

Part 1. Bonaire National Marine Park: Background information

Location

Bonaire is situated in the southern Caribbean (12°10'N, 68°15'W) approximately 100 km north of Venezuela. It is one of the five islands that form the Netherlands Antilles: Bonaire, Curaçao, and the Windward Islands of St. Maarten, Saba, and St. Eustatius (Statia) (See Figure 1).



Figure 1: Bonaire in relation to the other Dutch Caribbean Islands

Bonaire is a crescent shaped island, oriented NW-SE, approximately 40 km (27 miles) long by 11 km (5 miles) at its widest point, with a land area of 28,100 ha. The small undeveloped satellite island of Klein Bonaire ("small" Bonaire) is located some 750 m off the western shore of Bonaire and has a land area of approximately 600ha (see Figure 2).

The islands terrestrial park, Washington Slagbaai National Park[†] protects approximately 17% of the total land area of Bonaire and was established in May 1969. It is managed, like the Marine Park, by the local conservation foundation, STINAPA Bonaire. Other significant features include the salt lakes or Saliñas along leeward shore

Klein Bonaire, along with Pekelmeer, Saliña Slagbaai, Gotomeer and Lac, are the only Ramsar sites in the Netherlands Antilles. As Ramsar sites they are internationally recognised as wetlands of significance by the RAMSAR Convention on Wetlands (1971) (see Figure 3 and Appendix 1 for further details).

The Bonaire National Marine Park surrounds the islands of Bonaire and Klein Bonaire extending from the high water mark to the 60m (200') depth contour and including both the sea bottom and associated waters and extending up to 200m from the coast. The geomorphology, bathymetry and location of Bonaire combine to produce a unique marine environment shared only by its sister islands of Curacao, Las Aves and Los Roques. The park encompasses 2,700 hectares of fringing coral

[†]Washington Slagbaai National Park is not currently a 'National Park' – this designation can only be given by Central government and WSNP does not currently meet the criteria

reef, seagrass and mangrove ecosystems. The park therefore contains representative habitats of whole ecosystems from the shore to intertidal environments and from coral reefs to deep water environments. The satellite island of Klein Bonaire is also under the management of the marine park along with Lac (both Ramsar sites), the largest semi-enclosed seagrass and mangrove bay in the Netherlands Antilles.

The centrally located main town is called Kralendijk (or '*Playa*' in the local language). It has become the focus of the islands tourism industry with the majority of hotels, dive and watersports centres and restaurants located in these areas. The first settlement and older town of Rincon lies to the North and it has become the focus of the island's historical and cultural activities and has seen a significant revival in the last ten years (see Figure 2).



Figure 2: Key towns and features of Bonaire

Image courtesy of Earth Sciences and Image Analysis Laboratory, NASA Johnson Space Center.
(<http://eol.jsc.nasa.gov>) photo number: STS075-706-41.JPG

History and culture

The Caiquetio Indians of the Venezuelan Central Orinoco Region (a branch of the Arawak Indians) first populated the islands off the Venezuelan coast; Los Roques, Las Aves, Bonaire and Curaçao some time around 500 AD. Eventually, the Caiquetio Indians established a society on Bonaire that could make ceramics and manage forms of agriculture. The population of Bonaire during the 'Ceramic Age' probably never exceeded 800 to 1,200 people, living in wooden huts built in the vicinity of their land. The main crops were manioc and maize. Agaves may also have been farmed to make nails, needles and string.

The Spanish were the first Europeans to arrive on Bonaire in 1499. Finding little of commercial value and seeing no future for large-scale agriculture, the Spanish decided not to colonise the island. Instead, they enslaved the Indians and moved them off to work in the plantations on the Island of Hispaniola, effectively leaving the island unpopulated. The island remained an isolated outpost until 1526.

In 1526, cattle were brought to the island by the governor - Juan de Ampues. Some of the Caiquetios returned to act as labourers and eventually the island became a centre for raising live stock such as sheep, goats, pigs, horses and donkeys. The animals were being raised for their skins so they required little tending and roamed freely. The results were large herds of grazing animals that far outnumbered the human population.

The only permanent settlement was the village of Rincon (see Image 1), located inland where it was thought to be safe from pirates.



Image 1: Rincon, the original settlement on Bonaire

(Source: <http://www.atlantisbonaire.com/images/bonaire/rincon.jpg>).

In 1633, the Dutch took possession of Curaçao, Bonaire and Aruba. The largest island, Curaçao, became a centre of the slave trade. Bonaire became a plantation island belonging to the Dutch West Indies Company. The first African slaves to arrive on Bonaire were forced to work, cutting wood for dyes, cultivating maize and harvesting salt. The ownership of Bonaire then changed hands a number of times until 1816, when the island was returned to the Dutch as a result of the Treaty of Paris. A small fort, Fort Oranje, was built to protect the island. By 1837, Bonaire was a thriving centre of

government controlled, slave laboured salt production. Slave huts and the salt pans, which were constructed by hand, still exist and are an important relic.

The abolition of slavery in 1863 signalled an end to the era of exploitation of those first Bonaireans. It was almost a hundred years later that the salt industry was revitalized. Today it is a division of Cargill Incorporated, one of the largest businesses in the world.

Tourists started to visit the island when the island government constructed the first pier in the harbour in 1940[†], just before the airport was built in 1943. After the Second World War, the deserted Nazi internment camps were converted into the Hotel Zeebad, and the wooden shacks were replaced by charming stone bungalows. This became what is now the Divi Flamingo Hotel. A second hotel, the Bonaire Beach Hotel, was opened up in 1962 on the Playa Lechi. Other hotels began to spring up and cater to the early visitors who enjoyed the tranquillity of Bonaire.

Dive tourism did not start up on Bonaire until 1963 with the arrival of 'Capt Don Stewart'. Having grown from small beginnings - in 1980 there were just 4 dive operations catering to some 5,000 divers annually - it has become the mainstay of the island economy. Gross revenues from dive tourism in 1994 (the date of the most recent economic study), with 25,000 visiting divers, were estimated at US\$ 34 million. Currently there are 21 registered dive operators on Bonaire (Anon, 2002b) catering to around 28,000 (BNMP 2006) visiting divers annually. Accompanying Bonaire's diving tourists are an unspecified number of snorkellers, windsurfers and other water-sports enthusiasts so that the island now also has two windsurf centres and one kite school, kayak rental, parasailing, boating, sailing and fishing activities on offer to visiting tourists.

The name Bonaire is thought to have originally come from the Caiquetio word 'Bonay', a name that meant low country. The early Spanish and Dutch modified its spelling to Bojnaj and also Bonaire. The Bonairean culture has its origins in the ethnic roots of the 10,000 plus residents. The culture is based on strong family ties and a general respect for nature. The local people have a valuable understanding of their environment which was at first inhospitable to the settlers and slaves. African traditions of song and dance developed within the slave communities. These songs and dances evolved into festivals and have survived to become an important part of life and culture on Bonaire. Many of the festivals are regional, even on a relatively small island different traditions exist (Anon, 2002a).

†

Town pier (North pier) built 1940 reinforced in 1961 and renovated 1986,
Customs Pier (Middle pier) built 1978,
Cargo pier (South pier) built 1973 renovated in 1986.

Population

Between 10,000 and 13,000 people are considered permanent residents of Bonaire (CBS, 2005). The population density of the permanent residents on Bonaire is 35 people per km², which is considerably lower than the other islands. Figure 3 illustrates how the resident and visitor populations have changed since 1992. The fact that visitors increase the population over the year by 5 or 6 times has a considerable impact on the islands infrastructure, although visitors generally do not stay on island for periods of time more than 2 weeks.

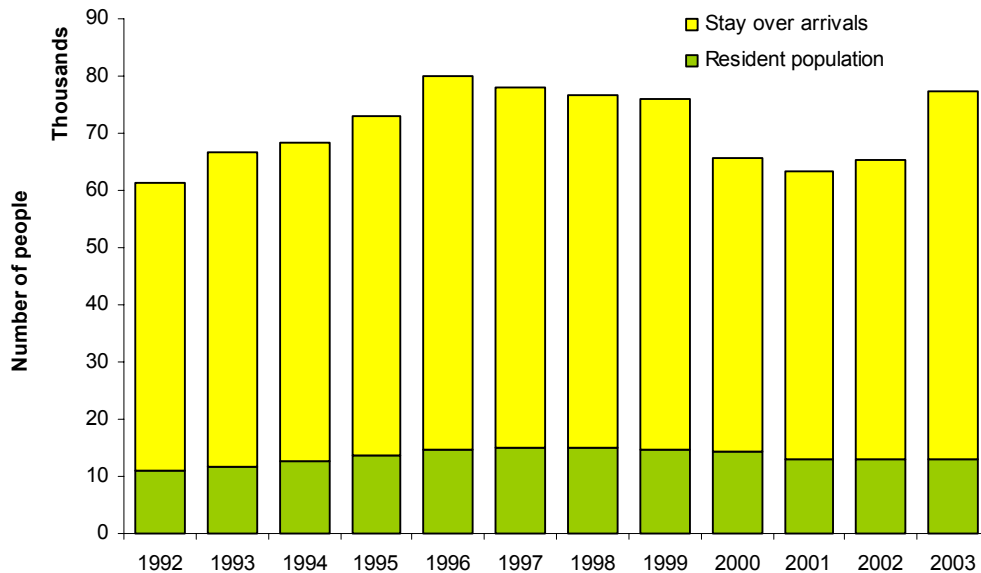


Figure 3: Population statistics for residents and visitors to Bonaire (CBS, 2005)

There has been a significant shift in the structure of the resident population from 1995 to 2004 as illustrated in Figure 4. The most striking difference is the out-migration of 20-35 year olds as well as the over all reduction in population by a factor of around 10%. It is believed this is due to the economically active population leaving Bonaire to find work.

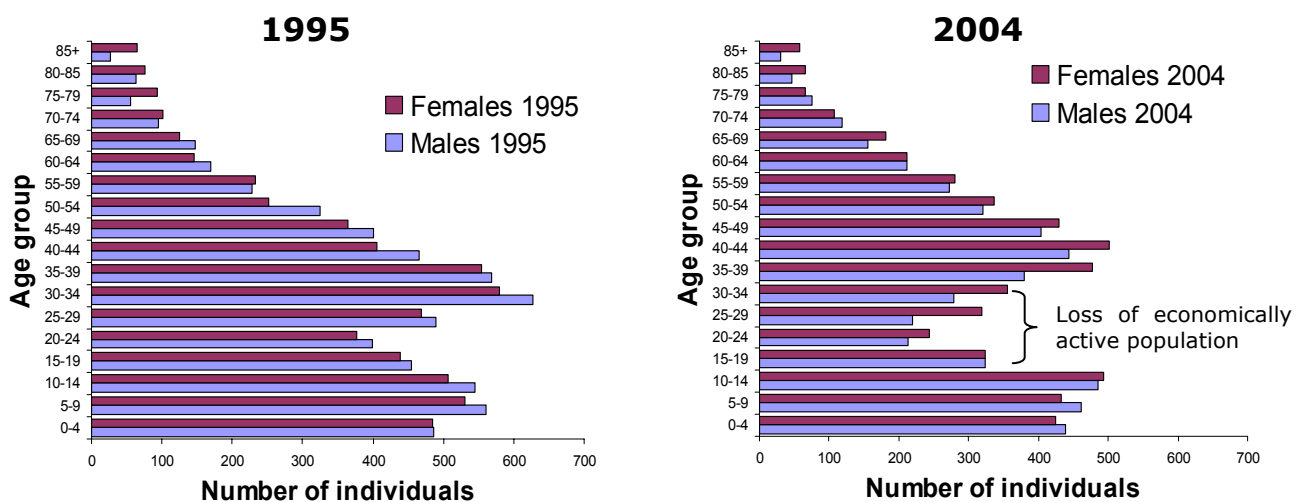


Figure 4: Population pyramids for the permanent population of Bonaire for 1995 and 2004 (numbers taken from (CBS, 2005))

The predominant religion on Bonaire is Christianity and a number of churches exist on the Island. More recently an Islamic mosque has also been built. The official language of Bonaire is Dutch, but most Bonairean's speak English and Spanish in addition to their local language, Papiamentu.

Politics and Economics

Politics

The Netherlands Antilles as a constitutional unit is described as "country" and is classed as an 'overseas country' by the European Union. Bonaire, along with Aruba, Curacao, Saba, St Eustatius and St. Maarten, forms part of the Kingdom of the Netherlands which has been administered for the past 50 years by a central government located on Curaçao.

Queen Beatrix of the Netherlands is represented in the Central Government of the Netherlands Antilles by a Governor, who is based in Curaçao. She is also represented on Bonaire by a Lieutenant Governor. There are three commissioners for the Executive Council (Bestuurscollege) who lead administrative units that perform the main government functions. There is a separate Island council (Eilandsrat), similar to a parliament. The Island has considerable political autonomy in relation to most issues, including natural resource management (Scura & van't Hof, 1993).

Economics

ECONOMIC DEVELOPMENT

Bonaire's Gross Domestic Product (at market prices) for 2003 was 293.8 million Nafls, an increase of 3.4% on the previous year. The relative contributions to the GDP from different sectors of the economy can be seen in Figure 5. The sector described by DEZA (Economic Department of Bonaire) that includes hotels, restaurants and cafés, saw an increase of production of 13% from 2002 to 2003. One of the other economic pillars is the construction sector which boomed from late 2003 onwards. Houses and hotels continue to be built as well as extensions and renovation projects (further economic analyses to 2003 can be found in Appendix 2).

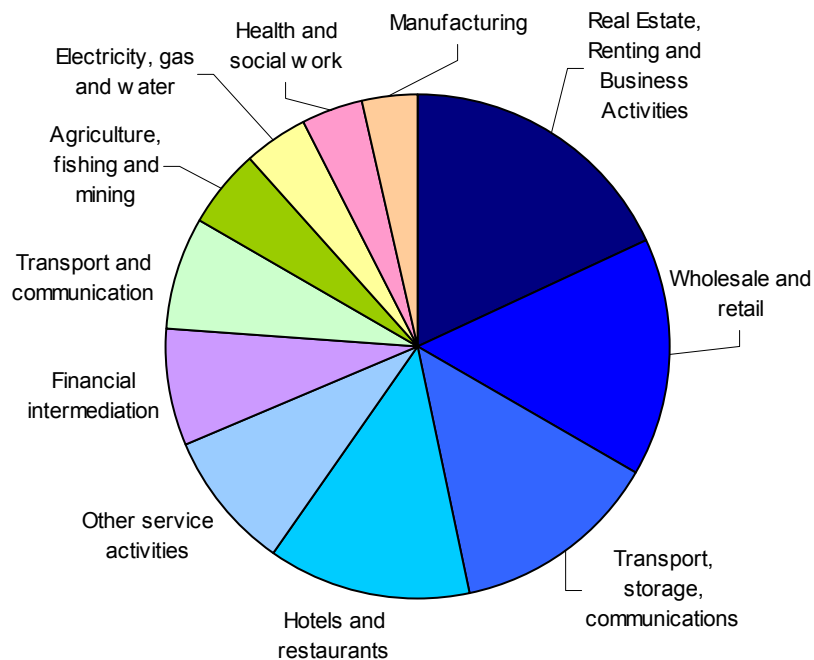


Figure 5: % contribution of different sectors of Bonaire's economy to the GDP in 2003 (CBS, 2005).

Since the early 1990's the Government's plans for economic development have been focussed on reducing the economies deficit, and encouraging economic growth. Schemes have been set up in the past to encourage the diversification of the tourism sector e.g. by attracting wealthy individuals to retire in Bonaire (through personal and development tax incentives) (Scura & van't Hof, 1993).

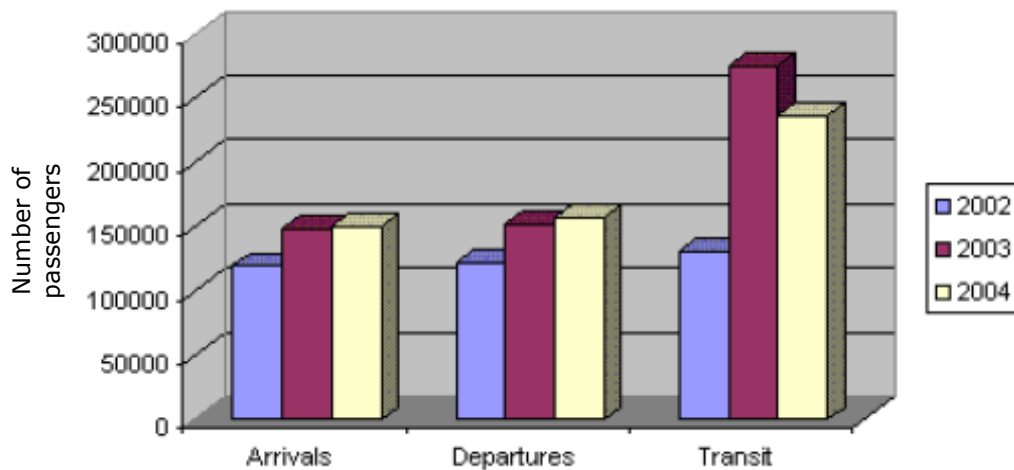


Figure 6: Changes in the nature of passenger transport on Bonaire, 2002-2004 (CBS, 2005)

More recently, focus has changed to bringing more travel related income to the island by changing the nature of flights to and from Bonaire. Bonaire's Flamingo Airport was recently extended to accommodate stop over flights with refuelling facilities for flights between Europe (Schipol), Ecuador and Peru in South America and there has been an associated increase in passenger transport, as shown in Figure 6.

AGRICULTURE AND FISHERIES

The climate and geography of the island do not offer a good environment for most types of commercial agriculture. Out of the islands total area of 28,100 ha only 2,800 ha (10%) is suitable for rain-fed agriculture and another 400 ha is suitable for irrigated agriculture. Similarly, only 195 ha are suitable for grazing (Scura & van't Hof, 1993). Rice production and export used to be an important part of agriculture on Bonaire. Aloe (Image 2) production and export continues to provide some income for farmers. There are a number of fisherfolk on the island who practice artisanal fishing and a small number who fish commercially (Image 3).



Image 2: Aloe plants growing in WSNP.



Image 3: Commercial fishing boats, Sorobon (Photographs by K. De Meyer).

A small number of staff are employed by the only aquaculture venture on Bonaire, 'Seahatch Bonaire', which was purchased from Fundacion Marcultura in 1999 to serve as a back up facility and or quarantine facility for shrimp brood stock. It houses two different species of shrimp that have been domesticated for over 15 years in a closed production cycle. Breeding shrimp are provided from Bonaire for different maturation facilities either in Aruba or in Venezuela. The breeding population is isolated in case of a viral outbreak in Venezuela. The facility also has the capacity to produce between 60 - 80 million post larvae shrimp in a 21 day cycle. Each production cycle is

usually followed by a 10 day dry out or disinfection period. No antibiotics are used at any of 'Seahatches' facilities and in Bonaire all of the effluent water passes to the salt flats belonging to the Cargill Salt Production Company. The effluent load reaching the salt flats is very small and it usually evaporates before it reaches Cargill's canal system, indeed, Cargill believes any slight increase in biological load would help with the process of salt crystallization.

MANUFACTURING

Manufacturing and the extraction of natural resources (other than salt) do not offer workable sources of income Bonaire's population. This is because the physical resources of the island that can be used, sold or extracted are very limited. The communications, infrastructure and working population of Bonaire do not suit the needs of a competitive manufacturing industry.

Cargill Salt Bonaire N.V. solar plant produces 400,000 tons of industrial grade salt per year. The main outlets for this salt are water treatment and the chemical industry for which the salt is being exported. A very small portion of the salt exported is processed to make table salt, another 1% is sold locally to the fishermen and the bakery and a tiny amount is used for cosmetics. Bonaire offers a unique salt quality with big crystals of salt produced nowhere else in the world as the island offers a unique combination of natural factors specific for the salt industry: flat land, deep water, wind and plentiful sunshine, ideal for the natural process of evaporation. Pekelmeer was physically modified in 1969 due to its inclusion in the solar salt works.

SHIPPING

In the mid-1970s the Bonaire Petroleum Corporation (BOPEC) set up an oil transfer depot with a deep-water port with facilities for transferring oil from ocean-going to coastal tankers (Image 4). The terminal continues to be used primarily as a storage and trans-shipment facility for Crude oil and derivatives.



Image 4: Tug boats used to guide BOPEC's shipping (Photograph by K. De Meyer).



Image 5: Cruise Boat visitors disembarking (Photograph by D.R. MacRae)

TOURISM

The wealth of natural resources on Bonaire, such as coral reefs and a number of other marine and terrestrial environments has lead the economy of Bonaire to be dependant on services relating to tourism. There are a variety of tourism associated activities which contribute to two thirds of the islands income, namely real estate, retail, transport, hotels and restaurants. Tourists are stop over tourists – arriving by aeroplane, yacht visitors or cruise ship passengers (Image 5).

Geology and geomorphology

Bonaire lies on a conservative plate boundary, where the South American and Caribbean Tectonic Plates meet and slide past one another. Along with its sister island of Curacao and the oceanic islands off Venezuela's north coast, it has been travelling eastward at a slow but steady rate having originated in the Pacific in the vicinity of the current day Galapagos Islands.

The geology of Bonaire is complex, with the core of the island consisting of strongly folded and faulted rocks of volcanic origin, silica rich sediments and turbidites (debris deposited from an underwater landslide) formed during the Cretaceous era some 120 million years before present (Beets, 1972a; Beets, 1972b)). Overlying this are later fossil reef and reef-generated calcareous (calcium rich) deposits. It is these limestone formations which make up the coastline in the form of coral-rubble beaches (coral shingle and calcareous sand) or iron shore, except in the north where low limestone cliffs are found (see Image 6) (Zonneveld, Buissonje & Herweijer, 1972) Klein Bonaire consists entirely of limestone formations (Buissonje, 1974) which are the remains of emergent reefs. Substantial changes in sea level have left up to four stranded terraces above the present mean sea level on Bonaire, and one below. These terraces can generally be distinguished by "solution notches" (undercutting caused by chemical erosion, physical erosion and in some cases biological erosion (see Image 7) in the elevated seaward facing limestone cliffs.



Image 6: The characteristic limestone cliffs (raised reefs) on the Leeward Shore of Bonaire (left)

Image 7: An active solution notch (Right) (Photographs by K. De Meyer)

Both Bonaire and Klein Bonaire are relatively flat. Little of the southern land area of Bonaire and Klein Bonaire is more than 2 m above sea level, with higher elevations found only in the north and reaching a maximum of 238 m (Brandaris, Washington Park). Roughly two thirds of the island of Bonaire and all of Klein Bonaire are made up of emergent reefs with associated former shorelines and wave eroded benches or solution notches which is a feature unique to these oceanic islands.

The water retention of the soil is poor so most rainfall quickly runs off into permanently or temporarily flooded "saliñas" (hypersaline lakes separated from the sea by a coral rubble barrier), or directly into the sea (Roos, 1971). Any water falling on exposed limestone swiftly percolates through the rock into the ground water and eventually discharges into the sea.

Climate

The climate of Bonaire is arid tropical characterised by low rainfall, high evaporation rates, year round high temperatures with little seasonal variation and almost constant easterly trade winds. Average monthly air temperatures range from 26.6°C (February) to 28.4°C (October), and average rainfall is just 490.5 mm/year (see Figure 7). Rainfall is unequally distributed geographically, with approximately four times as much rain falling in the northern portion of the island as in the south. The rainy season begins at the end of October and lasts until around the beginning of January; a second, shorter rainy season occurs in June/July. Commonly, no rainfall is recorded during the dry months.

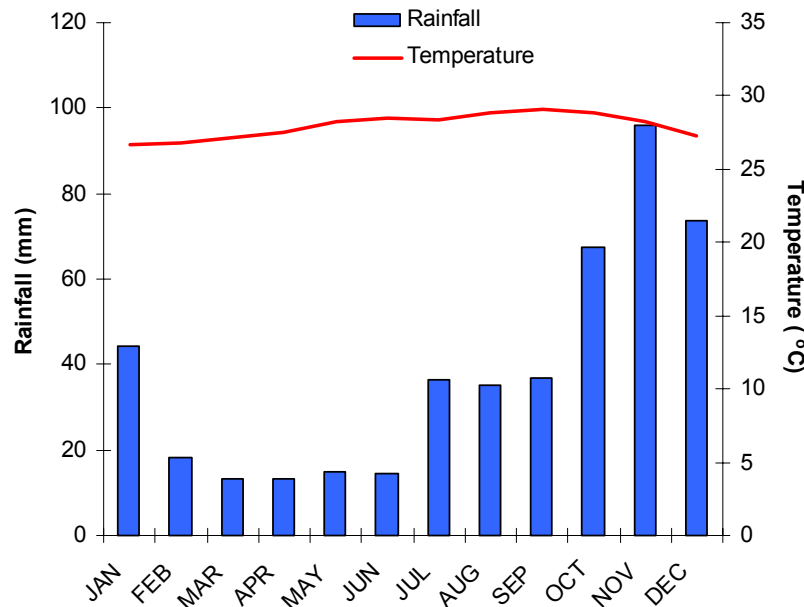


Figure 7: Average temperature/rainfall chart for Flamingo Airport 1971-2000.(Anon, 2000)

Because rainfall is seasonal and the bedrock is largely porous limestone the island has few reliable sources of fresh groundwater and no standing or running fresh water outside of the rainy season. Traditional water management practices such as inland dams have largely fallen into disrepair further reducing fresh water retention. Brackish wind driven wells which tap into subterranean water basins are scattered around the island but none provide fresh water and most are showing signs of nutrient enrichment and or salt water intrusion. Therefore drinking water is supplied through the desalination of seawater by a combined power and desalination plant operated by WEB.

Year round (over 97% of the time), Bonaire experiences constant easterly trade winds (from 70°-110°) with an average velocity of 6.7 metres per second. Wind speeds are generally highest in June and July and lowest in November at the start of the rainy season. The wind rose below (Figure 8) shows monthly average wind speeds and direction from 1977 – 2001. 55% of the wind comes from the East, half of which reaches speeds of 7-8. The rest of the winds come from the North East-East, 30% of which are between 6 and 7 metres per second. The wind is a significant natural resource on the island and many windsurfers and kite surfers travel to Bonaire for the reliable trade winds.

Technically Bonaire lies outside the hurricane belt, the last recorded hurricane strike occurred in 1877 but recent hurricanes that have had an impact on Bonaire include Hurricane Lenny (Nov. 99) which produced 10m waves on the leeward shore and Hurricane Ivan (Sep 2004) (de Leon, 2005) which passed 75 nautical miles north of Bonaire and battered Bonaire's windward shore causing considerable damage.

Tropical storms and hurricanes passing north of Bonaire can also cause the wind to swing around (locally known as a "wind reversal"), which creates high seas and intense wave action along Bonaire's exposed leeward shore for up to a week. Wind reversals have caused extensive, generally localized damage to the reefs and the coastal zone of the leeward shore. Damaging wind reversals have been recorded in 1976, 1981, 1985, 1990, and 1996 (De Meyer, 1998b).

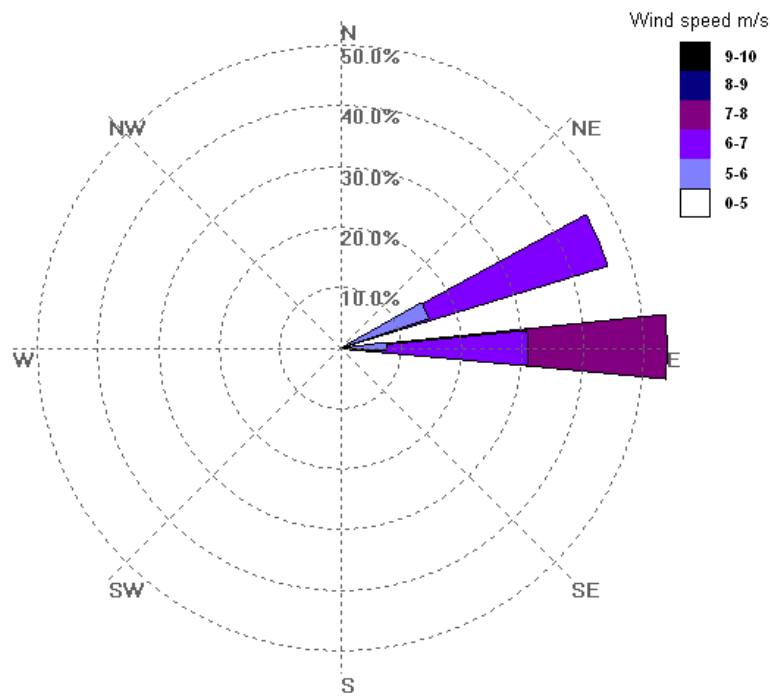


Figure 8: Wind rose showing the average wind speed and direction on Bonaire from 1977-2001.
(Anon, 2000)

Due to the strong prevailing trade winds the protected western (leeward, Image 8) and exposed eastern (windward, Image 9) shorelines are strikingly different. The windward shore is a very high wave energy environment characterized by rough water conditions and constant waves breaking against limestone cliffs or onto the iron-shore coast. Wind and water conditions on the leeward shore rarely exceed Beaufort Force 4, with only moderate swells affecting the northern and southern extremes of the island.



Image 8: Bonaire's South West Coast looking north towards the Salt Pier. (Left)



Image 9: The East Coast of Bonaire. (Right) (Photographs by D.R. MacRae)

Oceanography

Bonaire is located close to where Atlantic water flushes into the Caribbean Basin through the leeward island chain. Bonaire lies down stream of surface water flow from the direction of St Vincent and the Grenadines and wind driven currents from Las Roques and Las Aves (see Figure 9). When the surface currents strike Bonaire on the windward shore, near Spelonk, they are deflected to the north and south. There are pronounced eddies at the south of the island, around Willemstoren, at the north of the island around Malmok and Boca Bartol and just north of BOPEC. Currents are unpredictable but slight, rarely exceeding 0.5 m s^{-1} . The predominant current movement is toward the north along the leeward shore, but this pattern is complicated by local eddies and upwelling. Water conditions are stable, with a constant 34-36 ppt salinity and mean annual water temperatures ranging from 26°C to 28°C (De Meyer, 1998a). The speed and direction of deep water currents are thought to affect the nutrient content and temperature of surface waters.

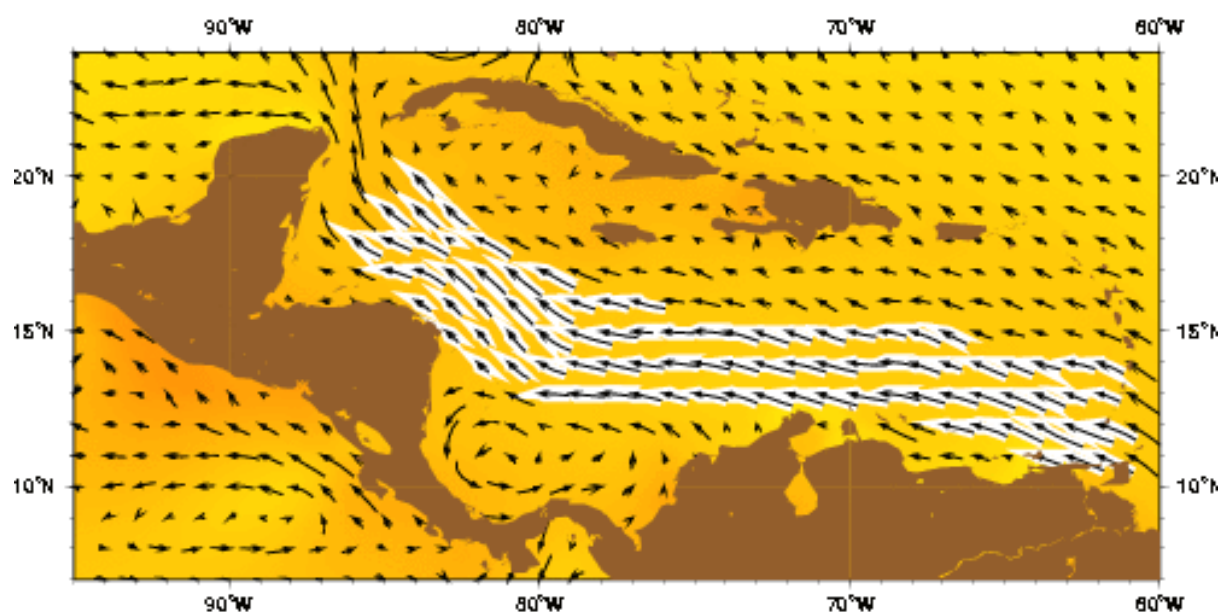


Figure 9 Sea surface currents influencing Bonaire; The Caribbean current that passes Bonaire is represented by the white arrows, flowing from the equatorial Atlantic into the Gulf of Mexico.

Source: <http://oceancurrents.rsmas.miami.edu/caribbean/caribbean.html>



Image 10: The high tide line marked by detritus (Photograph D.R. MacRae)

Tides are diurnal and the maximum annual tidal range is approximately 1 m, with an average range of 0.30 m during a lunar cycle (Bak, 1977). High tides deposit detritus on the windward shore (Image 10), which marks the spring tide line. Lac is anomalous as it has a pronounced semidiurnal tidal pattern with two high and two low waters daily. Spring tides cause extended periods (three to four weeks) of very low water to the mangrove areas at the back of causing extensive areas of

mangroves at Awa di Lodo and feeder channels around Boci Coco to dry up, bringing salinities in the remaining areas of standing water to over 100 ppt.

One of the most striking features of Bonaire is its bathymetry. By virtue of its location on the edge of a plate boundary, Bonaire is separated from the South American mainland by a deep water trench. There is a very rapid drop off from the shore line and fringing reefs (Image 11), water depths of 500m can already be found between the main island of Bonaire and satellite island of Klein Bonaire which lies only 750m off shore.



Image 11: Fringing reefs of Bonaire at '1000 Steps' (Photograph by K. De Meyer)

Both islands are the visible tip of a seamount that rises abruptly from a depth of 3000 metres (see Figure 10 and Appendix 3). This means that oceanic species such as migrating whales and dolphin as well as pelagic fish (Wahoo, Tuna, Dorado) are found very close inshore.

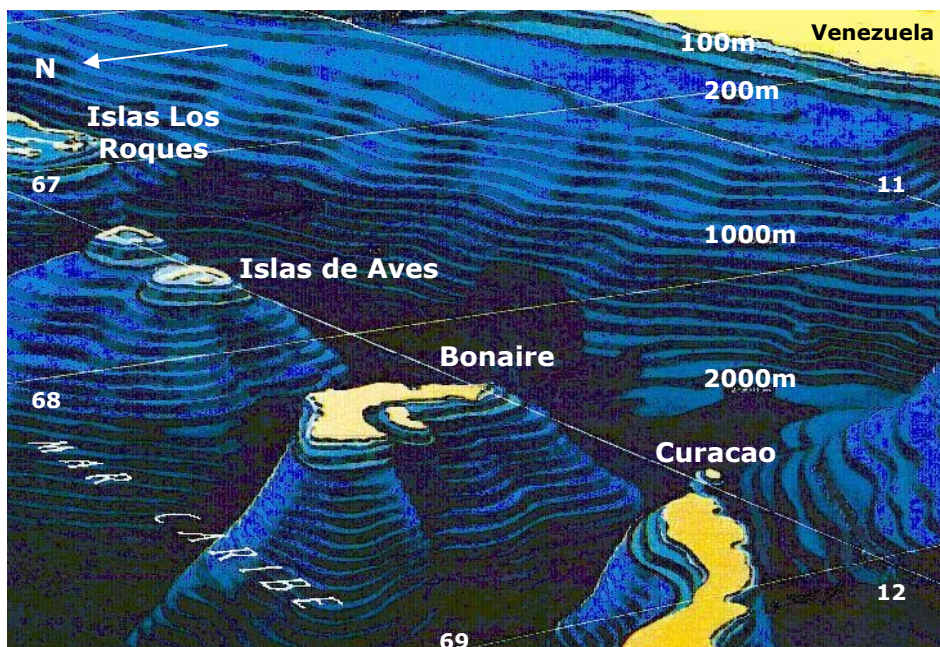


Figure 10: 3 Dimensional Representation of Bonaire's surrounding Bathymetry (depth).
(taken from the Venezuelan World Heritage Site presentation)

Terrestrial Habitats, flora and fauna

A wide range of habitats are represented on Bonaire and Klein Bonaire and within the surrounding waters. These range from the xerotrophic (drought resistant) forest covering the northern part of the Island, through sand dunes, salt pans, mangroves, seagrass beds to a number of different coral reef communities. The following descriptions focus on the marine and terrestrial habitats and species which are associated directly or indirectly with the Bonaire National Marine Park (species lists can be found in Appendix 4).

The northern part of the island is hilly consisting of fine grained volcanic rock and limestone. The southern part is flat and consists of fossil coral reef deposits enclosing some lagoonal areas which are either open (Lac) or enclosed (Pekelmeer).



Image 12: Drought resistant vegetation near Lac on the East Coast (Photograph by D.R. MacRae)



Image 13: Vegetation in WSNP in the North of Bonaire (Photograph by K. De Meyer)

The vegetation on Bonaire is xerotrophic (drought resistant - see Images 12 and 13), adapted to the semi arid climate. Native plants characteristically show leaf thickening, leaf angle changes through the day to avoid direct sunlight (negative phototropism), thorniness and/or presence of water storage tissues. The flora consists of some 340 species. Inland characteristic plants include Cacti (*Cactaceae*), Acacia (Obada/ *Acacia*), Mesquite (Kuida, *Prosopis*), Caper plants (Stoki/ Oliba, *Capparis*), Brasia (*Haematoxylon*), Lantana (*Lantana*) and Croton (Weli Sali/ *Codiaeum*). On the coastal flats Saltworts (*Batis*) and Sea-purslane (Banana di Rif/ *Sesuvium*) can be found and in lagoonal areas. Red Mangrove (Mangel Tan/ *Rhizophora*), White Mangrove (*Laguncularia racemosa*), Black Mangrove (Mangel blancu/ *Avicennia germinans*) and Buttonwood (*Conocarpus erectus*) are abundant around Lac and some of the salinas. Within Lac itself Turtle grass (Yerba di kania/ *Thalassia*) and Manatee Grass (*Syringodium filiforme*) are abundant (a detailed vegetation map can be seen in Appendix 4 along with terrestrial species paper and lists for Klein Bonaire).

The most abundant groups of terrestrial fauna are lizards, including the charismatic Green Iguana (*Iguana iguana*). 7 species live on the islands of which two are endemic – the Bonairian Anole (Kaku/ *Anolis Bonairensis*) and the Whiptail lizard (Lagadishi/ *Cnemidophorus murinus ruthveni*). Land snails (Kokol/ Kalakuna) are also abundant in places especially those belonging to the genera *Cerion* and *Tudora*. 8 bat species can be found on Bonaire, and the rest of the mammals (mostly goats and donkeys) and the only amphibian species (frogs) have been introduced by man. Some species of tree frog continue to find their way over to Bonaire on boats from Venezuela. The most abundant insects are *Drosophila* and *Tenebrinoid* beetles followed by a variety of ants and some other *Diptera sp.* Other terrestrial arthropods are scorpions and spiders none of which are considered dangerous to humans.



Image 14: The Lora; endangered by collection for the pet trade (source: K. De Meyer)



Image 15: The Green Iguana (source: K. De Meyer)

There are more than 170 species of birds recorded from Bonaire. Most common is the Bananaquit (Chibichibi/ *Coereba flaveola*) followed by the Southern Mockingbird (Chuchubi/ *Mimus gilvus*) and the Yellow Warbler (Para di misa/ *Dendroica petechia*). There is a local subspecies of Amazon Parrot (Lora/ *Amazona barbadensis rothschildi* – Image 14) and Bonaire is the only known breeding area for the southern population of the Caribbean Flamingo (Chogogo/ *Phoenicopterus ruber*) hence Bonaire is often referred to as the "flamingo island". The salt flats on Bonaire are used as breeding grounds by Cayenne Terns (*Sterna sandvicensis eurygnatha*).

Marine Habitats, Flora and Fauna

The marine habitats represented within the Marine Park can be categorized as follows:

- **Open water:** supporting planktonic and pelagic sea creatures including fish and migratory species such as dolphin and turtles
- **Sea bed** (benthos): supporting coral reefs, sea grass beds and including surface dwelling animals and plants and infauna (burrowing creatures like molluscs and crustacean), invertebrates, reef and bottom living fish (Images 16,17)
- **Intertidal:** formed at the interchange between land and sea including mangroves, rocky shores, sandy beach and dune areas (Image 18)

There is, of course, regular exchange between each of these habitats for feeding and reproduction and continuous movement of water and animals between the deep waters surrounding Bonaire, the coral reefs, seagrass and mangrove areas. Because most of Bonaire only has fringing reefs, the corals and other organisms on those reefs are exposed to any terrestrial influences directly. This includes freshwater runoff, sediments, nutrients and any form of pollution, which all stress and eventually kill marine organisms

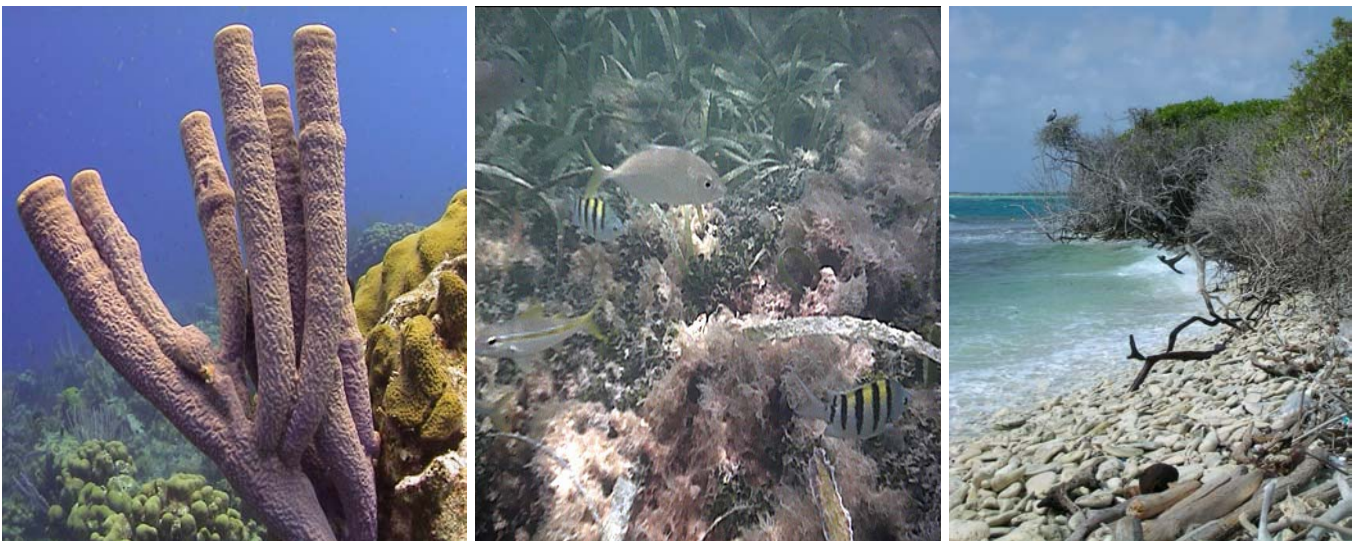


Image 16: Stove-Pipe sponge (*Aplysina archeri*) on one of Bonaire's reefs (By D. Yuchnovicz)

Image 17: Seagrass community in Lac (Renken, 2003)

Image 18: Intertidal coral beach near Cai (photograph by K. De Meyer)

There are few places on Bonaire where the typical sequence of tropical coastal environments can be found i.e a gradual change in habitat from mangrove forest, through seagrass beds to coral reefs and then open ocean. This 'typical' formation can be found at Lac and Lagoon and is represented in Figure 11. However, most of Bonaire's coastline is surrounded by fringing coral reef that slopes into deeper water. These different habitats have species zonation within them and they also play a wider role in the well-being of the coast. The forested areas of Lac have 4 distinct 'zones' where the plants are different. These change as conditions become more saline towards the sea:

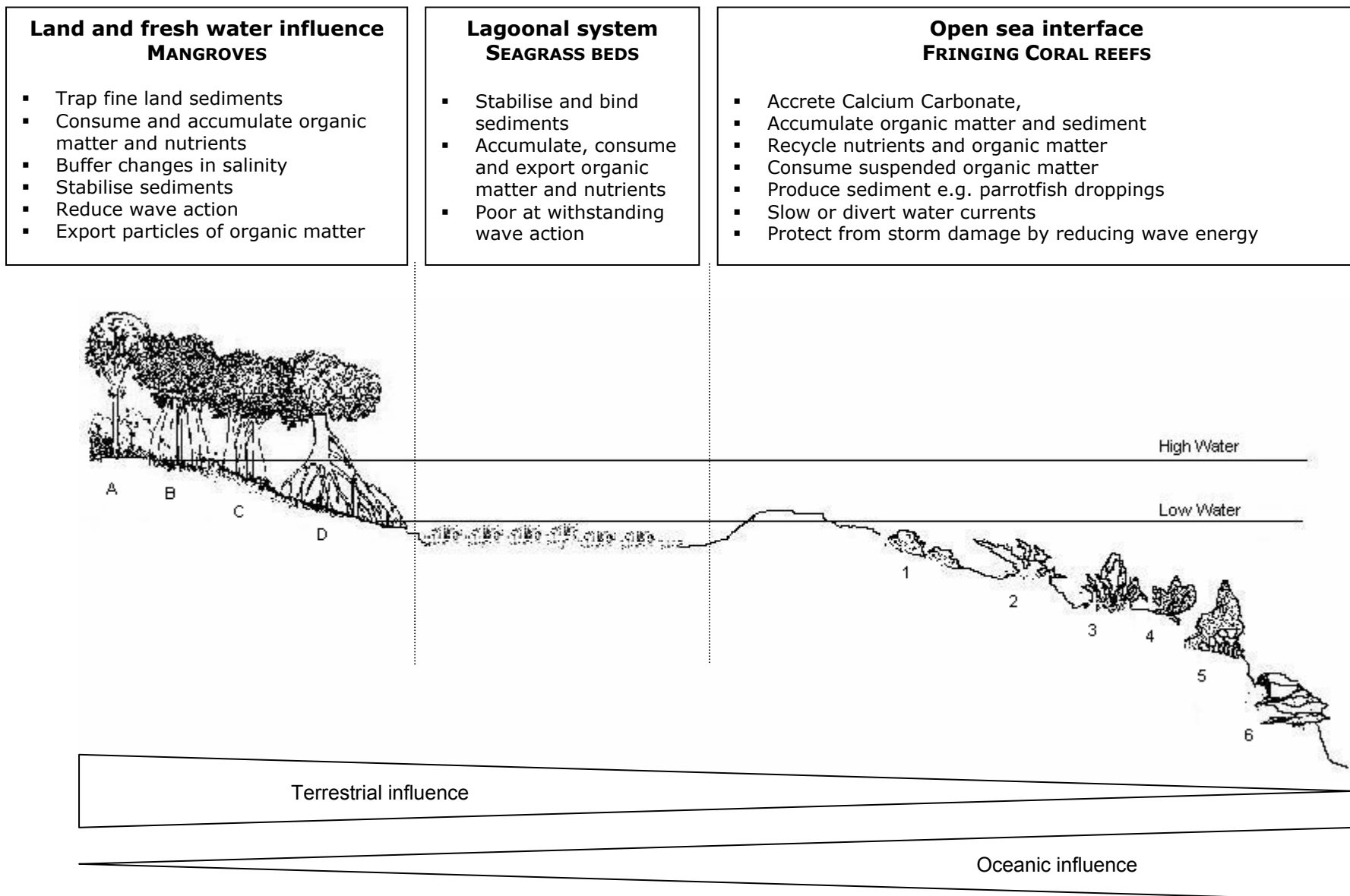


Figure 11: Schematic diagram of a typical tropical coastal seascape.

The majority of the coast of Bonaire does not have seagrass or mangrove – only fringing reefs. The large arrows at the bottom symbolise gradients created by the buffering of the influences of the land and the ocean on the seascape. The letters relate to mangrove zonation in the text, the numbers show model coral reef zonation (van't Hof, 1982)

Open Water

INTRODUCTION

The open water area within the marine park is confined to the waters from the shoreline out to the 60m (200') depth contour, which is no more than 200m from the shore line. The water is warm with constant salinity and is low in naturally occurring nutrients. The marine flora and fauna in the open waters around Bonaire are not very well known.

The water is full of phytoplankton (microscopic plants) which form the basis of the complex food web which supports not only the island's prolific coral reefs and associated animals but also zooplankton (microscopic animals) which are often the juvenile stages of species found in other habitats. There are no known studies of the plankton communities around Bonaire.

The open water supports pelagic fish populations, most of which are highly migratory such as Tuna (*Thunnus sp.*), Dolphin (Dorado / *Coryphæna hippurus*- Image 19) and Wahoo (*Acanthocybium solandri*) as well as Marlin (*Makaira SP.*) and swordfish (*Xiphias gladius*). In general these fish are found passing within the territorial waters of Bonaire but on occasion they can be found within the marine park itself.



Image 19: Dorado / *Coryphaena hippurus* (source: http://www.xcalak.info/images/florafauna/dorado_1.jpg)

Whale sharks, which are the largest fish in the world reaching lengths of over 12m, are occasional visitors. They are filter feeders and feast on plankton, small fish and squid. Their appearance on Bonaire is frequently associated with high densities of blue larval blue swimming crab which are blown into inshore waters. Whale sharks are listed by IUCN as vulnerable species. Sharks are infrequently seen at various points around the island indicating that they are present but cryptic. Most reports are of Reef Sharks (*Carcharhinus perezii*) and Blacktip Sharks (*Carcharhinus limbatus*) and come from South West Corner on Klein Bonaire and Lac. There are also periodic sightings of rays including manta rays, stingrays and spotted eagle rays. Most sightings come from the windward shore.

All four Caribbean species of turtle are frequently found in Bonaire's water: loggerheads, hawksbills, green turtles and leatherbacks, including rare sightings of Olive Ridley. A number of Cetaceans are regular visitors both to the reefs and the waters around Bonaire, including; Baleen Whale Species (*Balaenoptera sp.*), Pilot Whales (*Globicephala macrorhynchus*), Dwarf Sperm Whales (*Kogia simus*), Humpback Whales (*Megaptera novaeangliae*), Gervais's Beaked Whales (*Mesoplodon europaeus*), Killer Whales (*Orcinus orca*), Melon-Headed Whales (*Peponocephala electra*), Sperm Whales (*Physeter macrocephalus*), Pantropical Spotted Dolphins (*Stenella attenuate*), Striped Dolphin (*Stenella coeruleoalba*), Spinner Dolphins (*Stenella longirostris*), Bottlenose Dolphins (*Tursiops truncatus*), Cuvier's Beaked Whales (*Ziphius cavirostris*). Further details of the distribution of these species are given in Appendix 5 (Debrot, De Meyer & Dezentje, 1998).

There are a number of birds that live almost exclusively in the open ocean environment, using Bonaire as a breeding ground or migratory stop over. These include Gulls such as Laughing Gulls (*Larus atricilla*) and Ring Billed Gulls (*Larus delawarensis*), terns, cormorants and boobies.

There is currently no knowledge of the deep water dwelling organisms of Bonaire. Although a recent expedition to the deep water environments within one kilometre of the shoreline of Bonaire and Klein Bonaire, discovered many species of demersal fish and benthic (bottom dwelling) invertebrate, some of which may be new to science. A recent research voyage which used a deep water submersible to explore the waters between Bonaire and Klein Bonaire discovered, amongst other things, the presence of the rare Six Gilled Shark (*Hexanchus griseus*).

LOCATION

Although not strictly part of the marine park, the waters around Bonaire from the shore line to the 12 mile zone do constitute the territorial waters of the island of Bonaire. There is currently no organisation charged with the management of the territorial waters and new legislation is being drafted to regulate fishing activity within this zone. For this reason a description and some information on the deep water environments around Bonaire have been included.

Pelagic zone

With the exception of the seabed, everything in blue water beyond the 60m depth contour which marks the seaward extent of the Bonaire National Marine Park can be considered the pelagic zone. The pelagic environment is commonly thought of as being made up of number of different ecological zones; most importantly, the epipelagic, mesopelagic and the bathypelagic.

- Epipelagic: The epipelagic zone stretches from the surface down to 200 meters. This is where most plants and animals (flora and fauna) live due to the abundance of light and nutrients. Pelagic fish species found in this part of the sea around Bonaire include small bait fish such as Herring (*Clupea harengus*) – a major food source for marine mammals, and larger, predatory fish such as the tuna, Wahoo (*Acanthocybium solandri*), Dolphin (Dorado - *Coryphæna hippurus*) and Rainbow Runner (*Elagatis bipinnulata*) all of which are commercially important species.
- Mesopelagic: The water from 200-1,000 meters is classified as the mesopelagic zone, a twilight zone where some light filters through but does not reach a level of brightness necessary for photosynthesis to occur. The channel between Bonaire and Klein Bonaire reaches depths beyond 200m and so it supports a mesopelagic zone and the associated animals.
- Bathypelagic: The bathypelagic zone extends from 1,000-4,000 meters depth and is completely dark. The waters around Bonaire plunge to depths exceeding 2000m, especially in the deep oceanic trench that separates Bonaire from Venezuela. Deep water animals rely on nutrients that rain down from productive surface waters. These nutrients arrive at the sea floor in a variety of forms dominated by decaying phytoplankton and zooplankton.

Sea bottom

Soft-bottom habitats dominate much of the sea floor beyond the epipelagic (light) zone. The sediments are usually comprised of a mixture of biologically fixed silica and calcium carbonate, as well as clays, silts, and sand sediments. Large varieties of mobile and stationary animals live on and within these sediments. Around Bonaire, these are likely to include mobile echinoderms such as brittlestars and sea cucumbers, crustaceans such as crabs, amphipods, and shrimps, molluscs such as snails and octopods, and a variety of worms such as polychaetes and nematodes. There are also many sessile (fixed) polychaetes, clams, sponges, and other invertebrates. These mobile and sessile animals typically range in size from megafauna (>1 cm), to the smallest microbes. Microbes such as bacteria play an important role in breaking down organic material.

Sea mounts

Whilst, strictly speaking both Bonaire and Klein Bonaire are the tops of submerged sea mounts there is evidence that there are other true seamounts exist within Bonaire's territorial waters. Sea mounts act as magnets for fish life and fishermen are routinely drawn to them. Seamounts to the east of Bonaire, seaward of the salt pans, are said to be frequented by sharks.

CONDITION

There is little known about the deep water environments around Bonaire which are beyond the reach of SCUBA divers. However pelagic and deeper water habitats need to be considered in protected

area management as they influence the ecology of other marine environments and are sure to be home to many as yet undiscovered life forms. The little available evidence indicates that water quality is generally good within open water environments. There have not been reports of 'die offs' of marine animals or birds which could be attributed to poor water quality or pollution and Bonaire does not suffer from ciguatera.

Considerable quantities of water bourn trash are deposited on Bonaire's windward shore annually. Whilst some is undoubtedly dumped overboard by passing ships, much of this material appears to originate in Venezuela, where sea dumping still occurs. Occasional oil slicks also wash up on the windward shore, usually as a result of the dumping of dirty bilge water at sea by passing tankers. Little can be done to address these issues.

Overfishing of Bonaire's territorial waters does seem to be a potential problem. Local fishermen report that their catch diminishes significantly after long liners and trawlers have been seen around the island. These fishing activities within Bonaire's territorial waters are illegal and usually involved Venezuelan fishing vessels. In this context it is also important to note that in addition to pelagic fish, globally endangered sea turtles, sea birds and dolphin are threatened by these illegal fishing activities. Central Government has issued six permits to long lining vessels, which would be able to legally fish around Bonaire, but so far have not done so.

VALUE

Bonaire is a true oceanic island and its location adjacent to the South American mainland and at the inflow to the Caribbean Basin make the open water environment around Bonaire unique. Research voyages in the Florida Keys which have explored deep water environments have recorded considerable numbers of new invertebrate and fish species. There is every reason to believe that the same would be true of the deep water benthic environment around Bonaire and Klein Bonaire.

Healthy and abundant migratory pelagic fish stocks of Tuna, Dolphin and Wahoo are critical to support Bonaire's small scale local fishing industry. Globally endangered cetaceans and sea turtles regularly migrate through Bonaire's waters.

Sea Bed

The two most important ecosystems found on the seabed within the marine park are sea grass beds and coral reefs. Both are highly productive, fragile and valuable marine resources

SEAGRASS BEDS

Introduction

Seagrasses are flowering plants that live underwater. Like land plants, seagrasses produce oxygen. The depth at which seagrasses are found is limited by water clarity which determines the amount of light reaching the plant. Seagrass beds form in shallow coastal lagoon areas. Lac bay has extensive sea grass beds. The main species of seagrass found around Bonaire are Turtle grass (*Thalassia testudinum*) and Manatee grass (*Syringodium filiforme*).

Seagrass ecosystems are considered to be amongst the most productive in the world; an average growth rate of seagrass leaves is about 5mm per day, with entire stands of seagrass being turned over every 16 weeks with 3-4 crops annually (Edwards, 2000). In addition to this, the leaves of seagrasses provide a huge surface area for settlement of epiphytes (plants that live on the surface of another organism such as calcareous green algae, crustose coralline red algae, cyanobacteria, diatoms and epifauna (animals that live on the surface of another organism such as sponges, hydroids, bryozoans, foraminiferans). For a square metre of seabed, a dense seagrass stand may have 20m² of leaf area for other organisms to settle on. The productivity of the epiphytes can be twice that of the seagrasses themselves.

The seagrass stands in Lac are dominated by Turtle grass (*Thalassia testudinum*) together with Manatee grass (*Syringodium filiforme*) and banks of calcareous alga (*Halimeda* sp). Through a succession of growth (see Figure 12), seagrasses can turn vast areas of unconsolidated sediments into highly productive plant dominated, structured habitat with a diversity of microhabitats, such as that found within Lac on Bonaire.

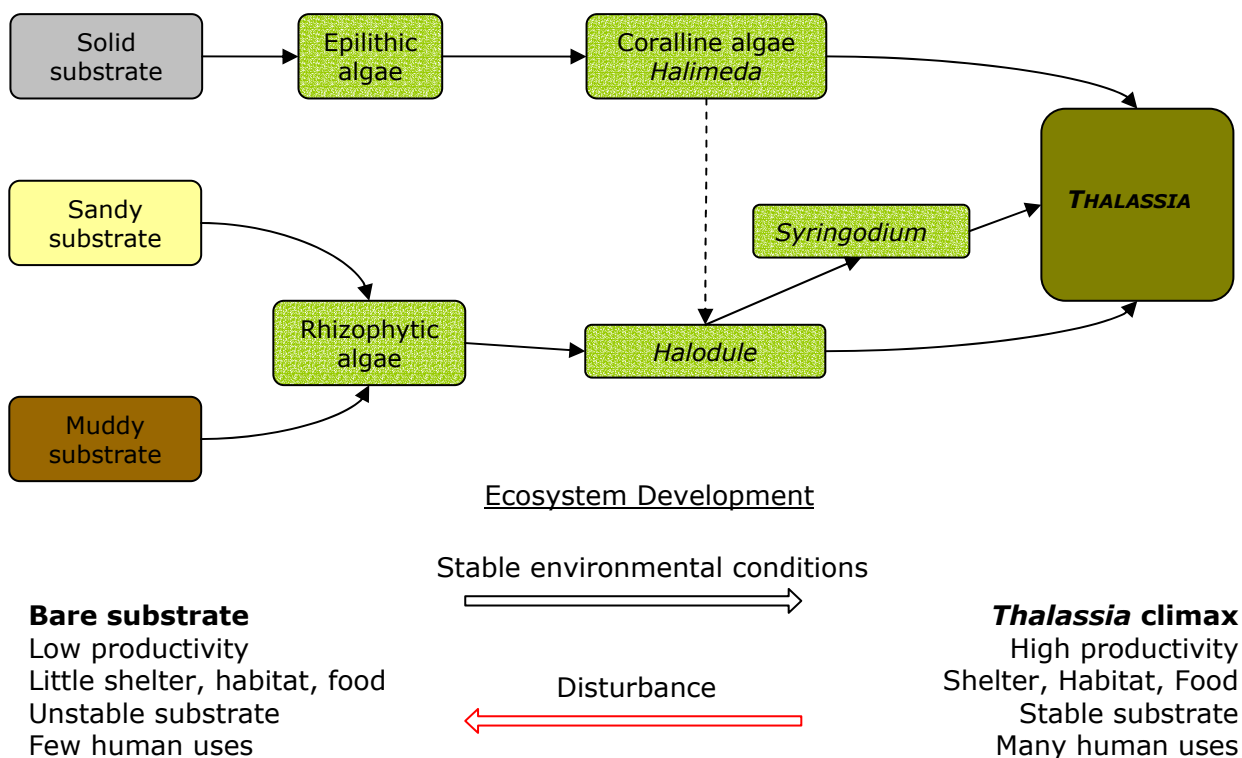


Figure 12: Seagrass succession diagram
(Edwards, 2000)

Location

There are two main areas of seagrass on Bonaire both on the windward shore. Sparse sea grass beds and fringing mangroves can be found at Lagoen, adjacent to the island's landfill and the most significant seagrass fields are found at Lac (Image . Lac is the largest inland bay in the Netherlands Antilles, with a flooded area of approximately 7.5 km², and is internationally protected as a RAMSAR site (see Appendix 1). The maximum water depth within the bay is 4.5 m; tidal range is limited to approximately 0.3 m (van Moorsel & Meijer, 1993) and shows distinct double high and double low tides. The bay is protected from the open ocean by exposed fringing coral reefs that protect the bay from wave action. Waves break over the reef, flood the bay, driving a clockwise circulation pattern with water flowing out though a deep water channel at the northernmost tip of the bay adjacent to Cai (see Figure 18), creating a rip current.

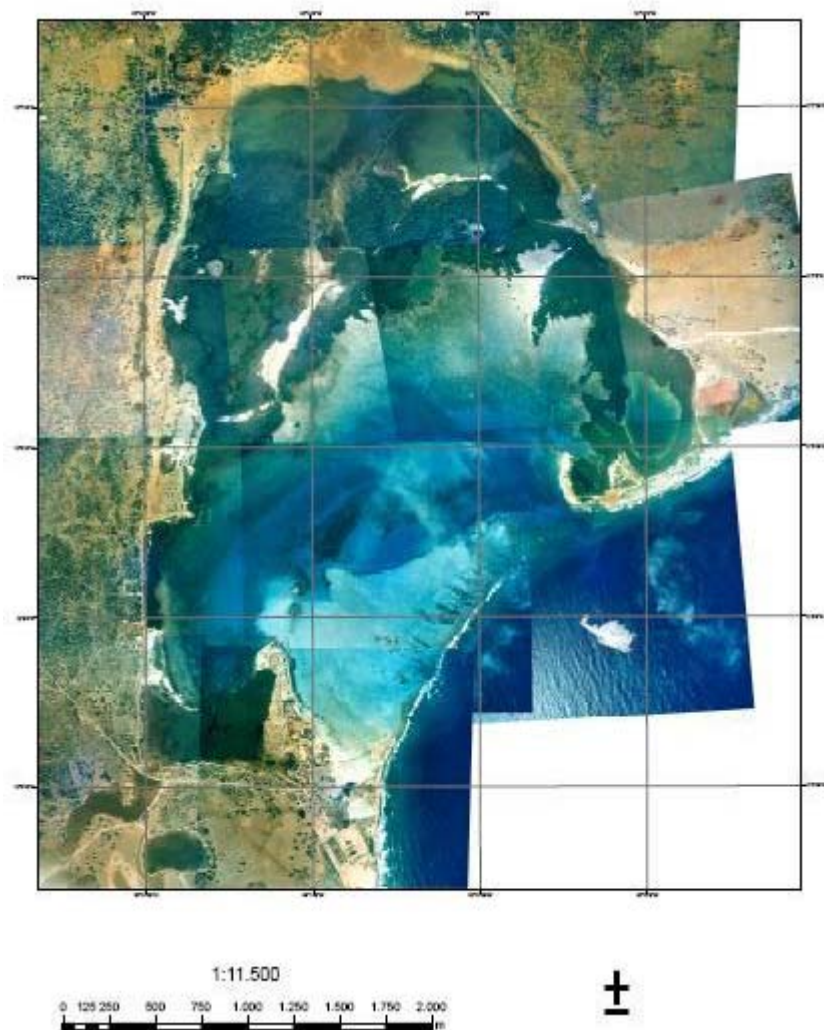


Image 20: Aerial Photograph of Lac 1996

Appendix 6 contains full resolution maps of Lac from 1961 and 1996

(Source: Erstellt 2006 - Wibke Erdmann - Universität Duisburg-Essen - Campus Essen - Institut für Geographie)

Condition

In the shallow waters around Lac, some of the seagrass has been damaged and is being continually eroded by trampling. When swimmers, snorkellers, windsurfers and other users stray into seagrass areas, any contact with the seagrass disturbs the habitat. In severe cases, the seagrass is removed or damaged beyond regrowth. This leads to blowouts in the seagrass beds, where mobile sediment makes it difficult for seagrass to re-colonise. Any further coastal developments around Lac will put pressure on the seagrass.

The Conch population in Lac Bay on the brink of collapse. Historically, the Conch of Lac have been fished extensively (Images 21 and 22), resulting in small individuals being removed before they

have had a chance to breed. This has meant those animals removed have not been replaced by juveniles



Image 21 and Image 22 : Conch shell piles at Cai (Photographs by D.R. MacRae)

Value

The seagrass beds of Lac provide a biological filter system for the waters within the bay. This gives the water its striking azure blue colour which is an essential feature to attract Tourists to the area, which in turn supports local businesses. The seagrasses also prevent terrestrial sediments from reaching the reef where they would smother and kill coral reef organisms.

The seagrass beds of Lac and the Saliñas are within the Ramsar sites, and are internationally significant examples of wetland ecosystems. The Seagrass beds also provide a nursery and habitat for numerous commercially and recreationally valued marine animals such as Conch and juvenile fish. Internationally endangered species such as turtles also depend on the well being of the seagrass for their survival.

CORAL REEFS

Introduction

Bonaire supports some of the most well developed coral reefs in the Caribbean, with high coral cover and diverse populations of fish (Roberts & Hawkins, 1994). Both Bonaire and Klein Bonaire are surrounded by continuous, fringing coral reefs exhibiting around 60 different species of corals. Reefs stretch from the shoreline seaward to depths in excess of 70 m, covering an area of some 2,700 ha (see Image 23). An AGRRA study carried out in 1999 Bonaire had an average of 47% hard coral cover, compared to 14% in the Bahamas and 20% in Belize (See Appendix 7).

Reef formation begins at the shoreline with a gradually shelving submarine terrace extending seaward for between 10 and 250 m. Beyond this, at depths of 10-12 m, the terrace drops off and the reef slope commences. The drop-off zone exhibits maximum diversity of benthos and maximum coral cover (Bak, 1977) The reef slope drops down steeply at a 20-50° angle to depths of 25-55 m where it flattens out onto a shelf. A second drop-off occurs beyond this (Duyf, 1985) to depths of >500m. There is some zonation within the coral community with shallow water dominated by a mix of stony and soft corals, mid-depth reefs (15-25 metres) being dominated by *Montastrea sp.* and deeper waters being dominated by *Agaricia sp.*

In addition to supporting a wealth of marine organisms, the coral reefs of Bonaire also support the Islands economy which is dependant on tourism. The reefs are the basis of the fishing activity that takes place on the island and the structure of the reef protects coastal developments from waves and storm surges.



Image 23: Aerial view of The Town Pier and Kralendijk, showing the form of the fringing reef.
(Anon, 2005)

Location

Both Bonaire and Klein Bonaire are surrounded by continuous, fringing coral reefs from the shoreline seaward to depths in excess of 70 m. Reef features of particular interest include:

- Vertical reef slopes can be found at a few known sites on the East coast and on Klein. Carls Hill Annex on Klein Bonaire has a vertical wall stretching from 10m to 20m depth, recent explorations using mixes of gas for diving have discovered more walls at greater depths. Cliff, Small Wall, Rappel and La Danias dive sites also have walls of interest to underwater explorers.
- A double reef stretches from Punt Vierkant in the South of the Island to Salt city dive site. At these sites, a 'second' reef can be found after a sand channel at the bottom of the initial reef slope. The Hilma Hooker wreck is located in the channel between the two reefs.

- A conspicuous geological feature of parts of the reef slope, especially around Karpata on the north western shore, are coral spurs and sediment channels which form as a result of the inherent instability of corals at the top of the reef slope causing the reef to collapse locally. Spur-and-groove coral formations occur in shallow water in high wave energy environments. Spur and groove can only be found at only two sites on Bonaire on the north-western shore (Boca Bartol and Playa Benge).
- Bonaire's reefs were mapped in 1983, and detailed maps were produced of the shallow coral communities to a depth of 10-12 m along the leeward shore and Klein Bonaire (Duyf, 1985). Along the windward shore, coral development is virtually absent in water shallower than 12 m, where there is an abundance of crustose coralline algae and dense stands of *Sargassum platycarpum* that may extend to 40 m water depth.

Condition

Van't Hof (1982) recognized six distinct coral zones from the shoreline to 50 m. These are: a shore zone (0-1 m), characterized by Knobby Brain Coral (*Diploria clivosa*); an Elkhorn zone (1-4 m), dominated by Elkhorn Coral (*Acropora palmate*), Fire Coral (*Millepora*) sp., and crustose coralline algae; a Staghorn zone (4-7 m), characterized by Staghorn Coral (*Acropora cervicornis*) interspersed with Yellow Pencil Coral (*Madracis mirabilis*), Boulder Brain Coral (*Colpophyllia natans*), and Boulder Star Coral (*Montastraea annularis*) and bounded by Gorgonians; a dropoff zone (7-12 m), characterized by Gorgonians, Boulder Star Coral (*Montastrea annularis*), Yellow Pencil Coral (*Madracis mirabilis*), and Smooth Flower Coral (*Eusmilia fastigiata*); an upper reef slope (12-25 m), characterized by massive Boulder Star Coral (*Montastrea annularis*) and Lettuce Coral (*Agaricia* sp.); and finally a lower reef slope (25 m+), dominated by Lettuce Coral (*Agaricia* sp.) and some flattened forms of Boulder Star Coral (*Montastraea annularis*), Great Star Coral (*Montastraea cavernosa*), and Blushing Star Coral (*Stephanocoenia michelinii*) but with few other abundant corals. These are summarise in Table 5 .These descriptions are historical and the current status of Bonaire's reefs is very different.

1	Shore zone	0-1m, characterised by Encrusting Knobby Brain coral adapted to the strong water movement of the surf
2	Elkhorn zone	1-4m, dominated by Elkhorn Coral, Fire Coral and Coralline Algae. In a number of places the Elkhorn coral occurs infrequently
3	Staghorn zone	4-7m, dominated by Staghorn Coral, with Fire Coral, Yellow Pencil Coral and gorgonians on the seaward edge
4	Drop-off zone	7-12m, gorgonians just above the drop off and mountainous star coral at the drop-off. Large patches of Pencil Coral in this zone.
5	Upper reef slope	12-25m, Mainly Large, towering Mountainous Star Coral colonies with Leaf Coral, Giant Brain Coral and Smooth Starlet Coral covering significant areas
6	Lower reef slope	>25m Sheet and scroll corals, some mountainous star coral in flattened growth form. 2 species of black coral are also found on the lower reef slope.

Table 1: Historical zonation of Bonaire's Reefs

The reefs as they were described in 1982 no longer exist. The impact of Hurricane Lenny in November 1999 along with nutrients, sediments and other pollution from the land as well as disease and bleaching, have reduced the reef flat and upper reef slopes in places to algae dominated coral rubble, with a few recovering small colonies of hardy coral (see Image 24 compared to Image 25). Extensive stands of Staghorn and Elkhorn Coral are rare. The reef slopes from 12m to 25m continue to show an abundance and diversity of stony coral and other sessile (fixed) organisms in most places. The deeper, lower reef slopes continue to be dominated by Encrusting Fan-Leaf Alga (*Lobophora variegata*), with some Lettuce, Plate and Star Corals in between.



Image 24: Algae dominated upper reef slope at Cliff dive site
(Photograph by D.R. MacRae)



Image 25: 'Healthy' Reef at 1000 steps dive site in 2006.
(Photograph by D. Yuchnovicz)

Bonaire's reefs support some of the most abundant and best studied parrotfish populations in the Caribbean. It is the abundance of parrotfish which is believed to have saved Bonaire's reefs from algal overgrowth after the diadema die off in the early 1980s. Bonaire has had the highest fish counts in the Caribbean (other than the Florida Keys). A total of 362 fish species have been reported

in Bonaire National Marine Park, where volunteers have reported 270 species on Bari Reef alone, the highest species richness of all sites in the 'REEF'[†] database, locally and Caribbean-wide (note that Bari Reef is the most surveyed site in the database). The composition of the fish assemblage on Bonaire reefs is similar to that found throughout the southern Caribbean. The five most frequent species sighted were Blue Tang (*Acanthurus coeruleus*), Bicolor Damsel (*Stegastes partitus*), Stoplight Parrotfish (*Sparisoma viride*), Brown Chromis (*Chromis multilineata*), and Bluehead Wrasse (*Thalassoma bifasciatum*) (Pattengill-Semmens, 1998).

Along with countless species of invertebrate, many different species of algae also inhabit the waters around Bonaire from the aptly named Sea pearl (*Ventricaria ventricosa*) and Mermaids Tea Cup (*Udotea Cyathiformis*) to the reef building crustose coralline algae's.

Bonaire's coral reefs face a number of pressures, some natural and some man-made, though global warming is clearly the most significant. In addition to storm damage, significant natural impacts on Bonaire's reefs during the 1970s and 1980s include an outbreak of white band disease (1980-1982), which caused the death of 90% of the standing stock of Staghorn Coral (*Acropora cervicornis*) and Elkhorn Coral (*Acropora palmata*). This was followed by the mass mortality of *Diadema antillarum* (Black spiny urchin) one of the most important grazers on Caribbean reefs. Both events were thought to have been caused by a water-borne pathogen and both impacted on the entire Caribbean Basin. Bonaire's reefs have also suffered from a number of ongoing disease outbreaks including yellow band disease (affecting primarily the Boulder star coral (*Montastrea* sp)), rapid wasting disease and black band disease.

There have been repeated Caribbean wide coral bleaching events since 1989 some of which have caused wide spread mortality of corals. Particularly severe episodes were recorded in 1990, 1992, 1993, 1995, with the most significant global mass bleaching event ever recorded in 1998. In 2005 a particularly intense coral bleaching event which effected most parts of the Caribbean, had little impact on Curacao and Bonaire where only minor bleaching was observed.

Roberts (1994) observed that Bonaire's reefs supported substantially greater numbers of fish species per survey count than other sites in the Caribbean such as Saba or Belize. In the same study, Bonaire's reefs were seen to support a very high biomass of groupers and snappers. However more recent personal observations by Roberts indicate a significant drop in predator numbers and biomass. Predator counts from 1975 (Bak, 1975) also indicate Bonaire grouper, snapper and grunt populations may be at the point of collapse.

Value

The coral reefs attract around 28,000 tourists a year, most of whom take part in diving and snorkelling activity. Bonaire's economy depends on this tourism which provides income for business as diverse as coral reef education visits, restaurants and realty. The reefs are also valuable as a habitat for many animals and plants which commercial, artisanal and sport fisheries depend on. The building blocks of the reef, hard corals, give protection to shore side developments by reducing wave energy. Hard corals and calcareous algae along with other organisms with shells produce coral sand which has been used for building and a range of other applications.

The coral reefs of Bonaire provide a habitat for countless creatures other than fish and coral. Countless species of crustaceans, worms, anemones, jellyfish, molluscs, echinoderms (cucumbers and star fish) bryozoans, sponges and tunicates live on the reefs.

[†] The REEF/TNC Fish Survey Project is a volunteer fish monitoring program developed by the Reef Environmental Education Foundation (REEF) with support from The Nature Conservancy (TNC), see <http://www.reef.org/data/surveyproject.htm> for further details.

Intertidal

DUNES AND BEACHES

Introduction

Sand dunes form when sand is carried by the wind from the beach towards the land. Dunes are highly dynamic terrestrial features, and especially when they are not anchored by vegetation, they may undergo rapid changes over short time periods. They can move inland as a result of onshore winds and are eroded by wave action and high water associated with severe storms. The vegetation cover represents the difference between a mobile pile of sand and a stabilized dune (Anon., 1998)

Generally, native dune grasses, trailing vines and small perennials are the most hardy species and are found on the seaward face of the dunes. Shrubs and trees are more abundant in the back-dune zone. Dunes can be found around Sorobon and the beaches on the windward shore, and around Klein Bonaire. Some of the plant species found on the sand dunes of Bonaire can be found in Appendix 4

Beaches are formed by waves, currents and tidal action, with waves generally being the predominant force. Within the surf zone, deep water waves begin to interact with the seabed. This results in changes in the direction and height of the incoming waves, which tend to align themselves in a direction parallel to the shoreline. Depending on the actual direction from which these waves approach, sand or other material may be transported along the shore or in an onshore/offshore direction, or a combination of both.



Image 26: Playa Chikitu looking North

Image 27: Playa Chikitu - view to the South (Photographs by K. De Meyer)

Location

Bonaire's beaches are active and mobile and their features depend on the maritime conditions at any point in time. In 1999 Hurricane Lenny for example shifted the major turtle nesting beach on Klein Bonaire, No Name, approximately 500m eastwards and reduced Pink Beach to coral rubble. The most extensive beaches are found on the windward coast of Bonaire in sheltered areas such as Boca Cocolishi and Playa Chikitu in the Washington Slaagbai National Park, and at Sorobon on the south side of Lac, on the leeward coast such as Pink Beach and Donkey Beach and No Name beach on Klein Bonaire. There are numerous small pockets of sand in coves and inlets along the leeward shore and the length of the north shore including in the Washington Park (Playa Lechi, Chachachi, Nucove, Slagbaai, Funchi etc)

Condition

With the exception of Boca Cocolishi and Playa Chikitu (Images 26 and 27) which are protected within the Washington Park, all of Bonaire's coastal dunes along the length of the windward shore have been extensively mined for sand with the attendant destruction of flora and threat to wildlife such as nesting turtles (see Image 28). Ironically sand mining may have improved the environment

for ground nesting birds such as the endangered Least Tern (*Sterna antillarum*), but has removed all dune vegetation which makes sand re-accumulation a painfully slow process.

The dunes and beaches at Sorobon are in mixed condition. The Government sanctioned sand mining to the south of the Sorobon Beach Resort has resulted in a 500m+ area of dune being entirely removed along with historical middens and Indian artefacts. This area is now more or less permanently under water. The result has been severe beach erosion in front of the adjacent resort exacerbated by partial removal of dune vegetation.

The rest of that shoreline still appears to be in moderately good condition with removal of beach vegetation and localised trampling in front of the windsurf centres causing localised pockets of beach erosion. Pink Beach has not existed as a sandy beach since November 1999 when it was washed away by Hurricane Lenny. The sand now lies in shallow water in front of the beach and can be expected to re-accumulate over time. The remaining beaches appear stable and in relatively good condition although high levels of visitation at No Name and Donkey Beach have resulted in beach pollution particularly from BBQs.

Value

The value of Bonaire's beaches and dunes lies not only in the money which can be made from selling the sand for construction and to create artificial beaches but also in tourism dollars. Tourists demand various physical attributes of the tropical destinations they visit and sandy beaches are definitely one of the features in high demand. Additionally beaches support fragile but important flora which binds the sand, prevents erosion and speeds further sand accumulation. Beaches are important nesting sites for 3 species of turtles; Green turtles (*Chelonia mydas*) Hawksbill turtles (*Eretmochelys imbricata*) and Loggerhead turtles (*Caretta carreta*) with occasional Leatherback nests on the windward shore. No Name beach on the north eastern shore of Klein Bonaire is Bonaire's most important turtle nesting site and is frequently checked for turtle nesting activity by staff and volunteers from the Sea Turtle Conservation Bonaire foundation.



Image 28: Threats to dunes and beaches

(Photograph by Ramon de Leon)

A staff member of Sea Turtle Conservation Bonaire stands by and watches as bulldozers remove sand for building as well as turtle nests and eggs from one of Bonaire's Beaches.

MANGROVES

INTRODUCTION

Mangrove forests world-wide are under severe pressure and disappearing in an alarming rate. It is estimated that about 60% of the total mangrove area in the world have disappeared. This is mainly contributed to large scale land clearance for coastal development. Mangroves are trees growing in inter tidal areas. Around Bonaire, four species of mangroves can be found; Red mangrove (*Rhizophora mangle* – Image 29), Black mangrove (*Avicennia germinans*), White Mangrove (*Laguncularia racemosa*) and Buttonwood (*Conocarpus erectus*). Lac has the most significant stand of mangroves with about 2.5km² of a total of 7.5km² supporting mangrove species.



Image 29: A stand of Red Mangrove (*Rhizophora Mangle*) near Cai, within Lac.
(Photograph by D.R. MacRae)

Mangrove forests grow in a pattern from the native terrestrial plants through to the highly adapted Red Mangroves with their specialised prop roots. Table 2 summarises the characteristics of the different vegetation zones.

A Terrestrial vegetation	Vegetation that grows on land and is intolerant of salty soil or water, such as cacti and other the other xerotrophic species described above.
B White mangrove zone	The white mangrove, <i>Laguncularia racemosa</i> , usually occupies the highest elevations farther upland than either the red or black mangroves. Unlike its red or black counterparts, the white mangrove has no visible aerial root systems. The easiest way to identify the white mangrove is by the leaves. They are elliptical, light yellow green and have two distinguishing glands at the base of the leaf blade where the stem starts (See Appendix 8).
C Black mangrove zone	The black mangrove, <i>Avicennia germinans</i> , usually occupies slightly higher elevations upland from the red mangrove. The black mangrove can be identified by numerous finger-like projections, called pneumatophores, which protrude from the soil around the tree's trunk.
D Red mangrove zone	The red mangrove, <i>Rhizophora mangle</i> , is probably the most well-known. It typically grows along the water's edge, especially in Lac and around the Saliñas. The red mangrove is easily identified by its tangled, reddish roots called 'prop roots'. The roots are usually exposed at low tide but covered at high tide, such exposed roots can be seen in the Awa di Lodo areas of Lac (see Figure 13)

Table 2: Typical Mangrove zonation in Bonaire

The mangrove forests on Bonaire, and especially those around Lac, provide a habitat for a number of different plants and animals dispersed from the muddy sediments through the trees into the canopy (see Figure 13). These include many invertebrates, reptiles, fish and birds

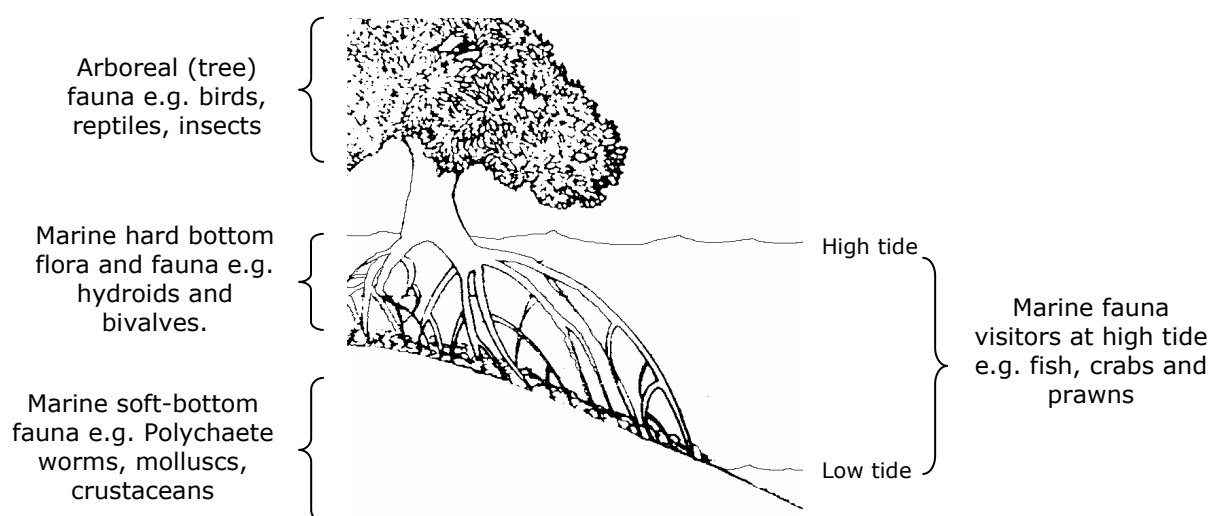


Figure 13: Representation of the vertical distribution of macrofauna in mangrove forests

Significant invertebrates in the bay include a juvenile population of Queen Conch (*Strombus gigas*), Milk Conch (*Strombus costatus*), Cushion Stars (*Oreaster reticulata*), Sea Cucumber (*Holothuria mexicana*), Sea Urchins (*Tripneustes venricosus*, *Lytechinus variegates*, *Meoma ventricosa*) and the Upside Down Jellyfish (*Cassiopeia frondosa*). The Atlantic Triton (*Charonia variegata*), formerly found in the bay, appears to be no longer present in Lac.

At least 100 different fish species use the mangroves of Bonaire as a habitat (see Appendix 4). The species most likely to be seen include; Striped Parrotfish (*Scarus croicensis*), Bluehead (*Thalassoma bifasciatum*), Gray Snapper (*Lutjanus griseus*), Schoolmaster (*Lutjanus apodus*) Silversides, Herrings and Anchovies (families *Atherinidae*, *Clupeidae*, *Engraulidae*) (Porter, 2006). Other interesting species that also use the mangroves and seagrass areas include Spotted Eagle Rays (*Aetobatus narinari*), various species of Moray Eels and young sharks.

On Bonaire, the water-dominated habitats: coastlines, inland saltwater lakes (saliñas), and mangrove marshes harbour many species of egrets, herons, and other species of marsh and shorebirds. Some of which nest in the mangroves and others that roost in the mangroves during migration.

Wherever water accumulates many species of waders and shorebirds, such as both color morphs, normal and white, of Reddish Egret (*Egretta rufescens*), Tricolored Herons (*Egretta tricolor*), Green Heron (*Butorides virescens*), Great Egrets (*Ardea alba*), Snowy Egrets, (*Egretta thula*) and Great Blue Heron (*Ardea herodias*) can be found. Also many of the smaller shorebirds, both Greater and Lesser Yellowleg species, dowitchers, sandpipers, plovers, including the rare Collared Plover (*Charadrius collaris*) from South America, are here in winter or on migration.

In the mangrove marshes along the eastern coast, one can find many of the previously mentioned water dwelling birds and roosting Magnificent Frigate birds (*Fregata magnificens*), Brown Pelicans (*Pelecanus occidentalis*). Also, this is the most likely site for both species of night herons, Black-crowned (*Nycticorax nycticorax*) and Yellow-crowned Night Heron (*Nyctanassa violacea*) and Little Blue Heron (*Egretta caerulea*) (Ligon, 2002).

LOCATION

There are two areas of seagrass and mangrove on Bonaire both on the windward shore. Sparse sea grass beds and fringing mangroves can be found at Lagun, adjacent to the island's landfill and the most significant seagrass and mangrove stands are found at Lac. A sheltered shallow inland bay, Lac, is located on the south-eastern shore of Bonaire. It is the largest inland bay in the Netherlands Antilles, with a flooded area of approximately 7.5 km², and is internationally protected as a RAMSAR

site (see Appendix 1). The maximum water depth within the bay is 4.5 m; tidal range is limited to approximately 0.3 m (van Moorsel & Meijer, 1993) and shows distinct double high and double low tides. The bay is protected from the open ocean by exposed fringing coral reefs that protect the bay from wave action. Waves break over the reef, flood the bay, driving a clockwise circulation pattern with water flowing out through a deep water channel at the northernmost tip of the bay adjacent to Cai (see Figure 18), creating a rip current

Within the mangroves there are a number of permanently dry, islands- Isla Fogon, Isla Pedro, Isla di Yuwana, Isla di Chico, Isla di Rancho, as well as several important areas of open water and feeder channels. Approximately 50% of the mangrove is made up of Red Mangrove (*Rhizophora mangle*) with its distinctive prop root system and the other 50% is made up of Black Mangrove (*Avicennia germinans*) with occasional White Mangrove (*Laguncularia racemosa*) and Buttonwood (*Conocarpus erectus*) on drier ground. Further, detailed descriptions of the mangrove species can be found in Appendix 8.

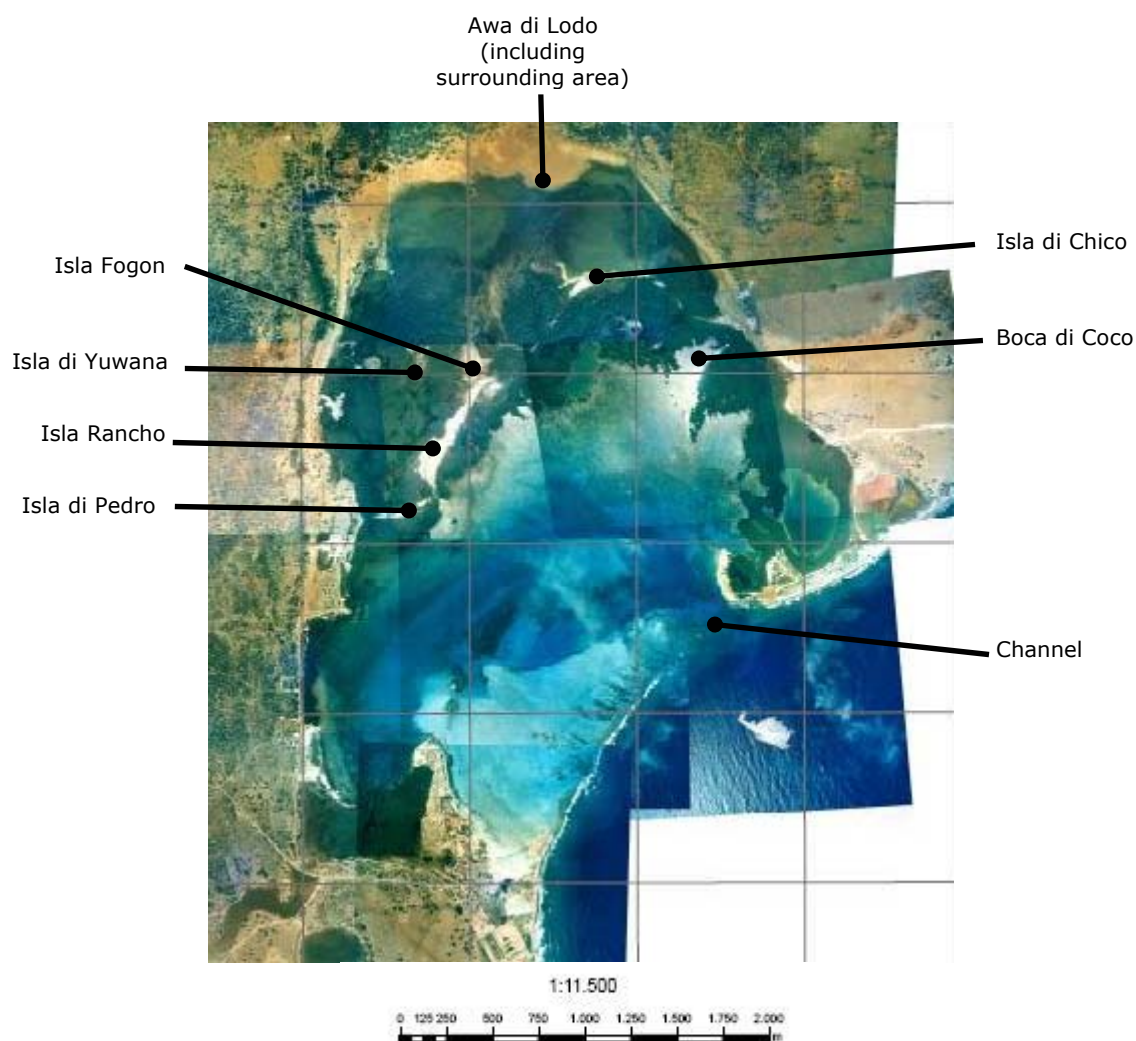


Figure 14: A colour composite aerial Photograph of Lac, including features mentioned in the text

CONDITION

Lac supports Bonaire's only significant mangrove and seagrass ecosystems. The open water area of the bay is blanketed by seagrass beds. Along the landward edge of the bay is an actively growing fringe of red mangroves which is steadily encroaching on the bay (see Figures 18/19). The mangrove system in Lac is unique within the Caribbean because being entirely seawater driven with no fluvial (river or estuary) input into the system and only limited seasonal inflow of fresh water from rainfall and runoff. There is also an extensive underwater sandy area in the bay (Awa di Mewchi) which is biologically important as it provides a critical habitat for the settlement of larval conch, as well as abundant annelids (worms) and other infauna (animals living in the sediment) which form the basis of the food chain within the bay.

Also atypical is the water circulation pattern within the mangroves. The mangrove area consists of two separate but adjacent basins, each with their own water circulation regime. Water circulation to

the back of the mangroves is driven not by water flowing in and out of the feeder channels, as might be expected, but by sheet flow. When the water height in the bay reaches a critical level, fresh seawater flows over and around the sand cays and through the mangroves to the very back of the mangroves. The feeder channels are therefore most important in draining water out of the mangroves.

An important feature of the feeder channels are the 'sills' or shallow bars which are ubiquitous. During low water episodes these sills prevent hypersaline water from draining back out into Lac. They are therefore a critical feature, the most important of the sills can be found at Boca di Coco at the start of the channel which feeds the Awa di Lodo (see Figure 18).

Because of its unusual hydrological regime, the mangroves do not show the classical pattern of succession typical of tropical mangrove systems. Instead the landward and seaward fringes are dominated by Red Mangrove (*Rhizophora mangle* – see Figure 19) and Black Mangrove (*Avicennia germinans*) thrives within the mangroves and around the drier ground associated with the cays. Red mangroves are actively encroaching on the bay, encircling areas of deeper water as they march into the bay. The Red Mangrove stands have an average height of 8 m and an average diameter at breast height (dbh) of 17 cm. Within the Black Mangrove zone, average tree height is 5 m and average dbh is 8.1 cm.

One of the dominant features of the mangrove system is a significant die-back of Red Mangrove at its north western extreme (Awa di Lodo), thought to be due to hypersaline conditions created by the landward damming of freshwater and choking of feeder channels on the seaward side resulting in water temperatures of 40°C and salinities of up to 100 ppt (van Moorsel & Meijer, 1993). This area is being recolonized by Black Mangrove, but the process is slow due to adverse environmental conditions typified by seasonal lack of water exchange lasting up to three weeks when salinity and temperatures soar.



Image 30 and Image 31: Mangrove die-off around Awa di Lodo (Renken, 2003)

VALUE

Lac is a Ramsar site and is therefore internationally recognised as a uniquely valuable wetland. Many of its mangroves are completely inaccessible and therefore pristine. Within the bay water quality is generally excellent, with the mangroves and seagrass acting as biological filters. The Bay is an important sanctuary, breeding and foraging ground for many wetland birds, marine invertebrates and fish. Lac is also home for two globally endangered species: Green Turtles (*Chelonia mydas*) and Queen Conch (*Strombus gigas*).

The Mangroves of Lac act as a filter for water being washed off the land by preventing harmful sediments smothering the coral reef. By establishing themselves successfully, the mangrove trees become a thriving habitat for many other plants and animals as well as an important nursery for many species of fish. Fish using the mangroves as a nursery include Schoolmasters (*Lutjanus*

apodus), Gray Snapper (*Lutjanus griseus*), Great Barracuda (*Sphyraena barracuda*) and the Four-eye butterfly (*Chaetodon capistratus*) (Lott, 2001).

The well being of Lac is essential for a range of human uses. The Bay attracts beach users, snorkellers and kayakers that financially support local tourist orientated businesses. The consistent onshore trade winds make the bay an internationally outstanding location for windsurfing, where beginners and intermediates can practice in safety (Image32). The small fishery based at Cai relies on the maintenance of stocks and the well being of the mangroves. Traditionally the mangroves and the islands within have been used for charcoal and lime production.



Image 32: The mangroves of Lac afford protection to many recreational users
(Photograph by D.R. MacRae)

ROCKY SHORES

INTRODUCTION

Rocky shores form the transition between terrestrial and marine environments, and are thus exposed to very different physical conditions. In the course of a day, rocky shores are covered with seawater at high tide and exposed directly to the air at low tide. On Bonaire, rocky shores are found in close vicinity to the fringing coral reefs. With high tides and storm surges, the rocky shores become covered, at low tides, rock pools form (Image 33). The rocky shores on Bonaire are mostly limestone – old coral reefs that have become exposed by changes in sea level.



Image 33: Interesting formations on the rocky shores of Bonaire (Photograph by K. de Meyer)



Image 34: Rock pools formed on the rocky shores (Photograph by D.R. MacRae)

LOCATION

The main rocky shore environments on Bonaire are found on in the south of the island on both the leeward and windward shores

CONDITION

Around Bonaire the rocky shores are intact. Some interesting formations exist (Image 34), the significance of which is unknown. On the windward shore in the south, the rocky shores have gathered piles of wood and rubbish which have been deposited by waves. The source of the rubbish is likely to be the coastline of Venezuela and neighbouring countries to the east, since the main currents effecting Bonaire run in an east to west direction.

The limestone around Bonaire is being continually eroded by chemical, biological and physical erosion. These processes take many years to operate, and result in the formation of craggy cliffs and plateaus as well as complex drainage channels.

VALUE

The rocky shores provide essential protection from the sea by acting as a barrier from the pounding waves. Little is known about the many different plants and animals inhabit the rock pools.

Special interest habitats and species

RAMSAR SITES

Bonaire has 5 internationally recognised RAMSAR Sites: Lac, Klein Bonaire, Slagbaai, Gotomeer and Pekelmeer. These sites are a hub of biological activity and they demand special attention and integrated management since they include terrestrial, intertidal and marine habitats. Further details of these sites can be found in Appendix 1.

Site	Description
Lac	Lac is located at about 7 km southeast of Kralendijk. The site is an important feeding area for waterbirds, including <i>Fregata sp.</i> , and members of the <i>Pelecanidae</i> , <i>Ardeidae</i> , <i>Laridae</i> and waders. Mangroves also support breeding waterbirds, including <i>Egretta tricolor</i> , <i>E. caerulea</i> , <i>E. thula</i> and <i>Butorides striatus</i> .
Klein Bonaire	Klein Bonaire is located about 2 km west of the mainland town of Kralendijk. The coral reefs support an extremely rich marine fauna and the beaches have nesting turtles. The vegetation on Klein Bonaire (all of which is within the marine park) is of particular interest because it is no longer grazed by animals. There are a few building foundations on the island which have some historical value
Slagbaai	Slagbaai is located about 20 km northwest of the town of Kralendijk. The lagoon is a resting area for <i>Phalacrocorax olivaceus</i> (max. 50), and a staging area for a variety of shorebird species that breed in the Nearctic. Brine shrimps (<i>Artemia salina</i>) and brine flies (<i>Ephydriidae</i>) are abundant in the hypersaline areas, and provide a valuable food source for birds, including <i>Ardeidae</i> , <i>Phoenicopterus ruber ruber</i> (300) and <i>Recurvirostridae</i> .
Goto lake	Goto is located about 17 km northwest of Kralendijk. The area supports many breeding and staging bird species. Breeding birds include <i>Anas bahamensis</i> , <i>Haematopus palliatus</i> , <i>Himantopus himantopus</i> , <i>Charadrius wilsonia</i> , <i>C. alexandrinus</i> , <i>Larus atricilla</i> and <i>Sterna albifrons</i> . The site is also important for staging shorebirds which nest in North America, including <i>Pluvialis squatarola</i> , <i>Charadrius semipalmatus</i> , <i>Numenius phaeopus</i> , <i>Arenaria interpres</i> , <i>Limnodromus griseus</i> , <i>Calidris canutus</i> , <i>C. alba</i> , <i>C. pusilla</i> , <i>C. mauri</i> , <i>C. minutilla</i> , <i>C. melanotos</i> and <i>Micropalama himantopus</i> . The brine shrimp <i>Artemia salina</i> and brine fly (<i>Ephydriidae</i>) are abundant in the hypersaline areas, and provide a valuable food source for birds, including <i>Phoenicopterus ruber ruber</i> (100-500).
Pekelmeer	Pekelmeer is located about 10 km south of Kralendijk. The site supports one of the most important nesting colonies of <i>Phoenicopterus ruber ruber</i> in the Caribbean (averaging 1,000 pairs). Other breeding birds include <i>Himantopus himantopus</i> , <i>Charadrius alexandrinus</i> and <i>Sterna sp.</i> The lagoon is also an important feeding area for <i>Pelecanidae</i> , <i>Ardeidae</i> and migratory shorebirds which breed in North America.

Table 3: Ramsar sites on Bonaire

HABITATS OF INTEREST

Other environments on Bonaire which have considerable environmental value and are associated with or occur within the Marine Park:

- Saliñas (hypersaline lakes). Saliñas are an important permanent wetland feature on Bonaire. They are found along the leeward shore and are very numerous: Saliña Bartol, Saliña Funchi, Saliña Wayaka, Saliña Slagbaai, Saliña Tam, Gotomeer and Saliña Vlijt on the outskirts of the main town of Kralendijk. Whilst they are hypersaline they are far from abiotic (devoid of life) having significant fish populations, and are a stop over habitat for many migratory birds, hence the Ramsar designation. The Saliñas are also critical drainage features that prevent sediment in run-off from the land adversely affecting coral reefs



Image 35: Salinas in WSNP with Mt. Brandaris in the background (Photographs by K. de Meyer)

Image 36: Salinas such as Slagbaai, are an important breeding grounds for Flamingos.

- Karstic (Limestone) Caves located in the marine and terrestrial fossilised coral reefs in the North and South of the island. These are unique ecosystems that contain species endemic fish and crustaceans (Debrot 2003).
- The 'coral' reef on the East coast of the island is in some places dominated by algal assemblages which may also have an important ecological role
- Bacterial mats in intertidal areas around the island, particularly within the mangroves of Lac. These bacterial mats that cover parts of the ground near the mangroves of Lac and low lying intertidal areas may have an important ecological role. Further investigations are required. Similar blue/green algae found on Curaçao has been found to contain important chemicals that can be used in various medications.



Image 37 and Image 38 : The value of Bacterial mats, such as these at Lac is unknown (Photographs by D.R. MacRae)

SPECIES OF INTEREST

Endangered species

Bonaire is a home, breeding site or migratory stop-over for 6 IUCN Red list species, 11 CITES Appendix I species (see Table 5) and 94 Appendix II species, including many fish, crustaceans and all of the corals that can be found in the surrounding waters. For further details on the IUCN and CITES classifications, please refer to Appendix 9. Further information on each species can be found at <http://www.redlist.org> or <http://www.cites.org/>

SPECIES	COMMON NAME	STATUS
<i>Chelonia mydas</i>	GREEN TURTLE	IUCN Red list, CITES Appendix I
<i>Dermochelys coriacea</i>	LEATHERBACK	IUCN Red list, CITES Appendix I
<i>Eretmochelys imbricata</i>	HAWKSBILL TURTLE	IUCN Red list, CITES Appendix I
<i>Caretta caretta</i>	LOGGERHEAD TURTLE	CITES Appendix I
<i>Lepidochelys olivacea</i>	OLIVE RIDLEY	CITES Appendix I
<i>Physeter catodon</i>	GREAT SPERM WHALE	CITES Appendix I
<i>Balaenoptera edeni</i>	BRYDE'S WHALE	CITES Appendix I
<i>Balaenoptera physalis</i>	FIN WHALE	CITES Appendix I
<i>Megaptera novaeangliae</i>	HUMPBACK WHALE	CITES Appendix I
<i>Amazona barbadensis</i>	YELLOW-SHOULDERED AMAZON	IUCN Red list, CITES Appendix I
<i>Falco peregrinus</i>	PEREGRINE FALCON	CITES Appendix I
<i>Leptonycteris curasoae</i>	SOUTHERN LONG-NOSED BAT	IUCN Red list
<i>Guaiacum officinale</i>	LIGNUM-VITAE	IUCN Red list

Table 4: Key Red list and CITES species on Bonaire

Human use of the marine environment

The most important human use of the marine park is for recreational activities on and around the reef. There is some recreational fishing and boating. Commercial fishing activity in the park is very limited as most of it is focused off shore. The marine park is also used by some commercial shipping traffic.

Tourism and recreation

Around 28,000 tourists a year make use of the marine environment on Bonaire. The majority of visitors and locals alike take part in diving and snorkelling activities (Image 39). Diving and related activities are the mainstay of Bonaire's economy. It is frequently rated as the number one dive destination for shore diving in the world by the diving press. Sales of dive tags to divers and other water users sustainably finances STINAPA Bonaire. Many visitors to the island, including cruise boat passengers take part in snorkelling along the coral reefs or around the mangroves.

Many other water activities take place on Bonaire including Power boating (including Banana Boat rides and parasailing), jet skiing, kayaking, glass bottom boating, waterskiing, kitesurfing, windsurfing and yachting. The latter wind sports benefit from the constant trade winds from the East. Lac is an internationally recognised windsurfing destination and kitesurfing is rapidly establishing itself as a popular sport on the west coast.



Image 39: Divers are a significant user group of the marine environment



Image 40: Artisanal fishing boats near Atlantis on the leeward coast (Photographs by D.R. MacRae)

Fishing

A small number of sport fishing operators run businesses on the island. Charter boats take visitors fishing for larger pelagic fish in deeper waters than the current marine park boundary. Some local fishermen at Lac use the bay as fishing grounds and others use Sorobon pier and the beaches on the West coast (Image 40) to moor their boats which they use to fish in pelagic environments. Commercial fishing mainly takes place beyond the boundaries of the marine park, though some of the fish caught in Lac are sold on.

Shipping

There are three active harbour areas: in the main town which is used by freight carrying ships, in front of CARGILL the salt company which is used to ship salt to destination and in front of BOPEC the oil transshipment facility. Around 6 cruise ships visit the Island every month, using the piers in the town centre. A total of around 80 cruise ships per year visit and the passengers disembark for tours of the island and the marine park.

References

- Anon. (2000). Climatological figures for Flamingo Airport Bonaire 1971-2000. <http://www.weather.an/>.
- Anon. (2002a). Culture of Bonaire, vol. 2005. <http://www.infobonaire.com/history.html>.
- Anon. (2002b). Dive operators on Bonaire, vol. 2005. <http://www.infobonaire.com/diveoperators.html>.
- Anon. (2005). Aerial view of the Town Pier and Kralendijk, vol. 2005. http://www.shorediving.com/Earth/ABC/BonaireN/Town_Pier/.
- Anon. (1998). Manual for Sand Dune Management in the Wider Caribbean, pp. 66. Caribbean Environment Programme, United Nations Environment Programme.
- Bak, R. P. M. (1977). Coral Reefs and their zonation in the Netherlands Antilles. *Studies in Geology* **4**, 3-16.
- Bak, R. P. M., 45:181-190. (1975). Ecological aspects of the distribution of reef corals in the Netherlands Antilles. *Bijdr. Dierk* **45**, 181-190.
- Beets, D. J. (1972a). Lithology and Stratigraphy of the Cretaceous and Danian Succession of Curacao, vol. 7. *Natuurwetenschappelijke Studiekring voor Suriname en de Nederlandse Antillen*, pp. 153, Utrecht, The Netherlands.
- Beets, D. J. (1972b). Outline of the Cretaceous and Early Tertiary history of Curacao, Bonaire and Aruba. In *Guide to the field excursions on Curacao, Bonaire and Aruba, Netherlands Antilles*. *Natuurwetenschappelijke Studiekring voor Suriname en de Nederlandse Antillen*, Utrecht, The Netherlands.
- BNMP. (2001). Dive tag sales 1991 - 2001.
- Buissonje, P. H. d. (1974). Neogene and Quaternary Geology of Aruba, Curacao and Bonaire., vol. 78. *Natuurwetenschappelijke Studiekring voor Suriname en de Nederlandse Antillen*, Utrecht, The Netherlands.
- CBS. (2005). National Economic Statistics, vol. 2005. Central Bureau of Statistics Netherlands Antilles: <http://www.central-bureau-of-statistics.an/>.
- Cesar, H., S.J. (2000). Collected Essays on the Economics of Coral Reefs. CORDIO, Kalmar, Sweden.
- de Leon, R. (2005). Hurricane dates.
- De Meyer, K. (1998a). Coastal Region and small Island papers 3: Bonaire, Netherlands Antilles. In *Environment and development in coastal regions and small Islands*.
- De Meyer, K. (1998b). Environment and development in coastal regions and in small islands. Bonaire, Netherlands Antilles, vol. 2005. <http://www.unesco.org/csi/pub/papers/demayer.htm>.
- Debrot, A. O., De Meyer, J. A. & Dezentje, P. J. E. (1998). Additional Records and a Review of the RCetacean Fauna of the Leeward Dutch Antilles. *Caribbean Journal of Science* **34**, 204-210.
- Duyf, F. C. v. (1985). *Atlas of the Living Reefs of Curacao and Bonaire (Netherlands Antilles)*. Foundation for Scientific Research, Utrecht, Netherlands.
- Edwards, A. J. (2000). MSc notes on the ecology of seagrasses.
- Ligon, J. (2002). Birding on Bonaire, vol. 2006. <http://www.infobonaire.com/birdwatching.html#article>.
- Lott, C. E. (2001). Lac Bay: Then and Now. Environics N.V.
- Pattengill-Semmens, C. V. (1998). The reef fish assemblage of Bonaire Marine Park: an analysis of REEF Fish Survey Project data. In *52nd Gulf Carrib. Fish. Inst. Proc.*
- Porter, S. (2006). Fish species of Lac.
- Renken, H. (2003). Lac Bay Management Plan. Bonaire National Marine Park.
- Roberts, C. M. & Hawkins, J. P. (1994). Report on the status of Bonaire's Coral Reefs, pp. 31. Eastern Caribbean Centre, University of the Virgin Islands, St Thomas, US Virgin Islands.
- Roos, P. J. (1971). The shallow water stony corals of the Netherlands Antilles. In *Studies of Fauna: Curacao and other Caribbean Islands*, vol. 37. *Natuurwetenschappelijke Studiekring voor Suriname en de Nederlandse Antillen*, pp. 1-108.
- Scura, L. F. & van't Hof, T. (1993). The ecology and Economic of Bonaire Marine Park, pp. 48. The World Bank, Environment Department.
- van Moorsel, G. W. N. M. & Meijer, A. J. M. (1993). Base-line Ecological study van het Lac op Bonaire, pp. 120. Bureau waardenburg BV, Holland.
- van't Hof, T. (1982). *Guide to the Bonaire Marine Park*. Orphan Publishing Company, Curacao, Netherlands Antilles.
- Zonneveld, J. I. S., Buissonje, P. H. d. & Herweijer, J. P. (1972). Geomorphology and denudation processes. In *Guide to the Field Excursions on Curaçao, Bonaire and Aruba, Netherlands Antilles*. *Natuurwetenschappelijke Studiekring voor Suriname en de Nederlandse Antillen*, pp. 59-69, Utrecht, The Netherlands.