Some Observations Made From ROV on Mid-Depth Habitats and Reef Fish Communities of Saba Bank, Netherlands Antilles

Wes Toller[1], Shelley Lundvall[1], and Paul Hoetjes[2]

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1 Saba Conservation Foundation
Saba, Netherlands Antilles

2 Department of Environment & Nature (MINA)
Ministry of Public Health & Social Development (VSO)
Schouwburgweg 26 (APNA building)
Curaçao, Netherlands Antilles

Abstract

A small submersible remotely operated vehicle (ROV) was used to explore mid-depth habitats of Saba Bank – a submerged carbonate platform in the northeastern Caribbean Sea. The ROV enabled observation and specimen collection to greater depths (40 to > 150 m) than possible with conventional scuba methods. The topography, substrate, benthic communities and fish assemblages of a prominent front reef system at Overall Bank were examined in some detail. Observations made from ROV indicate that substrate and benthic communities show consistent zonation patterns along the depth gradient of the front reef slope. A transition in the reef fish assemblage was also evident, though less pronounced, along this same depth gradient. Fish diversity (number of species observed per survey) was greatest in the reef crest zone and declined with depth, however sightings of commercially important lutjanids species such as silk and blackfin snapper increased with depth. Significant cover by reef-building corals (i.e. constructional reef development) was only evident in the reef crest zone, and terminated at 38 to 42 m depth. Substrate of the transition slope zone, from 42 m to 75 m depth, was primarily a hard bottom consisting of consolidated reef structures and rubble with sand interspersed. Sponges, gorgonians and macro algae dominated the benthic community there. In the deep slope zone (> 75 m depth), a soft bottom substrate predominated that was composed of fine, readily resuspended sediments together with scattered rubble fragments. Benthic invertebrates were very sparse in the deep slope zone. In addition to the surveys at Overall Bank, four ROV surveys were made at two other Saba Bank areas: Poison Bank and Grapplers Bank. The substrate at Poison Bank was comprised of coralline algal nodules or "rhodoliths" which formed extensive rhodoliths beds. At Grapplers Bank, a steep rocky escarpment was explored. The near-vertical rocky scarp began at 120 m depth and extended down slope beyond the limits of the ROV survey (157 m depth). Observations made from ROV at Overall Bank suggested a continuous reef system that is relatively uniform and predictable at mid-depths in terms of its structure, substrate composition, and community zonation patterns. In contrast, the few observations made by ROV at Poison Bank and Grapplers Bank revealed habitats that were quite different from those at Overall Bank. This implies that future ROV explorations to new areas of Saba Bank are likely to reveal still greater diversity in mid-depth habitat types.

Introduction

Saba Bank, Netherlands Antilles, is a large and completely submerged island located in the northeastern Caribbean Sea. Saba Bank is a flat-topped carbonate platform whose geological origin sparked some controversy among geologists (Vaughan, 1919, Davis, 1926). Most recent authors consider Saba Bank to be a submerged coral reef atoll (Van der Land, 1977, Meesters et al., 1996). To date, two factors have impeded an adequate survey of the marine resources of Saba Bank - its size and its depth. Saba Bank occupies > 2,200 km^2 above the 200 meter isobath (Meesters et al., 1996), which makes it challenging to sample on an adequate spatial scale. In addition, much of Saba Bank lies below 40 m depth, thus complicating the use of conventional scuba diving for surveying, sampling, or direct observation.

Despite the challenges of surveying Saba Bank, many recent studies indicate that the coral reefs of Saba Bank are - at least potentially - quite large. Percentage bottom cover by scleractinian corals is reported to be high (Meesters et al., 1996, Klomp and Kooistra, 2003). In addition, recent surveys of Saba Bank coral reef communities suggest an unanticipated abundance and diversity of marine organisms in groups such a shallow water reef fishes (RAP Survey Report, 2006, J. Williams, pers. comm.), commercially-harvested fisheries resources (Dilrosun, 2000, Toller and Lundvall, 2008), crustaceans (Kilgour and Shirley, in prep.), octocorals (Etnoyer et al., in prep.), and macro algae (M. Littler, pers. comm.). Saba Bank may have the richest diversity of marine life known from the Caribbean (Conservation International, 2006). Yet these observations and collections were largely confined to the shallowest habitats of Saba Bank. The deeper environments of Saba Bank have hardly been explored.

Little is known of coral reefs beyond scuba diving depths, leading some researchers to conclude that deep reefs "... are a neglected and understudied marine environment" (Bak et al., 2005). There are a number of compelling reasons to study the deeper reef habitats of Saba Bank. Deep reef habitats may form refugia from anthropogenic stressors or from natural catastrophic events such as hurricanes. Such deep reef refugia would serve as important reservoirs for repopulating degraded coral reef habitats in shallower, near shore areas (e.g. Armstrong et al., 2006). Studies of deep reef habitats may also support a better informed management of the commercially important fish species which are harvested from mid-depth habitats of Saba Bank. Additionally, recent efforts to develop taxonomic inventories for Saba Bank marine communities would simply be incomplete without exploration of deep reef areas.

Use of submersibles, whether manned (Liddell et al., 1997, Weaver et al., 2006) or unmanned (Armstrong et al., 2006), allows direct observation of mid-depth or deep reef habitats that lie beyond the depth limits of conventional scuba diving. This report presents observations made from a remotely operated vehicle (ROV) on the distribution of physical substrate, benthic community structure, and species composition of fish assemblages in mid-depth habitats (30 m to >150 m depth) of Saba Bank. Observations presented here are preliminary and largely qualitative. However, it is felt that results of this study will encourage more extensive and quantitative investigations of deep reef habitats of Saba Bank in the future.

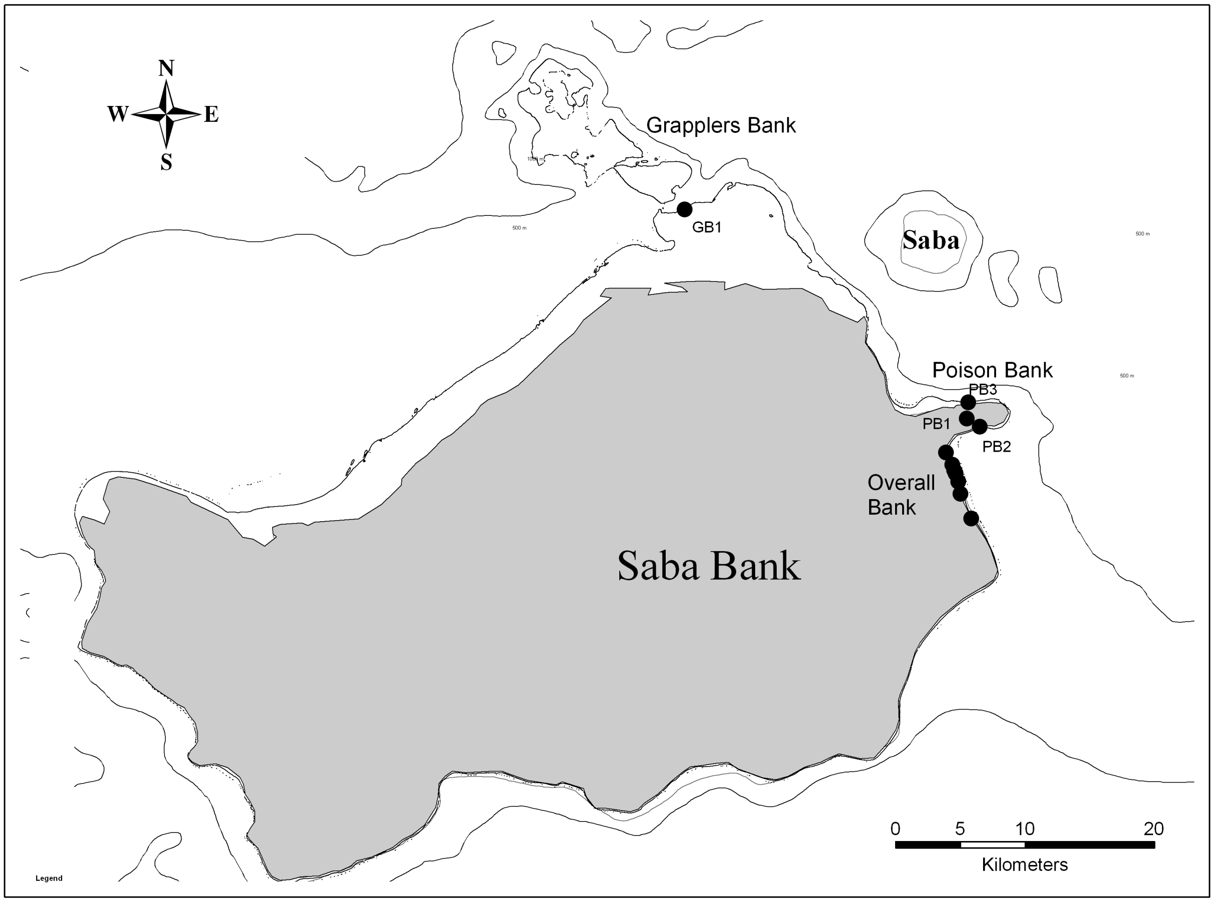


Figure 1. Map of Saba Bank, Saba, Netherlands Antilles, showing ROV survey sites. Gray polygon shows area enclosed by the 50-m depth contour.

Methods

<u>Study Area:</u>
Saba Bank is located 3-5 km southwest of the Saba Island, Netherlands Antilles, in the northern Lesser Antilles (Meesters et al., 1996). Saba Bank is a flat-topped structure, approximately 60 km long by 40 km wide (Figure 1). The platform is gently tilted along a southwest to northeast axis, such that depth increases as one proceeds to the north and west. The shallowest depths and the most abundant reef structures known to occur on Saba Bank are located along the southern and eastern margins (Van der Land, 1977). The reef areas on western and northern Saba Bank have been considered "drowned" reefs (Van der Land, 1977).

In the present study, ROV surveys were targeted to a "front reef" feature (Van der Land, 1977) located at the shelf-edge (Figure 2) at Overall Bank. The front reef is a zone of rather complex topography located on eastern Saba Bank. Surveys were designed to complement ongoing habitat-mapping studies in the adjacent shallow areas of Overall Bank (see Toller, 2008). In addition to surveys at Overall Bank, limited ROV surveys were conducted at two other areas of Saba Bank (Figure 1) as described below.

ROV:
A small, surface-tended Remotely Operated Vehicle (ROV) - the "Little Benthic Vehicle" or LBV 200L[2] (Seabotix, Inc., San Diego, CA) – was used to explore mid-depth habitats. This lightweight ROV (200 m depth rating) was selected because it could be deployed from a small vessel without requirements for specialized shipboard equipment. It was also a comparatively economical option suitable for work in the remote location of Saba. The pilot operated the ROV from a shipboard integrated control console with 15-inch color monitor. A floating umbilical cable (250 m) with optical fiber provided video/command communications between pilot and ROV. Surface-supplied power (Honda EU2000i gas-powered generator) was delivered via the umbilical cable.

The ROV was equipped with a primary color video camera (570 line Ex-View HAD, 0.2 Lux light requirement) and a secondary black & white video camera (430 line resolution, 0.03 Lux light requirement). Video images were captured on a 73fifty Pelicase Unit digital video recorder (NETmc Marine, Aberdeenshire, UK) in time-restricted mode. The real-time menu display for ROV operation was recorded simultaneously and included information for heading (magnetic compass bearing), depth (m), temp (°C), time, and date. Video files (MPEG format) of five minute duration (~ 223 Mb per file) were recorded continuously during ROV surveys. Video files were later transferred to personal computer for review and archiving. The ROV unit was nicknamed "sharkbait" after the video recorded a close inspection by a tiger shark (*Galeocerdo cuvier*) during surface haulback on 6-Nov-07.

Quantification of Observations:
The ROV pilot attempted to make on-the-spot identification of fish species, invertebrates, and substrate characteristics while conducting surveys. In addition, video recordings were reviewed *post hoc* in the lab on a large screen television. Examination of video tapes by independent viewers allowed for either confirmation or rejection of diagnoses made during initial observation.

Fish were identified to species where possible and scored for presence/absence in each of the habitat zone. Scleractinian corals were identified to genus. Most other invertebrates (gorgonians, sponges, macro algae) were either identified to genus or placed into broad morphological groupings.

Bathymetry:
In 2006, a detailed multibeam sonar bathymetric survey of Saba Bank was conducted by the Dutch Hydrographic Service aboard the *HNLMS Snellius*. With the assistance of Conservation International, this dataset was assembled as map layers in a geographic information system (GIS) database (ArcGIS 9.2, ESRI, Inc.). The 2-m resolution bathymetric maps proved to be highly accurate and were extremely useful for planning survey missions and examining bottom profiles of mid-depth sites.

Collections:
At a limited number of stations, the ROV was used to collect live benthic specimens (primarily gorgonian colonies). A Seabotix mechanical "grabber" arm, consisting of three opposing pincer elements, was fitted to the front of the ROV. Gorgonian specimens were collected by

deliberately maneuvering the ROV into position, closing the pincers at the colony base, and then forcibly rocking/twisting the ROV until the specimen was dislodged.

Results

From 14-Aug-07 to 5-Nov-07, a total of 11 sites on Saba Bank were surveyed with ROV. Most of the surveys were made along the front reef system at Overall Bank (seven sites). Four additional sites were surveyed by ROV at two other Saba Bank locations: Poison Bank (three sites) and Grapplers Bank (one site). ROV survey and site information is presented in Table 1. The range of depths surveyed (Table 1), as well as survey duration, varied from site to site, often being determined by prevailing weather/sea conditions.

Table 1. ROV Surveys of Saba Bank

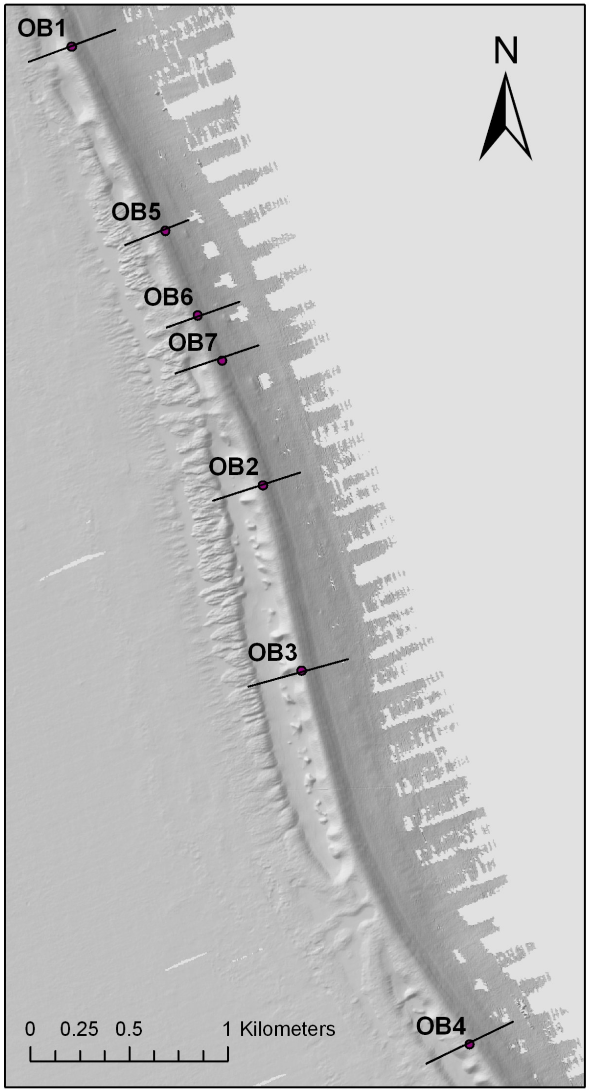
Area	Survey Date	Site	Depth Range (m)	Lat (°N)	Lon (°W)	Reef Zones Observed
Overall Bank	14-Aug-07	OB3	25 - 40	17 27.336	63 13.089	Trench, Crest
Overall Bank	24-Aug-07	OB2	25 - 108	17 27.847	63 13.185	Crest, Slope
Overall Bank	24-Aug-07	OB1	20 - 106	17 29.065	63 13.696	Trench, Crest, Slope
Overall Bank	24-Aug-07	OB5	24 - 132	17 28.553	63 13.439	Crest, Slope
Overall Bank	21-Oct-07	OB4	22 - 52	17 26.300	63 12.641	Crest, Slope
Overall Bank	23-Oct-07	OB6	40 - 58	17 28.319	63 13.356	Slope
Overall Bank	25-Oct-07	OB7	40 - 78	17 28.192	63 13.290	Slope
Poison Bank	20-Sep-07	PB1	32 - 37	17 30.487	63 12.828	Shelf Platform
Poison Bank	24-Oct-07	PB2	85 - 112	17 30.148	63 12.290	Slope
Poison Bank	28-Oct-07	PB3	60 - 72	17 31.167	63 12.777	Slope
Grapplers Bank	5-Nov-07	GB1	104 - 157	17 39.258	63 24.581	Escarpment

Three additional survey missions, which were unsuccessful, are also noted here. On 21-Jul-07, a deepwater region of mound-like features located on northern Saba Bank was explored with ROV (site HMP; 17º 36.072’ N, 63º 19.083’ W) but video recording failed. On 6-Aug-07, a survey mission to site OB1 was aborted due to excessive currents. On 27-Sep-07, an ROV survey was initiated at the anchoring site of the tanker *Eagle Vienna* on northwestern Saba Bank (17º 34.970’ N, 63º 27.893’ W) but was terminated early due to mechanical difficulties.

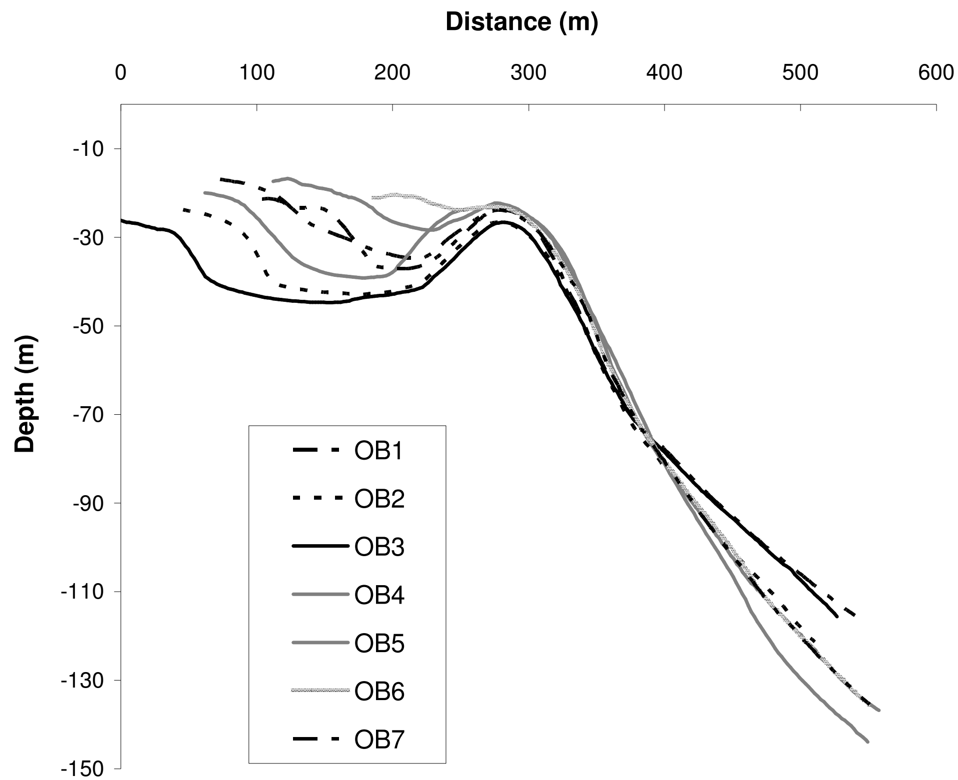
<u>Observations at Overall Bank:</u>
Bathymetric information for Overall Bank indicates a distinctive ridge-like structure oriented from north-northwest to south-southeast along the eastern (seaward) margin of the shelf edge (Figure 2a). This “front reef” feature (Van der Land, 1977) was examined along 5.5 km of reef tract. Using bathymetric information, front reef topography can be described as follows.

Figure 2. Front reef feature at Overall Bank. **A.** Depth profiles were obtained from cross-shelf transects (Spatial Analyst, ArcGIS 9.2) using 2-meter resolution multibeam sonar datasets. **B.** Individual profiles were aligned by positioning the peak of the reef crest.

A.



B.



The shallowest depth of the front reef crest (i.e. the summit) is approximately 24 m. This summit depth was relatively uniform along the axis of the ridge system, averaging 24.2 ± 1.7 (± st. dev.) and ranging from 22.3 to 26.7 m. Inshore or west of the ridge crest, a "trench" is present. Trench width (< 40 to > 160 m wide) and depth (32 to > 44 m deep) were highly variable along the axis of the ridge system (Figure 2a, b). The two ROV surveys that explored the trench indicated a substrate comprised primarily of sand with some scattered rubble. Available hard substrate was covered by sponges, gorgonians and macro algae. Although not quantified, fish diversity and abundance was low within the trench. Fishes observed in the trench were typical of soft bottom habitats, and included species such as the margate (*Haemulon album)*, sand tilefish (*Malacanthus plumieri*), and southern stingray (*Dasyatis americana*).

Farther inshore (westward) of the front reef crest and trench zone, the reef sloped upward to a depth of 15 - 20 m. The reef located in this inner zone had a spur & groove morphology. ROV surveys were not conducted in the inner spur & groove zone because it was surveyed more effectively using scuba (see Toller, 2008).

A combination of scuba observations and ROV surveys confirmed the accuracy of bathymetry datasets for the front reef system at Overall Bank. A generalized picture of the front reef is shown schematically in Figure 3. The terms used to describe zones of the front reef system were adopted or modified from Van der Land (1977). The spur & groove reef is not considered part of the front reef system. Three zones of the front reef were recognized: a reef crest zone, a transition slope zone, and a deep slope zone. Each is described below.

Crest Zone (< 42 m)
The "crest zone" of the front reef system extended from summit (~ 24 m) to a depth of about 42 m. The crest was a uniform and continuous ridge oriented north-northwest to south-southeast. The substrate of the crest zone was a topographically complex limestone (coral) reef with little or no sand. Benthic cover was dominated by large mound-shaped or plate-shaped colonies of *Montastraea annularis* complex, smaller *Porites* colonies and occasional large *Colpophyllia* colonies. Large gorgonian colonies (e.g. *Plexaura*) were also common. Planktivorous reef fish were particularly abundant in the reef crest zone.

Transition Slope Zone (42 – 75 m)
The "transition slope zone" extended from 42 m to 75 m depth. Consolidated hard bottom substrate persisted to a depth of about 60 m. Below ~ 60 m, the substrate composition became a mixture of rubble, consolidated reef and sediments that extended to a depth of 75 m. Benthic cover in the transition slope zone was dominated by sponges, small gorgonian colonies, and macro algae (*Lobophora*). Occasional small antipatharian and hydroid colonies were noted. The large coral colonies that were observed in the shallower reef crest zone terminated rather abruptly at 38 - 42 m depth and were not seen in the transition slope zone. However, a few small coral colonies (*Agaricia* sp., *Montastraea cavernosa*) were observed within the transition zone, at depths of 45-50 m. Similarly, the large gorgonian colonies observed in the crest zone also terminated rather abruptly at 38 - 42 m depth. They were replaced by smaller and more highly-branched gorgonian morphs in the transition slope zone.

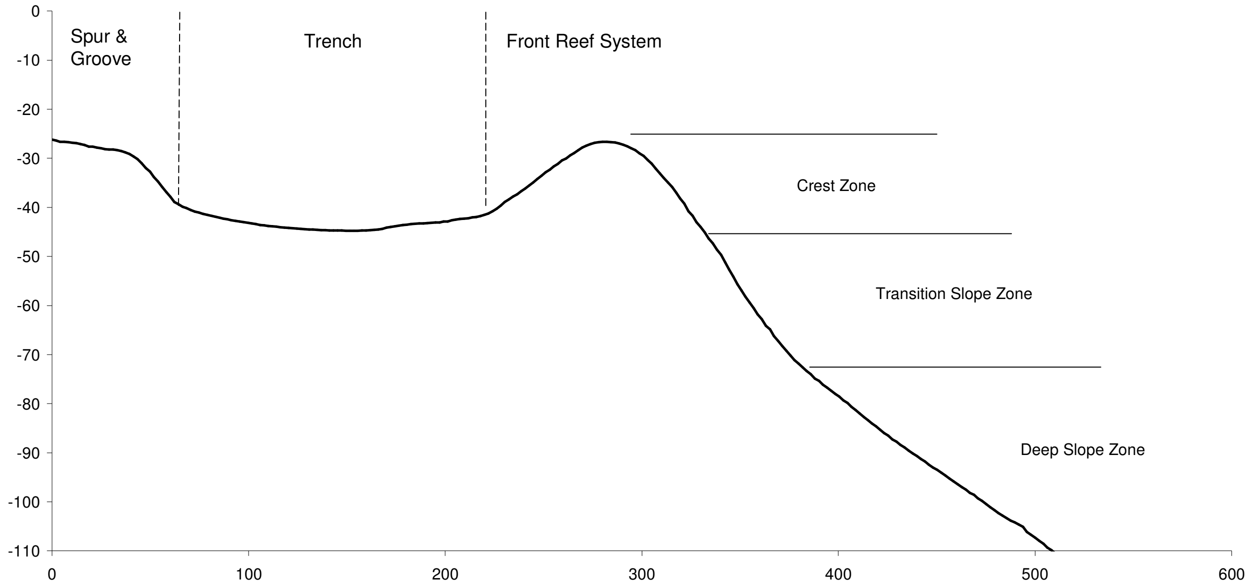


Figure 3. Schematic illustration of zones observed at Overall Bank shelf-edge.

Deep Slope Zone (> 75 m)

The "deep slope zone" extended from 75 m to the limits of ROV survey depths (132 m at Overall Bank). At approximately 75 m depth, a distinct change in slope was generally discernable. The slope inflexion appeared as a sandy bench extending more gradually down slope. This point coincided with the deepest extent of consolidated reef and rubble, below which soft bottom substrate predominated. The depth of the observed inflexion point was corroborated in bathymetric profiles of survey sites (Figure 2). Sediments in the deep slope zone were very fine and were easily resuspended by turbulence created by the ROV thrusters. The soft-bottom substrate of the deep slope zone was largely devoid of benthic invertebrate cover. Small tube structures (1-2 cm) projected from the sand in some areas. In some areas, meandering tracks were seen crossing the smooth sediment surface. One set of tracks was followed to a hermit crab. At OB2, a small rocky outcrop was found and fish were noticeably more abundant near this structure.

At site OB6, a lost lobster trap was found on the sandy bench at 76 m depth. The trap was heavily fouled with telestos, sponges and hydroids - an indication that it had been in place for quite some time. Fortuitously, the vessel captain recognized the trap as his own construction. He estimated that it was lost about four years ago. Fishes (graysby, rock beauty) were observed entering and exiting the trap. An attempt was made to recover the lost trap in order to examine its fouling community, but the trap was firmly lodged into place by sediment accumulation.

<u>Observations at Poison Bank:</u>

Poison Bank or "copper bank" has long been known to the fishermen of Saba. As its name implies, ciguatera poisoning is commonly associated with fishes taken in this area (Boeke, 1907). To this day, Saban fishermen rarely fish on Poison Bank (W. Toller, pers. obs.).

Poison Bank is a submerged peninsula (~ 7.2 km long by 3.1 km wide) that extends eastward from the northeast portion of Saba Bank. According to bathymetric data, the peninsula shoals to approximately 14 to 16 m depth in the west, however most of Poison Bank (> 75%) lies in 35 to 38 m depths. The peninsula slopes abruptly into deep waters on the southern side and eastern end, with a more gradual slope into deep waters along the northern side.

The initial survey at Poison Bank (site PB1) was undertaken to examine habitat impacts caused by anchoring of the tanker *Amazon Brilliance*. Substrate at the initial ROV search area (approximately 200 m west of PB1) was a continuous reef pavement with scattered patches of rubble and sand. The benthic community there was dominated by macro algae and cyanobacterial mats (*Schizothrix*), with a sparse cover of isolated head corals and sponges including large colonies of the barrel sponge, *Xestospongia muta*. As the ROV survey progressed westward towards the anchoring scar, an abrupt substrate transition was encountered. Limestone pavement was replaced by a continuous layer of cobble-sized rubble. The rubble was clearly biogenic in origin, and appeared to be non-living unattached nodules of calcareous algae or “rhodoliths” (Foster, 2001).

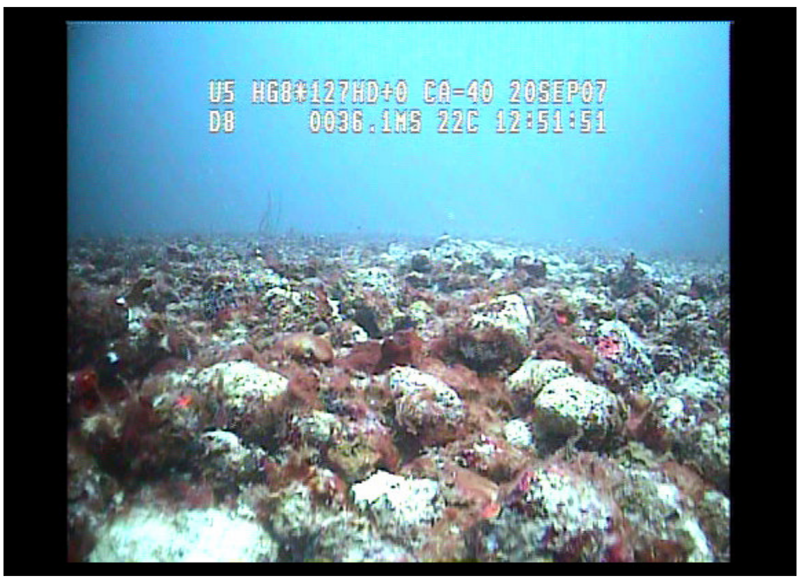


Figure 4. Rhodolith bed observed at Poison Bank, site PB1 (36 m depth).

ROV survey of the anchor scar itself provided additional insights into the nature of the rhodolith substrate at site PB1. The large anchor (est. 10,000 lbs) had plowed a 2-m wide “trough” across > 100 m of rhodolith bed. In this trough, unconsolidated rhodolith fragments were seen to extend to at least 0.5 m depth. Fine sediments, that were not visible atop the undisturbed rhodolith bed, were revealed as a subsurface layer mixed with rhodoliths fragments. Rhodoliths from this deeper layer were white, whereas rhodoliths from the superficial undisturbed layer were dark in color and covered with fouling organisms (especially *Schizothrix*).

The second ROV survey at Poison Bank was made along the southern slope (site PB2). The substrate at PB2 was again dominated by rhodoliths. Benthic cover was dominated by a dense layer of *Schizothrix* as well as calcareous green algae (*Halimeda*) and discoidal fleshy brown algae (*Lobophora)*. Few corals were observed. Large sponges and gorgonians were sparse. The rhodolith-dominated substrate at PB2 extended to a depth of ~ 87 m. Below this, a more gradually sloping sand bench extended to a depth of 100 m. Few invertebrates were observed on this sand bench. At 100 m depth, an abrupt drop off occurred at an exposed rocky scarp. Fish were comparatively abundant at this drop off. Gorgonians (sea fans and sea whips) were dense along the scarp as well.

The third ROV survey at Poison Bank was made along the northern slope (site PB3). At PB3, only a narrow depth range (60 to 72 m) could be surveyed by ROV. Throughout this range, the substrate was dominated by rhodoliths. Benthic cover was dominated by dense layers of *Schizothrix* and macro algae (*Lobophora*, *Halimeda*). Sponge and gorgonian cover was sparse. However there was an abundance of small agariciid colonies (20 - 35 cm diameter) that were growing atop the rhodoliths bed. Fish species composition was not quantified at PB1 or PB3.

<u>Observations at Grapplers Bank:</u>
The Grapplers Bank is an irregularly-shaped underwater peninsula that extends > 16.5 km to the northwest from northernmost portion of Saba Bank. It lies between 17.5 and 32 km to the west-northwest of Saba Island. Recent bathymetric data indicates that Grapplers Bank has an uneven topography, with shoal areas occurring from 75 to 100 m depth (Figure 1). Average depth is ~ 85 m across most of Grapplers Bank. Bathymetry also shows that Grapplers Bank is marked by numerous precipitous fissures and canyon-like features. The extent of these submarine features, however, cannot be determined with existing datasets that are limited to < 200 m depth. Only a single Grapplers Bank site (GB1) could be visited in this study.

Site GB1 was visited on a day of exceptionally calm weather and sea conditions (5-Nov-07). At the initial point of ROV descent (104 m), the seafloor was a gently sloping soft sediment bottom with scattered rhodoliths and rubble. As the survey progressed westward, the slope increased rapidly. A sheer rock escarpment occurred at 120 m depth. This near vertical scarp was explored to a maximum depth of 157 m. The rocky surface was irregular and punctuated with ledges and overhangs. Sediments had accumulated on the horizontal surfaces, suggesting periodic sand flows from above. Scattered gorgonians, sea whips, and sponges lined the wall but benthic cover by macro invertebrates was generally sparse. Closer inspection of the substrate indicated a benthic cover of diminutive black corals and hydroids on the rock surface. One gorgonian colony (colony height ~ 35 cm) was collected at 138.6 m depth from a rock ledge at GB1. This specimen was sent to P. Etnoyer, Texas A&M University, for identification. Fishes were not particularly abundant at GB1, and only two species were recorded at this site: blackfin snapper (*L. buccanella)* and red hind (*E. guttatus)*.

<u>Fish Observations:</u>
A total of 51 fish species representing 21 families were observed during ROV surveys (Table 2). When examined by depth zone, observed fish diversity decreased with depth. On average more species were observed in the reef crest (15.6 ± 5.2 species per survey, range: 8 - 22) than in the transition zone (6.8 ± 5.5 species per survey, range: 3 - 14) or in the deep slope zone (6.0 ± 3.8 species per survey, range: 1 - 9). The cumulative number of taxa observed was also greater in the shallow reef crest zone (35 species) than in the transition zone (26 species) or in the deep

slope zone (17 species). However, there was substantial overlap in the composition of fishes observed among zones: 15 taxa co-occurred in reef crest and transition zones, nine taxa co-occurred in transition slope and deep slope zones.

The most frequently observed fish species were the rock beauty (*Holocanthus tricolor)*, the bar jack (*Caranx ruber)*, and the black jack (*C. lugubris)*. Some species were observed in all depth zones, including bar jack, black jack, red hind (*Epinephelus guttatus*), and great barracuda (*Sphyraena barracuda*). Observed taxa that are generally reported from deeper waters included the silk snapper (*L. vivanus*), blackfin snapper (*L. buccanella*) and greater amberjack (*Seriola dumerili)*. Each of these species was observed only at depths greater than 42 m. In addition, one adult Caribbean spiny lobster (*Panulirus argus*) was observed at a depth of 63 m sheltering beneath a large sponge-encrusted rubble fragment at site OB5.

Fish behavior may have influenced observations to some extent. It was evident that some fish species were positively attracted to the ROV. Larger predatory species, such as black jack, bar jack, greater amberjack, and great barracuda, seemed to make deliberate inspections of the ROV at close range (< 1 m). Ocean triggerfish were also particularly inquisitive. Other fish species were evidently attracted by disturbances of the substrate caused by the ROV thrusters. This group included blackfin and silk snappers.

<u>Invertebrate Collections:</u>
In late October of 2007, a multi-national team of scientists joined the project to conduct more detailed studies on the taxonomic diversity of gorgonians and crustaceans of Saba Bank. Collections using ROV were instrumental in procuring a number of gorgonian colonies and crustacean from depths > 40 m. The results from gorgonian studies (Etnoyer et al., in prep.) and crustacean studies (Kilgour and Shirley, in prep.) will be presented elsewhere.

<u>Limitations of the Methods used:</u>
A number of limitations were identified with the ROV methodology used in this study. These limitations should be considered carefully in the experimental design of future investigations.

Video-based observation does not provide unequivocal identification to the species level. This limitation was most evident when dealing with unfamiliar deepwater fauna such as many of the benthic invertebrates observed below 60 m depth. The accuracy of video-based identification was further compromised when the organisms 1) were fast moving, 2) were relatively small-bodied (< 5 cm), and 3) did not allow close approach by ROV. Collection of high quality, color still photographs may improve the ability to make accurate species diagnoses.

ROV deployment from a small vessel was also not without problems. Despite a depth rating to 200 m, such depths were never realized on the open seas of Saba Bank. A number of factors contributed to reduced maximum operating depths. Factors included: current, wind, sea surface state, and length of umbilical cable deployed. In addition, currents and agitated seas acted synergistically to render the ROV unsteady at depth. The resulting unsteady video images made it difficult to quantify observations, and in extreme cases, made it impossible to provide positive taxonomic identifications.

Table 2. Fish Taxa Observed in ROV Surveys.

		Crest Zone, Front Reef (<42 m)					Transition Slope Zone (42-75 m)						Deep Slope Zone (>75 m)			
Family/Species	Common Name	OB3	OB2	OB1	OB5	OB4	OB2	OB1	OB5	OB4	OB6	OB7	OB2	OB1	OB5	PB2
Dasyatidae																
Dasyatis americana Hildebrand and Schroeder, 1928	southern stingray												+			
Myliobatidae																
Aetobatus narinari (Euphrasen, 1790)	spotted eagle ray														+	
Holocentridae																
Holocentrus adscensionis (Osbeck, 1765)	squirrelfish												+			
Holocentrus rufus (Walbaum, 1792)	longspine squirrelfish			+		+						+				
Myripristis jacobus Cuvier, 1829	blackbar soldierfish		+										+			
Serranidae																
Cephalopholis cruentata (Lacepède, 1802)	graysby										+					+
Cephalopholis fulva (Linnaeus, 1758)	coney					+			+			+				
Epinephelus guttatus (Linnaeus, 1758)	red hind	+					+					+				+
Hypoplectrus puella (Cuvier, 1828)	barred hamlet		+	+				+								
Paranthias furcifer (Valenciennes,1828)	creolefish	+		+	+	+										
Serranus tortugarum Longley, 1935	chalk bass											+				
Opistognathidae																
Opistognathus aurifrons (Jordan and Thompson, 1905)	yellowhead jawfish										+	+				
Malacanthidae																
Malacanthus plumieri (Bloch, 1786)	sand tilefish						+					+				
Carangidae																
Caranx lugubris Poey, 1860	black jack	+		+	+					+					+	+
Caranx ruber (Bloch, 1793)	bar jack	+				+		+		+		+				+
Seriola dumerili (Risso, 1810)	greater amberjack												+			
Lutjanidae																
Apsilus dentatus Guichenot, 1853	black snapper															+
Lutjanus buccanella (Cuvier, 1828)	blackfin snapper											+	+		+	+
Lutjanus vivanus (Cuvier, 1828)	silk snapper							+					+	+	+	+
Ocyurus chrysurus (Bloch, 1791)	yellowtail snapper	+	+	+		+										
Haemulidae																
Haemulon plumierii (Lacepède, 1802)	white grunt		+	+	+											
Mullidae																
Mulloidichthys martinicus (Cuvier, 1829)	yellow goatfish			+												
Pseudupeneus maculatus (Bloch, 1793)	spotted goatfish		+	+												
Chaetodontidae																
Chaetodon capistratus Linnaeus, 1758	foureye butterflyfish		+	+		+										
Chaetodon sedentarius Poey, 1860	reef butterflyfish											+	+			
Chaetodon striatus Linnaeus, 1758	banded butterflyfish			+						+						
Pomacanthidae																
Holacanthus ciliaris (Linnaeus, 1758)	queen anglefish					+				+						
Holacanthus tricolor (Bloch, 1795)	rock beauty	+	+		+			+	+	+	+	+				
Pomacanthus arcuatus *(Linnaeus, 1758)*	gray angelfish														+	
Pomacanthus paru (Bloch, 1787)	French angelfish					+		+		+						
Pomacentridae																
Chromis cyanea (Poey, 1860)	blue chromis	+	+	+		+	+									
Chromis multilineata (Guichenot, 1853)	brown chromis		+			+										
Microspathodon chrysurus (Cuvier, 1830)	yellowtail damselfish			+												
Stegastes partitus (Poey, 1868)	bicolor damselfish		+			+				+		+				

Table 2 continued. Fish Taxa Observed in ROV Surveys.

		Crest Zone, Front Reef (<42 m)					Transition Slope Zone (42-75 m)						Deep Slope Zone (>75 m)			
Family/Species	Common Name	OB3	OB2	OB1	OB5	OB4	OB2	OB1	OB5	OB4	OB6	OB7	OB2	OB1	OB5	PB2
Labridae																
Clepticus parrae (Bloch and Schneider, 1801)	creole wrasse	+	+	+	+	+										
Halichoeres garnoti (Valenciennes, 1839)	yellowhead wrasse					+				+	+					
Scaridae																
Scarus taeniopterus Desmarest, 1831	princess parrotfish	+	+	+		+										
Sparisoma aurofrenatum (Valenciennes, 1840)	redband parrotfish			+	+	+										
Sparisoma viride (Bonnaterre, 1788)	stoplight parrotfish	+		+		+										
Acanthuridae																
Acanthurus bahianus Castelnau, 1855	ocean surgeon		+	+												
Acanthurus chirurgus (Bloch, 1787)	doctorfish									+		+				
Acanthurus coeruleus Bloch and Schneider, 1801	blue tang		+	+		+						+				
Sphyraenidae																
Sphyraena barracuda (Edwards, 1771)	great barracuda			+					+			+				+
Scombridae																
Scomberomorus regalis (Bloch, 1793)	cero	+														
Balistidae																
Balistes vetula Linnaeus, 1758	queen triggerfish			+									+			+
Canthidermis sufflamen (Mitchill, 1815)	ocean triggerfish	+		+	+											
Melichthys niger (Bloch, 1786)	black durgon	+	+	+	+	+										
Xanthichthys ringens (Linnaeus, 1758)	sargassum triggerfish								+	+			+			
Ostraciidae																
Acanthostracion polygonius Poey, 1876	honeycomb cowfish		+													
Lactophrys triqueter (Linnaeus, 1758)	smooth trunkfish	+														
Tetraodontidae																
Canthigaster rostrata (Bloch, 1782)	sharpnose puffer									+						

Discussion

Early geological investigations of Saba Bank noted the unusual reef features present at the shelf edge at Overall Bank and its vicinity. Van der Land (1977) termed these features “front reefs.” He provided a remarkably detailed account of front reef morphology based on very limited bathymetric information. Macintyre et al. (1975) also investigated these curious shelf edge features using a combination of still photography of benthic grab sampling along the front reef slopes. They described patterns of sediment/substrate change with depth, and gave a cursory description of the habitats. In the present study, observation made from ROV confirm and extend these early descriptive accounts of front reef topography and substrate. The present study also adds important observations on the biological communities of Saba Bank front reefs.

The crest zone of the front reef was found to support an impressive scleractinian coral community. These front reef crests may represent localized areas of maximal coral reef development on Saba Bank. Coral growth, as inferred from colony size and percent coral cover, appears to cease at 38 to 42 m depth which appears to be the maximum depth of reef development at Overall Bank. The observations from Saba Bank are consistent with reported maximum depths for reef development of shelf edge reefs from St. Croix (Hubbard, 1989), but are shallower than depths reported from Jamaica, Bahamas, and Bermuda (Liddell et al., 1997 and references therein) where reef development occurs to depths > 60 m. It should also be noted that at Poison Bank, plating agariciids were observed at considerably greater depths (> 60 m) than at Overall Bank. Thus, it is also possible that maximum depth of reef development varies as a function of the specific location on Saba Bank.

The discovery of extensive rhodolith beds on Poison Bank is novel, and represents a new "class" of mid-depth habitat on Saba Bank. Foster (2001) suggested that rhodoliths beds may be one of the world's most ecologically significant habitat types. The extent of such rhodoliths beds on Saba Bank is unknown at present. If initial indications from Poison Bank are substantiated, then the extent of rhodolith beds there (as much as 17 km^2) may be substantial. It is important to consider that only a trivial portion of Saba Bank mid-depth habitats have been surveyed. Forthcoming side scan sonar datasets should be useful for identifying rhodolith beds and quantifying their spatial extent.

Isolated carbonate platforms or "banks" such as the Pedro Bank of Jamaica (Aiken and Kong, 2000) may support valuable commercial fisheries. Despite their economic importance to regional Caribbean fisheries, the habitats of such banks, as well as the processes controlling reef development on them, remain poorly known (Hallock and Elrod, 1998). Saba Bank is no exception. Commercial finfish harvests from Saba Bank are dominated by silk snapper, *Lutjanus vivanus*, and blackfin snapper, *L. buccanella*, captured with trap or hook & line from mid-depths (Dilrosun, 2000, Toller and Lundvall, 2008). Effective management of these finfish resources requires a more detailed understanding of specific fish-habitat associations and knowledge of habitat distribution.

In conclusion, the results from this study give an initial glimpse of mid-depth habitats of Saba Bank. Additional studies are clearly needed. Future work should focus on acquiring quantitative estimates of fish and benthic invertebrate abundance. The sampling design of future Saba Bank mid-depth habitat studies will be greatly facilitated by existing and forthcoming remote sensing mapping products for Saba Bank (i.e. multibeam sonar, sidescan sonar). Conversely, ROV studies may provide critical ground-truth observations to facilitate accurate mapping of the distribution of habitats across Saba Bank.

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