Environment and development
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Saba, Netherlands Antilles

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In comparison to other CARICOMP sites, the tiny island of Saba, in the Windward Islands arc of the Lesser Antilles, can be described as atypical in terms of its topography, geology, and marine environment. Saba has a small human population and anthropogenic impacts on the nearshore marine environment are limited. Sedimentation, dive tourism, and fishing are the three main impacts in coastal waters. Saba is devoid of mangrove stands; Thalassia seagrass beds and coral communities are restricted to a narrow shelf and offshore seamounts. CARICOMP sampling occurs only at one reef area on the leeward west coast. Physical oceanographic data are available for this site, and meteorological data are available for the island. Benthic composition is described based on CARICOMP surveys carried out to date and on a baseline monitoring program that was executed in 1993 as part of a study for the Saba Marine Park.

Introduction

Saba is located in the northeastern Caribbean (17°36'59'N, 63°15'09''W), part of the Windwards Islands and the Netherlands Antilles. The island has an area of 13 km^2 and a maximum elevation of 866 m above sea level, resulting in an extremely mountainous topography. Saba has a small population, approximately 1200 inhabitants, and for the most part, access to the ocean from the population centers is impossible because of the steep slopes of the mountain. Typically, supplies to the island and access to the ocean is only via Cove Bay, Fort Bay, Ladder Bay, and Wells Bay (Fig. 1). The nearshore marine environment (from the high tide mark to the 60 m depth contour) is a protected area maintained under the auspices of the Saba Marine Park.

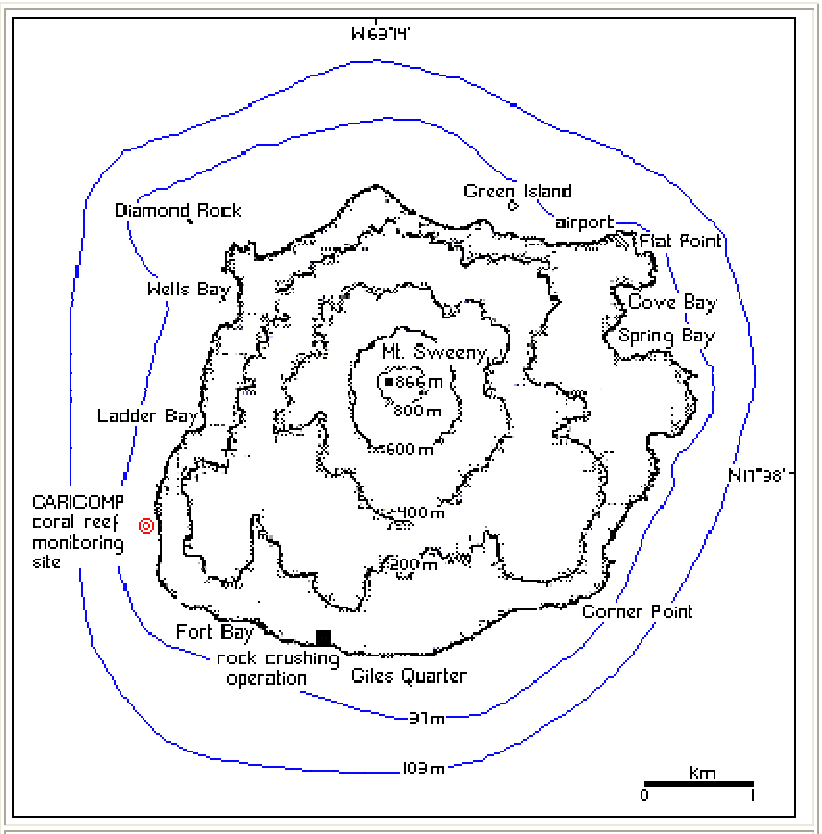

Fig. 1. Map of Saba, Netherlands Antilles, showing CARICOMP and other relevant sites.

With population centers on the island lying at least 240 m above sea level, direct human impacts on the marine resources are limited. There is little industry on the island and no significant agriculture. Thus, effluents such as pesticide and industrial chemicals are nonexistent. The three main impacts on the marine environment are sedimentation, dive tourism, and fishing.

Sedimentation comes from a rock-crushing plant in the Fort Bay area and from natural runoff during heavy rains. At the end of 1995, a large-scale operation to export rocks and sand was initiated at the rock-crushing site. This has added significantly to the amount of sedimentation on Tent Reef and other sites in the southwest portion of the island. Natural runoff is significant and for the most part discharges directly into the ocean because of the steep slopes of the island, which are made up of loose agglomerates. In most places, the slopes are separated from the ocean by a thin fringing boulder beach.

The economy of Saba is dependent on tourism; 66% is dive related. The Saba Marine Park, which surrounds the entire island, hosts about 5,000 divers per year who carry out approximately 25,000 dives. Undoubtedly some damage results from diving activities, although this is limited and has been decreasing since 1993. Roberts *et al.* (1993) reported damage to 3.2% of coral colonies close to marine park mooring lines at the study sites (high use areas 0-20 m from mooring) and to 2.4% of colonies in low use areas (40-60 m from mooring). The number of divers visiting Saba is slowly increasing. The results of a 1996 study of the carrying capacity of the park are not yet

available but will be used to reduce or alleviate development and diving pressure on the marine ecosystem.

Various studies have assessed the impact of fishing on the surrounding reefs (Polunin and Roberts, 1993; Roberts *et al*., 1993; Roberts, 1995; Roberts and Hawkins, 1995). Within the no-fishing zone of the marine park (the coral reef site is also located in this area), fish biomass was greater for five commercially fished families than in the fishing zones. Between 1991 and 1995, overall biomass of commercially important families increased by over 60%. Fish populations within the study site are healthy.

To date the island government , on the advice of the Saba Marine Park, has declined proposals for coastal development. However, with future political changes there may be pressure to develop a marina and hotel/dive resort in the southern part of the island at Giles Quarter. According to island law, all coastal developments must be preceded by an independent environmental impact assessment.

Island and Marine Geology

Saba is a single, composite, dormant volcano (Westermann and Kiel, 1961) rising from depths of 600 m (Roos, 1971). The island consists of a main peak surrounded by several individual peaks and domes. The slopes of the main mountain are characterized by numerous relatively straight V- and U-shaped valleys, locally known as guts. The petrological composition of the island has been described by Baker *et al.* (1977) as mostly andesites (volcanic boulders) formed through processes such as fractionation and magmatic mixing from both mantle and crustal sources. The relatively narrow shelf of the island is principally remnants of the abraded volcano, consisting of boulders that have slid from the eroded walls over time (Zonneveld, 1977; Van't Hof *et al*., 1991). There is no permanent running water on the island, but during heavy rains the guts act as channels carrying water and sediments directly to the ocean.

The bathymetry of Saba is characterized by nearshore dropoffs at Flat Point, Spring Bay, and Corner Point (Deslarzes, 1994). Within 60 m depth limits, the shelf surrounding Saba is typically 300-500 m wide; at its widest point north of the island, the shelf measures approximately 1,000 m.

Reef development in the Windward Islands (St. Maarten, St. Eustatius, and Saba) of the Antilles is poor in comparison to those of the Leeward Islands (Curaçao and Bonaire). According to Bak (1977), coral communities are common in the Dutch Windward Islands but no structural reefs were observed. Contrary to this observation, Van't Hof *et al.* (1991) suggested that, overall, coral communities around Saba are made up of encrusted andesites and rock, but noted that true biogenic reef does exist in one location — at the Giles Quarter reef complex (Fig. 1). Approximately 1.8 km off the western coast of Saba lies the third category of coral communities common to Saba, described by Van't Hof *et al*. as seamounts and pinnacles. Bak (1977) and Deslarzes (1994) described 33 and 30 hermatypic coral species, respectively, in comparison to the 50 found in the leeward Netherlands Antilles. According to Deslarzes (1994), mean hard coral cover in Saba on average ranges from 7.8% to 21.9% and reaches 29% in some reef areas; 11 coral species were common throughout

his sample sites: *Agaricia* spp., *Colpophyllia* spp., *Diploria labyrinthiformis*, *Diploria strigosa*, *Madracis decactis*, *Millepora* spp., *Montastraea annularis*, *Montastraea cavernosa*, *Porites astreoides*, *Porites porites*, and *Stephanocoenia michelinii*. Of these, *Montastraea annularis* was most dominant overall, followed by *Agaricia* spp., *Millepora* spp. and *Diploria strigosa*.

Saba lacks mangrove stands and *Thalassia* seagrass beds because of its exposed coast. There is a small patch of *Syringodium* east of Fort Bay, a remnant of a large bed which once existed but was affected by sedimentation from the rock-crushing plant adjacent to this area. There are other small patches of *Syringodium* on the leeward western coast of the island.

Climate and Oceanography

The mean annual rainfall on Saba is approximately 1,000 mm (Westermann and Kiel, 1961). The dry season is normally between December and July, and precipitation varies depending on altitude and exposure to the eastern tradewinds. Annual rainfall has been known to exceed 1,920 mm on the higher windward slopes and the summit of the island. Data collected from January 1992 through December 1995 show an average rainfall of 776.8 mm annually (Table 1). This is far below the figures quoted by Westermann and Kiel (1961) and is an indication of the serious drought that occurred in Saba in 1994. Variation in rainfall intensity over the small area and different elevations of the island may partly account for the low readings.

Table 1. Rainfall data (mm) for Saba, Netherlands Antilles, 1992-1995.

	1992	1993	1994	1995
January	71.4	66.6	22.8	22.7
February	19.6	30.8	44.8	30.6
March	93.0	46.4	6.0	30.7
April	117.7	78.3	16.0	64.1
May	140.9	213.3	12.3	71.3
June	28.4	38.8	70.2	39.6
July	48.5	72.8	15.0	35.8
August	54.5	49.10	60.8	79.1
September	30.2	68.5	57.3	300.5
October	30.2	63.2	58.2	34.4
November	191.3	68.3	56.2	127.3
December	53.0	62.6	32.3	73.7
Total Annual Rainfall	878.7	858.7	451.9	909.8

Saba is located within the hurricane belt and has been exposed to numerous tropical storms and hurricanes, the most significant being Hugo in 1989 and Luis in 1995. The prevailing wind is from the southeast and, since 1988 (only records available), has averaged 5.6 m s^{-1}. Because of Saba's exposure, sea conditions in the south and east

are usually rough. Air temperatures vary from monthly maxima exceeding 33°C in June-August, to monthly minima less than 25°C in January-March (Table 2).

Table 2. Maximum and minimum air temperatures (°C) on Saba, October 1992 through December 1995.

	1992		1993		1994		1995	
	max	min	max	min	max	min	max	min
January			26.2	24.3	27.1	28.8	27.8	23.9
February			27.0	24.2	26.2	23.5	28.9	24.2
March			28.0	24.1	28.2	24.0	28.0	23.9
April			31.8	24.9	30.4	25.5	31.3	25.7
May			32.8	25.0	33.9	27.2	32.5	27.8
June			34.4	26.2	34.3	27.0	34.0	29.8
July			34.7	26.3	33.8	27.8	32.1	28.9
August			35.0	27.1	33.4	28.3	33.0	27.8
September			34.1	26.2	32.0	27.2	31.9	28.0
October	31.6	25.9	33.7	25.9	30.5	27.1	30.0	26.0
November	28.3	25.0	28.3	26.1	29.7	26.4	28.9	25.2
December	27.0	25.0	27.7	25.0	27.8	24.9	28.1	24.3

With Saba's exposed nature, narrow shelf and surrounding deep water, strong currents and rough seas (1-2 m average wave height) are prevalent around most of the island. Information on ocean currents is limited; there have been no field investigations to date, and available data are inconclusive. The intensity of the prevailing southeasterly winds makes for rough seas on the southern and eastern coasts of the island for much of the year. From November to March, powerful swells that originate in the North Atlantic impact the leeward western side of the island.

Although no tidal data have been recorded for Saba, it may be possible to estimate tidal variations from data recorded on adjacent islands. From 45 tide gauge locations in the Caribbean, Kjerfve (1981) concluded that, for the most part, the Caribbean has a microtidal range of 10-20 cm. Saba is located in an area with a predominantly mixed diurnal tide, with a mean tidal range of 15 cm.

Coral Reef Site

The CARICOMP coral reef monitoring site is located at 17° 37'34.0"N, 63° 15' 35.5"W (Fig. 1 and Fig. 2) on the leeward western coast of the island about 100 m north of a dive mooring in an area known as the Ladder Labyrinth. The transects are 100 m from the shore on a reef characterized by parallel coral ridges separated by sand channels. Van't Hof *et al.* (1991) hypothesized that coral colonies in this area, which originally encrusted a volcanic boulder substrata, have fused to form a reef structure.

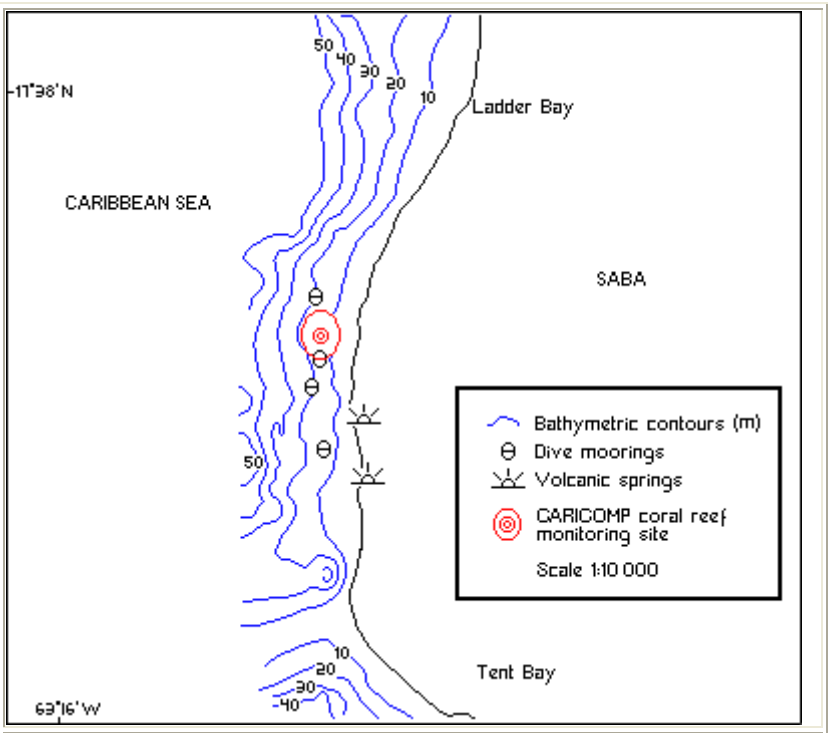

Fig. 2. Map showing the CARICOMP coral reef monitoring site on the west coast of Saba, Netherlands Antilles.

This site has been characterized as a spur-and-groove reef. According to Deslarzes (1994), there is an average hard coral coverage of 24.3% ± 3.8 (SD). Impacts on this area are limited to sedimentation and recreational diving. Some volcanic hot springs occur near the shore but, according to seawater temperatures collected at this site, there are no unusually high temperatures. CARICOMP surveys to date have shown that the reef benthos is dominated by fleshy algae, turf algae, and sand. The dominant hard coral species are massive in structure, with *Montastraea annularis* covering approximately 42% of the total hard coral area. The results from the CARICOMP benthic surveys are presented in Table 3.

Table 3. Results of benthic surveys at the CARICOMP coral reef site, Saba, Netherlands Antilles.

Classification	% Occ	Classification	% Occ	Species	% Occ
Turf algae	30.7	Anemones	—	*Agaricia* spp.	15.9
Fleshy algae	18.2	Zooanthids	0.01	Ascidians	3.4
Calcareous algae	2.7	Erect sponges	1.8	*Diploria strigosa*	6.0
Crustose algae	—	Encrusting sponges	1.1	*Meandrina* spp.	2.4
Branching corals	0.2	Other organisms	0.5	*Millepora* spp.	0.1
Massive corals	10.4	Bare rock	1.5	*Montastraea annularis*	42.7
Encrusting corals	5.8	Bare rubble	0.08	*Montastraea cavernosa*	22.0
Foliaceous corals	0.07	Holes, gaps, overhangs	5.4	*Porites porites*	4.9
Milleporines	0.04	Recent dead coral	—	*Siderastrea* spp.	2.4

		Sand	21.5		
% Occ = occurrence, and refers to the percentage of a particular classification or species relative to others present.					

Physical data, including surface water temperature, light attenuation, and salinity, have been recorded weekly at the reef site since September 1992. Generally, salinity does not deviate much from 35‰. Light attenuation ranges from 12.5 to 30 m, averaging 22 m at this site. The average surface water temperature ranges from 26.5°C to 29.1°C.

Conclusions

Saba is unique in the CARICOMP program, with the existence of only one of the three ecosystems specified for determining coastal marine productivity. Anthropogenic impacts on the coast are limited, but the threat of development, increased dive tourism, and erosion require continuous monitoring. Saba is one protected area in the CARICOMP program and, as such, can be useful for comparison with other, more impacted sites.

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