Assessment of Ramsar site Lac Bonaire – June 2010

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Summary

Following a helpdesk question from the Dutch Ministry of Agriculture, Nature and Food Quality (LNV) concerning potential threats to the Ramsar Site, Lac Bonaire, the authors visited Lac Bay from 27-29 May 2010. The mangroves, seagrass beds and the reef, both inside and outside of the bay were visited, and we were generously helped by many people on the island, including STINAPA Bonaire, DROB, STCB, and CIEE. In this study we review the main issues, recommend studies, and propose various pilot projects and solutions.

The problems that Lac faces have been well known for a long time. Increasing pressures on Lac ecosystem are leading to renewed concerns: mangroves are dying, seagrass beds are being trampled by tourists, corals are damaged by snorkelers and kayakers and nutrient enrichment may be the cause of a harmful algal bloom which is also killing soft and hard corals. Recently, recreational pressures have increased rapidly with the arrival of more cruise ship tourists. While much of the current legislation is not being enforced, the lack of funding hampers structural monitoring. Apart from these threats from recreational activities the one and foremost important aspect that is causing the degradation of Lac (and its surrounding area) is the overgrazing by extensive livestock husbandry resulting in an accelerated infilling of the bay with sediment, which hampers water circulation and causes mangrove die-off. We propose measures and actions to address all of these problems.

IMARES provided extra funds to be used within this project as it is part of one of the special interest areas of the institute.

This research is performed within 'Beleidsondersteunend Onderzoek' (BO-11), cluster NLP of LNV-programs.

1 Introduction

The lagoon of Lac Bay on Bonaire covers an area of 700 ha, includes important habitats such as mangroves and seagrass beds, is home to rare and endangered sea turtles and the Caribbean queen conch, and is an important roosting site for birds. Other endangered species include the threatened corals *Acropora palmata* and *A. cervicornis* and *A. prolifera* as well as the rainbow parrotfish *Scarus guacamaya* and some IUCN vulnerable species. Based on its nature values this 7km^2 bay has been designated as a legally protected Ramsar site (STINAPA Bonaire 2003) and identified as a IUCN IBA (Important Bird Area) (Wells and Debrot 2008). The area is managed by the National Parks Foundation of Bonaire, STINAPA Bonaire, based on their recent management plan in which several issues are addressed. Nevertheless, Lac Bay is under increasing development pressure from recreational use and has been in long-term decline (e.g. Lott 2001).

Based on these concerns, the Ministry of LNV, The Netherlands, asked IMARES to assess the situation and come with recommendations (Helpdesk question HD3270_Impact recreatie op rif in Ramsar wetland Lac Bay). Because a Helpdesk question concerns only a very limited study (mostly desk study) actual field research is hardly ever possible. However, since the research team was already visiting Bonaire for the Dutch Caribbean EEZ conference a few field visits were possible. These visits included a snorkelling tour inside of Lac, together with Rita Peachy of CIEE Bonaire and a dive at the sea side of Lac organized by Ramon de Léon of the Bonaire Marine Park. Furthermore we interviewed a number of people and were given a large number of documents.

We like to thank the following people for giving us valuable insights and material:

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2 Ramsar site Lac Bonaire

The Ramsar Convention was brought into operation for the entire Dutch Kingdom on September 23 1980, therefore also for the Netherlands Antilles (Trb. 1975, 84). The Antillean Ordinance for Nature Management and Protection' (P.B. 1998, nr. 41) states in article 10 that the regulations of the Ramsar Convention apply to the registered Ramsar areas.

Parties' commitments under the Convention

(From Ramsar web site, last update 10/08/2009)

When countries join the Convention, they are enlisting in an international effort to ensure the conservation and wise use of wetlands. The treaty includes four main commitments that the Contracting Parties have agreed to by joining.

1. Listed sites (Article 2 of the Convention)
The first obligation under the Convention is for a Party to designate at least one wetland at the time of accession for inclusion in the List of Wetlands of International Importance (the "Ramsar List") and to promote its conservation, and in addition to continue to "designate suitable wetlands within its territory" for the List (Article 2.1). Selection for the Ramsar List should be based on the wetland's significance in terms of ecology, botany, zoology, limnology, or hydrology. The Contracting Parties have developed specific criteria and guidelines for identifying sites that qualify for inclusion in the Ramsar List.

In Article 3.2, each Party has committed itself **"to arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the List has changed, is changing or is likely to change as the result of technological developments, pollution or other human interference. Information on such changes shall be passed without delay"** to the Ramsar Secretariat.

2. Wise use (Article 3 of the Convention)
Under the Convention there is a general obligation for the Contracting Parties to **include wetland conservation considerations in their national land-use planning**. They have committed themselves to formulate and implement this planning so as to promote, as far as possible, "the wise use of wetlands in their territory" (Article 3.1).

The Conference of the Contracting Parties has approved guidelines on how to achieve **"wise use", which has been interpreted as being synonymous with "sustainable use**". The COP has also adopted detailed guidance on the development of National Wetland Policies and on management planning for individual wetland sites.

3. Reserves and training (Article 4 of the Convention)
Contracting Parties have also undertaken to establish nature reserves in wetlands, whether or not they are included in the Ramsar List, and they are expected to promote training in the fields of wetland research, management and wardening.

4. International cooperation (Article 5 of the Convention)
Contracting Parties have also agreed to consult with other Contracting Parties about implementation of the Convention, especially in regard to transboundary wetlands, shared water systems, and shared species.

Compliance with the commitments
The Ramsar Convention is not a regulatory regime and has no punitive sanctions for violations of or defaulting upon treaty commitments – nevertheless, its terms do constitute a solemn treaty and are binding in international law in that sense. The whole edifice is based upon an expectation of common and equitably shared transparent accountability. Failure to live up to that expectation could lead to political and diplomatic discomfort in high-profile international fora or the media, and would prevent any Party concerned from getting the most, more generally, out of what would otherwise be a robust and coherent system of checks and balances and mutual support frameworks. Failure to meet the treaty's commitments may also impact upon success in other ways, for example, in efforts to secure international funding for wetland conservation. In addition, some national jurisdictions now embody international Ramsar obligations in national law and/or policy with direct effect in their own court systems.

Reporting
One extremely important part of the Parties' responsibilities has to do with reporting on the implementation of the Convention within their territories. The Parties report on their progress by submitting triennial National Reports to the Conference of the Contracting Parties – these are prepared following a format adopted by the Parties which is derived from the Convention's Strategic Plan and Work Plan for the triennium, and they become part of the public record. In addition, under Article 3.2 of the treaty, Parties are expected to report to the Secretariat any changes or threats to the ecological character of their listed wetlands and to respond to the Secretariat's inquiries about such reports received from third parties.

3 Historical perspective

The first larger research program in Lac was carried out by Wagenaar-Hummelinck and Roos in 1967 and published in 1969. Based on this effort, in 1969 the Rijksinstituut voor Natuurbeheer, The Netherlands, had identified Lac as a national conservation priority (Morzer Bruyns 1969). The development of management measures for Lac since then has taken a great deal of effort and time. The first "Voorstel voor beheersmaatregelen voor het Lac" was presented to the Central Government of the Netherlands Antilles and Island Government of Bonaire by the Nederlandse Commissie voor Internationale Natuurbescherming (NCIN) and the Natuurwetenschappelijke Studiekring voor Suriname en de Nederlandse Antillen in a letter dated 31 October 1970 (NCIN 1970). This had been based on a meeting that took place at the zoological laboratory in Utrecht, 12 October 1970 (Steen 1970). In the early 1980s environmental concerns about the BONIL development project for Lac focused renewed attention on the bay. In 1991, sand mining north of Lac, construction of a levy, and tree mortalities at Cai were causes for concern (Newton 1991a,b,c). A draft management plan from 1990 was finally treated in 1996 by the Island Government of Bonaire. With funding by WWF, STINAPA Bonaire implemented its first Lac Management Project in June 1998 (Meyer 1998). Finally, by 2003 the Lac Management Plan was completed. It was developed in close cooperation with the local community, the user community and the Island Government..
The results of international archaeological and ecological research projects that took place in Lac in the 1970s and 1990s clarified the need to conduct deeper and more scientific investigations to protect and conserve Lac in the future in a better and a more efficient way (Moorsel & Meijer 1993, Lott 2000, Lott, 2001). In 2005 Stichting ABC Advies produced a pre environmental effects study for a planned hotel (Antonius 2005) and STINAPA funded a new long-term monitoring program to get a reliable impression of the hydrology of Lac and arrive at suitable and accurate solutions for the most pressing problems in Lac: the mangrove die back in the upper Lac area and the sand accumulation at Awa Blanku.

Before the Ramsar Convention regulations in 1998 and the Antillean Ordinance for Nature Management and Protection became legally effective in the Netherlands Antilles several buildings had already been constructed in the area of Lac, notably a hotel, two windsurfing centers and a café/restaurant with apartments at Sorobon.

The current use of Lac Bay has changed from about 50 years ago. Tourist activities have increased, and traditional uses declined or stopped. Traditional use of the bay included fishing for conch and turtle, mangrove wood harvesting for boat building, basket making, charcoal and limestone burning. During the last 30 years all of these traditional activities but the fishing have stopped. Recreational use has been limited to leisure activities, especially at Cai, where locals gather in the weekend.

Fisheries

Fishermen at Lac Bay fish either inside or outside the bay. At Sorobon, local fishermen use the fishermen-pier for anchorage and cleaning fish. These fishermen go out to sea to fish. There is also fishery inside the bay from fisherman from the Sorobon pier in small boats, one fisherman next to Kontiki, and a little north of Kontiki along the road is a gap between the mangroves where fishermen can launch their boats At Cai a few fishermen are residing permanently. They mainly fish in the bay. Occasional outside fishermen enter the bay to fish indiscriminately with fine mesh nets. Local fishermen are much against these practices. Illegal conch fishing is still taking place (Figure 1). Occasionally turtles are caught as well.

Nevertheless, overall fishing pressure in Lac has decreased significantly in the last 15 or so years. In the 90's you could see 20 or more boat any given day. Now you can see just a few, no more than 2 or 3 and perhaps a few more during the week end (R. de León, pers. comm.). The same is the case with illegal conch fishing. Since the BNMP started to heavily enforce the ban in conch harvesting they have noticed a great reduction in poaching activities. In past years incidents and conch poaching court cases were regular. Nowadays there still is some poaching but it is more incidental and not longer a constant pressure (R. de León, pers. comm.).

Figure 1. Largely immature conch, *Strombus gigas*, taken from Lac (photo: A. Debrot).

Windsurfing

20 years ago an occasional windsurfer could be seen. Nowadays two windsurf centers and a windsurf club are present. At top days sometimes around 100 surfers could be seen in the bay in 2004. Each year several races are held in the bay and international windsurf competitions have also started (PWA tour: King of the Caribbean in 2002). Apparently, nowadays full moon surfing nights are also organized every now and then (comm. M. Beckman Lapré).

Kayaking

At least 4 Kayak operators have regular trips in the mangroves. One operator starts its kayak trips from a place named Kreek di Coco. The other two operators mainly use the beach at Cai as a starting point.
Occasionally people rent kayaks from the windsurf centers to go kayaking near the patch reefs. According to Progressive Environmental Soultions, snorkelers and kayakers primarily visit the patch reefs within the Lac basin, but an increasing number also cross the barrier reef in an effort to reach the dive spot called “white hole”. The shallow water conditions of the area and rough waters leave the corals here particularly vulnerable to human impact. Novice kayakers/snorkelers can easily lose control in the strong current ending up on the corals. Others, when realizing the shallow water depth, walk across the barrier reef sometimes dragging kayaks behind. Therefore, Progressive Environmental Solutions points to the need for monitoring of the human impact to the corals in this area (K. Kats, pers. comm.).

Snorkeling

Snorkel trips are regularly held mainly at Boca Djukfes and in the area called Puitu. In the Awa Blanku area people go snorkeling around the patch reefs. Permits have been given to one company to conduct group snorkels to the barrier reef area and at least 3 dive operations offer dives near this area. According to Progressive Environmental Solutions, the boat of one company has already run aground on the reef on 2 separate occasions, and with the increasing number of cruise ship visitors to the area has come an increasing number of people snorkeling, wading and kayaking at the barrier reef. With increased usage, increased damage should be anticipated. It may be necessary to restrict the use of this area for commercial purposes.

Kitesurfing

Around 2000 kite surfing made its appearance in the bay. In 2003 however, the Island Government banned the sport from the bay because the disturbance threats to the resident birds were deemed too high.

Hotels and restaurants

Two hotels remain in the area namely, Sorobon Beach Resort and Kontiki Beach Club. Overnight stays are possible at both places. Both hotels are located in the Sorobon area. Sunbathing and swimming occurs near the beaches. Both hotels also include restaurant(s). Another restaurant is operated by a windsurf centre Jibe City. Sorobon beach resort will change ownership in 2010. With a change in concept for the resort and an increase in capacity, it is foreseen that activities around the resort will change and become more intrusive.

Toilets

The lack of functioning toilets is experienced as a real problem by the BNMP. Near the fisherman pier at Sorobon toilets have been placed which are in very bad shape and not accessible to the public. They were installed in 2002 and drain into a steel tank buried in the sand behind the toilets. By now that tank must be completely corroded and leaking to the bay. The toilets at Cai are composting toilets and according to BNMP they stopped functioning soon after opening because of lack of maintenance.

The BNMP is concerned about the wastewater management in in the Lac area. Recently The Bonaire Windsurf Place constructed new toilets with new septic tanks. Both the toilets and the septic tanks were constructed above ground level, which is good. However, Jibe City also constructed a new septic system but below ground level. This last option may make the concrete more susceptible to salt water and corrosion. In such environments, only heavy duty plastic septic tanks should be allowed (R. de León, pers. comm.).

Day tourists near Sorobon beach

Cruise ship tourists visit the beaches in Sorobon. Anecdotal stories report 100's of tourists visiting the beaches on such days. Since cruise ships visits to Bonaire have increased recently, the number of day tourists have presumably increased as well. Because of lack of other alternatives in the area, most of these tourists concentrate in a very small area. This may be beneficial by limiting impact and disturbance to specific areas. However, certain habitats in these areas may experience excessive pressure and degrade. The damage may become extensive if users then move to other areas.

Livestock

Livestock as donkeys, goats and sheep, are frequenting Lac Bay and are found throughout the larger watershed area which ultimately drains nutrients and sediment into Lac. Hundreds (possibly thousands) of donkeys and goats are using the area for foraging, particularly the northwest sector, which roughly includes the area between Boki Coco and the Kadaster mark north of Kontiki. Recently also sheep have appeared. Free roaming livestock is however prohibited at Bonaire, but this is not enforced.

4 Conservation values

Mangroves form a key habitat for Lac, which provides the only main mangrove area for Bonaire. The mangroves of Lac are well developed and represent all three mangrove species found in the Netherlands Antilles (red mangrove, *Rhizophora mangle*, black mangrove, *Avicennia germinans* and white mangrove, *Laguncularia racemosa*), as well as the green buttonwood (*Conocarpus erectus*). The mangroves of Lac play several key ecological roles for Bonaire, especially as important habitat for fauna (Nagelkerken et al. 2007). They not only protect the reefs of the east coast of Bonaire by entrapping nutrients and sediment caused by deforestation and runoff, but also constitute critical nursery area for many (also commercially) important reef species and serve as a roosting area for birds. Three recent studies have examined the nursery function of Lac Bay mangroves and seagrass beds to coral reef fish species (Nagelkerken et al. 2000, 2002; Nagelkerken et al. 2004). A number of contributions document and discuss the value of Lac, and particularly its mangroves as a habitat for birds (Debrot 1999, Debrot et al. 2009, Harms and Eberhardt 2003, Prins et al. 2009, Voous 1983, Wells and Debrot 2008). As a result of its value as avian habitat Lac has been designated a Ramsar site and an IBA area (Important Bird Area) by IUCN (Wells and Debrot 2008). Rare and/or endangered species of particular concern are a dwarfed form of the Caribbean crown conch, *Melongena melongena* (Bruggeman-Nannenga and Wagenaar-Hummelink 1986), rare fields of perennial glasswort, *Salicornia perennis* (Proosdij 2001), in the Netherlands Antilles practically only found at Lac and at Eastpoint in Curaçao (de Freitas, pers. comm.) (Figure 2), the rare native evergreen beach shrub *Scaevola plumieri* at Sorobon (Figure 3), as well as endangered sea turtles and queen conch (Lott 2000, 2001). More extensive biological inventories assessing the general biodiversity of Lac are provided by Hoek et al. 1972, Moorsel and Meijer 1993, Lott 2001).

Figure 2. Rare *Salicornia perennis* vegetation found practically only at Lac (photo: A. Debrot).

As pointed out by Moorsel and Meijer (1993), optimal conditions for mangroves are typically found in tropical estuaries dominated by riverine freshwater influx. This is certainly not the case with Lac, as Lac is non-estuarine in nature. The mangroves of Lac are found in an arid climate, with only seasonal inflow of surface runoff, while beneath the surface, Lac is underlain by an expansive karst limestone platform (Meer Mohr 1972), sloping upwards and west into the large catchment areas of Lima, south Bonaire, where karst wells and caves are common (Grontmij & Sogreah 1968, Rowbottom and Winkel 1979, Debrot 2003) and much of the freshwater influx into Lac likely occurs subterraneously.

Figure 3. *Scaevola plumieri* at Sorobon (photo: A. Debrot).

5 Threats, issues, and recommended solutions

5.1 Filling-in and reduced water circulation

The back of Lac Bay is filling in relatively rapidly as the mangroves migrate seaward within the bay. Filling in can be caused by or contributed to such processes as input of terrigenous sediments due to runoff, organic leaf litter production by the mangroves themselves, accumulation of sand inside the bay which originates from the coral reef outside the bay, and endogenous sediment production, for instance by calcareous algae in the bay. In most situations, such as in river deltas or along open coasts, expansion due to such succession processes in mangrove communities is not an ecological problem, as they have space to freely expand. Therefore, Lott (2001) considers that from a conservation perspective it is important to "become aware, that these dynamics, or changes in an ecosystem, are parts of the normal functioning of the system". The main problem is that in the case of Lac, free expansion of mangroves seaward has essentially reduced the effective surface area of the lagoon by 82 ha during a 35 year period (average: 2.34 ha per year) as illustrated in the 2006 map by Erdman and Scheffers, Univ. Duisberg-Essen) (Fig 4).

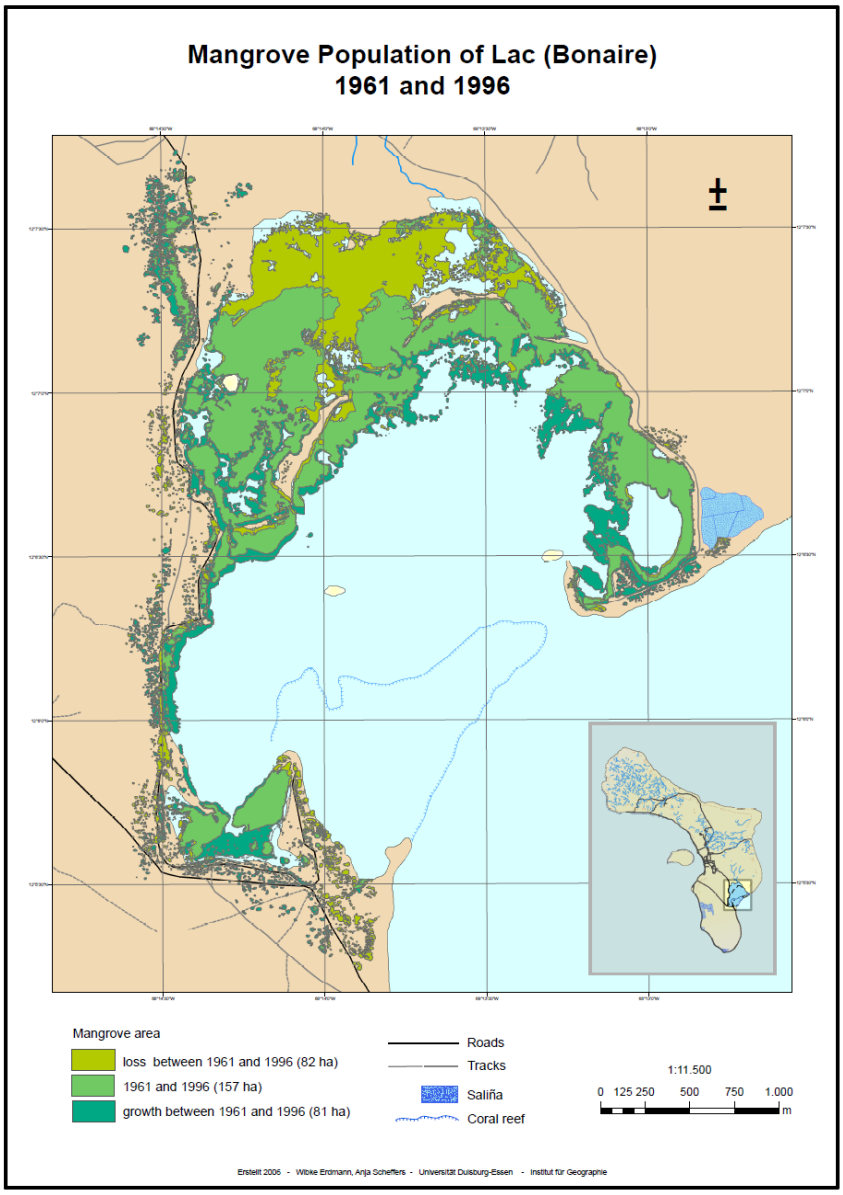

Figure 4. (Map from Erdmann and Scheffers 2006). The loss of mangroves in Lac has been balanced by new growth during a 35 year period, but in the process combined healthy open water surface of Lac has declined by the same (average of 2.34 ha per year).

This process will bring everything Lac signifies today to an end (Figure 5). Wagenaar-Hummelink and Roos (1969) were the first to be alerted to the ecological dangers of the natural tendency of mangroves to cause land building ("verlanding") and to express their worries about the impoverishment and habitat loss that this causes in Lac. Filling in due to terrigenous water born sediment from the hinterlands was pinpointed as an important cause for mortalities in the mangroves in the northwestern section of the bay, and triggers the migration of the mangroves seaward (Wagenaar-Hummelink and Roos 1969).

Figure 5. Dead mangroves at the back of Lac. In front a flock of red flamingos (*Phoenicopterus ruber*).

In a nearby example for Curacao studying sedimentary cores, Klosowska (2003) has shown that traditional agricultural land-use practices such as the felling of trees, clearing of fields and extensive livestock grazing have caused a highly elevated rate of filling in of the shallow lagoon of St. Michiel in Curaçao. The same processes are evident for Lac where barren ground cover caused by excessive grazing by feral animals and poor land-use practices (Figure 6), is considerably worse than in Curaçao (compare Freitas et al. and Beers et al. 1997).

Figure 6. Nonsustainable landuse practices in the Lac drainage area of Bacuna (photo: A. Debrot)

The dung from livestock present in the large Lac watershed area releases nutrients which enter the Lac system via both terrestrial and subterranean runoff. The Lac watershed drainage area expands well away from the vicinity of the bay and happens to be home to hundreds of goats (possibly thousands!) and feral burrows. Calculations of the nutrients freed in dung from, for instance donkeys (Suss 2005), show that livestock may potentially contribute to eutrophication of Lac bay. Lovelock et al. (2009) furthermore found that the benefits of increased mangrove growth in response to coastal eutrophication (in the case of Lac due to both subterraneous leaching of sewage and dung nutrients from livestock (goats and donkeys) is offset by the costs of decreased resilience due to greater mortality during drought as caused by higher nutrient concentrations, with mortality increasing with soil water salinity.

Lott (2001) also specifically mentions the effects of erosion caused by the dirt road, the increased traffic on the dirt road and the 'reconditioning' of the dirt road with more dirt. On the inner margin of Lac, prehistoric Indian shell middens, have been described by Haviser (1991), including for the rear 'dead zone". Indian shell middens have been extensively found in Bonaire and Curacao, and are typically located directly along the shores of the inland bays (NAAM & BMA 2009). The fact that the old shell middens of the "dead" zone of Lac, are now separated from the waters edge by several 100 meters of terrigenous sediment, is further retrospective evidence of the problem of sediment accumulation (Fig. 7).

Figure 7. Terriginous sediment smothering prehistoric Indian shell middens (center) which were formerly on the shore. Wagenaar-Hummelink and Roos (1969: Fig 33) described this part of Lac as follows: "The red brown plains at Rooi Grandi sediments washed in from the north, with "islands" of cactus scrub. (photo: A. Debrot)

Even though, according to Lott (2001) freshwater run off into Lac has likely declined greatly since 1951 when a dam at Bacuna was constructed (Moorsel and Meijer 1993), the fact of terriginous sediment inflow into Lac is quite evident from aerial photographs today (Google Earth), as it was in 1967 (Wagenaar-Hummelink and Roos 1969) (Figure 8). Already in 1970 a team of experts pointed out the need to open water flow to the dying rear sections of the mangroves of Lac (Netherlands Commission for International Nature Protection, NCIN 1970).

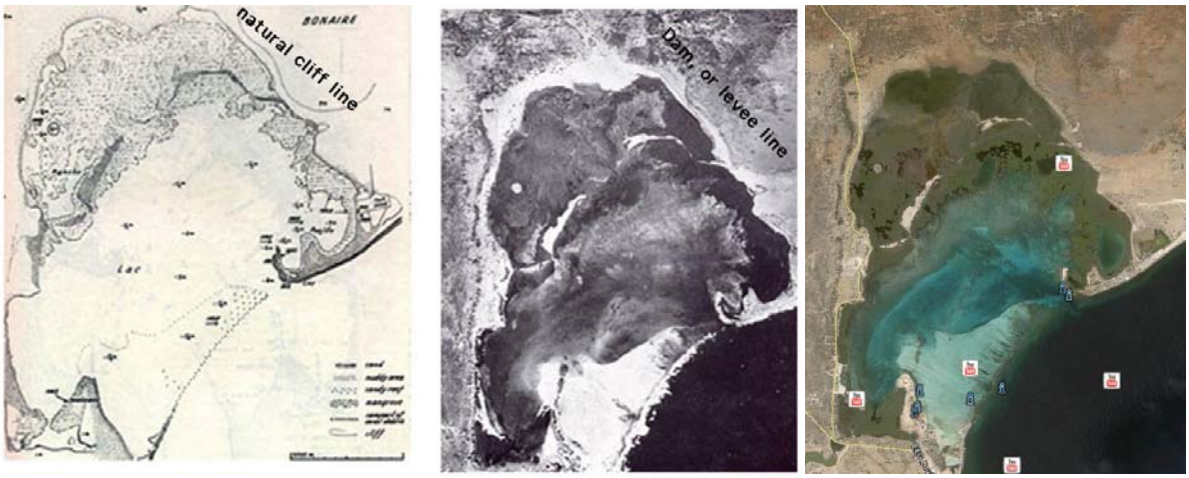

Figure 8. Comparison of Lac from 1949 and 1969 showing infilling with sediment and seaward growth of Mangroves (Lott 2000) and right picture from Google Earth, presumably from relatively recent.

Both internationally and locally mangroves have proven to be quite resilient to human perturbation. Large swaths of mangroves cut in Lac in 1965 (Wagenaar Hummelink and Roos 1969, fig 33) have fully recuperated. In Curaçao areas of the Schottegat with extensive filling and dredging for roads have been rapidly repopulated with dense mangrove thickets without any replanting effort. Planting of mangroves using naturally produced propagules has also been proven to be very simple and effective in Curacao (Figure 9), as long as the habitat conditions (hydrology: water exchange and salinity) are adequate (Debrot pers. observ.). This coincides with studies conducted elsewhere (Lewis 1999, Lewis and Gilmore 2007, Lewis and Streever 2000). A telling example of simple mangrove restoration using minimal methods is provided by Lewis and Streever (2000) (Fig. 10).

Figure 9. *Avicennia* and *Conocarpus* successfully restored to the island of Klein Curaçao, 2010, where trees and shrubs have been absent for more than 100 years (photo: A. Debrot)

According to Lewis and Streever (2000), "the single most important factor in designing a successful mangrove restoration project is determining the hydrology (frequency and duration of tidal flooding) typical of existing mangrove plant communities near the restoration site". "A surrogate for costly tidal data gathering or modeling is the use of a tidal benchmark and survey of existing healthy mangroves to generate"……. "a construction model for the project".

Lewis and Streever (2000) further point out that "excavation of fill or backfilling of an excavated area to achieve the same general slope and the elevations relative to a benchmark at the reference site ensures that hydrology is correct". We point out that in the case of Lac only excavation is relevant.

Figure 3. A time sequence over 78 months from the completion of hydrologic restoration at West Lake near Fort Lauderdale, Florida. Although no active planting was undertaken, all three Florida mangrove species became established

Figure 10. From: Lewis and Streever (2000), showing rapid natural mangrove restoration following excavation to restore hydrology.

For a part, filling in of the bay is certainly also by endogenous sediment production in the bay, not only by the mangroves, but also by calcareous green algae. Wagenaar-Hummelink and Roos (1969) and Lott (2001) speak of dense *Halimeda* algal fields in much of the bay, whereas most of the calcareous sand in the lagoon is largely made up of degraded Halimeda (Wagenaar-Hummelink and Roos 1969, Lott 2000). In 2007 Engel repeated the queen conch and seagrass survey as done by Lott in 1999. She noticed an increase in *Halimeda*, and revisited

together with Lott some areas in Lac, where both researchers came to the same conclusion. However, no quantitative data were collected (S. Engel, pers. comm..)

Halimeda algal communities have been more extensively been described by Kuenen and Debrot (1995) for Curaçao and are principally comprised of *H. incrassata* and *H. opuntia*. In Curaçao these sand-producing green algae have led to filling-in of isolated sections of the eutrophic Spanish Water. Chazottes et al. (2008) point out that eutrophication leads to an increase in *Halimeda* and a change in sediment characteristics. As such *Halimeda* abundance may be an important indication of eutrophication. Due to calcification, *Halimeda* is less palatable to predators and is also an important carrier of coral disease (Nugues et al. 2004). Encroachment of mangroves and *Halimeda* in the various channels has filled-in the channels which formerly kept the northwest section of Lac vital, and these no longer function. In the past fishermen kept the channels open (Lott 2001). In addition, likely related to overall sediment production and accumulation in the bay, the deepest part of the entrance to Lac Bay has decreased in depth from 8 to 5 meter since 1949 (Lott 2001).

Recommended action points

- The ultimate cause of the accelerated infilling of Lac is the over-grazing of the vegetation by feral live stock and detrimental land-use practices that destroy the top soil of Bonaire enhancing erosion (Coblentz 1980). A start should be made as soon as possible to tackle the livestock overgrazing problem in the whole watershed and reduce sediment runoff both inside and outside the bay. This would reduce the rate of infilling, re-vitalize the surrounding vegetation, improve bottom hydrology and likely also reduce the sediment impacts on the reefs. Ideally an integrated watershed approach should be applied.

- Regularly open up the former channels to the rear areas of the mangroves and reestablish circulation and water quality, as recommended in the Lac Bay management plan. A project for this has already been designed. This needs to be done after thorough planning is conducted based on historical data regarding former channels and current hydrology (K. Kats, pers. comm.). The BNMP have been opening several channels at least every 2 years (at least for the last 6 years) and are currently opening them again (R. de León, pers. comm.). Simple monitoring of the project should be conducted to evaluate the results, in terms of both exacted damage to mangroves and effectiveness in terms of water circulation.

- Design and implement a pilot project to remove filled-in sediments and reforest with red mangroves in the rear stagnant areas of Lac so as to re-establish mangrove and fish nursery habitat. This should preferably be done in a small scale, in such a way as to cause little sediment transport to the outer, open sections of Lac. Simple monitoring of the project should be conducted to evaluate the results before proceeding on a larger scale. In Curaçao and Bonaire, several successful reforestation projects have been conducted in recent years based on the most simple concepts and methods (Debrot 2009).

- A pilot project on how to rehabilitate the recovered topsoil (efficiently remove the salt) for use in sustainable agriculture elsewhere on the island.

5.2 Degradation of sea grass bed quality

Seagrass beds, particularly turtle grass, *Thallassia testudinum*, are important as food to the green turtle and provide shelter for young fish. They also serve to stabilize sediments. Very few studies have quantitatively described seagrass communities, and those of Lac have only been qualitatively described (E.g. Lott 2000, 2001, Wagenaar-Hummelinck and Roos 1969). Even so the trends in development of the seagrass beds appear to be be quite disturbing. In 1998 compared to 1961, Lott (2001) points out that now there appears to be less seagrass bottom coverage. Also, Engel (2008) concludes that since 2001, seagrass coverage appears to have largely decreased in the bay, including near shore areas where trampling is a major problem (Giardini 2008) (Figure 11). Recreational use of Lac may be growing rapidly and there are currently no limits set to this growth. Based on the conversations held and documented declines in seagrass bed coverage, it appears that Lac may already be at its environmental and social carrying capacities. The effects of environmental change act often indirect on seagrass beds e.g. overfishing may alter fish community composition which may change the number of fish preying on fouling organisms that grow on seagrass and are food to the queen conch. Also increases in nutrients may increase the amount of fouling on seagrass blades (e.g. Waycott et al. 2009). Health of seagrasses is intimately linked with coral reef processes (Hughes et al. 2003).

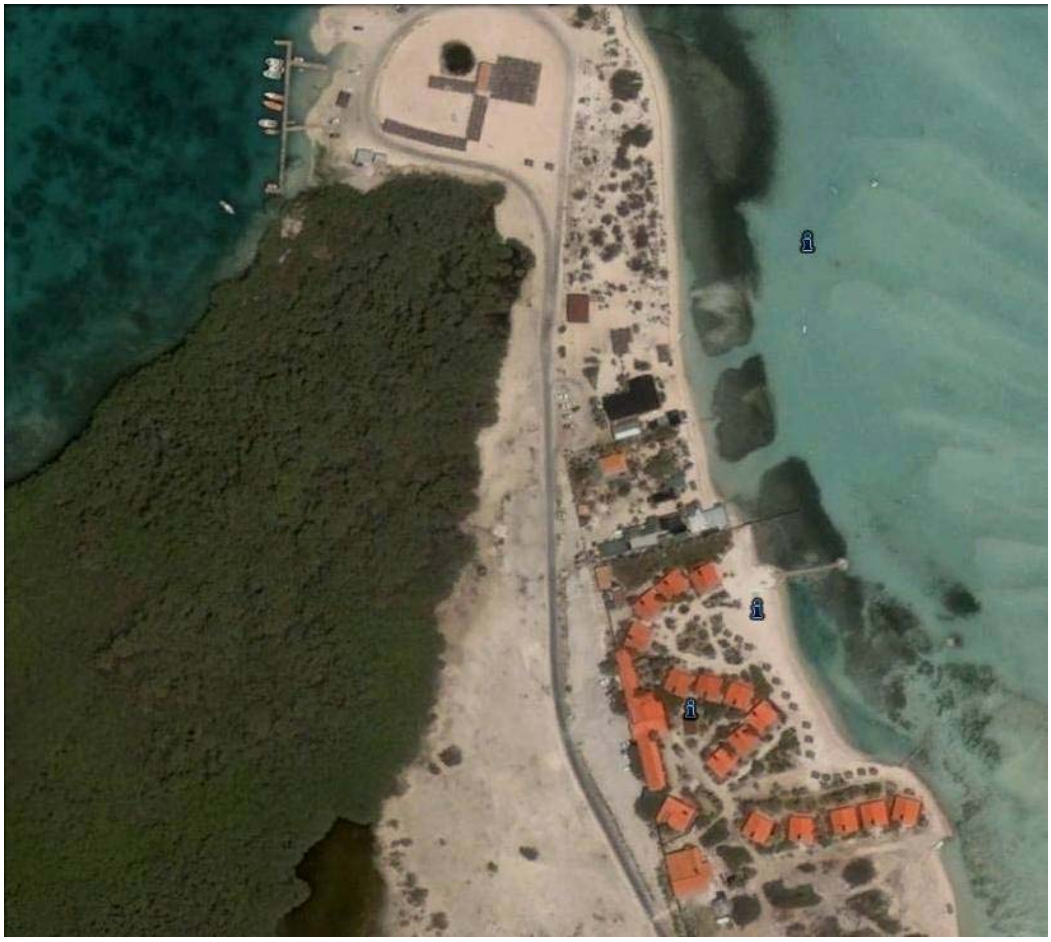

Figure 11. Seagrass beds in front of beach show clear lanes devoid of seagrass as a result of trampling. Buoyed lines have been set around seagrass beds near the shores to 'guide' the people through these lanes, instead of having them trample everything

Recommended action points

Based on the conversations held and documented declines in seagrass bed coverage, it appears that Lac may already be at its environmental and social carrying capacities.

- Upper limits should be set for the various users, and public access to seagrass areas should be strictly limited using a combination of zoning, demarcation and enforcement, as recommended in the current management plan.

- Visitor facilities designed to limit or steer user impact towards low sensitivity areas need to be upgraded and kept up.

- Conduct a quantitative baseline description of the seagrass meadows of Lac to determine coverage using GIS and aerial photography and start monitoring a number of permanent quadrats to be revisited every year to asses long term trends in seagrass community development and health (e.g. fouling species, rate of fouling).

5.3 Disturbance

Lac Bay is intensively used for various kinds of recreation, ranging from kayak tours to snorkel tours, scuba diving, boating, artisanal fishing, wind surfing, hiking, horse back riding and beach recreation. Humans are present in the area day and night. Endangered species such as turtles and nesting birds are vulnerable to human disturbance, but data is needed, especially considering Lac's status as both Ramsar wetland and regional IBA.

Recommended action points

- A survey of current bird use of the Lac area and an assessment of their vulnerability to disturbance.
- Monitoring of human use of the bay, identification and prioritization of threats.

5.4 Litter contamination

Litter contamination is a chronic problem for bays and beaches on the wave-exposed northern and eastern shores of the leeward Dutch Antilles. Based on a study of the country of origin, it can be concluded that most of such marine litter is washed in from the open sea and is not derived from local littering (Debrot et al 1999). Nevertheless, litter concentrations along the shores of Lac can be quite high, including inside the mangrove forest areas (Figure 12). Plastics may contain poisonous chemicals (e.g. polycyclic aromatic hydrocarbons) and disturb the physiology of plants and animals. Furthermore, plastics can trap and kill or cause serious injury to sea turtles.

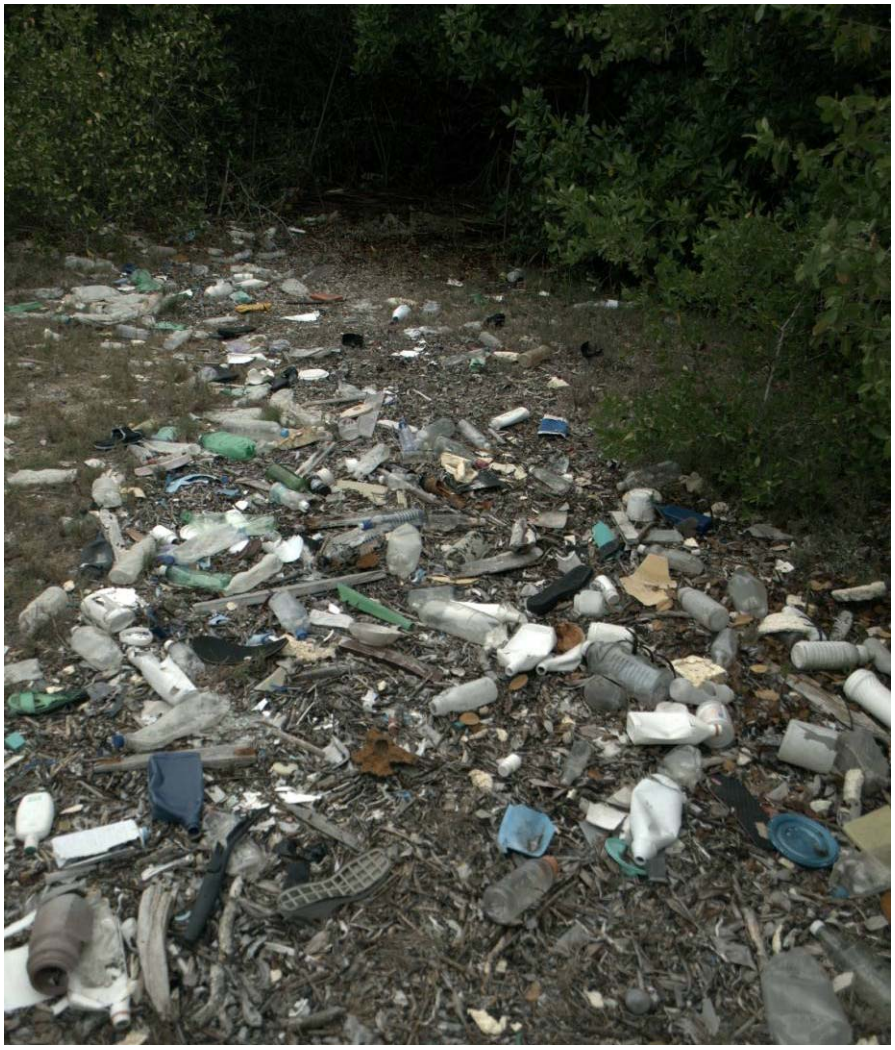

Figure 12. Litter is a clear problem in Lac. (Photo A. Debrot)

Apart from apparent littering on the shores of Lac and in the mangrove forests, there is also serious littering under water. Personal observation and communication from STCB indicated that abandoned fishing lines are common in the deeper parts of Lac (3).

Figure 13. Fishing Lines collected from the main exit of Lac during one morning (Photo M. Nava).

Recommended action points

- Conduct regular cleanups with volunteers and monitor litter densities.
- Clean submarine gullies of abandoned fishing lines and limit and regulate fishing inside of Lac.
- Conduct PAH (polyaromatic hydrocarbon) studies of the water in Lac

5.5 Reef status and algal blooms

On the 26th of May, the authors were taken by the marine park manager on a dive of the reefs outside of Lac Bay, at the location known as White Hole. The area had high coral cover, with a dominance of growth forms typical of high wave energy reefs (eg. *Millepora complanata* and Gorgonians). Practically no disease or bleaching (e.g. Meesters and Bak 1993; Nagelkerken 2007) was observed in either the coral or the sea fans, both of which have been suffering disease at many places in the Caribbean (Williams and Bunkley-Williams 2000). Algae indicative of eutrophication such as *Lobophora* and *Halimeda* were rare or absent. The reef further had high densities of subadult nursery species such as schoolmaster snappers, mahogany snappers, and black margate, *Anisotremus surinamensis.* A large school of tarpon, and green moray eel were seen, as were schools of black durgeon, several conch and many sea turtles. The outer reef was obviously in exceptionally good health.

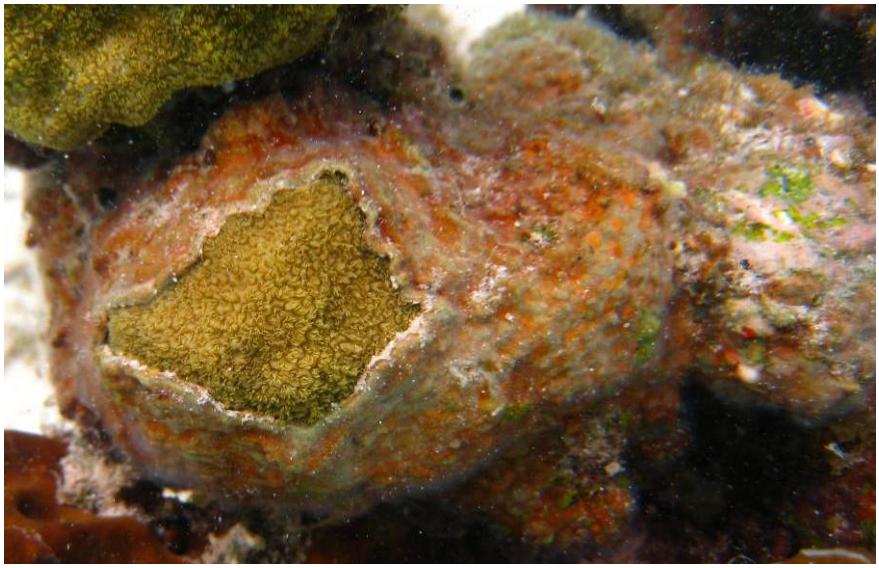

Figure 14. Overgrowth of *Porites astreoides* colony by *Ramicrusta* alga. The coral beneath the alga dies (Photo D. Slijkerman).

The inner reef was visited on the 27th of April, accompanied by Dr. R. Peachey. There we were pointed out a problematic bloom of a crustose calcareous alga *Ramicrusta* sp. which is smothering and overgrowing many sessile benthic species such as corals, gorgonians and sponges (Figures. 14, 15). This appears to be a recent issue and has not been recorded in the scientific literature before (Eckrich et al., submitted). Potentially, this overgrowing alga may cause a serious decline in living corals inside the bay. *P. astreoides* , *P. porites* and *M. complanata* appear to be very susceptible. Other species seem to fare better. (S. Engel, pers. comm.). Algal blooms are often related to increased nutrient concentrations (Heisler et al. 2008), but this has not yet been measured inside the bay.

Regarding the increase of recreation in Lac, bacterial water quality is a relevant parameter to take into account. In 2009-2010, CIEE took 6 samples from the same site at the outer edge of the bay along the "coral dam" using the EPA recommended Enterolert test and has found no signs of enteric bacterial contamination (R. Peachey, pers. comm.). Based on these first results, no conclusions about swimming water quality in Lac can be made yet.

Recommended action points

- Periodic annual monitoring of enteric bacterial presence at high risk locations.
- Install a monitoring program to assess the nutrient situation in Lac at several locations.
- Continue monitoring of coral overgrowth by *Ramicrusta* sp. and conduct more research on the biology of this alga, as already initiated by CIEE.

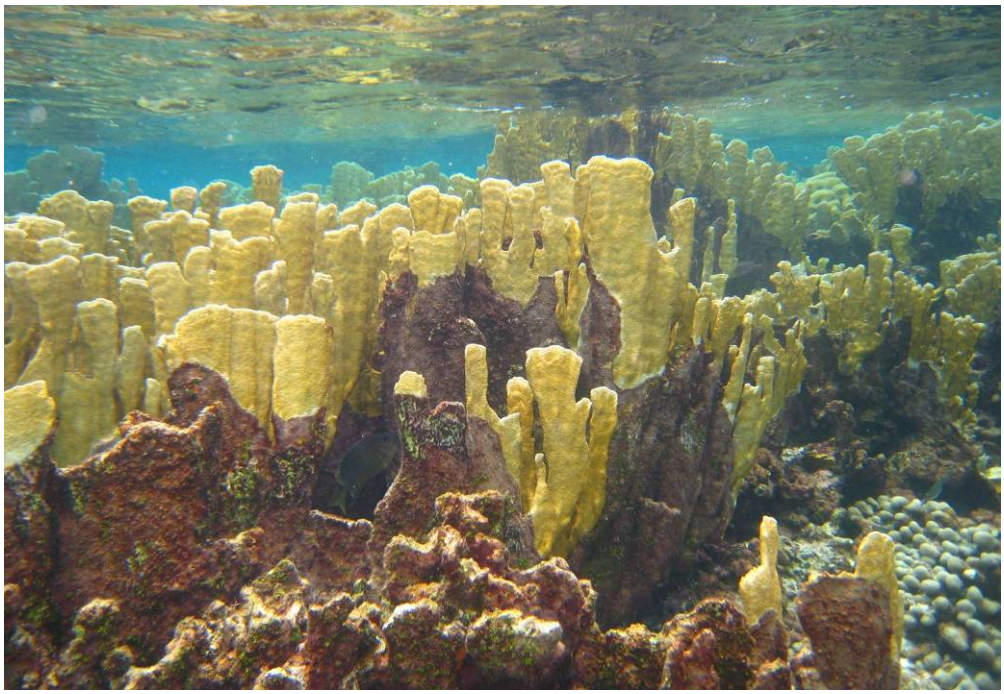

Figure 15. *Ramicrusta* alga overgrowing fire coral *Millepora complanata* (Photo D. Slijkerman.)

6 Legal tools

Lac Bay represents a high concentration of critical conservation values for Bonaire and needs effective legal protection. Based on infringement of the Ramsar Convention as applied to Lac, the construction of a large resort was blocked by court in 2007 (Verschuuren 2008). However, oftentimes, and until tested, the legal significance of existing legislation is not fully appreciated or understood. At island level, protection is given via the Nature Ordinance "Verordening Marien Milieu (VMM)"). However, in their management plan, STINAPA Bonaire point out important shortcomings in this legal tool and recommend a general update of the VMM. Several international treaties that apply to Lac are the SPAW protocol of the Cartagena Convention, the Ramsar convention, the Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC) and the Convention for Migratory Species (in this case sea turtles) and the CITES convention. The Convention on Migratory species was agreed upon in 2005 and ratified by the Netherlands. CITES aims to protect animals and plants threatened in their survival by international trade. Many species are covered, including several species found in and about Lac Bay. The Kingdom has ratified CITES for the Netherlands Antilles as well as for the Netherlands. Possibly most interesting is the fact that SPAW requires EIAs for example for new development new developments. But also in the Landsverordening Grondslagen Natuurbeheer en –Bescherming 1998 artikel 10 (in force from 1999 (PB 1999, Nr. 24) states that requirements from SPAW and Ramsar should be followed. Additionally, EIAs should be evaluated by independent agencies with sufficient expert knowledge. However, EIAs appear not to have been made for the recent increases in recreational use of Lac. Furthermore, there has always been very little attention to potential impacts on the migratory waterbirds using Lac. This should be assessed as soon as possible. Evaluation of and enforcement of property lines is also critical. According to informants (K. Kats, pers. comm.), several businesses have been illegally expanding their operations, either through the clearing of mangroves for views, clearing of plants for beach "maintenance", creating temporary structures for events that are never removed, and expanding parking areas.

<u>Recommended action points</u>

- Analyse the various legal options available for the protection of Lac and its inhabitants and evaluate the legality of current activities.
- Evaluate and enforce property lines and adherence to building plans and permits.
- Adapt the Verordening Marien Milieu (VMM) to accommodate the threats from development and human disturbance. The by laws of the Nature law waiting at this moment to be approved by the BC contain several regulations that will improve the situation in Lac.

7 Conclusions

Lac Bay represents critical conservation values for Bonaire and provides important ecosystem services. A great deal of research has been funded in recent years on the ecology of the bay. Several Lac environmental assessment projects were carried out on behalf of the Bonaire National Marine Park (STINAPA-Bonaire) to assist with managing and sustaining Lac for the future enjoyment of Bonaire (Lott, 2001, Engel 2008). They were developed in close cooperation with the local community, the user community and the Island Government.

This has contributed to a better understanding of the ecological value that Lac represents, the dangers it faces, and how to deal with various issues. While most researchers have recognized and expressed concern about the semi-natural destructive processes taking place in the bay, the studies have been largely qualitative or descriptive and have not directly addressed the most critical issue of mangrove mortality. Management efforts implemented include the zoning of Lac for different users, deployment of moorings for kayakers, code of conduct for Kayak-guides, and buoys excluding recreational activities from the seagrass beds.

As a consequence of natural filling in, accelerated by non-sustainable land-use practices in the hinterlands draining into Lac, the former surface of Lac has become shallow and choked with sediment. This has lead to a gradual reduction of the effective nursery and habitat surface of the bay over the last decades, and will in due time lead to a complete destruction of everything this bay represents for endangered fauna and flora, and its human users. This process, is accelerated by various factors including deleterious land-use practices such as barren fields and extensive livestock grazing in the hinterlands of the drainage area. Integrated watershed management is dearly needed. All the available evidence indicates that action is urgently needed to preserve Lac.

Worldwide, habitat destruction was and still is the most significant cause of biodiversity loss (Vitousek 1992, Secretariat of the Convention on Biological Diversity 2010). Therefore studies of habitat restoration are of high priority. Responsibly tackling the large threats that are facing Lac, keeping in mind the uncertainties and gaps in knowledge, requires an integrated ecological and experimental approach. While mangroves are notoriously robust systems and very capable of handling severe disturbance, the great importance of Lac as the only large mangrove habitat of Bonaire, nevertheless calls for a cautionary approach, whereby restoration measures are tried and evaluated on a small, controlled scale first.

Since the seminal study of Wagenaar-Hummelink and Roos (1969) Lac has suffered a range of direct and indirect anthropogenic impacts. Particularly, uncontrolled recreational pressure has intensified in recent years, and the Lac ecosystem has been modified or altered by construction of roads, the building of hotels, subterraneous nutrient enrichment by untreated sewage and more. A great deal of insufficiently evaluated environmentally adverse activity has actually taken place and been carried out. However, so far this has only been countered by measures used to zone disturbance and limit user impacts such as disturbance and exploitation. These measures have proven insufficient to either halt or reverse the inexorable destructive forces of mangrove succession. Active habitat restoration is ultimately unavoidable if the habitat and ecosystem functions of Lac are to be preserved for posterity.

By definition, knowledge will never be perfect. Therefore, the decision to proceed without perfect knowledge will be a key success factor in the sustainable management of Lac, just as it has, for instance, been in the much larger and more complicated challenge to effectively protect the Great Barrier Reef of Australia (Fernandes et al 2005). Even so, mangrove ecosystems are resilient and robust by nature and based on both local and international experience, have proven to respond well to simple restoration measures. Therefore, we here recommend an applied adaptive learning approach to explore solutions, whereby pilot restoration projects are done jointly with, in support of and under auspices of the managing organization STINAPA Bonaire. This should be combined with efficient and internationally-proven monitoring to asses the condition of Lac and evaluate practical measures that might be taken to restore the dead sector of the bay to its former glory as critical fish nursery and mangrove habitat.

Research and monitoring are not the sole solution. Direct enforcement of existing and new legislation is crucial as well as a permanent presence of one or more officials.

The various recommendations are listed separately under each section of chapter 5. While all of these will require funds to implement, as explained, for many measures costs can be kept low by using simple means (e.g. habitat restoration), participation of volunteers (clean ups) and help of university students (monitoring, baseline studies). Of highest priority is to finally (though carefully and responsibly) start habitat restoration.

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Justification

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Approved: Dr. M. de Graaf
Researcher

Signature:

Date: 2 July 2010

Approved: Drs. F.C. Groenendijk
Head of Department Ecosystems

Signature:

Date: 5 July 2010