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# Diversity, abundance, distribution and habitat use of reef-associated sharks in the Dutch Caribbean

Field studies using Baited Remote Underwater Video (BRUV) and acoustic telemetry  
As part of the DCNA 'Save Our Sharks' project (Nationale Postcode Loterij)

Author(s): H.V. Winter & M. de Graaf

Wageningen University &  
Research report C105/18

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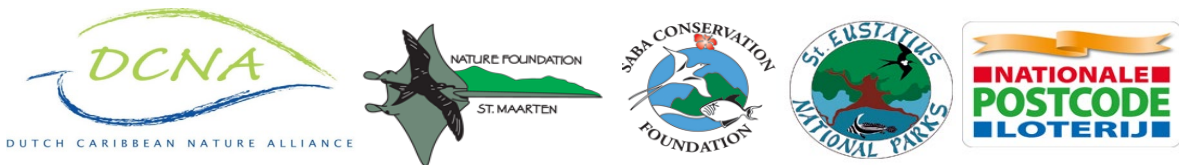
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# Summary

Sharks are in serious decline in the Caribbean due to fishing pressure and slow reproductive life-history. The Dutch Caribbean Nature Policy Plan in 2013-2017 was implemented to gain more knowledge on sharks, ensure sustainable fisheries, build an adequate management framework and invest in communication, education and outreach. Distribution and abundance of sharks in the Dutch Caribbean is poorly known. Several studies have been recently carried out on the occurrence, diversity and relative abundance of shark and ray species in the Dutch Caribbean e.g. baited remote underwater video (BRUV) studies on Saba, Saba Bank and St Eustatius and a pilot acoustic telemetry study on reef associated sharks around Saba.

In this study, three BRUV studies were conducted in the shallow coastal waters of Bonaire, Curaçao and St Maarten during 2015-2017 and the acoustic telemetry study on Saba was extended to St Maarten, St Eustatius and the Saba Bank. This study is part of the Save Our Shark (SOS) project carried out by the Dutch Caribbean Nature Alliance and financed by the Dutch Postcode Lottery (PostcodeLoterij).

The aim of the project is to conduct a base-line survey to describe diversity, abundance, distribution and habitat use of reef-associated sharks in the Dutch Caribbean. The BRUV surveys can serve as a reference point to evaluate management measures and marine parks. The acoustic telemetry study is to assess individual movement patterns of sharks that use coral reefs during different life stages.

The BRUV study on St Maarten was carried out in March to May 2015 (133 BRUV deployments), on Bonaire in September to December 2016 (110 deployments) and Curaçao in September 2016 to January 2017 (164 deployments). For the acoustic telemetry study in addition to the existing array of 8 receivers around Saba, 8 receivers were placed on the Saba Bank, 8 on the Dutch side of St Maarten and 8 around St Eustatius. Thus the entire network comprised 32 detection stations. In addition to 12 sharks that were equipped with acoustic transmitters lasting 4.5 years in 2014 on Saba (8 Caribbean reef shark and 4 nurse sharks), 11 sharks were equipped with transmitters on Saba Bank, 4 on St Eustatius and 1 on St Maarten in October 2015 to January 2016, totalling 28 sharks (21 Caribbean reef sharks and 7 nurse sharks). Telemetry data retrieved until March 2018 is presented in this report.

At the SOS BRUVs at St Maarten, a maximum number of sharks per frame per deployment (MaxN) of 37 sharks were observed, 21 were Caribbean reef shark, 15 nurse shark and 1 tiger shark; at Bonaire, 12 MaxN sharks, 11 Caribbean reef shark and 1 Great Hammerhead; at Curaçao, 9 MaxN sharks, 5 Caribbean reef shark, 3 blacktip shark and 1 great hammerhead and in addition a MaxN of 7 Cuban dogfish were observed with the submarine 300m deep BRUV pilot. More sharks were observed in marine parks and conservation zones than outside these areas, especially in Curaçao and St Maarten.

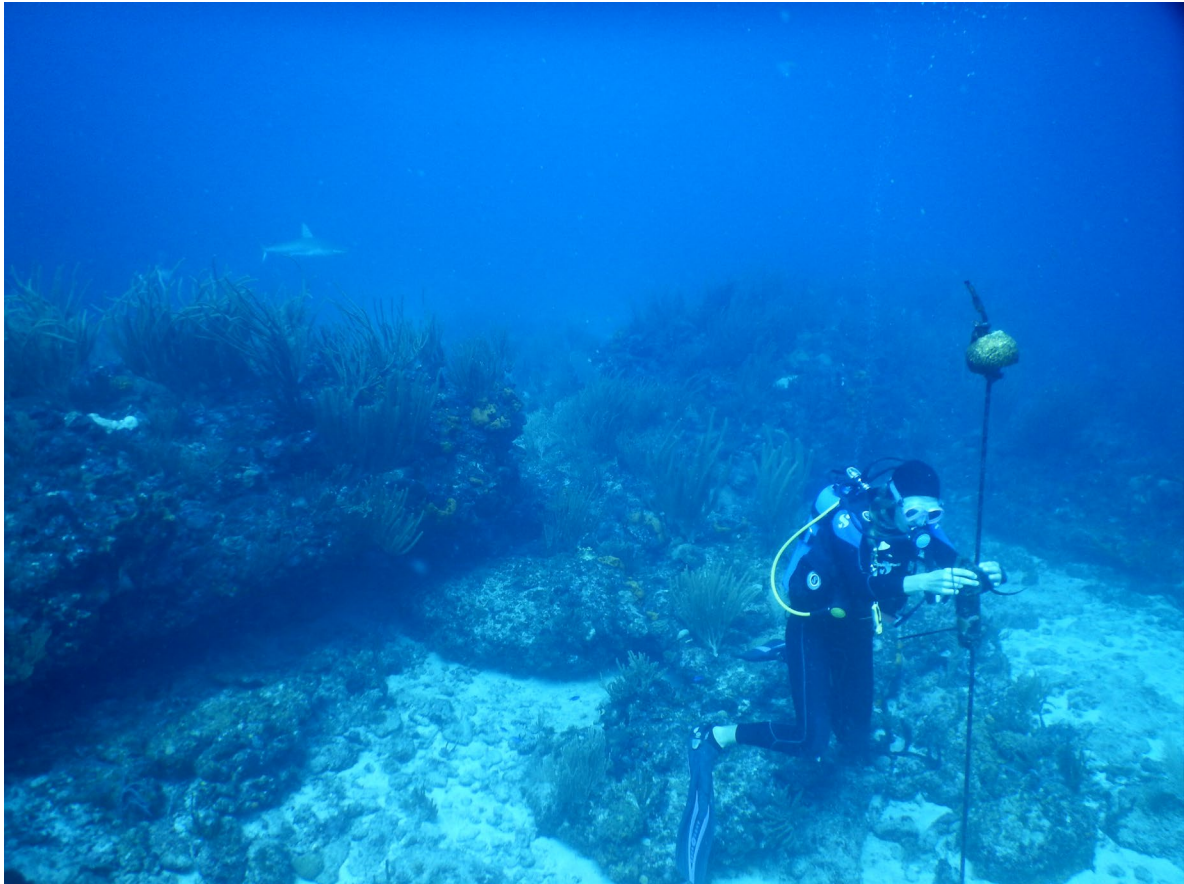
When comparing these SOS BRUV surveys to earlier BRUV surveys at Saba, St Eustatius and Saba Bank and a BRUV survey at Aruba in 2017, shark species richness in these BRUV surveys was highest at Aruba with 8 species and lowest at Bonaire with 2 species. On Saba 5 shark species were observed, Saba Bank 4 shark species, Curaçao 3 shark species in the regular BRUV survey and 1 more species in the BRUV submarine pilot in 300m deep water, and St Eustatius and St Maarten all 3 shark species. At least 10 shark species were observed within all BRUV studies in the Dutch Caribbean combined.

Acoustic telemetry revealed that both Caribbean reef sharks and nurse sharks showed strong residency to relatively small home ranges (order of magnitude of a few km). This was observed on all four reef systems studied (Saba, Saba Bank, St Maarten, St Eustatius), although numbers on some sites and species were low on St Maarten and St Eustatius, where they stayed within the borders of the marine parks for long periods. Larger movements were more scarce; two adult Caribbean reef sharks residing for years around Saba made short back trip excursions to the Saba Bank, one nurse shark tagged on Saba Bank showed up more than two years later on the Saba Bank before moving back to Saba. The detection network is still in place and given the battery life of 4.5 years the tagged sharks will yield more data

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after March 2018. Tagged sharks from other studies were also observed within the network set-up: one nurse shark tagged in a study around the U.S. Virgin Islands moved ca. 160 km to the Saba Bank in 2017, and one juvenile tiger shark from another SOS project moved from St Maarten to the Northwest side of Saba.

The SOS BRUV and acoustic telemetry showed higher presence of reef associated sharks within the marine parks combined with strong residence for longer periods within the relatively small home ranges. These results suggest that protecting smaller areas of the size of the current marine parks will help in the conservation of at least part of local populations of sharks. Also larger scale movements and connections between adjacent coral reefs over deeper waters (>500m) were found. For this, larger scale reserves, such as Yarari protecting a network of important habitats and safeguarding pathways between them might be necessary to protect entire populations of reef associated sharks.



*Melanie Meijer zu Schlochtern replacing a receiver at St Maarten with a Caribbean reef shark in the the background (photo Erwin Winter)*

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# 1 Introduction

## 1.1 Sharks in the Dutch Caribbean

Many elasmobranchs are in decline in the Caribbean and the most likely cause for is the combination of high fishing pressure and slow reproductive life-history characteristics (Ward-Paige et al., 2010). Elasmobranchs are a subclass of cartilaginous fishes comprising sharks and rays. A key ambition of the Dutch Caribbean Nature Policy Plan 2013-2017, is the effective implementation of elasmobranch protection. The main objectives of the protection plan are:

- 1) to broaden the knowledge of shark and ray species and their population status;
- 2) to ensure that fisheries activities are sustainable;
- 3) to ensure that an adequate management framework is in place;
- 4) to ensure that an effective communication, education and outreach strategy is implemented;

Distribution and abundance of elasmobranchs in the Dutch Caribbean has been poorly understood (Meesters et al., 2010). Several studies have been conducted recently to start documenting the occurrence, diversity and relative abundance of shark and ray species in the Dutch Caribbean (Van Beek et al., 2013; Van Kuijk, 2013; Van Looijengoed, 2013; Stoffers, 2014; Van Beek et al., 2014; Winter et al., 2015). These studies revealed that at least 30 shark and ray species potentially occur in the Dutch Caribbean, of which 13 species are internationally recognized as threatened by the IUCN Red list. Recent studies using baited remote underwater video (BRUV) on Saba, Saba Bank and St Eustatius demonstrated a possible relatively high abundance of reef associated sharks, in particular Caribbean reef sharks and nurse sharks (Van Kuijk, 2013; Van Looijengoed, 2013; Stoffers, 2014). However, knowledge about the status of elasmobranchs in the shallow coastal waters of Bonaire, Curaçao and St Maarten was still lacking. In the coastal waters of these three islands BRUV studies were conducted within this project during 2015-2017.

In addition to BRUV research, this project made use of acoustic telemetry to gain knowledge on dispersal, migration, between island connectivity and meta-population structure. In 2014 WMR (IMARES) conducted an acoustic telemetry pilot study on two shark species, Caribbean reef shark (*Carcharhinus perezi*) and nurse shark (*Ginglymostoma cirratum*) in the waters around Saba to collect data on individual movement and habitat use of these key species (Winter et al. 2015). This telemetry study was expanded to also include the Saba Bank, St Maarten and St Eustatius from 2015 onwards.

This study is carried out for the Dutch Caribbean Nature Alliance and financed by the Dutch Postcode Lottery (Postcodeloterij).

## 1.2 Aim of the project

The first aim of the project is to conduct a base-line survey to describe the current elasmobranch (shark and ray) diversity, distribution, abundance, spatial behaviour and population structure and exchange on inshore reefs (1-50 m depth) within the territorial waters of the Dutch Caribbean islands (Bonaire, Curaçao, Saba and Saba Bank, St Eustatius and St Maarten). The standardized BRUV base-line survey can serve as a reference point to evaluate the performance of future management actions on elasmobranch abundance such as the management of local marine parks and the Yarari reserve. Furthermore, the base-line survey can identify elasmobranch "hot spots" or nursery areas and this information may be used for the design of future reserves to improve protection.

The second aim is to assess individual movement patterns of sharks that use coral reefs during different life stages using acoustic telemetry. This provides insight in which habitats are used throughout the year (e.g. for feeding or nursery for juveniles), as well as the degree of site fidelity and scale of the home ranges of individual sharks. By building a network of detection stations (receivers) at several adjacent

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islands or reef systems movement patterns of sharks with transmitters give insight in the occurrence of longer migrations, dispersal and rate of exchange between different reef systems. This ultimately enables to determine meta-population structure; e.g. are there mainly local populations or is there a single large scale mixing population? These factors will affect to what extent Marine Reserves are effective in rehabilitating shark populations; e.g. these measures are more effective when these reserves contain important habitats or when local populations with a low rate of exchange occur.



*Caribbean reef shark showing up while retrieving a receiver on the Saba Bank (photo Guido Leurs)*



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## 2 Assignment

### 2.1 BRUV research

This DCNA SOS project was assigned to carry out 3 BRUV surveys at:

- 1) St Maarten (inshore demersal only) planned in 2015
- 2) Curaçao (inshore demersal only) planned in 2016
- 3) BRUV survey Bonaire (inshore demersal only) planned in 2017

Between 100-200 stereo-BRUV deployments should be conducted around each of these islands.

### 2.2 Acoustic telemetry

Within the in 2014 initiated acoustic telemetry pilot study around Saba, funded by the Ministry of Agriculture, Nature and Food Quality, 8 Vemco detection stations were placed around Saba and 12 reef sharks were equipped with Vemco transmitters This DCNA SOS project had planned to deploy 24 more detection stations in 2015 and to equip 12 more reef sharks with Vemco transmitters:

- 1) 8 detection stations on Saba Bank
- 2) 8 detection stations around St Eustatius
- 3) 8 detection stations south and west from St Maarten
- 4) Tagging 12 reef sharks with Vemco transmitters
- 5) Behaviour of all tagged reef sharks should be monitored with the detection network from 2015 until November 2016



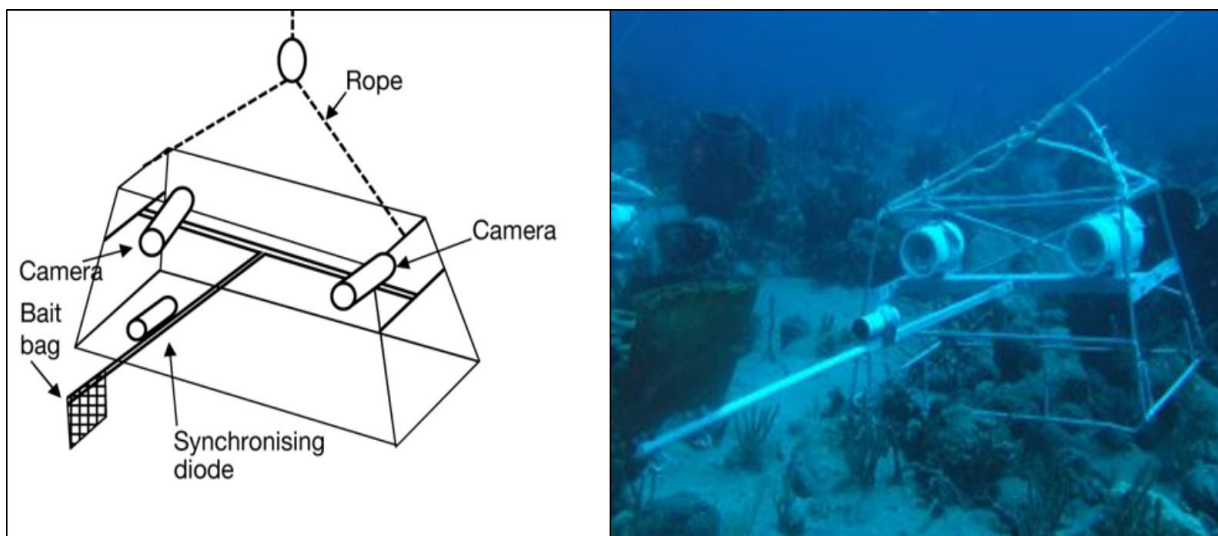
*Caribbean reef shark in the Marine Park conservation zone St Maarten (photo Erwin Winter)*

## 3 Materials and Methods

### 3.1 Baited Remote Underwater Video (BRUV)

#### 3.1.1 General method description BRUV

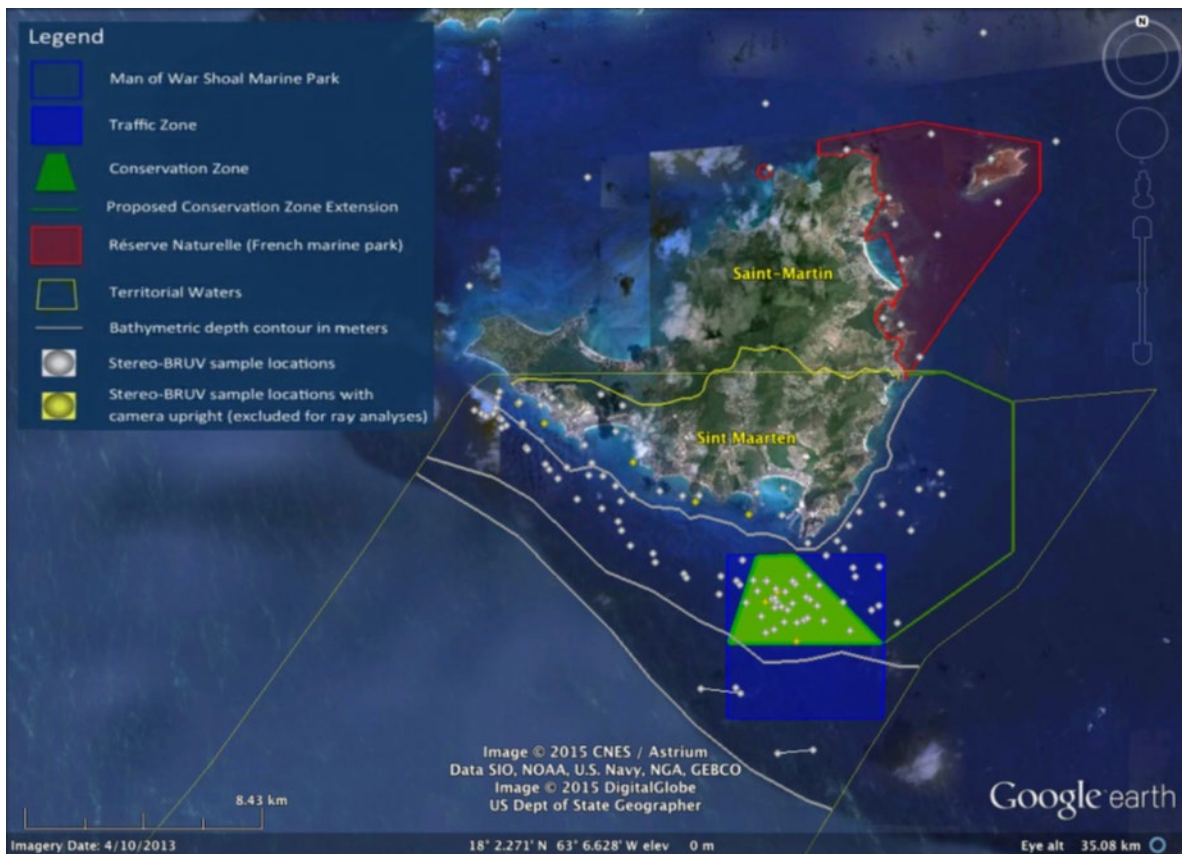
The baseline survey was conducted by using a Baited Remote Underwater Video (BRUV) sampling method. This method is increasingly used to sample both tropical and temperate fish assemblages, as well as elasmobranchs. The camera setup and operation was derived from successful studies from the past, Harman et al. (2003), Watson et al. (2005) and Langlois et al. (2010) and comprised of 2 Canon Legria HFG10 video cameras assembled to a steel frame, 70 cm apart and inwardly converged at 8 degrees (Figure 3.1). The frame is equipped with a synchronising diode and bait bag containing approximately 800 grams of fatty fish positioned at 1.5 meters distance in front of the cameras. More details on materials can be found in each of the reports from St Maarten (Kramer & Odinga 2015), Bonaire (Ruijs 2017) and Curaçao (Reid Navarro 2018). One (stereo) BRUV deployment obtained approximately 60 minutes of continuous video footage. In total, three camera systems were available during this study and could be operated concurrently provided that sample locations were at least 500 meters apart to reduce overlap of bait odour plumes (Willis & Babcock 2000; Harvey et al 2007; Heagney et al, 2007). Initial identification of sharks was later checked by other researchers based on the footage. The maximum number of sharks in one frame during a deployment was used (MaxN) to indicate abundance and to avoid double counting of sharks. Some areas remained under sampled due to adverse sea conditions during the survey periods, e.g. mainly on the wind exposed sides of the islands.



**Figure 3.1.** Example of a stereo BRUV set up as used in this study (photo Martin de Graaf).

#### 3.1.2 BRUV St Maarten (2015)

The BRUV study on St Maarten was carried out between 1 March and 3 May 2015. A total of 115 BRUV deployments were performed divided over different management zones and habitat types (Kramer & Odinga 2015). In addition to the St Maarten side of the island which was the target area of this BRUV study, in addition also 18 BRUVs were also placed on the French side of St Maarten (see Figure 3.2).



**Figure 3.2.** Stereo BRUV deployments on St Maarten (Kramer & Odinga 2015).

### 3.1.3 BRUV Bonaire (2016)

BRUV research on Bonaire was conducted between September 2016 and December 2016, executing a total of 110 standardized-BRUV deployments. To conduct an extensive baseline survey deployments were distributed over depths of 10m and 40m at every management zone (see Figure 3.3).



**Figure 3.3.** Stereo BRUV deployments on Bonaire (Ruijs 2017).

### 3.1.4 BRUV Curaçao (2016-2017)

This study was conducted between September 2016 and January 2017 in the surrounding waters of Curaçao (Reid Navarro 2018). In total 164 BRUV deployments were carried out (see Figure 3.3). In addition to the standard BRUV survey, also a pilot was carried out with placing BRUVs at 80m and 300m during 4 dives with a small submarine of substation Curaçao (Reid Navarro 2018).



**Figure 3.3.** Stereo BRUV deployments on Bonaire (Reid Navarro 2018).

## 3.2 Acoustic telemetry

To study movements of individual reef sharks, biotelemetry methods were used. The target species for this study were Caribbean reef shark (*Carcharhinus perezi*) and nurse shark (*Ginglymostoma cirratum*). The selected tracking method was acoustic telemetry, using Vemco VR2W receivers and V16 transmitters. V16 transmitters can be detected by the VR2W receivers within a range of about 450 m up to 850 m depending on the environmental conditions (e.g. wind). The life span of the batteries of the transmitters is 4.5 year. The battery life of the receivers is 15 months after which the batteries needed to be replaced. The V16-4H transmitters were programmed to emit a unique acoustic signal with an average interval of 80 seconds (programmed with random delays between 50-110 seconds to minimize collision rate between signals from different transmitters when more tagged sharks are present around one receiver).



**Figure 3.4.** Vemco VR2W receiver (left) and Vemco V16 transmitter (right)(photo VEMCO).

The network of 8 receivers that already existed around Saba since 2014 was expanded with 24 more receivers in 2015 to also include Saba Bank (8 receivers, mainly alongside the eastern reef drop off of the Bank), St Maarten (8 receivers) and St Eustatius (8 receivers) (Table 3.1). This network of 32 receivers enables to measure residency and movements of individual sharks within a reef system and detect eventual movements between these different reef systems. The method of deployment was using concrete blocks and a rope with a float about 1.5 m above the seafloor as described in Winter et al. 2015 (figure 3.5).

**Table 3.1.** Overview of the deployment details of the network of 32 receivers around the four different reef systems. The 8 receivers around Saba were already in place at the start of this project.

Island (reef)	Name Location	Receiver ID	Position Latitude	Position Longitude	Receiver depth m	Water depth m	Installation date	Installation time	Deploy method
Saba	Twilight Zone	125926	17.63280	-63.27462	17.0	30.0	21-10-2014	11:20	Mooring
Saba	Shark Shoal	125927	17.64614	-63.26499	19.0	28.0	21-10-2014	11:55	Mooring
Saba	Diamond Rock	125928	17.64755	-63.25658	17.1	25.0	21-10-2014	12:25	Mooring
Saba	Otto limits	125929	17.64632	-63.25190	5.8	7.0	22-10-2014	11:00	Mooring
Saba	Green Island	125930	17.64888	-63.23110	14.0	15.5	21-10-2014	12:55	Block
Saba	Core Gut	125931	17.63113	-63.21750	12.2	13.5	21-10-2014	13:15	Block
Saba	Big Rock Market	125932	17.61252	-63.23623	13.4	14.5	21-10-2014	13:35	Block
Saba	Hot Springs	125933	17.62463	-63.25958	13.4	14.5	21-10-2014	10:45	Block
St Eustatius	Mushroom Garden	480311	17.46198	-62.97802	20.5	22.0	26-10-2015	14:01	Block
St Eustatius	Double Wreck	128323	17.48458	-62.99738	18.3	19.8	26-10-2015	11:52	Block
St Eustatius	Doobie's Crack	128326	17.51013	-63.00820	25.2	26.7	26-10-2015	10:00	Block
St Eustatius	Gibraltar	128327	17.54177	-63.00028	16.7	18.2	26-10-2015	10:30	Block
St Eustatius	Northman	128328	17.52683	-62.99170	26.5	28.0	25-10-2015	11:45	Block
St Eustatius	English Quarter	128329	17.50570	-62.97135	13.0	14.5	25-10-2015	12:03	Block
St Eustatius	Botanical Garden	128330	17.47358	-62.94518	13.9	15.4	25-10-2015	12:30	Block
St Eustatius	Sugar Loaf	128331	17.46315	-62.95588	18.9	20.4	25-10-2015	13:15	Block
St Maarten	Tieglan	128319	17.98763	-63.05925	21.4	22.9	29-10-2015	14:53	Block
St Maarten	Fish Bowl	128320	17.98810	-63.05137	13.9	15.4	29-10-2015	15:24	Block
St Maarten	The Maze	128321	17.99162	-63.05650	7.8	9.3	29-10-2015	16:04	Block
St Maarten	Carib Cargo	128322	17.99380	-63.07033	10.5	12.0	29-10-2015	16:28	Block
St Maarten	Hen & Chick	128317	18.00945	-63.00955	10.5	12.0	30-10-2015	11:05	Block
St Maarten	Pelican Rock	128318	18.02400	-63.02078	14.5	16.0	30-10-2015	11:30	Block
St Maarten	The Bridge	128324	18.02157	-63.11300	13.1	14.6	30-10-2015	12:21	Block
St Maarten	The Gregory	128325	18.04187	-63.14113	13.2	14.7	30-10-2015	12:56	Block
Saba Bank	Receiver 69	114169	17.55112	-63.29323	14.9	16.4	05-11-2015	14:00	Block
Saba Bank	Receiver 70	114170	17.53967	-63.28720	13.1	14.6	05-11-2015	14:45	Block
Saba Bank	Receiver 71	114171	17.50633	-63.23983	20.5	22	11-11-2015	8:19	Block
Saba Bank	Receiver 73	114173	17.48132	-63.22827	13.5	15	11-11-2015	8:45	Block
Saba Bank	Receiver 75	114175	17.40118	-63.19963	14.1	15.6	11-11-2015	9:42	Block
Saba Bank	Receiver 74	114174	17.36443	-63.23717	24.4	25.9	25-11-2015	16:15	Block
Saba Bank	Receiver 76	114176	17.28923	-63.27580	23.2	24.7	25-11-2015	14:15	Block
Saba Bank	Receiver 77	114177	17.44647	-63.59173	24.5	>40m	26-11-2015	9:30	wreck

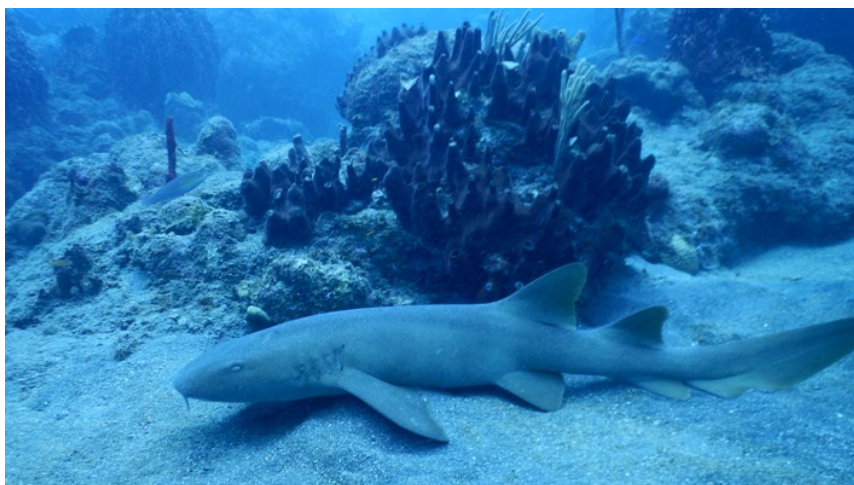
Based on the pilot study around Saba, rod and line was selected as the preferred method for catching sharks (Winter et al. 2015). We used rounded hooks to enhance optimal hooking in the outer jaw with minimal chance on deeper hooking (during this study all sharks were neatly hooked in the corner of the mouth). With help of the staff and assistance of the local Nature Foundations and students, in total 16 sharks (13 Caribbean reef sharks and 3 nurse sharks) were caught and released with a Vemco V16 transmitter implanted according to the method described in Winter et al. (2015) (see Table 3.2. for details on species, date and location of tagging). During this study we could also use the data and presence (battery life of the used transmitters is minimal 4.5 years) of the 12 sharks (8 Caribbean reef sharks and 4 nurse sharks) that were tagged in 2014 around Saba (these are also included in Table 3.2).

In total 21 Caribbean reef sharks (9 males and 12 females) and 7 nurse sharks (2 males and 6 females) implanted with transmitters could be tracked within the network of 32 receivers. The batteries of the receivers last 15 months and were replaced on average each year. Then also a read out of the data was performed. During 2015-2016 two receivers were lost and replaced with new receivers. The network

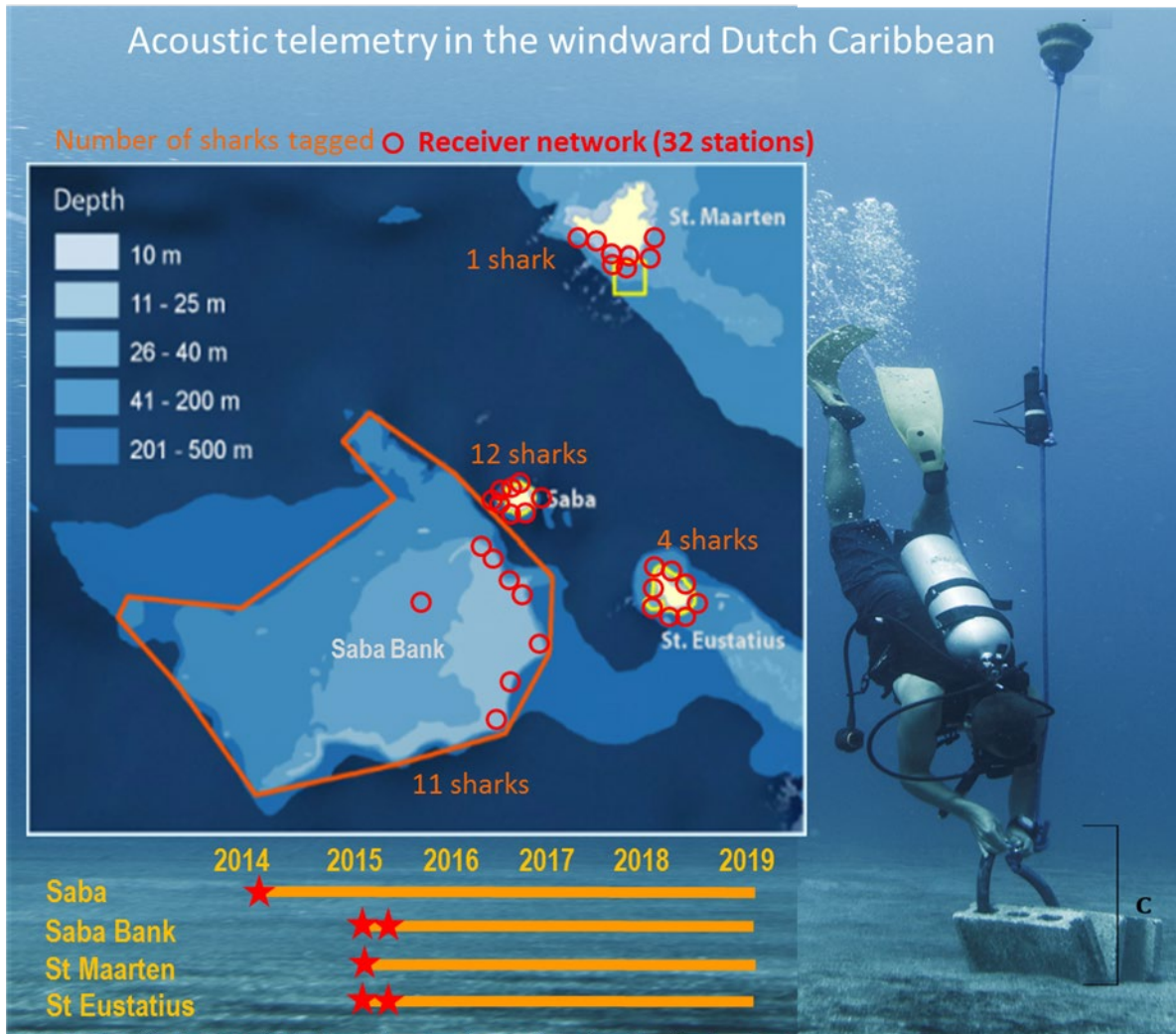
was kept in operation also after November 2016 as was originally assigned for in the project tender. In 2017, two devastating Cat. 5 Hurricanes Irma and Maria (September 2017) caused the loss of 6 more receivers and damaged 2 receivers around St Maarten. The last data retrieval for this report was performed during February-March 2018. Currently, the network is still in place and functioning. Therefore the tagged sharks will yield more data and results than presented in this report.

**Table 3.2.** overview of the reef sharks that were implanted with V16 transmitters. 12 sharks (8 Caribbean reef and 4 nurse sharks) were already tagged during a pilot study around Saba in 2014 (Winter et al. 2015). In addition, 16 reef sharks (13 Caribbean reef and 3 nurse sharks) were caught and implanted with V16 transmitters during the current DCNA SOS study. Minimum battery life of these transmitters was 4.5 years, which enabled long-term following of tagged sharks within the network.

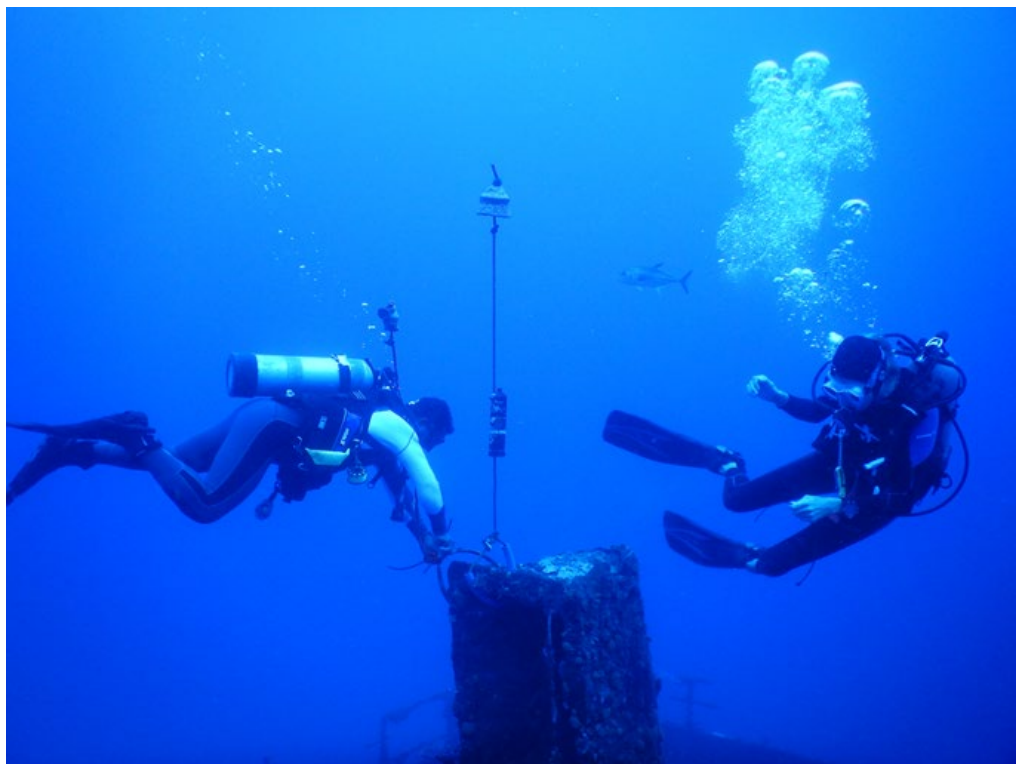
Transmitter ID number	Species name	stage juv/ad	Length cm	Sex m/f	Date catch	Island (Reef)	Location name	Catch Method
23809	Caribbean reef	juv	150	m	23-10-2014	Saba	Shark Shoal	Rod-Hook
23810	Caribbean reef	ad	184	f	23-10-2014	Saba	Shark Shoal	Rod-Hook
23811	Caribbean reef	ad	180	f	24-10-2014	Saba	Third Encounter	Rod-Hook
23812	Caribbean reef	juv	131	f	24-10-2014	Saba	Twilight Zone	Rod-Hook
23813	Caribbean reef	juv	115	m	24-10-2014	Saba	Twilight Zone	Rod-Hook
23814	Caribbean reef	juv	125	f	24-10-2014	Saba	Twilight Zone	Rod-Hook
23815	Caribbean reef	ad	178	m	25-10-2014	Saba	Green Island	Longline
23819	Nurse shark	juv/ad	210	f	25-10-2014	Saba	Green Island	Longline
23816	Caribbean reef	ad	163	m	26-10-2014	Saba	Hole in the Corner	Longline
23820	Nurse shark	juv	104	m	28-10-2014	Saba	SE Big rock market	Longline
23818	Nurse shark	juv	105	f	29-10-2014	Saba	Green Island (200 m E)	Lobster Pot
23817	Nurse shark	juv	94	f	29-10-2014	Saba	Green Island (400 m E)	Lobster Pot
20564	Nurse shark	juv	120	m	31-10-2015	St Maarten	Fish Bowl	Rod-Hook
20565	Nurse shark	juv/ad	206	f	07-11-2015	St Eustatius	Grand Canyon	Rod-Hook
20566	Caribbean reef	juv	105	f	11-11-2015	Saba Bank	Saba Bank (rec 75)	Rod-Hook
20567	Caribbean reef	juv	99	f	11-11-2015	Saba Bank	Saba Bank (rec 75)	Rod-Hook
20568	Caribbean reef	juv	103	f	11-11-2015	Saba Bank	Saba Bank (rec 75)	Rod-Hook
20569	Nurse shark	juv	163	f	11-11-2015	Saba Bank	Saba Bank (rec 75)	Rod-Hook
20570	Caribbean reef	juv	109	m	12-11-2015	Saba Bank	Saba Bank (rec 75)	Rod-Hook
20571	Caribbean reef	juv	112	m	12-11-2015	Saba Bank	Saba Bank (rec 75)	Rod-Hook
20572	Caribbean reef	juv	142	m	13-01-2016	Saba Bank	Saba Bank (rec 77, wreck)	Rod-Hook
20573	Caribbean reef	ad	162	f	13-01-2016	Saba Bank	Saba Bank (rec 77, wreck)	Rod-Hook
20574	Caribbean reef	juv	113	m	13-01-2016	Saba Bank	Saba Bank (rec 77, wreck)	Rod-Hook
20575	Caribbean reef	juv	150	f	13-01-2016	Saba Bank	Saba Bank (rec 77, wreck)	Rod-Hook
20576	Caribbean reef	ad	171	f	14-01-2016	Saba Bank	Saba Bank (rec 76, 1km E)	Rod-Hook
20577	Caribbean reef	ad	155	m	19-01-2016	St Eustatius	Grand Canyon	Rod-Hook
20578	Caribbean reef	juv	148	f	19-01-2016	St Eustatius	Grand Canyon	Rod-Hook
20579	Caribbean reef	juv	102	f	19-01-2016	St Eustatius	Grand Canyon	Rod-Hook



Juvenile nurse shark around Saba (photo Erwin Winter)



**Figure 3.5.** Overview of the acoustic telemetry study on reef sharks around Saba, St Maarten, St Eustatius and at Saba Bank. Red stars represent the timing of the tagging. The photo shows the deployment of a receiver on the sea floor (photo Guido Leurs)



Deploying a receiver on a shipwreck on the western side of the Saba Bank (photo Erwin Winter)

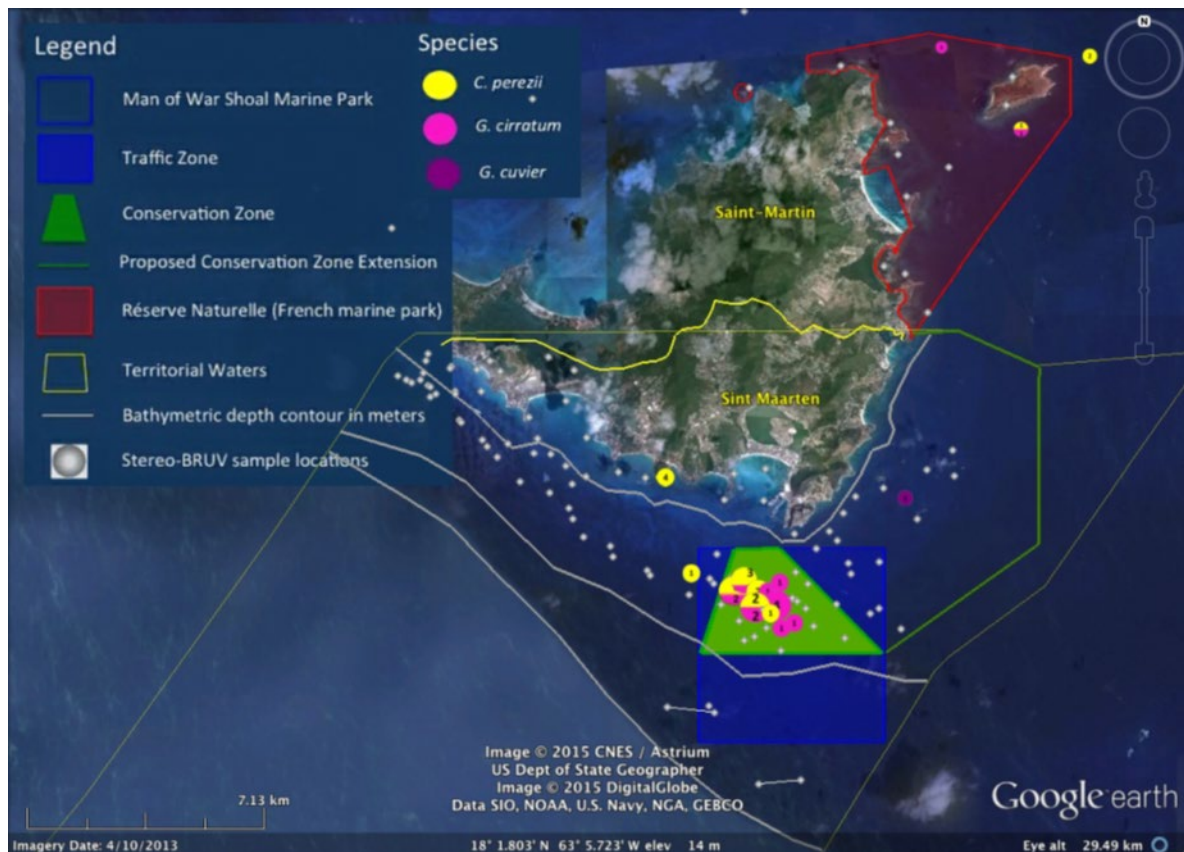
# 4 Results

## 4.1 BRUV studies

For the DCNA SOS project three BRUV studies (St Maarten, Bonaire and Curaçao) were performed during 2015-2017 financed by the Dutch Postcode Lottery (PostcodeLoterij). The results and data analyses of these studies are reported in Kramer & Odinga (2015) for St Maarten; Ruijs (2017) for Bonaire; and Reid Navarro (2018) for Curaçao. The most important findings are summarized below.

### 4.1.1 BRUV St Maarten

During 2015, 133 BRUV deployments were carried out around St Maarten, of which 109 were accepted for shark analyses (see Kramer & Odinga 2015). In 18 deployments, a total MaxN of 37 sharks were observed. Of these, 21 were Caribbean reef shark, 15 were nurse shark and 1 tiger shark. Most reef sharks (both Caribbean and nurse) were seen in the Conservation Zone (Figure 4.1). The tiger shark was observed on the east coast of the Dutch part of St Maarten.



**Figure 4.1.** Distribution of all the BRUV deployments and presence of shark species around St Maarten (Kramer & Odinga 2015). All BRUV sites are marked with a circle, small white circles represents no sharks observed, yellow circle Caribbean reef shark *C.perezii*; pink circle Nurse shark *G.cirrotum*; and purple circle tiger shark *G.cuvier*.

### 4.1.2 BRUV Bonaire

During 2016, 110 BRUV deployments were carried out around Bonaire (Ruijs, 2017). Two shark species were observed, 11 MaxN Caribbean reef shark and 1 Great Hammerhead (see photo). The Caribbean reef sharks were almost exclusively observed at the southern and northern tips of Bonaire, and only one more observation at the north-west side of the island. The Great hammerhead was observed at the most



easterly point of Bonaire. Besides the two shark species, two ray species, i.e. spotted eagle ray and southern stingray, were observed. As for the Caribbean reef sharks most rays were seen in the southern and northern tip of the island.



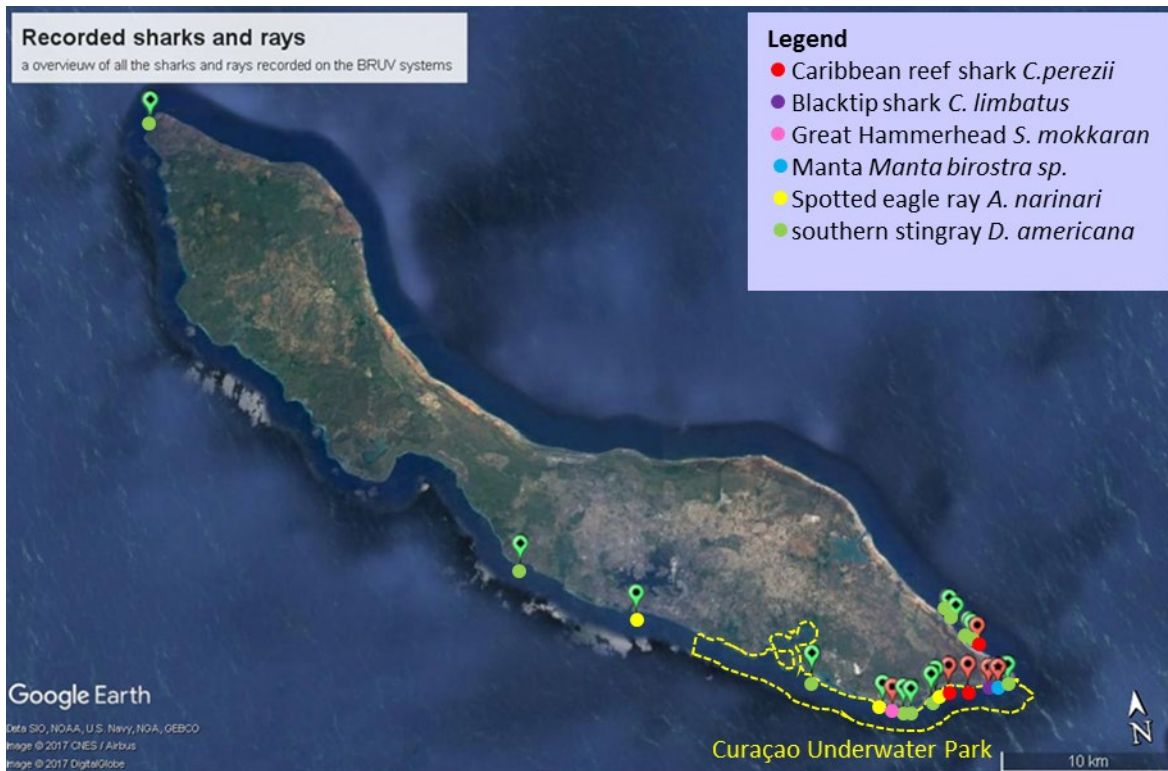
BRUV image of Great Hammerhead at the eastern side of Bonaire (still from BRUV footage)



**Figure 4.2.** Distribution of all the BRUV deployments and presence of shark species around Bonaire (Ruijs 2017). Red circles are Caribbean reef sharks *C. perezii*; orange circle is Great hammerhead *S. Mokarran*, spotted eagle ray *A. narinari* (yellow) and southern stingray *D. americana* (green).

#### 4.1.3 BRUV Curaçao

During 2016-2017, 164 BRUV deployments were carried out around Curaçao (Reid Navarro, 2018). In total 9 sharks were observed. Of these, 5 were Caribbean reef sharks, 3 were blacktip sharks and 1 was firstly identified as a scalloped hammerhead (Reid Navarro, 2018), but later corrected to great hammerhead based on the BRUV footage. All these sharks were observed at the south-easterly tip of Curaçao, with most observations within the Curaçao Underwater Park (figure 4.3). During the pilot BRUV dives with the submarine a MaxN of 7 Cuban dogfish *Squalus cubensis* were observed at 300m.



**Figure 4.3.** Distribution of all the BRUV deployments and presence of shark species around Curaçao (Reid Navarra 2018).

## 4.2 Comparison of SOS BRUV results with other BRUV studies in the Dutch Caribbean

In addition to the three BRUV surveys within the DCNA SOS project, WMR (IMARES) also carried out four BRUV studies in close cooperation with the local Nature Foundations during 2012-2017. Three of those BRUV studies, i.e. Saba (van Looijengoed, 2013), Saba Bank (Stoffers, 2014) and St Eustatius (van Kuijk, 2013) were financed by the Dutch Government; and one at Aruba in 2017 (van Breugel et al. in prep) was financed by Global Finprint. As such, all reef systems in the Dutch Caribbean, i.e. six islands and the Saba Bank, have now been surveyed by BRUV. Here we make a first comparison of shark presence (Table 4.1) and relative numbers, i.e. average MaxN/deployment (Table 4.2) between these different BRUV surveys. This comparison cannot be treated as differences in densities around the surveyed island and Saba Bank because MaxN is mostly an underestimation of the total number of sharks per deployment, and not all areas around the islands were equally sampled.

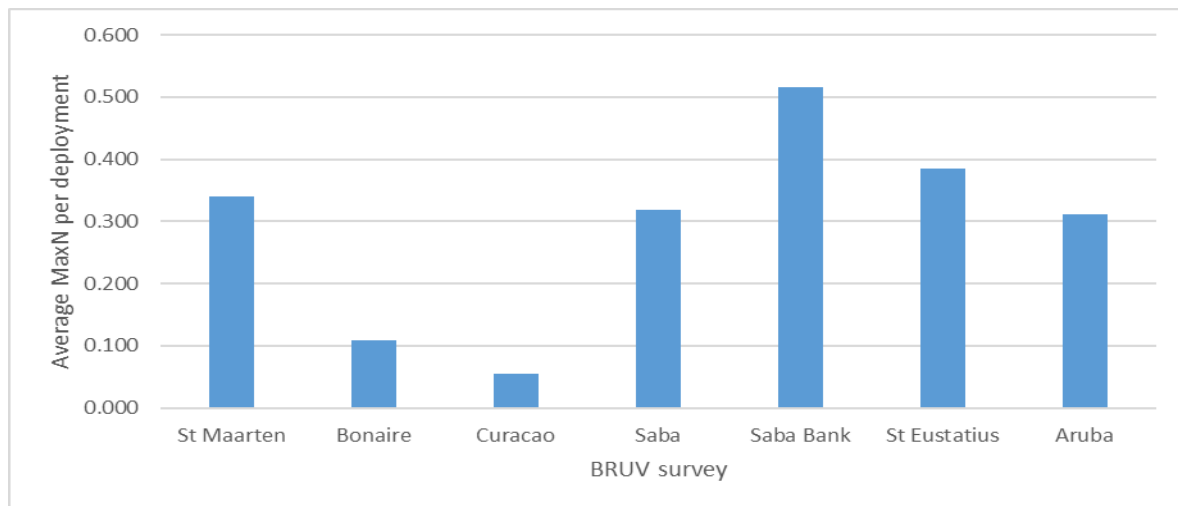
**Table 4.1.** Overview of the 3 BRUV studies at St Maarten, Bonaire and Curaçao compared to earlier BRUV studies at Saba, Saba Bank and St Eustatius and more recently also Aruba. Total numbers of deployments and numbers of sharks (MaxN) per species and location are given.

Total numbers of sharks (MaxN) observed in BRUVs	St Maarten	Bonaire	Curacao	Saba	Saba Bank	St Eustatius	Aruba
Number of BRUV Deployments	109	110	164	113	165	104	122
Caribbean Reef Shark	<i>Carcharhinus perezii</i>	21	11	5	21	36	27
Nurse Shark	<i>Ginglymostoma cirratum</i>	15			12	41	11
Tiger Shark	<i>Galeocerdo cuvier</i>	1				5	5
Blacktip Shark	<i>Carcharhinus limbatus</i>			3	1	3	2
Great Hammerhead	<i>Sphyrna mokarran</i>		1	1	1		1
Silky Shark	<i>Carcharhinus falciformis</i>				1		
Sharpnose shark sp.	<i>Rhizoprionodon spp.</i>						2
Bull Shark	<i>Carcharhinus leucas</i>						1
Lemon Shark	<i>Negaprion brevirostris</i>						1
Total number of sharks	37	12	9	36	85	40	38

**Table 4.2.** Overview of the 3 BRUV studies at St Maarten, Bonaire and Curaçao compared to earlier BRUV studies at Saba, Saba Bank and St Eustatius and more recently also Aruba. Average numbers of sharks per deployment (one hour) per species and sampled location are given. Note that this comparison cannot be treated as differences in densities around the surveyed islands and Saba Bank because MaxN is mostly an underestimation of the total number of sharks per deployment, and not all areas around the islands were equally sampled.

numbers of sharks/deployment (hour)		St Maarten	Bonaire	Curacao	Saba	Saba Bank	St Eustatius	Aruba
All shark species		0.339	0.109	0.055	0.319	0.515	0.385	0.311
Caribbean Reef Shark	<i>Carcharhinus perezii</i>	0.193	0.100	0.030	0.186	0.218	0.260	0.180
Nurse Shark	<i>Ginglymostoma cirratum</i>	0.138	0.000	0.000	0.106	0.248	0.106	0.041
Tiger Shark	<i>Galeocerdo cuvier</i>	0.009	0.000	0.000	0.000	0.030	0.000	0.041
Blacktip Shark	<i>Carcharhinus limbatus</i>	0.000	0.000	0.018	0.009	0.018	0.019	0.008
Scalloped Hammerhead	<i>Sphyrna leweni</i>	0.000	0.000	0.006	0.000	0.000	0.000	0.000
Great Hammerhead	<i>Sphyrna mokarran</i>	0.000	0.009	0.000	0.009	0.000	0.000	0.008
Silky Shark	<i>Carcharhinus limbatus</i>	0.000	0.000	0.000	0.009	0.000	0.000	0.000
Sharpnose shark sp.	<i>Rhizoprionodon spp.</i>	0.000	0.000	0.000	0.000	0.000	0.000	0.016
Bull Shark	<i>Carcharhinus leucas</i>	0.000	0.000	0.000	0.000	0.000	0.000	0.008
Lemon Shark	<i>Negaprion brevirostris</i>	0.000	0.000	0.000	0.000	0.000	0.000	0.008

The number of sharks per BRUV deployment (MaxN) were highest in the survey at the Saba Bank; relatively high in the surveys at St Maarten, Saba, St Eustatius and Aruba, and relatively low at the surveys of Bonaire and Curaçao (Figure 4.4).

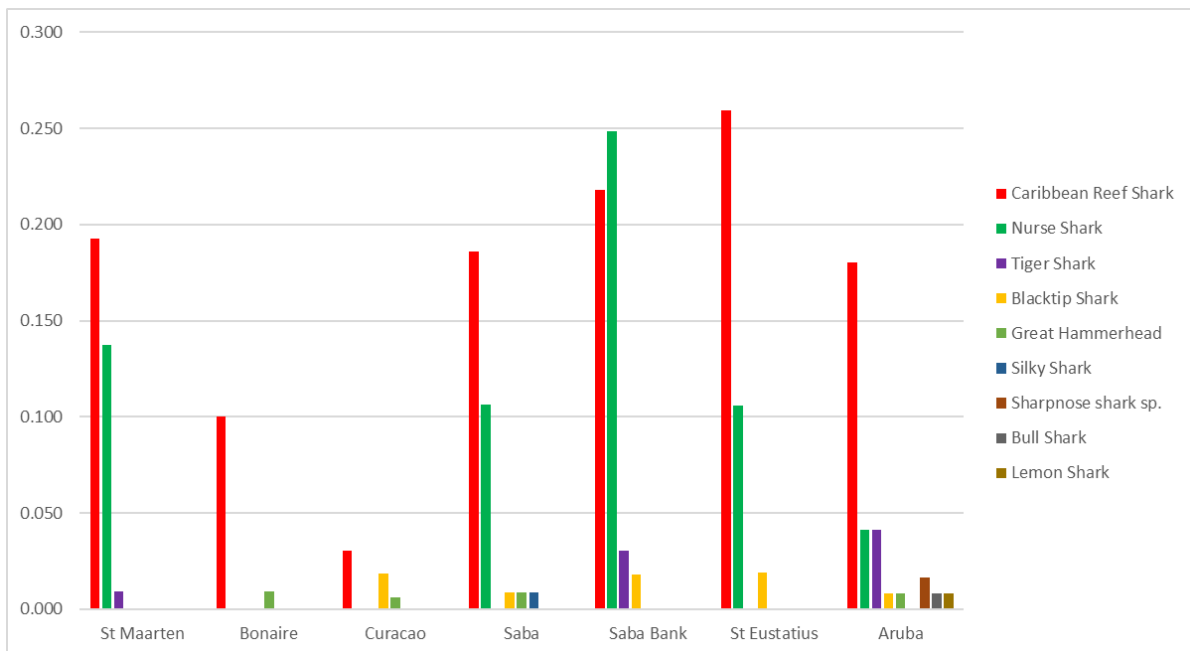


**Figure 4.4.** Average number (MaxN) of sharks per deployment of the 3 BRUV studies at St Maarten, Bonaire and Curaçao compared to earlier BRUV studies at Saba, Saba Bank and St Eustatius and in 2017 also Aruba. Note that this is a comparison between the MaxN of the different BRUV surveys, not in densities between the different islands.

Shark species richness in these BRUV surveys was highest at Aruba with 8 species and lowest at Bonaire with 2 species). On Saba 5 shark species were observed, Saba Bank 4 shark species and St Eustatius, Curaçao and St Maarten all 3 shark species.



Nurse shark attacking the bait on the BRUV (BRUV footage still)



**Figure 4.5.** Average number (MaxN) per shark species per deployment of the 3 BRUV studies at St Maarten, Bonaire and Curaçao compared to earlier BRUV studies at Saba, Saba Bank and St Eustatius and more recently also Aruba. Note that this is a comparison between the different BRUV surveys, not in densities between the different islands.

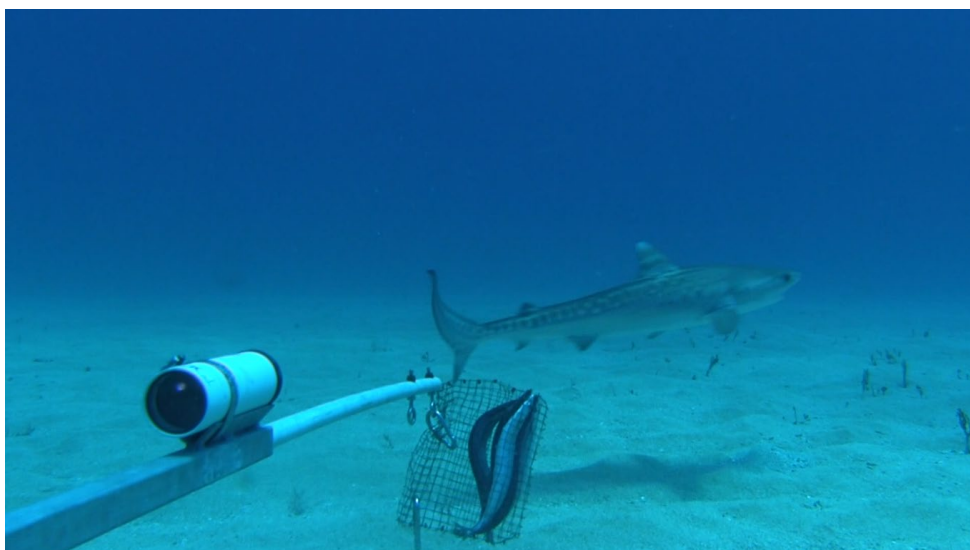
Caribbean Reef sharks were observed at all 7 sites with relative high numbers at St Eustatius, Saba Bank, Saba, St Maarten and Aruba and lower numbers at Bonaire and Curaçao (Figure 4.5).

Nurse sharks were mostly seen at the Saba Bank and also relatively much around St Maarten, Saba, St Eustatius. Lower numbers were found at Aruba, whereas no nurse sharks were observed in the BRUV studies around Bonaire and Curaçao.

Several Tiger sharks were observed at the Saba Bank and Aruba, and one on St Maarten.

Blacktip sharks were seen on Curaçao, Saba Bank, St Eustatius, Saba and Aruba, however only in low numbers.

On Bonaire, Curaçao, Saba and Aruba a Great Hammerhead was seen. One silky shark was observed at Saba; and two sharpnose shark spp. (exact species unknown), one bull shark and one lemon shark at Aruba.



Juvenile tiger shark observed in the BRUV study of St Maarten (east side, BRUV still)

## 4.3 Acoustic telemetry windward Dutch Caribbean

### 4.3.1 General results of the acoustic telemetry during 2014-2018

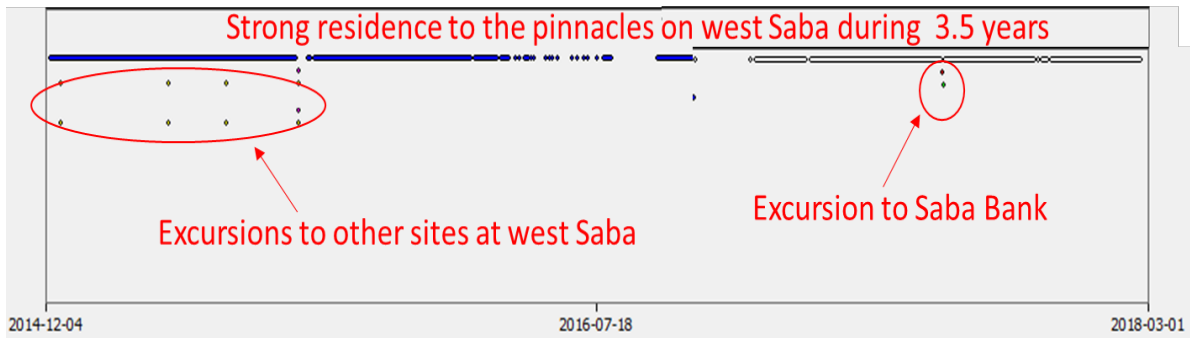
Of the 28 sharks tagged, 15 were detected for more than one year, up to 3.5 years for 5 sharks on Saba (where the study already started in 2014) and up to more than 2 years for 7 sharks on Saba Bank and St Eustatius (Table 4.3). Of these, 8 were still present in the vicinity of a receiver during the last read out in Feb-Mar 2018. Number of detections ranged from 0 (never detected after release) for 2 Caribbean reef sharks at the Saba Bank and St Eustatius to up to ~150,000 for 2 Caribbean reef sharks on Saba and Saba Bank. Most sharks were seen on only one or a few receivers, with a maximum of 5 different receivers. Movements were restricted to only part of the reef system around an island or on the Saba Bank, with usually high residence around a single receiver area.

**Table 4.3.** Overview of the acoustic telemetry results during Oct-2014 until Mar-2018. For each individual shark the transmitter ID, shark species, length, sex, reef system where it was tagged and in brackets reef system where it was also observed, the total number of detections at any receivers, the date of the first detection (usually the date of release) and last date of detection, the duration in days between first and last detection ('time at liberty') and the number of receivers on which it was recorded.

Transmitter ID number	Species name	stage juv/ad	Length cm	Sex m/f	Island (Reef)	Number of detections	first detection	last detection	Time at liberty	n receivers recorded
23809	Caribbean reef	juv	150	m	Saba	23	23-Oct-2014	13-Dec-2015	416	1
23810	Caribbean reef	ad	184	f	Saba	72762	23-Oct-2014	25-Feb-2018	1221	4
23811	Caribbean reef	ad	180	f	Saba (Saba Bank)	150423	24-Oct-2014	1-Mar-2018	1224	5
23812	Caribbean reef	juv	131	f	Saba	20340	24-Oct-2014	9-Jan-2015	77	2
23813	Caribbean reef	juv	115	m	Saba	15	24-Oct-2014	28-Oct-2014	4	2
23814	Caribbean reef	juv	125	f	Saba	17634	24-Oct-2014	20-Sep-2017	1062	2
23815	Caribbean reef	ad	178	m	Saba	24	24-Oct-2014	29-Oct-2014	5	4
23816	Caribbean reef	ad	163	m	Saba (Saba Bank)	472	26-Oct-2014	22-Feb-2018	1215	3
23819	Nurse shark	juv/ad	210	f	Saba (Saba Bank)	11	25-Oct-2014	8-Dec-2017	1140	4
23820	Nurse shark	juv	104	m	Saba	3319	28-Oct-2014	20-May-2015	204	1
23818	Nurse shark	juv	105	f	Saba	33621	29-Oct-2014	25-Feb-2018	1215	2
23817	Nurse shark	juv	94	f	Saba	1004	29-Oct-2014	8-Apr-2015	161	1
20566	Caribbean reef	juv	105	f	Saba Bank	2	11-Nov-2015	11-Nov-2015	0	2
20567	Caribbean reef	juv	99	f	Saba Bank	11651	11-Nov-2015	1-Mar-2018	841	4
20568	Caribbean reef	juv	103	f	Saba Bank	109	11-Nov-2015	20-Sep-2017	679	3
20570	Caribbean reef	juv	109	m	Saba Bank	128	12-Nov-2015	27-Mar-2016	136	2
20571	Caribbean reef	juv	112	m	Saba Bank	2451	12-Nov-2015	21-Jan-2018	801	3
20572	Caribbean reef	juv	142	m	Saba Bank	117604	13-Nov-2015	2-Mar-2018	840	1
20573	Caribbean reef	ad	162	f	Saba Bank	146487	13-Nov-2015	2-Mar-2018	840	1
20574	Caribbean reef	juv	113	m	Saba Bank	47383	13-Nov-2015	7-Oct-2016	329	1
20575	Caribbean reef	juv	150	f	Saba Bank		13-Nov-2015	4-May-2016	173	1
20576	Caribbean reef	ad	171	f	Saba Bank	0	14-Nov-2015	14-Nov-2015	0	0
20569	Nurse shark	juv	163	f	Saba Bank	1495	11-Nov-2015	26-Feb-2018	838	2
20564	Nurse shark	juv	120	m	St Maarten	3067	31-Oct-2015	2-Jan-2016	63	3
20577	Caribbean reef	ad	155	m	St Eustatius	1	19-Jan-2016	19-Jan-2016	0	1
20578	Caribbean reef	juv	148	f	St Eustatius	0	19-Jan-2016	19-Jan-2016	0	0
20579	Caribbean reef	juv	102	f	St Eustatius	30265	19-Jan-2016	27-Oct-2017	647	3
20565	Nurse shark	juv/ad	206	f	St Eustatius	28	7-Nov-2015	8-Nov-2015	1	2

### 4.3.2 Spatial behaviour and residence around Saba

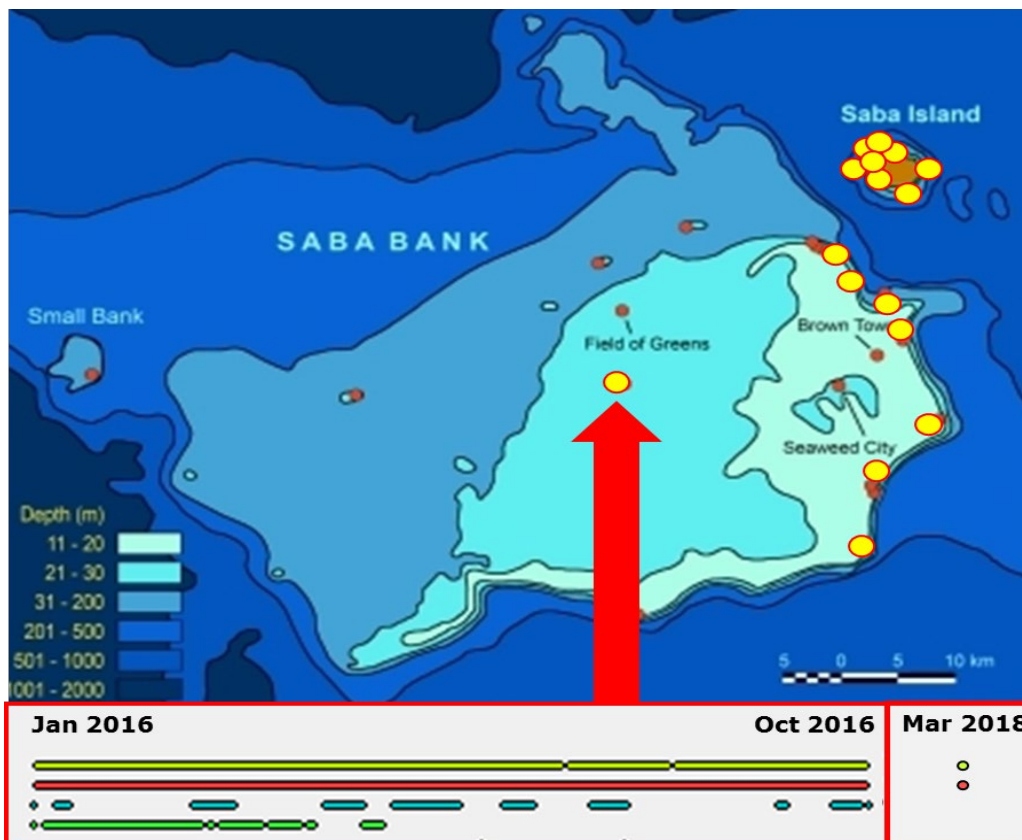
Most Caribbean reef and nurse sharks showed strong residency to a small area, e.g. one side of the island Saba. All sides were used by the different reef sharks, but individuals do not appear to roam around the entire island (see also Leurs 2016). Out of the 12 sharks, 6 remained present around Saba in relatively small home ranges since 2014 for more than 3 years. As an example Caribbean reef shark 23811, an adult female, stayed at the western side of Saba from late 2014 to early 2018, and has used mainly the pinnacles with short excursions to other sites on the western side of Saba (Figure 4.6). It was never observed on the other sides of Saba. It did however, perform an excursion to the Saba Bank in 2017, where after it returned to the pinnacles. This individual was still present during the read out in March 2018.



**Figure 4.6.** Time line of detections of Caribbean reef shark 23811, an adult female, at the western side of Saba, that was recorded on the pinnacles for more than 3.5 years.

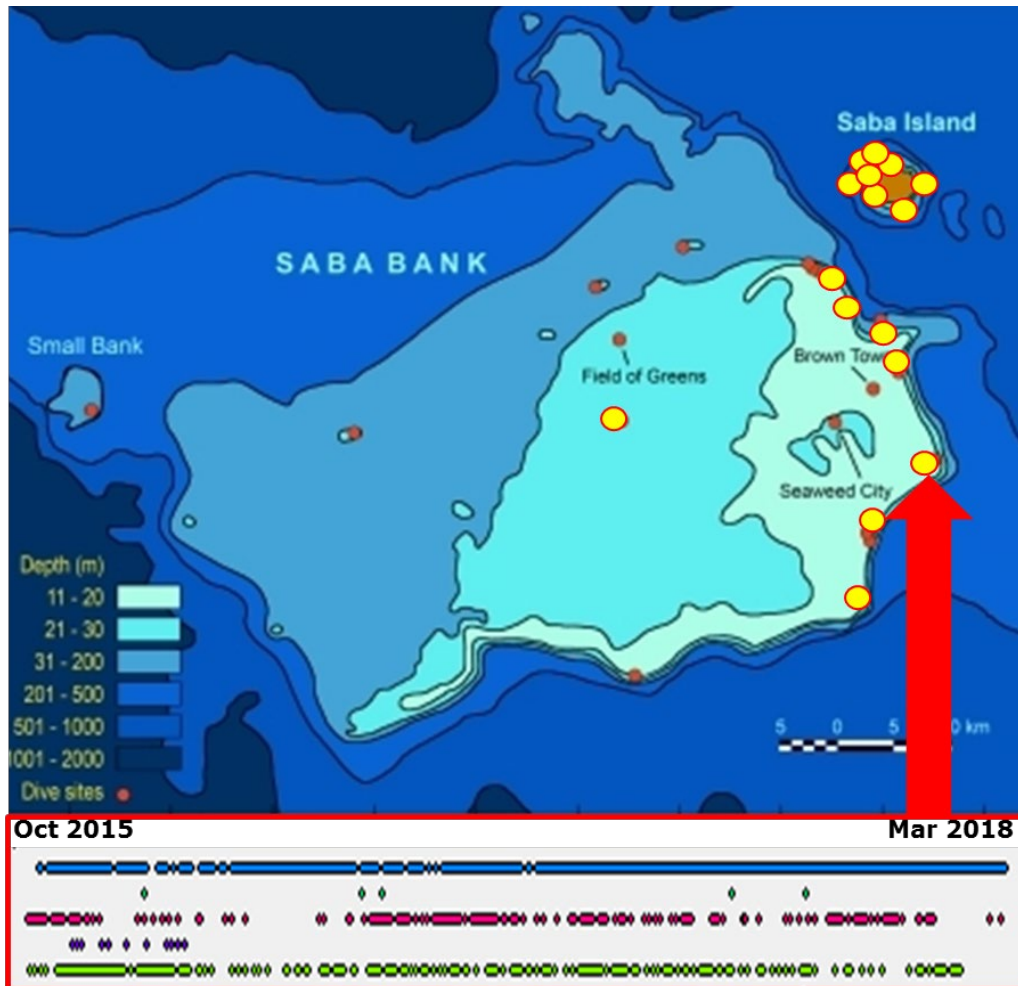
#### 4.3.3 Spatial behaviour and residence at the Saba Bank

As was observed for Saba, tagged individuals on the Saba Bank showed a strong residence to only part of the Saba Bank reef system. Two batches of 4 and 6 sharks were tagged and released at a shipwreck in western Saba Bank (figure 4.7), and on the north east of the Saba Bank (figure 4.8) respectively. All four sharks tagged and released around the shipwreck in the western part of the Saba Bank were detected throughout the first year, except one that was last seen in May 2016. None of these 4 sharks was detected on the other receivers in the network. Unfortunately the receiver was lost in the year after Oct 2016, perhaps in one of the two Cat 5. Hurricanes that swept the area in September 2017. In March 2018 we dove with two temporary receivers around the shipwreck and on this single day still two of the four tagged sharks were present around the site, suggesting that these sharks also show strong residency (Figure 4.7).



**Figure 4.7.** Presence in time of the 4 sharks (Caribbean reef), each line of detections represents an individual shark, that were tagged at receiver 77 on a shipwreck in the west of the Saba Bank. The receiver was unfortunately lost in the year after Oct 2016. When checked with a temporary receiver, two of the 4 sharks were still present in the area around the shipwreck in March 2018. None of these sharks was detected at an adjacent receiver on the day of release and thereafter not anymore.

At the north-eastern side of the reef drop off, (as indicated in figure 4.8), 5 Caribbean reef sharks and one nurse shark were tagged. Three of these (2 Caribbean reef and 1 nurse) were detected at the site of catch and release during long periods from Oct 2015 to March 2018 (figure 4.8). All of these six sharks tagged at receiver 75 at the north eastern side of the Saba Bank were also detected on 1-3 other adjacent receivers along the reef drop-off. But, not at the western receiver on the bank, nor at any of the other islands (Saba, St Maarten or St Eustatius). The results of the sharks tagged on the Saba Bank are in line with what was observed around Saba, i.e. most individuals were observed in relatively small areas for long periods, indicating high residency at small home ranges for at least a substantial part of the sharks at the Saba Bank. Although it should be noted that the receiver coverage of the vast Saba Bank was very small compared to the large coverage of Saba, which increases the chance that larger movements on the Saba bank outside the eastern drop off side remained undetected.

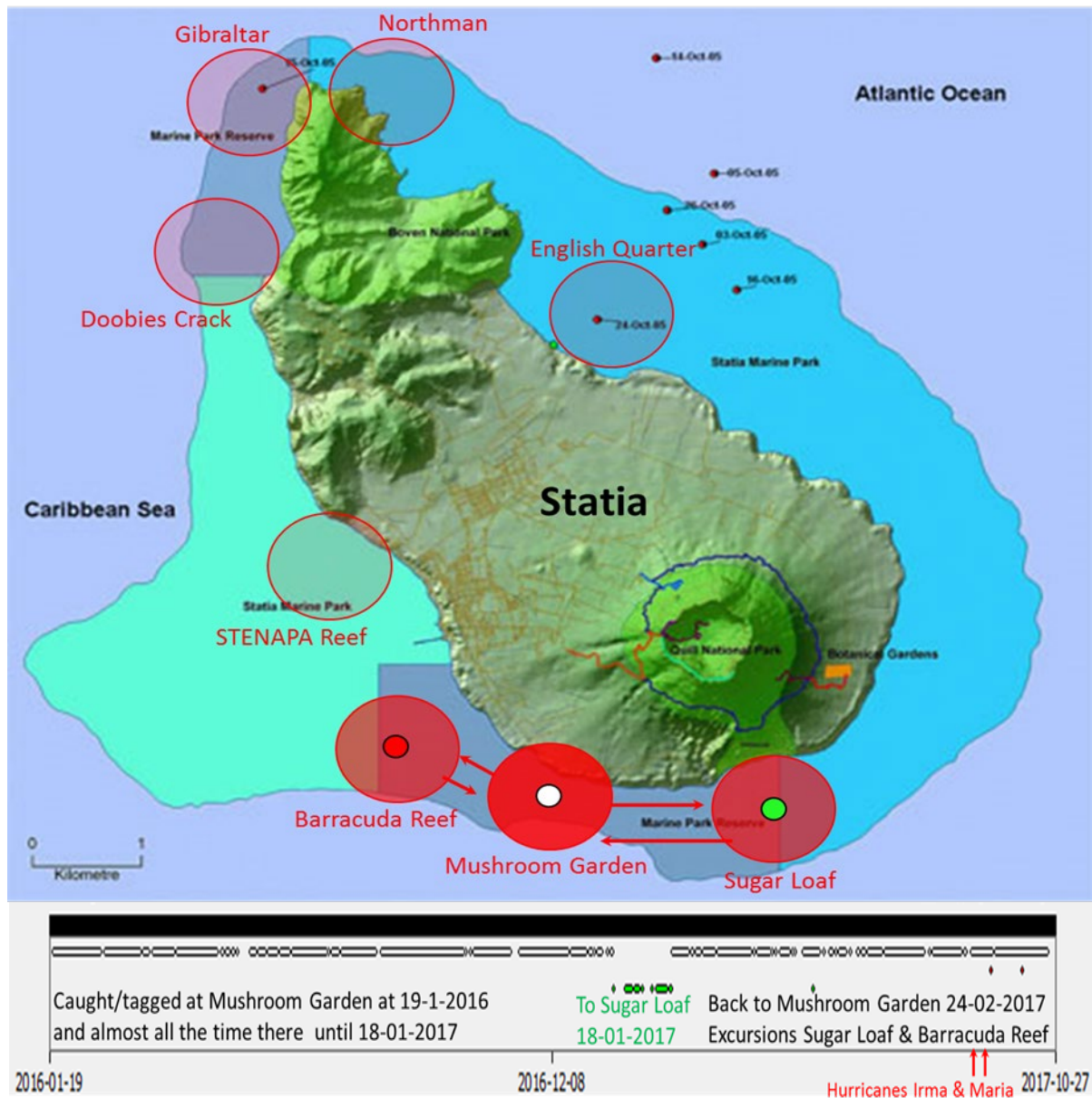


**Figure 4.8.** Presence in time of the 6 sharks (5 Caribbean reef and 1 nurse) that were tagged at receiver 75 in the north east of the Saba Bank as indicated by the arrow. The nurse shark (red) was detected at this station throughout Oct 2015 – Mar 2018, as two Caribbean reef sharks (light blue, light green), 2 Caribbean reef sharks were seen for shorter intervals during this period (dark green, dark blue), one Caribbean reef shark was not detected at one of the receivers after release.

#### 4.3.4 Spatial behaviour and residence around St Eustatius

In January 2016 we tagged three Caribbean Reef sharks and one nurse shark near Mushroom Garden in the central part of the southern Marine Park. Three sharks were only seen briefly after release. One, a young female Caribbean reef shark, stayed near Mushroom Garden almost continuously after release (Figure 4.9). It stayed there almost constantly for nearly two years from 19 January 2016 until 27 October 2017. In January 2017 it moved to Sugar Loaf to stay there for just over a month before going back to Mushroom Garden. After that she performed a few short excursions to Sugar Loaf again and Barracuda Reef, all still within the southern Marine Park. She also stayed at Mushroom Garden when the severe hurricanes Irma and Maria passed by. It was only seen within the southern Marine Park,

never around the other stations in the North West and East of St Eustatius. After 27 October 2017 it was not seen again.

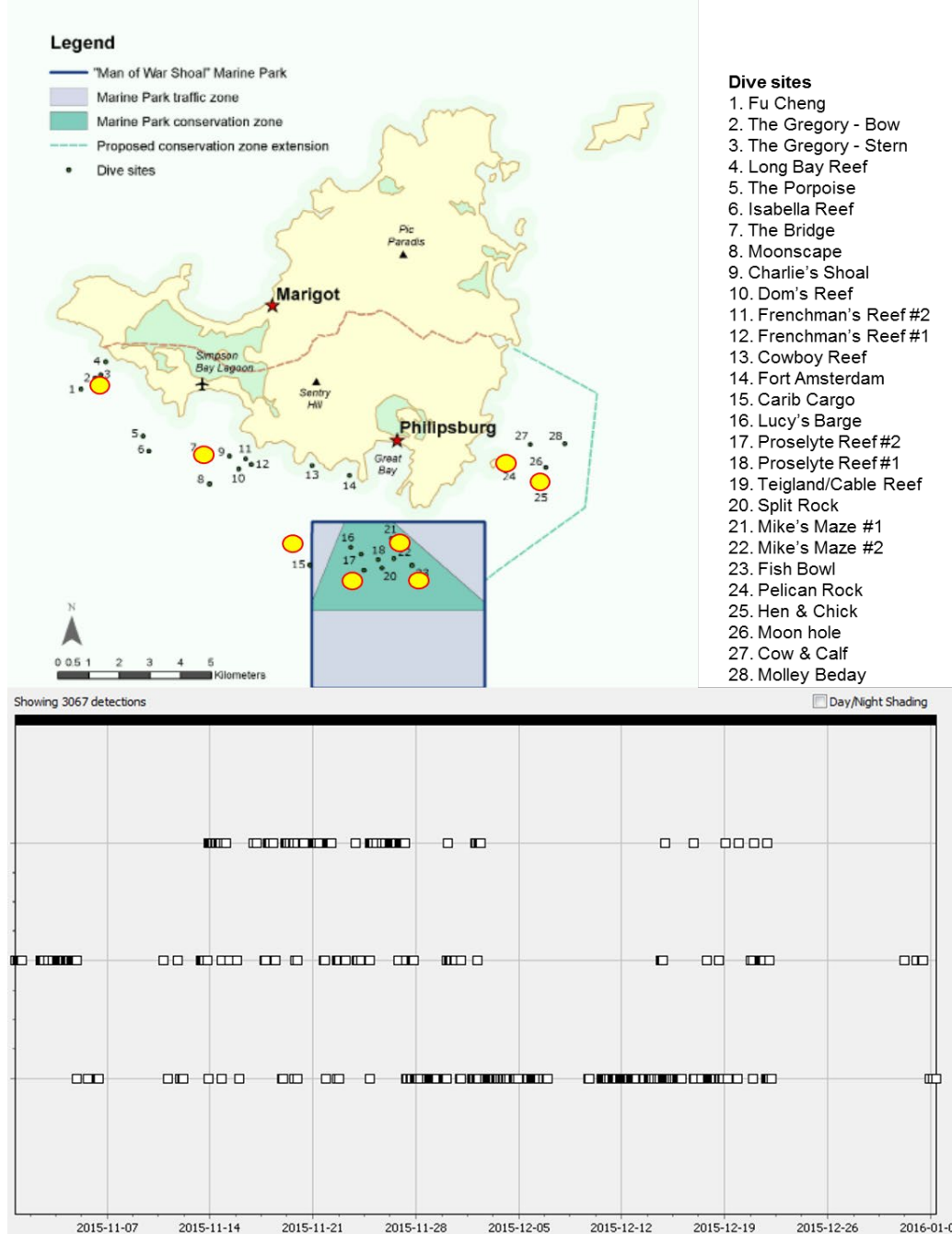


**Figure 4.9.** The areas used by shark 20597, a young female Caribbean Reef Shark tagged at Mushroom Garden. Larger red circles indicate receiver areas, the smaller coloured circles indicate the receivers where this shark was detected (top panel) and the time line of shark 20597, spending almost two years in the Southern Marine Park, mostly around Mushroom Garden, with a short interval to Sugar Loaf. The white dots at detections at receiver Mushroom Garden, the green dots at receiver Sugar loaf, the red dots at receiver Barracuda reef (lower panel).



### 4.3.5 Spatial behaviour and residence around St Maarten

Around St Maarten one nurse shark was caught and tagged within the conservation zone. It stayed within the conservation zone throughout 31 Oct 2015 to 2 January 2016 and was detected on all three receivers within the conservation zone. It was never detected on any of the other receivers outside the conservation zone (figure 4.10). After 2 January 2016 this shark was not detected anymore. Unfortunately all receivers were lost in the Cat. 5 hurricane Irma in September 2017.



**Figure 4.10.** Receivers network around St Maarten (top panel) with 3 receivers placed within the conservation zone (blue green shape) in the of the Marine Park (blue square). Time pattern of detections for a nurse shark that was tagged and released in the conservation zone at St Maarten (lower panel). It was detected at all three receivers within the conservation zone (white squares are detections from nurse shark 20564 at the three receivers within the Marine Park), but never on one of the other five receivers around St Maarten.

#### 4.3.6 Occurrence of larger scale movements (between reefs)

Movements between reef systems were rare in the collected data until February 2018:

- Two Caribbean reef sharks moved from Saba to the northern part of the Saba Bank, crossing waters of 700 m deep, for a short period and then returned back to Saba again.
  - o Caribbean reef shark 23811, an adult female, was last detected prior to the excursion on 28 July at 22:10 in 2017, arrived at the northern tip of the Saba Bank 30 July at 11:58 (28 hours later), was last seen on the Saba Bank on 31 July at 17:00 and returned to her range in Saba again on 1 August 4:48 (12 hours later). This pattern suggest very directed movements.
  - o Caribbean reef shark 23816, an adult male, that has been present on the south and eastside of Saba from January 2015 to January 2018, also made an excursion to the northern part of the Saba Bank were it was detected on 5 September 2016. During this excursion it was not detected at Saba from 16 March to 23 September 2016.
- Nurse shark 23818, an adult female of 210cm, was not seen after release on 25 October 2014 near Green island on the north side of Saba for over 2 years. Then it was detected on 3 and 6 December 2017 on the Saba Bank. Then it was detected on two receivers on the western side of Saba on 8 December. It was not detected thereafter.

Two sharks from other acoustic studies performed inter island movements that were detected within our network of 32 receivers:

- One juvenile tiger shark, a female of 151cm, tagged with an acoustic Vemco tag in another SOS project at St Maarten on 10 October 2016 (data from Tadzio Bervoets & Melanie Meijer zu Schlochtern) was detected on several detection stations west from the Marine Park at St Maarten until 30 October. It was thereafter detected at the north west side of Saba on 4 February 2017.
- One nurse shark tagged within a study on the U.S. Virgin islands, with a fork length of 122cm tagged in May 2017 and often detected until June 2017 around Buck Island Reef National Monument (data from Grace Casselberry) showed up on 22-23 September 2017 on the Poison Bank on the North Eastern side of the Saba Bank, and on 4 and 10 October on the Northern tip of the Saba Bank. From St Croix to the north eastern side of the Saba Bank is a distance of approximately 160 km over deep waters.



*Catching Caribbean reef shark with rod and line for acoustic telemetry at Saba (Photo Erwin Winter)*

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# 5 Conclusions and recommendations

Diversity, abundance, distribution and habitat use of reef sharks in the Dutch Caribbean:

- Baited Remote Underwater Video surveys (BRUVs) that were carried out at St Maarten, Curaçao and Bonaire during this DCNA SOS project showed that Caribbean reef shark was the most detected species around all three islands, with on St Maarten also nurse shark.
- More sharks were observed in marine parks and conservation zones than outside these areas, this appeared to be strongest in Curaçao and St Maarten.
- When comparing these three SOS BRUV surveys (St Maarten, Bonaire, Curaçao) to earlier BRUV surveys at Saba, St Eustatius and Saba Bank and a BRUV survey at Aruba in 2017, shark species richness in these BRUV surveys was highest at Aruba with 8 species and lowest at Bonaire with 2 species. On Saba 5 shark species were observed, Saba Bank 4 shark species, Curaçao 3 shark species in the regular BRUV survey and 1 more species in the BRUV submarine pilot in 300m deep water, and St Eustatius and St Maarten all 3 shark species. At least 10 shark species were observed within all BRUV studies in the Dutch Caribbean combined.
- Numbers of sharks observed in the RUV surveys (MaxN) was lowest in the BRUV survey around Curaçao and to a lesser extent also around Bonaire when compared to the other five BRUV surveys (St Maarten, Saba, St Eustatius, Saba Bank, Aruba). A more detailed analysis of shark numbers, assessing relative densities by taking coverage of the BRUV deployments of the different coastal areas into account, is aimed for to be addressed in follow-up scientific papers.
- Acoustic telemetry revealed that both Caribbean reef sharks and nurse sharks showed strong residency to relatively small home ranges (order of magnitude of a few km). This was observed on all four reef systems studied (Saba, Saba Bank, St Maarten, St Eustatius), although numbers on some sites and species were low on St Maarten and St Eustatius, where they stayed within the borders of the marine parks for long periods.
- Larger movements were rare within the detection dataset, but two adult Caribbean reef sharks residing for years around Saba made short back trip excursions to the Saba Bank, one nurse shark tagged on Saba showed up more than two years later on the Saba Bank before moving back to Saba.
- Tagged sharks from other studies were also observed within the network set-up: one nurse shark tagged in a study around the U.S. Virgin Islands moved ca. 160 km to the Saba Bank in 2017, and one juvenile tiger shark moved from St Maarten to the Northwest side of Saba.
- The results of both BRUV and acoustic telemetry: i.e. both higher presence of reef associated sharks within the marine parks combined with residence for longer periods within the relatively small home ranges, suggest that protecting areas of coral reef the size of the current marine parks will help in the conservation of at least part of local populations of sharks. Also larger scale movements and connections between adjacent reefs over deeper waters (> 500m deep) were found. Data is still limited and we do not know the purposes of those movements, but they appear to occur only in adult sharks. For this, larger scale reserves, such as Yarari protecting a network of important habitats and safeguarding pathways between them might be necessary to protect entire populations of reef associated sharks.

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# Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. This certificate is valid until 15 December 2021. The organisation has been certified since 27 February 2001. The certification was issued by DNV GL.

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 1<sup>th</sup> of April 2021 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](http://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 Wageningen Marine Research 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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# Justification

Report C105/18

Project Number: 4315100050

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved: Dr. J. Batsleer  
Researcher

Signature:

Date: 20 May 2019



Approved: Dr. T. Bult  
Director

Signature:

Date: 20 May 2019



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With knowledge, independent scientific research and advice, **Wageningen Marine Research** substantially contributes to more sustainable and more careful management, use and protection of natural riches in marine, coastal and freshwater areas.



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