

Results of Survey Lac Bay, Bonaire for Queen Conch (*Strombus gigas*) and Seagrass characterization in 2007.

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Abstract. In 1999 a survey was carried out (Lott, 2000) to estimate the conch population and determine the status of the seagrass beds in Lac Bay, Bonaire. Since 1999 the recreational use of Lac has increased, new structures have been built around Lac and illegal conch fishing still goes on (conch fishing is forbidden by Marine Ordinance of 1991). In order to assess the effects of the moratorium and the impact of increased activity in and around Lac the 1999 survey has been repeated, applying the same methods. Fieldwork was carried out from the end of May 2007 through the beginning of October 2007. The conch population has increased, in 51.000 m² survey area 223 live conch were found, against 111 in 1999. In previous survey no adult conch were found, now 9 (4%) of the population was adult.

The cover of turtle grass beds, macroalgae and other life forms have been examined in 17 grids (2.142 quadrats of 1 m²), spread over Lac Bay. The cover of turtlegrass has diminished in most grids. Where impact by trampling occurs this effect is more noticeable than in other grids. Cover by macro algae has changed too, in some grids the cover increased, in others decreased. Further study on species composition and water quality may be necessary.

Introduction.

Area description.

Lac Bay, is the largest lagoon on Bonaire and declared RAMSAR site in 1971. The importance of Lac Bay has been stressed numerous times (Wagenaar Hummelinck and Roos, 1969; Van Moorsel and Meijer, 1993; Lott, 2000).

The ecological importance of Lac lies, among others in its conch (*Strombus gigas*) population, turtlegrass beds, mangrove areas, turtle foraging area, and nursery area for numerous fish and invertebrate species.

Lac Bay is a shallow lagoon at the east site of Bonaire, with a more or less open connection to the sea and exposure to prevailing north eastern wind. At the north is a deep (approximately 8 m) narrow entrance. South of the entrance runs a reef NNE - SSW in a curve, that connects to the coast. Hurricane Ivan (September 8, 2004) caused some damage to the reef. North of the main entrance near Cai were other connections to the sea, but these have been closed of. A recent attempt to reopen them has failed. At Cai are some dwellings with more or less permanent habitation. Here the mounds of harvested conch shells can be found. At the north side of Lac runs a dirt road. North of this road a dam has been constructed for agricultural purposes. West of Lac is a paved road with areas to allow water to drain in the areas adjacent to Lac. Both the dam and the paved road may have changed the hydrology of the whole area. At the south end of this road, near the junction with the east west road are some small resorts, one fisherman. Part of the mangrove area has been cleared. Along the south road a new development was started, but this has been stopped as regulations for a Ramsar-site had not been followed. At the southwestern part of Lac, west of the reef on a sandbar is one resort and some semi-permanent dwellings for windsurfing. Plans for the construction of a large hotel and sand extraction initiated the research by Wagenaar Hummelink and Roos (1969). A start was made with a large hotel; the structure was eventually removed. At the end is a fishermen pier, 4

huts for daytime recreation, toilet facilities and a tank for old motoroil. In this area are also two subterranean connections to the sea.

The main basin of Lac is a relative shallow lagoon, with depths varying from 1 – 4m. Around Lac Bay are some minor interconnected bodies of water surrounded by mangroves.

A more detailed description of the area can be found in the publications by Wagenaar Hummelink and Roos (1969), Van Moorsel and Meijer (1993) and Lott (2000).

Use of Lac Bay

Formerly Lac was mainly an area for artisanal fishermen (using handlines, nets and fishtraps). The area is not considered overfished, but there are no historical data. The stock of conch has been overexploited though. The first time Wagenaar Hummelink visited Lac was in 1930 when there still was a good yield in the conch fishery. An estimate of a monthly yield of 500 animals per month in the years up to 1930 was made, but no exact figure exists. At the time of the 1969 study (Wagenaar Hummelink and Roos, 1969) the conch fishery had collapsed and has declined to virtual non-existence since.

Turtles have been caught in the past, but they are protected now.

Presently Lac is very popular for windsurfing, kayaking, and snorkeling. Stinapa has designated areas for these activities, and rules of conduct (see http://www.bmp.org/brochure_lac.html).

Purpose of survey.

The first study with baseline data (more qualitative than quantitative) is from 1969. Development of the area and overfishing of conch were part of the reason for conducting a survey in 1999 (Lott, 2000). These factors, development and fishing, are still very relevant in 2007.

Her study was an overall survey with emphasis on the stock of queen conch and the condition of the seagrass beds. Seagrass beds are essential in the life history of conch and prevent erosion of beaches: their status forms an integral part of the survey. One of the recommendations of this 1999 study was monitoring the conch population and executing the same survey at 5 year-intervals.

The effect of the fishing moratorium and the recent rapid growth of recreation in the area made this study essential for future management strategies.

Methods and Materials.

In total 17 grids have been surveyed in the study of Lott (2000) (Fig.1). Coordinates of the south corner have been relocated with the use of a GPS (Garmin eTrex). The accuracy of the GPS has been tested at Kadaster. Transect lines have been laid out at 330°. In order to facilitate conducting this study again after a given period permanent markers were made and set out. With the aid of the GPS we had no difficulty in finding these markers again. Algal growth, burrowing worm activities and other events may however prove them useless over a long period.

In each grid three 200 m transect lines, parallel to each other and 100 m apart were set out. The grid lines were marked every 10 m. Every 10 m, starting at 0 m and ending at 200 m, both left and right of the transect line a 100 x 100 cm quadrat was laid out and examined for coverage of seagrass (3 species), algae, sponge, soft coral, coral, bottom characteristics. Every 20 m, starting at 0 m and ending at 200 m in the lower left corner of the 100 x 100 cm quadrat a small quadrat of 25 x 25 cm was laid out for estimating epiphyte density on turtlegrass, measuring length and width of blades and counting of short shoots.

Total of 2142 m² has been examined in large quadrats, and 70,125 m² in mini quadrats. The total area of the main basin of Lac is estimated at 7.9 km². The total grid area (3 transect lines 100 m apart, 200 m long) cover an area of .68 km², being 8.6% of total area of Lac bay.

A 5 m width band (2,5 m right and left of the transect line) was surveyed for conch and species diversity. Following measurements of conch were taken: shell length, body whorl length and body whorl width. In case the lip was flared (sexually mature conch) this was noted. Empty shells were counted and examined for holes (illegally harvested conch). Turtle sightings were noted.

A Total of 51.000 m² has been surveyed for conch and species diversity.

Three forms, designed by Lott (2000) and Westmacott (1999) were used:

- Visual Estimation Data Sheet, for data on depth, cover by seagrasses, macroalgae, soft coral, coral, data on turtle gass to be used in the large and small quadrats
- Conch Strip Transect Survey and Sea Turtle Sightings Data Sheet (for 5m belt)
- Lac Bay Species Presence/Absence checklist for checking presence and/or counting numbers, to be used in 5 m width belt

The survey ran from May 29 through October 5, 2007.

Results.

For the presentation of the data the grids have been renamed, and grouped (see Fig. 1). Near the entrance of Lac is Cai, with a mean depth of 2 - 3 m. Along the north western edge of the main basin, near the mangroves are the grids named Ma, Mb, Mc, Md and Me. All these grids are in shallow water, with the exception of grid ME. The current here is clockwise. In the central, deeper part are 4 grids: Ca through Cd. At the east side, in Awa Blancu are 3 grids: AWA, AWB and AWc. In Secu Sorobon is one grid, and at the south western edge near the mangroves are three grids (Sa, Sb and Sc). Here the current is weak and counter clock.

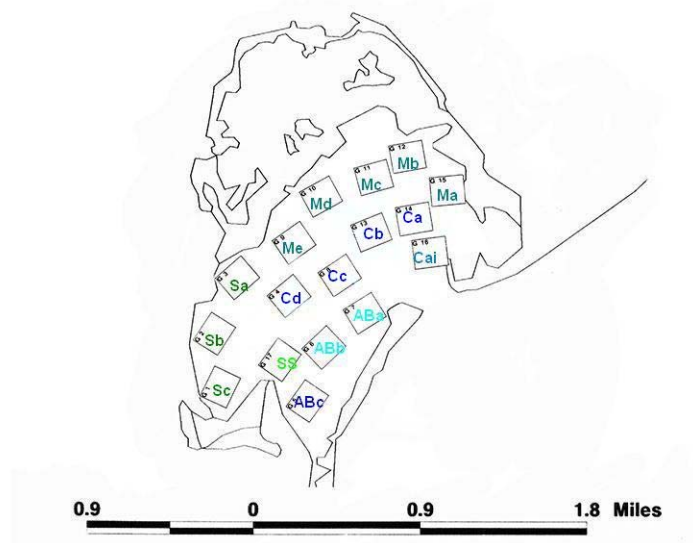


Fig. 1. Map Lac Bay with location of grids.

Conch.

Distribution.

In total 226 (live) conch were found in 17 grids, in comparison to 111 in 1999. If distribution of conch were uniform this would mean a density of 0,0044 m⁻², as compared to 0,0021 m⁻² in 1999. Even when disregarding the fact that distribution is not uniform and using this figure, density in Lac is very low when, for instance, compared with St. Eustatius (Davis, 2003).

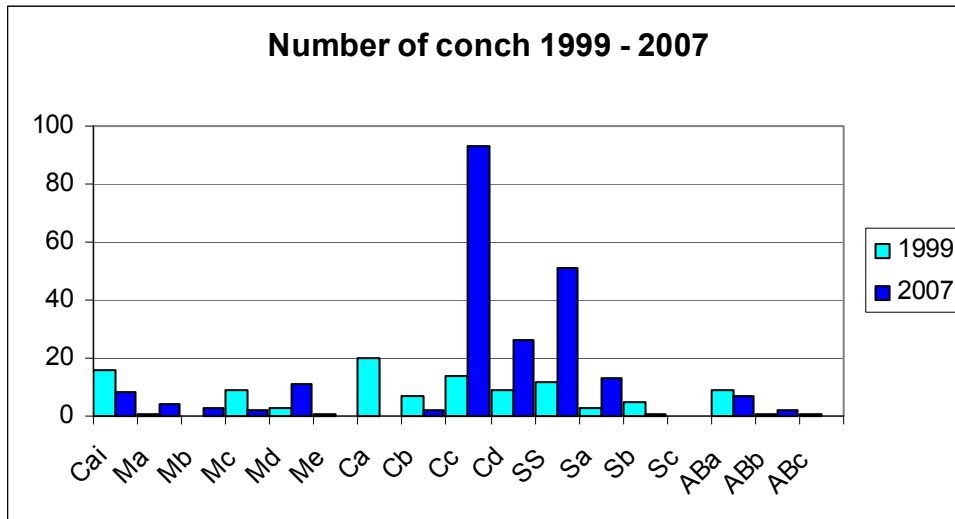


Chart. 1. Number of live conch per grid for 1999 and 2007

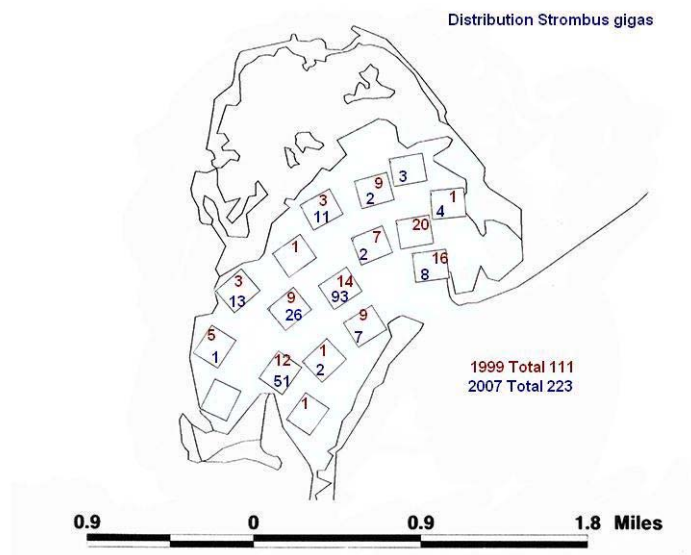


Fig. 2. Number of live conch per grid. Data of 1999 and 2007

The number of conch has mainly increased in two grids of the central part of Lac (Cc, Cc) and Secu Sorobon (SS). In the other grids the numbers are too low to be significant (decrease or increase)

Both fishing and ecological factors determine the present distribution of conch. Unfortunately there are no data on fishing. (BNMP has some data on illegal catches).

Size class.

The smallest conch found was 9 cm (total shell length), the largest being 30 cm. Smaller conch bury in the sand. Even these conch are being poached as numerous small shells with holes found near the southernmost part of Lac Bay prove. The size range of the conch in the 1999 survey was 14.3 to 20.2 cm total shell length.

As the reproduction period is extended over several months (April to late November) and the survey period took place over 3 months (July through September) the size classes will not be very distinct. Based on chart. 2 this suggests three year classes: 9 - 12,5 cm (1 year), 15 - 24 cm (2 year) and > 24 cm (3 year and older)

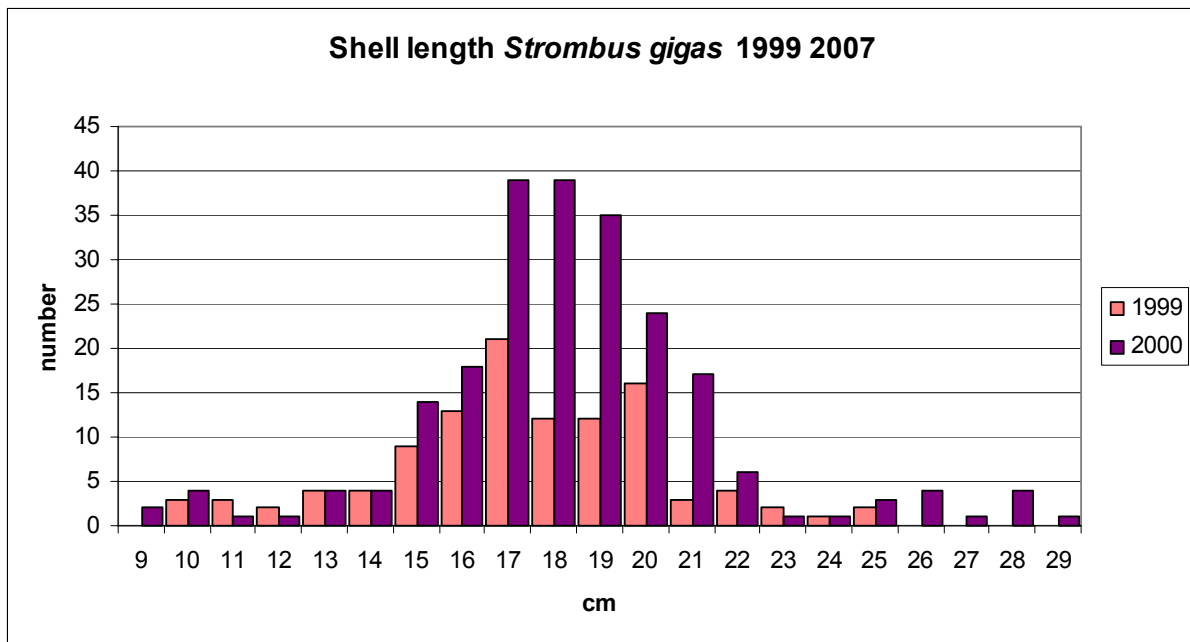


Chart. 2. Size class (total shell length) of *Strombus gigas*, data 1999 and 2007

Sexual maturity is reached between 3.5 and 4 years of age, when shell total length is over 25cm. A flared lip is a sign of maturity, this was found in 9 out of 223 (4%) conch, in 2 shells the lip started to flare.

Lott did not find sexually mature conch in her study and hypothesized that upstream sea current conch resources may be the larval recruitment resource. In this study one egg laying conch was found. Recruitment (cq. recovery of conch population) may very well depend on local reproduction.

Empty shells.

As enforcement of the moratorium on conch fishing has stepped up the last 5 years poachers empty the shell in the water and only take the meat to minimize detection. In total 133 empty shells were found in the grids, of which 8 without a hole. The majority was found in 3 grids: Cd (38 shells), Cc (54 shells) and Cai (15 shells). The Bonaire National Marine Park removes empty shells a regular intervals from the water.

Other observations.

Sometimes attached on the shell of *Strombus gigas* we found algae, sponges, or other fauna that occurred in the same area (e.g. *Acanthophora spicifera*, *Dididemnum sp.*)

Invertebrates.

In the 1999 survey the following invertebrates were noted on the forms: *Arenicola cristata*, *Cassiopeia sp*, *Condylactus giganteus*, *Stoichactis helianthus*, *Holothuria arenicola*, *Holothuria mexicana*, *Lytichinus spp.*, *Meoma ventricosa*, *Oreaster reticulata*, *Tripneustes ventricosus*, *Strombus gigas* and *Strombus costatus*.

Lytichinus spp., *Melongena melongena*, *Meoma ventricosa* and *Strombus costatus* were found in very low quantities.

In the 2007 study other invertebrates that were found in considerable quantities are: spaghetti worms, fanworms, the turtle grass anemone and ghost shrimp. Their presence was not quantified in the 1999 survey.

For some species the differences were very noticeable. In Fig. 3 -8 gives the distribution of these species.

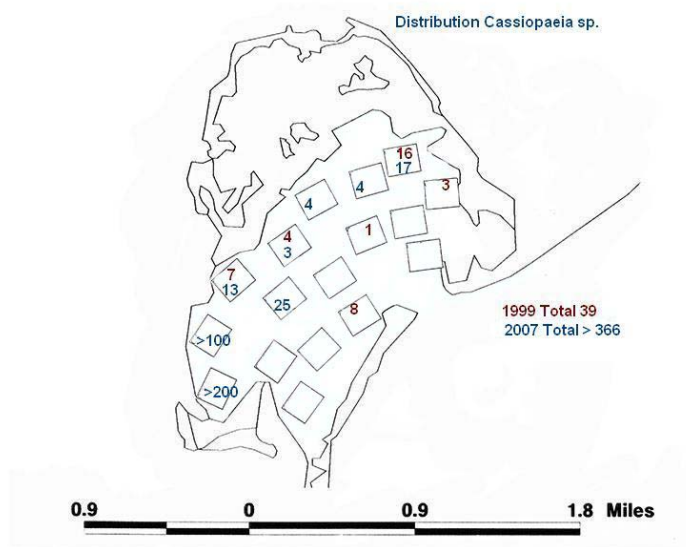


Fig. 3. Distribution of *Cassiopeia sp.*

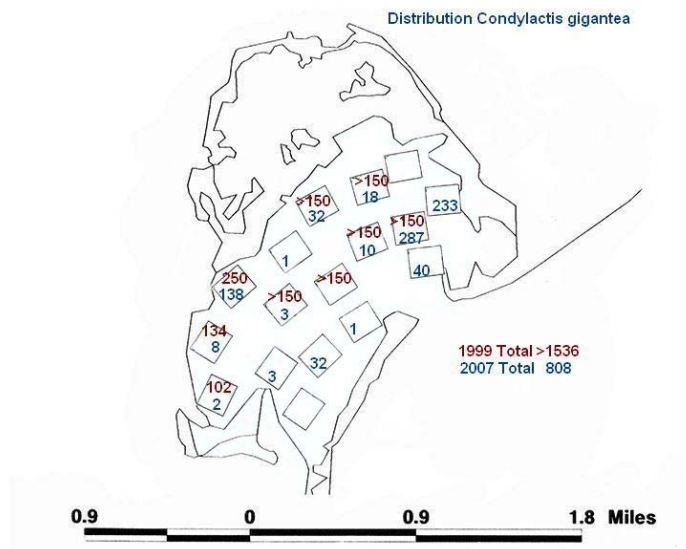


Fig. 4. Distribution of *Condylactus gigantea*.

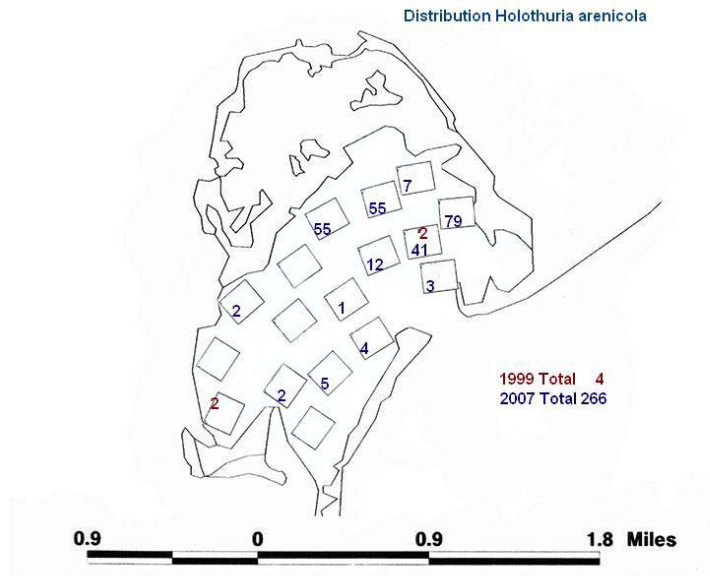


Fig. 5. Distribution of *Holothuria arenicola*.

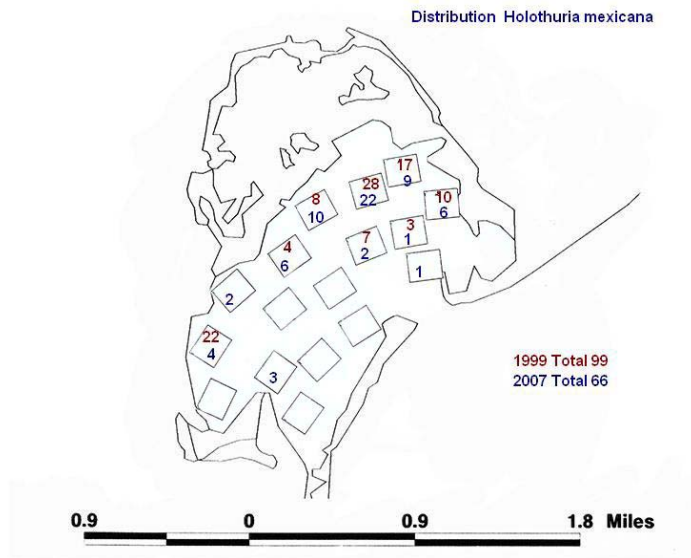


Fig. 6. Distribution of *Holothuria mexicana*.

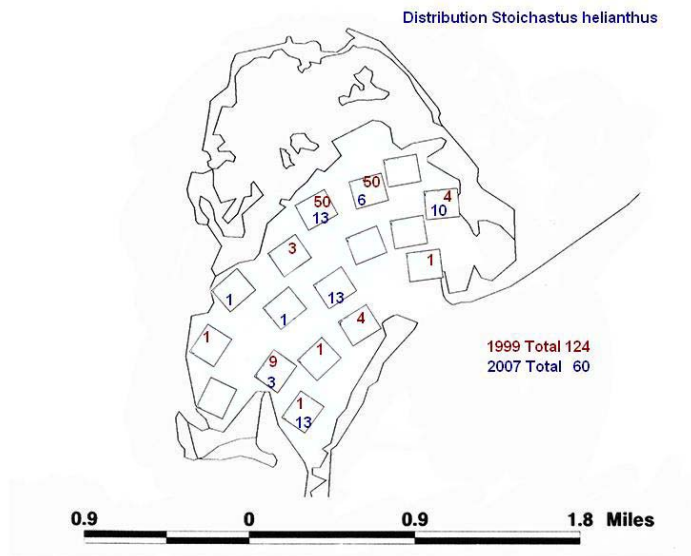


Fig. 7. Distribution of *Stoichastus helianthus*

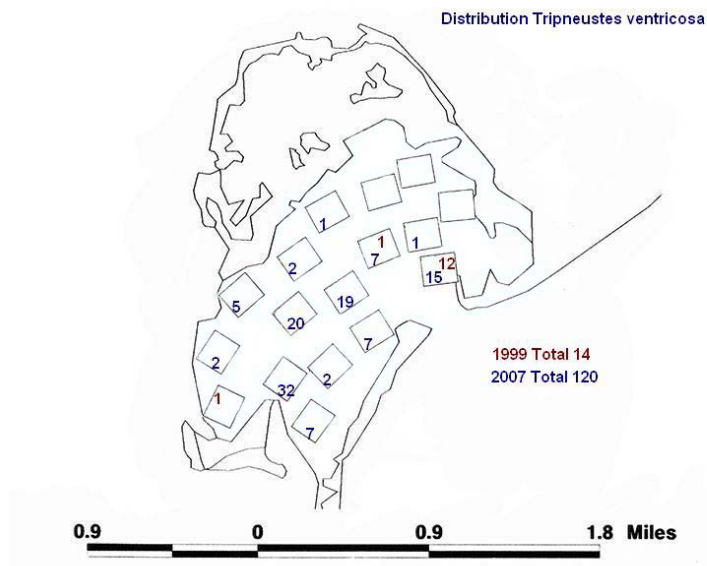


Fig. 8. Distribution of *Tripneustes ventricosa*

41 specimens of *Oreaster reticulatis* were found in 1999, only 2 in 2007.

Incidentally were found:

- flatworm (black. 2 - 3 cm, sometimes free swimming) *Thysanozoon* or *Acanthozoon* species
- a nudibranch: *Cerberilla cf. tanna* (its distribution has as yet to be established in the Caribbean)
- leech headshield slug: *Chelidonura hirundinina* (low numbers in several grids)
- a small tunicate, probably *Dididemnum sp.*, on turtle grass. There is only one location on Bonaire, in Lac (in part of a grid) where this species was found. A specimen has been sent away for identification.
- 2 *Diadema antillarum*
- 2 mantis shrimp

Seagrassbeds, macroalgae, sponges, soft coral and coral.

Seagrasses.

The dominant species in this survey is *Thalassia testudinum* (turtlegrass), *Syringodium filiforme* (manateegrass) has been found in some grids (Sb, Sc, ABa, Cb, Cc and Me) in small quantities, which is consistent with the 1999 findings and the data by Wagenaar Hummelink and Roos (1969). While *Syringodium filiforme* was found in Secu Sorobon in 1999 (chart. 13), it was absent here in present study. *Halodule beaudettei* has only been found in very small quantities in grid Me.

Macroalgae.

A number of species of macroalgae have been found of which the *Halimeda* (*Halimeda incrassata*, *H. opuntia* and *H. monile*) are the most prominent. The various species have been entered as 'absent/present' on the forms.

There have been a number of studies investigating the importance of *Halimeda* in sediment production. Figures range from 4.2 g of calcium carbonate m⁻¹ year⁻¹ in Florida (Bach, 1979) to 2,234-3,000 g of calcium carbonate m⁻¹ year⁻¹ on the Great Barrier Reef (GBR), (Drew, 1983).

In some researches the contribution *Halimeda* to sediment production is estimated at 65%. The cover of *Halimeda* has not been quantified, only its presence. In the 1999 survey both *Halimeda incrassata* and *H. opuntia* were found in most grids, except for Grid Cp (no *Halimeda spp.*), Grid ABc (only *H. incrassata*) and Grid ABb (only *H. opuntia*). In the 2007 survey both species were found in all grids. Lott remarked when snorkeling in Lac in 2007 that cover by *Halimeda* has increased considerably.

Sponges.

Most common sponges found were yellow finger sponge (*Aplysina fulva*), fire sponge (*Tedania ignis*), red finger sponge (*Amphimedon compressa*) and a unidentified filamentous black sponge. Chickenliver sponge (*Chondrilla nucula*) only in small quantities

Soft corals.

Soft corals were found incidentally. Mostly *Eunicea spp.*

Corals

Between Lac Bay and the open sea is in the north a deep, about 10m wide opening, and to the south a rock barrier, that lies slightly below sea level. To the lee side is a patchy reef that in the north is wide, and tapers to non existent in the south. Big colonies of *Acropora palmata* and *A. cervicornis* can be found, as well as *M. annularis* and other species can be found here. All grids were on the fringes of this reef. Here *Agaricia agaricites*, *Diploria strigosa*, *Favia fragum*, *Dichocoenia stokesii*, *Porites porites*, *P. astroides* and *Millepora sp.* were found. In the western shallow part of Lac *Porites divaricata* was often found. A metal frame in this part formed a substrate for a juvenile *M. annularis* and *Diploria strigosa*. Roos (1971) found the same distribution of corals in Lac.

Cover of these five groups of lifeforms has been established by visual assessment in 126 1m² quadrats per grid (nq gives the number of 1m² quadrats with valid data - for various reasons not all data could be used). Presentation has been done in percentage of grids. Codes used are:

+ = few, 1 = less than 5%, 2 = 5 - 25%, 3 = 26 - 50%, 4 = 51 - 75%, 5 = 76 - 100%.¹ 0 = no cover (blanc on the forms). The following graphs give the cover of these groups.

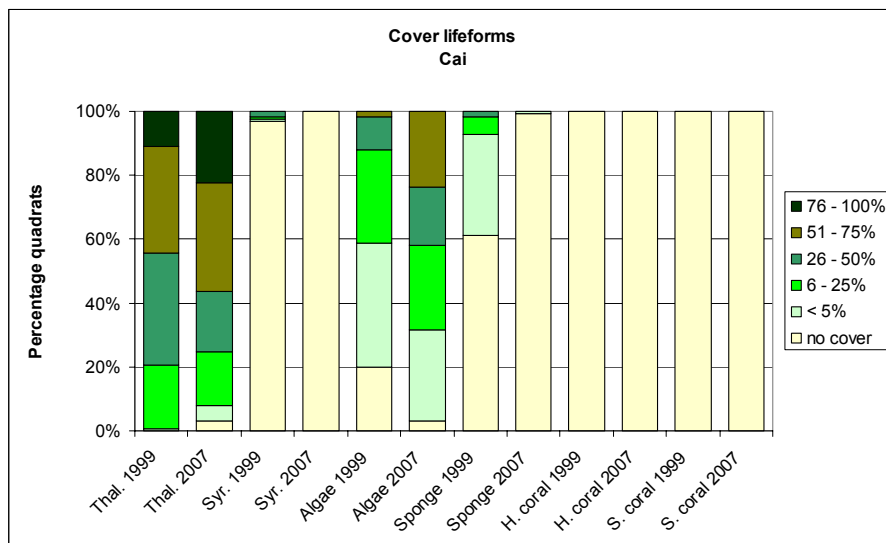


Chart. 3. Cover grid Cai, nq1999 = 126, nq 2007 = 126.

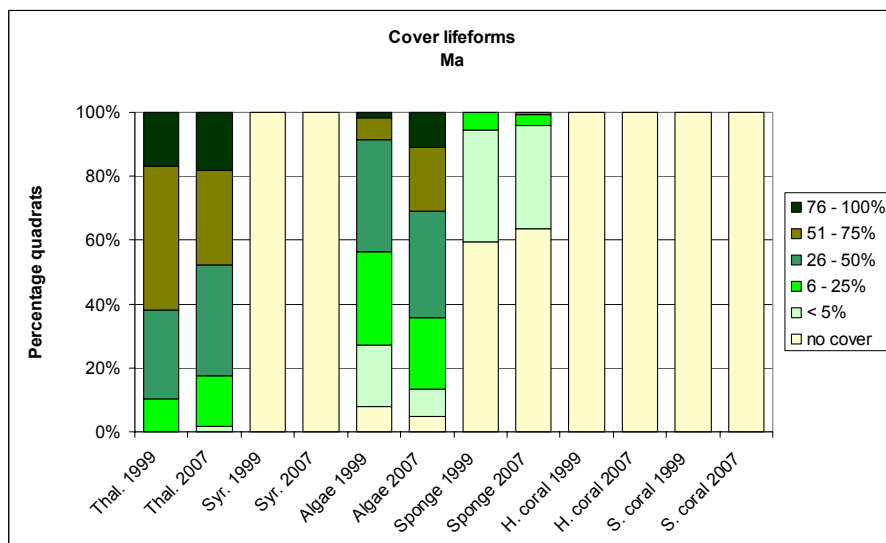


Chart. 4. Cover grid Mangrove a. nq1999 = 126, nq2007 = 126.

¹ For processing (of data) purposes '+' was lumped with 1.

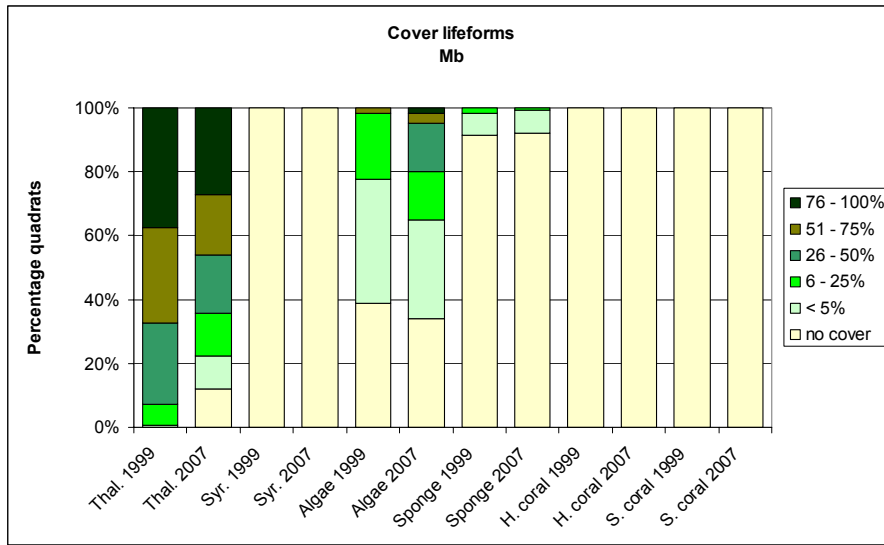


Chart. 5. Cover grid Mangrove b. nq1999 = 126, nq2007 = 126.

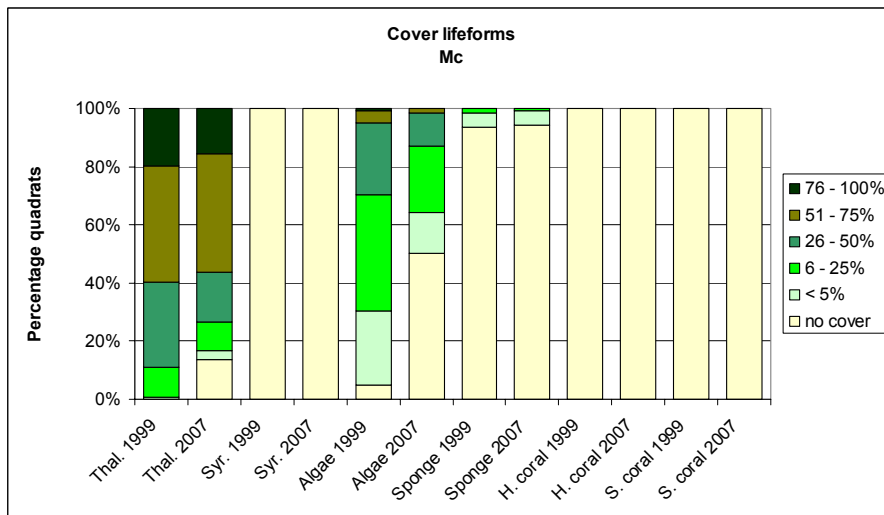


Chart. 6. Cover grid Mangrove c. nq1999 = 126, nq2007 = 126.

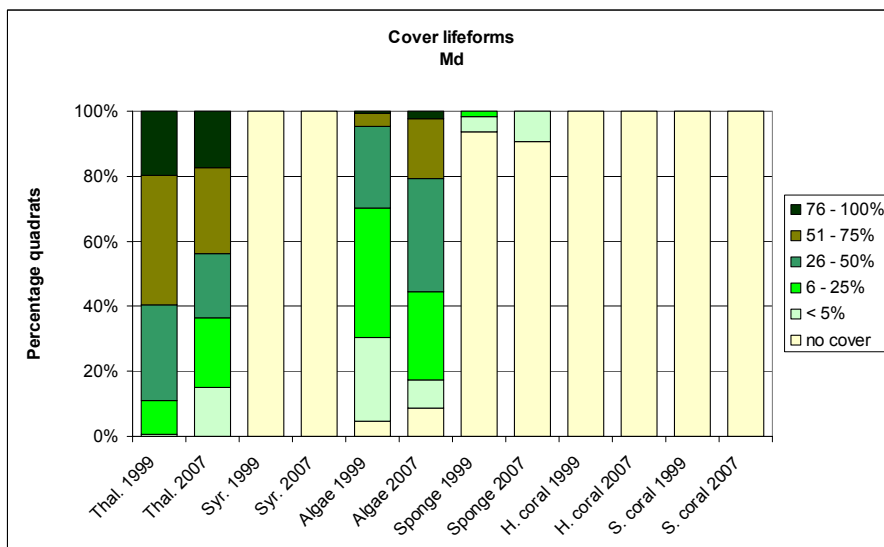


Chart. 7. Cover grid Mangrove d. nq1999 = 126, nq2007 = 126.

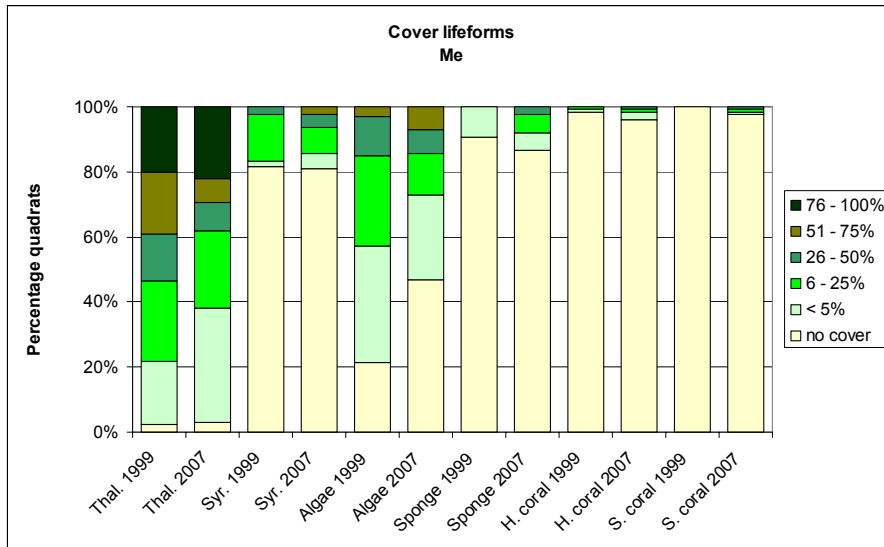


Chart. 8. Cover grid Mangrove e. nq1999 = 126, nq2007 = 126.

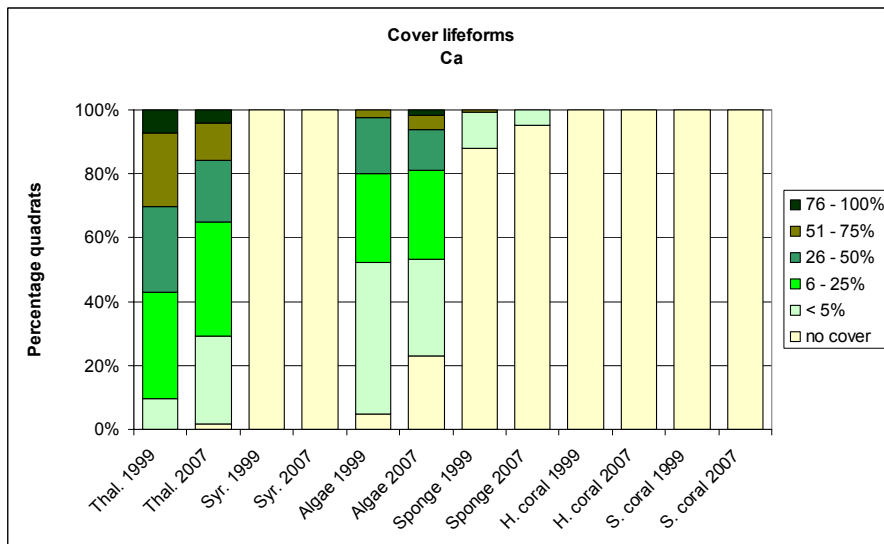


Chart.9. Cover grid Central Part a. nq1999 = 126, nq2007 = 126.

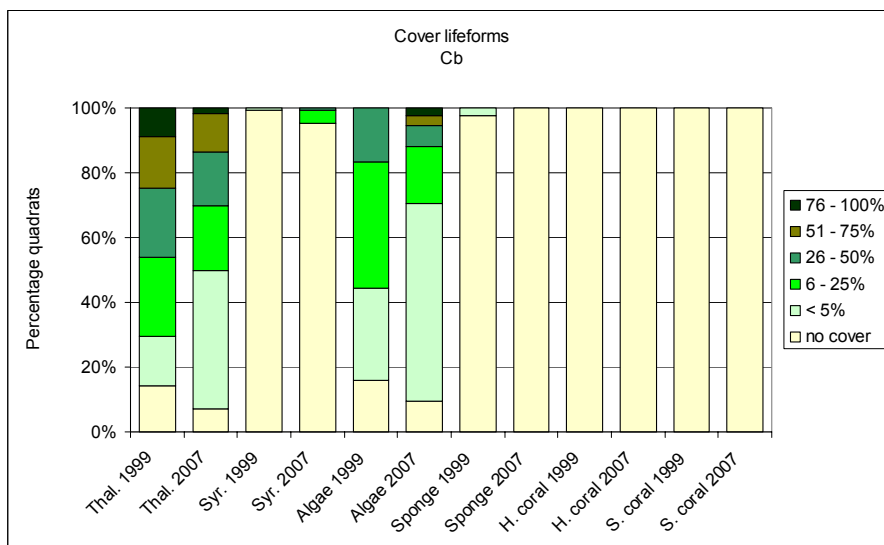


Chart. 10. Cover grid Central Part b. nq1999 = 126, nq2007 = 126.

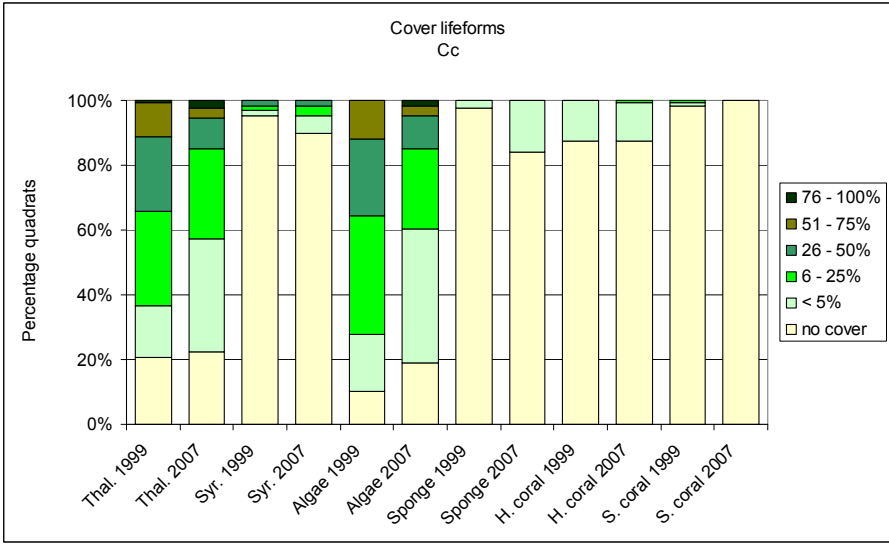


Chart. 11. Cover grid Central Part c. nq1999 = 126, nq2007 = 126.

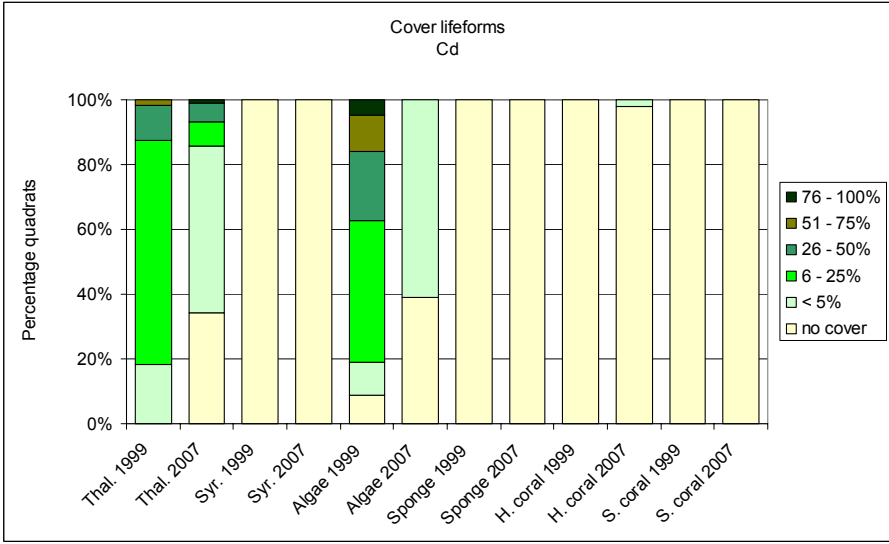


Chart. 12. Cover grid Central Part d. nq1999 = 126, nq2007 = 105.

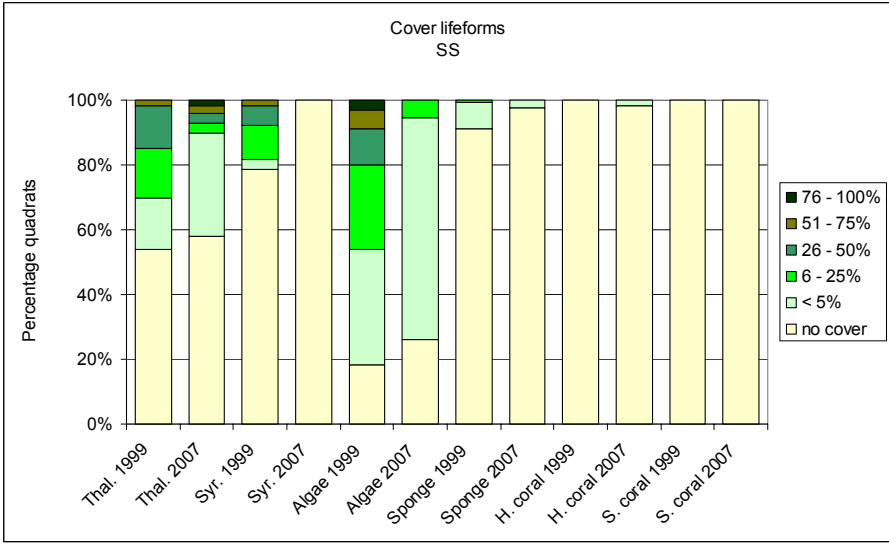


Chart.13. Cover grid Secu Sorobon. nq1999 = 126, nq2007 = 126.

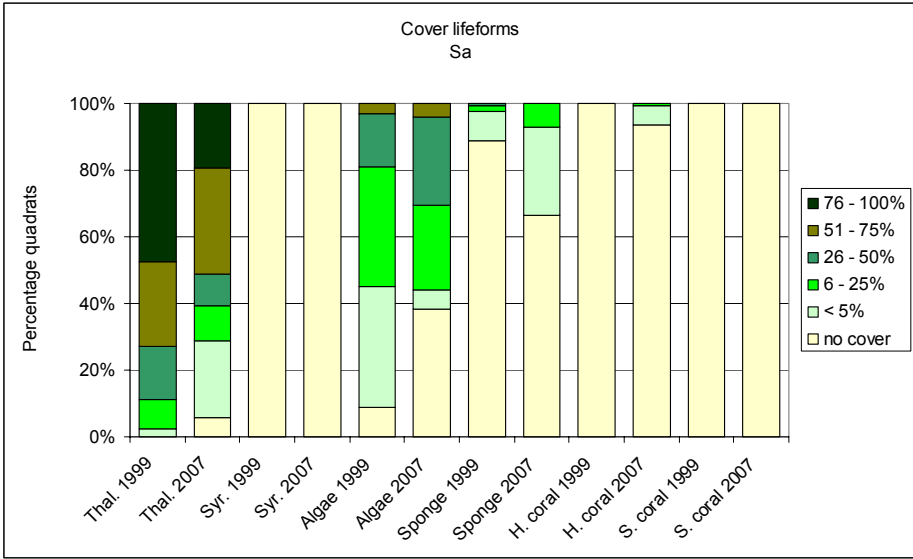


Chart. 14. Cover grid Sorobon a. nq1999 = 126, nq2007 = 125.

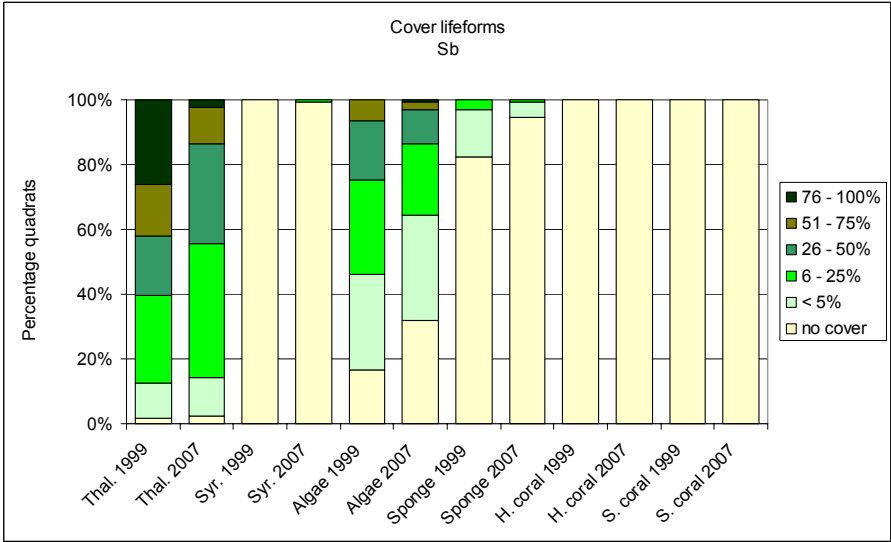


Chart. 15. Cover grid Sorobon b. nq1999 = 126, nq2007 = 126.

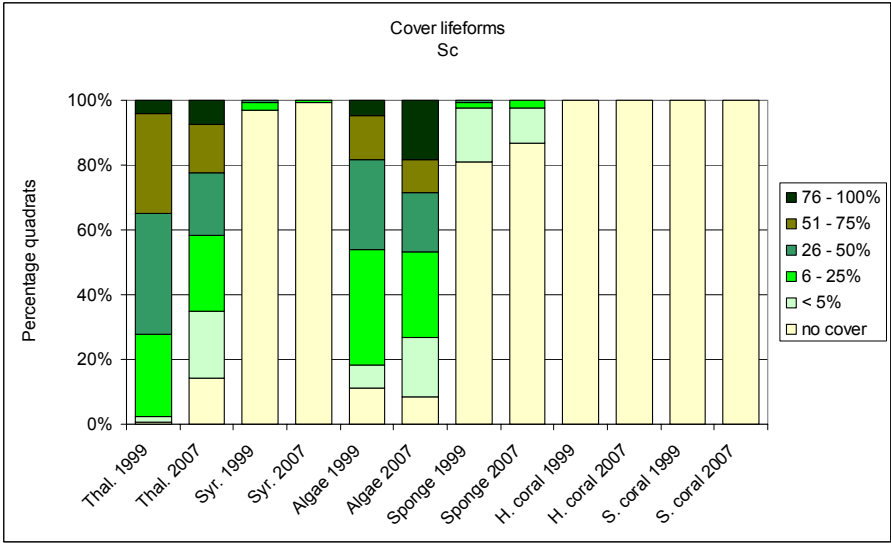


Chart. 16. Cover grid Sorobon b. nq1999 = 126, nq2007 = 120.

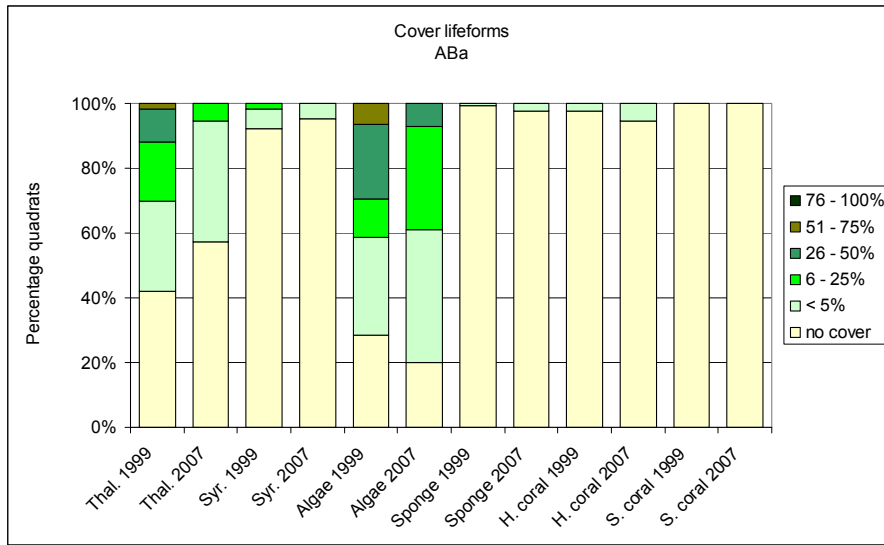


Chart. 17. Cover grid Awa Blancu a. nq1999 = 126, nq2007 = 126.

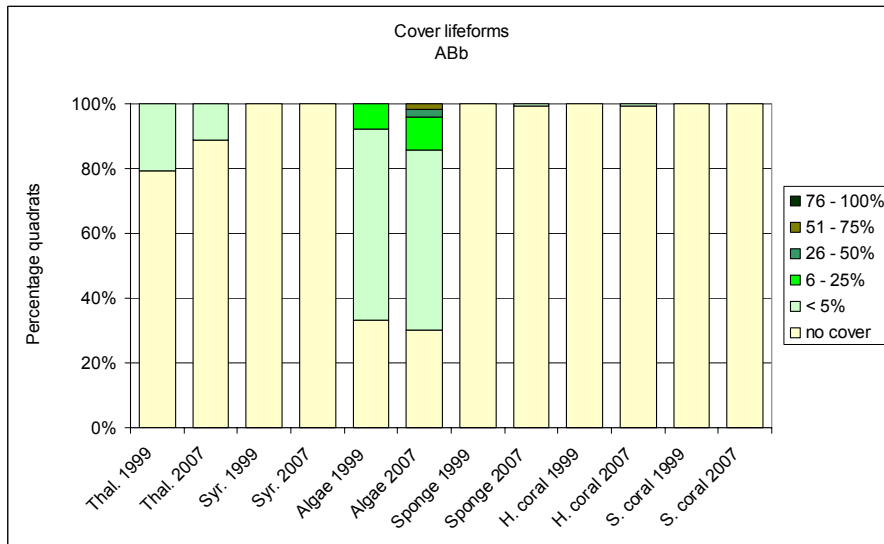


Chart. 18. Cover grid Awa Blancu b. nq1999 = 126, nq2007 = 126.

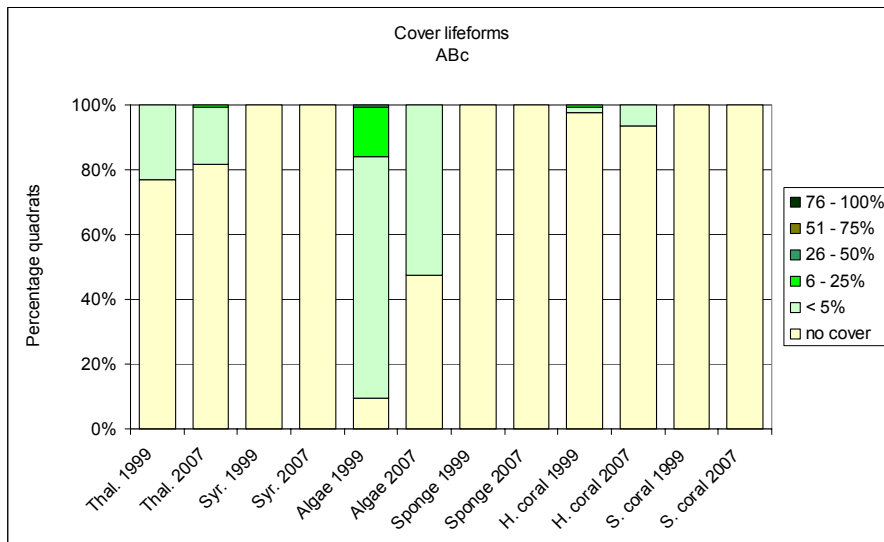


Chart. 19. Cover grid Awa Blancu c. nq1999 = 126, nq2007 = 126.

Chart. 2 - 19. Comparison of cover for *Thalassia*, *Syringodium*, macroalgae, sponges, hard coral and soft coral for 1999 and 2007 per grid. Given in percentage of grids and code 0 = no cover, 1 = <5%, 2 = 6 - 25%, 3 = 26 - 50%, 4 = 51-75% and 5 = 76 - 100%.

Status of seagrassbeds

Blade length, width and number of short shoots counted are data on the status of the seagrassbeds. The mean for a grid is calculated over the miniquadrats in which *Thalassia testudinum* was present (data on number of miniquadrats with *Thalassia testudinum* is given for 1999 and 2007)

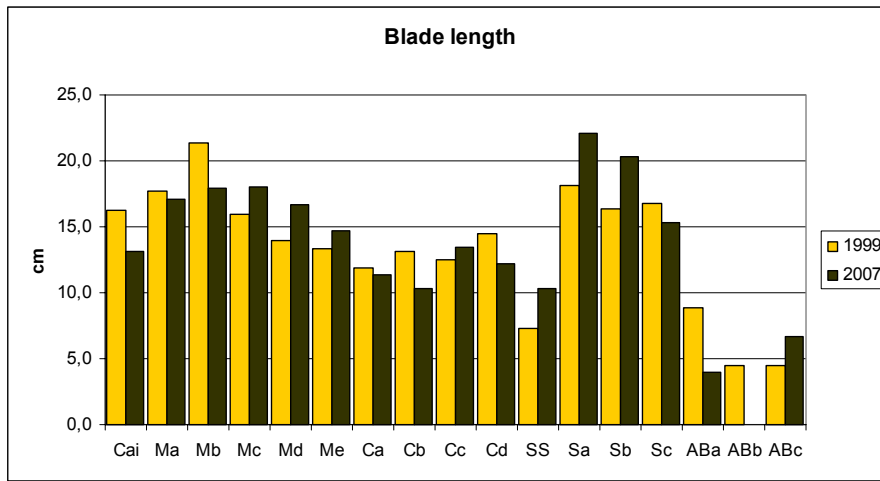


Chart 20. Mean blade length of *Thalassia testudinum* in small miniquadrats of 25 x 25 cm.

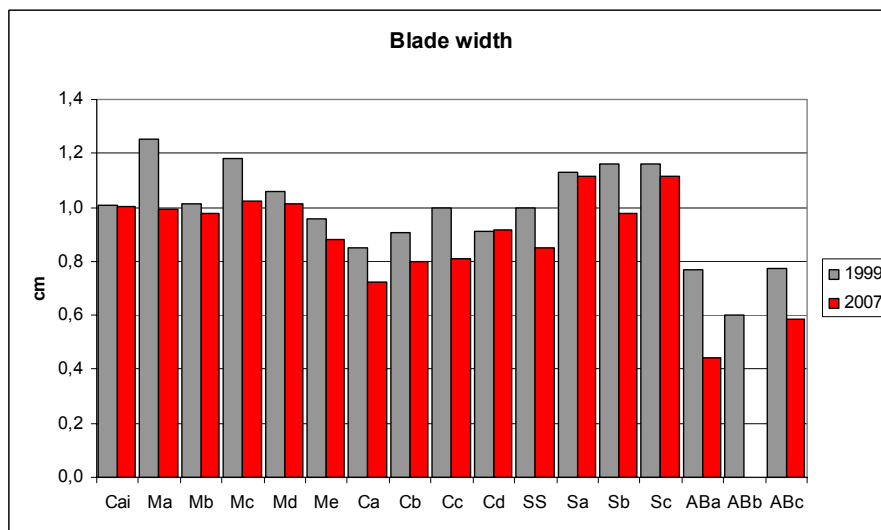


Chart 21. Mean blade width of *Thalassia testudinum* in small miniquadrats of 25 x 25 cm.

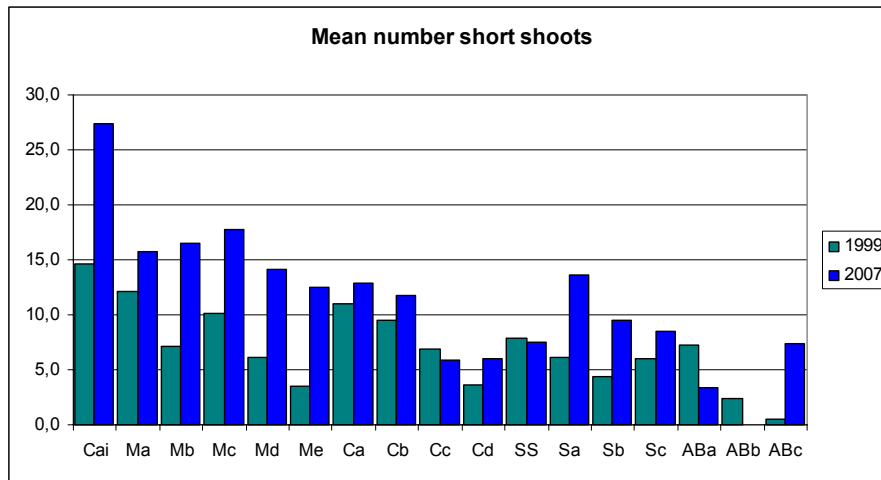


Chart 22. Mean number of short shoots for *Thalassia testudinum* in small miniquadrats of 25 x 25 cm.

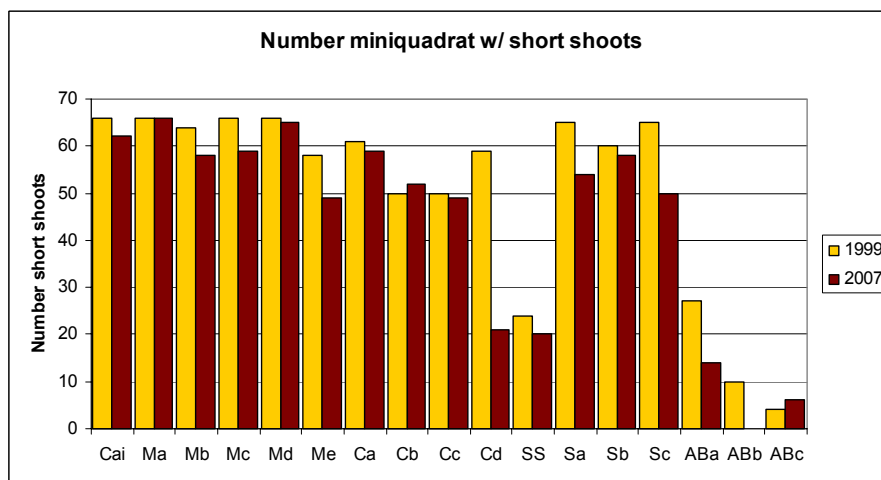


Chart 23 Number of mini quadrats (out of 66 per grid) with short shoots².

Blade length, blade width and mean number of short shoots follow the same trend in all grids, but:

- in some grids the blades are slightly longer, in others a bit shorter. In general the difference is less than 5 cm. Along the west side of the main basin (mangrove and Sorobon area) the blades are tallest, in Awa Blancu shortest. Herbivore pressure near the reef will be highest.
- the number in which *Thalassia testudinum* was found decreased since 1999.

Epiphyte density.

Main food sources for conch (juveniles and adults) are epiphytes on seagrass, seagrass detritus, but not the seagrass blades self (Stoner, 1989; Stoner and Waite, 1991). Visual assessment of epiphyte density was done in the mini quadrats and data compared.

Epiphyte density was visually assessed. The following codes were used: **1** = clean, **2** = light, **3** = moderate and **4** = heavy.

² Data of left side of the second transect in grid Cd were lost. On the right side only 2 mini quadrats had *T. testudinum* plants.

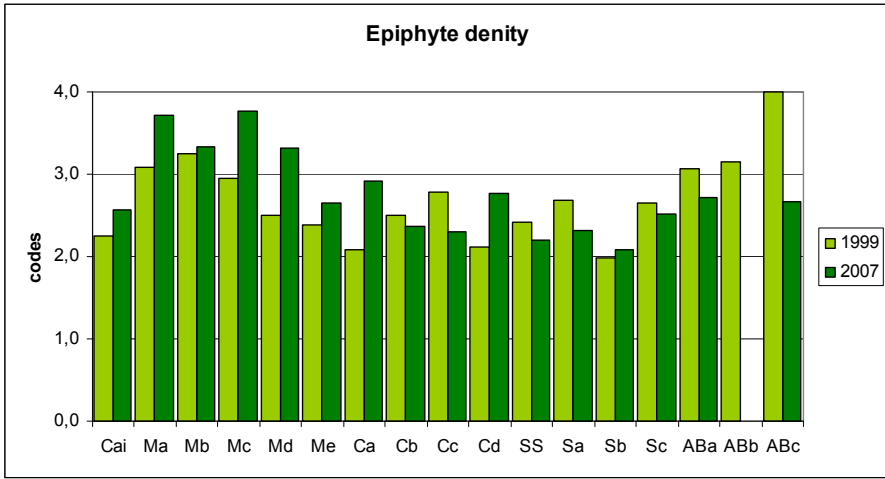


Chart 24. Epiphyte density data 1999, 2007

We find the same trends as in the 1999 study.

Turtles.

One entry on the 'Habitat Survey Form' is for sighting of turtles. No turtles have been seen while doing the survey (in the water), but they were often seen when going to the grids.

Bottom characterization

In the following chart bottom type for each grid is given. The distinction sand/mud and shelly coarse is determined by observer, and not measured. In general, no difference is found (or expected) with bottom characterization 1999. Production of sand by Halimeda, change in circulation may cause small changes over time

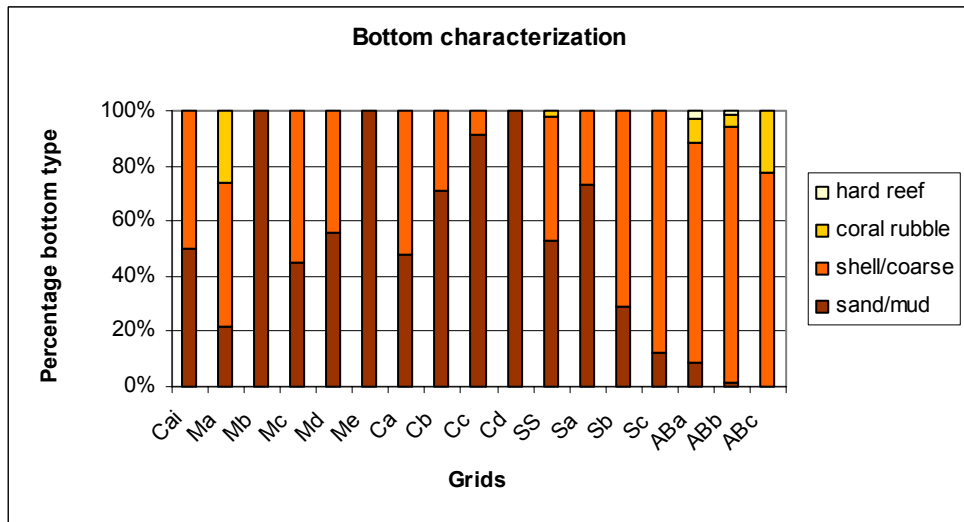


Chart 25. Percentage of bottomtype founf in grids.

Physical parameters

No data have been collected on salinity, dissolved oxygen, conductivity, temperature, except for one set of data at grid corners. Progressive Environmental Solutions have been monitoring these parameters in and around Lac for a period of one year, January 2007 - January 2008.

Discussion.

Conch.

The moratorium on conch fishing seems to be effective. Since enforcing the conch stock has increased. The extent of the illegal fishing is not known, there are some figures of catches whenever poachers have been caught.

Seagrassbeds.

There is no direct relation between cover and number of short shoots, as can be seen both in 1999 and 2007. Visual assessment in the 1m² quadrats and the number of miniquadrats in which *T. testudinum* has been found indicate the cover has decreased in general, except in grid Cai. The number of short shoots however increased in most grids. Blades in general are longer farther from the reef – along the western edge of the main basin, with an exception of Cai. Width varies between a little under 0,8 cm to a little over 1,2 cm.

There are a number of factors that influence the status of turtlegrass beds. Among them are anthropogenic disturbance, nutrients, herbivore activity, salinity and substrate composition. Anthropogenic disturbance has increased much over the last years. In the Awa Blancu area (windsurfing), Secu Sorobon (windsurfing and snorkeling). Cover here was low and has diminished even more. Grids in the Central Part are also in the windsurf area, but their mean depth is resp. 3,3 and 3 meter, so no risk of trampling.

Not surveyed are seagrassbeds very close to the shore of the sandbar, in front of the Windsurf shops. A quick assessment has been done here by Giardini (2008), showing the beds where a lot of people pass through are in a worse state than areas not directly in the 'trodden path'. Common use is to drop the windsurfboards in the seagrassbeds and 'anchor' them with their keel.

Macroalgae.

Cover by macro algae increased in 6 grids, was about the same 4 grids and decreased in 7 grids. No pattern can be discerned. Observations by a number of people indicate that *Halimedae* have increased over the past years. Unfortunately there are no data to determine whether the change in cover can be attributed to *Halimedae*.

Invertebrates.

While the number of most invertebrates decreased (*Condylactis gigantea*, *Stoichasthus helianthus*, *Holothuria mexicana*, *Oreaster ventriculatus*) *Cassiopeia sp.* and *Tripneustes ventricosa* have increased in the survey 2007.

The most noticeable change was found in grids Sc and Sb with respect to numbers of *Cassiopeia sp.* and *Condylactis gigantea*. While in 1999 no *Cassiopeia sp.* was found in the most southern part in Lac Bay, now most were found here. For *Condylactis gigantea* the numbers not only have halved, but their distribution seems to have shifted more to the north. Possible reasons for these changes in this area might be a change in hydrology and water quality.

The number of the other anemone counted, *Helianthus stoichastus* has halved, especially in grid Md and Mc. The numbers in other grids are too low to draw conclusions on distribution differences.

Holothuria mexicana was also less abundant, most conspicuous in grid Sb, but overall distribution doesn't seem to have changed very much.

Both *Arenicola cristata* and *Holothuria arenicola* and other bottom-dwelling species (ghost shrimp, mantis shrimp) are not actually seen, but there are tell-tale mounds, excrement to be found in the turtle grass beds. Results of counts have to be evaluated with some reservation.

Tripneustes ventricosa has increased from 14 specimens found in 1999 to 120 in this study. In 1999 they were found near Lac Cai and Boca Jewfish (grid Cai, Cb and Sc); in present survey they have been found in all but most northern grids and grid 1. The decrease in the *Oreaster reticulatus* can probably be attributed to collecting by souvenir hunters.

Recommendations.

Research/survey.

- Monitor Lac Bay for conch and seagrass/algae cover at regular intervals. Adjust survey methods (use of digital image, determination of epiphyte density by dry weight method).
- Develop ecological zonation of Lac based on multispecies distribution and abiotic parameters and focus monitoring on these zones.
- Execute exhaustive hydrology study for Lac Bay and direct environments, analyse water quality.

Management/protection.

- have permanent presence by BNMP in Lac for better enforcement of no fishing and water use.
- demarcate seagrass bed with instructions not to walk through. Boards have been set up with information on lifeforms and directions not to walk in seagrass beds. This information does not come across.
- declare small reef south of Cai, between main basin and open ocean as 'marine reserve'. Two *Acropora* species form an important part in this reef. *Acropora* colonies can be damaged easily by kayaks, inexperienced swimmers. In the United States two *Acropora* species have been listed as vulnerable on the list of endangered species.
- form informal interdisciplinary working group to address issues on Lac

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