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Ecological rehabilitation of Lac Bonaire by wise management of water and sediments

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Abstract

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Lac Bonaire is confronted with a gradually decreasing open water area because mangrove is occupying this area. At the same time mangrove growth deteriorates at the back of the mangrove belt, the area of hyper saline flats gradually increases and sediment is deposited in the bay area. During a field visit, the most prominent problems are identified and concrete management actions are proposed for the ecological rehabilitation of Lac Bonaire.

Keywords: mangrove, salinity, sediment trap, feeder channel, roaming livestock

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Alterra Report 2448
Wageningen, July 2013

Contents

Summary

This report gives an overview of the most prominent problems currently encountered at the Lac bay area. To change the currently negative situation at the Awa di Lodo area with dying mangrove and unfavorable conditions for fish, it is recommended to improve water circulation at the Awa di Lodo area. This will lead to a better water quality and especially to a lower salt concentration. Based on this analyses, recommendations are made for five specific management actions which individually or in combination could be part of a management plan for the ecological rehabilitation of Lac Bonaire.

Management actions are conducted both from the land and sea side, they are short or long term and they can be summarized as follows:

- To clear the upstream (north) section at the labado from sediments in order to restore its function as sediment trap.
- To clear the east and west side feeder channels from sediment and mangrove in order to improve water circulation in the Awa di Lodo area.
- To construct a new central feeder channel following an existing creek pattern to improve water circulation in the Awa di Lodo area. Whether or not this new feeder channel is going to be constructed, will depend on monitoring results of changes in salt concentration in the Awa di Lodo after the existing feeder channels have been cleaned.
- To start a discussion with livestock owners in the greater catchment area on how over-grazing by roaming livestock can be stopped while at the same time these owners can make a living from their business.
- To remove Rhizophora established propagules at the sea side in order to slow down mangrove occupation of the bay area.

Each operation can be separately budgeted and they can be phased in time.

1 Project scheme

STINAPA

Stichting Nationale Parken Bonaire (STINAPA Bonaire) is a non-governmental, not for profit foundation commissioned by the island government to manage the two protected areas of Bonaire: the Bonaire N ational Marine Park (BNMP) and the Washington Slagbaai National Park (WSNP)

- Ramón de León (Manager of the Bonaire National Marine Park)
- Sabine Engel (Conch Restoration Project Biologist)

ALTERRA

ALTERRA is a Research Institute from Wageningen UR that contributes by qualified and independent research to the realization of a high quality and sustainable green living environment.

- Henk Wösten (Senior Scientist Soil Ecosystems)

2 Problem definition

The problem at Lac is that mangrove growth is moving into the open water area of Lac bay thereby gradually reducing this area, while mangrove growth deteriorates at the back of the mangrove belt, the area of hyper saline flats gradually increases and sediment is deposited in the bay area. Figures 1, 2 and 3 show dying mangrove, dying fish which is however an annually repeated phenomenon, and sediment transport in the area.

Figure 1
The problem of dying mangrove at the Awa di Lodo (the backwaters).

Figure 2

The problem of dying fish at the Awa di Lodo (the backwaters).

Figure 3

The problem of sediment transport at the Awa di Lodo, the backwaters (after. Google Earth, 2003).

Labado is the location where overflow takes place. The Mona dam is preventing freshwater inflow while at the same time it may act as sediment trap.

2.1 Terms of Reference

On-going research in the area identified the following possible reasons for the deterioration of the Lac bay area:

1. Decrease of fresh water discharge into the flats due to blocking of surface runoff and intermittent streams draining the upstream catchment, leading to an increase of the salinity in the Awa di Lodo (the backwaters).
2. Decrease of tidal flushing in the flats due to feeder channel blocking by mangroves increasing resistance for water transport past the mangrove belt, leading to an increase of the salinity in the Awa di Lodo due to insufficient flushing with seawater.
3. Increase of sediment discharge into the flats due to activities in the upstream catchment, leading to gradual infilling of the flats and reduction of tidal flushing.
4. Blocking due to sediment transport within the backwater itself leading to reduced local freshwater flushing or reduced local tides.
5. Processes which may also cause differential growth are 1) nutrient status and 2) disease(s).

The mechanisms 1, 2, 3 and 4 assume that mangrove growth is reduced due to increases in salinity. 3 - increase in sediment discharge and 1 - decrease in freshwater discharge may be exclusive - if freshwater inflow is blocked, this could suggests that sediment inflow should also be reduced. However, in a historical sequence both processes could have occurred for instance in the case of some big rainfall events causing substantial sediment discharge into the flats. Alternatively mechanism 2 and 4 could also lead or could have led to stagnant water leading to the death of Rhizophora and Avicennia mangroves (due to root oxygen stress). Processes under 5 have to be excluded as explanations.

In response to the above problems a Terms of Reference (ToR) was prepared for the field visit of dr. Henk Wösten to Bonaire in the period 21-28 April 2013.
Tasks assigned are:

- Assess the data gathered so far with respect to the above mechanisms, and based on this information formulate the most likely mechanism concerning mangrove growth.
- Formulate a recommendation for management based on the most likely mechanism, as investigated during the field visit and based on the student research still to be reported.
- Make a recommendation for research in a pilot area to exclude possible mechanisms.

2.2 Background

Lac at Bonaire (770 ha) is registered as a RAMSAR site (a wetland of international importance) because of its highly productive waters and its importance as a feeding and breeding area for water birds and a nursery area for fish, invertebrates and crustaceans. Large part of Lac is covered by sea grass beds, on which green turtles graze and is habitat for conch. This ecosystem is a unique biotope for endangered species in the Caribbean Netherlands and it is also an important tourism site. In fact, together with Spaans Lagoen on Aruba (70 ha, also a RAMSAR site) it is the largest mangrove area in the former Netherlands Antilles. The mangrove has a well-known natural sequence for the Caribbean region, with (from land to sea) Conocarpus erectus in very dry areas of limited salinity, hyper saline flats with limited tidal influence, Avicennia germinans in tidal areas and Rhizophora mangle on the seaside. This Caribbean Rhizophora mangle has adapted to permanent flooding.

Table 1 (from: BNP management plan, 2003)

Terrestrial vegetation	Vegetation that grows on land and is intolerant of salty soil or water
White mangrove zone	*Languncularia racemosa*, occupies the highest elevations farther upland.
Black mangrove zone	*Avicennia germinans*, usually occupies slightly higher elevations upland from the red mangrove.
Red mangrove zone	*Rhizophora mangle*, grows along the water edge.

When the conditions on the landside become too extreme - due to sedimentation and/or salinization - the Avicennia trees will die, or will be replaced by Conocarpus in case salinity levels are not too high. On the seaside Rhizophora seedlings will develop into new mangrove forest. Literature analyses (Erdmann and Scheffers, 2006; Lott, 2001) suggest that this natural development is taking a very specific and from a management perspective non-desirable direction at Lac. Given the relatively small size of the mangrove (~ 150 ha), a large portion, 60 ha (40%), has died over the last decades, increasing the area of hyper saline tidal flats which are less valuable from a nature management point of view, e.g. on the basis of biodiversity. On the seaside Rhizophora turned 60 ha into mangrove forest. This implies that the total area of the mangrove is constant, but that the seaward movement is the only compensating process (Figure 4).

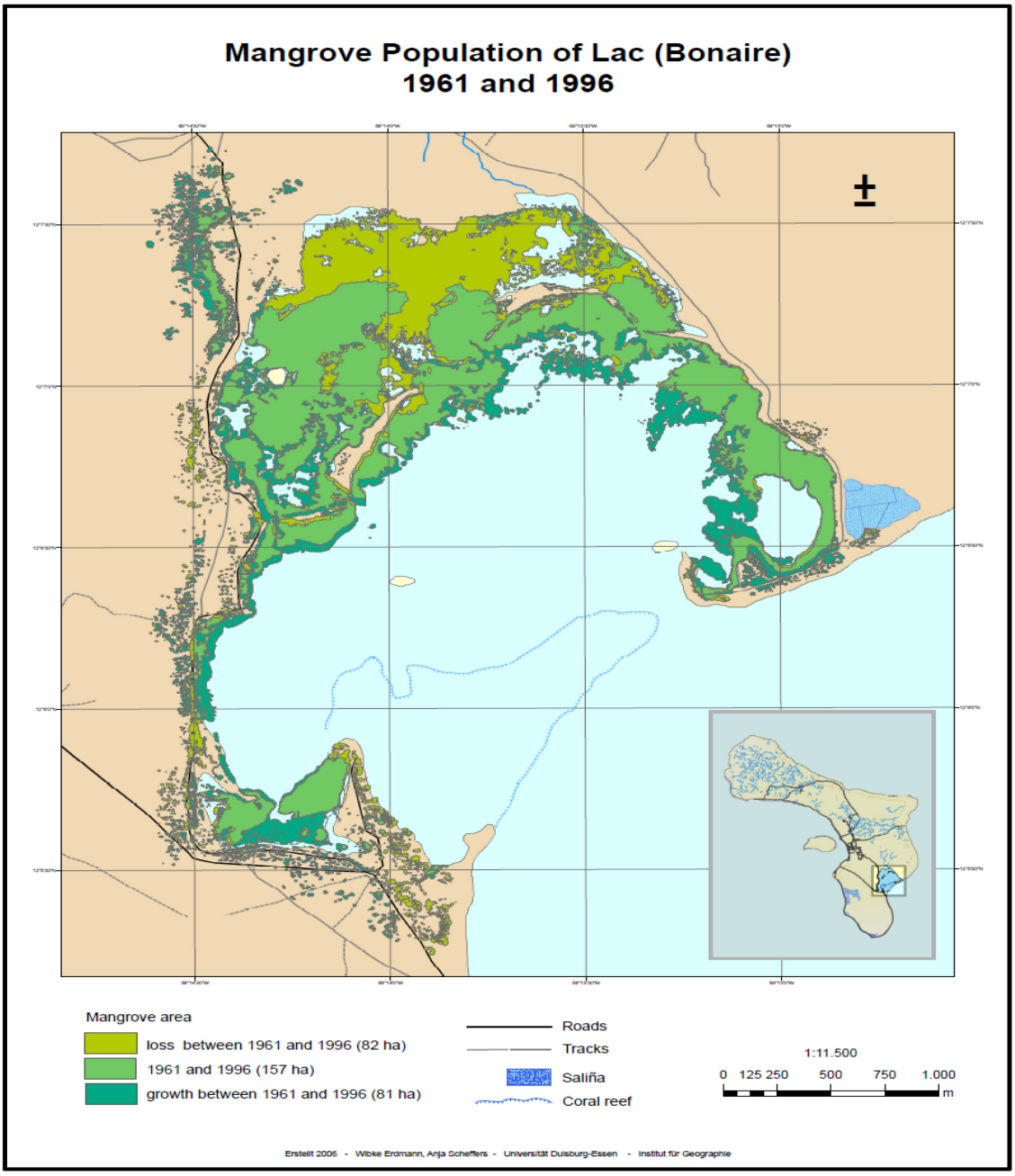

Figure 4

Loss and growth of mangrove at Lac (Erdmann and Scheffers, 2006).

Mangrove trees are well adapted to grow on oxygen poor, fine grained sediments. Their roots reduce the flow velocity causing sediments to settle from sediment rich fresh water entering from the land side. This sediment can be a welcome source of nutrients for biomass development. As a consequence, mangroves reduce the amount of sediments and nutrients entering the open water of Lac which is beneficial for the open water Lac ecosystem.

Under natural conditions mangrove trees at the most elevated locations can die due to unfavorable hydrological conditions, while new mangrove can develop on the lower locations. This development results in a slow but constant seaward development. Many mangroves show this development and it occurs also at Lac

Bonaire. At the land side (north) a relatively large part of the mangrove died, and changed into a hyper saline tidal flat. This is indicated as 'Awa di Lodo' in Figure 5. The middle part of the mangrove ('Medium' in Figure 5) is classified as healthy (Van Moorsel and Meijer, 1993), although some dying trees can be found along former creeks. At the seaside ('Young' in Figure 5) many young Rhizophora trees start to occupy Lac.

Figure 5
Lac at Bonaire (after Google Earth, 2003).

The causes for the seaward shift of Lac mangrove and the changes in relative areas of the hypersaline, Avicennia and Rhizophora zones are:

a) Increased sediment transport towards Lac.
b) Reduced interaction (tidal flow) between sea side and land side.
c) Less fresh water inflow during the rainy season.

Ad a)
Over-grazing by roaming goats and sheep, and detrimental land-use has (probably) caused erosion and will continue to do so. It is likely that this is not only causing local sediment transport but that these sediments have been and are silting up the backwaters of Lac. At the same time livestock browsing in the Lac area limits mangrove development as is also known from other arid and semi-arid regions (Spalding et al., 2010; Debrot et al., 2010). Sediment transport seems to occur with rains of more than 10 mm and in that case also fresh water inflow occurs. In all other cases there is no inflow of fresh water.

Ad b)
Intensive research on water flow in mangrove forests in Vietnam and Indonesia has shown that sea water circulation to the back of a mangrove is driven by feeder channels and by sheet flow through the forest. The feeder channels are most important in draining water and removing salt from the backwaters of the mangrove. This process is also happening at Lac mangrove. However, over the last decades the feeder channels have been partly filled up by fresh sediments and are overgrown with mangrove (*Rhizophora mangle*).

Ad c)
Annual rainfall at Bonaire amounts to about 500 mm y^{-1} but is highly variable. There are only a few months during which rainfall exceeds evapotranspiration (November - January). A proportion of rainfall (10 - 14% in case of more than 5 - 10 mm rainfall per day, based on data for Curacao (Sogrea, 1968)) quickly runs off to permanently or temporarily flooded salinas or directly to the sea. In the past, fresh water could enter the mangrove from the North and West. Starting in the sixties it seems that an unknown but probably significant proportion of this water coming from the land side is blocked by small dams and/or roads (Wagenaar Hummelinck and Roos, 1969). Whether part of this water seeps into Lac as groundwater is currently a topic of research.

As a consequence, the unfavorable conditions for mangrove and fish in the Awa di Lodo area is most likely due to multiple stress factors partly associated with sedimentation and stagnant water:
- High salinity (> two times Electric Conductivity of sea water).
- Anaerobic conditions in the water.
- High water temperature.

2.3 Objectives

In order to improve the negative situation in the Awa di Lodo the challenge is to increase water quality by means of a better water circulation which could be achieved by:
- Use of surface water runoff on the land side for improvement of water quality while decreasing sediment transport from the upstream catchment into the bay.
- Increase tidal water movement in the mangroves from the sea side to improve water circulation.

In addressing these challenges a distinction is being made in objectives that need to be met on the land and on the sea side. These objectives are:

Land side:
- Reduce sediment discharge caused by erosion into the flats. Erosion is caused by elimination of vegetation by grazing of free roaming goats in the upstream catchment. This leads to gradual infilling of the flats and reduction of tidal flushing.
- Increase fresh water discharge into the flats. Currently this discharge is limited due to blocking of surface runoff and blocking of intermittent streams draining the upstream catchment. Consequently, salinity levels in the Awa di Lodo (the backwaters) increase.

Sea side:
- Increase tidal flushing in the flats. Currently this flushing is limited as feeder channels are blocked by mangroves and sediments increasing resistance to water transport past the mangrove belt. This reduction of flushing with seawater also leads to increased salinity levels in the Awa di Lodo.

3 Recommendations for actions

3.1 Considerations

The recommendations for actions are best based on the above mentioned objectives for the land and sea side. For the land side a distinction is made between a short- and a long term approach. For the sea side a distinction is made between maintenance of existing feeder channels and creating a new channel in the central part. Below the recommendations for solutions are further detailed.

3.2 Land side recommendation: short term

Influx of fresh water from the upstream catchment helps to prevent mangrove deterioration as it lowers the salt concentration (salty soils and salt water). Existing dams and roads partly block surface runoff towards Lac during the rainy season. At the same time they act as sediment traps preventing silting up of the bay. Figure 6 gives an overview of the catchment delineation north of Lac.

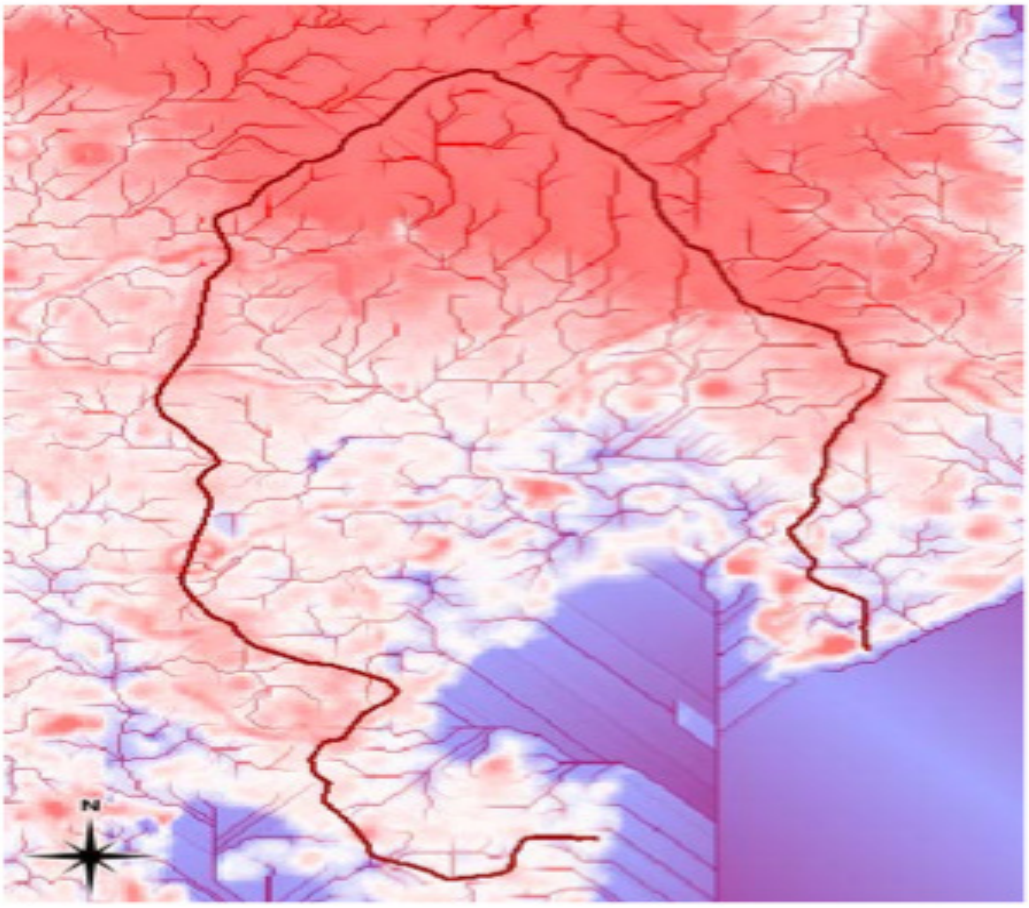

Figure 6
Delineation of the catchment north of Lac (source: Debrot et al., 2012).

The catchment area which drains towards the bay has an estimated surface of 2260 ha (Debrot et al., 2012) which is large compared to the Lac area of 770 ha. As a consequence, agriculture and livestock activities in this in large hinterland do have their effect on the conditions in the bay. Figure 6 in combination with Figure 3 shows that the existing labado or water passage acts as the main outlet of the upstream catchment shown in Figure 6 and that significant amounts of sediments are transported over this labado from the upstream catchment towards Lac. Figure 7 shows the situation north of the labado towards the upstream catchment and Figure 8 shows the situation south of the labado towards Lac.

Since this existing labado acts as the main inlet of water and sediments from the upstream catchment towards Lac, it is recommended to restore its function as sediment trap and to remove the sediments currently filling up the inlet canal as shown in Figure 7 on the right hand (or north) side of the labado. Sediments at this location can be removed relatively easy by using a backhoe machine. Also costs involved in removing sediments are relatively limited. Removing of the sediments needs to be done annually before the rainy season starts. Maintenance of the labado will guarantee its function as effective separator of water and sediments.

Figure 7
Situation north of the labado towards the upstream catchment.

Figure 8
Situation south of the labado towards Lac.

Figure 9 gives a schematic picture of the construction of a labado similar to the one shown in the Figures 7 and 8.

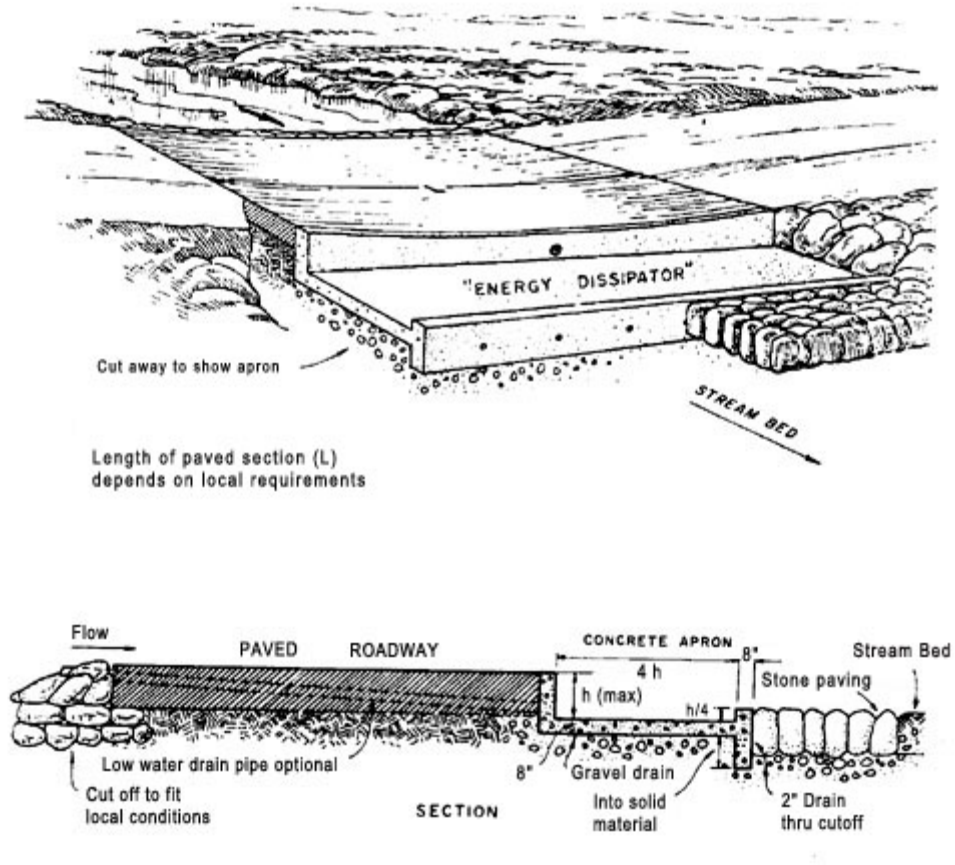

Figure 9
Schematic picture of the construction of a labado (source: Sheng, 1990).

3.3 Land side recommendation: long term

Over-grazing by roaming livestock accelerates erosion which leads to sediment transport to Lac and consequently causes deterioration of mangrove at the land side. Donkeys were introduced in the 17th century by the Spaniards and they were used for hard labor. Since the introduction of modern equipment donkeys are not used anymore and have the freedom to graze on the entire island. Currently especially free roaming goats and sheep cause removal of the natural vegetation as shown in Figure 10 where the enclosed area has a lush vegetation while the unfenced area is practically stripped of vegetation. Experiments have shown that approximately three years after free roaming of goats has stopped, the vegetation is back to the situation without grazing. The vegetation itself has an important positive effect on stabilizing soil and thus preventing soil erosion. At the same time roots increase the infiltration capacity of the soil having a positive effect on the water retention capacity of the upstream catchment area and thus helps to prevent large floods in the rainy season. When erosion is prevented the remaining soil thus prevents peak floods and consequently also decreases sediment transport from the upstream catchment towards Lac.

Figure 10
Effects of preventing free roaming of goats and sheep on the vegetation.

Officially free roaming of goats and sheep is not allowed, but in practice it is observed everywhere. Since the majority of goats and sheep grazing in the immediate surroundings of the Lac area have a single owner it is important to get this owner involved in the rehabilitation process and to discuss solutions with him. The goat owner complains that animal feed is expensive and that he therefore prefers free roaming. However, at the same time he also says that due to free roaming he loses considerable numbers of goat and sheep due to steeling and killing by dogs. The interview with the goat owner can be viewed at: http://www.whatifwechange.org/index.php#/stories/256/1. It is not considered helpful to blame livestock owners for causing problems. Instead it is recommended to start a serious dialogue with them and to involve them in creating solutions. It is realized that this is a long term process. The livestock owner with grazing areas close to Lac, however, would seem to constitute an excellent test case to negotiate a sustainable solution for keeping livestock in the area. Once an agreement has been reached this has the potential to offer a blueprint for other livestock owners in the larger upstream catchment area. In addition to stopping free roaming of goat and sheep it is also recommended to construct or maintain additional sediment traps (tankis) in other, major flow paths in the catchment.

3.4 Sea side recommendation: maintenance of existing feeder channels

Recently developed mangrove at the sea side blocks the sheet flow and also the feeder channel flow. Over the last decade several attempts have been made to keep existing feeder channels open. The rationale for this is that narrow feeder channels have insufficient capacity to increase water circulation in the Awa di Lodo. Since narrow channels are quickly overgrown with new mangrove it is recommended that wider feeder channels are maintained. Figure 11 shows the existing feeder channels at the west and east side of the bay. Figure 12 shows a well-functioning feeder channel.

Figure 11
Location of existing feeder channels (after Google Earth, 2003).

Figure 12
Well-functioning feeder channel.

Given the limited tidal movement (approximately 30 cm), wide channels are needed to allow sufficient water circulation during cycles of low and high tide. Preliminary calculations based on the Manning equation (Hamill, 2011), assuming half of the discharge, current depth, and a literature based resistance indicate that such channels should be at least 7 m wide. It is also recommended to do yearly maintenance of the existing water feeder channels at the east and west side of the Lac area by locally removing water flow barriers consisting of sediments and/or mangrove. Removal of these barriers helps to unplug the system and to restore water circulation in the Awa di Lodo. To increase water circulation it is not considered necessary that water is transported from the east feeder channel through the Awa di Lodo to the west feeder channel or vice versa. Each proper functioning feeder channel on its own is considered to contribute sufficiently to water circulation in the Awa di Lodo. Cleaning the feeder channels from sediments and/or mangrove can be done manually as was done in the past. In addition, it can be tested if a relatively light weighted backhoe is an appropriate machine for maintenance of the existing feeder channels. It is recommended to test mechanical maintenance work on the east side feeder channel because this channel can be cleaned while the machine operates from the relatively stable bank of the channel. To avoid corrosion, thorough rinsing of the machinery with sweet water is required.

3.5 Sea side recommendation: creation of a new feeder channel

In addition to yearly maintenance on the existing east and west side feeder channel the creation of a new water feeder channel in the central area following an existing creek pattern can be considered. Figure 13 shows an overlay of the aerial photograph presented by Wagenaar Hummelinck and Roos (1969) and a Google earth map (2003) with the existing channel in red and the trajectory for the possible new feeder channel in yellow. In identifying this trajectory an existing old creek pattern is followed because using existing landscape features offers the best guarantee for a well-functioning channel. Figure 14 shows the trajectory for the new central feeder channel on the Google earth map.

Figure 13

Overlay of old and new maps to identify the location for a new central feeding channel.

Figure 14

Location of the new central feeder channel (after Google Earth, 2003).

The possible new central feeder channel together with the existing east and west side feeder channels will allow optimal, tidal driven, water circulation in the Awa di Lodo area thereby removing stresses currently responsible for the dying of mangrove and fish. The possible new central feeder channel should be created by manually removing sediments and mangrove starting from the sea side. As with the maintenance work on the existing west side feeder channels, it is not recommended to use a relatively light weighted backhoe. This recommendation is based on contacts with water boards in the Netherlands who pointed out the difficulties in carrying out mechanical channel clearing operations when access is restricted to navigating through the same channel. It is recommended to start opening existing and creating new feeder channels from the sea side as this guarantees the best accessibility to the area. As with the existing channels, yearly maintenance of the new central channel is required in order to have it well functioning. Figure 15 shows the different feeder channels, the existing channels in red, the yellow line indicates the trajectory for the possible new central feeder channel and the yellow circles indicate places where sediments and/or mangrove have to be removed in order to have these channels well-functioning. It is recommended to first start maintenance on the existing east and west side feeder channel and to evaluate the effects of these management actions by monitoring the salt concentrations in the Awa di Lodo area. Based on the results it can be decided if a new central feeder channel is required to further improve the water quality at the Awa di Lodo.

Figure 15
Feeder channels in Lac bay (after Google Earth, 2003).

At the sea side the development of mangrove (*Rhizophora mangle*) has accelerated over the last decades. Many propagules established in shallow water will create new forest in the coming decades. This process can be slowed down by removing as many established propagules as possible. Especially where new forest would block sheet flow towards the land side of the mangrove, seedlings should be removed. Figure 16 indicates locations in red where removal of seedlings could have priority.

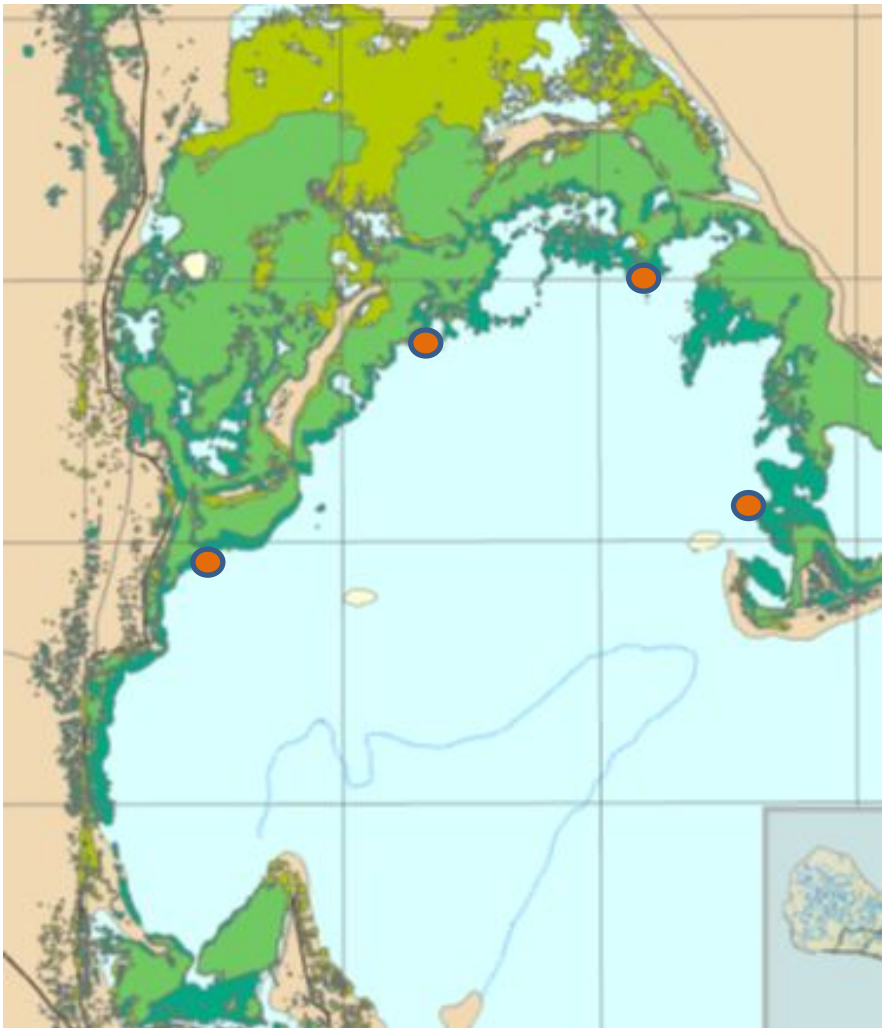

Figure 16
Locations for removal of Rhizophora propagules (Erdmann and Scheffers, 2006).

3.6 Description of the annexes

The following annexes are included:

- Annex 1 gives a description of the five main management actions that are recommended to be executed in the coming years and are expected to contribute to the ecological rehabilitation of Lac. Each operation can be presented to donors as a separate funding package by which they become contributors to the overall rehabilitation of Lac. Management actions can be phased in time over a total period of approximately four years and management actions are separately budgeted in order to increase the change of allocating an appropriate yearly budget.
- Annex 2 shows the itinerary of the visit of Henk Wösten to Lac in the period 21 - 28 April 2013.
- Annex 3 presents a new joint initiative on integrated coastal management and maritime spatial planning as launched by the European Commission on 12 March 2013. As such this initiative presents a framework for future developments in the Lac bay area.
- Annex 4 gives an overview of the most important landmarks in the Lac bay area.

4 Conclusions and recommendations

- Management actions have to focus on restoring water circulation in the deteriorated stagnant water locations in the north of the Lac area at Awa di Lodo. Improvement of water circulation will remove current stress factors such as high salinity, anaerobic conditions, and high water temperature which are held responsible for the current dying of mangrove and fish in this area.
- Management actions are in line with existing operations and do not call for drastic new changes but they are rather modifications of on-going processes. In this sense no new silver bullets exist that will solve all problems, but rather maintaining what has been developed over several years has the priority.
- Solutions are not prohibitively costly to implement and they can be presented to donors as separate funding packages making them contributors to the overall rehabilitation process. As such actions can be phased in time opting for sizable yearly available budget instead of requiring a single large budget which would be more difficult to acquire.
- Solutions can be implement by using locally available manpower, expertise and machinery. This makes it easier to implement solutions than when one had to rely on help from outside Bonaire.
- For the solutions to be effective in the long run yearly maintenance is an absolute requirement. It is important to realize that only yearly maintenance can ensure that actions take effect and that without proper maintenance effort and money will not be well spent in the long run.
- Whether or not a new central feeder channel is required in addition to the existing east and west side feeder channels, should depend on the results of the monitoring of changes in salt concentration in the Awa di Lodo after the existing feeder channels have been cleaned.
- Maintenance of the west side feeder channel and creation of the new central channel should be done manually. At the same time it is recommended to test whether a relatively light weighted backhoe machine can be used to facilitate cleaning of the east side feeder channel.
- Reserve sufficient yearly budgets for maintenance of feeder channels and sediment traps and for removal of newly emerging Rhizophora mangrove in the open bay area. These are the primary maintenance targets and they deserve proper attention.
- Ensure that feeder channels are sufficient wide (minimum of 7 meters) to avoid rapid infilling of the channels with mangrove. As a consequence, it is wise to invest in channels that meet this minimum width instead of investing in a long channels which are too narrow.
- Involve local stakeholders (goat owners, kayak centre, guesthouse owners and others) in the rehabilitation discussion by organizing meetings at which they express their interests and views. Solutions will be much more sustainable when they are understood and supported by all stakeholders in the area.
- Formulate a settlement with the goat owner close to Lac and use this as a test case for possible settlements with other goat and sheep owners in the total catchment area. In the long run, decreasing erosion and increasing water retention in the catchment area are important elements in the rehabilitation process. In this context it is required to arrive at a sustainable livestock and sustainable land use management in the greater catchment area.

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Annex 1 Description of the main management actions including an approximate cost estimate

Operation 1:	**Restore the sediment trap function of the labado.**
Objective:	To clear the upstream (north) section at the labado from sediments to have the labado continue to function as trap for sediments transported from the upstream catchment area towards the bay.
Period:	Annually before the rainy season starts.
Mode of operation:	Use of a backhoe machine which can operate easily under dry conditions and which has good accessibility to the site.
Estimated costs:	5 000 US$ annually for mechanical removal and transport of sediments. In case the sediment trap itself needs to be restored at the labado a one-time investment of 50 000 US$ is estimated.

Operation 2:	**Maintenance of east and west side feeder channels.**
Objective:	To clear the east and west side feeder channels from sediment and mangrove in order to improve water circulation in the Awa di Lodo area.
Period:	Annually, rather independent from the season.
Mode of operation:	Manually for the west side feeder channel and after testing, possibly mechanically using a light weighted backhoe machine for the east side feeder channel.
Estimated costs:	30 000 US$ for manual clearance of the west side feeder channel over a length of 450 m. 40 000 US$ for manual clearance of the east side feeder channel over a length of 650 m. If a light weighted backhoe machine can be used for mechanical clearance of the east side feeder channel costs could reduce to approximately 10 000 US$. In case the east and west side feeder channels need also to be widened over a length of 1100 m this will cost approximately 25 000 US$. Next maintenance of both feeder channels over a total length of 2000 m is estimated to cost 40 000 US$ per year.

Operation 3:	**Creation of a new central feeder channel.**
Objective:	To construct a new central feeder channel following an existing creek pattern to improve water circulation in the Awa di Lodo area.
Period:	Single operation, rather independent from the season.
Mode of operation:	Manually.
Estimated costs:	75 000 US$ for manual creation of this feeder channel over a length of 500 m. Next maintenance of this feeder channel over a length of 500 m is estimated to cost 10 000 US$ per year.

Operation 4:	**Restricting free roaming of goats and sheep.**
Objective:	To start a discussion with livestock owners in the greater catchment area on how over-grazing by roaming livestock can be stopped while at the same time these owners can make a living from their business.
Period:	Long term operation, independent from the season.
Mode of operation:	Multi-stakeholder meetings and experimenting with case studies and demonstration projects.
Estimated costs:	20 000 US$ for the containment of goats and sheep of the herd Chaparall grazing close to the Lac area.

Operation 5:	**Removal of Rhizophora propagules at the sea side.**
Objective:	To remove Rhizophora propagules at the sea side in order to slow down mangrove occupation of the bay area.
Period:	Annually, rather independent from the season.
Mode of operation:	Manually.
Estimated costs:	10 000 US$ annually.

Annex 2 Itinerary of the visit of Henk Wösten to Lac in the period 21 - 28 April 2013.

- Sunday 21 April. Flight Amsterdam - Curacao - Bonaire. Welcome by Drs. Sabine Engel.
- Monday 22 April. Meeting with Mr Ramón de León, manager Bonaire Marine Park and Sabine Engel at the STINAPA office. Field visit by car of the complete Lac area from the land side guided by Sabine Engel. Literature search.
- Tuesday 23 April. Field visit by boat of the Lac area from the sea side guided by Sabine Engel and Gevy Soliana. Accompanying junior rangers on their field work in Sabine's research on Karko at Lac.
- Wednesday 24 April. Office work at STINAPA to review existing information on Lac. Discussions with Sabine and preparation of a story line and first sketch of a powerpoint presentation on the recommendations.
- Thursday 25 April. Field visit to the area with Sabine Engel and Merel Notten (What If). Movie shooting and discussion with old fisherman on the change in navigability of the feeder channels.
- Friday 26 April. Presentation and discussion of preliminary findings to Ramón de León and Sabine Engel. Exchange of views on the setup of the story line in a format that can be used to interest donors.
- Saturday 27 April. Preparing first draft of the report and sightseeing.
- Sunday 28 April. Flight Bonaire - Curacao - Amsterdam.

Annex 3 Coastal Zone Policy: Proposal for a Directive establishing a framework for maritime spatial planning and integrated coastal management

The European Commission launched on 12 March 2013 a new joint initiative on integrated coastal management and maritime spatial planning.

The proposal, which takes the form of a draft Directive, aims to establish a framework for maritime spatial planning and integrated coastal management in EU Member States with a view to promote the sustainable growth of maritime and coastal activities and the sustainable use of coastal and marine resources.

The proposal will require Member States to map human activities at sea and identify their most effective future spatial development in maritime spatial plans and to coordinate relevant policies affecting coastal areas in integrated coastal management strategies. To ensure the sustainability and environmental health of the various uses in marine and coastal areas, maritime spatial planning and coastal management will have to employ an approach that respects the limits of ecosystems. This approach includes the assessment of plans and strategies in accordance with the provisions of Directive 2001/42/EC on strategic environmental assessment and will ensure that economic activities factor in the protection of natural resources at an early stage as well as risks related to climate change and natural hazards to which coastal areas are extremely vulnerable. This has economic benefits as natural resources are often an essential basis for activities such as fishing and aquaculture, which rely on clean seas.

Member States will also be required to cooperate to ensure coherent approaches across marine and coastal regions. The coherent application of maritime spatial planning and integrated coastal management will improve interaction between land- and sea based activities. The optimal distribution of maritime space among the various uses and coordinated management of coastal zones across sectors will enable concurrent activities to achieve their full potential. Using a single instrument to balance all instruments should also increase certainty for investors and reduce the administrative burden for national administrations, while preserving ecosystem services.

Maritime spatial planning and integrated coastal management will help the implementation of several other EU policies relevant for marine and coastal areas. Relevant environment policies include the Marine Strategy Framework Directive, the Water Framework Directive, the Natura and Habitats Directives and the Biodiversity Strategy. Other relevant EU policies are the Integrated Maritime Policy, the upcoming Strategy on Climate Change Adaptation, the Renewable Energy Directive, the Motorways of the Sea Initiative and the Common fishery Policy.
Environment Commissioner Potočnik welcomed the initiative: *This initiative will contribute to a healthy environment and better living conditions for the 200 million EU citizens who live in coastal regions. It should also help preserve unique and diverse coastlines and ecosystems that offer invaluable habitats for plants and animals.*

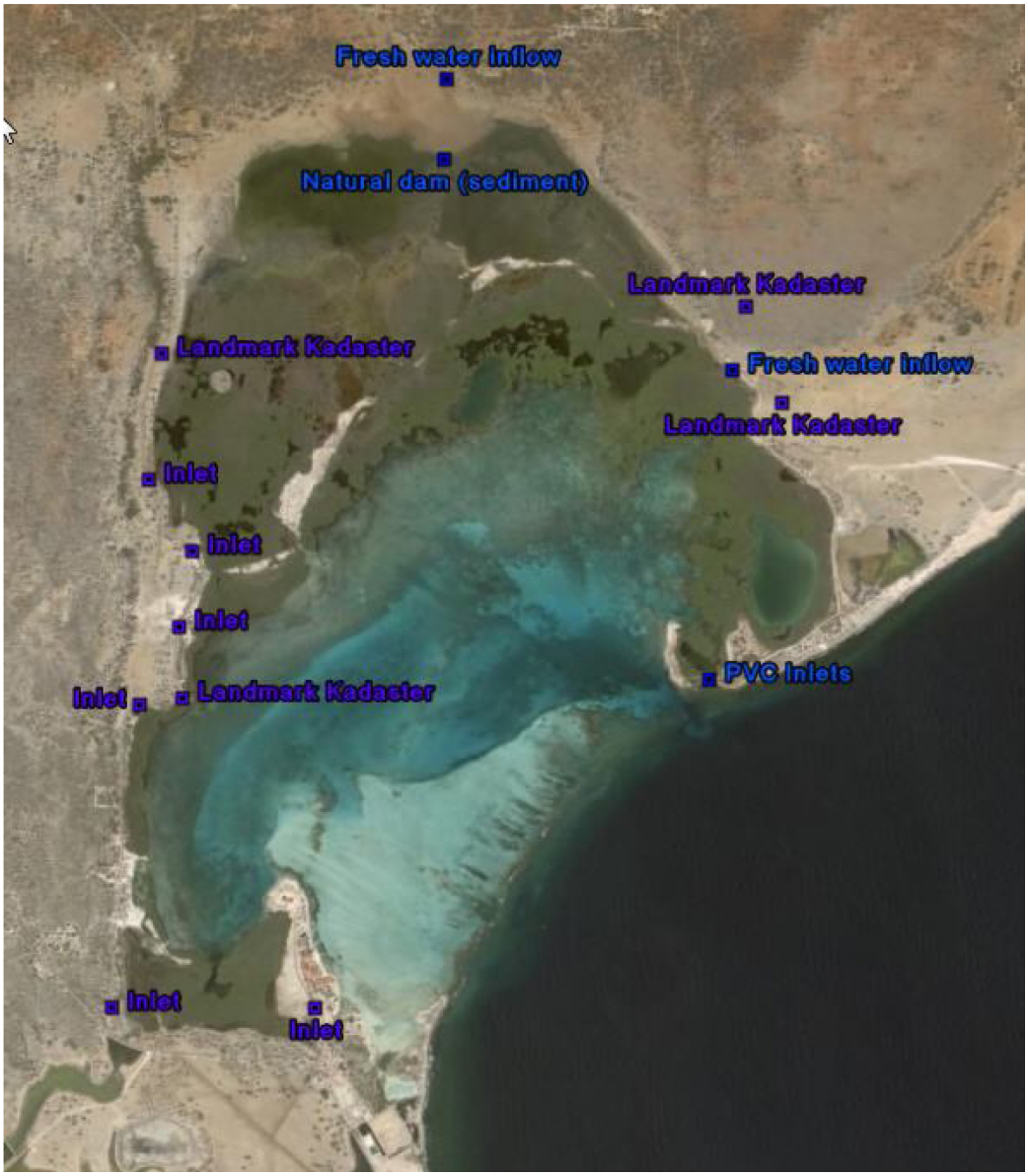
The full press release can be consulted here.

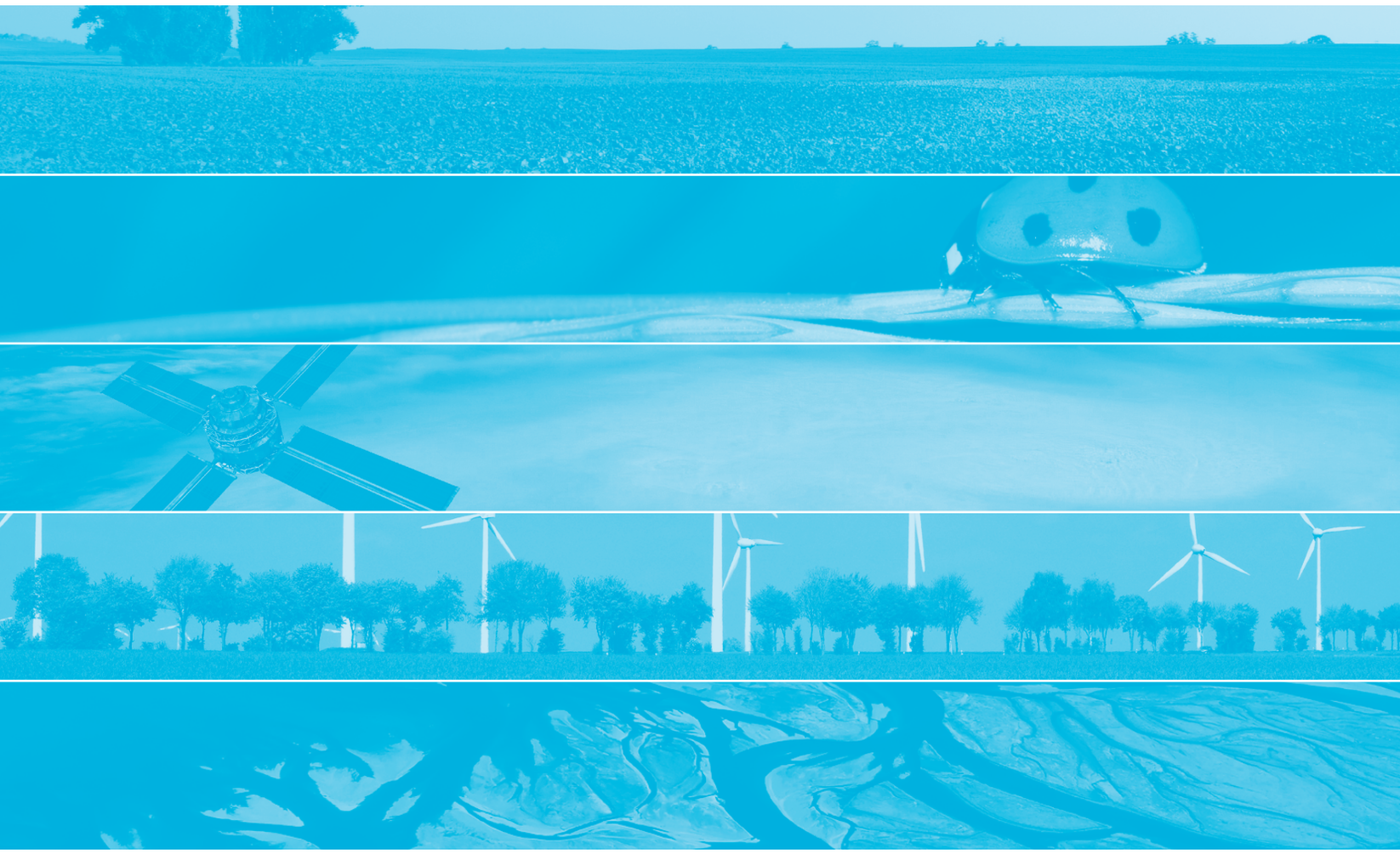
The Commission proposal will now be considered by the Council of the European Union and the European Parliament. Once adopted, the new initiative will become EU law.
The full text of the proposal, the accompanying documents which include the impact assessment and the further follow up of the different stages in the decision making process can be consulted on the pre-lex webpages.

What are the concrete obligations for Member States in the draft Directive?

- Member States will be required to establish and implement maritime spatial plans and integrated coastal management strategies.
- Maritime spatial plans should at least map the actual and potential spatial and temporal distribution of maritime activities in marine waters.
- Integrated coastal management strategies should at least contain an inventory of existing measure applied in coastal zones and an analysis of the need for additional action for the appropriate management of activities in coastal zones.
- The plans and strategies will need to be mutually coordinated, provided they are not integrated, and be reviewed at least every six years.
- All relevant stakeholders and authorities should be appropriately consulted on the draft plans and strategies and have access to the results once available.
- Plans and strategies should be based on best available data that should be collected, as far as possible, by making use of existing instruments established under other EU initiatives.
- Member States have to cooperate together and with third countries to ensure that plans and strategies are coherent across coastal zones and marine regions.
- Plans and strategies will need to be subject to applicable procedures in relation to strategic environmental assessments.
- Member States will need to designate the authority or authorities for the implementation of the Directive and will need to report to the Commission on the implementation of the Directive on a regular basis.

Annex 4 Landmarks in the Lac bay area (after Google Earth, 2003)





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