of species of special interest for fisheries

It has to be pointed out that two important sites for snappers were identified on the western part of Maahuruvalhi and Maa Faru in the north of Thulaadhoo, but these would need to be revisited over time to understand if they are permanent and caused by a special configuration of the reef or seasonal and present during the southwest monsoon only.

5.1.2.3 Hotspots of invertebrate key indicator species and black coral

Figure 5.3 shows the map of hotspots for the key invertebrate indicator species of interest for biodiversity that were not described in the two former maps. Here again we can observe that hotspots, with respect to each species, are distributed all over Baa atoll. No hotspots were identified in Goidhoo.

Four sites were selected as hotspots for the clams (*Tridacna* sp). Two were located in the same reef, Nagilifalhu, in the centre of the main atoll, and two were located in the eastern part of the main atoll at Dhigufaru and Mudhdhoo. Hotspots densities ranged between 84.7 and 141.7 ind.km^{-1}

Four sites also were selected as hotspots for the sea star *Culcita schmedeliana*. The two highest densities occurred in Keyodupperu (76.9 and 60.2 ind.km^{-1}). The other two hotspots were located in Hanikandu faru (58.1 ind.km^{-1}) and Maaneigaa (52.9 ind.km^{-1}).

The three hotspots of sea cucumbers were distributed in a line between Hanikandu faru (94.1 ind.km^{-1}), the north part of Binmathee faru (39.9 ind.km^{-1}) and Nelivarufinolhu (45.7 ind.km^{-1}).

Hotspots of black coral *Antipathes* sp. were located in the north of Baa; the two highest densities occurred in Reethi Beach (48.4 and 21.8 colonies.km^{-1}). Two other hotspots were located in Gaagadufaruhuraa with 14.8 and 14.3 colonies per km. The last site was in R21, near Fares with 13.6 colonies per km. The winged pearl oyster was not taken into account for the hotspot calculation as they were present in too few sites, and could have easily be missed during the manta tows.

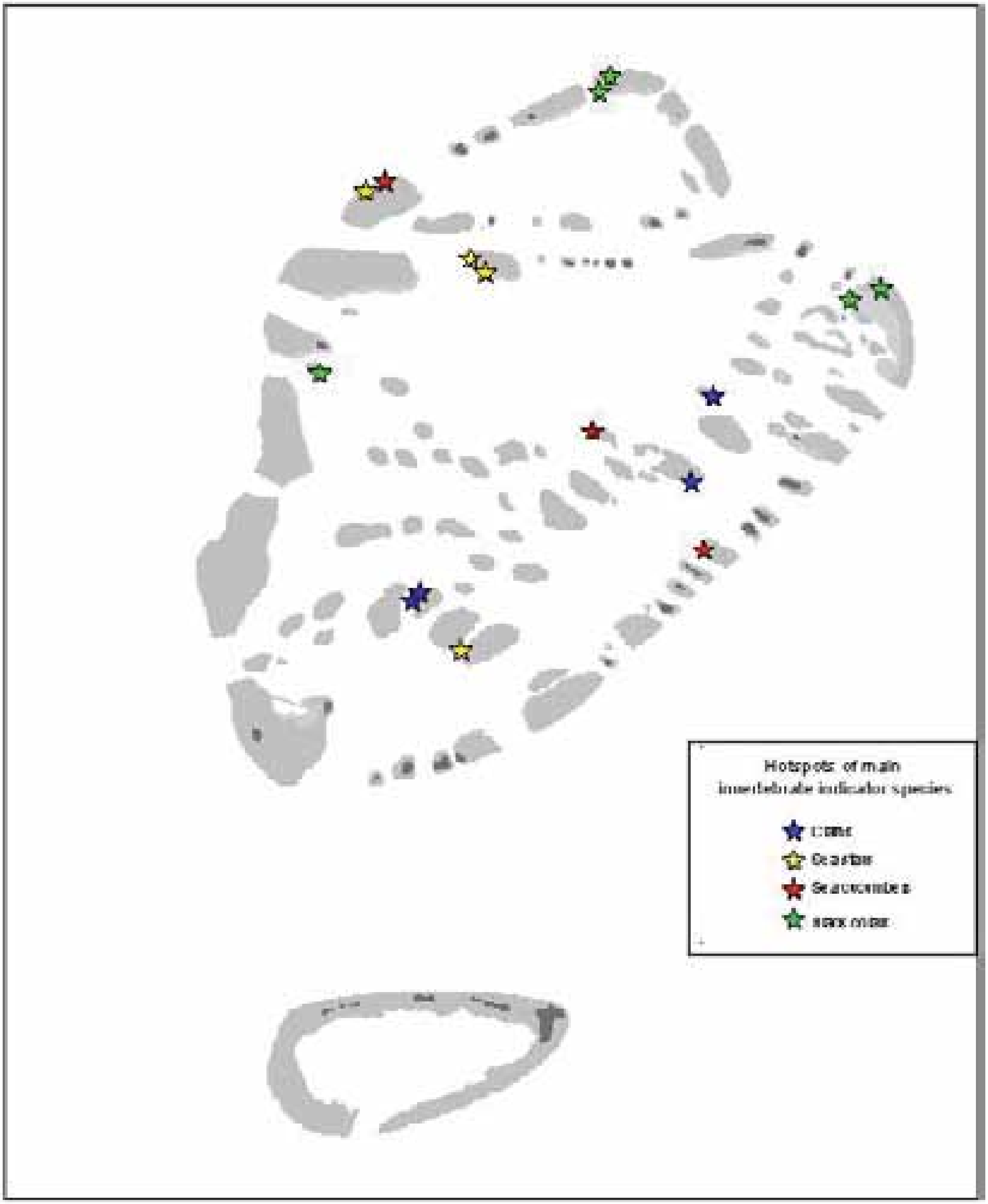

Figure 5.3. Hotspots of invertebrate species of special interest for diversity

5.1.2.4 Coldspots of potentially invasive and corallivore species

None of the coldspots were situated in Goidhoo atoll. In general, sites were located mainly in the centre of the atoll and in the north part (figure 5.4).

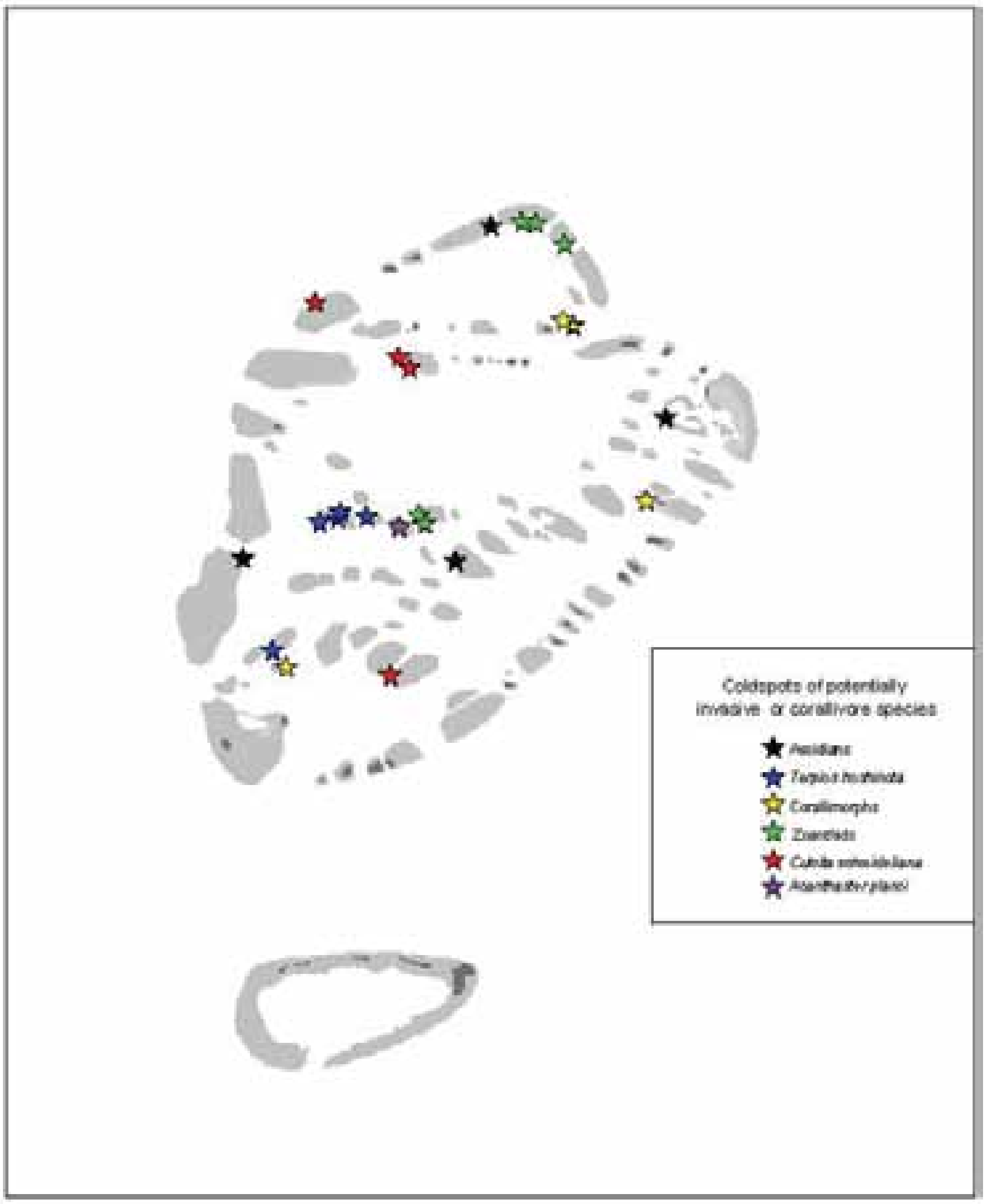

Figure 5.4. Coldspots of corallivores and potentially infesting species

5.1.2.4.1 Acanthaster planci

During the monitoring of Baa Atoll, only seven individuals of *A. planci* have been observed during three manta tows, all located at Nibiligaa, where high percentages of coral cover have been recorded (figure 5.5).

Figure 4.5. ***Acanthaster planci*** **eating corals at Nibiligaa**

5.1.2.4.2 Culcita schmedeliana

The pin-cushion sea star was very widespread all over Baa Atoll and was observed in 77.7% of the manta tows, with a mean of 6.13 individuals per km (± 8.97 ind/km) (see results section). Four sites were selected as hotspots for the sea star *Culcita schmedeliana*. The two highest densities occurred in Keyodupperu (76.9 and 60.2 ind.km^{-1}). The other two hotspots were located in Hanikandu faru (58.1 ind.km^{-1}) and Maaneigaa (52.9 ind.km^{-1}).

5.1.2.4.3 Ascidians (Ascidiacea)

During the monitoring, ascidians, mainly the soft Didemnum species (*Didemnum molle,* Fig. 5.6) were observed in 14 % of the samples (see results section). Four sites are highlighted for ascidians abundance: Dhigufaruvinagadu (11.1 % of cover), Borangali (7.3 % of cover), Veyofushi (6.8 % of cover) and Maafaru (6.4 % of cover). It does not seem that ascidians constitute a threat.

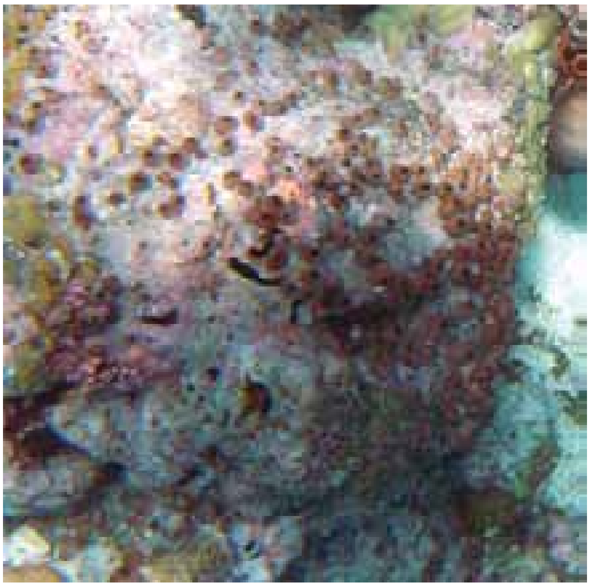

Figure 5.6. High concentration of ascidians on a rock in Dhigufaruvinagadu

5.1.2.4.4 Zoanthids (Zoantharia)

Zoanthids, mainly *Zoanthus mantoni*, were only present in 3.8 % of the samples (Figure 5.7). Zoanthid distribution was very patchy and restricted to a few places. However high percent cover were recorded and their contribution to the overall cover was not negligible (see results section). Six sites were identified as hotspots. From the six sites, three were situated at the reef R9 with percentage cover of 60 % (the highest cover values recorded), 39.7 % and 38.6 %. The three other sites were situated in the north, one in Bathalaa (59.4 % of cover) and two in Gaagadufaruhuraa with 37.4 and 23.8 % of cover.

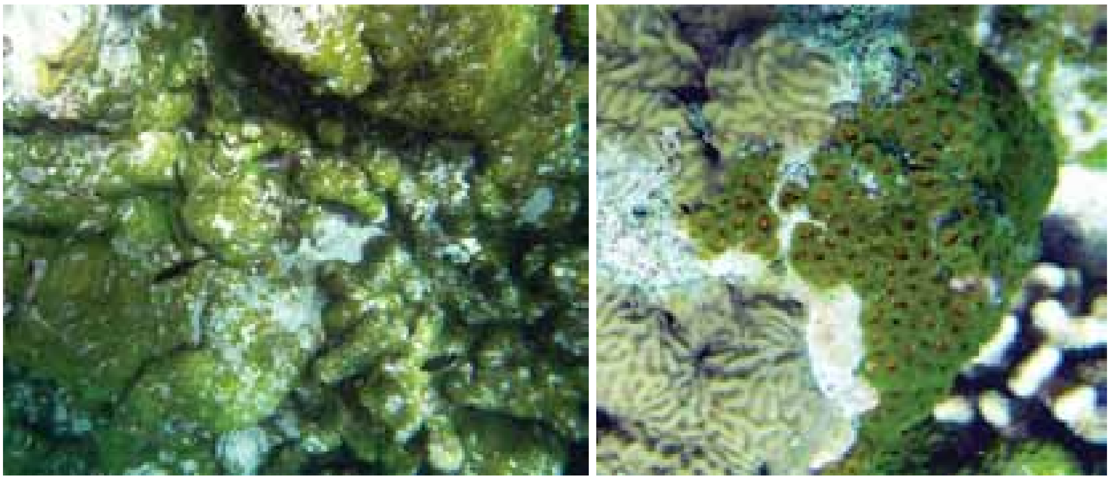

Figure 5.7. Zoanthids covering large part of the reef in the north of Baa atoll

It is not clear whether this species is competing with the corals for space, as there are often many healthy colonies, in an otherwise zoanthids dominated areas. They do seem to pose a problem when it comes to coral recruitment though, and it seems important to keep an eye on the evolution of this species at the sites given.

5.1.2.4.5 Corallimorphs (Zoantharia)

Carpet corallimorphs (*Discosoma sp*, Fig 5.8) have been recorded at five areas within Baa Atoll. Three of them regroup the five hotspots identified. Three of the five sites were located in Kudarikilu with a mean cover of 64.7 % (± 19.7 %) and the highest percentage recorded, reaching 80 % of cover. The entire reef of Kudarikilu was covered with corallimorphs (figure 5.8). The two other hotspots of corallimorphs occurred in Muthaafushi (52.8 % of cover) and Dhonfanu (20.6 % of cover). In opposition to the zoanthids, the corallimorphs seems to actively compete with corals with clear signs of tissue injuries on the progressing fronts.

We observed the presence of corallimorphs at two other sites : Kendhoo and Funadhoo, with percentage cover less than 20 %. Moostleiner (1989) reports another corallimorph, *Rhodactis sp.*, from South Male' atoll. *Rhodactis* is an older name for the genus *Discosoma.* These have also been reported in different EIA reports from the Maldives.

Figure 5.8. Corallimorphs covering the entire reef surface at Kudarikilu

5.1.2.4.6 The sponge Terpios hoshinota (Demospongiae)

Very high proportions of grey sponge were recorded in the central inside reefs of the main Atoll. We believe that this species is *Terpios hoshinota* (Suberitidae. Hadromerida, Fig 5.9), described by Rutzler and Muzik in 1993. During our survey, the presence of *Terpios* has been observed in eight areas in Baa Atoll: Nibiligaa, R5, R8, R7, R6, Anhenunfushi, Muthaafushi and R2.

Five sites were identified as coldspots with percentage cover ranging from 55.9 % in R6 to 19.4 % in R7. Four of the five hotspots were gathered in the centre of the atoll, around the reefs 6, 7 and 8. The last area was in R2 with 38.7 % of cover. Even though not recorded Dhakandhoo also had a significant amount of these sponge on its northern and southern sides. This species is reported to progress on live corals and smother them (Ruetzler 1993). These have also been reported in different EIA reports from the Maldives.

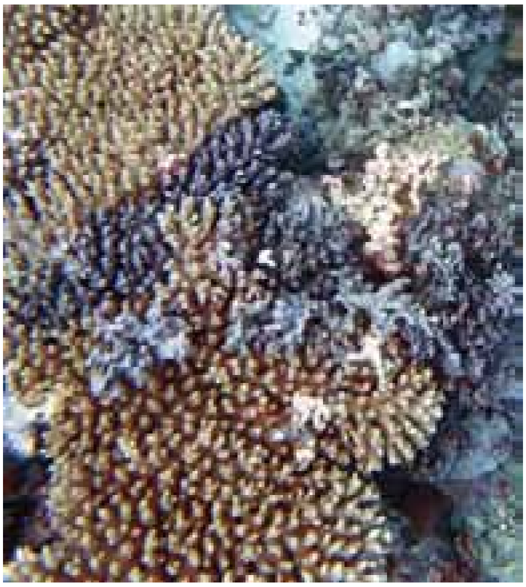

Figure 5.9. Presence of *Terpios hoshinota* in Vakkaru. The species spreads over living coral

5.2 Indices

5.2.1 Methods

Diversity indices are useful to aggregate the information provided by a number of indicator species. They allow for the characterisation of sites and their ranking according to a set of indicators chosen for a specific aim. However, the set of indicators should adequately reflect the objectives that are to be described. Furthermore, the range of variation as well as the trend of variation of diversity indices is very sensitive to how they are built and the comparative values of each site attributed.

Here, two different methods have been selected to compute site marks. These two methods point to different biological realities, the amplitude method promotes the idea that exceptionally high number of a given indicator should stand out, while the decile method puts forward any place where some sightings have been done should score quite high, even with lower densities. They provide complementary information, which facilitate and enhance decision making. The principle of both mark attributions is to order sites into 10 classes depending on the density and coverage of each indicator. Depending on the classes they fell into, the sites were then given a mark. The marks for all indicator species were finally added to compute the index. The advantage of this principle is to combine presence data with abundance data, and to use descriptors (the ranks) to combine different indicator species and different natures of data.

The two methods only differ in the way classes were computed. For the amplitude method, equal intervals defining classes were set as the maximum value of density (or cover percentage) divided by 10, the marks given are then proportional to the highest value, which automatically gets 10. For the decile method, the number of sample in a class was calculated as the total number of samples where the species were present divided by 10. For this method, we selected only samples where the species were present so that rare and locally abundant species could be integrated in the index without bias, as compared to very common or very abundant species. The two methods provide different perceptions of the importance of a site. The amplitude method gives more weight to sites yielding very high values of few indicator species, and is then directly related to the hotspot calculation. In contrast, the decile method gives a better mark to a site showing the presence of different indicators. To illustrate the differences, there are 45 sites scoring 10 for the coral cover with the decile method, but only 3 with the amplitude method (Figure 5.10). A site where two napoleon fish were actually seen would get a 7 with the decile method, and a 2 with the amplitude method. Hence, the amplitude method favours the hotspots while the decile method favours the diversity of a site.

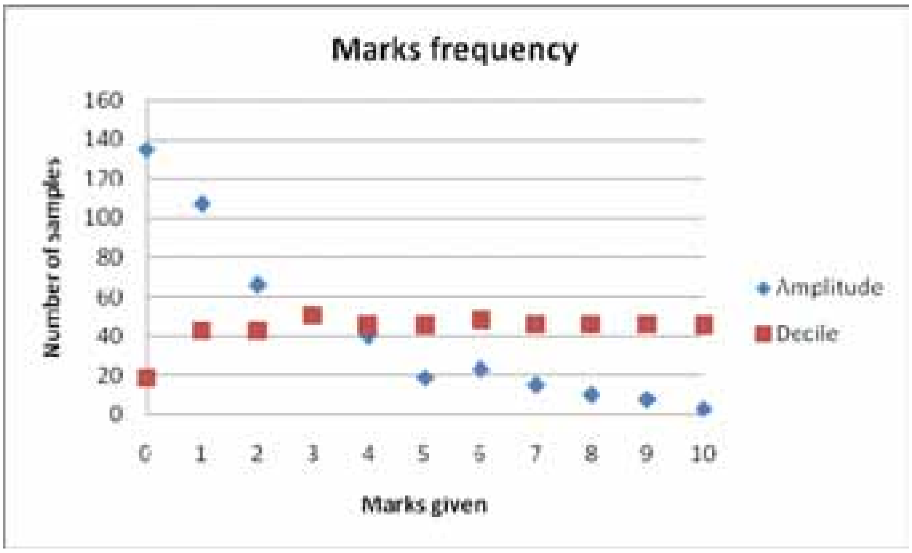

Figure 5.10. Frequency of marks attributed by the two methods based on coral cover.

Various indices were compiled here from the list of key indicator species to provide a comprehensive view of main management issues for MPA implementation. The principle is to add the information provided by each species composing the group of species considered.

Four groups of indicators were considered: 1) key indicators species for tourism industry, i.e. species of special interest for divers; 2) key indicators species for fishing industry, i.e. species of high economical value; 3) key indicators species for IUCN, i.e. species needing special protection and appearing in the IUCN Red List; and 4) the total diversity index, gathering all key indicators analysed in this survey. For the two first indices, the groups were identical to the groups made previously for hotspot calculations. For the third index, all the indicators that were listed as either "vulnerable", "endangered" or "critically endangered" in the IUCN Red List were taken into account. These key species are: *Plectropomus laevis* (Black-saddle coral grouper), classified as “Vulnerable – VU”; *Chelonia mydas* (Green turtle) classified as “Endangered – EN”; *Eretmochelys imbricata* (Hawksbill turtle) classified as “Critically Endangered – CR”; *Cheilinus undulatus* (Napoleon fish) classified as “Endangered – EN”, and hard corals, as a group, even though all the species are not concerned. Finally, the last index added all the indicators studied (17 variables including the percentage of live corals) and subtracted the groups of species listed in the coldspots (5 variables), since these species represent a potential imbalance which would lower the diversity of a site where they are abundant.

In summary, four thematic indices calculated by means of two complementary methods will be presented, resulting in a total of eight indices.

5.2.2 Results

5.2.2.1 Tourism index

The two maps (figures 5.11 and 5.12) show the location of the sites with highest tourism indices. Maximum index would be 40 (meaning indices of 10 for the four species selected). The maximum index obtained with our data was 26 with the decile method and 16 with the amplitude method. At none of the sites it was possible to observe the presence of the four species (or group of species) together. Sharks were especially rare and reduced the value of the total tourism index. We can also conclude that the species selected for tourism index do not occur in the same habitat or under the same conditions. Thus the creation of protected areas should take into account this diversity of habitats in order to protect the entire community.

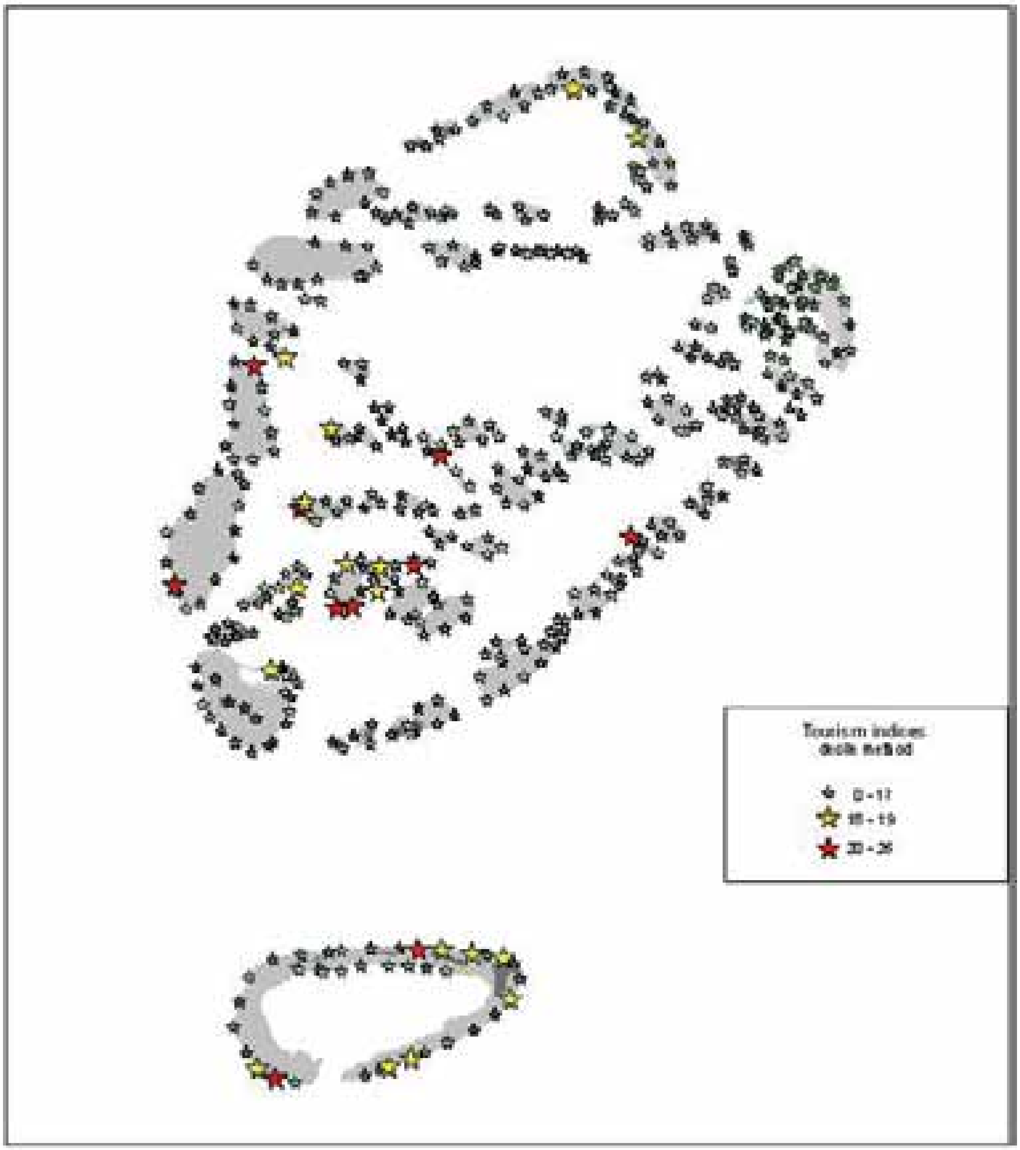

Figure 5.11. Map of the highest tourism index sites (calculated with the decile method)

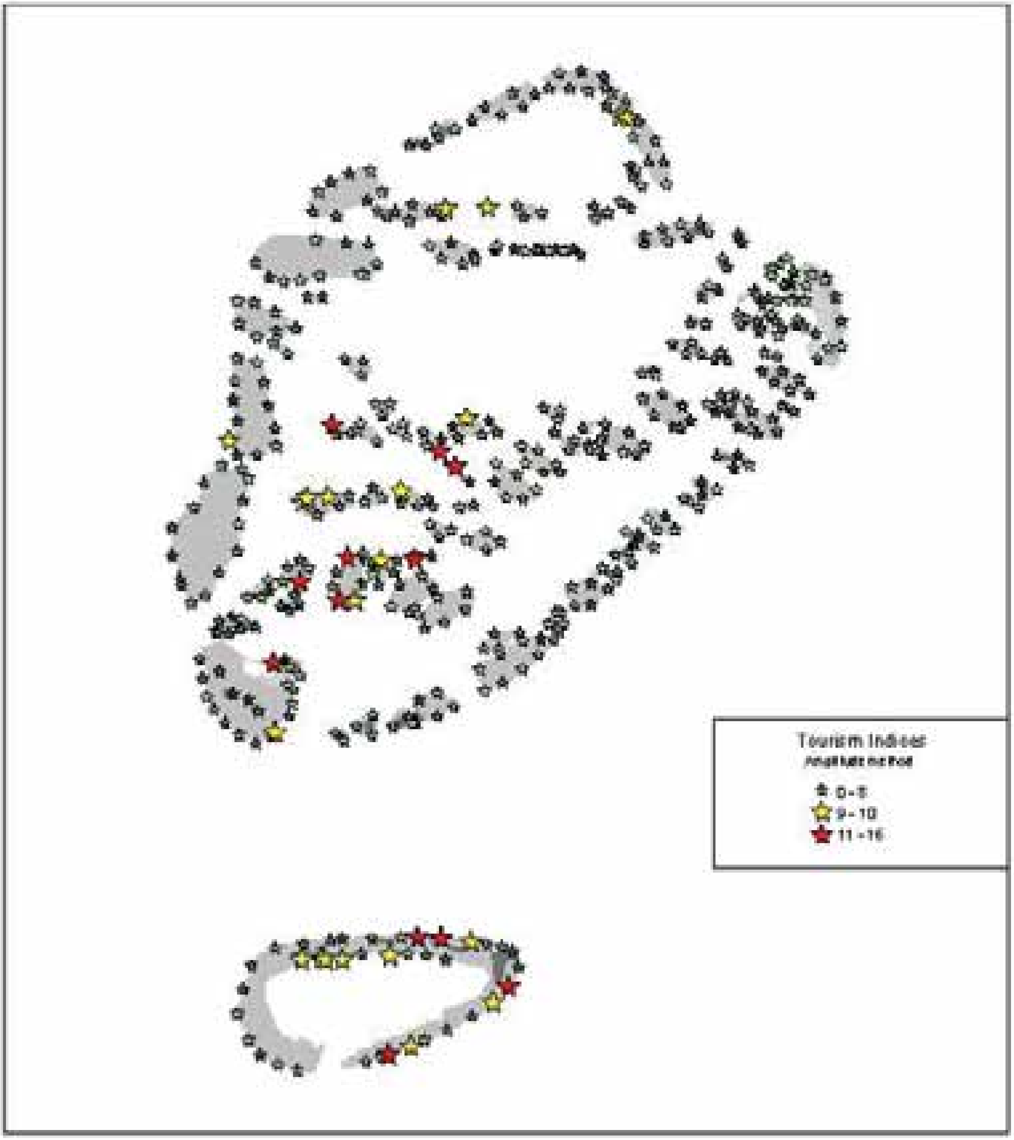

Figure 5.12. Map of the highest tourism index sites (calculated with the amplitude method)

With the decile method (figure 5.11), sites were situated mainly in the southern part of the main atoll. Highest index were situated in Goidhoo atoll (Table 5.1) due to the presence of live corals, turtles and napoleon fish. The centre of the main atoll gathered five sites with high tourism index : Maafaru (index 22), Vakkaru (index 22), Bodugaa falhu (indices 21) and R15 (index 20). Vakkaru and Bodugaa falhu had a high shark index, with middle to high coral and turtle indices, putting them on the top ten of tourism indices. Three sites occurred at some other places of the atoll: on the east side at Sonevafushi (index 20), on the west side at

Maahuruvalhi (index 21) and at Maafaru (index 22), the only site located on the outer reef of the atoll, due mainly to the presence of turtles and napoleon fish.

Goidhoo atoll gathered nine sites with relatively important tourism index (from index 26 to index 18) mainly due to high indices for turtles.

Table 5.1. Sites with the highest tourism index calculated with the decile method

Area	Live corals	Turtles	Sharks	Napoleon fish	Tourism Index
Goidhoo	6	10	0	10	26
Goidhoo	4	10	0	8	22
Maafaru	5	9	0	8	22
Vakkaru	8	6	8	0	22
Bodugaa falhu	5	9	7	0	21
Bodugaa falhu	6	5	10	0	21
Maahuruvalhi	5	8	0	8	21
R15	10	10	0	0	20
Sonevafushi	6	8	0	6	20
Nibiligaa	10	10	0	0	20
Goidhoo	9	10	0	0	19
Goidhoo	9	10	0	0	19
Thulhaadhoo	10	9	0	0	19
R2	10	9	0	0	19
Bodugaa falhu	9	10	0	0	19
Vakkaru	10	9	0	0	19
Goidhoo	4	4	0	10	18
Goidhoo	8	10	0	0	18
Goidhoo	9	9	0	0	18
Goidhoo	8	10	0	0	18
Goidhoo	8	10	0	0	18
Nagilifalhu	10	8	0	0	18
Nagilifalhu	10	8	0	0	18
Vinaneiyfaruhuraa	9	4	0	5	18
Gaagadufaruhuraa	8	10	0	0	18
R21	9	2	0	7	18
R6	9	0	9	0	18

With the amplitude method (figure 5.12), some sites with high tourism index appeared in the north of the atoll and in the inner reef of Goidhoo. However, most of the sites with high index were located in the centre of the atoll. Highest index was also situated in Goidhoo (index 16) followed by Nibiligaa (index 16) (Table 5.2). With this method sharks seemed to have less importance, which is licit given the little sightings, only one site at Bodugaa falhu had an index of 10 (two sightings). Napoleon fish had also lower marks than with decile method, only three sites (Goidhoo, Maahuruvalhi and Thulhaadhoo) had positive indices. Thus tourism index with the amplitude method points out mainly high live coral covers coupled with turtles, combination which have the best indices (three out of four red stars), but shows the hotspots of each indicators mostly in yellow.

Four sites appeared with a high tourism index with both methods: Nibiligaa, R15, Bodugaafalhu and the north outer reef of Goidhoo.

Table 5.2. Sites with the highest tourism index calculated with the amplitude method

Area	Live corals	Turtles	Sharks	Napoleon fish	Tourism Index
Goidhoo	2	6	0	8	16
Nibiligaa	9	7	0	0	16
Goidhoo	4	9	0	0	13
Goidhoo	5	8	0	0	13
Bodugaa falhu	2	1	10	0	13
R2	9	3	0	0	12
Bodugaa falhu	6	6	0	0	12
Goidhoo	6	5	0	0	11
Thulhaadhoo	8	3	0	0	11
R15	7	4	0	0	11
R11	10	1	0	0	11
R6	5	0	6	0	11
Goidhoo	10	0	0	0	10
Goidhoo	4	6	0	0	10
Nagilifalhu	8	2	0	0	10
Bathalaa	0	10	0	0	10
R4	9	1	0	0	10
R9	10	0	0	0	10
Maahuruvalhi	0	0	0	10	10
Vakkaru	3	1	6	0	10
Goidhoo	8	1	0	0	9
Goidhoo	9	0	0	0	9
Goidhoo	9	0	0	0	9
Goidhoo	8	1	0	0	9
Goidhoo	6	3	0	0	9
Goidhoo	9	0	0	0	9
Thulhaadhoo	1	0	0	8	9
Bodugaa falhu	1	3	5	0	9
Bathalaa	2	7	0	0	9
Boifushi	9	0	0	0	9
Kashidhoogiri	9	0	0	0	9
Vakkaru	7	2	0	0	9
Vakkaru	6	0	3	0	9

5.2.2.2 Fishing index

The two maps (Figures 5.13 and 5.14) show the location of the sites with highest fishing indices. Maximum index would be 30 (meaning indices of 10 for the three species or groups of species selected). The maximum index obtained with our data was 28 with the decile method and 18 with the amplitude method. Thus indices were much closer to the maximum than tourism indices. However, for both fishing indices, numerous values were lowered due to the relative rarity of lobsters in our observations. Finally, it was possible to observe the presence of the three groups of species at many sites, which was better reflected by the decile method.

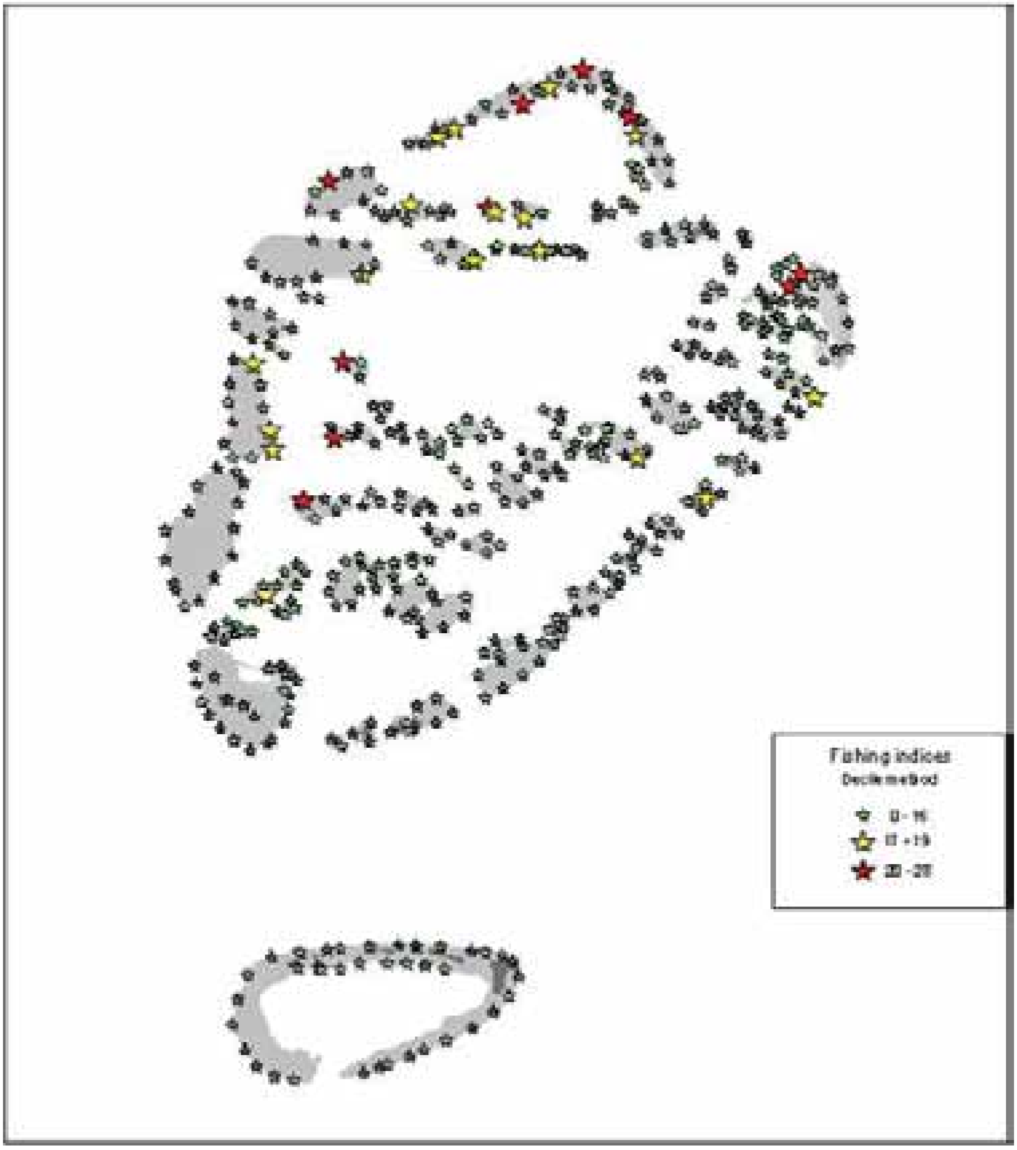

Figure 5.13. Map of the highest fishing index sites (calculated with the decile method)

With the decile method, sites were located in the centre-west and in the north parts of the main atoll (figure 5.13). No site was situated in Goidhoo. The site with the highest index (28 over 30) was in Dhigufaruvinagandu with high indices for little groupers, big groupers and lobsters (three individuals) (Table 5.3). It was followed by Vandhoomaafaru (index 25) and Gaagadufaruhuraa (index 22) with middle to high ranks for each species. Other sites on the north of the atoll (Bathalaa, Hanikandu faru and Boifushi), as well as Vakkaru, did not have any lobsters but obtained the highest rank for little and big groupers (total index of 20). The sites at R6 and Boatu Urunu Faru obtained high indices due to the presence of little groupers and lobsters. Even if it did not appear amongst the sites with the highest indices, Maahuruvalhi had four sites with high ranks for little and big groupers (Table 5.3).

Table 5.3. Sites with the highest fishing index calculated with the decile method

Area	Little groupers	Big groupers	Lobsters	Fishing Index
Dhigufaruvinagadu	9	10	9	28
Fonimagoodhoo	10	10	5	25
Gaagadufaruhuraa	5	9	8	22
R6	9	3	9	21
Fonimagoodhoo	10	0	10	20
Bathalaa	10	10	0	20
Hanikandu faru	10	10	0	20
Boifushi	10	10	0	20
Boatu urunu faru	10	0	10	20
Vakkaru	10	10	0	20
R1	2	7	10	19
Dhigufaru	10	9	0	19
Hibalhidhoo	9	10	0	19
Huraifaru	9	10	0	19
Vinaneiyfaruhuraa	10	4	5	19
Maahuruvalhi	9	10	0	19
Maahuruvalhi	10	9	0	19
Gaagadufaruhuraa	9	9	0	18
Anhenunfushi	10	6	2	18
Boifaru	9	9	0	18
Keyodupperu	8	10	0	18
Maafaru north	10	0	8	18
Maahuruvalhi	10	8	0	18

Maahuruvalhi	10	7	0	17
Kashidupper	7	7	3	17
Gemendhoo	7	10	0	17
Boifushi	9	8	0	17

With the amplitude method (figure 5.14), only two sites, Vandhoomaafaru and Dhigufaruvinagadu, recorded the presence of the three variables at the same time but with relatively low ranks, especially for lobsters (Table 5.4), stressing the fact that when the three indicators are present together, their densities are quite low.

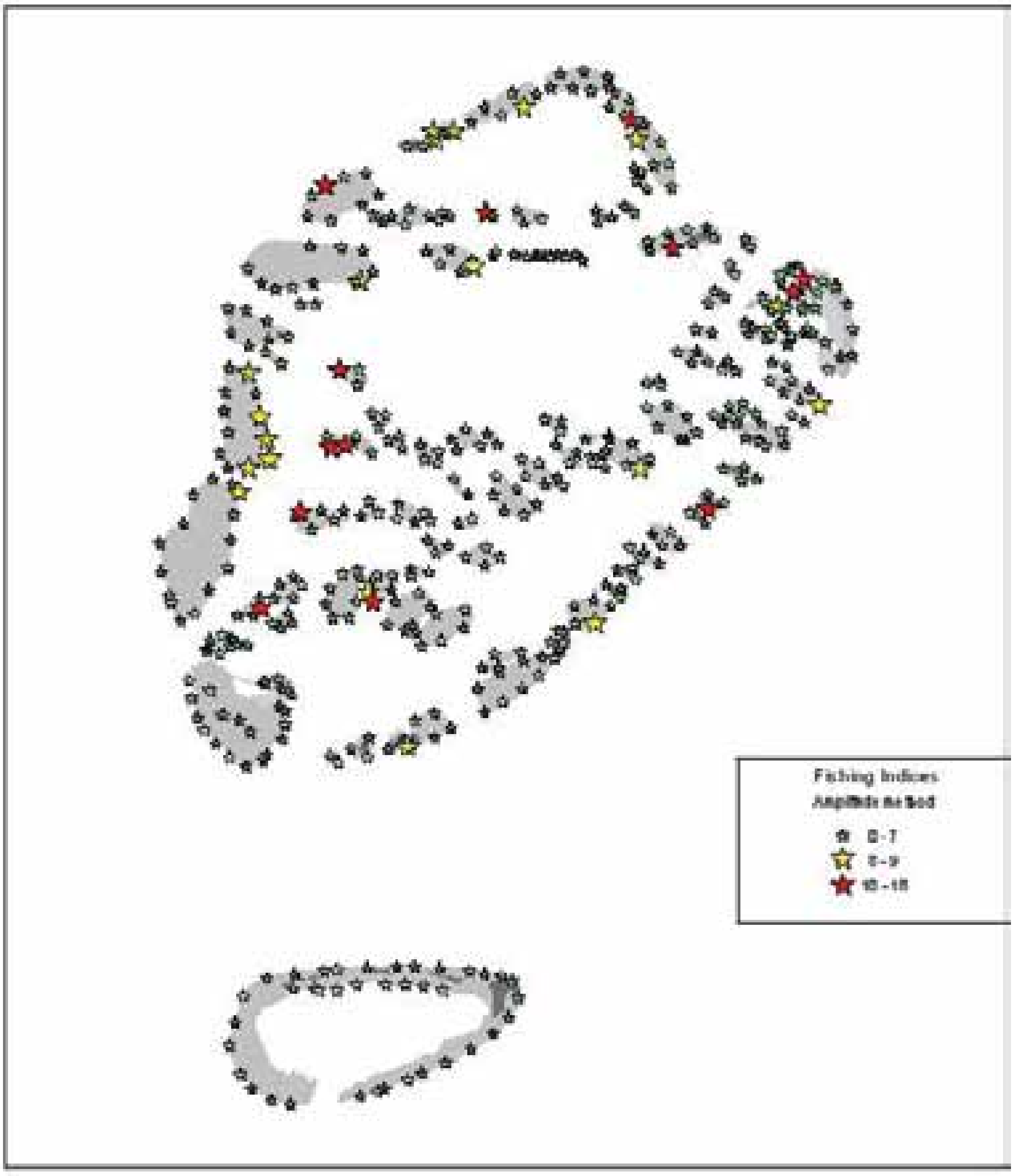

Figure 5.14. Map of the highest fishing index sites (calculated with the amplitude method)

Highest indices (index 18) occurred in Vakkaru due to the presence of little and big groupers (Table 5.4). It was followed by sites at Vandhoomaafaru (index 17) and Boatu Urunu Faru (index 16) due to high ranks for little groupers and lobsters. Here again, Maahuruvalhi showed high ranks for groupers, especially the little ones; as well as Anhenunfushi.

Table 5.4. Sites with the highest fishing index calculated with the amplitude method

Area	Little groupers	Big groupers	Lobsters	Fishing Index
Vakkaru	8	10	0	18
Fonimagoodhoo	9	0	8	17
Boatu urunu faru	6	0	10	16
Bathalaa	8	4	0	12
R1	0	1	10	11
Fonimagoodhoo	7	3	1	11
Nagilifalhu	10	0	0	10
Hibalhidhoo	5	5	0	10
Landaa giraavaru	10	0	0	10
Hanikandu faru	7	3	0	10
Boifushi	7	3	0	10
R6	4	0	6	10
R6	10	0	0	10
Maamaduvvaree	9	0	0	9
Vinaneiyfaruhuraa	8	0	1	9
Dhigufaruvinagadu	4	3	2	9
Keyodupperu	3	6	0	9
Maahuruvalhi	9	0	0	9
Maahuruvalhi	4	5	0	9
Maahuruvalhi	9	0	0	9
Maahuruvalhi	7	2	0	9
Maahuruvalhi	8	1	0	9
Maafaru south	7	1	0	8
Nagilifalhu	8	0	0	8
Koraidhoo	8	0	0	8
Dhigufaru	6	2	0	8

Huraifaru	4	4	0	8
Veyofushi	8	0	0	8
Anhenunfushi	7	1	0	8
Anhenunfushi	8	0	0	8
Anhenunfushi	7	1	0	8
Maafaru north	6	0	2	8

5.2.2.3 IUCN index

The two maps (Figures 5.15 and 5.16) show the location of the sites with highest IUCN indices. The calculations take into account separately those indicators on the red list of the IUCN, green turtles, hawksbill turtle, napoleon fish, black saddled grouper and the live coral cover. Although not all coral species are protected, it is assumed that there are on Baa atoll some of the protected species. Maximum index would be 50 (meaning indices of 10 for the three species or groups of species selected). The maximum index obtained with our data was 36 with the decile method and 25 with the amplitude method.

With the decile method (Figure 5.15) sites are concentrated in the middle of the atoll, giving a relative importance to live coral cover. On the other hand, a site like Thulhaadhoo (32) with high ranks for all the species except live corals is one of the most important for the IUCN index. For the sites with the highest indices at least three of the five species selected were present and scoring high marks. It means that these sites are very interesting from a conservation point of view because it gathers several species listed on the IUCN Red List (Table 5.5). Another interesting site according to this calculation is the northern side of Vinaneiy faru.

Sites with lower indices were also present in Goidhoo and in the south and east parts of the main atoll. These sites are more specific to one species in particular and are less interesting concerning the entire group of IUCN species. However, they are important to consider for the protection of a specific species e.g. the green turtle did not obtain high rank within the sites with highest indices but was present in Angaafaru and Hitaadhoo.

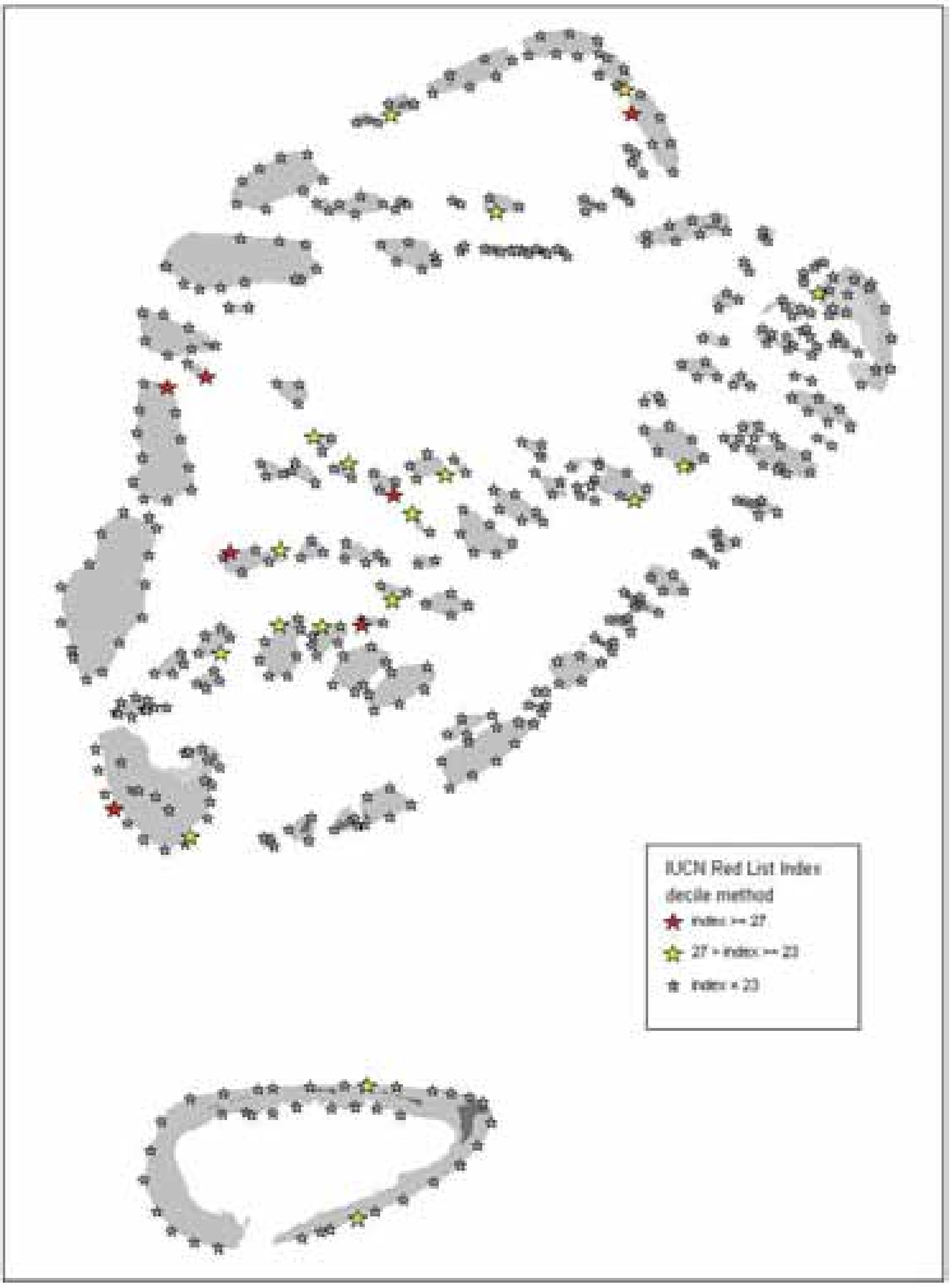

Figure 5.15. Map of the highest IUCN index sites (calculated with the decile method)

Table 5.5. Sites with the highest IUCN index calculated with the decile method

Area	Green turtles	Hawksbill turtles	Napoleon fish	Black-saddle grouper	Hard corals	IUCN Index
Nibiligaa	7	10	0	9	10	36
Thulaadhoo	7	9	6	9	1	32
Maahuruvalhi	0	8	8	10	5	31
Vakkaru	9	0	0	10	10	29
R15	0	10	0	7	10	27
Vinaneiyfaru	0	5	5	8	9	27
R21	0	2	7	9	9	27
Goidhoo	0	10	10	0	6	26
Bathalaa	0	10	0	10	6	26
Boifaru	0	8	0	10	8	26
R11	0	7	0	9	10	26
R8	0	7	0	9	10	26
Anhenfushi	0	0	7	9	9	25
Bodugaa falhu	0	10	0	5	9	24
Angaafaru	10	9	0	0	5	24
Vandhoomafaru	0	0	8	10	6	24
R9	0	8	0	8	8	24
Vakkaru	0	7	0	8	9	24
Goidhoo	0	9	0	5	9	23
Thulaadhoo	0	0	10	9	4	23
R2	0	9	0	4	10	23
Nagilifalhu	0	8	0	5	10	23
Dhigufaru	0	7	0	10	6	23
R14	0	9	0	9	5	23
R5	6	6	0	2	9	23

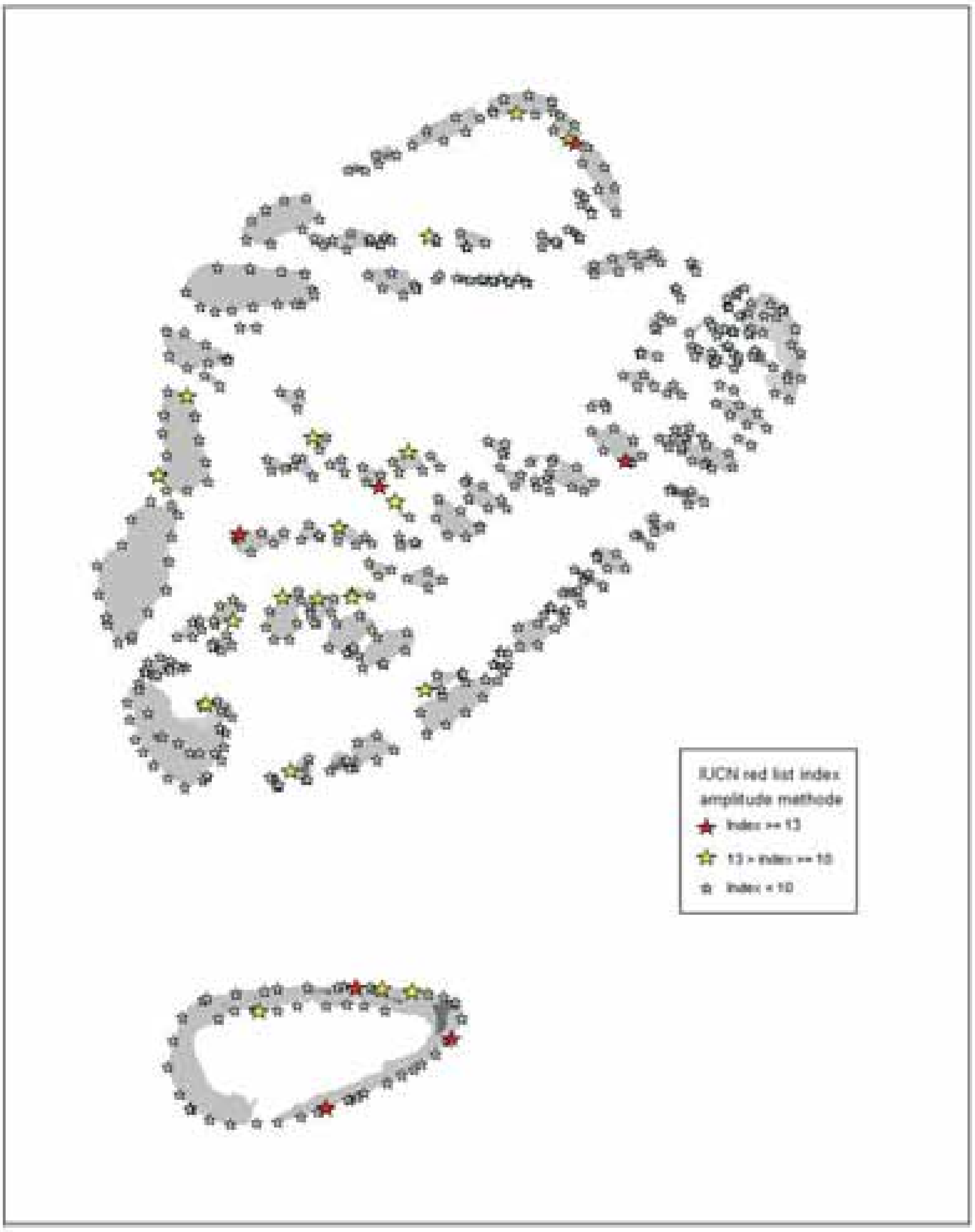

Figure 5.16. Map of the highest IUCN index sites (calculated with the amplitude method)

With the amplitude method (figure 5.16), sites with the highest indices were more widely distributed all over the atoll and less concentrated in the central region, with six sites on Goidhoo atoll and 4 sites in the northern atoll. The highest index was recorded in Vakkaru, thanks to groupers and green turtles, coupled with a good coral cover (index 25), (Table 5.6). With this method, sites with the highest indices only gathered two of the five species selected. Consequently, these sites are more focused on high rank for one specific species than on the presence of several of the species. Still it does not deal with situations of very low densities or actual sightings such as Angaafaru, which score 9 for green turtles on the account of a single sighting. This would appear more as a mathematic exception rather than a really outstanding site.

Table 5.6. Sites with the highest IUCN index calculated with the amplitude method

Area	Green turtles	Hawksbill turtles	Napoleon fish	Black-saddle grouper	Hard corals	IUCN Index
Vakkaru	8	0	0	10	7	25
Nibiligaa	4	5	0	0	9	18
Goidhoo	0	6	8	0	2	16
Goidhoo	0	9	0	2	4	15
Goidhoo	0	8	0	0	5	13
Angaafaru	9	3	0	0	1	13
Bathalaa	0	7	0	4	2	13
R2	0	3	0	0	9	12
Bodugaa falhu	0	6	0	0	6	12
Bathalaa	0	10	0	2	0	12
Boifushi	0	0	0	3	9	12
Goidhoo	0	5	0	0	6	11
Thulhaadhoo	0	3	0	0	8	11
Hithaadhoo	10	0	0	0	1	11
R15	0	4	0	0	7	11
R11	0	1	0	0	10	11
Maahuruvalhi	0	0	10	1	0	11
R5	3	1	0	1	6	11
Goidhoo	0	0	0	0	10	10
Goidhoo	0	6	0	0	4	10
Nagilifalhu	0	2	0	0	8	10
Ohgali	3	0	0	0	7	10
Gaagandufaruhuraa	0	5	0	2	3	10
R4	0	1	0	0	9	10
R9	0	0	0	0	10	10
Maahuruvalhi	0	1	3	5	1	10

5.2.2.4 Total index

The two maps (figures 5.17 and 5.18) show the location of the sites with highest Total index. Maximum index would be 170, meaning marks of 10 for all the species in green (important for biodiversity) – indices 0 for all the species in red (potentially dangerous, or denoting a lack of biodiversity). The maximum index obtained with our data was 89 with the decile method and 37 with the amplitude method. Some of the sites obtained a negative index because they had more of ‘negative’ species than ‘positive’ ones. The humphead parrot fish is taken out of the discussion as it was never recorded as discussed above.

With the decile method (figure 5.17), sites with the highest total index were mainly situated in the northern atoll (7 sites over 11). The highest index was recorded in Dhigufaruvinagadu with 11 of the 17 species present and all ranks equal or above 6. Sharks, turtles and napoleon fish were the species missing. It was followed by Vandhoomaafaru (index 77), Anhenunfushi (index 76), Boifaru (index 74), Vinaneiyfaruhuraa (index 72) and Gaagadufaruhuraa (index 72). On average, these sites had over 10 species of the 17 species selected. The green turtles and the sharks were the main species missing.

We can observe that green turtles, sharks, napoleon fish, as well as lobsters, black coral and winged pearl oyster were the rarest species of the 17 selected. Therefore sites selection was mainly lead by their presence while the live corals and groupers represented the bulk of the points at each site. It is important to keep that in mind when choosing protected areas in order to consider all the variables.

Six sites with relatively high total indices (between 68 and 54) were situated in Maahuruvalhi, mostly on the inner side. On average, over 8 of the 17 species were present within this area. Therefore, it seems that this area has an interesting overall diversity : green turtles and sharks were absent and ranks for live corals was relatively low but it obtained high ranks for all the groupers, the clams and the sea cucumbers (Table 5.7).

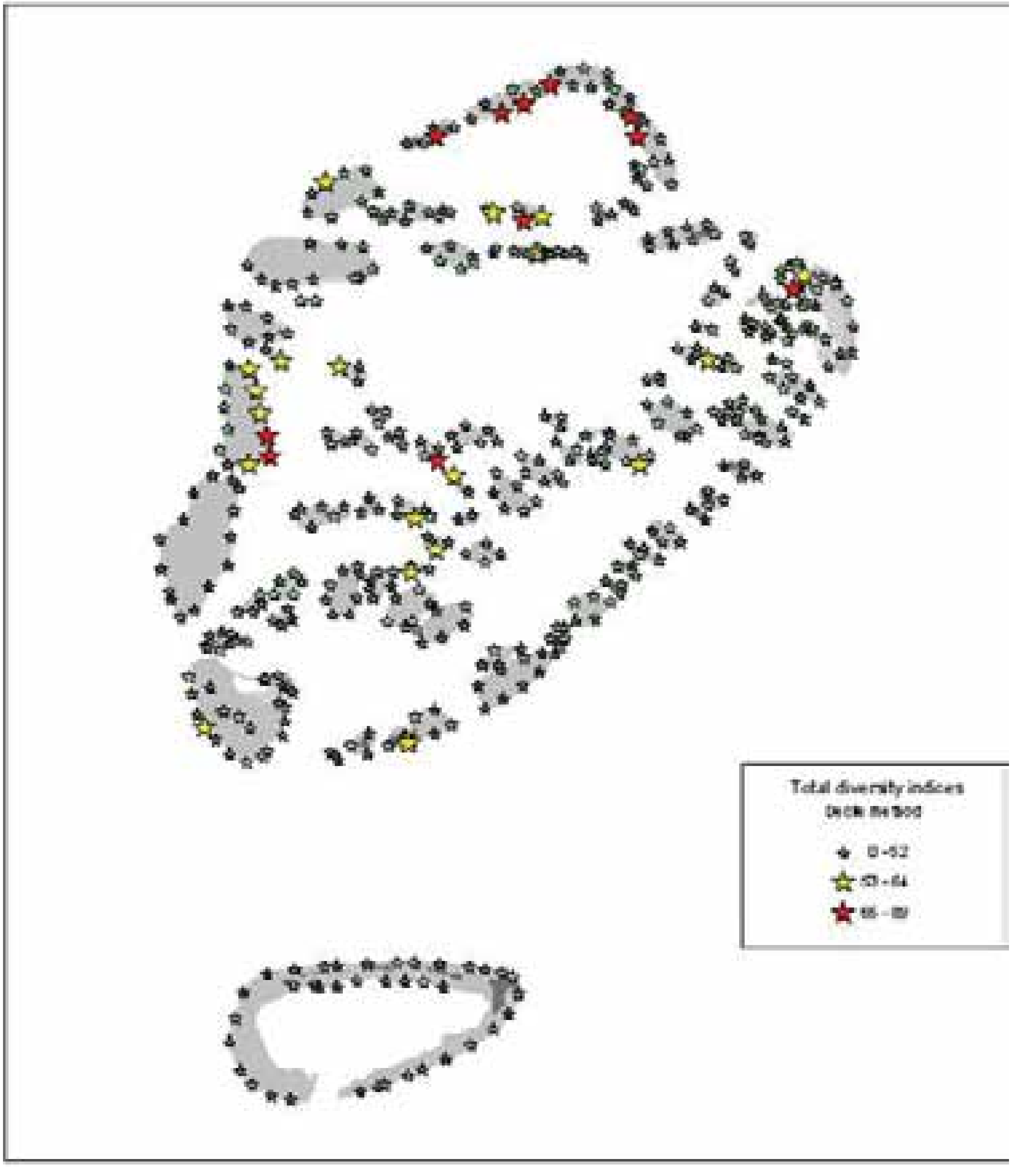

Figure 5.17. Map of the highest total index sites (calculated with the decile method)

Table 5.7. Sites with the highest Total index calculated with the decile method

Area	Live corals	*C.mydas*	*E.imbricata*	*C.melano-pterus*	*C.amblyr-hynchos*	Other sharks	*C.argus*	*V.louti*	*P.laevis*	*E.fusco-guttatus*	Other groupers	*C.undulatus*	*Tridacna* sp.	Sea cucumbers	*P.versi-color*	*Antipathes* sp.	*P.penguin*	Sea stars	Ascidians	Sponges	Corallimorphs	Zoanthids	Total Index
Dhigufaruvinagadu	10	0	0	0	0	0	7	10	10	9	10	0	10	8	9	9	6	2	0	7	0	0	89
Vandhoomaafaru	6	0	0	0	0	0	8	10	10	0	9	8	8	8	10	10	8	10	0	8	0	0	77
Anhenunfushi	9	0	0	0	0	0	10	9	9	2	9	7	7	9	0	9	0	4	0	0	0	0	76
Boifaru	8	0	8	0	0	0	7	10	10	9	8	0	10	10	0	0	0	6	0	0	0	0	74
Vinaneiyfaruhuraa	9	0	5	0	0	0	10	8	8	4	10	5	10	8	5	0	0	9	1	0	0	0	72
Gaagadufaruhuraa	2	0	3	0	0	0	7	10	10	8	10	0	6	7	0	9	3	3	0	0	0	0	72
Dhigufaruvinagadu	10	0	0	0	0	0	8	9	9	7	10	0	9	6	0	0	0	0	0	0	0	0	68
Maahuruvalhi	4	0	2	0	0	0	10	9	9	9	8	0	7	10	0	7	0	7	0	0	0	0	68
Nibiligaa	10	7	10	0	0	0	4	9	9	0	6	0	5	9	0	0	0	1	0	0	0	0	68
Bathalaa	6	0	10	0	0	0	10	10	10	10	8	0	8	5	0	7	0	10	3	0	0	4	67
Maahuruvalhi	7	0	0	0	0	0	10	8	8	8	10	7	7	10	0	0	0	6	0	0	4	0	65
Vandhoomaafaru	1	0	0	0	0	0	6	10	10	10	7	9	6	5	5	6	0	8	0	3	0	0	64
Boifushi	7	0	0	0	0	0	9	10	10	8	9	0	9	6	0	0	0	4	0	0	0	0	64
Dhigufaru	6	0	7	0	0	0	9	10	10	9	10	0	10	9	0	0	0	7	0	10	0	0	63
R11	10	0	7	0	0	0	7	9	9	3	3	0	6	8	0	0	0	1	0	0	0	0	61
Kihaadhoobinmatheefaru	5	0	0	3	0	0	9	10	10	4	8	0	10	9	0	0	0	5	0	3	0	0	60
Boatu urunu faru	8	0	0	0	0	0	10	7	7	0	9	0	8	10	10	0	0	10	0	0	0	0	59
Maahuruvalhi	5	0	8	0	0	0	7	10	10	10	1	8	0	2	0	0	0	2	0	0	0	0	59
R15	10	0	10	0	0	0	6	7	7	0	9	0	8	8	0	0	0	7	0	0	0	0	58
R21	9	0	2	0	0	0	3	9	9	0	8	7	2	6	8	9	0	1	4	9	0	0	58
Maamaduvvaree	3	0	0	0	0	0	10	10	10	0	10	0	8	10	0	0	0	0	0	0	4	0	57
Maahuruvalhi	2	0	8	0	0	0	10	9	9	0	7	0	9	10	0	0	0	4	0	3	0	0	57
Boifaru	6	0	6	0	0	0	7	9	9	1	3	0	9	9	0	0	0	4	0	0	0	0	55
Maahuruvalhi	5	0	3	0	0	0	10	10	10	3	9	0	6	4	0	0	0	1	0	0	0	4	55
Gemendhoo	9	0	0	0	0	0	7	9	9	0	9	0	9	7	0	0	0	0	0	5	0	0	54
Gemendhoo	7	0	0	0	0	0	5	9	9	10	10	0	10	4	0	0	0	6	4	0	0	0	54
Hanikandu faru	7	0	0	0	0	0	8	10	10	10	0	0	9	10	0	0	0	10	0	0	0	0	54
Maahuruvalhi	2	0	0	0	0	0	10	9	9	2	8	0	7	8	0	6	0	7	0	0	0	0	54
Thulhaadhoo	1	7	9	0	0	0	0	9	9	6	7	6	0	0	0	0	0	1	0	0	0	0	53
R14	5	0	9	0	0	0	5	9	9	0	4	0	9	10	0	0	0	7	0	0	0	0	53
R4	10	0	0	0	0	0	4	9	9	9	4	0	9	3	0	0	0	0	0	0	4	0	53

With the amplitude method (Fig 5.18), sites were more widely distributed over the atoll : three sites on the northern atoll, four sites on the north-east side and three sites in the centre of the atoll. However total indices were much lower in general than with the decile method (Table 5.8). The highest index was also recorded at Dhigufaruvinagadu with 11 of the 17 species. It was followed by Vandhoomaafaru (Reethi Beach) (index 36), Vakkaru (index 32) and Vinaneiyfaruhuraa (index 30). On average these sites obtained 8 species of the 17 selected.

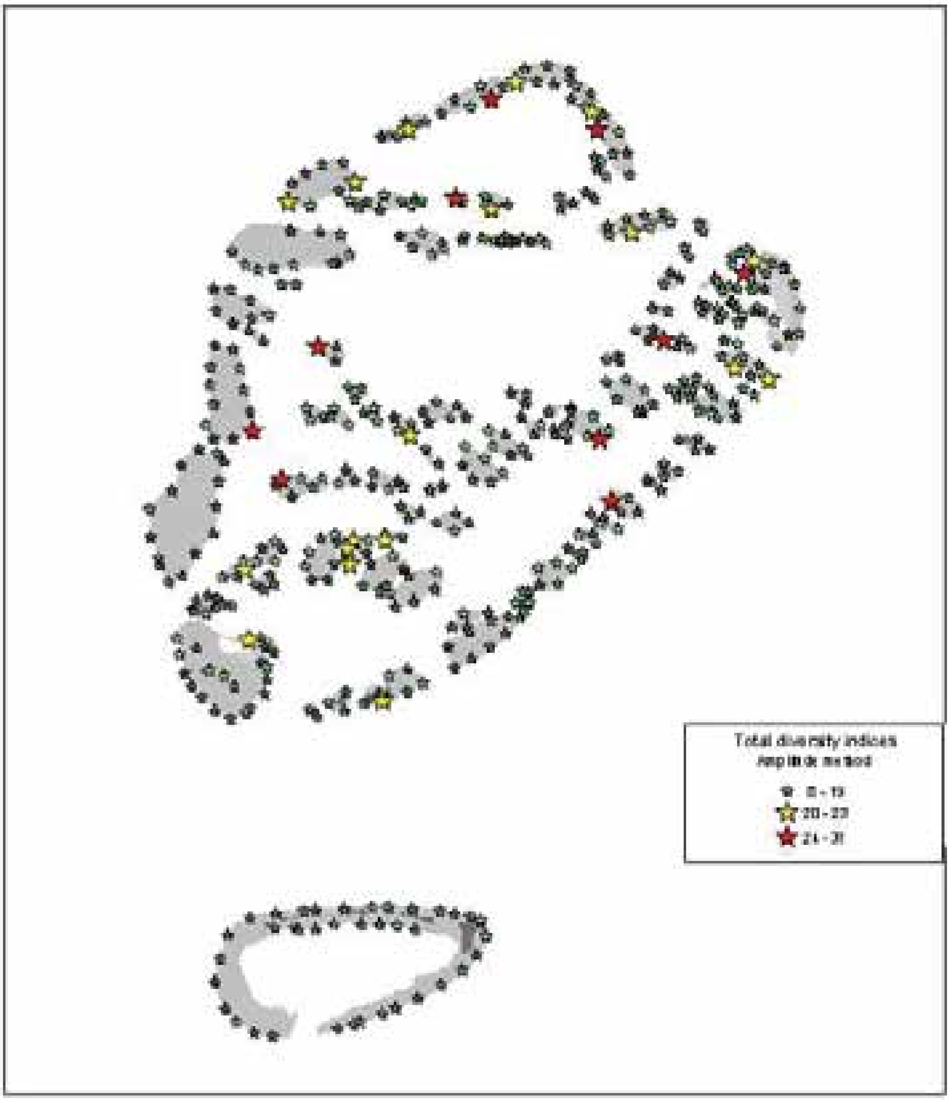

Figure 5.18. Map of the highest total index sites (calculated with the amplitude method

Table 5.8. Sites with the highest Total index calculated with the amplitude method

Area	Live corals	*C.mydas*	*E.imbricata*	*C.melano-pterus*	*C.amblyr-hynchos*	Other sharks	*C.argus*	*V.louti*	*P.laevis*	*E.fusco-guttatus*	Other groupers	*C.undulatus*	*Tridacna* sp.	Sea cucumbers	*P.versi-color*	*Antipathes* sp.	*P.penguin*	Sea stars	Ascidians	Sponges	Corallimorphs	Zoanthids	Total Index
Dhigufaruvinagadu	7	0	0	0	0	0	2	4	2	3	10	0	3	1	2	1	2	0	0	0	0	0	37
Vandhoomaafaru	2	0	0	0	0	0	2	10	0	0	5	3	1	1	8	4	4	4	0	0	0	0	36
Vakkaru	7	8	0	0	0	0	4	6	10	0	0	0	0	0	0	0	0	3	0	0	0	0	32
Vinaneiyfaruhuraa	6	0	1	0	0	0	7	1	0	0	9	1	5	1	1	0	0	1	1	0	0	0	30
Boifushi	9	0	0	0	0	0	7	0	3	0	3	0	5	0	0	0	0	1	0	0	0	0	26
Dhigufaru	2	0	1	0	0	0	4	3	2	0	8	0	6	1	0	0	0	1	0	1	0	0	25
Boatu urunu faru	3	0	0	0	0	0	5	1	0	0	4	0	1	3	10	0	0	2	0	0	0	0	25
Maahuruvalhi	3	0	0	0	0	0	6	2	1	0	6	2	1	4	0	0	0	0	0	0	0	0	25
Nelivarufinolhu	4	0	0	0	0	0	1	0	1	5	1	0	5	5	0	0	2	0	0	0	0	0	24
Kihaadhoobinmatheefaru	1	0	0	7	0	0	3	3	0	0	4	0	5	1	0	0	0	0	0	0	0	0	24
R1	7	0	0	0	0	0	0	0	0	6	0	0	0	0	10	0	0	0	0	0	0	0	23
Nagilifalhu	8	0	2	0	0	0	2	0	0	0	0	0	9	0	2	0	0	0	0	0	0	0	23
Nagilifalhu	6	0	1	0	0	0	10	0	0	0	0	0	5	1	0	0	0	0	0	0	0	0	23
Huraifaru	1	0	0	0	0	0	4	1	1	9	4	0	2	1	0	0	0	0	0	0	0	0	23
Anhenunfushi	4	0	0	0	0	0	6	2	0	2	4	2	1	1	0	1	0	0	0	0	0	0	23
Nibiligaa	9	4	5	0	0	0	1	2	0	0	1	0	0	1	0	0	0	0	0	0	0	0	23
Boifaru	4	0	1	0	0	0	2	3	2	0	3	0	5	2	0	0	0	0	0	0	0	0	22
Maamaduvvaree	0	0	0	0	0	0	4	6	0	0	8	0	1	2	0	0	0	0	0	0	0	0	21
Nagilifalhu	5	0	0	0	0	0	5	0	0	0	0	0	10	1	0	0	0	0	0	0	0	0	21
Landaa giraavaru	4	0	0	0	0	0	7	4	0	0	6	0	1	0	0	0	0	1	0	0	0	0	21
Bathalaa	2	0	7	0	0	0	6	2	4	0	3	0	1	0	0	0	0	3	1	0	0	0	21
Thulhaadhoo	8	0	3	0	0	0	7	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	20
R15	7	0	4	0	0	0	1	1	0	0	5	0	1	1	0	0	0	0	0	0	0	0	20
Huraifaru	0	0	0	0	0	0	5	3	0	0	10	0	0	2	0	0	0	0	0	0	0	0	20
Vandhoomaafaru	0	0	0	0	0	0	1	9	3	0	2	4	1	0	1	0	0	1	0	0	0	0	20
Gaagadufaruhuraa	0	0	0	0	0	0	2	4	1	2	7	0	0	1	0	3	0	0	0	0	0	0	20
Gemendhoo	3	0	0	0	0	0	1	2	4	0	7	0	4	0	0	0	0	0	1	0	0	0	20
Hanikandu faru	3	0	0	0	10	0	3	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	20
Hanikandu faru	3	0	0	0	0	0	5	0	0	0	7	0	3	3	0	0	0	1	0	0	0	0	20

5.3 Discussion

5.3.1 Threatened areas and infesting species

5.3.1.1 The potential threats

5.3.1.1.1 *Acanthaster planci*

The crown-of-thorn sea star is a large sea star (up to 80 cm diameter), widely distributed in coral reef areas throughout the Pacific, Indian Ocean and the Red Sea. *A. planci* is known to reproduce mainly via sexual reproduction with females producing up to several tens of millions of eggs during one season (Yokochi, 2004). Therefore a small increase in survival rate can result in large increases of adult populations, recorded as outbreaks. Outbreaks events of *Acanthaster*, reported at various locations, have caused large damage to coral communities. Large outbreaks can kill most of the living corals, reducing coral cover to less than 1%. The juveniles settle on the reefs approximately six months after spawning and begin to feed on corals. Two years after spawning they have their adult size and feed massively on corals. Results from fine-scale surveys indicate that coral cover of more than 10% is needed for juvenile starfish to survive and grow (CRC, http://www.reef.crc.org.au). In normal situation, *A. planci* will feed mainly on tabular coral species but during intense food competition it will eat all types of living corals.

At the time of the assessment, with only seven individuals observed, it is not possible to say that *A. planci* is a major threat for corals in Baa. Scientists estimate that a healthy coral reef with about 40 - 50% coral cover can support about 20 – 30 individuals of *Acanthaster* per 10,000 m^2 (CRC, http://www.reef.crc.org.au). In New Caledonia, densities were considered high when it reached 3 individuals per 100 m^2 (http://www.ifrecor.nc). With no records of infestation in the Maldives, and little targeted monitoring, it is not clear what alarming levels would be.

However, it seems important to continue to monitor this species and to report any increase in its population. Extermination would be more successful if it begins before large outbreaks appear (Yokochi, 2004). One of the known predators of *A. planci* is the giant triton *Charonia tritonis,* which can regulate the population by eating them. However, this species was never seen during our monitoring of Baa Atoll.

5.3.1.1.2 *Culcita schmedeliana*

The pin-cushion sea star is less known as a coral predator than the crow-of-thorn even if it could possibly destroy large areas of corals. In experiments Glynn and Krupp (1986) found that they could eat up to 0.9 m2/year of coral, but downsized the threats due to low densities of 25 individuals/hectare, far below the levels noticed in this study. *Culcita* seem to be able to feed only on small corals and could consume larger colonies only partially (Birkeland & Lucas, 1990). Moreover its diet is more diverse and the species will not feed exclusively on live corals. Nevetheless, it could affect coral communities by feeding on small recruits of the preferred prey families (Acroporidae, Pocilloporidae). Further studies are necessary in order to determine if this species could be a major threat for the ecosystem in Baa, where the species was observed very frequently. This could be a specificity of the Maldivian reefs, which would give an explanation as to the slow recovery of the reefs. However, due to the limited range of the prey size and its more generalised diet, *Culcita* does not seem to be able to clear large areas of corals (Birkeland & Lucas, 1990).

5.3.1.1.3 Ascidians (Ascidiacea)

Didemnum sp. are known to be colonial ascidians competing for space (Dijkstra *et al*., 2007). Dijkstra *et al*. (2007) showed that ascidians synthesize allelopathic chemical compounds that inhibit the recrutment of other organisms. Ascidians can settle on different types of substrate such as corals, rubble, algae or rocks. Even if they can be highly invasive and compete for space, no serious invasion of ascidians on coral reefs have been reported. Their presence in Baa was relatively rare and in low proportions. Thus it does not represent a major threat for corals for the moment.

5.3.1.1.4 Zoanthids (Zoantharia)

Zoanthids seem to be locally abundant species but can reached high proportions in some parts of the atoll. We observed that high densities of hawksbill turtles (*Eretmochelys imbricata*) were recorded at the two sites with high zoanthid cover. Literature on hawksbill's diet confirmed that this species, althrough it prefers sponges, also prey on other organisms such as zoanthids, sea urchins, bivalves, ascidians or crustaceans (Stampar *et al*. 2007). Predation of hawksbill on the anemone-like zoanthid *Zoanthus sociatus* has been reported at St. Croix, U.S. Virgin Islands by Mayor *et al.* (1998) while Stempar *et al*. (2002) observed predation by hawksbill on the zoanthid *Palythoa caribaeorum* in Southern Brazil. Results of Leon & Bjorndal (2002) indicate that the diet of hawksbill is determined by the combination of selective feeding and prey abundance. Hawksbill turtles show a strong selectivity for certain sponge species as food items but prey on others organisms when sponges are not fully available. This observation shows that predation by hawksbill turtles could regulate the abundance of zoanthids, corallimorphs and sponges and thus maintain reef diversity by allowing competition for space (Leon & Bjorndal, 2002). More than its ‘critically endangered’ status in the IUCN Red List, the Hawksbill turtle should benefit from protection due to its position within the trophic web and its role in the ecosystem. Selection of protected areas intended to benefit hawksbills should consider their selective feeding patterns (Leon & Bjorndal, 2002). We believe that protection of hawksbill at specific locations should benefit corals health and diversity.

5.3.1.1.5 Corallimorphs (Zoantharia)

Corallimorphs are sessile cnidarians and may be a major component of some temperate and tropical marine communities. It is reported from the literature to be an aggressive competitor for space, forming large aggregations that can overgrow a variety of organisms and dominate the substrate (Langmead & Chadwick-Furman, 1999 ; Kurugu *et al*. 2004). Some species in the Caribbean and the Indo-Pacific are known to use tentacles to kill corals and to defend its space. Langmead & Chadwick-Furman (1999) studied *Rhodactis* (= *Discosoma*) *rhodostoma*, one of the most common corallimorph species in the Red Sea. Their results showed that *Rhodactis* occurred in localized patches, up to 1700 polyps/m^2. Experiments on corallimorpharians growth conducted in Tanzania (Kurugu *et al*. 2004) showed that corallimorpharians seemed more competitive in shallow waters and that highest densities were recorded in areas with the highest nutrients content. Turbid waters with high plankton and detritus seemed to act in favour of corallimorpharians (Kurugu *et al*. 2004).

It is not clear why corallimorpharians were only observed at few places but in high proportions such as in Kudarikilu. A resort is under construction at the neighbourgh island Kihavahhuruvalhi and might generate a source of unsual turbidity and detritus, or the waste disposal mechanism of the island is for some unknown reason particularly bad. Further studies are necessary in order to determine possible factors enhancing corallimorpharians growth, and the impact from the resort construction are probably not the main factor as these works are quite recent.

In most cases, corallimorphs damaged corals from the Poritidae, Acroporidae and Pocilloporidae families. Massive corals such as Mussidae and Faviidae seemed to avoid damages from corallimorphs (Langmead & Chadwick-Furman, 1999). In 1988 Moosleitner reported the presence of *Rhodactis* (= *Discosoma*) corallimorphs in a small reef within the

Rannali Kuda Giri atoll. Half of the reef was overgrown by corallimorpharian *Rhodactis* sp. Nearly all the corals living there were destroyed, except corals with large polyps such as Goniopora, Euphyllia, Plerogyra and Physogyra (Moosleitner, 1989). The same species has been noticed in high numbers by the authors in other places of the Maldives, such as Kuda Fari in Noonu atoll, Innamadhoo in Raa atoll or Maafahi in Haa Alifu Atoll. Pictures taken at Kudarikilu during Baa survey show that *Discosoma* is overgrowing any type of substrate, covering even live clam shell *Tridacna* sp. Although *Discosoma* seems locally abundant and present at only few places in Baa atoll, it seems important to monitor and manage its population. Not much information is available to date on species in the Maldives. Similar to the case of the zoanthid, Leon & Bjorndal (2002) showed that the corallimorph *Ricordea florida* was the dominant prey found in diet of hawksbill turtles in Dominican Republic, and therefore conservation of Hawksbill could help with this spreading species.

5.3.1.1.6 The sponge Terpios hoshinota (Demospongiae)

Terpios hoshinota is an invasive sponge that lives symbiotically with a photosynthetic cyanobacterium. It is recognized by its extensive greyish to blackish thin encrustations (Rutzler & Muzik, 1993). It can grow on a diversity of substrates and can encruste live coral tissues through the use of cytotoxic chemicals produced by the sponge (Petterson, http://www.nova.edu/ncri/11icrs/abstract_files/icrs2008-002324.pdf). Small oscula are usually discernible and are at the center of radiating vein networks. The sponge grows by lateral propagation, extending short fine tendrils across crevices to new surface (Rutzler, 1993) Therefore, the sponge advances easily over corals, and can even make bridges between branches of corals. After encrustation, all polyps die and reefs show large grey dead areas. *Terpios* has been recorded as invasive encrusting sponge in different places in some Pacific islands, such as Guam, American Samoa or Ryuku Archipelago (Rutzler & Muzik, 1993 ; Yokochi, 2004). During their survey in Japan, Rutzler & Muzik (1993) observed that *Terpios* encrusted and killed a dozen species of living corals (such as *Porites*, *Montipora, Acropora*, *Goniastrea*) and covered shells of some benthic invertebrates such as *Tridacna* sp. The ability of this species to overpower live organisms and its high competitive potential for space may become a major threat for reef ecosystems. Therefore the island of Kudarikilu and the surroundings should be monitor to understand better if this condition will spread to nearby reefs.

5.3.1.2 Need for monitoring

Competition for space is one of the most important factor gouverning reef communities. Competition among sessile organisms may be direct (overgrowth or cnidoblast) or indirect (food or shading). One solution to fight against pest species is to control their growth by managing their predator species populations. However this is not always feasible, and all the predator species are also poorly understood.

For the moment, in Baa atoll major threats seem under control but it is important to set up regular monitoring at the sites identified as ‘coldspots’, especially where *Acanthaster*, *Terpios* and *Discosoma* have been seen. The relationship between hawksbill turtles and zoanthids in particular at Bathalaa, is an interesting study case where the reptiles may maintain the presence of an optimal cover while enabling more coral recruitment through removal of zoanthids.

It would also be useful to evaluate the benefit or loss of these particular habitats on the overall fish and invertebrate biodiversity.

5.3.2 Anthropogenic Activities

Before using the above maps to make recommendations for marine biodiversity management measures, it is important to keep in mind what activities are carried out on the islands. Protection of marine protected areas is indeed fore and foremost protection from all anthropogenic activities and their impacts. There is a well documented horde of them such as overfishing, direct and indirect impacts from construction or anchors, eutrophication, bad disposal of waste and garbage etc...It therefore seems more difficult to protect areas where these activities will be intense. On the other hand, it is the regulation of these activities, which will procure a real protection not only to the marine protected areas but to the atoll in general. In some circumstance, some areas of biological occur in areas where some activities are already carried out. The following map (figure 5.19) tries to illustrate these conflicts at atoll scale.

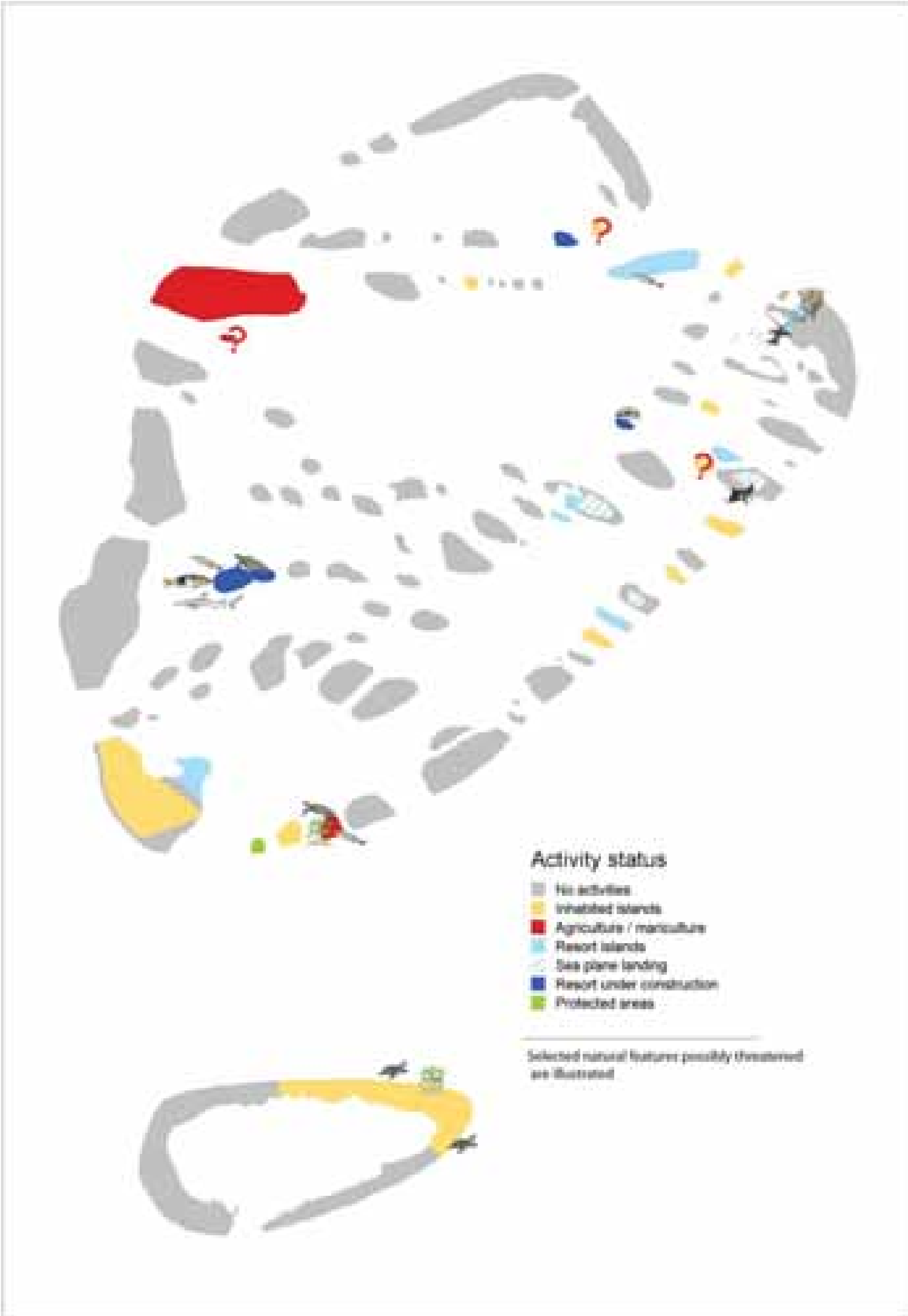

Figure 5.19. Activities on the islands of Baa with prominent biological features

In addition to the activities, two other islands have changed status very recently or will very soon. This is the case for Hanifaru and Mendhoo. If the island of Mendhoo could finally not be protected, it would be important to protect either Aidhoo or Dhandhoo to allow for bird protection.

It seems important to issue more precise codes of conduct that the different stakeholder groups should follow. There is already a regulation regarding the tourist resorts providing some protection to the house reefs of resort, in particular from fishing, making them some sort of MPAs in their own right. It seems that some precisions and documentation would be required as to the boundaries of these areas. The resorts are also supposed to submit a yearly environment report, but this is not well practised and a standardization of the methods should be implemented. This information should then be used in a GIS system such as the one used for the present survey. This form of protection, monitoring and management would already create different categories of use zones, which will include some protection for the biological features. This of course calls for more awareness, education and training for all stakeholders.

This being a process outside the scope of the present report, it is not dealt with in details. For the purpose of this study, it is important to mention that these areas have been mostly avoided for any special protection status except if they were significantly standing out.

5.3.3 Proposed areas for Marine Protection

5.3.3.1 Broad atoll view

Drawing on the indices maps and hotspot maps from above, a number of areas have been highlighted to create Marine Protected Areas. This is not intended as being boundaries of actual marine protected areas, but based on our surveys, these sites have the biological significance at atoll scale justifying priority protection. It is quite clear that different islands should have different protection status, especially given the activities which are carried out on the islands. The strategy here has been to favour large size MPAs rather than many small size ones, and there are mainly three zones, which should afford better potential. These areas are located in the very north of the atoll, in its center and the western part of Goidhoo atoll. It seems that enforcement would be easier in large MPAs than an array of small MPAs with boundaries harder to understand and remember. In general, large MPAs may be ideal for biodiversity conservation because they encompass more species and may limit the exploitation of fish stocks to well below sustainable levels. Small MPAs may provide a protective umbrella for the biodiversity of sedentary species but are unlikely to provide an effective refuge for highly mobile exploited species (Hilborn et al., 2004; Nardi et al., 2004), and this is why several sites of a particular interests have been highlighted. Nonetheless, getting the right balance between reserve design for both exploitation and conservation requires a detailed understanding of larval dispersal patterns for the widest possible range of marine species. In the absence of such data, it has been assumed that large MPAs or MPAs linked with buffer zones allowing for self-recruitment would probably be more effective than many small ones. Recent studies using isotopes and other markers show that even though pelagic larval durations may be important, many coral reef fish larvae settle much closer to home than previously thought (Jones, 2007). On the other hand, the reefs in the Maldives being quite close one to another, population recruitment from one reef to an adjacent one may be more important than in that study.

Quite remarkably, the areas proposed are so far the most remote from the inhabited islands. It could therefore be that the reefs the most visited are the ones, which generally speaking score the lowest, maybe due to the sum of the impacts. Of course it could also be that the patterns encountered are mostly related to hydrodynamic patterns and larval dispersal. The present study can definitely not tell the two influences apart. Nevertheless, this configuration is quite adapted to the protection of the most diverse areas, while the reefs closer to the islands can still be harvested at the least costs. It would therefore seem quite easy to extend the protection to the furthest reefs, even if they are not mentioned on the map below (figure 5.20).

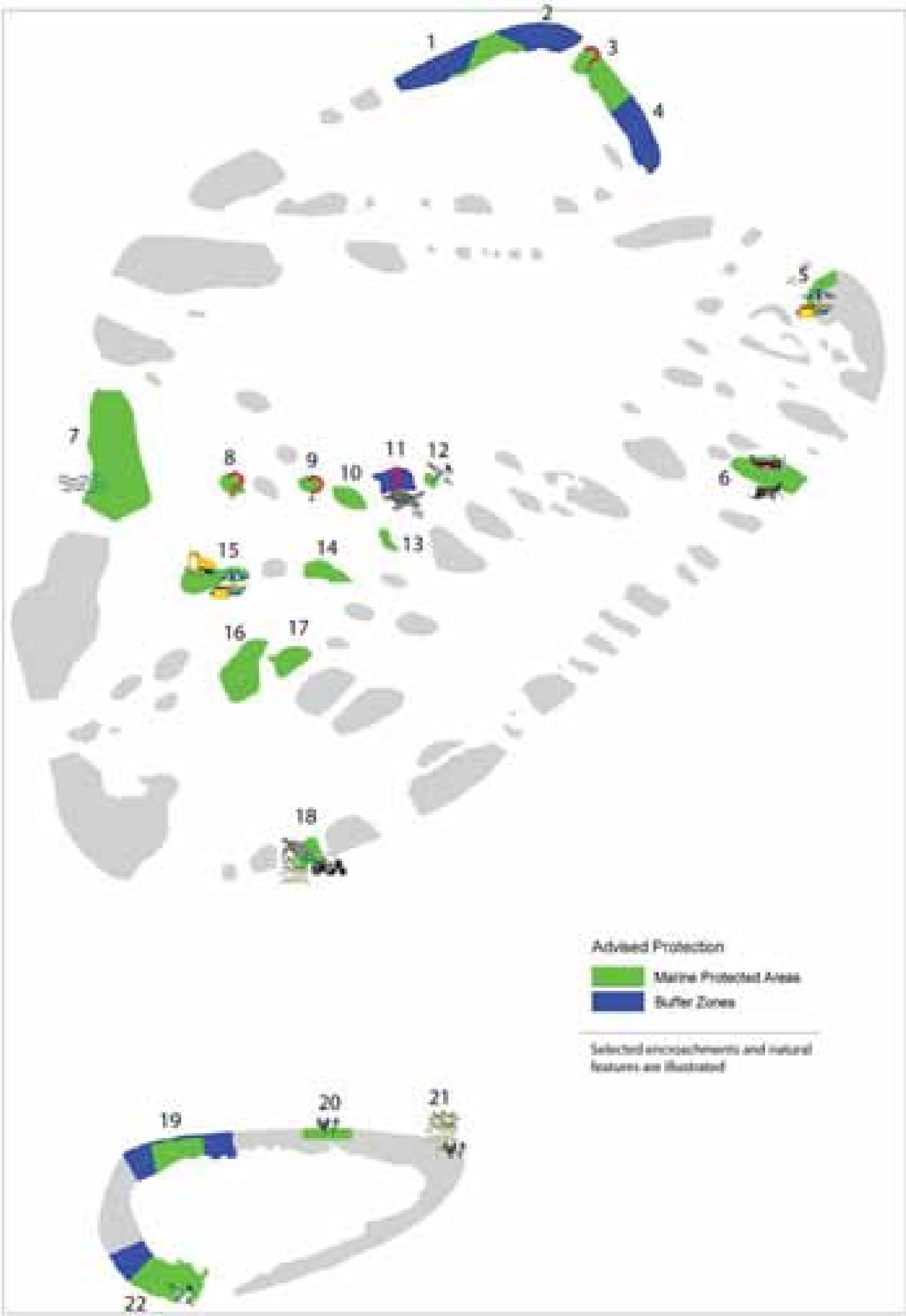

Figure 5.20. Map of potential areas for the creation of Marine Protected Areas (MPAs).

5.3.3.2 Proposed reefs characteristics

The different reefs proposed for special protections are briefly described below. Even though they are described separately each area can be seen as part of a cluster. The proposed areas on the eastern side are somewhat more isolated as there are more inhabited islands and the zone tend to target a particular feature.

5.3.3.2.1 Area 1 : Dhigufaruvinagadu

This area appeared with a high total index with several sites selected. The live coral cover on the lee side is quite important with a high percentage of branching and tabular corals standing out in the northern atoll. The most interesting side is the channel side on the Dhigufaru side. Even though the outside corner is quite poor, the inside is rich with interesting features and black corals.

5.3.3.2.2 Area 2 : Dhigufaru

On Dhigufaru the inside of the Dhigufaru Kandu also has interesting with some black corals. Different points appear in a number of indices calculations. The lee side of the reef is covered with zoanthid and is a hotspot for hawksbill turtles. The Dhigufaru Kandu being the richest area, together with the lee side of the reef, it is proposed to emphasize the protection of these areas, the rest of the reefs making buffer zones.

5.3.3.2.3 Area 3 : Bathalaa

The island of Bathalaa and its associated reef is an interesting area. There is a large sand bank as well as a small island, which procure some habitat for a number of birds. The lee side is heavily colonized by zoanthids but is the place where the most hawksbills have been seen. This could be the place where this relationship can be observed and studied, enhancing the protection effort.

5.3.3.2.4 Area 4 : Vinaneiy Faru

Vinaneiy faru shows up in most indices calculation, especially its northern part facing Bathalaa. It therefore seems judicious to expend the protection to the northern side of this reef as well. The outer side of the reef is also in a better state than the outer sides of the main atoll.

5.3.3.2.5 Area 5 : Fonimagoodhoo

The reef of Fonimagoodhoo (Reethi Beach) has been going under the name of Vandhoomaafaru, as the boundaries are not clear. It is nonetheless the Reethi Beach side of the reef which has the richest marine life. In fact the eastern side of the Vandhoomaafaru has very poorly recovered. The side of the channel into the atoll is quite rich with usually good water quality on a steep wall, and stands out in a number of indices calculations. This area being in a resort, it already enjoys some level of protection. Given the significance of that area, it could be that some special attention should be directed there.

5.3.3.2.6 Area 6 : Hanifaru

Even though the Hanifaru area does not stand out based on the data collected during this survey, it seems that this area is of biological significance, especially for plankton feeders such as whale sharks and manta rays. This particular site is the prime location for sightings of these mega fauna by the Maldivian Manta Ray Project and the Maldivian Whale Shark Project based at the Four Seasons Resort at Landaa Giraavaru. The sightings of whale sharks was provided to us by the Maldivian Whale Shark Project (Fig. 5.21, Table 4.9)

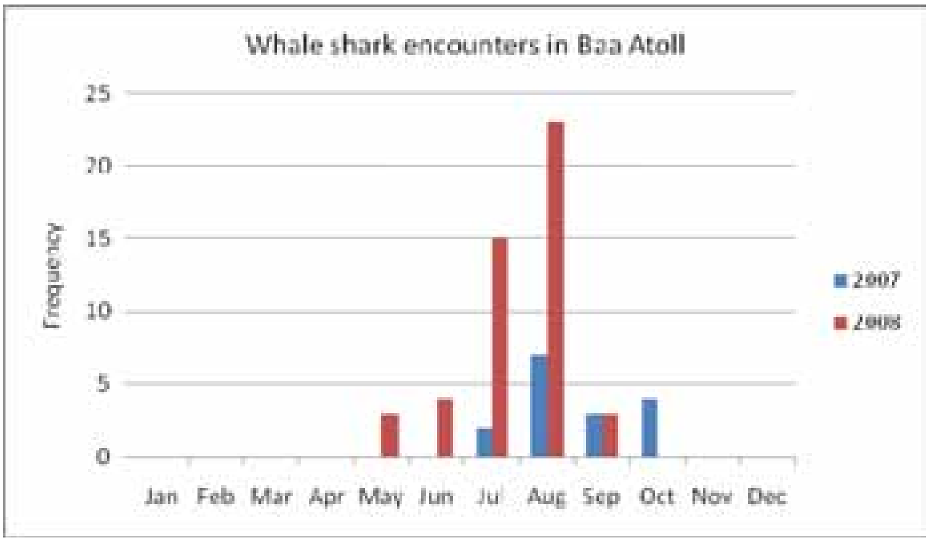

Figure 5.21. Whale shark seasonal encounters within Baa Atoll

Table 5.9. Encounter location and frequency within Baa Atoll

Location	2007	2008	Total	Frequency (%)
Hanifaru	13	46	59	92
Dhigu thila	2	-	2	3
Nelivaru thila	-	1	1	2
Reethi Beach Resort	-	1	1	2
Landaa Giraavaru Resort	-	1	1	2

N.B. 2008 data period May-August only

Table 5.10. Re-sightings of whale sharks at Hanifaru

	Number of individuals
Total whale sharks identified	20
Intra-annual re-sightings	11
Inter-annual re-sightings	10
Re-sightings from outside Baa Atoll	9

The project concludes that Hanifaru is clearly an important feeding location for whale sharks as the same individuals are known to return to the bay several times throughout the season, and also between years. Using photo-identification methods, 20 whale sharks have been identified feeding in Hanifaru to date. Of these, 13 have returned to Hanifaru to feed again at some point (Table 5.10). Within the same season, the interval between re-sightings varies between a few days to several months. Between years, of the 10 sharks identified in Hanifaru in 2007, 5 were seen again in 2008 showing that whale sharks make seasonal migrations to feed at Hanifaru.

5.3.3.2.7 Area 7 : Maahuruvalhi

Maahuruvalhi is very interesting for several reasons. First of all this is one of the site where high density of napoleon fish was recorded. Consequently this area obtained a good rank for the tourism index, also due to the presence of hawksbill turtles. The outer slope is lined all along with a large overhang, which is probably a good refuge for large groupers, even though this would need to be explored further while scuba diving. A large school of snapper seems to enjoy a particular site on the western site, where napoleons are also present. High densities of big groupers were also recorded especially in the northern part and for the black-saddle grouper. Thus five and two sites with respectively the decile and amplitude methods appeared within the IUCN index.

Secondly several sites appeared to have a middle to high fishing index and, even if it did not obtain the highest rank, it was the area with the highest numbers of sites identified (4 sites with the decile method and 5 sites with the amplitude method) for fishing index. The peacock groupers were present at each site on the inner reef, while the lunar-tailed groupers were present all around the reef. Thus Maahuruvalhi constituted a hotspot for little groupers. Finally, Maahuruvalhi arrived on third position for the total diversity index.

In conclusion we can say that Maahuruvalhi appears with a high rank for several indices and hotspots. This site regroups species from the IUCN Red List such as napoleon fish, black saddle grouper and turtles as well as species with special interest for fishing such as little groupers. A marine protected area at this site could then have a double objective of protection.

5.3.3.2.8 Area 8: R6

The reef does not have an very good coral cover and *Terpios* is also largely present. On the other hand, the presence of sharks, turtles and groupers gets this reef to stand out in some of the index calculations. Monitoring of this site would yield some useful information about the ecology of *Terpios*.

5.3.3.2.9 Area 9: R8

The coral cover is one of the best of the atoll, with lots of tabular on the top and a good diversity below but dominated by *Acropora.* A small island is already used for picnic purposes and a channel has been dug. Some *Terpios* is also present.

5.3.3.2.10 Area 10: Nibiligaa

Nibiligaa is the site where most Acanthaster were seen. Therefore it seems important to monitor for any outbreaks. The live coral cover and diversity are very good and it has very good tourism indices. Compared to other places, the colonies may be larger.

5.3.3.2.11 Area 11: R9

The reef is heavily colonized by Zoanthids on its southern side and many hawksbill turtles were seen in that area, similar to the lee side of Bathalaa. The comparison between the two sites would be ideal to test hypothesis in two different areas. In addition, the coral cover is very good on its northern side.

5.3.3.2.12 Area 12: Mendhoo

Even though not exceptional, the coral cover in Menhoo is good. More importantly, the island is a shelter for a colony of white tailed tropic bird, which has been previously reported from Horubadhoo (Royal Island) before it was a resort (Coleman, 2000).

5.3.3.2.13 Area 13: R11

Even though the live coral is inequal, the western part is one of the densest areas in the atoll. The site also scores well with the total diversity index and gets good tourism index thanks to the few turtles that were seen.

5.3.3.2.14 Area 14: R4

Live coral cover is excellent around the reef. Similarly to the previous reef, the it scores nicely on total diversity index.

5.3.3.2.15 Area 15: Vakkaru

Vakkaru is a very interesting site in terms of protected species. We observed the presence of green turtles and sharks which are rare elsewhere in the atoll. There are also some little and big groupers, which also gave this site a high fishing index.

This site is put under anthropogenic impacts because a resort is under construction on the island (decision has been confirmed at the time of the survey). We believe that its future resort status will allow for some protection of the fish and the turtles as fishing will be prohibited. However, we are concerned about the construction phase, and special care should be taken in order to reduce the impacts of construction on the marine environment. The monitoring of the construction (included in the EIA) should be implemented to limit potential impacts and prevent irreversible changes.

5.3.3.2.16 Area 16: Bodugaafalhu

This is the area where the most sharks has been seen with one black tip and two nurse sharks. It has interesting features with caves and overhangs. The tourism indices are good despite a few areas with very little live corals, and this is mainly due to the sharks and turtles.

5.3.3.2.17 Area 17: Nagilifalhu

Nagilifalhu has good fishing indices thanks to a large number of little and big groupers. It also scores high in the overall diversity and has a very high density of clams.

5.3.3.2.18 Area 18: Maamaduvari

Maamaduvari is a nice island with a little mangrove, which is not very developed. Although the reef is not excellent, it showed a large number of small groupers and clams. The presence of green turtles makes this island a good candidate for protection. The island has been given for agriculture purposes, and this should be carried out in an eco-friendly way. Conservations of turtles can also be carried out, especially when it comes to not digging the nests. Hithaadhoo also is interesting for green turtles, but being an inhabited island, conservation there would be harder to implement.

5.3.3.2.19 Area 19: Innafushi

The island of Innafushi has a good coral cover on the interior side of the atoll. This high coral cover area extends almost all the way to Fulhadhoo on the east. In addition, sand banks present in the area are sometimes colonized by birds.

5.3.3.2.20 Area 20: Fulhadhoo – Fehendhoo

This part of Goidhoo atoll was particularly rich for hawksbill turtles and napoleon fish and thus providing this site with high tourism and IUCN indices. Presence of sea birds and dolphins were also recorded.

However, this zone represents a fishing area for the people living on Goidhoo, Fehendhoo and Fulhadhoo and therefore may be difficult to protect.

5.3.3.2.21 Area 21: Goidhoo Mangrove

The mangrove in Goidhoo is the most significant in the atoll, and therefore it is proposed to protect it to increase the range of protected habitats. The species encountered are different from those typically found in the northern mangroves of Maldives. In addition, this area has been the object of different onservation attempts in the past and was partly cleaned from the garbage that used to be dumped in the area.

5.3.3.2.22 Area 22: Goidhoo Maafushi

The island of Maafushi is a rocky islet with a lighthouse marking the western side of the Dhoru Kandu, the only natural pass into Goidhoo atoll. A number of birds colonize the island while underwater, turtles and napoleon were seen in numbers, giving good IUCN index to the site.

5.3.4 Further studies

As pointed out in the discussions above, there are several biases and lack of information in the present study, which brings limitations to this rapid assessment. Therefore there are several points which will need to be further looked into, and are presented below.

First of all, this survey is a one off event, which could not be representative of the year round situation and does not give us very good ideas on the different influences such as lunar cycle, tidal cycle, diurnal cycle as well as the monsoons. It is therefore advised that a more thorough survey is carried out at each site to establish a better baseline for the protected site. Even though the present survey will offer some points for comparison in the unprotected areas, the same survey as that of the protected areas should be carried out in unprotected areas as well. In addition, more secondary data must be available from the different ministries of the Government of Maldives. This concerns in particular the monitoring of resorts or fisheries statistics.

This in fact calls for setting up a comprehensive monitoring program in which the different stakeholders should take part. A lot of different monitoring programs can be envisaged, but will probably be incorporated together with enforcement in the final plan. It will therefore be possible to follow the reef evolution in Baa, and in particular the peculiarities such as the colonizing sponges, zoanthids and corallimorphs. This monitoring should not solely have to do with the status of the reef, but should encompass the catching effort and atoll internal marine products consumption. This monitoring will eventually lead to a wide recognition of the benefits of the protection for the fisheries and tourism industry. This would retroactively strengthen the protection and hopefully reduce the need for enforcement.

It was also discussed that a separate "code of conduct" or management plan should be issued for the resorts and inhabited islands separately in order to minimize the adverse effects caused by anthropogenic activities.

Finally, the most crucial point when it comes to designing marine protected areas lies in the lack of any hydrodynamic data for the atoll. Models even not so elaborate could provide important key to understand the ecology of the atoll. If this is done in the future, the areas could be redesigned in order to increase the yield of the protection while increasing the reef overall resilience.

6 References

Survey Manual for Tropical Marine Resources, 2nd Edition. English, S., Wilkinson, C. And V. Baker (Eds). Australian Institute of Marine Science

Kohler, K.E. and S.M. Gill, 2006. Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. **Computers and Geosciences**, Vol. 32, No. 9, pp. 1259-1269, DOI:10.1016/j.cageo.2005.11.009.

Uychiaoco, A.J., S.J. Green, M.T. dela Cruz, P.A. Gaite, H.O. Arceo, P.M. Aliño, and A.T. White. 2001. Coral Reef Monitoring for Management. University of the Philippines Marine Science Institute, United Nations Development Programme Global Environment Facility-Small Grants Program, Guiuan Development Foundation, Inc., Voluntary Service Overseas, University of the Philippines Center for Integration and Development Studies, Coastal Resource Management Project, and Fisheries Resource Management Project. 110 p.

Hiscock, K. & Breckels, M. 2007. Marine Biodiversity Hotspots in the UK. A report identifying and protecting areas for marine biodiversity. WWF UK.

Birkeland, C. and J. Lucas (1990) Acanthaster planci : major management problem of coral reefs. CRC Press, Taylor and Francis Group. 272 pp

Dijkstra, J., Sherman, H., and L.G; Harris (2007) The role of colonial ascidians in altering biodiversity in marine fouling communities. Journal of Experimental Marine Biology and Ecology 342 : 169-171

Yokochi, H. (2004) Predation damage to corals. p. 49-55 in the Japanese Coral Reef Society and Ministry of Environment (Editors) Corals reefs of Japan. Ministry of Environment, Tokyo, Japan, 356 p. www.coremoc.go.jp/english/pub/**coral**reefjapan/0202_predation.pdf

Iping Petterson, I. Chemistry and ecology of a coral encrusting marine sponge, *Terpios spp*, from Guam. http://www.nova.edu/ncri/11icrs/abstract files/icrs2008-002324.pdf

Rützler, K. and K. Muzik (1993) *Terpios hoshinota*, a new cyanobacteriosponge threatening Pacific reefs. Scientia Marina 57 (4) : 395-403

Stampar, S.N., Da Silva, P.F. and O.J. Luiz Jr (2007) Predation on the zoanthid *Palythoa caribaeorum* (Anthozoa, Cnidaria) by a Hawksbill turtle (*Eretmochelys imbricata*) in Southeastern Brazil. Marine Turtle Newsletter 117 : 3-4.

Langmead, O. and N.E. Chadwick-Furman (1999) Marginal tentacles of the corallimorpharian *Rhodactis rhodostoma*. 1. Role in competition for space. Marine Biology 134 : 479-489

Mayor PA, Phillips B, Hillis-Starr ZM (1998) Results of the stomach content analysis on the juvenile hawksbill turtles of Buck Island Reef National Monument, USVI. In: Epperly SP, Braun J (comp) Proc 17th Annual Sea Turtle Symp. NOAA Technical Memorandum NMFS-SEFSC-415, p 230–232

http://www.seaworld.org/Animal-info/info-books/sea-turtle/diet.htm

http://conservationinstitute.org/anemonebarrens.htm

CRC Reef Research Center Ltd. Crown of thorn starfish.
http://www.reef.crc.org.au/discover/plantsanimals/cots/index.html

Ifrecor, Initiative française pour les récifs coralliens. http://www.ifrecor.nc/Acanthaster

Kurugu, B.L., Mgaya, Y.D., Öhman, M.C. and G.M. Wagner (2004) The reef environment and competitive success in the Corallimorpharia. Marine Biology 145 : 875-884

Moosleitner, H. (1989) A note on the occurrence of a ``killer anemone" in the Indian Ocean. Coral Reef Newsl 6: 20-21

Richmond, M.D. (ed.), 2002. A field guide to the seashores of Eastern Africa and the western Indian Ocean islands. Sida/SAREC – UDSM. 461 pp.

Milchakova, N.A., Phillips, R.C. & Ryabogina, V.G., 2005. New data on the locations of seagrass species in the Indian Ocean. Atoll Research Bulletin, 537 : 178-187.

Miller, M.W. & Sluka, R. D., 1999. Patterns of seagrass and sediment nutrient distribution suggest anthropogenic enrichment in Laamu Atoll, Republic of Maldives. Marine Pollution Bulletin, 38 (12) : 1152-1156.

Bers,A.V., 2005. Biodiversity assessment for Maldives' Baa Atoll. Baseline information for UNDP's Atoll ecosystem-based conservation programme. UNDP Maldives – Ministry of Environment, Energy and Water Maldives. 47 pp.

MRC., 1999. (Draft) Proposed new marine protected areas (Dive Sites) in the Maldives. MRC publication.

Godfrey, Tim. (2008) Dive Maldives: a guide to the Maldives Archipelago ISBN 0 646 28638 2.

Appendix

Reefs and Islands reference with transects and manta tows details

Reef Name	Map Reference	Transects	Manta	References
Goidhoo - 1	A02	28	23	A01 (2,3,4,6,7,8,9,11,12,13,14,15,16,18,20,21,22,23,24,25,26,27,28)
Goidhoo - 2	A01	23	17	A02 (2b,3b,4b,5b,12,13,15,17,19,20,21,22,23,24,25,26,27
Thulhaadhoo - 1	A03	20	13	A03 (1,2,3,4,5,6,7,8,9,11,12,13,14)
Thulhaadhoo - 2	A04	7	9	A04 (11,12,13,14,15,16,17,18,19)
Maafaru south - 2	A05	9	8	A05 (2,3,4,5,6,7,8,16)
Maafaru south - 1	A06	7	7	A06 (9,10,11,12,13,14,15)
Kanifushi	A07	6	5	A07 (2,3,4,5,6)
Maamaduvvaree	A08	4	3	A08 (8,9,10)
Hithaadhoo	A09	4	3	A09 (12,13,14)
Olhugiri	A10	3	2	A10 (16,17)
Gaaviligili	A11	8	7	A11 (2,3,4,5,6,7,8)
R16	A12	1	1	A12 (09)
Eboodhoo	A13	4	2	A13 (11,12+13)
Muthaafushi	A14	6	4	A14 (16,17,18,19)
R1	A15	6	4	A15 (21,22,23+24,25)
R2	A16	6	5	A16 (28,29,30,31,32)
Bodugaa falhu	A17	9	6	A17 (2,3,4,5,6,7,8)
Nagilifalhu	A18	7	6	A18 (11,12,13,14,15,16)
Marogoali	A19	7	6	A19 (9,10,11,12,13,14)
Maaneigaa	A20	7	6	A20 (2,3,4,5,6,7)
R15	A21	4	3	A21 (18,19,20)
Kudadhoo	A22	10	9	A22 (2,3,4,5,6,7,8,9,10)
Ohgali	A23	5	4	A23 (11,12,13,14)
Miriyandhoo	A24	4	3	A24 (16,17,18)

Hulhudhoo south	A25	3	2	A25 (20,21)
Koraidhoo	A26	6	5	A26 (2,3,4,5,6)
R10	A27	1	1	A27 (8)
Maddoo	A28	4	3	A28 (10,11,12)
Eydafushi	A29	4	3	A29 (7,8,9)
Sonevafushi	A30	5	4	A30 (2,3,4,5)
Nelivarufinolhu	A31	5	4	A31 (14,15,16,17)
Maalhos	A32	3	2	A32 (19,20)
Royal Island (Horubadhoo)	A33	4	4	A33 (2,3,4,5)
Dhigufaru	A34	11	9	A34 (7,8+9,10,11,12+13,14,15,16,17)
Binmathee faru - 1	A35	4	3	A35 (18,19+20,21)
Binmathee faru - 2	A36	4	3	A36 (24,25,26)
Hibalhidhoo	A37	4	3	A37 (3,4+5,6)
Daravandhoo	A38	5	4	A38 (6,7,8,9)
Angaafaru	A39	8	7	A39 (2,3,4,5,6,7,8)
Dhonfanu	A40	4	3	A40 (10,11,12)
Valtur kihaad	A41	5	4	A41 (14,15,16,17)
Hanifarurah	A42	9	8	A42 (11,12,13,14,15,16,17,18)
Mudhdhoo	A43	4	3	A43 (2,3,4)
Aidhoo	A44	3	2	A44 (2,3)
Kihaadhoobinmatheefaru	A45	5	4	A45 (6,7,8,9)
Huraifaru	A46	7	6	A46 (5,6,7,8,9,10)
Finolhas	A47	3	2	A47 (11,12)
Hirundhoo	A48	3	2	A48 (12,13)
Veyofushi	A49	19	11	A49 (2,3,4,5,7,8,9,14,15,16,17)
Vandhoomaafaru	A50	16	13	A50 (15,16,17,18)
Kihaadhoo	A51	4	3	A51 (2,3,4)
R17	A52	3	2	A52 (31,32)
R18 - 1	A53	4	3	A53 (11,12,13)
Dhandhoo	A54	3	2	A54 (34,35)
Thiladhoo	A55	3	2	A55 (15,16)
Madhirivaadhoo	A57	3	2	A57 (18,19)
Kamadhoo	A58	3	2	A58 (40,41)

Dhoogandu finolhu	A59	4	3	A59 (21,22,23)
R19	A60	2	1	A60 (7)
Milaidhoo	A61	3	2	A61 (2,3)
Vinaneiyfaruhuraa	A62	7	6	A62 (9,10,11,12,13,14)
Landaa giraavaru	A63	9	8	A63 (5,6,7,8,9,10,11,12)
Bathalaa	A64	6	5	A64 (16,17,18,19,20)
Kudarikilu	A65	3	2	A65 (14,15)
Gaagadufaruhuraa	A66	8	7	A66 (2,3,4,5,6,7,8)
Voavah	A67	5	4	A67 (17,18,19,20)
Dhigufaruvinagadu	A68	7	6	A68 (10,11,12,13,14,15)
Kihavahhuruvalhi	A69	4	3	A69 (22,23,24)
Anhenunfushi	A70	4	3	A70 (17,18,19)
Undoodhoo	A71	3	2	A71 (2,3)
Maarikilu	A72	3	2	A72 (21,22)
Funadhoo	A73	3	2	A73 (5,6)
R20	A74	2	1	A74 (2)
Hulhudhoo north	A75	3	2	A75 (8,9)
Kashidupper	A76	7	6	A76 (4,5,6,7,8,9)
Gemendhoo	A77	3	2	A77 (11,12)
Hanikandu faru	A78	9	8	A78 (11,12,13,14,15,16,17,18)
Kendhoo	A79	3	2	A79 (14,15)
Dhakandhoo	A80	3	2	A80 (2,3)
Boifaru	A81	4	3	A81 (17,18,19)
Keyodupperu	A82	7	6	A82 (2,3,4,5,6,7)
Boifushi	A83	3	2	A83 (21,22)
Maafaru north	A84	14	12	A84 (9,10,11,12,13,14,15,171,8,19,20,21)
Kashidhoogiri	A85	3	2	A85 (24,25)
Fares	A86	8	7	A86 (2,3,4,5,6,7,8)
Keyodhoo	A87	3	2	A87 (27,28)
Boatu urunu faru	A88	4	3	A88 (5,6,7)
R21	A90	3	2	A90 (9,10)
Borangali	A91	7	6	A91 (2,3,4,5,6,7)
Mendhoo	A92	3	2	A92 (2,3)

R12	A93	4	2	A93 (9,10)
Dhigali	A94	6	5	A94 (5,6,7,8,9)
R13	A95	5	4	A95 (2,3,4,5)
R22	A96	1	1	A96 (10)
R14	A97	4	3	A97 (7,8,9)
R11	A98	3	2	A98 (2,3)
R4	A99	6	5	A99 (12,13,14,15,16)
R3	B01	4	3	B01 (18,19,20)
R9	B02	5	4	B02 (5,6,7,8)
Maahuruvalhi	B03	13	12	B03 (2,3,4,5,6,7,8,9,10,11,12,13)
Nibiligaa	B04	5	4	B04 (10,11,12,13)
R5	B05	4	3	B05 (2,3,4)
R8	B06	4	3	B06 (15,16,17)
R7	B07	4	3	B07 (6,7,8)
R6	B08	4	3	B08 (10,11,12)
Vakkaru	B10	7	6	B10 (14,15,16,17,18,19)

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