Ecological values of the 12 miles zone of Bonaire

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Summary

In 2015 an Expert group assessed the ten Dutch World Heritage candidate sites and advised the Ministry of Education, Culture and Science with regards to the potential nomination of Bonaire National Marine Park. The conclusion was that further research is needed to demonstrate its Outstanding Universal Value (OUV). According to the Expert group, the current size and boundaries of BNMP do not contain features which qualify the property as unique, hence extension of the BNMP boundaries was recommended. Possibilities for extension are the island Curaçao, the islands off the coast of Venezuela and the 12 miles zone.

In collaboration with the Ministry of Economic Affairs it was decided to start by studying the nature values of the 12 miles zone of Bonaire, because this is the most feasible boundary extension. The 12 miles zone of Bonaire has a total area of almost 360,000 ha, which is a 74-fold enlargement compared to the 4,860 ha of the current boundaries of BNMP.

The objective was to determine the existence of potential nature values per zone based on the following criteria: rare, threatened or characteristic species; rare, untouched or undisturbed geomorphological features; important physical oceanographic features; potential ecosystem services. An inventory of previous studies by IMARES and available data from two deep sea expeditions in 2000 and 2013 were incorporated in this study.

Our review updates the current state of knowledge on the deep sea of the Caribbean Sea, focussing on the 12 miles zone of Bonaire. It provides a general framework for the decision making process on the boundary extension of the potential World Heritage Site and how to strengthen the potential OUV.

The available information shows that the 12 miles zone contains some attributes that will strengthen the OUV to some extent, such as the discovery of 16 species new to science at the deeper reef of Bonaire and the presence of some species endemic to the Southern Caribbean Ecoregion. Convincing documentation is still lacking, however evidence from past deep sea expeditions indicates that further studies of deep water biodiversity will likely easily yield a wealth of new species. Also potential offshore sea mounts within the 12 miles zone of Bonaire may be worthwhile investigating, by mapping the seafloor through a bathymetric survey. These potential habitats, structures and new species in the 12 miles zone of Bonaire could greatly add to the OUV of the BNMP.

1. Introduction

Natural World Heritage sites are globally recognized as the world's most important protected areas. The 1972 UNESCO World Heritage Convention provides a framework for securing the conservation of over 200 of the world's most important natural areas, recognized as being of Outstanding Universal Value (OUV). The identification of these sites through the Convention is based on criteria that include the scale of natural habitats, intactness of ecological processes, viability of populations of rare species, and rarity, notwithstanding aesthetic appeal which almost always accompany these natural features [1].

In 1992, the Kingdom of the Netherlands ratified the UNESCO World Heritage Convention. In 2011, the State of the Netherlands developed a national tentative list for candidate sites to be submitted for World Heritage nomination. The Bonaire National Marine Park (BNMP) has been selected as the only natural site on this list, the other nine being cultural sites. The project aims at developing a tentative nomination dossier for the prioritization of the ten candidates to be submitted by the Kingdom of the Netherlands for World Heritage nomination.
In 2014 the feasibility for nomination of BNMP as UNESCO World Heritage Site was assessed (Wolfs 2014). As part of this feasibility study, IMARES studied the potential Outstanding Universal Value (OUV) and the integrity of BNMP to maintain this OUV, and IMARES set up a Comparative Analysis framework to demonstrate the uniqueness of BNMP on a global scale compared to other World Heritage sites (Van Beek et al. 2014).
In 2015, an Expert group assessed all ten candidates on the national tentative list and advised on the order of nomination. The advice for BNMP was to enlarge the boundaries of the property as there is yet no clear and strong case for World Heritage status within the current boundaries of BNMP. The BNMP is a serial site of 4,860 ha, one part of the property being the fringing coral reefs, sea grass beds and Lac Bay mangroves, and the other part being the uninhabited island Klein Bonaire and its fringing coral reefs (Table 1.1 and Appendix A).

Table 1.1: Coordinates and size of the two parts of Bonaire National Marine Park: Bonaire and Klein Bonaire

Name of the component part	Coordinates of the central point	Size in hectare
Bonaire	12° 10' 53'' N 68° 16' 35'' W	3,940
Klein Bonaire	12° 9' 24'' N 68° 18' 41'' W	920
Total Property		4,860

Despite the ecological and aesthetic values of BNMP, its regional importance and the proper management and conservation of the property, the comparative analysis made clear the Outstanding Universal Value is not yet convincing compared to other coral reef World Heritage Sites. Therefor it was advised to assess the nature values of the adjacent 12 miles zone, adjacent terrestrial area and adjacent islands in Venezuela (Las Aves and Los Roques archipelagos) and potentially Curaçao. Based on this a new assessment will take place in 2017.

Since the 12 miles zone is the most feasible extension (that does not require a trans-boundary joint nomination by multiple countries), it was decided to first study the ecosystems and ecological values of the 12 miles zone, with the aim to identify attributes which could strengthen the Outstanding Universal Value of Bonaire National Marine Park.
The 12 miles zone is also known as the "Territorial Waters" of Bonaire and extends 12 nautical miles out from the coastal baseline (Fig. 1.1). The Territorial Waters fall under the island jurisdiction and national jurisdiction of the Caribbean Netherlands. The 12 miles zone of Bonaire includes the Bonaire National Marine Park (BNMP), which extends from the high water mark to the 60 meter depth contour line.

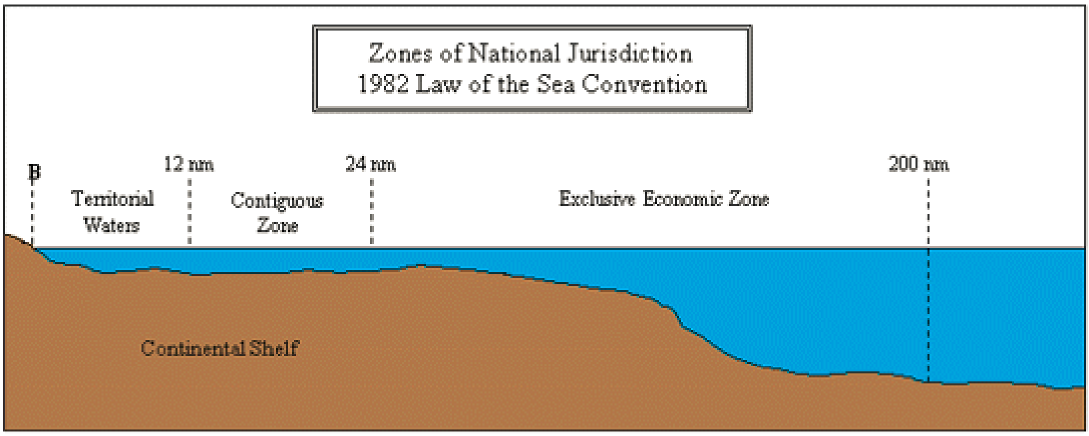


Figure 1.1: Zones of national jurisdiction under Law of the Sea Convention (Meesters et al 2010)

1.1 Assignment

The objective is to determine the existence of potential nature values in the 12 miles zone based on the following criteria:

- Common fish and benthic species;
- Species which are rare or threatened, key species or characteristic species for the ecosystem
- Geomorphological features such as rare, untouched and undisturbed structures
- Physical oceanographic features such as important surface oceanic currents, deep ocean currents, upwelling areas and tidal currents
- Potential ecosystem services

The above criteria link to the four UNESCO natural criteria for world heritage selection: (vii) aesthetic nature values; (viii) geological processes on long time-scales; (ix) ecological and biological processes; and (x) biological diversity.

The potential nature values are here assessed through literature study and an inventory of previous studies by IMARES (Couperus et al 2015; Meesters and Becking, 2014; Debrot et al 2014; Debrot et al, in prep); available data from 24 deep sea video transects with the Harbour Branch; and anecdotal accounts from fishermen).

2. Ecosystems and nature values in the 12 miles zone of Bonaire

2.1 Bathymetry and vertical zonation of the open ocean

The open ocean can be divided vertically into five different depth zones that correspond to the amount of light (Fig. 2.1):

- the epipelagic zone is the uppermost part of the oceanic zone, that receives enough sunlight to allow photosynthesis. It is therefore also called the *photic* or *sunlight zone*. It extends from the surface to 200 meters. The part of this zone above the drop-off of the continental shelf is called the neritic zone, the part beyond the shelf break is the oceanic zone.
- The mesopelagic zone is the part of the pelagic zone that extends from a depth of 200 to 1,000 meters below the ocean surface. It is also called the *twilight zone*, because it lies between the photic epipelagic zone and the aphotic bathypelagic zone, where there is no light at all.
- The bathypelagic zone is the part of the pelagic zone that extends from a depth of 1,000 to 4,000 meters below the ocean surface. It is also know as the *midnight zone*, because sunlight does not reach this zone.
- The abyssopelagic zone extends from a depth of 4,000 to 6,000 meters below the ocean surface. This zone remains in perpetual darkness and is characterized by continuous cold and lack of nutrients. Its permanent inhabitants such as the giant squid are able to withstand the immense pressures of these ocean depths.
- The hadalpelagic zone is the delineation for the deepest trenches in the ocean found from a depth of 6,000 meters to the bottom of the ocean. It is also known as the *trench zone*. This zone is characterized by low population and low diversity of marine life.

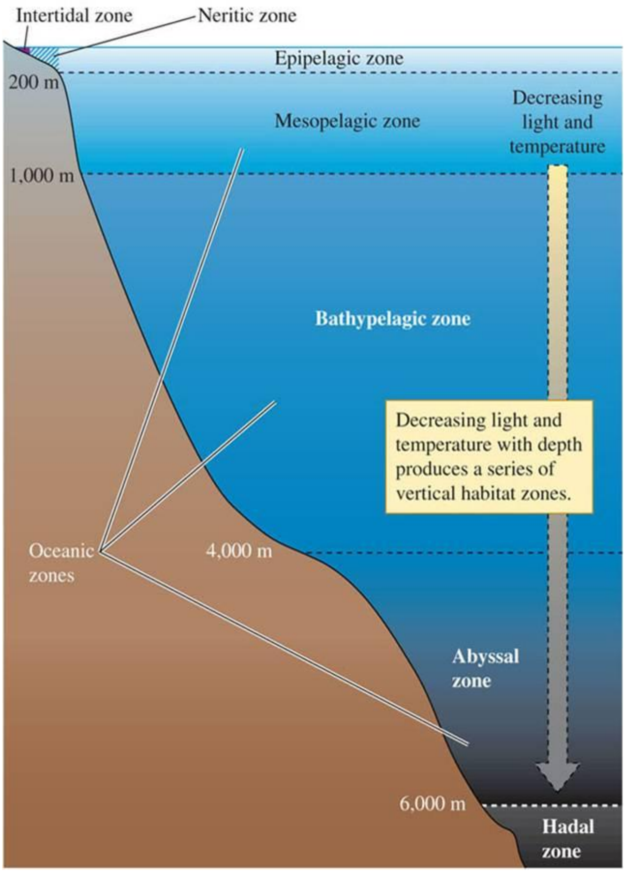
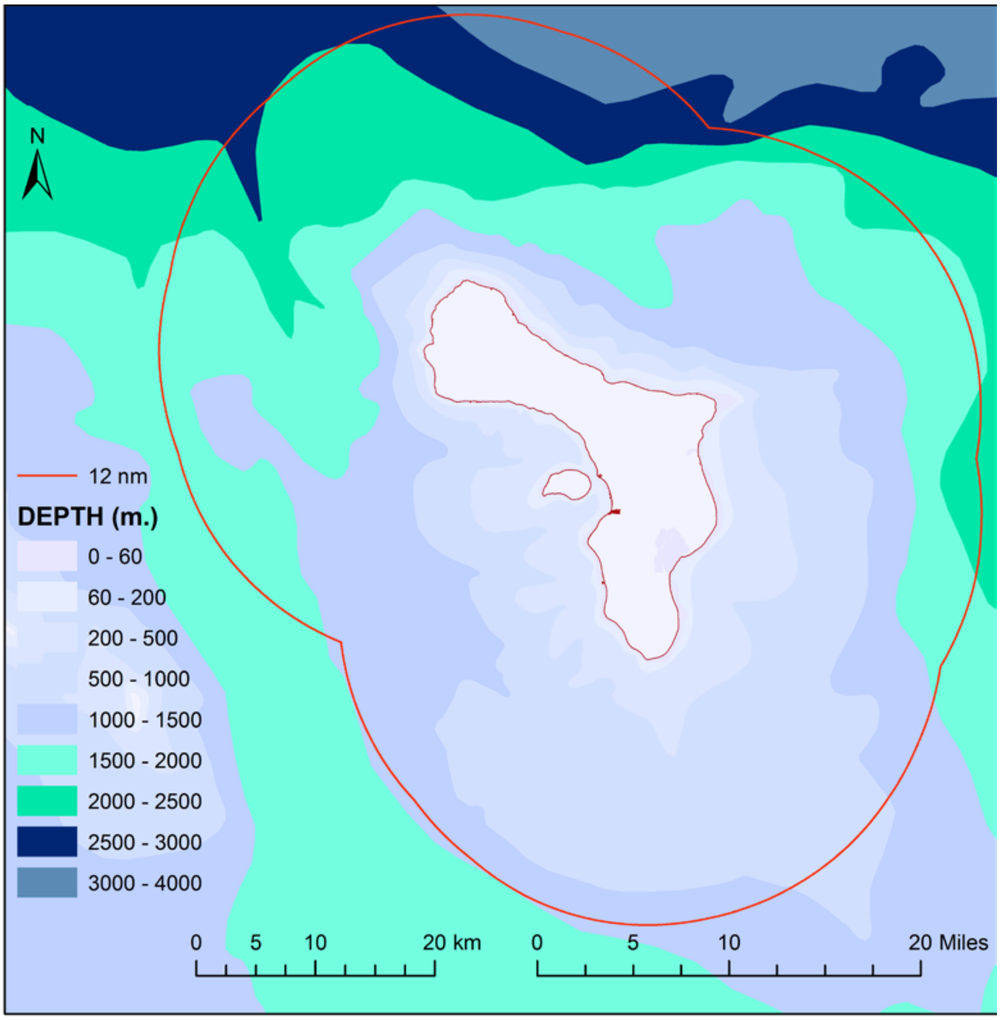


Figure 2.1: Different habitat zones in the open ocean [2]

The map of the 12 miles zone of Bonaire shows a number of depth contours or isobaths, indicating the depth of the ocean floor around Bonaire (Fig. 2.2). From this map it can be concluded that the 12 miles zone of Bonaire contains three of the five pelagic zones: the epipelagic zone, the mesopelagic zone and the bathypelagic zone. The maximum depth in the 12 miles zone around Bonaire is 4,000m, therefor the abyssopelagic zone and hadalpelagic zone do not occur.



Depth (m.)	Area (ha)
60	4432.4
200	7522.9
500	31825.6
1000	92284.2
1500	85273.8
2000	76512.3
2500	39942.2
3000	15526.9
4000	5833

Figure 2.2: Isobaths or depth contours in the 12 miles zone of Bonaire (red line) and surface areas of the different depths.

The epipelagic zone from 0-200m has the largest surface area of 359,153 ha, which is basically the entire surface of the 12 miles zone; the mesopelagic zone from 200-1000m spans an area of 347,198 ha

(97% of the 12 miles zone); the bathypelagic zone from 1000-4000m is the smallest area with 223,088 ha (62% of the 12 miles zone).

In the following paragraphs, the above three distinct habitats occurring in the 12 miles zone of Bonaire are further described, including the main habitat characteristics and communities of organisms and species. Furthermore, the geomorphology and oceanography of the Caribbean Sea are described, in an effort to identify rare geological structures and important oceanographic currents that may occur in the 12 miles zone of Bonaire.

2.2 Geomorphological and Oceanographic features

2.2.1 Oceanographic features in the Caribbean Sea

The Caribbean Sea is approximately 2,640,000 km^2 . It is a semi-enclosed basin, bounded on the west by Central America, on the south by Central and South America, on the east by the Lesser Antilles and on the north by the Greater Antilles. The Caribbean Sea generally exceeds 1,830 m in depth with many sections exceeding 3,660 m in depth. Its greatest known depth is 7,535 m in the Cayman Trench located between Cuba and Jamaica. The extensive shallow areas are the Bahamas Banks and the Nicaragua Rise (Lutz and Ginsburg 2007).
Several gaps between islands on the north and east are major channels and passages for ocean currents connecting the Caribbean Sea with the Atlantic Ocean and Gulf of Mexico. The main channels are in the Greater Antilles island chain: the Windward Passage between Cuba and Hispaniola; the Mona Passage between Puerto Rico and Hispaniola; and the Anegada Passage south of the Virgin Islands. Smaller channels are in the Lesser Antilles island chain: the St. Lucia Channel, the St. Vincent Passage; and the Grenada Passage between the Lesser Antilles and the South American continent (Fig. 2.3).

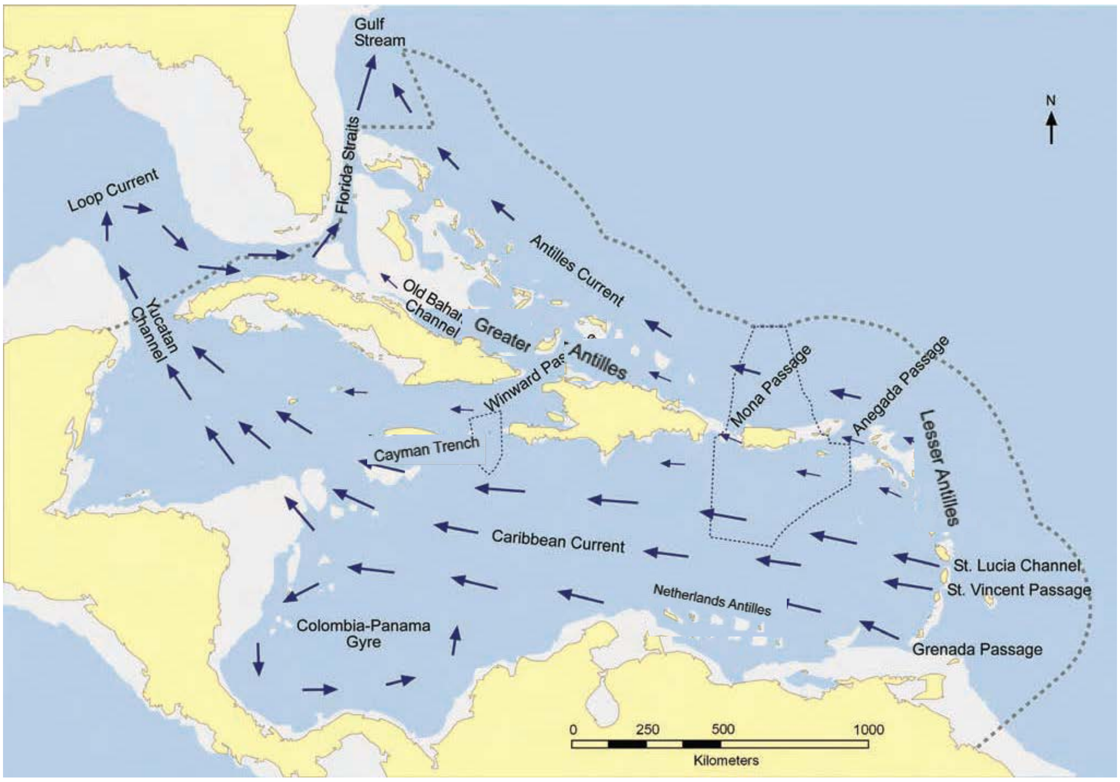


Figure 2.3. Regional currents, channels, and passages (Lutz and Ginsburg 2007)

As a result of the exchanges with the open Atlantic, there is little seasonal variation in surface water temperatures, with a general range from 25.5ºC in the winter to 28ºC in the summer. Below the surface, the water structure is highly stratified in the upper 1200 meters; weakly stratified between 1,200 and 2,000 meters and uniform below 2000 meters (Gyory et al. 2005; Lutz and Ginsburg 2007). Through much of the Caribbean there is a permanent thermocline (a steep temperature gradient) at a depth of about 100m. This prevents deep nutrient-rich water from rising to the surface (Day 2013). This stratification is directly related to the shallow depth of passages between the Lesser Antilles (between 1600-1630m). They act as sills and impede deep-water flow into the Caribbean (Gordon 1967; Gyory et al. 2005; Lutz and Ginsburg 2007). This results in bottom temperatures of the Caribbean Sea close to 4ºC as compared with the Atlantic Ocean bottom temperature of 2ºC [3].

Most water flows into the Caribbean Sea from the Atlantic through the Grenada, St. Vincent and St. Lucia Passages in the southeast (Gyory et al. 2005a). This water flow is characterized by its rich oxygen content and by a salinity of slightly less than 35 parts per thousand [3]. From these passages, water flows clockwise across the Caribbean Sea basin as the Caribbean Current, the main surface circulation in the Caribbean Sea. It reaches high surface velocity (70 cm/sec) along the Netherlands Antilles and adjacent coastline of South America (Fratantoni 2001; Gyory et al. 2005; Lutz and Ginsburg 2007). The current then flows to the northwest, over the Colombian basin, towards the Nicaragua Rise and a trough southwest of Jamaica, with a branch forming an counter-clockwise Panama-Colombia Gyre (where the current meets Central America). Strong flow (up to 60 cm/sec) has been recorded along the Panamanian and Colombian coasts (Gyory et al. 2005a). Where currents are diverted by or constricted between landmasses, current velocities increase. The larger and deeper inter-island spaces produce major seaways; the more numerous, smaller and shallower ones produce similar but smaller increases in velocity. Current velocities will also increase when water flow meets elevations of the sea floor, typically platforms or banks of calcareous deposits.
Strong currents (170 cm/sec) have been reported in the Yucatan Channel, where water flow exits the Caribbean Sea into the Gulf of Mexico. It doubles back as the Loop Current before entering the Straits of Florida where it is joined by waters passing through the Old Bahama Channel to form the Florida Current. When this Florida Current exits the Straits it is joined by the Antilles Current and turns eastward and becomes the Gulf Stream (Lutz and Ginsburg 2007).

Because of the relatively deep water and the lack of major upwellings, much of the regioin is naturally nutrient deficient. However, in the past few decades, river discharge have added heavy loads of nitrates and other nutrients from agricultural land. Rivers also discharge copious amounts of freshwater, silt, and pollutants that affec coastal waters for many hundreds of miles (Day 2013). The southern/central Caribbean Sea is influenced by several large and small rivers. The Amazon, Orinoco, and Magdalena are the largest rivers affecting the Caribbean region, with the Orinoco and Magdalena discharging directly into the basin (Fig. 2.4) (Rueda-Roa and Muller-Karger 2013). Sediments of the Orinoco and Amazon rivers are being deposited on the West Aves apron (Matthews and Holcombe 1985).

The Caribbean is considered a class II moderately productive system of 150-300 gCm_{-2} yr_{-1} (Heileman and Mahon, 2009; in Couperus et al. 2014), but there is considerable heterogeneity in both space and time throughout the region. Highest productivity occurs in the south-eastern part, off the coast of Venezuela where surface productivity is about 500 gCm-2 yr-1 (Couper, 1983; Richardson and Young, 1987; Tyler, 2003 in Couperus et al., 2014). There is no information on the particulate organic carbon fluxes to deep waters but it is assumed to fit the pattern of productivity. It is known however, that the deep waters receive considerable inputs of organic carbon in the form of wood and *Thalassia testudimum* blades, particularly after hurricanes (Tyler, 2003 in Couperus et al 2014).
The southern Caribbean Sea experiences strong wind-driven coastal upwelling from approximately January to May along the continental margin, between about 61ºW to 75.5ºW and 10–12.5ºN (Fig. 2.4)

(Rueda-Roa and Muller-Karger 2013). A major submarine ridge (Aves Ridge) that deflects the Caribbean Current away from shore, plays an important role in reinforcing the wind-induced upwelling. Here westward advection during the first half of the year limits phytoplankton blooms to principally the southern half of the Caribbean. In the second half of the year, the influx of Atlantic water decreases and allows local Ekman transport driven by the trade winds to drive algal blooms to the northwest towards the central and north eastern Caribbean (Müller-Karger et al., 1989). The upwelling process maintains a highly productive ecosystem in the region, called the southern Caribbean upwelling system. The total biomass of small pelagic fish in the southern Caribbean upwelling system is estimated at 1,580,000 metric tons, which includes clupeids, anchovies, carangid, scombrids and barracudas. Nearly all (95%) is concentrated in two areas, the eastern (63–65°W) and western upwelling (70–73°W) areas. Literature reports that the eastern area (of greatest relevance to the Bonaire area) has a much higher biomass of small pelagics (78%) than the western upwelling (18%) (Rueda-Roa and Muller-Karger 2013). Satellite-derived Sea Surface Temperature (SST) and chlorophyll-a (Chl) production serve as a proxy for upwelling in this tropical region. Strong upwelling here occurs primarily during the northern hemisphere winter, but the southern continental margin of the Caribbean shows lower sea surface temperatures than surrounding waters year-round. The eastern area featured the lowest SST (25.24°C), the highest Chl (1.65 mg m^{-3}), a shallower 22°C isotherm (85m) and a longer upwelling period (SST < 26°C during 8.5 months). According to the 'optimal environmental window' theory, small clupeoid recruitment has an optimum wind speed of around 5-6m s^{-1}, with the eastern area wind speed close to this optimum value (6.12m s^{-1}). The western area has a winds > 8m s^{-1} during most of the year, higher SST (25.53 °C), lower Chl (1.15 mg m^{-3}), a shallower 22°C isotherm (115m) and a shorter upwelling period (SST < 26°C during 6.9 months). The western area also had a higher energetic wind field (2.5 higher turbulance) and stronger upwelling (1.5 higher), but nevertheless the SST was slightly warmer because of the deeper position of the Subtropical Underwater core. The 22 °C isotherm traces the Subtropical Underwater core that feeds the upwelling (Rueda-Roa and Muller-Karger 2013).

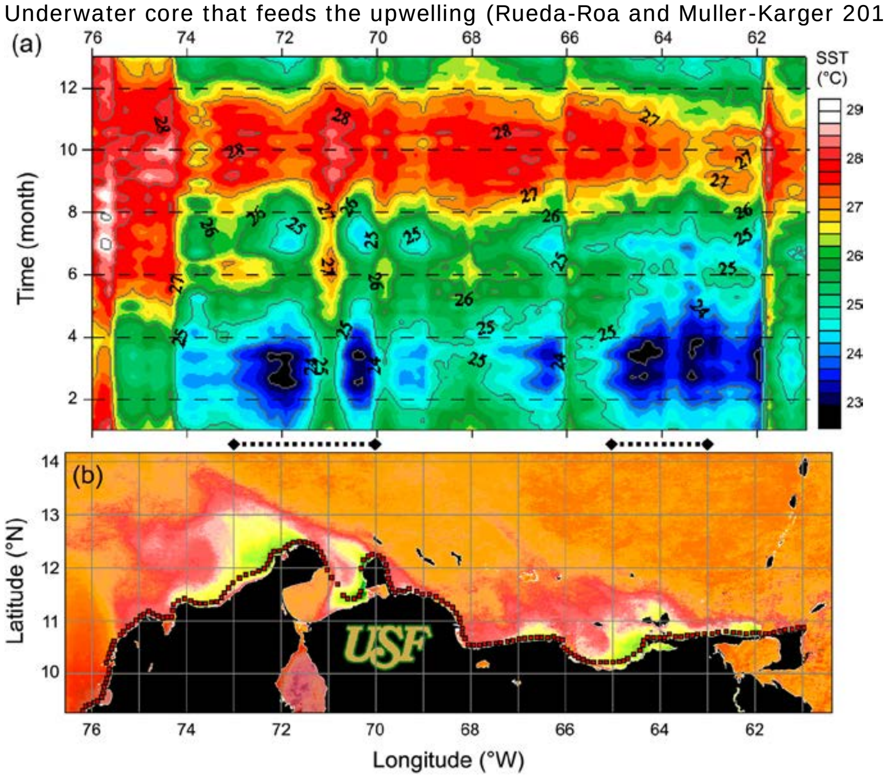


Figure 2.4. (a) Seasonal cycle in satellite Sea Surface Temperature (SST) along the coast of the southern Caribbean upwelling system. SST time searies were extracted at 172 coastal stations approximately 13km offshore, shown as red dots in (b). The western upwelling area (70-73° W) and the eastern area (63-65° W) are highlighted by the black dotted line under (a) (Rueda-Roa and Muller-Karger 2013).

Sea surface temperatures are also affected by global warming. The rising temperature has become a major threat to coral reefs globally as the severity and frequency of mass coral bleaching and mortality events increase. In 2005, high ocean temperatures in the tropical Atlantic and Caribbean resulted in the most severe bleaching event ever recorded in the basin. Thermal stress during the 2005 event exceeded any observed from the Caribbean in the prior 20 years, and regionally-averaged temperatures were the warmest in over 150 years. Comparison of satellite data against field surveys demonstrated a significant predictive relationship between accumulated heat stress (measured using NOAA Coral Reef Watch's Degree Heating Weeks) and bleaching intensity (Eakin et al 2010). The connection of reefs with the deeper ocean is important when we consider that increased maximum temperature appears to be most manifest in shallow water. Temperature records show that the deep reef is bathed in waters originating in the deeper ocean. This is demonstrated by the frequency of cold-water influx in the deep-reef environment (Bak et al 2005). Extreme low temperatures occur in deep reefs (Leichter et al 1996 in Bak et al 2005). Cold-water influx has been recorded to cause bleaching on coral reefs as well (Roberts et al 1982; Walker et al. 1982; Coles and Fadlallah 1991 in Bak et al 2005).

2.2.2 Geological features in the Caribbean Sea

The Caribbean Sea basin, the islands within it and the Bahamas Archipelago, are centered on the Caribbean plate. Several continental plates meet in this region, which are hotspots for seismic activity. Interactions between the Caribbean plate, North American plate and the South American plate produced the major topographic features and allow the Caribbean basin to be divided into four smaller basins; the Yucatan, Colombian, Venezuelan and Granada basins (Fig. 2.5). Both tectonic activity and biological activity produce features significant to deep water corals in this region. Tectonic activity is responsible for deep-water trenches, ridges, basins and interisland passages and channels. Products of biological activity include deep coral mounds and lithoherms (Lutz and Ginsburg 2007).

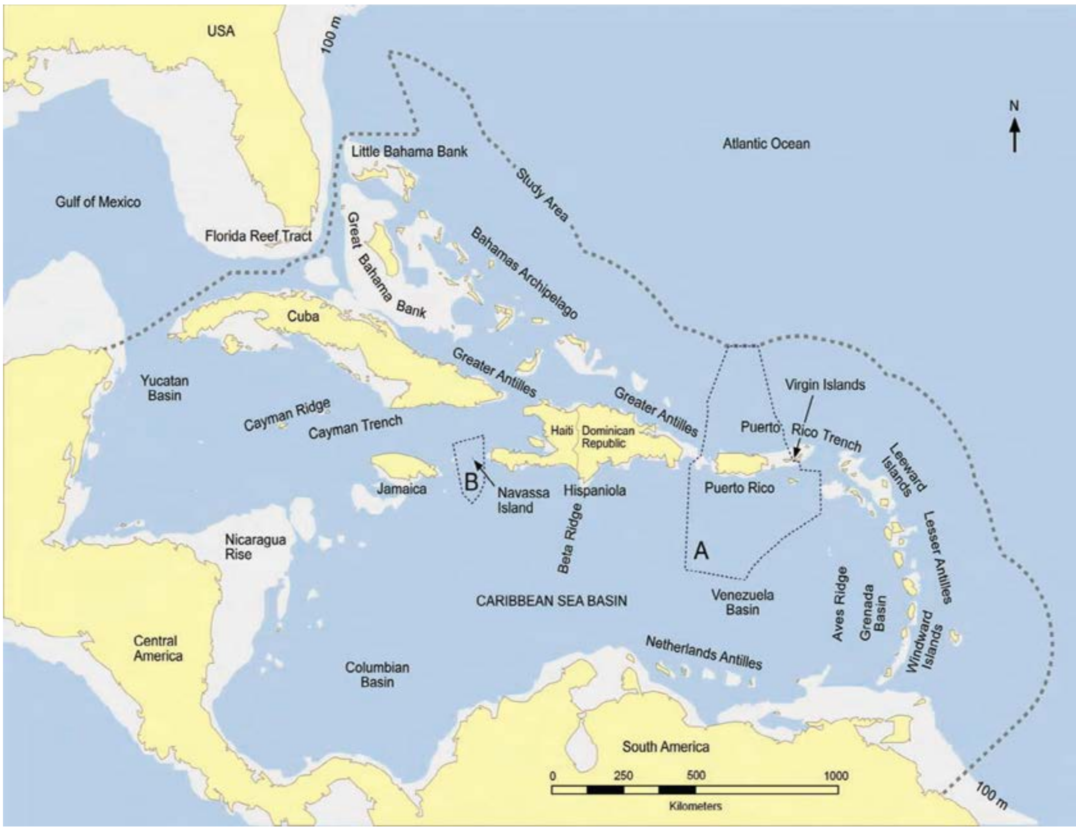


Figure 2.5. Regional basins, trenches and ridges (Lutz and Ginsburg 2007)

North of Bonaire lies the Venezuela Basin. The Venezuela Basin is partly separated from the Colombian Basin by the Beata Ridge and partly connected with the Colombian Basin by the submerged Aruba Gap at a depth of 4.078m, which is the deepest entrance to the Venezuela Basin (Fig. 2.6 and 2.7). The southern margin of the Venezuela Basin is formed by the Curaçao Ridge, an active subduction zone on the margin of the South American continental plate (Matthews and Holcombe 1985). A subduction zone is a region where one tectonic plate moves under another tectonic plate and sinks into the mantle as the plates converge.

The Leeward Antilles - the islands of Los Monjes, Aruba, Curaçao, Bonaire, Las Aves, Los Roques, and La Orchila (Fig. 2.7) - are exposures of a largely submarine ridge whose pre-middle Eocene rocks consist of weakly metamorphosed mafic (Bonaire and Curaçao) and intermediate igneous rocks suggestive of an island arc (Pindell and Barrett 1990). Metamorphosed and igneous rock are two of the main rock types, the third is sedimentary rock. Igneous rock is formed through the cooling and solidification of lava or magma (molten rock located deep within the mantle of the Earth). Metamorphosed rocks have been formed by the change from one form to another by the high pressure and temperature environment of the Earth [4]. The geological evolution of the Leeward Antilles island arc from a plate-tectonic perspective is not entirely clear, as the number of arcs and the effects of Cenozoic strike-slip offset (horizontal, side-way movement of plates) on the original geography are unknown. The Leeward Antilles and northern South America are treated together as a single arc system in figure 2.8 due to uncertain geological relationship (Pindell and Barrett 1990).

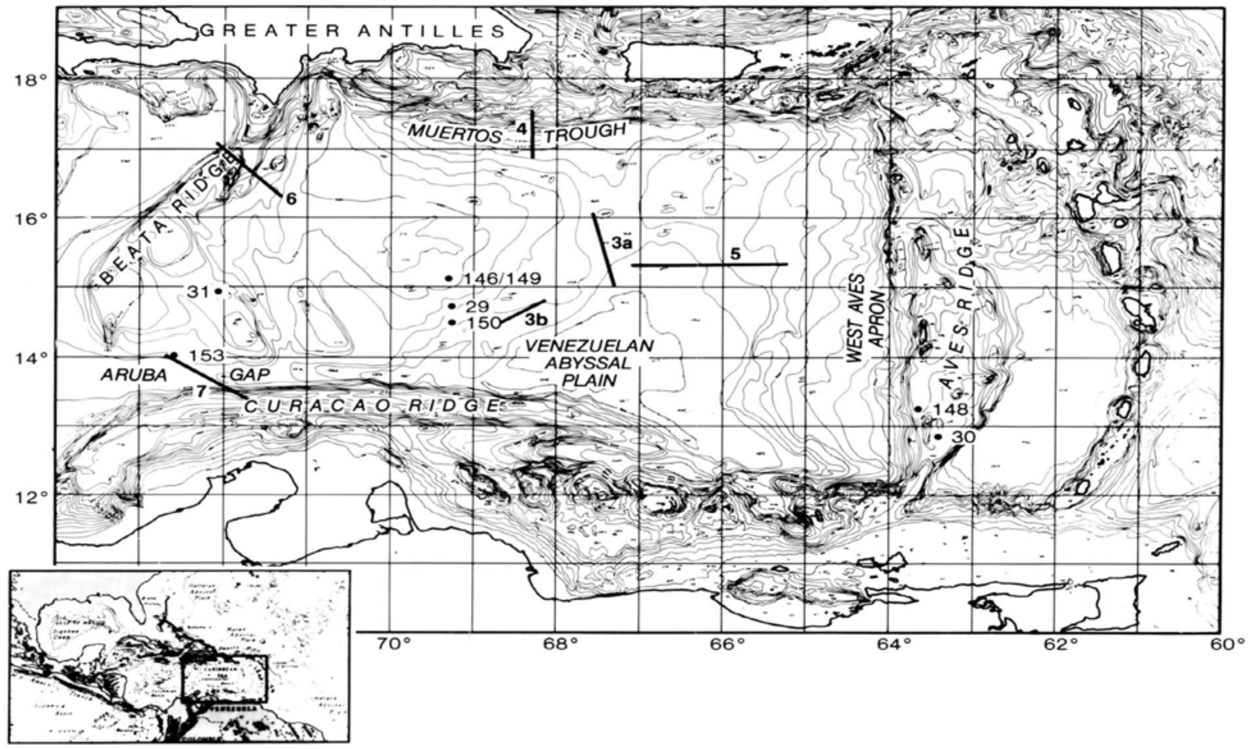


Figure 2.6. Bathymetric map of Venezuela Basin, Aruba Gap and Curaçao Ridge (Matthews and Holcombe 1985)

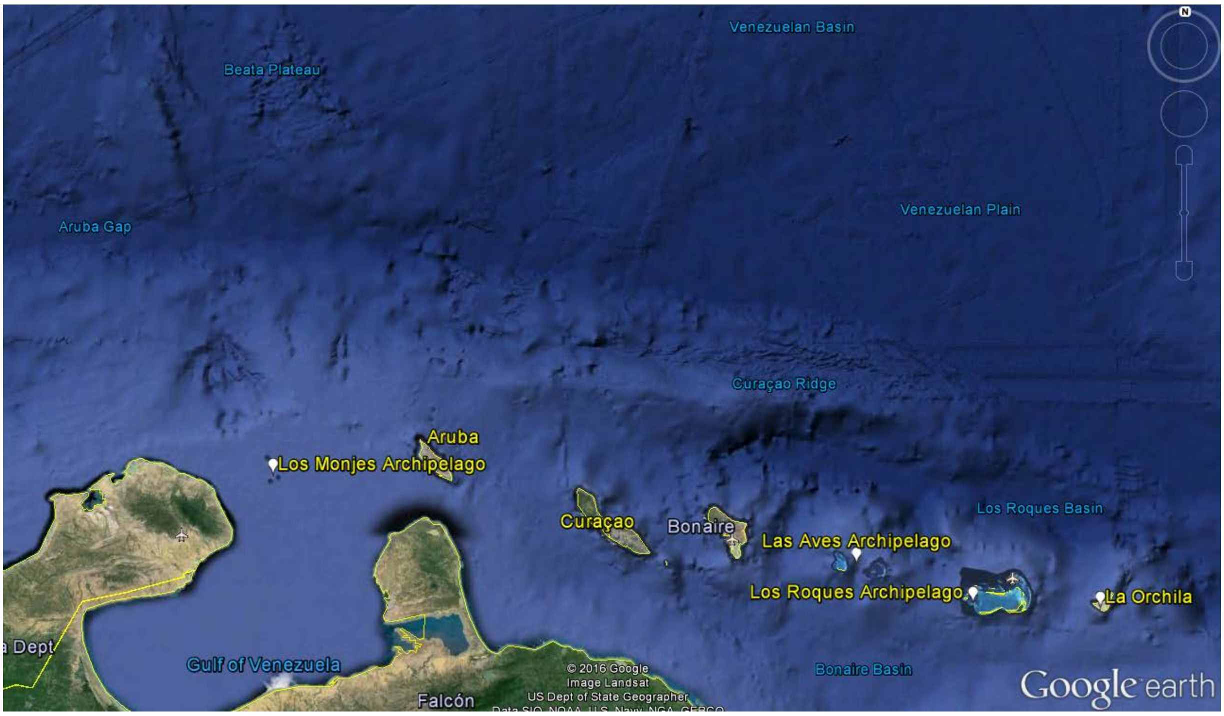


Figure 2.7. Google earth map showing the Leeward Antilles island arc and surrounding main geological features

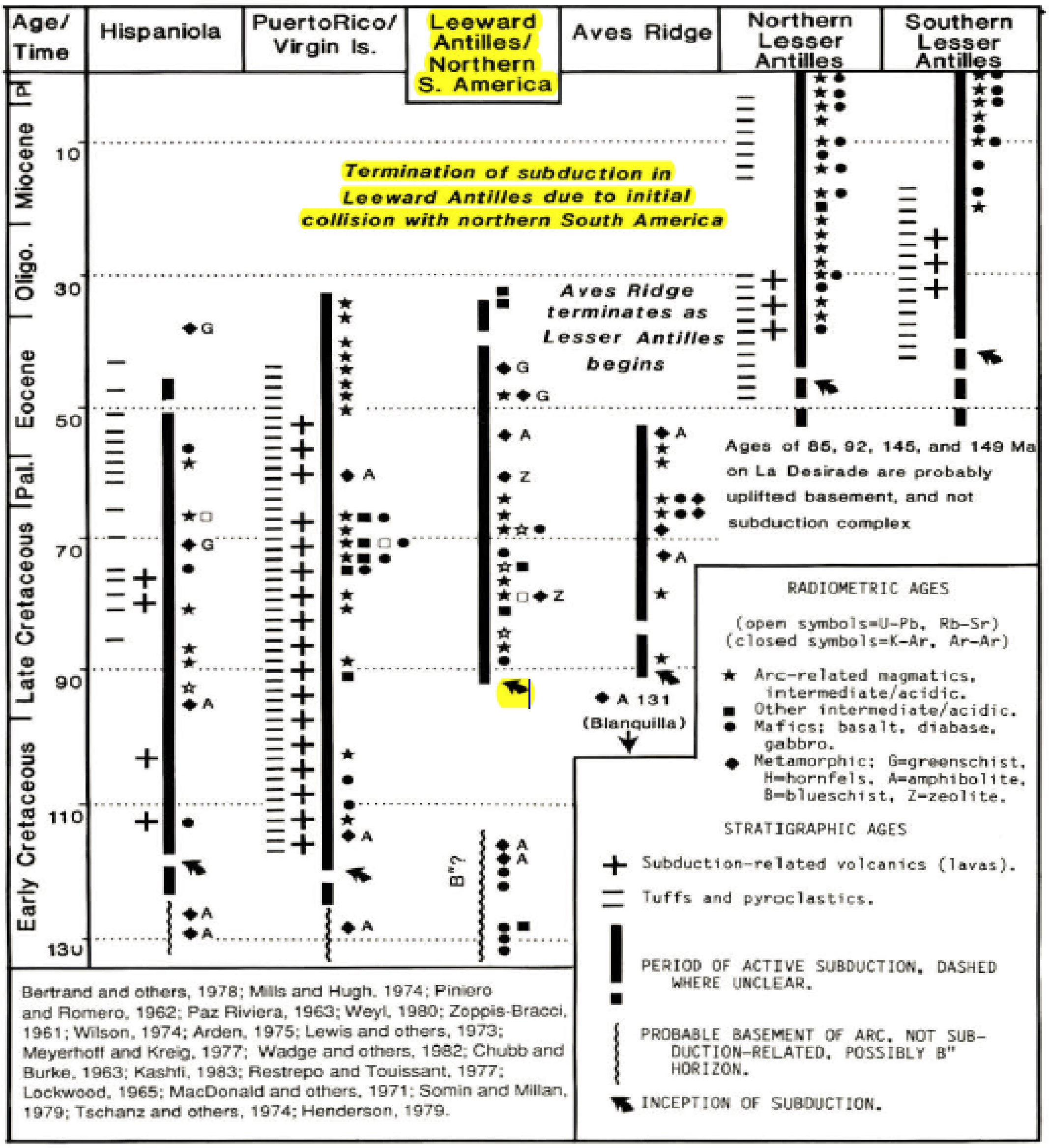


Figure 2.8. Geological evolution of the Caribbean region from a plate-tectonic perspective: Igneous history of the Leeward Antilles arc (highlighted column) with the arrow indicating the start of the subduction (Pindell and Barrett 1990). Radiometric age symbols represent one or more ages, from one or more igneous bodies, at a 2 m.y. sampling interval

The geologic age of the Caribbean is not known with certainty. As part of the Central American Sea, it is presumed it was connected with the Mediterranean during Paleozoic times (i.e., about 541 to 252 million years ago) and it was separated gradually from it as the Atlantic Ocean was formed. The ancient sediments overlying the seafloor of the Caribbean, as well as of the Gulf of Mexico, are about a half mile (about one kilometre) in thickness, with the upper strata representing sediments from the Mesozoic and Cenozoic eras (from about 252 million years ago to the present) and the lower strata presumably representing sediments of the Paleozoic and Mesozoic eras (from about 541 to 66 million years ago). Three phases of sedimentation have been identified. During the first and second phases the basin was free of deformation. The Central American Sea apparently became separated from the Atlantic before the end of the first phase. Near the end of the second phase, gentle warping and faulting occurred, forming the Aves and Beata ridges. Forces producing the Antillean Arc were vertical, resulting in no ultimate horizontal movement. The sediment beds tend to arch in the middle of the basins and to dip as landmasses are approached. The younger Cenozoic beds (formed during the last 65 million years) are generally horizontal, having been laid down after the deformations occurred. The existing sediment cover of the seabed consists of red clay in the deep basins and trenches, globigerina ooze (a calcareous marine deposit) on the rises, and pteropod ooze on the ridges and continental slopes [3].

The coastal waters of Venezuela and Colombia are known to be areas of endemism, with quite different species composition (Diaz 1995, Smith et al, 2002). The differences may reflect the fact that these areas represent distinct continental faunas that were separated by the Inter-American Seaway during most of the history of the Caribbean Basin. These areas could be viewed as distinct and unique hotspots for marine biodiversity (Smith et al 2002).

2.2.3 Geomorphological and oceanographic nature values of the 12 miles zone of Bonaire

From the description of geological and oceanographic features in the Caribbean Sea the following conclusions can be drawn for the geomorphological and oceanographic features in the 12 miles zone of Bonaire.

Physical oceanographic features

There are no important physical oceanographic features such as surface oceanic currents, deep ocean currents, upwelling or tidal currents within the 12 miles zone of Bonaire.

The Caribbean Current, the main surface circulation in the Caribbean Sea, passes by Bonaire from east to west (Fratantoni 2001; Gyory et al. 2005; Lutz and Ginsburg 2007). The predominant current movement around Bonaire is toward the north along the leeward shore, but this pattern is complicated by local eddies and upwelling (Bak 1977). Surface current velocities are high (70 cm/sec) along the Netherlands Antilles (Fratantoni 2001; Gyory et al. 2005; Lutz and Ginsburg 2007). Currents around Bonaire are unpredictable but slight, rarely exceeding 50 cm/sec (Bak 1977).

Surface water temperatures in the Caribbean are highly stratified in the upper 1200 meters; weakly stratified between 1,200 and 2,000 meters and uniform below 2000 meter. Because of the exchanges with the open Atlantic, there is little seasonal variation in surface water temperatures, ranging from 25.5°C in the winter to 28°C in the summer (Gyory et al. 2005; Lutz and Ginsburg 2007). Bottom temperatures are close to 4°C and salinity is slightly less than 35 parts per thousand (ppt) [3]. Water conditions around Bonaire are stable too, with mean water temperatures varying from 26°C to 28°C and a constant 34-36 ppt salinity (Bak 1977). The maximum annual tidal range is approximately 1 m, with an average range of 0.30 m during a lunar cycle (Bak 1977).

The southern Caribbean upwelling system lies south from Bonaire. The 12 miles zone of Bonaire (67.99-68.63 °W and 11.82-12.51 °N) is not at the center of this upwelling system, since this is a coastal upwelling and it is concentrated in two areas, the eastern (63–65°W) and western upwelling (70–73°W) areas at 10–12.5°N (Fig. 2.4). Although the upwelling system is not within the 12 miles zone, the small pelagic fish biomass associated with upwelling systems is considered significant for Bonaire (Couperus et al 2014).

Sea surface temperatures in Bonaire appear to be rather stable. For example, high ocean temperatures in 2005 caused the most severe bleaching event in the Caribbean Basin, yet the thermal stress was lower off Venezuela, including Los Roques, Aruba, Bonaire and Curaçao (Eakin et al 2010).

Geomorphological features

There might be a rare geological structure of which the 12 miles zone of Bonaire is part: the Leeward Antilles island arc (including the islands of Los Monjes in Colombia, Aruba, Curaçao, Bonaire, and Las Aves, Los Roques, and La Orchila in Venezuela (Fig. 2.7)), are exposures of a largely submarine ridge whose pre-middle Eocene rocks consist of weakly metamorphosed mafic (Bonaire and Curaçao) and intermediate igneous rocks suggestive of an island arc (Pindell and Barrett 1990). However, there are much larger underwater mountain ranges, with the mid ocean ridge systems being the largest geological features on the planet. An example is the Mid Atlantic Ridge which is not on the World Heritage List,

despite its biological, cultural and geological heritage. Constraints are that most of the submarine part has to be left out of consideration, because most of the underwater ridge lies outside any national territory and is therefore not covered by provisions of the World Heritage Convention. Furthermore it requires a serial trans-boundary joint nomination of serial sites within multiple countries. Another important question is how to define the limits of the phenomenon [5]. The latter two arguments are also valid for the submarine ridge and Leeward Antilles island arc.
The Curaçao Ridge, positioned at 64 °W and 13 °N [6], lies approximately 17 miles north of the northern boundary of the 12 miles zone of Bonaire (67.99-68.63 °W and 11.82-12.51 °N). Part of the Curaçao Ridge is located within the EEZ boundaries of Bonaire (67.99-68.72 °W and 11.66-14.37 °N).

2.3 Epipelagic, mesopelagic and bathypelagic biological and ecological features

2.3.1 Epipelagic habitat, species and nature values

The epipelagic zone is the photic or sunlight zone in which most of the visible light exists. With the light comes heating from sun. This heating is responsible for wide change in temperature that occurs in this zone, both in latitude and seasonality. Interaction with the wind keeps this layer mixed and thus allows the heating from the sun to be distributed vertically. At the base of this mixing layer is the beginning of the thermocline (Fig. 2.9). The thermocline is a region where water temperature decreases rapidly with increasing depth. It is a transition layer between the warmer, less dense layer at the surface and deeper, colder and denser water. The depth and strength of the thermocline varies from season to season and year to year. It is strongest in the tropics and decrease to non-existent in the polar winter season [7].

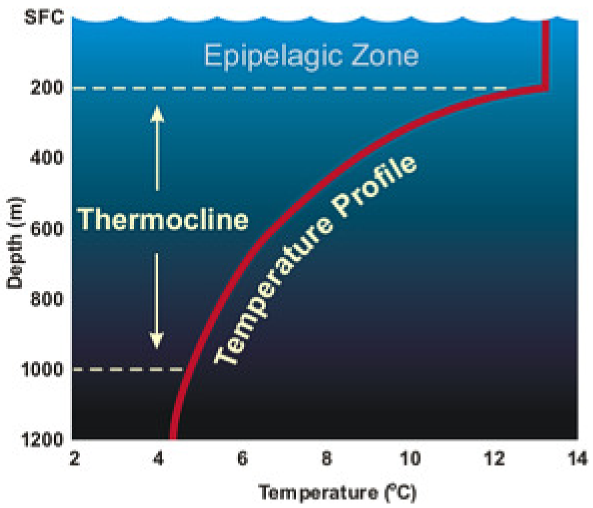


Figure 2.9. Thermocline [7]

In the epipelagic zone there is plenty of light for photosynthesis. Epipelagic ecosystems differ from many coastal ecosystems in that nearly all the primary production takes place within the epipelagic system itself. Coastal ecosystems often receive large amounts of nutrients input from elsewhere. The intertidal zone, for example, gets plankton and drifting seaweeds from offshore, and organic material from rivers, bays and estuaries. The pelagic realm, far from the shore and bottom, gets almost no external input of organic matter (Castro and Huber 2008).
The epipelagic does supply food to other communities. Organic matter sinks out of the epipelagic to feed the organisms in deeper zones below. Ocean currents carry epipelagic plankton into shallow water. Since food is suspended in the water column, there are many suspension feeders. Epipelagic fishes and plankton provide food not only to other marine species such as other fishes, squids and marine mammals, but also to birds and humans (Castro and Huber 2008).

The primary producers, phytoplankton that perform photosynthesis, can be categorized by size from the picoplankton to the megaplankton. Large producers like seaweeds and seagrasses are largely absent from the epipelagic, because they have no place to attach. Floating seaweeds are important in a few places like the Sargasso Sea, but in most of the epipelagic the only primary producers are single-celled or simple chains of cells. Phytoplankton perform more than 95% of the photosynthesis in the ocean. This amounts to nearly half the world's primary production and produces nearly half the oxygen in our atmosphere. Cyanobacteria are the most abundant picoplankton and account for at least half the ocean's total primary production. One group, the single-celled *Prochlorococcus*, is the most abundant of all marine phytoplankton and is especially dominant in nutrient-poor tropical and subtropical waters. The closely related *Synechococcus* is also very abundant in all but polar waters. *Coccolithophorids* are a dominant group of nanoplankton and important primary producers in tropical waters. Most common net plankton (micro, meso, macro and megaplankton which can be caught in a net) in tropical waters are dinoflagellates and the colonial cyanobacteria *Trichodesmium* (Castro and Huber 2008).
The primary consumers are a vital part of the epipelagic food web, because many large epipelagic animals cannot feed on the tiny phytoplankton which form the base of the food web. Herbivorous zooplankton transfer energy stored in organic matter. Protozoans consume the smallest pico- and nanoplankton. Copepods, small crustaceans, are the most abundant zooplankton and make up as much as 70% of the zooplankton. Copepods not only consume phytoplankton, but also other zooplankton. While this zooplankton spend their whole live in the plankton (holoplankton), a vast number of organisms have planktonic larvae and are temporary living in the plankton (meroplankton). Coastal waters are particularly rich in mesoplankton (Castro and Huber 2008).
Although plankton are by far the most abundant organisms in the sea and they form the base of the epipelagic food chain, more familiar is nekton: Fishes, marine mammals and squids are the most abundant nekton. Practically all nekton are carnivorous. Planktivorous nekton include small fishes like herrings, sardines and anchovies (Castro and Huber 2008).

The photosynthesis in the epipelagic zone can be either light or nutrient-limited. Important nutrients are nitrogen, iron and phosphorus. In tropical waters there is usually enough light to support photosynthesis throughout the year. Most of the nutrients come from nutrient recycling: dissolved nutrients are incorporated in organic matter by phytoplankton. When organisms die nutrients are regenerated through decomposition of material. Since much of the organic material ends up as detritus and these organic particles tend to sink, many sink out of the epipelagic into deeper waters before they decay and nutrients are released below the photic zone. Therefor surface waters are usually depleted in nutrients and deep water is usually nutrient rich (Castro and Huber 2008).

Mesophotic coral reefs, reefs at depths of 30 m to 150 m, are linked physically and biologically to shallow water reefs. The upper mesophotic zone typically extends to 60 m and comprises communities that are generally similar to those found in shallow reef systems. Below 60 m, the lower mesophotic zone is dominated by sponges and algae that are uncommon or absent from shallower areas, and a fish fauna that is largely specialized to these intermediate depths (Slattery et al 2011).
Mesophotic coral reefs have the potential to be refugia for shallow coral reef taxa and can be a source of larvae that could contribute to the resilience of shallow water reefs. Critical knowledge gaps are the connectivity between deep and shallow water coral reefs, and the potential refugia function of deep water reefs because disturbances in the upper 30m may leave deeper reefs intact (Lesser et al 2009). Ontogenetic movement and spawning migrations by reef fishes provide an important ecological component to connectivity between shallow and mesophotic reefs and may represent the effective range of larval dispersal. However, there is currently limited information on genetic connectivity between deep and shallow coral reef populations, and the role of mesophotic reefs in coral reef resilience (Slattery et al 2011). Understanding the sources and sinks of larvae for different populations on deep and shallow reefs

and the processes that connect those populations is essential to understand the ecology of mesophotic coral reefs and the potential refugia function of mesophotic reefs (Lesser et al 2009).

2.3.2 Mesopelagic habitat, species and nature values

Immediately below the epipelagic habitat lies the mesopelagic zone. In the upper part of this twilight zone (200m) is still some dim light, but not enough for photosynthesis. In the bottom of the twilight zone (1000m) there is no light at all. Most of the communities below the photic zone depend on the surface for food and for oxygen. Most organic material produced in the epipelagic zone gets eaten and about 20% sinks to the mesopelagic, therefor pelagic organisms become more scarce at greater depths. There are typically 5 or 10 times fewer organisms at 500m than at the surface, and perhaps 10 times fewer again at 4000m. In highly productive surface waters there is more mesopelagic life than in areas with low primary production. The deep sea has in most places sufficient supply of oxygen to support respiration, because it is constantly replenished by the thermohaline circulation (ocean circulation driven by differences in water density) and the great ocean conveyor (global water circulation patterns between ocean basins) (Castro and Huber 2008).

The mesopelagic is the zone where the main thermocline occurs (Fig. 2.9), so organisms that move up and down the water column encounter large temperature changes. The mesopelagic supports a rich and varied community of organisms, often called midwater animals. Zooplankton is much the same as in the epipelagic with copepods and krill as dominant groups. Squids are also prominent midwater organisms, some being planktonic and strong-swimming squid are part of the nekton. Nearly all midwater fishes are quite small, about 2 to 10 cm long. Bristlemouths and lanternfishes account for 90% or more of the fishes collected by midwater trawls, of which bristlemouths are the most common and one species (*Cyclothone signata*) is the most abundant fish on earth. Many other fishes live in the mesopelagic: viperfish, dragonfish, barracudina, sabertooth fish, lancetfish, snake mackerels are all long, eel-like fishes with large mouths and eyes. Most are less than 30 cm with very few exceptions: the lancetfish *Alepisaurus ferox* and the black scabbard fish *Aphanopus carbo* get about 2m and 1m respectively (Castro and Huber 2008).

Midwater organisms are adapted to the environment in a number of ways. It is thought that their small size is due to limited food supply. Large mouths with extendible jaws and often long, sharp teeth allow them to eat a wide range of prey. Large, light-sensitive eyes provide good vision in dim light. Camouflage is more important as defence strategy than fast swimming, so organisms in the upper mesopelagic tend to be transparent, whereas deeper in the mesopelagic, fishes tend to be more silvery and in the darkest parts often reddish. Bioluminescent photophores are another strategy to break up their silhouette and blend in with the background light from the surface (Castro and Huber 2008).

Midwater animals fall into two major groups: vertical migrators and non-migrators. Most non-migrating midwater fishes, shrimps and squids are sit-and-wait predators that have lost their swim bladder and have soft, weak bones to make them neutrally buoyant, allowing them to float at a constant depth without wasting energy. Most midwater organisms, such as lanternfishes, shrimps, squids, jellyfishes and copepods, make vertical migrations to feed at night in the rich surface layers. The fishes have well developed muscles and bones and have retained the swim bladder for buoyancy, however filled with fat instead of gas as that does not expand with pressure changes (Castro and Huber 2008).

2.3.3 Bathypelagic habitat, species and nature values

Below the mesopelagic habitat are the perpetually dark waters. The deep sea, from 1,000m and beyond, is the largest habitat on earth. The conditions in the deep sea hardly change, it is always dark and cold and salinity and other chemical parameters are also uniform. The deep sea is not completely dark as bioluminescence is common. The primary use of bioluminescence is not camouflage, but probably prey attraction and communication. Many deep sea organisms have functional eyes, but generally they are small because there is not even dim light. Since only about 5% of the food produced in the photic zone reaches the deep sea, most deep sea fishes have huge mouths. They lack functional swim bladders, hang in the water column and spend as little energy as possible. Besides food availability, the extremely high pressure in the deep sea is a major factor causing zonation in deep-sea pelagic organisms. Although there are adaptations in organisms, pressure probably limits the depth range of most organisms and the number of species declines going deeper. The pressure is also a reason why so little is known about the deep sea. Research instruments must be able to withstand the pressure and organisms die when brought to the surface (Castro and Huber 2008).

2.3.4 Deep sea floor habitat, species and nature values

The deep ocean floor shares many characteristics with the pelagic waters immediately above, but the benthic communities are very different from pelagic communities because of the presence of the bottom. Although a bit more research has been done of the deep ocean benthos, only about 500 m2 has been quantitatively sampled (Huber and Castro 2009). Food shortage is also critical on the deep sea floor, yet benthic organisms have more time to find it. Most of the deep sea floor is covered in fine, muddy sediment. Not all of the organic matter is immediately digestible, but bacteria decompose for example chitin. The meiofauna (tiny organisms living among the sediment particles) are the most abundant organisms and they graze on bacteria and dissolved organic matter. Macrofauna, dominated by deposit feeders in and on the sediment, graze on the meiofauna. Polychaete worms are usually the most abundant macrofauna, followed by crustaceans, bivalve molluscs, sea cucumbers, brittle stars and sea stars, although there is considerable variation from place to place (patchy distribution). Especially crustaceans can become very large, known as deep sea gigantism, the reverse of the usual trend of small size in deep water organisms. Besides the slow rain of food to the bottom there are occasional large pieces of food that sink rapidly, like dead fish or marine mammals. These are known as bait-falls. This is another important source of food to the benthos. Bottom scavengers are crustaceans, especially amphipods, and various fishes, such as grenadiers, cusk eels, deep sea spiny eels and hagfishes. Above 2,000m sharks may also show up at deep-sea bait falls.

2.3.5 Current knowledge on deep sea habitats and species of Bonaire

Surprisingly little is known about the biota of the deep reef and the epipelagic and mesopelagic zone. Nothing is known of the bathypelagic zone. Only two deep water submarine research expeditions were conducted on Bonaire (and Curaçao and Aruba): the first took place in May 2000, during which 24 dives were conducted with the Johnson Sealink II submersible of Harbor Branch at depths of 80-900m (Reed and Pomponi 2001) at an average 2.25km from shore (Debrot et al 2014); the second was the Bonaire Deep Reef Expedition in May 2013 exploring the lower epipelagic and upper mesopelagic zones at depths of 140-250m surrounding the islands of Bonaire and Klein Curaçao in the submersible Curasub of the Substation Curaçao (Becking and Meesters 2014).

The focus of the first expedition was on deep sea biodiversity and the discovery of biomedically interesting taxa, particularly of lithistid sponges which are a dominant group of hard-bottom macroinvertebrates at depths greater than 150m (Debrot et al 2014). The expedition did not result in species descriptions, with one exception: a member of the rare hexactinellid genus Verrucocoeloidea Reid, 1969, V. liberatorii was recently described by Reiswig and Dohrmann (2014). Later studies by Debrot et al (2014; in prep) analysed the video footage made during the expedition of all fish and seafloor debris. The expedition targeted areas of steep topography such as steep rock faces, large boulders and seamounts to maximize chances for benthic macroinvertebrates, as complex and steep topographic features typically possess more sponge and hydrocoral fauna. The distance covered per dive depended on how much macroinvertebrate fauna was encountered and how much collecting was done. Although generalizations on habitat features are therefore difficult, at depths above 100m hard substrate was dominated by coralline rock and below 100m volcanic rock abutted from the sandy slopes. From 80-300m steeper 30-60° rocky slopes dominated, while at depths greater than 300m slopes were generally

20-40° with muddy or sandy substrate (Debrot et al 2014). Debrot et al (in prep) has documented the occurrence of 45 deep reef and mesopelagic fish species based on in situ observations (Appendix B) and an additional 14 species from unpublished opportunistic catch records. None of these species are new to science, but a number of species are typical deep sea fish: Tripod fish (*Bathypterois viridendis*) is a deep-sea benthic predator, nearly blind these fishes sit on the bottom on their elongated fins, facing into the current and snapping up passing plankton (Castro and Huber 2008); Grenadiers (*Macrouridae sp.*), deepwater cardinalfish (*Epigonidae sp.*), Deep-sea scalyfin (*Bathyclupea sp.*) and Thorny tinselfish (*Grammicolepis braschiusculus*) are species observed in the mesopelagic zone around Bonaire.

The focus of the second expedition was to explore the floral and faunal diversity of the deeper reef of Bonaire. In Bonaire 3 dives were conducted (Fig. 2.10), two in the lower mesophotic zone of the epipelagic to maximum depths of 148m and 206m and one to a maximum depth of 248m, thereby also reaching the upper dysphotic zone of the mesopelagic. The dysphotic zone is the zone within which light penetration is such that oxygen consumption by respiration exceeds oxygen production by photosynthesis.
Habitats features observed during the three dives at Bonaire first of all showed a distinct depth zonation of the substrate: living coral reef was observed until approximately 45 m depth, followed by a zone of sand mixed with varying amounts of dead coral. Here rubble mounds of tilefish nests were also observed. From approximately 45-90m depth there was a zone of sand covered by cyanobacterial mats (Fig. 2.11). The only macrofauna observed in this zone were yellow gorgonians (Fig. 2.12) and small groups of garden eels in occasional patches of sand that were not covered by cyanobacteria. The depth from 90-100m was dominated by sand with occasional small rocks on which fan corals (Fig. 2.13) and sponges resided. Between 100 and 150 m depth fossil barrier reef formations (Fig. 2.14) and rodolith beds (nodules created by coralline algae, Fig. 2.15) were observed, either in long stretches or in patches within a barren sandscape. By providing hard substrate, these fossil reefs displayed a heightened biodiversity in a desert landscape of sand. Below 150 m the substrate was generally dominated by fine sand, with occasional rocks. The sponge assemblage below 100 m was dominated by rock sponges (lithistid Demospongiae) and glass sponges (Hexactinellida).

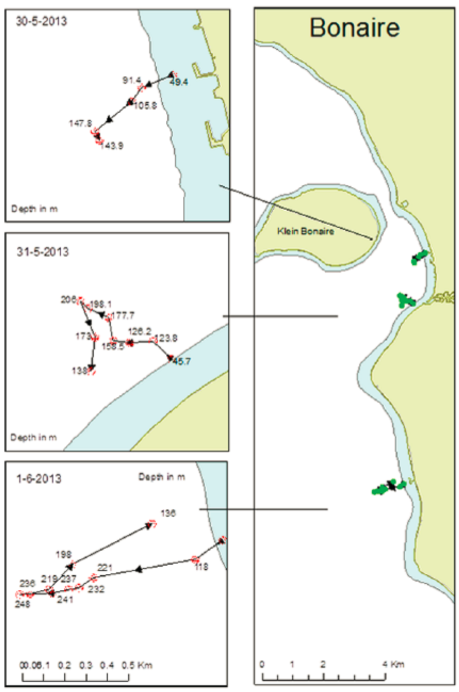


*Figure 2.10. Map showing the details of locations and course of the Curasub dives in the epipelagic and mesopelagic zone of Bonaire (*Becking and Meesters 2014*)*

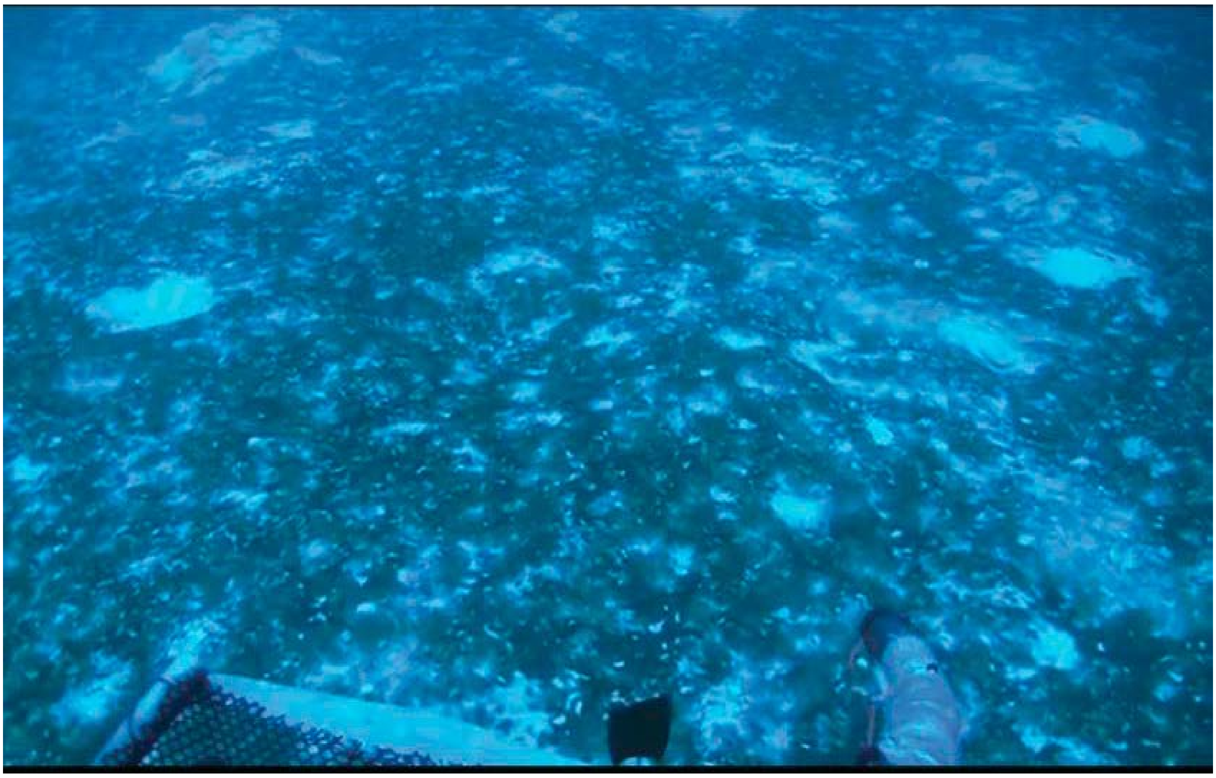


Figure 2.11. Cyanobacteria mats as seen from the sub during the first dive off Kralendijk (Becking and Meesters 2014)

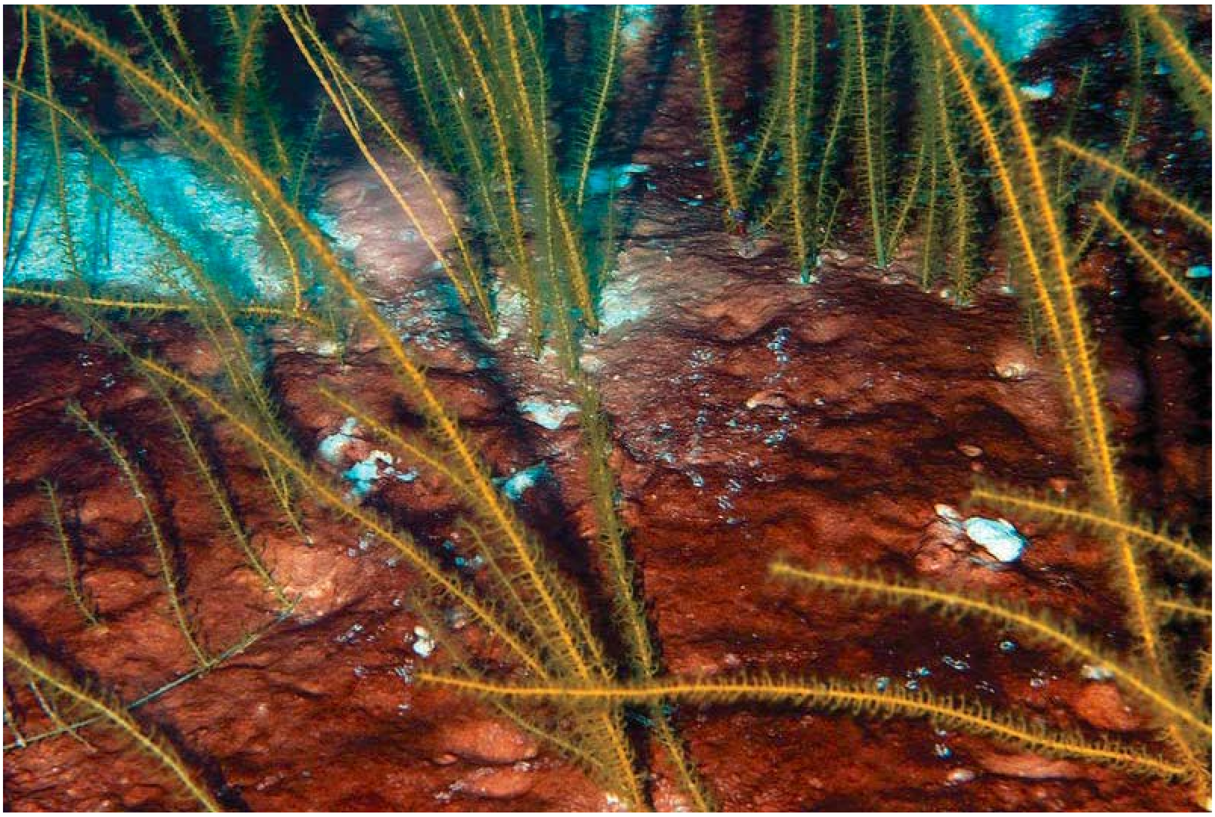


Figure 2.12. Close-up of cyanobacteria mat with soft corals (Leptogorgia virgulata) (Becking and Meesters 2014)

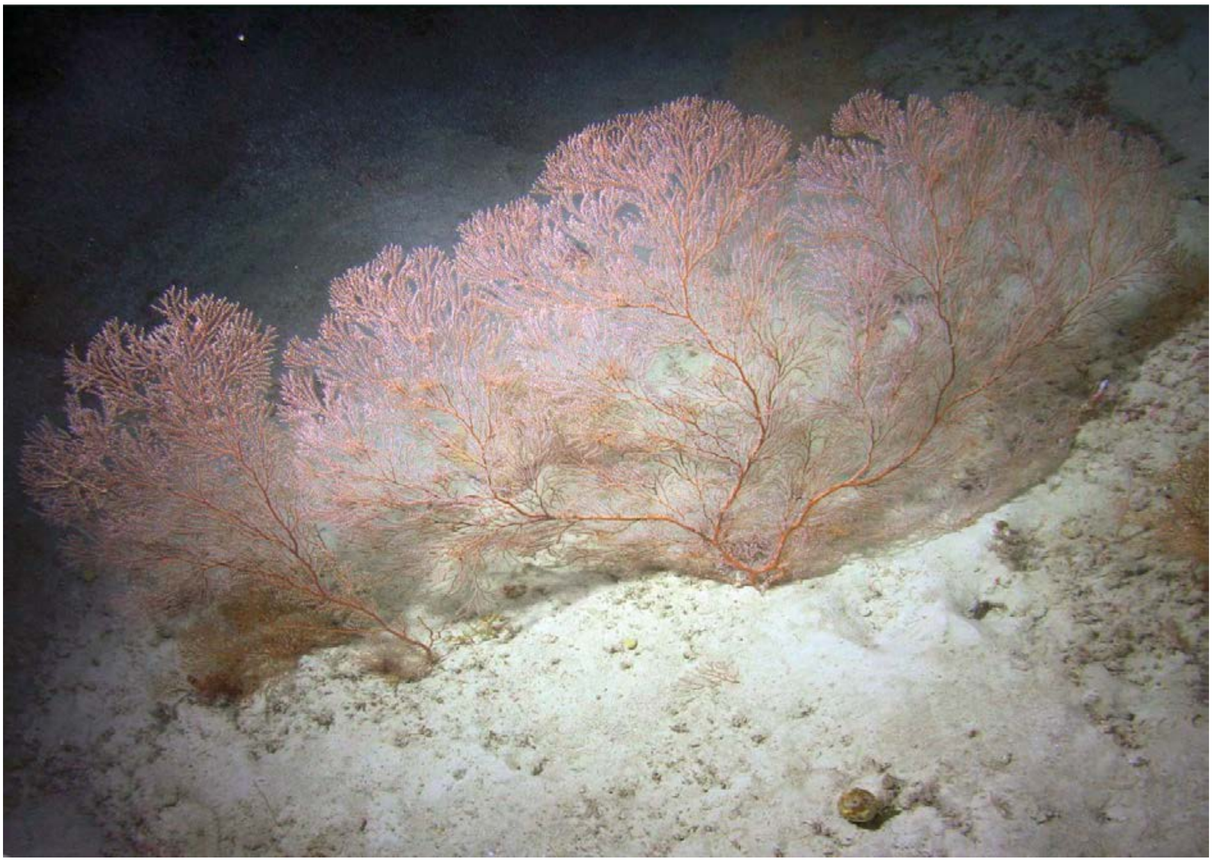


Figure 2.13. Gorgonian (Nicella guadalupensis) (Becking and Meesters 2014)

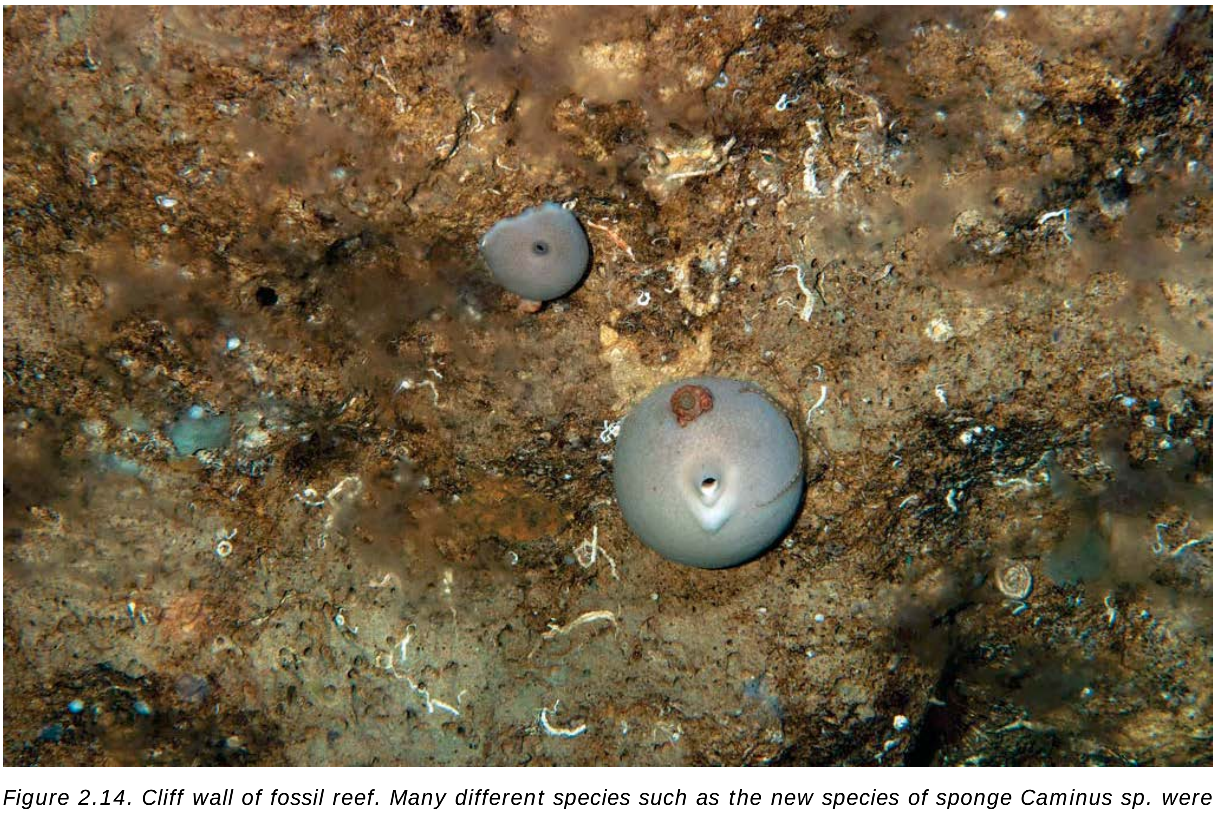


Figure 2.14. Cliff wall of fossil reef. Many different species such as the new species of sponge Caminus sp. were living on the wall (Becking and Meesters 2014)

Figuree 2.15. *Rhodoliths are structures that are formed by calcareous algae (Becking and Meesters 2014).*

In total 72 species were recorded (Appendix C), which is a subset of the true biodiversity of Bonaire's deep reef. At least 17 species new to science were discovered: sponges, shrimp and fish. The major focus was on sponges due to their importance in the deep reef in terms of diversity, filtering activities, biomass, and source of pharmaceutical compounds. Research in these practically unexplored depths will undoubtedly lead to the discovery of many more novel species. For example, as part of the Smithsonian Deep Reef Observation Project in Curacao, Baldwin and Robertson (2013) described a new deepwater blennoid fish species from the Dutch Caribbean. It is estimated that between 1-10 million species reside in the sea, of which at least one third is still undescribed (Mora et al. 2011, Appeltans et al. 2013 in Becking and Meesters 2014).

The 17 species new to sciences included 13 sponges, 1 crustacean and 3 fish species (Appendix C). Also an euretid hexactinellid was collected, which belongs to the rare genus *Verrucocoeloidea*, recently described as *V. liberatorii* by Reiswig and Dohrmann (2014). The habitat investigated, steep limestone rocks, likely representing Pleistocene fossil reefs, is similar to deep-water fossil reefs at Barbados of which the sponges were sampled and studied by Van Soest and Stentoft (1988). A comparison is made between the two localities, showing a high degree of similarity in sponge composition: 53% of the present Bonaire-Klein Curaçao species were also retrieved at Barbados. At the level of higher taxa (genera, families) Bonaire-Klein Curaçao shared approximately 80% of its lower mesophotic and upper dysphotic sponge fauna with Barbados, despite a distance between them of 1000 km. This indicates high faunal homogeneity. In contrast a preliminarily comparison of the shallow-water (euphotic) sponge fauna of Curaçao with the combined data available for the Barbados, Bonaire and Klein Curaçao mesophotic and upper dysphotic sponges, showed that the two faunas show only little overlap.

3. Conclusions and recommendations

The objective was to determine the existence of potential nature values in the 12 miles zone based on the following criteria:

Physical oceanographic features such as important surface oceanic currents, deep ocean currents, upwellings and tidal currents
Our study describes important upwelling areas 4° W and 4° E from Bonaire, off the coast of Colombia to the west and Venezuela to the east. Although the Southern Caribbean upwelling system is of major importance it is not within the 12 miles zone of Bonaire, so this is not an argument to strengthen the OUV of BNMP.

Geomorphological features such as rare, untouched and undisturbed structures
There are two geological features described in this study: 1) The Curaçao Ridge, an active subduction zone on the margin of the South American continental plate, located 17nM north from the 12 miles zone, but within the EEZ of Bonaire. 2) the island arc of the Leeward Antilles (Los Monjes, Aruba, Curaçao, Bonaire, Las Aves, Los Roques, and La Orchila), exposures of a largely submarine ridge whose pre-middle Eocene rocks suggest an island arc. Another potential geological feature are offshore seamounts: from anecdotal accounts of fishermen it appears that there exists a large seamount (at least 1 km^2) is rising from the seafloor to approximately 200m below the surface. The location is a few km N-NE from Boca Spelonk. These structures likely concentrate rare species like deep-water sharks and deep-diving cetaceans and are likely to be biodiversity hotspots. However, as yet the existence of this site and its likely biodiversity value have not been documented.
It would require considerable research into grey literature such as historic cruise reports to try to collect more information on the Curaçao Ridge and the Leeward Antilles island arc. It is questioned here if these geological phenomena are feasible to use as attributes under criterion viii [1], mainly because of the efforts and costs involved to prove geological heritage through further research. Furthermore, the Curaçao Ridge and the Leeward Antilles island arc are transboundary sites, and would require a joint nomination. Finally, the Curaçao ridge is outside the boundaries of the 12 miles zone, so an extension of the nomination property to the EEZ of Bonaire would be needed. It may be worthwhile investigating the biodiversity, habitat and structure of the main and several other potential offshore sea mounts within the 12 miles zone of Bonaire. An excellent opportunity would be to request the Netherlands Hydrographic Service to conduct their upcoming bathymetric survey which is planned to take place at the end of 2016 (A. Meurink, pers. comm.) in the 12 miles zone and EEZ of Bonaire.

Species which are rare or threatened, key species or characteristic species for the ecosystem
Two studies of the deeper reef of Bonaire resulted in 16 species new to science at depths of 45-245m: 13 sponges, 2 fish and 1 shrimp species. No deep sea fish species endemic to Bonaire were identified, although some (Catshark spp.) may be endemic to the Southern Caribbean Ecoregion of which Bonaire is part. The coastal waters of Venezuela and Colombia in the Southern Caribbean Ecoregion are known as areas of endemism with quite different species composition and hotspots for marine biodiversity. Since the Southern Caribbean Ecoregion is not yet represented as World Heritage Site (Van Beek et al 2014), the uniqueness of the ecoregion will strengthen the OUV if it is described in greater detail. However, this would also requires a lot of research into grey literature sources. The 16 species new to science alone, will not be sufficient for OUV as these species may not be unique to Bonaire. The importance of the 12

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[1] *Criterion viii: to be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features (UNESCO 2013)*

miles zone for migratory species such as the threatened sea turtles, sharks and marine mammals can be used as attributes under criterion x [2], whereby the emphasis should be on the presence of crucial habitats. The Yarari reserve is a strong argument for the integrity of the property to maintain healthy shark and marine mammal populations. However, little is documented about the diversity, abundance and distribution of sharks (Van Beek et al 2013) and marine mammals (Debrot et al 2011, Geelhoed et al 2014). Further research would be recommended on abundance, distribution and habitat use of sharks and marine mammals through i.e. acoustic surveys and BRUV (Baited Remote Underwater Video) fish surveys.

Common fish and benthic species (which are not yet inscribed in a WHS)
Rhodoliths and crustose coralline algal reefs are both structures formed by calcareous algae and worldwide one of the world's four largest macrophyte-dominated benthic communities together with kelp forests, seagrass beds and coralline algal reefs. Although common throughout the world these two phenomena could be used as attributes to criterion ix [3] and thereby strengthen the OUV, especially if these phenomena are not yet inscribed as attributes by other World Heritage Sites. Rhodoliths were discovered on the Bonaire Deep Sea Expedition I and crustose coralline algal reefs are known to be present i.e. at the entrance to Lac on the east coast of Bonaire (Zaneveld 1958).

Potential ecosystem services
The refugium function of the mesopelagic reef and the ecological connectivity with the shallow coral reef can be used as an attribute under criterion ix. Although the scientific evidence is still lacking and requires further research, the inclusion of the 12 miles zone is likely to strengthen the OUV in terms of larval replenishment for genetic and population integrity of coastal resources. Upstream larval replenishment has been described in Van Beek et al (2014) as attribute under criterion ix.

The overall conclusion is that inclusion of the 12-mile zone certainly possesses potential to strengthen the OUV of the BNMP, especially in terms of new and likely unique biodiversity but that at present the information available is too little and too indirect to allow definitive substantiation of the OUV. of the 12 mile-zone of Bonaire.

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[2] *Criterion x: to contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation (UNESCO 2013)*

[3] *Criterion ix: to be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals (UNESCO 2013)*

4. Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 187378-2015-AQ-NLD-RvA). This certificate is valid until 15 September 2018. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V.

Furthermore, the chemical laboratory at IJmuiden has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation. The chemical laboratory at IJmuiden has thus demonstrated its ability to provide valid results according a technically competent manner and to work according to the ISO 17025 standard. The scope (L097) of de accredited analytical methods can be found at the website of the Council for Accreditation (www.rva.nl).

On the basis of this accreditation, the quality characteristic Q is awarded to the results of those components which are incorporated in the scope, provided they comply with all quality requirements. The quality characteristic Q is stated in the tables with the results. If, the quality characteristic Q is not mentioned, the reason why is explained.

The quality of the test methods is ensured in various ways. The accuracy of the analysis is regularly assessed by participation in inter-laboratory performance studies including those organized by QUASIMEME. If no inter-laboratory study is available, a second-level control is performed. In addition, a first-level control is performed for each series of measurements.
In addition to the line controls the following general quality controls are carried out:

- Blank research.
- Recovery.
- Internal standard
- Injection standard.
- Sensitivity.

The above controls are described in IMARES working instruction ISW 2.10.2.105. If desired, information regarding the performance characteristics of the analytical methods is available at the chemical laboratory at IJmuiden.

If the quality cannot be guaranteed, appropriate measures are taken.

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6. Justification

Report: C026/16
Project Number: 4318100045

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of IMARES.

Approved: Dr. A.O. Debrot

Signature:

Date: 18 march 2016

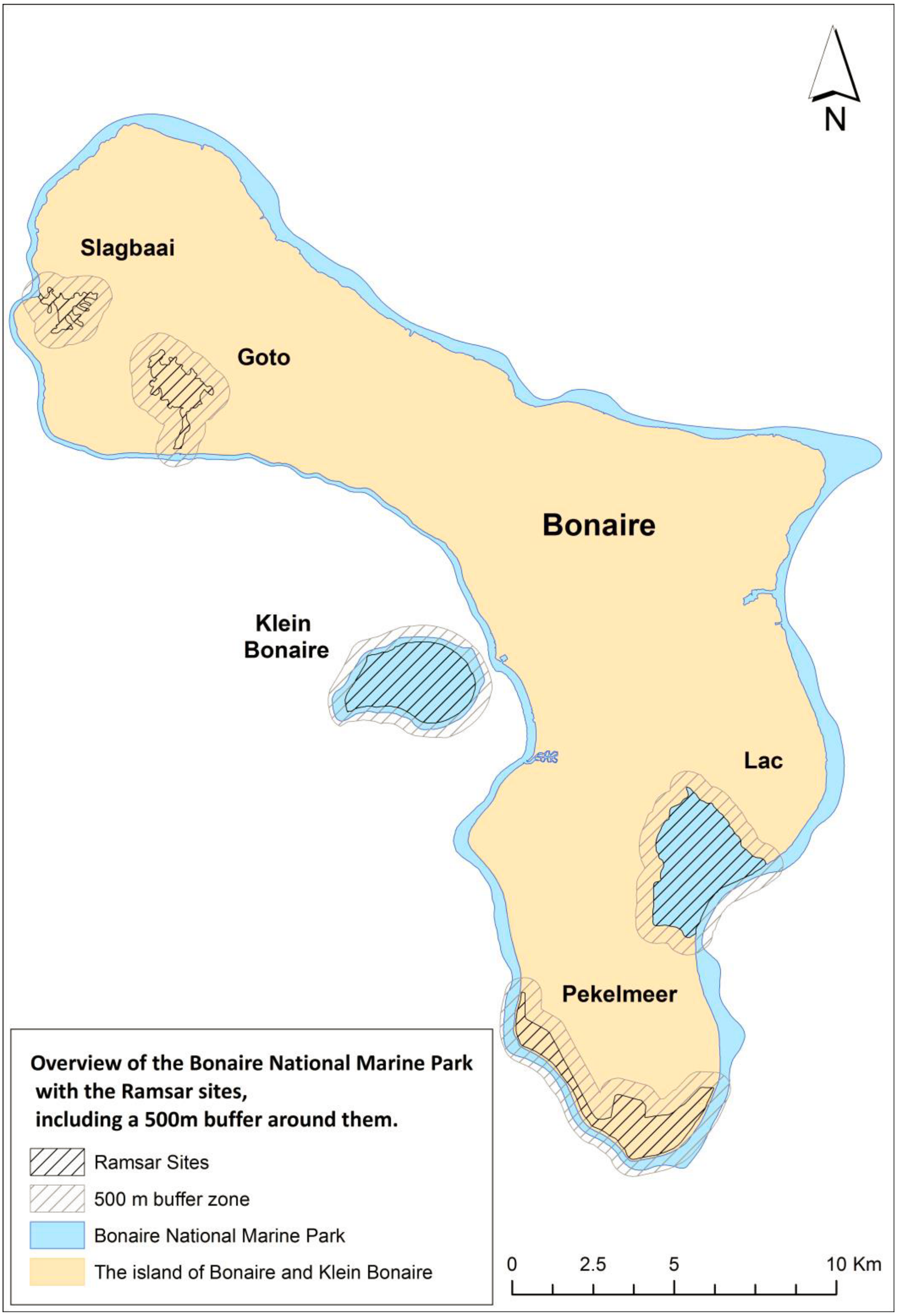
Approved: Dr.ir. T.P. Bult

Signature:

Date: 18 march 2016

Appendix A: Map of Bonaire National Marine Park

Bonaire National Marine Park boundaries (serial sites Bonaire and Klein Bonaire) and Ramsar site boundaries and buffer zones, of which Lac and Klein Bonaire are within the Bonaire Marine Park boundaries and saliñas Pekelmeer, Gotomeer and Slagbaai are located adjacent to the Bonaire Marine Park.



Appendix B: Fish species observed in the deep sea expedition of May 2000

Depth zone (m)		50 - 75		75 - 100		100 - 200		200 - 300		300 - 400		400 - 500		500 - 600		600 - 700		700 - 800		800 - 900	
Number of sites sampled (N)		5		10		13		14		12		11		8		7		4		2	
# specimens (A)/ # sites (S) encountered		(A)	(S)	(A)	(S)	(A)	(S)	(A)	(S)	(A)	(S)	(A)	(S)	(A)	(S)	(A)	(S)	(A)	(S)	(A)	(S)
Spec #	Species name*																				
	Elasmobranchii																				
Carcharhiniformes																					
Scyliorhinidae																					
1	*Apristurus sp. 1*																			1	1
2	*Apristurus sp. 2*																			1	1
3	*Apristurus sp. 3*																			1	1
4	*Parmaturus campechiensis* (Campeche catshark)																	1	1		
Hexanchiformes																					
Hexanchidae																					
5	*Hexanchus griseus* (Bluntnose Sixgill shark)									3	3										
Squaliformes																					
Squalidae																					
6	*Squalus cubensis* (White tip shark)									1	1										
	Actinopterygii																				
Anguilliformes																					
Muraenidae																					
7	*Gymnothorax maderensis* (Sharktooth moray)					2	2	4	4	1	1										
Aulopiformes																					
Ipnopidae																					
8	*Bathypterois viridensis* (Tripod fish)																			2	2
Synodontidae																					
9	*Synodus sp.* (Lizardfish)									1	1										
Beryciformes																					
Holocentridae																					
10	*Holocentrus sp.* (Squirrelfish)	8	1																		
11	*Ostichthys trachypoma* (Bigeye soldierfish)					5	2	8	6												
Trachichthyidae																					
12	*Gephyroberyx darwinii* (Darwin's slimehead)			3	1			9	2	5	2	3	2	2	1	1	1				
13	*Hoplosthetus sp.* (Slimeheads)									2	2										
Gadiformes																					
Macrouridae																					
14	*Coryphaenoides sp.* (Rattail)																	1	1		
15	*Macrocephalus laevis* (Softhead grenadier)																	1	1		
16	Macrouridae sp.																	1	1		
17	*Nezumia aequalis* (Common Atlantic grenadier)															1	1				
Lophiiformes																					
Chaunacidae																					
18	*Chaunax sp.* (Sea Toad)															1	1				
Polymixiiformes																					
Polymixiidae																					
19	*Polymixia sp. 1* (Beardfish)									1	1										
20	*Polymixia sp. 2* (Beardfish)											1	1								
Perciformes																					
Acropomatidae																					
21	*Acropomatid sp.* (Lanternbellie)									1	1	1	1								
Bathyclupeidae																					
22	*Bathyclupea sp. 1* (Deep-sea scalyfin)															1	1				
23	*Bathyclupea sp. 2* (Deep-sea scalyfin)													1	1						
24	*Bathyclupea sp. 3* (Deep-sea scalyfin)															1	1				
Bramidae																					
25	*Eumegistus brevorti* (Tropical pomfret)									1	1										
Caproidae																					
26	*Antigonia capros* (Deepbody boarfish)					7	3	8	7												
Carangidae																					
27	*Caranx lugubris* (Black jack)							3	2												
28	*Seriola rivoliana* (Longfin yellowtail)					21	2														
Chaetodontidae																					
29	*Chaetodon sedentarius* (Reef butterflyfish)	9	3	2	1																
Epigonidae																					
30	*Epigonidae sp.* (Deepwater cardinalfish)									4	4			1	1						
Haemulidae																					
31	*Haemulon striatum* (Striped grunt)	50+	1																		
Lutjanidae																					
32	*Etelis oculatus* (Queen Snapper)							1	1												
33	*Lutjanus buccanella* (Blackfin snapper)	1	1	2	1	2	1														
Pomacanthidae																					
34	*Pomacanthus paru* (French angelfish)	1	1																		
Serranidae																					
35	*Chromis insolata* (Sunshine fish)	15	2	5	1																
36	*Gonioplectrus hispanus* (Spanish flag)	3	1			1	1														
37	*Acanthostracion polygonius* (Honeycomb cowfish)	1	1																		
38	*Mycteroperca bonaci* (Black grouper)	1	1																		
39	*Paranthias furcifer* (Creole fish)	26	2	11	1																
40	*Pronotogrammus martinicensis* (Roughtongue bass)					5	3														
41	*Serranus notospilus* (Saddle bass)					1	1														
Symphysanodontidae																					
42	*Symphysanodon octoactinus* (Insular bunquelovely)					2	1														
Syngnathiformes																					
Fistulariidae																					
43	*Fistularia sp.* (Cornetfish)							1	1												
Scorpaeniformes																					
Scorpaenidae																					
44	*Pontinus longispinus* (Longspine scorpionfish)							1	1	1	1										
Zeiformes																					
Grammicolepididae																					
45	*Grammicolepis braschiusculus* (Thorny tinselfish)											1	1								
Total number of species:			10		5		9		8		11		4		3		5		4		4

* Sharks identified from video by D. Ebert, macrourids by T. Iwamoto, and all other fishes by D. R. Robertson

Appendix C: Fauna observed and discovered at the Bonaire Deep Reef Expedition 2013

Table 1 List of observed and collected sponge species (Becking and Meesters 2014)

Class	Order	Family	Species
Demospongiae	Agelasida	Agelasidae	*Agelas flabelliformis*
	Astrophorida	Geodiidae	*Caminus* **new species**
	Astrophorida	Pachastrellidae	*Characella aspera*
	Astrophorida	Pachastrellidae	*Characella* **new species**
	Astrophorida	Pachastrellidae	*Pachastrella* sp. aff. *abyssi*
	Halichondrida	Heteroxyidae	*Parahigginsia* **new species**
	Halichondrida	Axinellidae	*Phakellia folium*
	Halichondrida	Halichondriidae	*Spongosorites ruetzleri*
	Halichondrida	Halichondriidae	*Topsentia pseudoporrecta*
	Haplosclerida	Phloeodictyidae	*Calyx* **new species**
	Haplosclerida	Phloeodictyidae	*Siphonodictyon viridescens*
	Haplosclerida	Petrosiidae	*Neopetrosia* **new species 1**
	Haplosclerida	Petrosiidae	*Neopetrosia* **new species 2**
	Homosclerophorida	Plakinidae	*Plakinastrella* **new species**
	Lithistida	Scleritodermidae	*Aciculites cribrophora*
	Lithistida	Corallistidae	*Corallistes typus*
	Lithistida	Neopeltidae	*Daedalopelta nodosa*
	Lithistida	Theonellidae	*Discodermia dissoluta*
	Lithistida	Theonellidae	*Discodermia* **new species**
	Lithistida	Siphonidiidae	*Gastrophanella implexa*
	Lithistida	Azoricidae	*Leiodermatium lynceus*
	Lithistida	Neopeltidae	*Neopelta perfecta*
	Lithistida	Theonellidae	*Theonella atlantica*
	Poecilosclerida	Acarnidae	*Acarnus* **new species**
	Poecilosclerida	Microcionidae	*Antho (Acarnia)* **new species**
	Dendroceratida	Darwinellidae	*Aplysilla* sp
	Poecilosclerida	Hamacanthidae	*Hamacantha* sp.
	Haplosclerida	Chalinidae	*Haliclona* sp.
Hexactinellida	Hexactinosida	Tretodictyidae	*Cyrtaulon sigsbeei*
	Hexactinosida	Dactylocalycidae	*Dactylocalyx pumiceus*
	Hexactinosida	Euretidae	*Verrucocoeloidea* **new species**
Unidentified			Encrusting 1 (unidentidied)
			Encrusting 2 (unidentidied)
			Encrusting 3 (unidentidied)
			Encrusting 4 (unidentidied)

Table 2 List of observed and collected crustacean species (Becking and Meesters 2014)

Order	Family	Species
Decopoda	Palaemonidae	*Pseudocoutierea* **new species**
		Majid crab
Decopoda	Pandalidae	*Plesionika longicauda*
Decopoda	Disciadidae	*Discias vernbergi*
Decopoda	Hippolytidae	*Lysmata* aff. *olavoi*
Decopoda	Palaemonidae	*Periclimenes pandionis*

Table 3 List of observed and collected fish species (Becking and Meesters 2014)

Order	Family	Species
Anguilliformes	Muraenidae	*Gymnothorax moringa*
Perciformes	Apogonidae	*Apogon affinis*
Perciformes	Apogonidae	*Apogon pillionatus*
Perciformes	Apogonidae	*Apogon pseudomaculatus*
Perciformes	Gobiidae	*Antilligobius nikkiae*
Perciformes	Gobiidae	Gobiidae 1 **new species**
Perciformes	Gobiidae	Gobiidae 2 **new species**
Perciformes	Grammatidae	Lipogramma evides
Perciformes	Serranidae	*Choranthias* sp. **new species**
Perciformes	Serranidae	*Serranus notospilus* or *S. phoebe*
Scorpaeniformes	Scorpaenidae	Scorpaenidae 1
Scorpaeniformes	Scorpaenidae	Scorpaenidae 2
Scorpaeniformes	Scorpaenidae	*Pterois volitans*

Table 4 List of observed and collected octocoral species (Becking and Meesters 2014)

Order	Family	Genus
Alcyonacea	Ellisellidae	*Nicella guadalupensis*
Alcyonacea	Ellisellidae	*Ellisella* sp.
Alcyonacea	Gorgoniidae	*Leptogorgia virgulata*
Alcyonacea	Nephtheidae	*Stereonephthya* sp.
Alcyonacea	Nidaliidae	*Nidalia* sp.
Alcyonacea	Nidaliidae	*Chironephthya* sp.
Alcyonacea	Plexauridae	*Bebryce Cinerea*
Alcyonacea	Plexauridae	*Hypnogorgia pendula*
Alcyonacea	Plexauridae	*Thesea guadalupensis*
Alcyonacea	Primnoidae	*Callogorgia gracilis*
Antipatharia	Antipathidae	*Stichopathes* sp.
Antipatharia	Myriopathidae	*Cupressopathes gracilis*
Pennatulacea	Kophobelemnidae	*Sclerobelemnon* sp.

Table 5 List of observed and collected hard coral species (Becking and Meesters 2014)

Order	Family	Species
Scleractinia	Caryophylliidae	*Caryophyllia* sp.
Scleractinia	Caryophylliidae	*Thalamophyllia riisei*
Scleractinia	Caryophylliidae	*Desmophyllum dianthus*
Scleractinia	Dendrophylliidae	*Balanophyllia* sp.
Scleractinia	Flabellidae	*Javania* sp.
Scleractinia	Stylasteridae	*Stylastra* sp.