Status and trends of St. Eustatius coral reef ecosystem and fisheries: 2015 report card

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EXECUTIVE SUMMARY

Caribbean coral reefs have been declining for decades due to a combination of anthropogenic drivers such as unsustainable fishing practises, pollution, erosion and coastal development and natural phenomena like hurricanes. The degradation of coral reefs is characterised by, among others, a decline in coral cover, three dimensional structure, sharks, large groupers and snapper, herbivorous fish and invertebrates and an increase in macroalgal cover. In the past 40 years throughout the Caribbean large-scale shifts have occurred from coral dominated to macroalgal dominated reef communities.

Healthy coral reef ecosystems and sustainable fisheries are of utmost importance for the small island economies of Bonaire, Saba and St Eustatius. St. Eustatius (21 km^2) is located in the north-eastern Caribbean and is surrounded by the 2700 ha St Eustatius National Marine Park (SNMP) which was established in 1996. From 1996 the SNMP included two marine reserves, the Northern Reserve (163 ha; rezoned in 2015 as harbour area) and the Southern Reserve (364 ha), in which no fishing or anchoring is allowed. In this report we document the 2015 status of a range of indicators for the health of St Eustatius coral reef ecosystem and its fisheries. Where possible the current status and trends of the indicators are discussed in a historical and wider geographical (Caribbean) perspective.

KEY FINDINGS

Status coral reef: **Coral cover declined to a historic low.** In 2015 coral cover had declined to only 5% compared to a coral cover of >20% before 2007. Without adaptive management, recovery of coral cover is unlikely due to high macroalgae cover, low *Diadema* urchin densities and continued fishing pressure on herbivorous fish while the status of the water quality is unclear due to a lack of data. **Dominance of macroalgae is established.** Macroalgae cover is critically high (>25%) and a shift from coral to macro-algal community dominance has occurred. Large grouper species are nearly absent. **The grouper species composition is characteristic for highly fished areas with little management.** Commercial fish biomass (grouper and snapper) remained higher than the average for the Wider Caribbean Region but the lack of large grouper species since 1999 remains undesirable. Herbivorous fish play an important role in controlling macroalgae. **The status of key herbivorous fish (parrotfish and surgeonfish) biomass is reasonable at best.** At present the herbivorous biomass is at the same level as observed in the wider Caribbean Region, although the high contribution of surgeonfish to the catch of the trap fishery is a reason for concern. **Using the most conservative survey results (precautionary approach), the overall Reef Health Index scored the reefs St Eustatius as "poor" in 2015.**

Status reef sharks: Reef sharks are not targeted by the coastal fishery. **Reef sharks were regularly observed and their status appeared to be fair.** However, the lack of historical data and reference points for shark abundance makes it difficult to draw firm conclusions about the current status of these apex predators.

Status fishery: The capacity of the coastal fishery has remained roughly the same over the past 15 years, and possibly even since 1908. The fishery consists of 15-20 small (<10m) wooden boats with only 5 active fishermen resulting in ~500 active boat days per year. The ~200 lobster and fish traps are the main fishing gear. The total annual catch is around 18 tonnes (11 t of Caribbean spiny lobster, 4 t mixed reef fish, 2 t queen conch and 1 t large pelagic fish) or ~1 t/km^2/y. The lobster fishery contributes less than 0.05% to the total annual Caribbean wide landings of the spiny lobster (30 000 tonnes), however, the landings per km^2 within the SNMP (250-500 kg/km^2/y) are among the highest recorded throughout its range. 41% of the landed lobsters were under the minimum legal size of 95mm CL and average size decline from 110 mm CL in 2003 to 99 mm CL. It is questionable whether the current lobster fishery is sustainable and maximum economic yield is being achieved. Small groupers species (Serranidae) and key herbivorous surgeonfishes (Acanthuridae) made up ~50% of the catch of the annual mixed reef fish catch. The landings (~0.2 t/km^2/y) of mixed reef fish appear modest compared to reef fish yields (0.2-27 t/km^2/y) reported for other tropical areas. However, the observed low yield of mixed reef fish may be characteristic for a reef system

dominated by algae, rubble and low relief gorgonian habitats such as is the case in SNMP. The contribution of key herbivorous fish to the catch is undesirable. The fishery on large pelagic fish is underdeveloped. St Eustatius has a healthy adult conch stock and the small-scale directed artisanal fishery operates well within sustainable limits.

Overall, the current evaluation of status and trends of coral reef health, elasmobranchs and fisheries was hampered by the lack of regular, standardized historical surveys and, most importantly, a management plan with quantifiable objectives, targets and reference points. The external review of the St Eustatius National Marine Park Management Plan 2007 (MacRae & Esteban, 2007) indicated the absence of "management effectiveness indicators, corresponding monitoring programmes and an adaptive management framework".

It is recommended to:

a) develop a management plan with clearly defined indicators and quantifiable objectives, targets and reference points with regards to coral reef health, elasmobranchs and sustainable fisheries,

b) continue standardised monitoring of coral reef health, elasmobranch and fisheries indicators; develop and implement a standardised monitoring of water quality,

c) address water quality to ensure the highest water quality possible (e.g. water treatment, minimize erosion) and reduce the fishing mortality of herbivorous fish to enhance the recovery of stony coral cover and reduce macro-algae cover, and

d) report results regularly to evaluate the performance of implemented management by comparing the status of the indicators against the quantified targets, objectives and reference points to facilitate adaptive management.

It is desirable to implement adaptive legislation and regulations to:

a) stimulate the development of a fishery targeting fast-growing, large pelagic species,

b) reduce fishing mortality of sharks and rays to as close to zero as possible; release sharks and rays immediately after capture,

c) reduce fishing mortality of large grouper and snapper species to as close to zero as possible to enhance the recovery of these apex predators; release large grouper and snappers immediately after capture and enhance survival by venting the fish before release,

d) reduce fishing mortality of herbivorous fish, especially surgeonfishes (Acanthuridae), possibly with the introduction of escape slots in the lobster and fish traps,

e) improve compliance with the minimum landing size (95mm CL) for Caribbean spiny lobster, and

f) ensure lobster management is in line with CRFM guidelines with regards to restrictions on minimum landing size, closed season and gear restriction and adjustments (i.e. escape slot, biodegradable panel).

1 INTRODUCTION

Overall the health of Caribbean coral reefs has been declining for decades due to a combination of anthropogenic drivers such as unsustainable fishing practises, pollution, erosion and coastal development and natural phenomena like hurricanes (Jackson et al., 2014 and references therein). Outbreaks of coral diseases (e.g. decimated *Acropora* species) and the dramatic and rapid decline of the long-spined sea urchin (*Diadema antillarum*) due to an unknown pathogen in the early 1980s have had detrimental effects on the health of coral reefs in the Caribbean. The degradation of coral reef ecosystems is characterised by, among others, a sharp decline in coral cover, sharks and other apex predators (large groupers and snappers), large parrotfish and an increase in macroalgal cover. It is, however, not always easy and straight forward to link possible anthropogenic factors of reef degradation to their likely measurable effects. Despite the overall negative trend in the status of Caribbean coral reefs, there are regional differences in the condition of reef ecosystems. Although the causes for these regional differences are not fully understood, the healthier coral reefs are often found in areas with (a combination of) well developed conservation and fisheries management, regulation and compliance, little pollution, erosion, (coastal) development and/or lower occurrences of disease outbreaks, coral bleaching events and hurricanes (Jackson et al., 2014 and references therein).

In the Netherlands, fisheries (~0.05%) and tourism (<0.01%) only contribute marginally to GDP (~800 billion), however, in the Caribbean Netherlands, fisheries (1%) and especially (diving) tourism (>50%) contribute significantly to GDP (~350 million; www.cbs.nl).

Healthy coral reef ecosystems and sustainable fisheries are of utmost importance for the economies of Bonaire, Saba and St Eustatius. Management of the natural resources requires: a) a management plan with clearly defined quantifiable objectives, targets and reference points of coral reef health indicators (coral, fish, fisheries, water quality), b) a continuous robust and standardised monitoring of coral reef health indicators, and c) a transparent decision framework with respect to conservation, coastal development, environmental and fisheries management strategies with active participation of all relevant stakeholders.

Table 1.1: *Overview of international treaties and conventions and reporting obligations for the islands of the Caribbean Netherlands with regards to coral reef fisheries and coral reef ecosystems.*

Treaty, Convention, Organisation	Species/habitats
Food and Agricultural Organisation (FAO)	status and trends landings spiny lobster, conch and mixed reef fish; status and trend fishing effort
Convention on international trade in endangered species of wild fauna and flora (CITES)	international trade in Queen conch; status and trends conch population and its fishery to determine quota (non-detriment finding)
Specially Protected Areas and Wildlife (SPAW) (Multilateral Environmental Agreement, a Protocol under the Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region (WCR) or Cartagena Convention	status and trends whales and dolphins; status and quality coral reef ecosystem; queen conch and spiny lobster Annex III SPAW protocol
Convention on the Conservation of Migratory Species of wild animals (CMS)	status and trends population and distribution sharks
International Commission for the Conservation of Atlantic Tunas (ICCAT)	status and trends catch and effort ICCAT listed fish species (e.g. tunas, marlin, sharks)
International Coral Reef Initiative (ICRI) and its Global Coral Reef Monitoring Network (GCRMN)	status and trends of coral reefs

In the current form of government the Caribbean Netherlands (Bonaire, Saba, St Eustatius) fall directly under the State and hence the Minister of Economic Affairs is directly responsible for the realisation and implementation of international treaties and conventions regarding the management of fish stock, biodiversity and coral reef habitats in the territorial waters and economic exclusive zone of the three islands. The Kingdom of the Netherlands has ratified international treaties and conventions (Table 1.1) and made regional agreements and national laws for the protection of nature and biodiversity on the islands of the Caribbean Netherlands.

These treaties request reporting on status and trends of fisheries, biodiversity, coral reef ecosystems and threatened species (Table 1.1). Good insight in local indicators of the health of coral reefs and its fisheries is not only important to guide local management to maintain or regain healthy coral reef ecosystems but also to provide standardised, comparative data to gain insight in the processes impacting coral reef ecosystems in the Wider Caribbean Region. Most importantly simplifying and standardizing monitoring and ensuring regular data collection will facilitate adaptive management by the responsible authorities on the islands of the Caribbean Netherlands. Since 2012 IMARES has been working with local organizations on baseline marine resource studies and the development and implementation of robust, efficient and (internationally) standardized monitoring programs of coral reef health indicators in the Caribbean Netherlands on request by the Dutch Ministry of Economic Affairs.

St. Eustatius is a small island (21 km^2) located between 17°28' and 17°32' N latitude and 62°56' and 63°0' W longitude. The St Eustatius National Marine Park (SNMP) was established in 1996 and extends from the high tide level out to a depth of 30 m all around the island. The total surface area of the SNMP is 2700 ha (27 km^2). SNMP includes two marine reserves, the Northern Reserve (163 ha) and the Southern Reserve (364 ha), in which no fishing or anchoring is allowed. The Timeline Table provides a brief overview of events impacting the biodiversity and conservation of biodiversity on St Eustatius (Buchan et al., 2014).

Timeline

Since 1983	Mass mortality *Acropora cervicornis* species (Staghorn coral) due to White Band Disease, over the following decades followed to a lesser extent by *A. palmata* (Elkhorn coral)
1983-1984:	Mass mortality *Diadema antillarum* (sea urchin) Caribbean wide
1989:	Hurricane Hugo (Category 4)
1995:	Hurricane Luis and Marilyn (Category 4 and 2 respectively)
1996:	St Eustatius Marine Environmental Ordinance establishes the Statia National Marine Park
1999:	Hurricane Lenny (Category 4)
2005:	Extensive bleaching event
2010:	First invasive Lionfish detected
2012:	Start regular fish and shark (baited remote underwater video) and fisheries research programme
2015:	20% (500 ha) of Statia National Marine Park, including the Northern Reserve, converted to Harbour Area
2015:	Start fish and reef survey using GCRMN protocol

On St Eustatius with GDP $ 100 million (www.cbs.nl) a ~11 million of revenue is generated through coral reef associated tourism and fishery (Bervoets, 2010). In this report we document the 2015 status of a range of indicators (coral cover, macroalgal cover, coral disease, coral recruitment, biomass commercial fish, biomass herbivorous fish, abundance *Diadema*, abundance reef sharks, mixed reef fish and lobster fisheries) for the health of St Eustatius coral reef ecosystem and its fisheries. Where possible the current status and trend of each indicator will be discussed in a historical and/or wider geographical (Caribbean) perspective.

2 METHODS

2.1 STATUS AND TRENDS CORAL REEF ECOSYSTEM HEALTH INDICATORS

MONITORING SITES

An overview of the historical data sources and monitoring locations are presented in Fig. 2.1 and Table 2.1. In 2015 20 sites were selected ranging in depth from 8-15 m and representing the variation of coral reefs in the SNMP (Fig. 2.1; map code 5). Study sites in 2014 and 2015 were not randomly random selected but were predominantly chosen to replicate historical sites. Current and previous sites were mainly selected for accessibility to fixed mooring sites as anchoring is not allowed in the two Marine Reserves. Nearly all reefs on St. Eustatius are not true coral reefs, i.e. structures built by hard corals, but are better described as encrusted boulders and low relief rock ledges (solidified lava flows). The reef habitat is restricted to a narrow band of encrusted rocky ledges, most commonly observed in the two Marine Reserves (Debrot et al. 2014). The sites are, therefore, principally representative for reef habitat in the Marine reserves. Transects for fish and benthic organisms were placed on continuous sections of reef habitat.

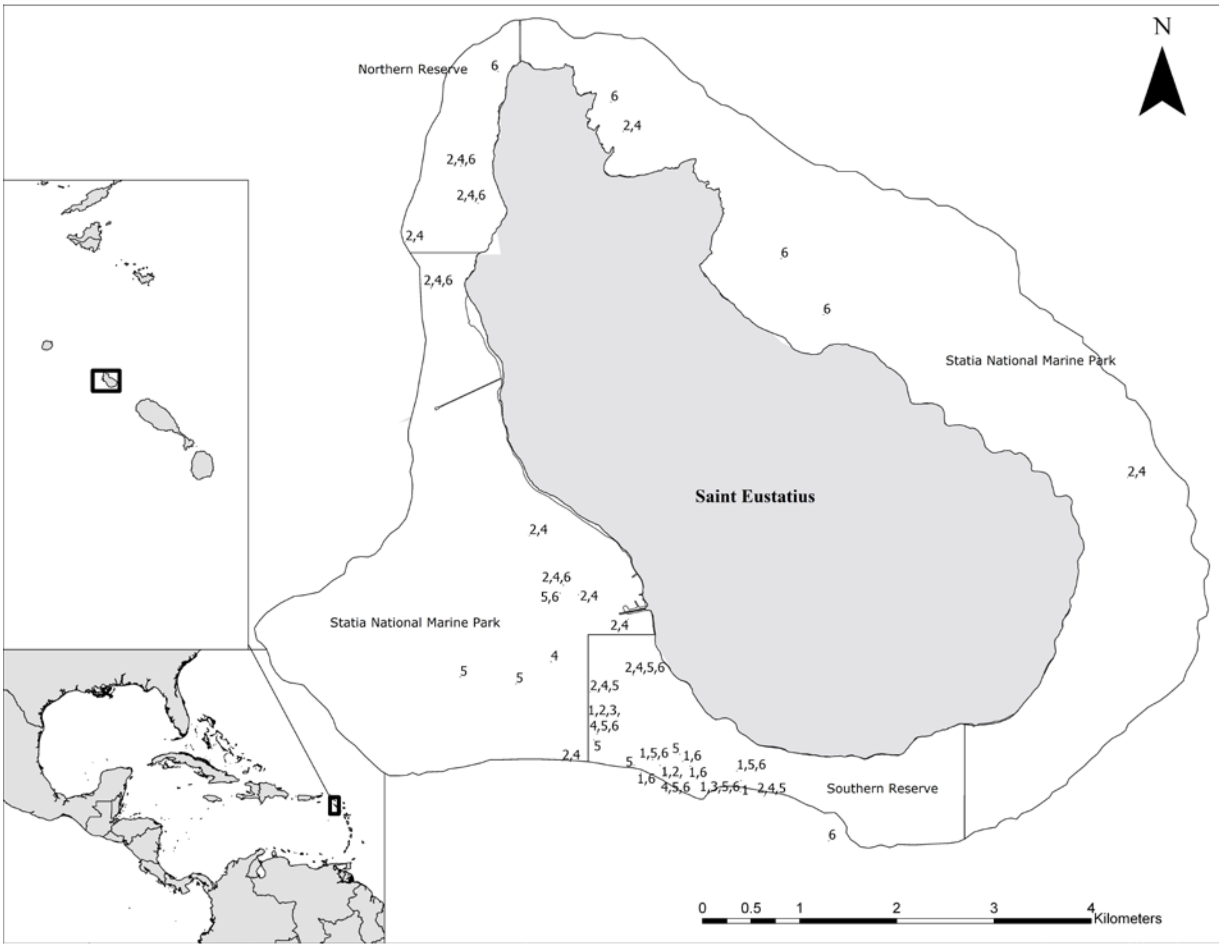


Figure 2.1 *Map of St. Eustatius, codes represent studies listed in Table 2.1.*

Table 2.1 *Overview of the data sources used in this report to determine status and trends indicators of coral reef ecosystem health.*

Map code	Contributor	Location	Time period	Year count	Coral	*Diadema antillarum*	Macroalgae	Fishes
1	AGGRA (Klomp & Kooistra, 2003)	10 sites	1999	1	X	X	X	X
2	White et al. (2006)	16 sites	2004	1				X
3	Reef Check	2 sites	2005, 2007, 2008	3	X	X	X	
4	McClellan (2008)	17 sites	2008	1	X		X	X
5	Data Monitoring Officer	15 sites*	2013-2014	1				X
6	GCRMN & CARIPES (Fishes)	20 sites	2015	1	X	X	X	X**

**only ~50% of the video transects analyzed to date ** two fish surveys in 2015*

GLOBAL CORAL REEF MONITORING PROTOCOL

The Global Coral Reef Monitoring Network (GCRMN) baseline scientific monitoring methods as preceded by CARICOMP (Caribbean Coastal Marine Productivity Program) and AGGRA (Atlantic and Gulf Rapid Reef Assessment; www.aggra.org), provide the latest basic framework to contribute data that support a regional understanding of status and trends of Caribbean coral reefs. The purpose of these methods is to collect data that will promote the health of coral reefs by providing actionable advice to policy makers, stakeholders, and communities.

The GCRMN methods as described below (www.icriforum.org) have been developed to provide a systematic snapshot of the ecosystem health of coral reefs for regional comparisons. These methods reflect long-standing, vetted scientific protocols and provide a compromise between practical applicability and ease of comparison between existing methods and long-term datasets.

The GCRMN methods describe six elements of the coral reef ecosystem:
(1) abundance and biomass of key reef fish taxa (i.e. parrotfish, surgeon fish, groupers, snappers)
(2) relative cover of reef-building organisms (corals, coralline algae) and their dominant competitors (macroalgae)
(3) assessment of health of reef-building corals
(4) recruitment of reef-building corals,
(5) abundance of key macro-invertebrate species (i.e. *Diadema antillarum*), and
(6) water quality (i.e. water transparency (Secchi-disk))

These six elements provide an overview of the current condition of a coral reef ecosystem as well as an indication of likely future trajectories. These methods are designed to provide a basic and regional summary of reef health. Importantly, the elements that are included for GCRMN monitoring are not all-inclusive, and allow partner members in collecting more detailed or spatially expansive data. However, the GCRMN methods should be viewed as a minimum and required snapshot of reef condition – data elements should not be selected individually but instead will be collected at the same time. The multi-dimensional description of coral reef health is essential to provide a coherent 'baseline' of coral reef condition in a dynamic and changing world.

In 2015 20 sites were selected (Table 2.2 and map code 5 in Fig. 2.1) and each site the key elements were monitored using the GCRMN recommended methods as described below.

(1) Fish: The goal of data collection for the fish taxa is to characterize the key species of economic and ecological importance. In total, ***the core data to collect are the density and size structure of all species of snappers (Lutjanidae), groupers (Serranidae), parrotfish (Scaridae), and surgeonfish (Acanthuridae)***. These species are among the principle food fishes among Caribbean small-scale fisheries, as well as being critical species for maintaining reef ecosystem health. All fish observed (of all species) are counted within a belt transect (30m length x 2m width), with the survey time limited to approximately 6 minutes per transect. At each site, five transects are surveyed and the data are pooled to provide an average assessment of the density and size structure of all fishes at the site.

(2) Reef-building organisms and their dominant competitors: The goal of data collection for the assessment of benthic environment (i.e., corals, algae) is to document the relative cover of reef-building, stony corals and their dominant competitors. As such, ***the core data to collect is the percent of the reef bottom that is covered by stony corals, soft corals, and various types of algae (turf algae, macroalgae, and crustose coralline algae)***. The stony corals and some of the calcifying algae are the dominant taxa that build the coral reef structure, while the turf and macroalgae can compete with reef-builders and thereby limit growth of the reef structure. The GCRMN highly recommended method for estimating the cover of key taxa on the reef benthos is the photoquadrat method. This approach depends upon taking digital photographs of the reef surface in standardized quadrat areas (0.9m x 0.6m). Photographs are taken along the transect line set for counting fish, with 15 images captured per transect line (i.e., one image taken at every other meter marker on the transect tape).

(3) Health of reef building corals: The goal of data collection for assessing coral health is to **document the prevalence of disease in stony corals**. Disease prevalence is a metric describing the proportion of coral that shows signs or pathologies of any disease. The GCRMN highly recommended method for estimating disease prevalence in corals depends upon use of the photoquadrats collected following the methods for benthic cover assessment. Data will be recorded as the proportion of images collected that contain a coral with any disease pathology. For example, if there are four colonies in a particular photoquadrat and any of these colonies shows signs of disease, this image would be tagged as "with disease". The number of images that are "with disease" is divided by the total number of images (15 per transect) to generate a proportional estimate of disease prevalence.

(4) Recruitment of reef-building corals: The goal of data collection is to **estimate the density of young corals that are likely to contribute to the next generation of adult corals** on the reef. The GCRMN highly recommended method for estimating coral recruits is similar to the AGRRA methods (http://www.agrra.org/method/methodhome.html). Coral recruits are defined operationally for this assessment as any stony coral that is greater than 1.0 cm^3 and smaller than 4.0 cm^3. Estimates of coral recruit density are recorded from replicate 25cm x 25cm (625cm^2) quadrats. A total of 5 quadrats were surveyed along each of the first three transects used for fish and benthic surveys. The coral recruit quadrats were placed at 2-m intervals along the transect line, i.e. with the lower corner of the quadrat placed at the following meter marks: 2, 4, 6, 8 and 10m. Within each quadrat, each coral within the target size range will be recorded to the finest taxonomic level.

(5) **Abundance of key macro-invertebrates**: The goal of data collection for key macro-invertebrate species is to provide an estimate of the density of biologically and economically important species on the reef. ***The core data to collect are the densities of the longspined sea urchin (*****Diadema antillarum*****), other sea urchins, and all sea cucumbers.*** Many species of sea urchin, especially the historically common long-spined sea urchin (*Diadema antillarum*), are important herbivores on Caribbean reefs with a capacity to control the density of many groups of seaweed. As such, sea urchins can play an important role comparable to that of seaweed-consuming herbivorous fishes. The other key group of invertebrates, the sea cucumbers, includes important fisheries targets in some locations. Many species of sea cucumber are harvested and sold to export markets. The sea cucumbers thus can contribute to local reef-based economies. The GCRMN highly recommended method for estimating the density of sea urchins and sea cucumbers relies on the use of benthic photoquadrats. The 15 photographs from each of the 5 transect lines (75 photographs total) will be inspected. The number and species identity of each echinoid (i.e., sea urchin) and holothurian (i.e., sea cucumber) will be recorded for each image. The density of these key macro-invertebrate species will be calculated by dividing the total number of sea urchins and sea cucumbers recorded by the product of the number of images (highly recommended as 75) and the size of each photoquadrat (highly recommended as 0.54 m^2 [i.e., 0.6 m x 0.9m]).

(6) Water quality: The goal of data collection for water quality is to provide an estimate of the concentration of particulates in the water column. Water quality is influenced by many factors, ranging from oceanographic delivery of nutrients, algal growth in the water column, terrestrial contribution (e.g., mud and silt), and anthropogenic inputs (e.g. spills, accidents, sewage). As an estimate of the integrated water quality, ***the core data to collect are the depths at which standardized Secchi disks are visible in the surface waters of the reef.*** Concentrations of particulate nitrogen, phosphorus, suspended solids and chlorophyll are known to be correlated with Secchi depth. The GCRMN highly recommended method for estimating water quality is to deploy regularly a Secchi disk at sites around the study region. It is a quick, easy and therefore cheap estimate and first indication of changes in water quality when deployed over longer periods. The Secchi disk is a black-and-white disk (20 cm in diameter, for the purpose of GCRMN) that is attached to a measured and marked pole, rope, or chain. Note that at many tropical locations, the depth of the fore reef site will be less than the vertical Secchi depth (e.g., in cases where one can see the reef from the water's surface). In these cases, horizontal Secchi distances can be substituted. It is *highly recommended* to collect information on water quality at weekly intervals at standardized sites (1-8 total) that are ideally co-located with the benthic sampling sites. It is *recommended* to collect information on water quality at monthly intervals with a comparable spatial distribution. Results should be evaluated regularly to be able to react to any changes in water quality and to determine possible causes.

The Reef Health Index was developed by the Healthy Reef Initiative (Kramer, 2003; McField & Kramer, 2007; Healthy Reef Initiative, 2008; www.healthyreef.org) and the description of the four key reef health indicators is given by Kramer et al. (2015).
The Reef Health Index (RHI) is based on four key coral reef health indicators:

- Coral cover - the proportion of benthic surface covered by live stony corals, contributors to the three-dimensional framework
- Fleshy macroalgae cover – the proportion of benthic surface cover by fleshy macroalgae, an increase in macroalgae limits stony coral recruitment and recovery
- Herbivorous fish – a measure of biomass of herbivorous reef fish (e.g. parrotfish and surgeonfish), these grazing species play a major role in controlling (macro)algae that could overgrow coral reefs
- Commercial fish – a measure of biomass of reef fish (e.g. groupers and snappers) with commercial importance to people

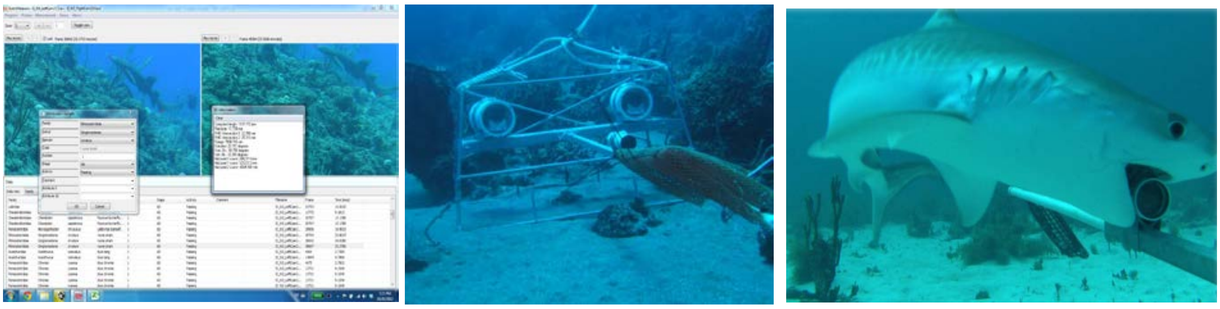
The mean values of the indicators are compared to the criteria listed in Table 2.2. The indicators are given a grade from one ('critical') to five ('very good'). The four grades are combined and equally weighted to obtain a RHI score. An overall score of 1-1.8 is "critical, >1.8-2.6 is "poor", >2.6-3.4 is "fair", >3.4-4.2 is "good" and >4.2-5 is "very good".

Table 2.2 *Overview of the criteria for the four key coral reef health indicators (Source Kramer et al., 2015).*

REEF HEALTH INDEX (RHI)					
Reef Health Index Indicators	Very good (5)	Good (4)	Fair (3)	Poor (2)	Critical (1)
Coral Cover (%)	≥40	20.0-39.9	10.0-19.9	5.0-9.9	<5
Fleshy Macroalgae Cover (%)	0-0.9	1.0-5.0	5.1-12.0	12.1-25	>25
Key Herbivorous Fish (g/100m^2) *(only parrotfish and surgeonfish)*	≥3480	2880-3479	1920-2879	960-1919	<960
Key Commercial Fish (g/100m^2) *(only snapper and grouper)*	≥1680	1260-16.79	840-1259	420-839	<420

2.2 STATUS AND TRENDS REEF SHARKS

Stereo Baited Remote Underwater Video (sBRUV) is a method to study species richness, relative abundance and accurate length frequency distribution of large mobile fish species such as sharks that are difficult to sample with traditional fish survey techniques such as underwater visual survey (UVC) using scuba. More importantly, compared to conventional longline surveys, baited video surveys are a non-invasive method to study shark assemblages across broad spatial scales. The use of BRUV systems to study species richness, population structure, spatial distribution and abundance of reef sharks is spreading rapidly (Bond et al., 2012; Brooks et al., 2011; White et al, 2013; Espinoza et al., 2014).



Example EventMeasure software (left), a BRUV deployed on an inshore reef (middle), and a tiger shark (*Galeocerdo cuvier*) recorded during the BRUV survey on the Saba Bank (right).

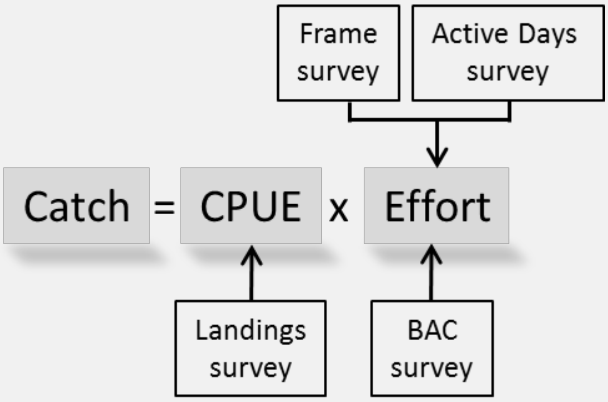
2.3 STATUS AND TRENDS REEF FISHERY

A sample based fishery survey (Stamatopoulos, 2002) was implemented in 2012 to collect basic data on catch, effort, species composition and length frequency of the fishery on St Eustatius. Rather than directly counting all catches, the total catch for each boat/gear category was estimated by using data on the number of boats, the activity level of the boats and the average catches per boat per day.

Schematic representation of the survey design

The generic formula for estimating catch is:

Catch = CPUE x [BAC x F x A]



Frame Survey: A frame survey is a census-based approach to collate a list of homeports and boat/gear categories which is used as the basis for the Active Days, Boat Activity and Landings surveys. The frame surveys is conducted at the start of each year and is updated monthly throughout the year.

Active Days Survey: Active Day Surveys are conducted at the end of each month to determine the number of active fishing days for each strata in the survey design (e.g. home port, boat/gear category).

Boat Activity Survey: Boat Activity Surveys are conducted at homeports separately for each boat/gear category to determine how many boats are active on a given day. If required, homeports are weighed based on the number of fishing boats. Weighed homeports are then randomly selected on survey days. However, St Eustatius has only one homeport.

Landings Survey: Landings Surveys are conducted to collect data on catch, effort, species composition and length frequency with a minor stratum, for a calendar month and boat/gear category. Homeports are weighed based on the number of fishing boats. Weighed homeports are then randomly selected on survey days. However, St Eustatius has only one homeport. In addition to the standard landings data, information was collected on the observations of whales and dolphins by fishermen (Scheidat et al., 2015).

Data analysis: The analysis in this report is limited to the fishery on Caribbean spiny lobster and mixed reef fish using traps, hand-line, and/or spearfishing while free diving or scuba diving in the waters of the SNMP. Landings of large pelagic fish (e.g. wahoo, dolphinfish by trolling), small schooling pelagic fish (scads, mackerels by seine net), deep-water snappers (deep water hand-line) and mixed reef fish caught at the Saba Bank were excluded from the analysis in the current report. The status of the conch fishery on St. Eustatius has been analysed and published by de Graaf et al. (2014).

Length-based assessment model: A simple length-based assessment method developed for tropical reef fish stocks is applied in order to make a first assessment of the state of the reef fish resources on St Eustatius. The interest of this method is that it uses only length frequency data, which are easy to collect when no other information is available. Previous studies applied to Florida and to Puerto Rico reef fish have demonstrated the interest of the method to deliver information on stock status and exploitation levels (Ault et al. 2008, 2014), which can be used directly to develop management actions. In the case of the Dutch Caribbean, where no quantitative assessment of the resource is available, implementing this method presents the first step towards the elaboration of scientific advice for fisheries management.

3 RESULTS

3.1 STATUS AND TRENDS CORAL REEF ECOSYSTEM HEALTH INDICATORS

FISH BIOMASS

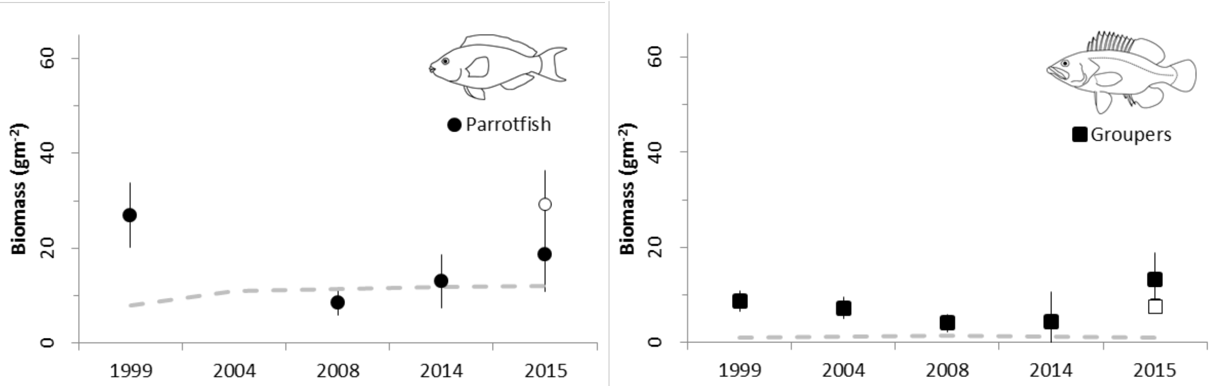
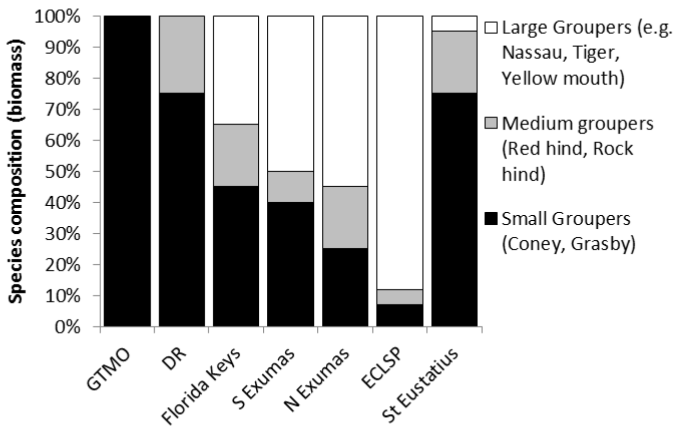


***Figure 3.1** Average biomass of parrotfishes (top left) and groupers (top right) in SNMP. The grey dotted lines represent the average value for the Caribbean (Jackson et al. 2014). White marker are GCRMN survey. Error bars are 95% CI. Composition of grouper assemblages (bottom left) in Guantanamo Bay Naval Base, southeastern Cuba (GTMO), southeastern Dominican Republic (DR), Florida Keys, Southern and Northern Exumas, and the Exuma Cays Land and Sea Park (ECLSP) (redrawn from Chiappone et al., 2000) compared with St Eustatius. From GTMO to ECLSP fishing pressure decreased and management and protection increased.*



<u>Current status:</u> In 2015 the CGRMN survey appeared to record lower biomass estimates for groupers than the CARIPES survey. The status of groupers is undesirable in 2015 despite the fact that the biomass of groupers (both CARIPES and GCRMN surveys) appeared higher than the average biomass observed on coral reefs in the Wider Caribbean Region. Of the 267 groupers observed during the 2015 GCRMN survey only 1 (0.3%) was larger than 40 cm. Furthermore, only two specimen of large grouper species (apex predators) were observed, 87% of the recorded groupers were the small-sized (<40 cm) coney (*Cephalopholis fulva*). An extensive fish survey using sBRUV (stereo baited remote underwater video) also reported that less than 2% of the observed groupers belonged to the large grouper species (Kuijk et al., 2015). The current grouper species composition on St Eustatius is characteristic for highly fished areas with little management (Chiappone et al., 2000; *see Fig. 3.1 bottom right*). The CGRMN survey (2015 left values) appeared to record higher biomass estimates for parrotfish than the CARIPES survey (2015 right values). The 2015 status of the coral reef ecosystem element 'biomass parrotfish' appeared to be 'fair', its biomass is higher than the average for the Wider Caribbean Region.

<u>Trend:</u> The biomass estimates (GCRMN and CARIPES) of parrotfish in 2015 appeared to be similar to the 1999 estimate. The biomass of groupers remained roughly at a stable level during the period 1999-2015. Since 1999 grouper biomass appeared higher than the average grouper biomass observed in the Wider Caribbean Region. However, little change has been observed in the species composition, with the small-sized coney also dominating (85%) the grouper assemblage during the fish survey in 1999 (Klompe &

Kooistra, 2003). The lack of large grouper species over a prolonged period of time is an undesirable situation.

CORAL AND MACROALGAE COVER

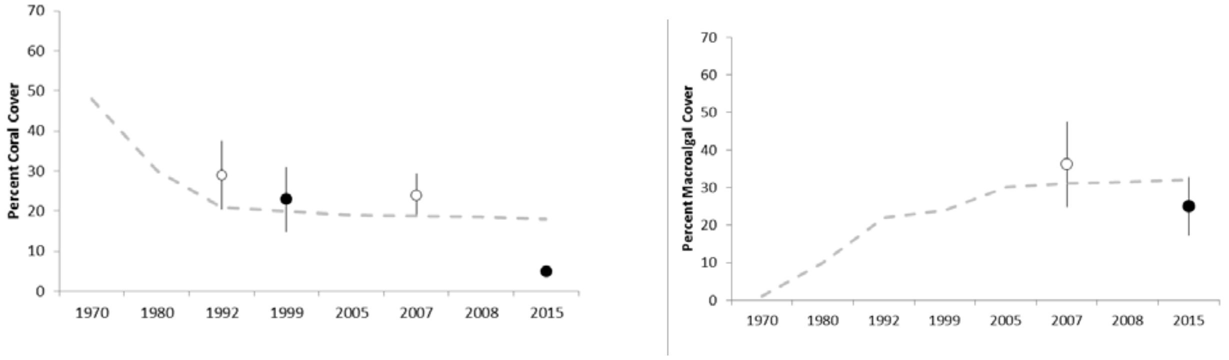
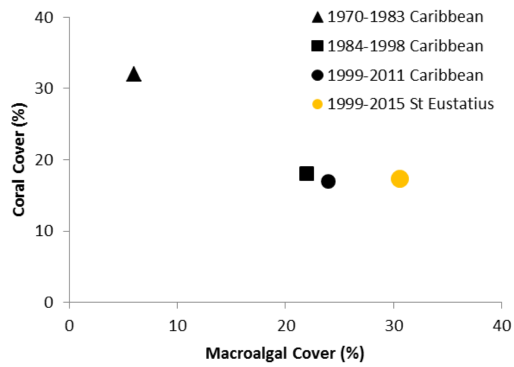


Figure 3.2 Average percentage of live coral (top, left) and macroalgae (top, right). Grey dotted lines represent the average of Caribbean data (Jackson et 2014). Note that during the surveys in 2005, 2007 2008 only two sites (4 transects) were monitored and for the three years were pooled (“2007”) and 1992 cover based on qualitative data from Sybesma et al. (1993). Error bars are 95% CI. Large-scale shift from to macro-algal community dominance in the Caribbean (Jackson et al. 2014) since the early 1970s the average situation on St Eustatius for the period 1999-2015 (bottom, right).



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Current status: Coral cover was low (~5%) in 2015 and markedly lower than the average coral cover reported for the Caribbean. Macroalgal cover was high (~25%) in 2015 and similar to the average macroalgal cover in the Caribbean. The 2015 status of the coral reef ecosystem elements ‘coral cover’ and ‘macroalgal cover’ is undesirable (low coral cover, high macroalgal cover).

Trend: The average coral cover in the Caribbean has declined sharply since the 1970s and has remained more or less stable since 1999 (Jackson et al. 2014). On St Eustatius, however, the trend in coral cover continued to decline since 1999 reaching a historic low level in 2015. Like in the rest of the Wider Caribbean Region, the macroalgal cover has been high since 2007 and the reef community is at present dominated by macroalgae.

RECRUITMENT AND HEALTH REEF BUILDING CORALS

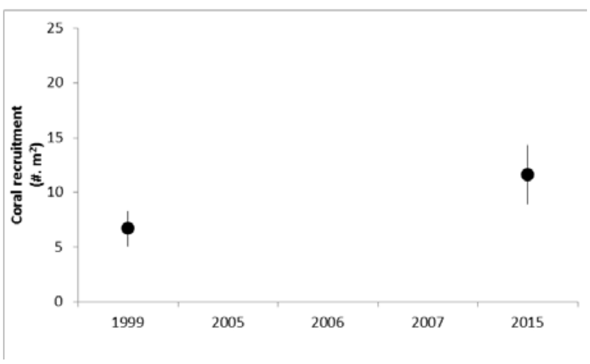

Figure 3.3 Coral recruitment (left) and prevalence of coral disease (right) on St Eustatius. Error bars are 95% CI.

Current status: In 2015 nearly 12 coral recruits per m^2 were observed and diseased coral colonies were observed in ~5% of the benthic survey quadrats. On the reefs of Bonaire ~10-20 recruits per m^2 has been reported between 2003 and 2015 (Steneck et al., 2015) while Kramer (2003) reported an average coral recruitment in the Wider Caribbean Region in the period 1997-2004 of ~4 coral recruits per m^2. The 2015 status of the coral reef ecosystem elements 'coral recruitment' is 'good'. In 2015 6.4% (±3.7 95% CI) of the benthic quadrates had one or more diseased stony coral colonies. Unfortunately no comparable values were readily available for prevalence of coral disease for the Wider Caribbean Region to determine the status of this coral reef element.

Trend: Coral recruitment appeared to be higher in 2015 compared to 1999 (Klompe & Kooistra 2003). Unfortunately, no comparable historical data were available for the prevalence of coral disease in stony corals.

ABUNDANCE KEY MACRO-INVERTEBRATES

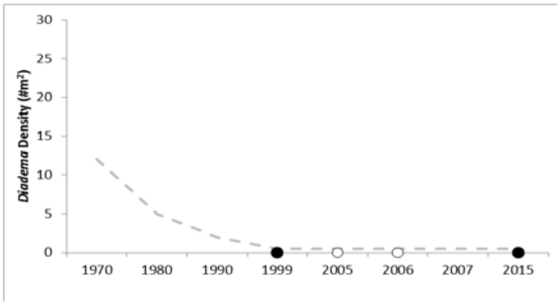

Figure 3.4 *Trend in the density of the long-spined sea urchin (*Diadema antillarum*) on St Eustatius. Dotted lines represent the average value for the Caribbean (Jackson et al. 2014).*

Current status: The density of long-spined sea urchin (*Diadema antillarum)* on St Eustatius was very low (<<1 urchin/m^2). On average recent densities in the Wider Caribbean Region remained low, although recovery of *Diadema* populations has been reported for certain areas (Idjadi et al., 2010). The 2015 status of the coral reef ecosystem element 'density *Diadema*' is undesirable.

Trend: Unfortunately for St Eustatius no reference data are available of historical densities of *Diadema* from before the Caribbean wide massive die-off in 1983-1984. Since 1999 the density (#/m^2) of *Diadema* on the surveyed reefs has remained near zero.

WATER QUALITY

Current status: In 2015 water transparency was measured once at each of the 20 survey sites. The average horizontal transparency near the bottom was 25m (±3.7 95% CI; range 10-43m). Unfortunately no comparable values are readily available for water transparency for the Wider Caribbean Region to determine the status of this coral reef ecosystem element.

Trend: No historical information on water transparency (Secchi disk) is available for St Eustatius.

REEF HEALTH INDEX (RHI)

The Reef Health Index (RHI) is based on four key coral reef health indicators: Coral Cover, Fleshy Macroalgae Cover, Key Herbivorous Fish and Key Commercial Fish (Kramer, 2003; McField & Kramer, 2007; Healthy Reef Initiative, 2008; Kramer et al., 2015). The mean values of the four indicators are compared to the criteria listed in Table 3.1. The indicators are given a grade from one ('critical') to five ('very good'). The four grades are combined and equally weighted to obtain a RHI score.

<u>*Current status:*</u> In 2015 the two indicators for health of the benthic community scored "poor" (coral cover) and "critical" (macroalgae cover). However, the overall RHI score for the selected sites on St. Eustatius was either "poor" (CARIPES) or "good" (GCRMN) depending on the two different fish surveys that were conducted at more or less the same sites and period. In the GCRMN fish survey both fish biomass indicators scored "very good", however, the CARIPES fish survey scored herbivorous fish as "fair" and commercial fish as "good". The high score of the GCRMN herbivorous fish biomass is caused by one of the highest observed biomass (nearly 6 kg/100m^2) of surgeonfishes (Acanthuridae) recorded for the Wider Caribbean Region (Williams and Polunin 2001). Despite the fact that the health indicator "commercial fish biomass" scored "good" (CARIPES) or "very good" (GCRMN) in the simplified RHI, large grouper species (*see Fig. 3.1*) were nearly absent in the current grouper species composition which is an "undesirable" status regardless of the biomass.

<u>*Trend:*</u> Live stony coral cover declined from "good" in 1999-2007 to "poor" since 2008 while macroalgal cover scored "critical" since 2005. The biomass of key commercial fish has been more or less stable over the past 15 years fluctuating between "fair" and "very good". The key commercial fish indicator only considers total biomass of grouper (and snapper) but does not take into account the species composition over small, intermediate and large grouper species (*see Fig. 3.1*). The biomass of key herbivorous fish was "very good" in 1999 but only scored "fair" since 2008 with the exception of the 2015 GCRMN survey scoring "very good".

Table 3.1 *Overview of current and historical Reef Health Index scores for St. Eustatius. (ND = no data, * =CARIPES).*

REEF HEALTH INDEX (RHI)								
Reef Health Index Indicators	**1999**	**2004**	**2005**	**2007**	**2008**	**2014**	**2015**	
Coral Cover (%)	23	ND	27	26	6.5	ND	*5*	*5*
Fleshy Macroalgae Cover (%)	ND	ND	43	18	14	ND	*25.2*	*25.2*
Key Herbivorous Fish (g/100m^2) *(only parrotfish and surgeonfish)*	4977	ND	ND	ND	2100	2514	*2400**	*9411*
Key Commercial Fish (g/100m^2) *(only snapper and grouper)*	921	1132	ND	ND	2261	1144	*1670**	*2035*
RHI Score	ND	ND	ND	ND	3	ND	2.5	3.5

3.2 STATUS AND TRENDS REEF SHARKS

A total of 42 shark sightings (Caribbean Reef Shark, *Carcharhinus perezii*: N = 29; Nurse Shark, *Ginglymostoma cirratum*: N = 11; and Blacktip Shark, *Carcharhinus limbatus*: N = 2) were recorded during 104 sBRUV deployments. Sharks were observed around the island. Nevertheless, the two main species appeared to show some contrast in distribution. Caribbean reef sharks appeared to be more or less evenly distributed around the island both inside and outside the two reserves. Nurse sharks were more frequently observed outside the reserves. No clear relationship between habitat complexity and abundance was observed for either Caribbean reef sharks or nurse sharks. Nearly all observed sharks were juveniles.

Current status: Reef sharks appeared to be more often observed in the SNMP compared to the few other published Caribbean video surveys (Brooks et al, 2011 Bahama's; Bond et al., 2012 Belize), however, the lack of historical data ("shifting baseline") on shark abundance in SNMP makes it difficult to draw at this stage firm conclusions on the current status.

Trend: No historical information on reef shark abundance is available for SNMP.

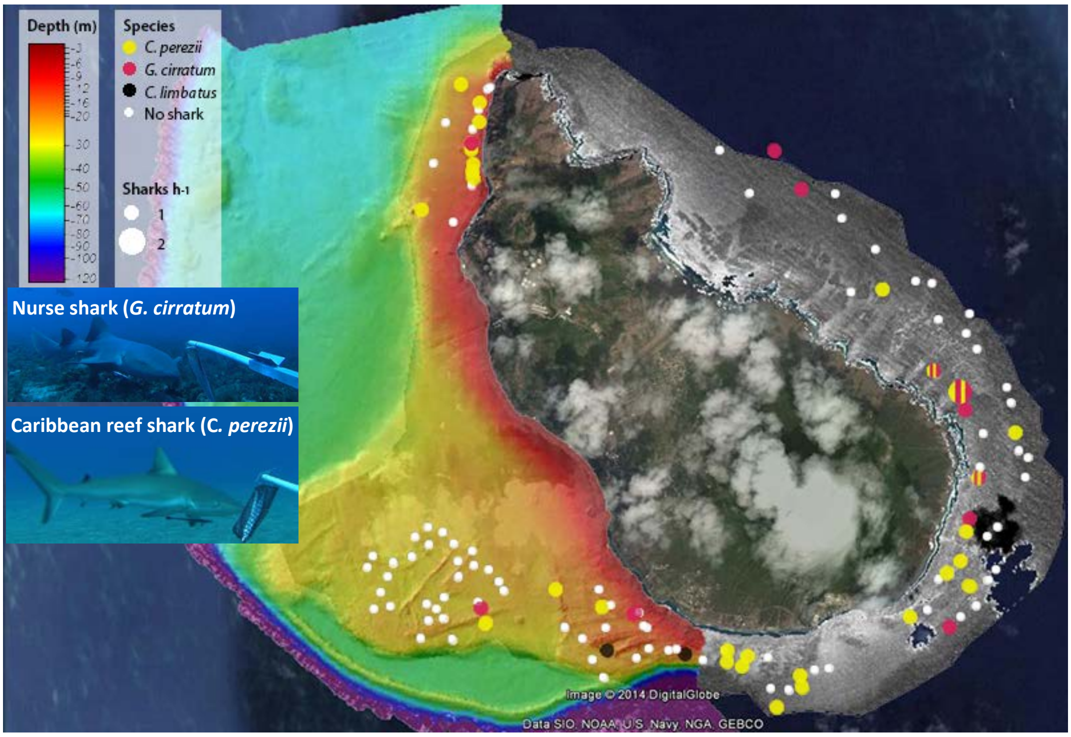

Figure 3.5 *Spatial distribution of reef sharks in the waters of the SNMP.*

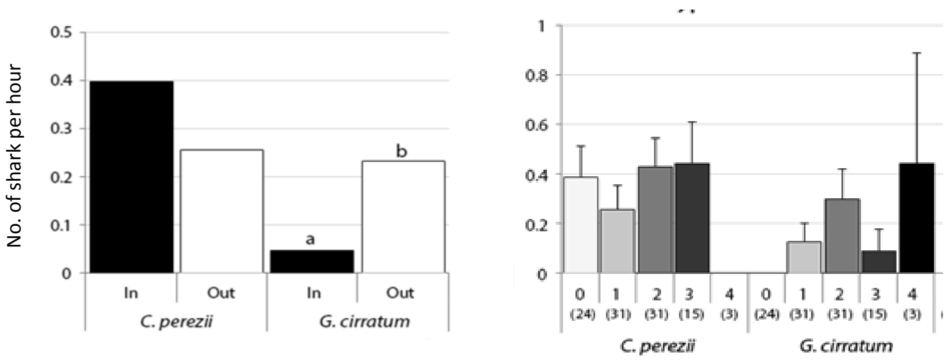

Figure 3.6 *Abundance of reef sharks in relation to management zone (left) and habitat complexity (Polunin-scale) (right) (source Kuijk et al., 2015).*

3.3 STATUS AND TRENDS REEF FISHERY

3.3.1 FISHING CAPACITY

Current Status: On St Eustatius there are around 20 fishing vessels. All boats are open boats ranging between 5-10 m in length and powered by single or twin outboard engines (25-600 total hp). During the period 2012-2015 roughly 1.5 boats were active per day (~500 boat days annually). The most commonly used fishing gear were Antillean style arrowhead traps, usually built from chicken wire around a wooden frame. Traps deployed on the windward side of the island are normally built around an iron frame. Roughly six of the registered boats use traps to target lobster and mixed reef fish, in total there are ~160 traps used in the coastal fishery. In addition to trapping, both mixed reef fish (speargun) and lobster (snare) were caught by free diving or scuba diving. Fishing effort is concentrated on a relatively small area on the leeward side of the island, limited by the two reserves and area actively used by the tankers of NUSTAR oil terminal. The rougher windward side of the island is often not accessible to the small fishing vessels due to the weather and wave conditions.

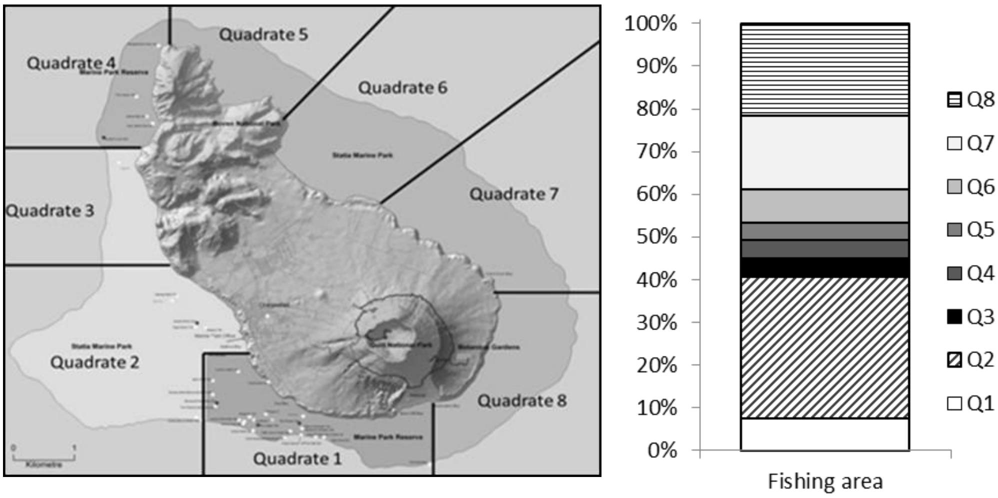

Figure 3.7 *Distribution of fishing effort over the different fishing zones in SNMP.*

Trend: The capacity of St Eustatius' small-scale coastal fishery has changed little over the past 25 years. Sybesma et al. (1993) reported that in the early 1990s, 15 predominantly part-time fishermen operated from Gallows Bay using mainly traps (~300 in total) and small boats (<5m) to target Caribbean spiny lobster during October to April for export to St Maarten. In 2004, Dilrosun (2004) described that 15 small open wooden hull fishing boats were operated by 25 fishermen of which only three were considered full-time, professional fishermen. In 2004 the main target species was also Caribbean spiny lobster. There are even indications that the capacity of the fishing fleet has remained relatively stable for more than a century. In 1905 the fleet consisted of four boats crewed by 9 full-time and 32 part-time fishermen, while in 1959 two full-time and 12 part-time fishers used eight boats to fish the coastal waters (Zaneveld, 1961).

3.3.2 CARIBBEAN SPINY LOBSTER

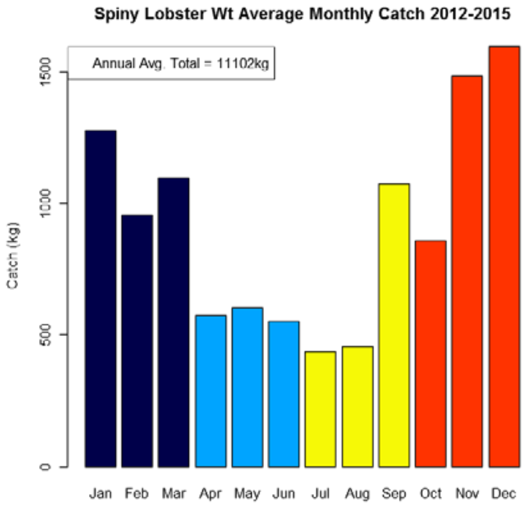

Figure 3.8 *Average monthly landings (kg) of Caribbean spiny lobsters (average weight individual lobster ~1.1 kg) from the 2700 ha SNMP during the period 2012-2015.*

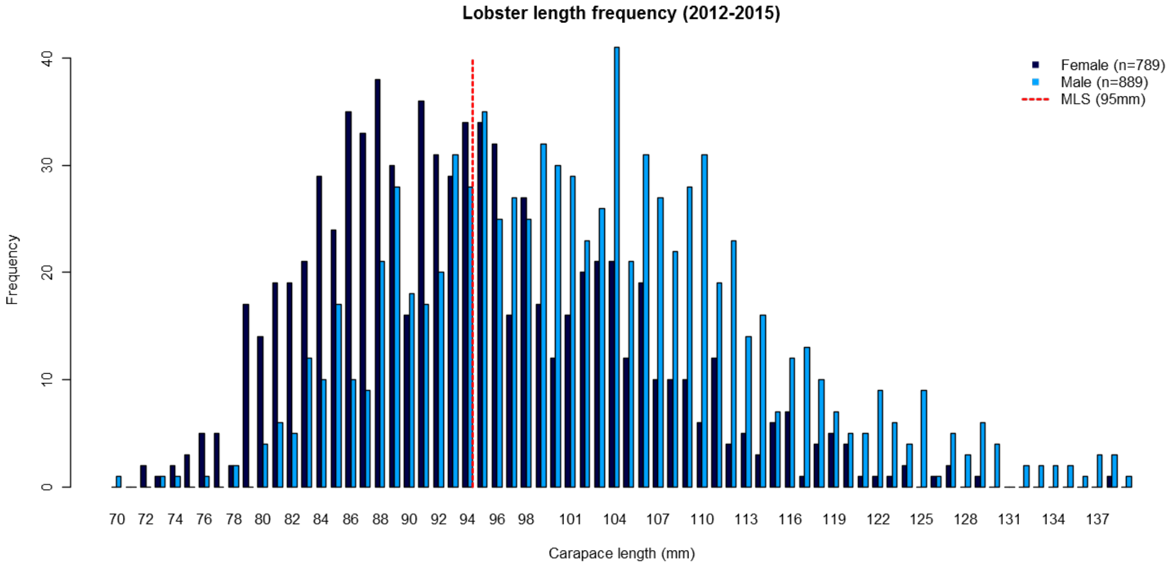

Figure 3.9 *Length frequency of landed male and female Caribbean spiny lobster on St. Eustatius.*

Monthly landings of spiny lobster were highly seasonal varying from 400 to 1500 kg per month between 2012 and 2015. During the high season (SEP-FEB) monthly landings were nearly double the landings of the low season (April-August). The average annual landings in 2012-2015 were estimated at 11 tonnes from the ~20 km^2 of fishing grounds (~500 kg/km^2 or ~5 kg/ha). The average carapace length of landed female (95 mm CL) spiny lobsters was smaller than landed males (103 mm CL)(Fig. 3.9) and a large part (41 %) of the landed lobsters were smaller than the legal minimum landing size of 95 mm carapace length.

<u>*Current status:*</u> At first sight, annual harvest of Caribbean spiny lobster may appear modest with ~11 tonnes, representing less than 0,05% of the total annual landings of this species throughout its range (Caribbean and Brazil). However, the surface area of the available fishing ground in the SNMP is small (~20 km^2) resulting in one of the highest landings (500 kg/km^2, *see also Table 4.1*) reported throughout the distribution area of the Caribbean spiny lobster. The high landings per km^2 and the high proportion of undersized male (27%) and female lobster (56%) in the landing are potential reasons for concern regarding the sustainability and/or optimization of the current fishery.

Trend: Little historical information on catch statistics of the lobster fishery is available for St Eustatius. Dilroson (2004) estimated the total lobster catch for 2003 at ~4 tonnes, though according to a local fish buyer 2003 was an "exceptionally bad" year for lobster. Sybesma et al. (1993) described the capacity of the fishery in the early 1990s and mentioned that spiny lobster was the main target species but that catch statistics were absent. It is highly likely that both effort and catch (5-10 tonnes annually) have remained relatively stable over at least the last 25 years. Average length of landed lobster was smaller (99 mm CL) in 2012-2015 than the 110 mm CL in 2003 reported by Dilrosun (2004).

3.3.3 MIXED REEF FISH

Figure 3.10 *Average monthly landings (left) and species composition in weight and number of mixed reef fish (right) from the 2700 ha SNMP during the period 2012-2015.*

Between 200 and 500 kg of mixed fish was landed monthly in the period 2012-2015 on St Eustatius, resulting in an average annual catch of just under 4 tonnes. Roughly 200 kg/km^2 or 2 kg/ha was harvested from the fishing areas within the boundaries of the SNMP. Small groupers species (Serranidae) and surgeonfishes (Acanthuridae) made up ~50% of the catch in both weight and number. At species level the most commonly harvested species (in number) were blue tang (25%), squirrelfish (10%), honeycomb cowfish (10%) and doctorfish (9%) and in weight were red hind (15%), blue tang (15%), nurse shark (12%) and honeycomb cowfish (10%). While only low numbers of nurse shark (0.5% in number) were landed, due to their large individual size, nurse sharks formed roughly 12% (~400 kg) of the annual catch in weight.

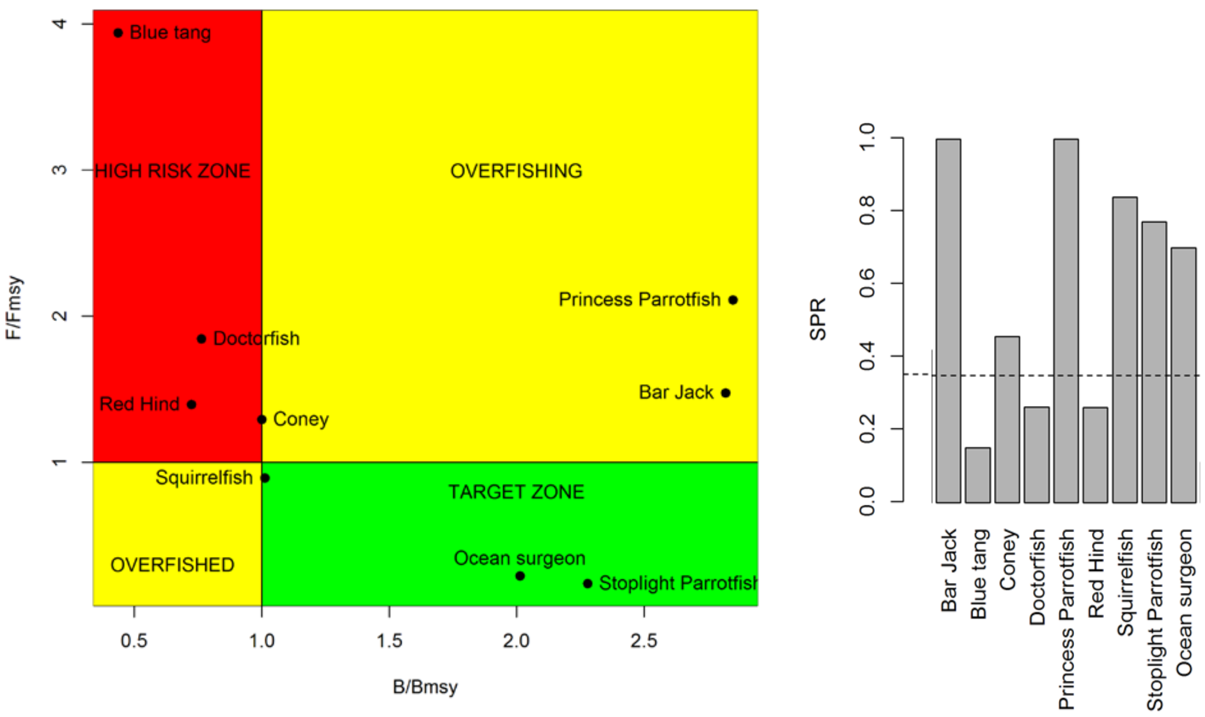

Figure 3.11 *Phase plot of preliminary estimates of stock status and fishing mortality relative to B_{msy} and F_{msy} for some reef fish stocks of St Eustatius. Stocks are considered in a good state when $B/B_{msy} >=1$, and are considered overfished when B/B_{msy} is below the limit threshold. Overfishing is defined by $F/F_{msy} > 1$ (left). Estimates of spawning potential ratio (current stock size compared to pristine state) for reef fish stocks of St Eustatius. The horizontal line represents SPR = 35%, defining the MSY state.*

The preliminary estimates of the status of several exploited reef fish stocks as estimated by the length based assessment model is presented in Fig. 3.12. Three species (blue tang and doctorfish (Acanthuridae) and red hind (Serranidae) appeared to be at high risk, as for these three species the stock biomass indicator was estimated to be low while fishing pressure is high. Four species (princess parrotfish, stoplight parrotfish (Scaridae); ocean surgeon fish (Acanthuridae); bar jack (Carangidae) were estimated to be in a pretty good shape with stoplight parrotfish and ocean surgeon fish being close to pristine state. While the estimated size of the stock was in good shape, princess parrotfish and bar jack are possibly being overfished. The coney (Serranidae) and the squirrelfish (Holocanthuridae) were at a biomass level close to maximum sustainable yield (MSY), however, coney appeared to be slightly overexploited. Unfortunately no life history parameters were available for the commonly harvested honeycomb cowfish to determine the status of this stock. The results of the length based assessment model need to interpreted with care, as rigorous sensitively analyses of the model remain to be done to determine the robustness of the model and its outcomes.

<u>*Current status:*</u> The landings (~4 tonnes) of mixed reef fish appeared, at first sight, to be modest with ~0.2 tonnes/km^2 compared to reef fish yields (0.2-27 tonnes / km^2) reported for other tropical areas (0.8–5 metric t /km^2/year Marshall (1980); 2–4 metric t/km^2/year of demersal fish, Kenya; Kaunda-Arara et al. (2003); 8–27 t /km^2/year American Samoa and the Philippines; Wass (1982), Dalzell (1996), Mapya et al. (2002). However, the observed low yield of mixed reef fish may probably be characteristic for a reef system dominated by algae, rubble and low relief gorgonian habitats (Debrot et al. 2014) and lack of highly productive, active coral reef in SNMP (Newton et al. 2007 and references therein). Fish species richness (Newman et al., 2015) but more importantly fish biomass and abundance (van Looijengoed 2013, Stoffers 2014, Kuijk et al. 2015, Vrooman 2015; *see also Fig. 4.1*) are positively correlated with habitat complexity. Also, the length based assessment model indicated that several target species were at high risk (overfished; low biomass, high fishing pressure). The high proportion of the ecologically important

Acanthuridae (herbivores) in the catch and the lack of large grouper species (*see Fig. 3.1*) are further reasons for concern regarding the sustainability of the current fishery. Sharks are not a target species and only a few nurse sharks were landed.

<u>*Trend:*</u> Little historical information on mixed reef fish fishery is available for St Eustatius. In 1908 a third of the catch (in number) consisted of mixed reef fish while the vast majority of observed landed fish was small, schooling pelagic fish such as scads and halfbeaks (Zaneveld, 1961). Assuming an average weight of 0.5 kg per reef fish, in 1908 (0.5 kg x 22000 fish) an estimated 11 tonnes of mixed reef fish was harvested. Salmon (1958) reported that in 1956 10 tonnes of fish was landed on St Eustatius although it is unclear how this catch was divided between mixed reef fish, small schooling pelagics and large pelagics.

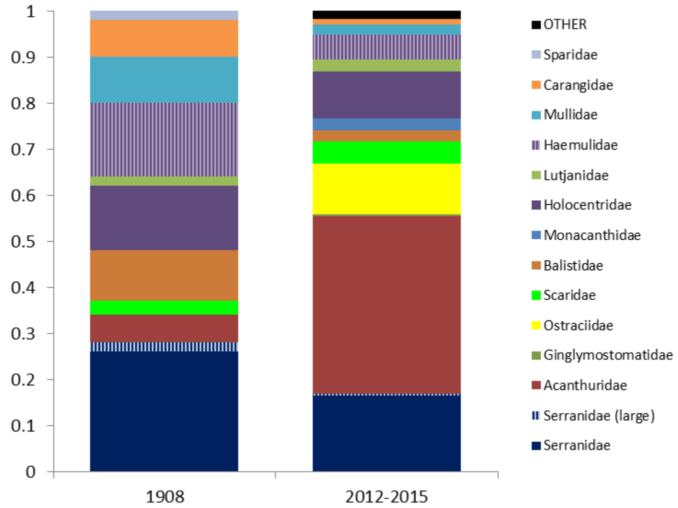

Figure 3.12 *Species composition (in number) of mixed reef fish in 1908 (Zaneveld, 1961) and during the period 2012-2015.*

The species composition (in number) of the landed mixed reef fish in 1908 was markedly different from the species composition observed in 2012-2015 (Fig. 3.12). In 1908 only 5% of the catch consisted of surgeonfishes (Acanthuridae; key herbivorous species) and boxfishes (Ostracidae) while in 2012-2015, these two groups of small reef fish made up almost 50% of the catch. In 2012-2015 the contribution of groupers (Serranidae), grunts (Haemulidae), jacks (Carangidae) and triggerfish (Balistidae) to the catch was halved compared to 1908.

3.3.4 PELAGIC FISHERY

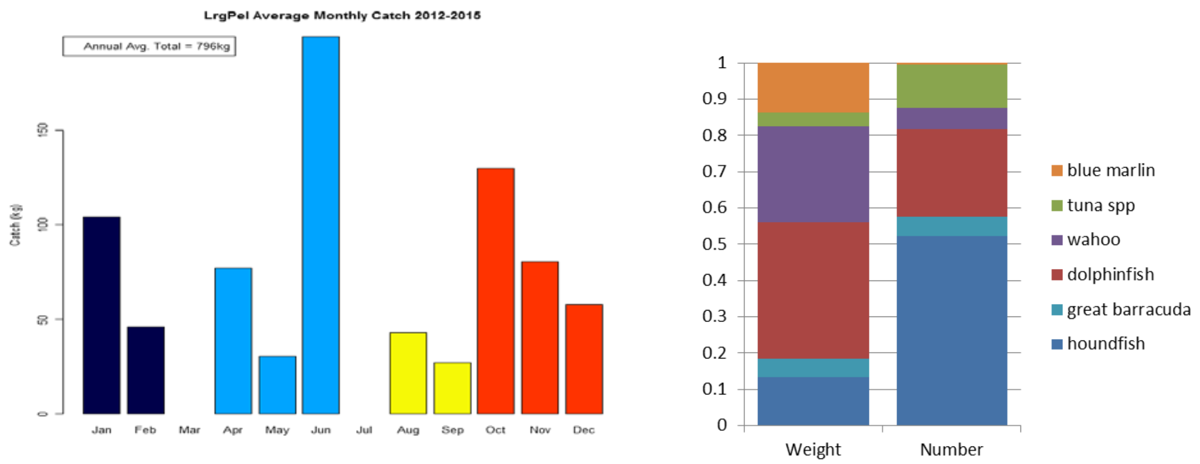

Figure 3.13 *Average monthly landings (left) and species composition in weight and number of pelagic fishery (trolling) (right) during the period 2012-2015.*

Roughly between 50 and 200 kg of large pelagic fish was landed monthly in the period 2012-2015 on St Eustatius, resulting in an average annual catch of 0.8 tonnes. Wahoo (*Acanthocybium solandri*) and dolfinfish (*Coryphaena hippurus*) were the most commonly landed species in weight, while the houndfish (*Tylosurus crocodilus*) was the most commonly landed species in number. Note that pelagic fishing trips are uncommon and that the estimates are based on a small number of landings surveys, i.e. the blue marlin in Fig 3.14 is only one large fish observed during the fisheries monitoring programme.

Status: Few fishing trips (<50) are conducted annually to target large pelagic fish. The annual landings are small (< 1 tonnes), the fishery on fast growing, short-lived large pelagic species is underdeveloped on St Eustatius.

Trend: Little historical information on pelagic fishery is available for St Eustatius. In 1908 the only large pelagic species recorded for St Eustatius was 129 skipjack tuna (*Katsuwonus pelamis*) over an eight month period. Assuming an average weight of 9 kg per fish, in 1908 an estimated 1.7 tonnes of skipjack tuna was harvested (Zaneveld, 1961).

4 DISCUSSION

4.1 STATUS AND TRENDS CORAL REEF ECOSYSTEM HEALTH INDICATORS

Fish Biomass: Care has to be taken when interpreting simplified tools such as the Reef Health Indicator. While the indicator of Reef Health Index for Key Commercial Fish was scored as "fair" in 2015 the status for groupers is more complex. Although the overall biomass of groupers appeared to be in reasonable shape compared to the Wider Caribbean Region, large grouper species (apex predators) were practically absent from the 2015 survey. The lack of large grouper species has been a persistent problem on St. Eustatius as the small-sized coney (*Cephalopholis fulva*) was the dominant grouper species in both the 1999 (85%; Klompe & Kooistra 2003) and 2015 (87%) surveys. Sybesma et al. (1993) did not conduct standardised fish transects but provided a detailed account of observed benthos and fish during 20 dives in 1992, reporting sightings of large grouper species (tiger grouper, nassau grouper, yellowmouth grouper) during six dives. The authors interpreted the low numbers of large groupers and snappers as a potential sign of overfishing and the shyness of large groupers when encountered as a sign of spear fishing activities. The lack of slow-growing, large (apex) predators such as groupers is a common phenomenon throughout the Caribbean (Kramer et al., 2015). In SNMP the status of groupers is undesirable as the grouper species composition is characteristic for highly fished areas with limited management and protection (Chiappone et al., 2000).

One of the possible drivers of the phase-shift in Caribbean coral reef ecosystems in the last 40 odd years from coral dominated to macro-algae dominated reef systems is the decline of herbivorous fish such as parrotfishes and surgeonfishes due to overfishing (Jackson et al., 2014 and references therein). Herbivorous fish, especially surgeonfish, form a significant part of the landings of Statia's artisanal trap fishery and the stock indicators estimated with the length based assessment model for surgeonfishes indicated these species to be at high risk (overfished). In addition to recent coral bleaching events and possible water quality issues, the fishing pressure on herbivorous fish may be one of the drivers of the observed decline in coral cover and the increase in macroalgal cover on St Eustatius. Herbivorous fish biomass appeared to have declined since 1999 (*see Table 3.1*.), scoring 'very good' in 1999 but only 'fair' in 2008, 2014 and 2015 (CARIPES survey only). However, this decline only holds true for 2015 using the CARIPES survey data but not for the GCRMN survey data. The two 2015 estimates of the biomass of key herbivorous fish species (surgeonfishes and parrotfishes) were remarkably different with an estimated 2.4 kg / 100m^2 by the CARIPES survey compared to 9.4 kg / 100m^2 by the GCRMN survey. The difference in herbivorous biomass between the two surveys is mainly caused by the estimates of surgeonfish biomass; <1 kg/100m^2 by CARIPES and ~6 kg/100m^2 by GCRMN. The CARIPES and GCRMN surveys were conducted at nearly the same sites during the same period. Furthermore, the surgeonfish biomass estimates by the 2015 GCRMN survey are one of the highest biomass estimates recorded for the Wider Caribbean Region (Williams and Polunin, 2001; Nemeth and Appeldoorn 2009) and also deviates significantly from the historical estimates for surgeonfishes in 1999 (2.3 kg/100m^2), 2008 (1.2 kg/100m^2) and 2014 (1.2 kg/100m^2). It is at this stage unclear what may have caused the difference in surgeonfish biomass between the two surveys. A possible explanation could be differences in habitat complexity within transects between the two surveys at the same sites because (herbivorous) fish density and biomass have a positive correlation with habitat complexity (Fig. 4.1). Unfortunately habitat complexity was only recorded during the CARIPES fish survey but not GCRMN fish survey. However, according to team members of both surveys habitat complexity within the fish transects was most likely similar. It is advisable to add a Rugosity Index (RI) [RI = 1 – (HLC/LC), where HLC is the horizontal distance between the two ends of the chain when draped over the substrate, and LC is the length of the chain] to the GCRMN survey protocol in 2016.

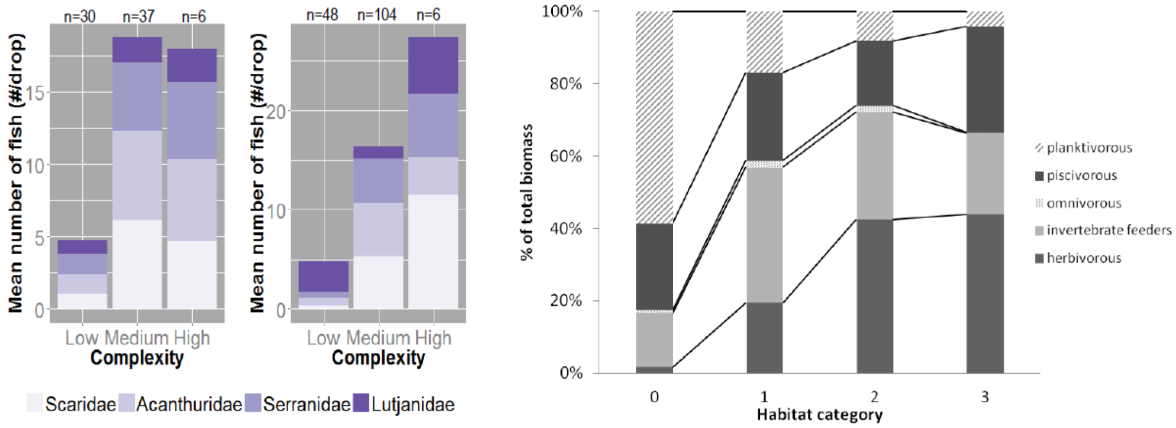

***Fig. 4.1** Fish density of key families on Saba and Saba Bank (left; Vrooman 2015) and biomass of key trophic groups on St Eustatius (right; Kuijk et al. 2015) in relation to habitat complexity.*

Another possible explanation for the difference in surgeonfish biomass could be the difference in depth between the fish surveys: 2015 GCRMN 13.5m (range 10-16m), 2015 CARIPES 18.8m (range 12-25m), 2014 depth 18.8m (range 11-29m), 2008 19.4m (range 10-30m) and 1999 14.7m (range 12-17m). Surgeonfish biomass does decrease with depth, however, the differences in biomass are usually most pronounced between shallow areas (<5m) of reef systems and deeper reefs (10-20m) with little difference within the 10-20m depth range. Nemeth and Appeldoorn (2009) observed a difference in surgeonfish biomass between 3m (2.2 kg/100m^2) and 10-15m (0.5 kg/100m^2) but not between 10m and 15m on the reefs of Puerto Rico. On Mexican reefs, Hernández-Landa et al. (2015) demonstrated a difference in surgeonfish biomass between deeper part of the reef (slope 12m, 0.4 kg/100m^2; terrace 20m, 0.4 kg/100m^2) and shallow reef habitats like lagoon (0.5-3m, 0.25 kg/100m^2) and front reef (6m, 0.5 kg/100m^2) but found no difference in biomass between reef slope (12m) and reef terrace (20m). Although the depth of the 2015 and historical fish surveys is not the same, the average depth of the fish surveys range from 13.5-19.4 and fall with-in the depth range (10-20m) for which other Caribbean studies have not observed a depth related change in surgeonfish biomass.

A final explanation for the difference in herbivore biomass between surveys could be observer bias associated with the underwater visual census method. The UVC method is popular as it requires minimal investment in equipment (pencil, slate, transect line) and post-collection data handling is short. However, UVC surveys require experienced staff with solid taxonomic knowledge and trained to estimate fish size and transect width. Furthermore, data cannot be validated after collection because no permanent record is kept. The UVC method is susceptible to inter and intra observer variation during data collection (Holmes et al. 2013 and references therein). The UVC fish surveys in 1999, 2008, and two surveys in 2015 have each been conducted by a different team of people, often visiting researchers and students and may explain some of the observed differences in especially surgeonfish biomass.

An alternative to UVC is stereo-Diver Operated Video (sDOV), this method allows staff with little expertise in fish taxonomy to easily collect permanent records of fish communities and precisely measure fish size, survey area and survey habitat. sDOV limits observer bias and data collection per transect is quicker than UVC. However, sDOV does require a substantial investment in equipment and, similar to processing the benthic photo, the processing of the video footage is time consuming. The preliminary biomass estimates of the first sDOV survey in 2014 in SNMP are presented Fig. 3.1 and Table 3.1. While UVC and sDOV can provide comparable results at higher taxonomic/functional levels of medium sized, non-cryptic fish species, the development of correction factors (if needed) is advisable (Holmes et al. 2013).

All fish survey methods have advantages and disadvantages; the choice of the most appropriate method depends on available expertise, funding and objectives of the fish survey (Holmes et al. 2013). The primary objective of the fish survey in SNMP is to study long-term trends of several non-cryptic, medium sized reef fish at a high (family, not species) taxonomic level, i.e. key herbivores like parrotfish (Scaridae) and surgeonfish (Acanthuridae) and key commercial fish like groupers (Serranidae), snappers (Lutjanidae) and grunts (Haemulidae). If trained staff with appropriate expertise and skill is readily available, than UVC is probably the most cost-effective method to use. However, at St Eustatius local expertise is likely to remain inconsistent in the future as it has been in the past. In situations with limited or inconsistent expertise, stereo-DOV might be a more appropriate method if sufficient resources are available for the post-field time to process and analyse footage and to invest in hardware and software. To reduce the longer data processing associated with stereo-DOV, initial analysis of the video transects can be limited to key fish families only. A permanent record of the video transects is archived, allowing for data validation and more detailed analysis in the future if required.

Coral and macroalgae cover: The majority of reefs on St. Eustatius are not true coral reefs in the sense that the reef structures were built by hard coral and other calcium carbonate producing organisms. Most reefs are encrusted volcanic boulders, low relief rock ledges or solidified lava flows ('fingers'). Intermediate forms of true coral reefs and encrusted rock do also occur (Debrot et al., 2014) as under appropriate environmental circumstances encrusted rock formations can develop into coral reefs.
In the past 40 years throughout the Caribbean large-scale shifts have occurred from coral dominated to macroalgal dominated reef communities. Macroalgae can reduce coral recruitment and growth, are often toxic and can be the cause of coral diseases. The drivers of the phase shift from coral to macroalgal dominated communities were the reduction of algae grazing herbivores such as the sea urchin *Diadema* (die-off early 1980s) and parrotfishes and surgeonfishes (overfishing), decline in water quality (excess nutrients, erosion, coastal development), ocean warming and invasive species.

The average coral cover in the Wider Caribbean Region declined sharply between 1970-1983 (average coral cover ~35% coral cover) and 1984-1999 (average coral cover ~20%) but remained stable since 1999 (average coral cover 1999-2011 was ~18%) (Jackson et al., 2014). In broad lines coral cover appeared to have followed similar patterns on St Eustatius. Sybesma et al. (1993) surveyed 30 sites on St Eustatius in 1992 and reported coral cover of 20-40% on the encrusted rock ledges and coral cover as high as 80% on the "buttresses" (lava fingers) in the southern part of the leeward side of the island. In the period 1999-2015 the average coral cover was a little over 20% but coral cover has not remained stable within this period. On St Eustatius, the trend in coral cover continued to decline from ~20% in 1999 to ~5% in 2015, well below the average coral cover reported for the Wider Caribbean Region. Like in the rest of the Caribbean, the macroalgal cover (25%) was high on St Eustatius in 2015. Macroalgal cover increased over the past 15 years on St Eustatius, the current cover (~25%) is similar to the average reported for the Wider Caribbean Region.

The 2015 status of the coral reef ecosystem elements 'stony coral cover' and 'macroalgal cover' is, however, clearly undesirable (critical) with low coral cover (~5%) and high macroalgal cover (~25%).

Recruitment and health reef building coral: Coral recruitment (~15 recruits per m^2) appeared to be higher in 2015 than the coral recruitment in 1999 (~10 recruits per m^2; Klompe & Kooistra, 2003). Between 1997-2004 the average coral recruitment in the Wider Caribbean Region was ~4 coral recruits per m^2, highest reported densities were 9-15 recruits per m^2 and overall with slightly higher recruitment (4.4 m^2) on deep reefs compared to shallow reefs (3.3 m^2) (Kramer 2003). On the reefs of Bonaire relatively high coral recruitment (~10-20 recruits per m^2) was reported between 2003 and 2015 (Steneck et al., 2015), however, in their survey quadrats were only placed on substrate with < than 25% invertebrate (adult coral, gorgonians and sponges) cover. Care has to be taken when comparing recruitment between different studies as subtle differences exist in the definition of a coral recruit, i.e. a colony ≤ 4cm diameter, ≤2cm diameter, ≤4 cm^2 or between 1-4 cm^3. The above mentioned coral recruitment data were all collected after the shift from a coral to an algae dominated reef system that occurred between the 70s and 90s. Macroalgae can inhibit coral recruitment and increased macroalgae cover is the most likely explanation for the decline in coral recruitment in the Wider Caribbean Region between the 70s and 90s.

Less than 5% of the benthic quadrate (0.54 m^2) had one or more diseased colonies (all sizes) in 2015. Due to the difference in methodology, a straightforward comparison of prevalence of diseased coral colonies with Klompe & Kooistra (2003) is not possible. In 1999 Klompe & Kooistra (2003) reported that 0.6% of stony coral colonies >10 cm were diseased. Sybesma et al. (1993) monitored 30 sites on St Eustatius as classified nearly all sites as healthy with very little signs of disease.

Water quality: St Eustatius has no waste water treatment plants and landfills, septic tanks and private cesspits may pose a threat to the water quality of the coastal zone. Excess nutrients from fertilizers and runoff (silt and mud) coming from large areas which are overgrazed by feral cattle, donkeys and goats may negatively impact stony coral growth. According to Debrot and Sybesma (2000) increased sediment load due to erosion is most likely the key and possibly only major factor impacting water quality on St Eustatius. Excess nutrients may stimulate macroalgal growth resulting in overgrown, abraded and even poisoned stony coral colonies, reduced coral recruitment and/or increased coral disease. The oil terminal NuStar may also negatively impact water quality both by acute oil spills (e.g. October 2012 spill) and/or by chronic seepage of chemicals and toxins in the environment. Hartmann et al. (2015) demonstrated a delayed negative impact of oil spill on settlement of stony coral larvae. Imposex is a disorder in marine snails caused by toxic effects of marine pollutants such as Tributyltin (TBT), an anti-fouling agent used on boats. Although banned since 2008, these compounds can still be found on larger vessels. Furthermore, these compounds can persist for longer periods in the environment depending on the circumstances. TBT can disrupt reproductive success as it causes female marine snails to develop male reproductive organs. Imposex has been observed in Queen conch (*Lobatus gigas*) on St Eustatius.

Despite the above mentioned potential threats to water quality and its negative impact on coral reef health, no monitoring data are available to determine status and trends of sedimentation, seawater turbidity, nutrients and/or toxins. The same unfortunately holds true for the Wider Caribbean region where only limited information on water quality is reported. Concentrations of particulate nitrogen, phosphorus, suspended solids and chlorophyll are known to be correlated with water transparency (Secchi depth). Water transparency is a quick, easy and cheap estimate and first indication of changes in water quality when deployed over longer periods. For example, monitoring water quality using the Secchi disk at the Belize Barrier Reef - Carrie Bow Cay- started in 1993. This simple but consistent time series of water transparency demonstrated a dramatic loss of water quality along that particular part of the Belize Barrier Reef. Between 1993 and 2008, water transparency declined from 12.8 m to 8.7 m (0.3 m/year loss) in the lagoon and from 23.8 m to 15.6 m (0.5 m/year loss) in deep water (>300 m deep) close to the drop off (Koltes & Opishinski 2009). The implementation of a simple, regular water transparency time series on St Eustatius would provide a cheap but valuable indicator for changes in water quality.

Reef Health Index: A (simplified) index like the Reef Health Index is a tool to communicate effectively with a range of stakeholders and visualize the health status of a coral reef ecosystem (Kramer et al., 2005; www.healthyreefs.org). It is of utmost importance to regularly report results of scientific surveys to facilitate adaptive management and to stimulate communication and the exchange of reported information. A 'report card' style document might be a suitable option to communicate information effectively to a wide audience but does not replace more detailed scientific reports or peer reviewed scientific publications. A (simplified) index cannot incorporate the complexity of the coral reef ecosystem or the subtle details of the scientific surveys. Furthermore, the RHI is developed for the average Mesoamerican reef and may not always be suitable for each reef system, i.e. the reefs of St Eustatius are predominantly encrusted rock ledges and not true coral reefs. The RHI may serve as a good first warning system for the trends and status of the different key elements of coral reef health. If however, the RHI demonstrates that certain elements are at risk more in depth research will be required to determine causal relationships to support adaptive management and policy development to ensure the recovery to "good" status.

4.2 STATUS AND TRENDS REEF SHARKS

Caribbean reef shark: Because of its low fecundity in combination with high vulnerability to fishing and local extirpation, the Caribbean reef shark is listed as "Near Threatened" by IUCN (Rosa et al. 2006b) for the Wider Caribbean Region). Caribbean reef sharks were observed in 45% of BRUV deployments in the marine reserve and in 30% of the BRUV deployments in the fishing zone. Bond et al. (2012) reported observations of Caribbean reef sharks in 27% of BRUV deployments in marine reserve and in only 8% of BRUV deployments in fishing zones in Belize. The mean number of Caribbean reef sharks observed per hour was 0.26, while Brooks et al. 2011) reported values ranging from 0.04 to 0.13 sharks per hour in the Bahamas. The majority of observed Caribbean reef sharks were juveniles (< 1.5m in length), as males and females only mature above 1.5 and 2 m, respectively (Scharfer 2009).

Nurse shark: The nurse shark is at present the most common shark seen on Caribbean reefs (Ward-Paige et al., 2010) and was the second most commonly observed shark species in the BRUV survey. It is listed by the IUCN as "Data Deficient" (Rosa et al. 2006a). The abundance of nurse sharks (0.15 per hour) in SNMP was roughly similar to Saba (0.15 per hour, van Looijengoed 2013) and the Bahama's (0.2 per hour; Brooks et al., 2011) but lower than the Saba Bank (0.3; Stoffers, 2014). The recorded nurse sharks were mostly juveniles with a length between 50 and 130 cm. The three largest sharks (180-190 cm) observed during the BRUV survey were all nurse sharks.

Black tip shark: The blacktip shark was only recorded twice. Adults of this migratory species are uncommon in nearshore fisheries but are widely impacted by offshore longline fisheries (Tavares 2008). Due to its vulnerability to fishing and its dependence on vulnerable near shore nurseries, this species is listed as "Near Threatened" by IUCN (Burgess and Branstetter 2009).

Sharks are important apex predators and are an indicator of healthy coral reef ecosystems (Robbins et al. 2006, Sandin et al. 2008). In the coastal zones of the Wider Caribbean Region human pressures, like coastal development and fisheries have most likely resulted in the absence of reef sharks on most reefs (Ward-Paige et al. 2010). Overall, fishing mortality of reef sharks appeared modest on St Eustatius with the occasional landing of especially nurse sharks by its small-scale, artisanal trap fishery. Most importantly reef sharks were not specifically targeted by fishermen. Despite the fact that, at first glance, reef sharks appeared to be more often observed in the SNMP compared to the few other published Caribbean video surveys, the lack of historical data ("shifting baseline") on shark abundance in SNMP makes it difficult at this stage to draw firm conclusions on the current status (van Beek et al. 2012; Overzee et al., 2012).

Recently a shark protection plan was drafted for the Dutch Caribbean (van Beek et al. 2014) and in September 2015 the EEZ waters around two of the Caribbean Netherlands islands (Saba and Bonaire) were declared shark sanctuaries by the Dutch Ministry of Economic Affairs and local island governments. The first steps towards effective protection are to: a) conduct a base-line survey to assess the current status with regards to elasmobranch diversity, distribution, abundance and population structure and, b) to develop robust, quantifiable objectives and reference points for conservation in order to be able to evaluate the performance of management actions. BRUV surveys to describe the current shark diversity, distribution and abundance on inshore reefs have been conducted on St Eustatius, Saba, Saba Bank and St Maarten and are planned for Bonaire (2017) and Curacao (2016). The standardized BRUV base-line survey will serve as a reference point to evaluate the performance of future management actions on the status of reef sharks in the Caribbean Netherlands.

4.3 STATUS AND TRENDS REEF FISHERY

Catch & effort coral reef fisheries: The capacity of St Eustatius' small-scale coastal fishery appears to have hardly changed over the past 25 years. In the early 1990s there were about 15 mostly part-time fishermen operating from Gallows Bay using predominantly traps (~300) and small boats (<5m) to target Caribbean spiny lobster during October to April for export to St Maarten (Sybesma et al., 1993). Although no catch statistics are available, lobster was the main target species. Mixed reef fish, large pelagic fish, small schooling pelagic fish and conch were caught with hook and line, trolling, seine nets and scuba diving respectively and were mainly sold on the island. Dilrosun (2004) conducted a brief inventory of the fishery on St Eustatius and reported similar characteristics. At that time 15 small open wooden hull fishing boats covered by fibre glass and propelled by 1 or 2 two stroke gasoline engines operated from Gallows Bay. Only three of the 24 fishermen were considered full-time, professional fishermen as the remainder also had on-shore fixed jobs. The fishery mainly targeted lobster, each fishermen using 15-20 3 ft Antillean chevron (arrow shaped) type traps constructed of uncoated chicken wire (Ø=1.5"), which were reinforced with wooden sticks or an iron frame. According to the main exporter who stated to buy roughly 50% of the landed lobsters, 2003 was an exceptionally bad year with an estimated total catch of 4 tonnes. In the period 2012-2015 the capacity of the fishery was very similar to the situation described by Sybesma et al. (1993) in the early 1990s and Dilrosun (2004) in 2003.

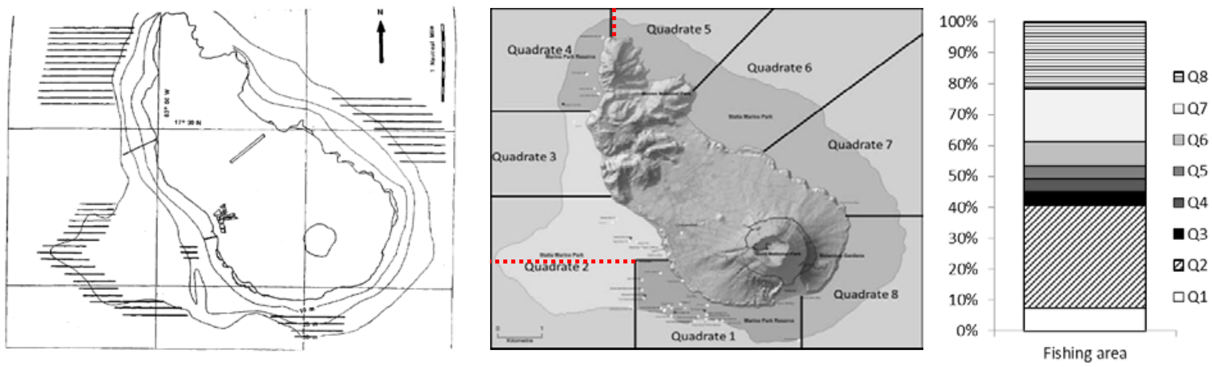

Figure 4.2 *Overview of the fishing grounds in the early 1990s (left; Sybesma et al., 1993) and in the period 2012-2015 (right). The area between the red dotted lines on leeward (west) side of St Eustatius was rezoned in 2015 from St Eustatius National Marine Park to Harbour Area.*

A shift in available fishing grounds occurred with the establishment of two reserves (no-fishing zones) in the SNMP in 1996 (Fig. 4.2). At that point access to traditional fishing grounds in the north (Quadrate 4; Northern Reserve) and south (Quadrate 1; Southern Reserve) on the leeward side of the island was denied to local fishermen with the objective to protect and conserve the vulnerable coral ecosystem in these two areas. On the leeward side of the island, fishing is restricted to Quadrates 2 and 3 but shipping and activities related to the operation of the NUSTAR oil terminal in this area conflicts with the fishery. The shipping activities; such as anchoring outside the designated anchoring zones and passing over fishing grounds, has been causing problems for the local fishing sector for a long time. Anchoring has a devastating impact on the reef both inside and adjacent to the anchoring zones (White et al., 2007). The development of proper shipping lanes were already part of the marine spatial planning proposal by Sybesma et al. (1993) but have not been implemented. In 2015, a large part of the SNMP (including the Northern Reserve, see Fig. 4.1) was rezoned from SNMP to Harbour Area. The possible consequences of this re-zoning for the environment and fishing opportunities are not clear at this stage. However, as the Northern Reserve no longer exists, and SNMP rules and regulations obviously do not apply anymore, fishing is allowed in this area again for the first time since its closure in 1996.

Reported coral reef fishery yields (fish, crustaceans, molluscs) range from 0.2-40 t/km^2/year with a median yield of 3 t/km^2/year (Newton et al. 2007 and references therein), keeping in mind that the reported high yields were not necessary long-term sustainable yields and often resulted in drastic declines in reef fish biomass and shifts in fish assemblages (Birkland, 1997 and references therein). The higher yields are associated with small, shallow areas of active growing coral reef, this type of habitat is, however, rare in the SNMP (Debrot et al., 2014). In present day St. Eustatius, coral formations growing on lava fingers appear concentrated in a relatively narrow zone at depths of roughly 24 m in the Southern reserve. The reef formations are further characterised by low rugosity and low stony coral cover. Most of the shallow (<30m) shelf area of the SNMP consists of rubble, sand, algae beds and patches of gorgonian reef, usually associated with lower end of the above mentioned fishery yields.

The total annual catch of the coral reef fisheries in the SNMP is around 18 tonnes (4 tonnes mixed reef fish, 1 tonnes of large pelagic fish, 11 tonnes of Caribbean spiny lobster, 2 tonnes queen conch) or ~1 $t/km^2/y$ and, at first glance, this may appear low compared to values reported for other coral reef fisheries. However, the total annual catch may actually be in agreement with what can reasonably be expected when considering the available habitat dominated by rubble, sand, algae and gorgonian reef and lacking in highly productive active growing coral reef in the SNMP. Secondly, while the overall landings (fish, lobster, conch combined) per km^2/y in SNMP may appear low, this is not the case for Caribbean spiny lobster for which some of the highest landings per km^2 throughout its distribution range were recorded (Table 4.1).

Mixed reef fish: Overall, the current status of the reef fish stocks and its fishery appear to be at most reasonable and, probably, in a slightly better shape than the average situation in the Wider Caribbean Region. There are, however, several issues of potential concern that may need to be addressed by the responsible management authorities in co-operation with the different relevant stakeholders.

The base-line shark survey suggests that reef sharks appear to be common in SNMP. The artisanal fishery does not specifically target reef sharks and only landed a few sharks, predominantly nurse sharks. The shark protection plan for the Dutch Caribbean (including a shark reserve similar to Saba and Bonaire) will probably be implemented over the coming years and one of its objectives is to reduce the fishing mortality to as close to zero as possible. Consultation and participation of the fishermen will be required to establish what agreement can be made to achieve the objective without effecting the day to day operations of the involved fishermen.

Groupers are one of the main target species of the current fishery. The current status of the grouper biomass is fair and appears to be in a better state than the average situation on the Wider Caribbean Region but there are several serious indications for concern. In the first place the stock status indicators as determined by the length based assessment model demonstrated that the red hind is at high risk and that the coney is exploited at the edge of its maximum sustainable yield. The continued lack of larger grouper species (apex predators) is an undesirable situation and has also been observed in many Mesoamerican reefs (Kramer et al., 2015). The current grouper species composition in SNMP is characteristic for highly fished areas with little management (Chiappone et al., 2000; *see Fig. 3.1 bottom right*). Reducing fishing mortality of apex predators (large grouper and snapper species) to as close to zero as possible may be considered by fisheries managers to assist the recovery of these key species in coral reef ecosystems. An option might be to stimulate the release of captured large groupers and increase the survival of released individuals by properly venting the fish.

A common hypothesis for the major shift in Caribbean coral reef ecosystems in the last 40 odd years from coral dominated to macro-algae dominated systems is the decline of herbivory due to overfishing of herbivorous fish (parrotfishes and surgeonfishes) and the mass mortality of the long-spined sea urchin in the early 1980s (Jackson et al., 2014). In the Caribbean, the majority of reef fish are captured with fish traps. Fish traps are rather unselective and can have high bycatch of narrow bodied species such as surgeonfishes and butterflyfishes. However, bycatch of herbivores can be reduced by the placement of narrow escape vents without reducing the harvest of target species (groupers, snappers) (Johnson, 2010). At present experiments are being conducted to determine the impact of 25mm and 38mm escape vents on the species and size composition of the catch in the trap fisheries operating on the Saba Bank and in the SNMP. A reduction of the fishing mortality on the herbivorous surgeonfishes (Acanthuridae) could possibly be achieved with the introduction of escape slots in the trap fishery on St Eustatius.

Pelagic fishery: Coral reef fisheries are in general more vulnerable to over-exploitation than tropical pelagic fisheries due to the life history characteristics of the target species and the ecosystem. Large, tropical pelagic fishes (e.g. dolphinfish) are fast-growing (1-5 kg/yr), early maturing short-lived species that live in schools covering wide areas and have a rapid population turn-over. In contrast, commercially interesting reef fish species (e.g. groupers) are slow growing (0.5 kg/yr), late maturing long-lived species that are often territorial and solitary with low adult and high juvenile mortality (Birkland, 1997). Although tropical pelagic fisheries are not immune to overfishing, overall they are able to sustain a higher yield than coral reef fisheries. If a management objective would be to increase the production of the fishery on St Eustatius it would be recommended to stimulate the development of the pelagic fishery instead of the coral reef fisheries. At present the fishery on large pelagic fish is underdeveloped with an annual catch of <1 tonnes.

Caribbean spiny lobster: Since 2000, landings of Caribbean spiny lobster have been declining and the stock is considered to be fully utilized or overexploited throughout most of its distribution area. In May 2015, the member states (MS) (Anguilla, Antigua and Barbuda, Bahamas, Barbados, Belize, Grenada, Guyana, Haiti, Jamaica, Montserrat, Saint Lucia, Saint Kitts and Nevis, Saint Vincent/Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos, Dominican Republic) of the Caribbean Region Fisheries Mechanism (CRFM) signed a (non-binding) declaration on the conservation, management and sustainable use of the Caribbean spiny lobster in order to halt a further decline of the stock and its fisheries. The objective of the May 2015 declaration was "*to ensure the long-term sustainable use of the spiny lobster (*Panulirus argus*) resources through effective implementation of conservation and management measures for the stocks and their habitats based on the best scientific evidence available."* The MS committed to improve the collection of scientific data on lobster fisheries and biology and share the information among states in order to improve (regional) management plans. Furthermore, MS will attempt to adopt similar regulations to reduce the impact of fishing on the lobster stock and the ecosystem such as: implementation of a Closed Season for the Spiny Lobster for a period of not less than 4 months, between 15th February and 31st August each year, maximum number of traps per fisher, ensure each traps has an escape slot and a biodegradable panel and adopt a legal size of minimum >80mm CL. Furthermore, MS are also committed to *"promote and encourage understanding of the importance of, and the measures required for, the conservation, management and sustainable use of the Spiny Lobster, and protection of its habitats and ecosystem."*

The St Eustatius lobster fishery (~10 tonnes) contributes less than 0.05% to the total annual landings of the Caribbean spiny lobster (30 000 tonnes). Annual landings (and effort) appeared to have been rather stable over the past 25 years on St Eustatius, fluctuating roughly between 5 and 10 tonnes and nearly all lobsters are exported to nearby islands of St Maarten and St Barth's. Despite the small (<0.05%) contribution to the total annual spiny lobster catch, the landings per km^2 within SNMP were very high (250-500 kg/km^2/yr) especially when compared to reported landings from other areas in the Caribbean (Table 4.1). The high landings in other Caribbean areas were mainly achieved during the developing phase of the lobster fishery between 1970 and 1990 and it is doubtful whether these high landings were sustainable.

Table 4.1 *Overview of lobster landings in kg/km2/year throughout its distribution range (Buesa, 2015 and references therein).*

Country or area	kg / km² / year	Country or area	kg / km² / year
Brazil (Southernmost fishing limit)	64	Cuba (total)	184
Lesser Antilles (Easternmost Caribbean limit)	27	*SE platform (fishing zone A)*	*103*
Greater Antilles East and South of Cuba (Puerto Rico, Hispaniola, Jamaica)	49	*SW platform (fishing zone B)*	*271*
Greater Antilles East and North of Cuba (Turks and Caicos, Bahamas)	62	*NW platform (fishing zone C)*	*136*
Venezuela to Yucatan (Caribbean mainland)	34	*NE platform (fishing zone D)*	*159*
Colombia, Nicaragua, Hispaniola	36	Total	66
Florida	143		
Bermuda (Northernmost fishing limit)	173	**Saba Bank** (~2000 km²/~400 km² lobster fishing grounds)	20 / 100
		St Eustatius (~20 km²)	250-500

The most common habitat type in SNMP is low relief (<0.5m) rubble, sand, algae and gorgonian reef (Debrot et al. 2014). Such hard-bottom gorgonian-sponge-algae dominated communities are prime nursery habitat for juvenile spiny lobster (<50mm CL) (Bertelsen et al. 2009). The high production of spiny lobster can be probably be explained by a combination of large nursery areas and unlimited recruitment of pelagic larvae from most likely other Caribbean islands (Kough et al. 2014).

Despite the stability in annual landings and the high landings per km² it is questionable whether the current fishery is sustainable and maximum economic yield is achieved. The current high harvest of (small) lobster may possibly hamper the production of larvae to downstream areas and may cause growth overfishing, i.e. harvesting the lobster at an average size that is smaller than the size that would produce the maximum yield per recruit. The size of the landed lobster may be a reason for concern. Average size of landed lobster was 98 mm CL and 41% of the landed lobsters were under the minimum legal size of 95mm CL. Dilrosun (2004) measured 43 harvested lobsters in November 2003 and reported an average length of 110mm CL, well above the minimum legal size. Size at maturity has not been determined successfully yet for male or female lobster on St Eustatius. Preliminary results indicated, however, that female $CL_{50\%}$ size-at-maturity falls below 80mm CL (Poiesz, 2013), clearly lower than the $CL_{50\%}$ of 93 mm reported for the nearby Saba Bank. Improved compliance with the minimum landings size of 95mm CL may be advisable, at least until size-at-maturity has been determined. It is important to understand why undersized lobsters are being landed by the fishermen. Are larger lobsters simply absent from the fishing grounds (growth overfishing) or is there possibly a demand for plate-sized undersized lobsters?

Continuation of a robust fishery monitoring (catch, effort, length frequency) will provide fishery dependent indices (time series) that could be used for adaptive management of the lobster fishery. Although St Eustatius and the Netherlands are not members of the CRFM and did not sign the May 2015 Lobster Declaration it is advisable that international co-operation and fine-tuning is aspired to with regards to the management and regulations of spiny lobster fishery.

Conch: Status of conch and its fishery has recently been described by de Graaf et al. (2014). St Eustatius has a healthy adult conch stock and the small-scale artisanal fishery operates well within sustainable limits.

4.4 MANAGEMENT, INTERNATIONAL OBLIGATIONS AND LONG-TERM MONITORING

A long-term continuation of different standardized surveys that have been developed and conducted in SNMP during 2012-2015 will provide the basic information regarding status and trends of key coral reef and fisheries indicators required to fulfill international reporting obligations but more importantly to implement and evaluate adaptive management by responsible island and Dutch authorities (Tables 4.2 and 4.3). Healthy coral reef ecosystems and sustainable fisheries are important for the economy of St Eustatius. To ensure sustainable management of the natural resources firstly, a transparent and realistic management plan with clearly defined quantifiable objectives, targets and reference points of coral reef health and fisheries indicators will need to be developed. Secondly a continuous robust and standardised monitoring programme of indicators will need to be put in place to evaluate to performance and progress of management actions. Thirdly, a transparent decision framework with respect to conservation, coastal development, environmental and fisheries management strategies with active participation of all relevant stakeholders will need to be developed. The current evaluation of status and trends of coral reef health, elasmobranchs and fisheries is seriously hampered by the lack of basic, robust standardized historical surveys and, most importantly, a management plan with quantifiable objectives, targets and reference points. The external review of the St Eustatius National Marine Park Management Plan 2007 (MacRae & Esteban, 2007) already indicated the absence of "management effectiveness indicators, corresponding monitoring programmes and an adaptive management framework".

Table 4.2: *Overview of local, national and international treaties and conventions and reporting obligations for St Eustatius with regards to coral reef fisheries and coral reef ecosystems.*

Treaty, Convention, Organisation	Species/habitats	Survey
Openbaar Lichaam, STENAPA St Eustatius; Ministry of Economic Affairs	Status and trends of reef health, fisheries and elasmobranch indicators to evaluate performance of adaptive management	1,2,3,4
Food and Agricultural Organisation (FAO)	status and trend landings spiny lobster, conch and mixed reef fish; status and trend fishing effort	1
Convention on international trade in endangered species of wild fauna and flora (CITES)	International trade in Queen conch	1,2
Convention of Biological Diversity (CBD) [Specially Protected Areas and Wildlife (SPAW)]	status and trends whales and dolphins (*see 2.3 Landing survey*); status and quality coral reef ecosystem; queen conch and spiny lobster Annex III SPAW protocol	1,2,4
Convention on the Conservation of Migratory Species of wild animals (CMS)	status and trends population and distribution sharks	3
International Commission for the Conservation of Atlantic Tunas (ICCAT)	status and trend catch and effort ICCAT listed fish species (e.g. tuna's, marlin, sharks)	1
International Coral Reef Initiative (ICRI) and its Global Coral Reef Monitoring Network (GCRMN)	status and trends of coral reefs	4

Table 4.3 *Overview of recommended monitoring programme of key coral reef and fisheries indicators to enable local adaptive management and fulfil international reporting obligations.*

Survey	Method	Indicator	Frequency
1	Fishery survey	status and trend catch and effort lobster, conch, mixed reef fish and pelagic fishery	Annual, continuous
2	Towed video survey	Status and trend distribution and abundance Queen conch	Every 3-5 years
3	sBRUV survey	Status and trend distribution and abundance sharks & rays (and reef fish)	Every 3-5 years.
4	GCRMN survey	status and trend key reef indicators; coral cover, macroalgae cover, coral recruitment, coral disease, biomass herbivore and commercial fish, macroinvertebrates, water quality	Annual, FEB-MAR (water quality continuous)

5 RECOMMENDATIONS

It is recommended to:

a) develop a management plan with clearly defined indicator and quantifiable objectives, targets and reference points with regards to coral reef health, elasmobranchs and sustainable fisheries,

b) continue standardised monitoring of coral reef health, elasmobranch and fisheries indicators; develop and implement a standardised monitoring of water quality,

c) report results regularly to evaluate the performance of implemented management by comparing the status of the indicators against the quantified targets, objectives and reference points to facilitate adaptive management, and

d) address (monitoring of) water quality to ensure the highest water quality possible (e.g. water treatment, minimize erosion) and reduce the fishing mortality of herbivorous fish to enhance the recovery of stony coral cover and reduce macro-algae cover.

It is desirable to implement adaptive legislation and regulations to:

a) stimulate the development of a fishery targeting fast-growing, large pelagic species

b) reduce fishing mortality of sharks and rays to as close to zero as possible; release sharks and rays immediately after capture

c) reduce fishing mortality of large grouper and snapper species to as close to zero as possible to enhance the recovery of these apex predators; release large grouper and snappers immediately after capture and enhance survival by venting the fish before release

d) reduce fishing mortality of herbivorous fish, especially surgeonfishes (Acanthuridae), possibly with the introduction of escape slots in the lobster and fish traps.

e) improve compliance with the minimum landing size (95mm CL) for Caribbean spiny lobster

f) ensure lobster management is in line with international regulation with regards to restrictions on minimum landing size, closed season and gear restriction and adjustments (i.e. escape slot, biodegradable panel.

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QUALITY ASSURANCE

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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JUSTIFICATION

Rapport C167/15

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The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Dr. Dolfi Debrot

Researcher

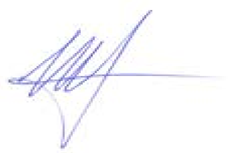
Signature:

Date: 9th of December 2015

Approved: Dr. ir. L.J.W. van Hoof

Head of department Fish

Signature:



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