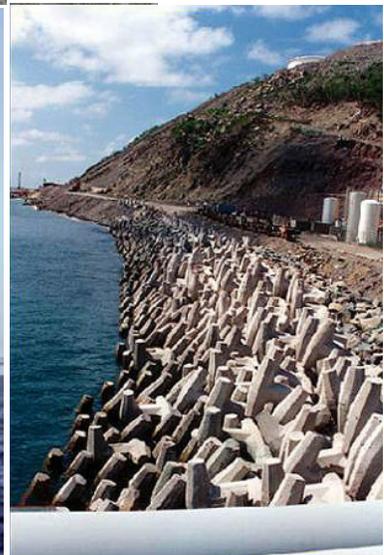
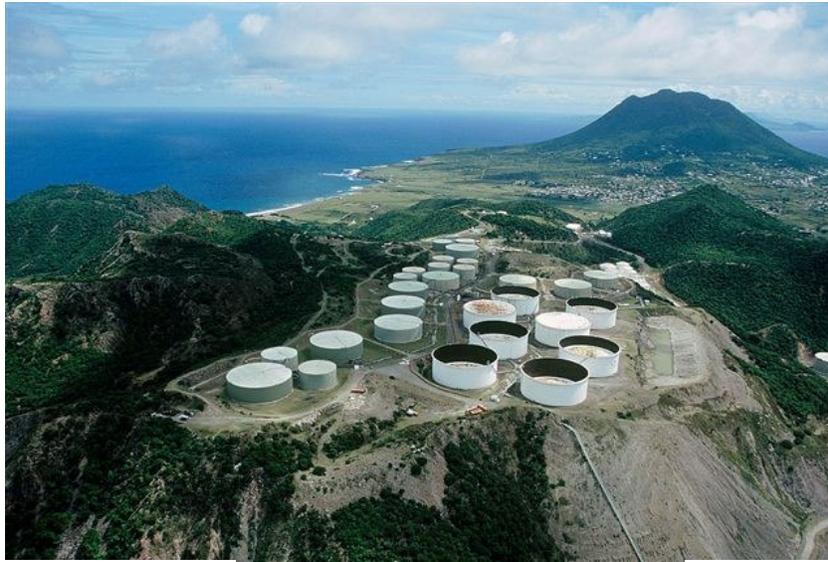


# Tanker Anchoring Impact Study and Recommendations St Eustatius Marine Park

October 2007



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This study was funded by KNAP grants from the Department of Environment and Nature Conservation (MINA) at the Ministry of Public Health and Social Development of the Government of the Netherlands Antilles in Curaçao.

Part funded by



DUTCH CARIBBEAN NATURE ALLIANCE

Cover photographs: Clockwise from top, an oblique aerial view of Statia Terminals looking South East, looking North East, Mooring buoys at Statia Terminals, shoreline protection at Statia Terminals

(source: STENAPA)

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## Executive Summary

St. Eustatius National Parks Foundation (STENAPA) is the only active environmental non-government organization on St. Eustatius, and was legislated in 1996 with a mandate from the Island Government to protect and manage the island's marine resources. St. Eustatius Marine Park was established in 1996 and became actively managed in 1997 to conserve and protect the marine environment surrounding the island from the high water line up to and including the 30 meter (100 feet) depth contour. The marine environment of St. Eustatius supports 27.5 km<sup>2</sup> of biologically diverse coral reef, seagrass, sandy seabed and open ocean communities. The Marine Park is one of the top 5 sites in the Caribbean to see healthy coral and fish populations. The 2 reserves have 43% hard coral cover and the Protected Area is a home, migratory stop over or breeding site for 14 IUCN Red List species, 10 CITES Appendix I species and 98 Appendix II species.

St Eustatius Marine Park attracts around 500 yacht visitors and 2500 diving/snorkeling visitors per year contributing to income for the 70% of the islands population employed in restaurants, hotels and other services<sup>1</sup>. Other uses of St Eustatius Marine Park are for Fisheries (25 fishermen use the waters of St Eustatius) and in excess of 1000 tankers a year using the oil storage facility at Statia Terminals NV. Anchoring is the main threat to the marine resources caused by the operations of Statia Terminals NV, although pollution is also an important issue with sewage and other wastes including ballast waters entering St Eustatius Marine Park waters from vessels.

Field work carried out involving survey dives, stakeholder consultation and photographic records found that significant damage has been done to the reefs within and beyond the designated anchoring zones for the vessels using Statia Terminals NV. The main impacts of the damage are:

### Direct impacts

- Broken individual coral colonies
- Structural damage to the reefs
- Sedimentation

### Secondary impacts

- Decreased fisheries production for subsistence, commercial and sport fishing.
- Decrease in dive tourism, and related activities.
- Change in community structure
- Ciguatera (poisonous) fish
- Decreased recruitment and coral larvae survivorship

Recommendations to manage the anchoring issues are: to:

- Install a Vessel Monitoring System with alerts to unsustainable practices.
- Monitor the current status, ongoing damage and recovery of the coral reefs
- Establish a protocol for response and restoration after damage has occurred.

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<sup>1</sup> Central Bureau of Statistics: [www.cbs.an](http://www.cbs.an).

## Introduction

### **St. Eustatius Marine Park**

St. Eustatius National Parks Foundation (STENAPA) is the only active environmental non-government organization on St. Eustatius, and was legislated in 1996 with a mandate from the Island Government to protect and manage the island's marine resources. St. Eustatius Marine Park was established in 1996 and became actively managed in 1997 to conserve and protect the marine environment surrounding the island from the high water line up to and including the 30 meter (100 feet) depth contour. Within the Marine Park there is a general use zone and two reserves which are located at the northern and southern ends of the island (See Figure 1). The northern reserve encloses Jenkins Bay up to the northern most point of the island<sup>2</sup>. The southern reserve runs from Gallows Bay to White Wall<sup>3</sup>.

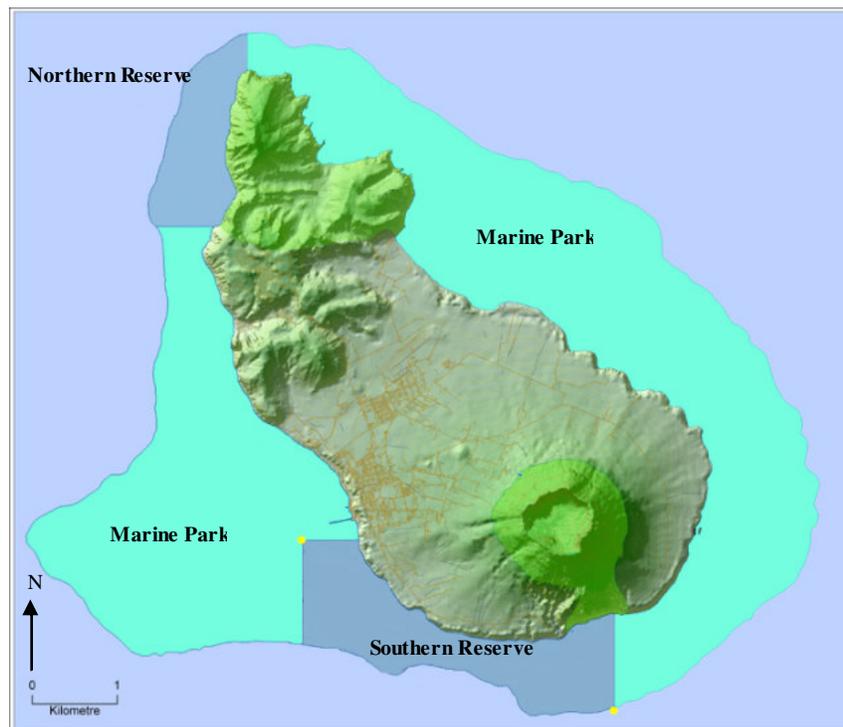


Figure 1: St. Eustatius Marine Park

### **Uses**

#### **Shipping in St Eustatius Marine Park.**

The principal commercial maritime activity in St. Eustatius occurs in and around Statia Terminals NV (see Figure 2) which is located immediately south of the northern marine reserve and has been in operation since 1982. The terminal is a for-hire bulk liquid terminal engaged in third party storage and handling, particularly as a trans-shipment point for oil being transported from the Middle East to the USA. It currently operates 50 storage tanks with a capacity of approximately 11 million barrels (1.75

<sup>2</sup> Northern Marine Reserve coordinates: 17° 30' .5 N along the high waterline to the northern point, to the north to the 30 meter depth limit, to the west and south along the 30 meter depth limit until these lines pass the coordinate 17° 30' .5 N and back to Jenkins Bay.

<sup>3</sup> Southern Marine Reserve coordinates: 17° 28' .5 N along the high waterline to the point of White Wall, south out to sea for half a nautical mile, to the west following the 30 meter depth limit to the crossing with the 17° 27' .7 N coordinate, to the north 17° 28' .5 N and back to Gallows Bay.

million  $m^3$ ), after a crude oil expansion project in 1993. The terminal has a jetty which serves two smaller tankers at a time and other berths include three floating barges, a floating hose station, floating dock and single point mooring (SPM) for larger tankers including very large crude carriers. The restricted zone established for the single point mooring overlaps the boundaries for the northern reserve. There are three designated anchorage zones which are for bunker vessels with drafts up to 15m (50ft). The zones are situated in Oranje Baai between the City Pier and the Statia Terminal Jetty. The zones are located in water of 24m to 40m (Figure 2). Two of the zones (B and C) fall entirely within the marine park while half of the remaining zone lies inside of the marine park (A). The Terminal also uses the area west of these designated zones for anchoring vessels (unofficially referred to as area D). There are current plans for further expansion of the Terminal, which means an increase in the 1000+ tankers that already visit the island every year.

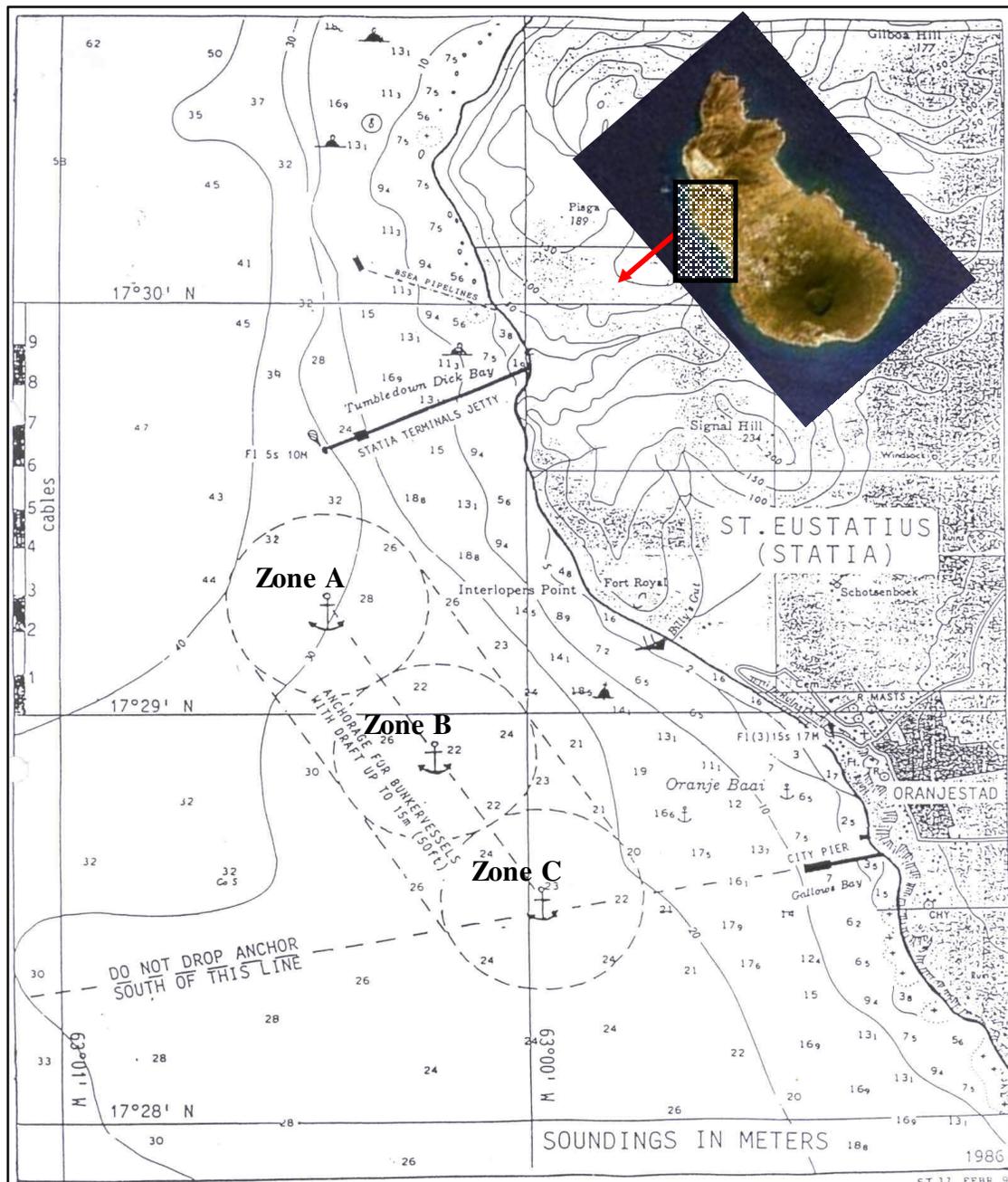


Figure 2: Anchorage zones for Bunker vessels with draft up to 15m.

## Fisheries

The St. Eustatius fishermen primarily fish on the narrow shelf surrounding the island. In 1996 STENAPA was granted effective control over the island shelf from the high water mark to the 30 meter (100 ft) depth contour. In addition fishing is restricted to hand line fishing within the Marine Reserves. Fishermen are restricted to catching a maximum of 20 queen conch (*Strombus gigas*) per year in the marine park area. Some recreational hand lining and trolling is carried out at the weekends. Local fishermen only are allowed to trawl a line with hook through the reserve on return from fishing trips. Bycatch is thought to be minimal. The principal fishing grounds were reported to be in four areas:

1. On the Atlantic side of the island in line with Bargine Bay to south of Compagnie Baai, from a depth of around 25 meters, for a distance of one nautical mile east.
2. In the area south of White wall in waters of 15-30 meters depth.
3. On the Caribbean side of the island from Cocoluch Bay to Jenkins Bay from 30 meters, for a distance of around one nautical mile west.
4. Traps were also laid in Oranje Baai from 26-35 meters and in the area of Gallows Bay immediately south of City Pier (Sybesma, van 't Hof & Pors, 1993)

There are about 25 fishermen on the island of St. Eustatius. Considering the small scale island economy this is a significant social economical factor that can not be overseen by the local Island Government. The money that is generated by the fishery sector, directly and indirectly, is invested back into the St. Eustatius economy, since all the fishermen are locals. In addition indirect taxes are generated from fuel, two stroke oil, fishing gear, spare parts and engines. The aggregated value of the fishery sector is also an important factor to the island economy. The spiny lobster (*Panulirus argus*) fishery is without doubt the most important fishery on the island, where chicken wire and bamboo traps are used. The total lobster catch for 2003 is estimated to be approximately 4 tons, which represents a gross value of 100,000 NAf (\$55,000),

In Gallows Bay St. Eustatius there is one facility for lifting the fishing vessels out of the water for maintenance or emergencies. Unfortunately the facility has never worked optimally and is currently out of order, because there is no money or no effort being undertaken to buy the necessary cables and mechanical winch. There is no dedicated pier in the harbour where the fishermen can tie their boat and subsequently most of the boats are moored outside of the harbour in open, un-protected water. The fish market located in Gallows Bay is quite good and would almost meet EU standards, would it not be for the fact that most of the infrastructure in the market is dysfunctional (Dilrosun, 2004).

## Tourism and recreation

The main reasons why people visit St Eustatius is for the diving and natural environment. Around 20,000 Non-Antillean visitors arrive on St Eustatius every year (Central Bureau of Statistics: [www.cbs.an](http://www.cbs.an)). The number of divers visiting the Protected Area is gradually increasing from one year to the next. During 2006, the number of divers registered with Statia Marine Park increased by 20% from 2005. The number of divers has steadily increased since the slump in tourism in 2001/2, and is consistently reaching record levels.

## **Key issues**

Conflict arises between the local fishermen and Statia Terminals NV when oil tankers going to the terminal run over fish traps, cutting away the fish trap markers turning them into ghost traps. Anchor damage to the reefs of St. Eustatius reduces marine biodiversity which directly effects fish populations. Passing sail boats and other boats also cut away fish trap markers (Dilrosun, 2004). Over 2000 foreign vessels visited St. Eustatius in 1996 and since the installation of the Single Point Mooring (SPM) the average size of the vessels calling at St Eustatius has increased (van't Hof et al., 1996). The increase in foreign traffic, combined with the expansion of the Terminals' own fleet (tugs, barges, response vessels) is furthermore responsible for the increase in traffic between Oranje Baai and the Terminal. The increased traffic gives rise to increased incidences of anchor damage and increased conflict with other users of Oranje Baai (van't Hof et al., 1996).

Anchoring is the main threat to the marine resources caused by the operations of Statia Terminals NV, although pollution is also an important issue with sewage and other wastes including ballast waters entering St Eustatius Marine Park waters from vessels.

## **Anchor damage**

Anchors cause damage to coral reefs during setting, retrieval, and while at anchor;

- **Setting:** Corals are broken, fragmented, or overturned as the anchor drops into the substratum.
- **While at anchor:** Once set, further damage occurs by the chain dragging across the substratum or wrapping around reef structures
- **Retrieval:** anchors are dragged along the substrate as the vessel manoeuvres, turning reef into rubble and leaving an anchorage scar.

Coral takes thousands of years to build and the dragging and swinging of large anchor cables and chains destroys coral heads and creates gouges and scars that destabilize the reef structure. The fragile nature of coral reefs also means that they do not provide for stable anchoring. Regeneration of coral reefs from such damage may never occur. These fragmented areas also contain large amounts of broken propellers, lines, personal effects and other debris, further reducing the condition of the coral reef (Dinsdale et al., 2004). Observations made on sections of reef off of Grand Cayman Island, West Indies, found that measurements showed 3150 m<sup>2</sup> of previously intact reef destroyed by one cruise ship anchoring on one day (Smith, 1988). On St Eustatius, three main habitats are represented within and adjacent to the anchoring zones for Statia Terminals NV;

**1. Encrusted rock boulders and rock ledges.** These are rock formations most likely to be volcanic in origin, which are encrusted with a variety of reef invertebrates. The soft coral found within this area included *Pseudoplexaura sp.* and *Plexaura flexuosa*, *Gorgonia ventalina* and *Eunicea sp.* Common species of sponges found were *Ircinia strobilina*, *I. campana*, *Chondrilla nucula*, *Aplysina lacunose*, *Neofibularia nolitangere*, *Cliona langae* (Sybesma et al., 1993).

**2. Sand/rubble.** This habitat consists of sand with rubble that is cemented together by coralline algae. Some of the green algal species observed to be present were *Udotea flabellum*, *Penicillus capitatus*, and *Cladosiphon occidentalis*. It also represents an important habitat for conch, both Queen conch, *Strombus gigas* and Milk conch, *Strombus costatus* were observed. *Xestospongia muta* was a common species of sponge found in the sand/rubble habitat (Sybesma et al., 1993).

**3. Offshore coral reefs.** Flat coral habitat dominated by flattened *Montastrea annularis* and *Colpophyllia natans*. Also present in the area were *Porites astreoides*, *P. porites*, *M. cavernosa*. There was a mixed community with sponges and soft corals. Coral cover was 30-40%. High cover by *Lobophora sp.* A fresh anchor scar was also observed at one of the offshore sites in April 1992 whilst surveying was being carried out (Sybesma et al., 1993).

These are commonly the habitats of spiny lobster, *Panulirus argus*, and queen conch, *Strombus gigas*, which are important commercial catch species for the local fisherman. At about 1.5 miles from the end of the City Pier, an extensive deep coral reef system starts (Sybesma et al., 1993). This is located within 27 meters (94 feet) and so is within the marine park. This reef system also extends to the area west of the anchorage zones that the tankers anchor within. Destruction of this habitat by the anchors and anchor chains of tankers is detrimental to the fishing potential in this area. Reports by local fishermen to the Marine Park management organization have signalled that fish catch rates have deteriorated in this area during the past five years. Fishermen diving for conch have reported anchor scars and broken corals in this area.

This study investigates the impact of tankers anchoring within the St. Eustatius Marine Park, using underwater surveys and stakeholder consultations and presents recommendations for tackling the main threats.

## Methods

Preliminary survey dives were carried out to identify the areas where further studies should be carried out. Interviews with Statia Terminals NV were held before final Rapid Assessment survey dives were carried out. The following pages contain details of the three methods.

### ***Preliminary Survey Dives***

The preliminary survey dives were carried out using a modified version of the manta tow technique. The manta tow technique is used to assess changes in the benthic coral reef. It enables large areas of reef to be visually assessed within a short time and is highly recommended for determining the effects of large-scale disturbances. The manta tow technique involves towing the observer slowly at the surface behind a boat however, for these survey dives an underwater torpedo was used for propulsion. Two preliminary rapid assessment dives were carried out within each of the three target anchorage zones used by the Terminal using the modified version of the manta tow technique. GPS coordinates were fixed for the start and finish points of each dive, giving the bearing for surveys to follow.

Before the rapid assessment survey dives, an initial practice torpedo dive was carried out by each survey team member to account for any complications with modifying the manta tow technique. The dives determined the distance that can be covered with the continued use of the torpedoes and the suitability of a torpedo mounted compass for navigation.

### **Equipment**

- 2 Torpedoes
- Self Contained Underwater Breathing Apparatus (SCUBA)
- Surface Marker Buoy (SMB)
- Compass
- Dive watch

### **Method**

The navigation torpedo was set up with the compass attached in a position where it was least affected by the magnets in the motor. The diver in control of the navigation torpedo also wore the dive watch, and the observation diver operated the SMB. A bearing from the end of the Ro-Ro pier to Smoke Alley was taken prior to entry into the water. The dive was then carried out following this bearing. Every four minutes the divers stopped to assess how the dive was going. After 20 minutes, the divers ascended to observe how accurate the navigation had been. They then returned from Smoke Alley to the pier on the reciprocal bearing.

### **Results**

The SMB created considerable drag and slowed the observation diver down. This would have made it hard to communicate between divers if either had had a problem; a method of obtaining each other's attention is required when carrying out the actual survey dives. It was also decided that the navigation diver would also be responsible for the SMB so as to leave the observation diver free to observe. The torpedo batteries lasted for roughly 45 minutes of constant use at a constant speed of 4 km/hour. During the initial survey dives the torpedoes will only be operational for around 20 minutes due to maximum bottom time limits as the surveys being carried out at depths of around 30 meters. The compass was not affected by motor activity.

### **Consultation with Statia Terminals NV**

Meetings with Statia Terminal operating staff were held in December 2003 and January 2004 to discuss the aims and reasons for the project. The usage of the three anchorage zones was also discussed and during this consultation it was discovered that the Terminal try not to use Zone C for the anchorage of tankers. Their reason for this is that the zone lies too close to the southern marine park reserve, and the shipping routes into the harbour. Instead they informed us that they use the area west of the anchorage zones (termed Area D), which lies within the marine park, as it is further out of the way. It was therefore decided that when the survey dives are carried out this zone (C) would not be investigated and the area to the west (Area D) would be surveyed instead. The technicalities of how the survey dives would be organized with the Terminal were discussed. It was arranged that the day prior to the survey the Terminal would be contacted and the dive would be arranged in accordance with which anchorage zone was suitable, in respect to the number and location of tankers that were due in port.

### **Rapid Assessment Dives**

#### **Equipment**

- 2 Torpedoes
- SCUBA
- SMB
- Compass
- Dive watch
- Data slate and survey form

#### **Method**

The survey dives were broken into 3 minute observational transects using underwater torpedoes. The navigator followed the pre-defined bearing and the observer followed behind. At the end of each transect the torpedoes were stopped, to enable the observer to record the data. Once the observer was ready to continue, a signal was given to the navigator to start another 3 minute transect. This procedure was repeated until the dive time approached the safe no-decompression limit. To ensure consistency one observer took part in all the survey dives. Navigators were trained to ensure that they were comfortable with maintaining a constant bearing whilst using the underwater torpedoes'. These rapid assessment dives fixed the locations for the ongoing site-specific monitoring of the anchorage area. At the end of each day the data were entered into the database. The following data was recorded:

Studies have found that the best indicators for differentiating the intensities of anchoring on the coral reefs systems are; the number of overturned coral heads, coral injury and coral cover (Dinsedale & Harriott, 2004). The dive and survey data collected is shown in Table 1.

<b>Dive data</b>		<b>Survey</b>
• Date	• Latitude/Longitude Start	• Coral: Hard Live, Soft Live, Dead
• Time	• Latitude/Longitude Finish	• Other substrates: Sand, Rubble, Algae
• Observer	• Start/End Depth	• Conch numbers
• Navigator	• Current	• Anchor scar: New, Old.
• Zone/Area	• Visibility	

Table 1: Data recorded.

## Results

### ***Literature Review and Stakeholder Consultations***

The literature review found that fisherman previously laid fish traps and lobster pots in the region to the west of the designated anchorage zones (Sybesma et al., 1993). This is the same region that the terminal declared to using for anchoring the tankers during the stakeholder consultations. The different usage of the survey region is demonstrated in Figure 3. There is clearly some level of conflict that occurs within the marine park between local fishermen and the terminal. During consultations with local fisherman they expressed complaints that the fish catch rates have deteriorated in this area during the past five years. There were also concerns that the oil tankers going to the terminal damage the underwater biodiversity and the fishing grounds through anchoring and also cut away the fish trap markers turning them into ghost traps.

### ***Rapid Assessment Survey***

The rapid assessment dives were carried out using a team of four divers, one observer throughout and three navigators. The dives were carried out over a period of 5 months from February to June 2004. This phase took longer than planned due to logistical difficulties of scheduling surveys when tanker traffic was low. Within the anchorage zones seven rapid assessment dive transects were carried out, site specifics are shown in Table 2, locations are shown in Figure 3.

Area	Transect	Depth	Start	Finish
Zone A	A1A	30m	17° 29.07' N 63° 00.32' W	17° 29.203 N 63° 00.390 W
	A3A	26m	17° 29.05' N 63° 00.50' W	17° 28.987 N 63° 00.233 W
Zone B	B1A	25m	17° 29.07' N 63° 00.22' W	17° 28.879 N 63° 00.101 W
	B3A	22m	17° 28.87' N 63° 00.45' W	17° 28.853 N 63° 00.337 W
Area D	D1A	30m	17° 28.85' N 63° 00.62' W	17° 29.095 N 63° 00.754 W
	D3A	30m	17° 28.70' N 63° 01.05' W	17° 28.877 N 63° 01.277 W
	D5A	27m	17° 28.60' N 63° 00.78' W	17° 28.448 N 63° 00.695 W

Table 2: Survey site specifics

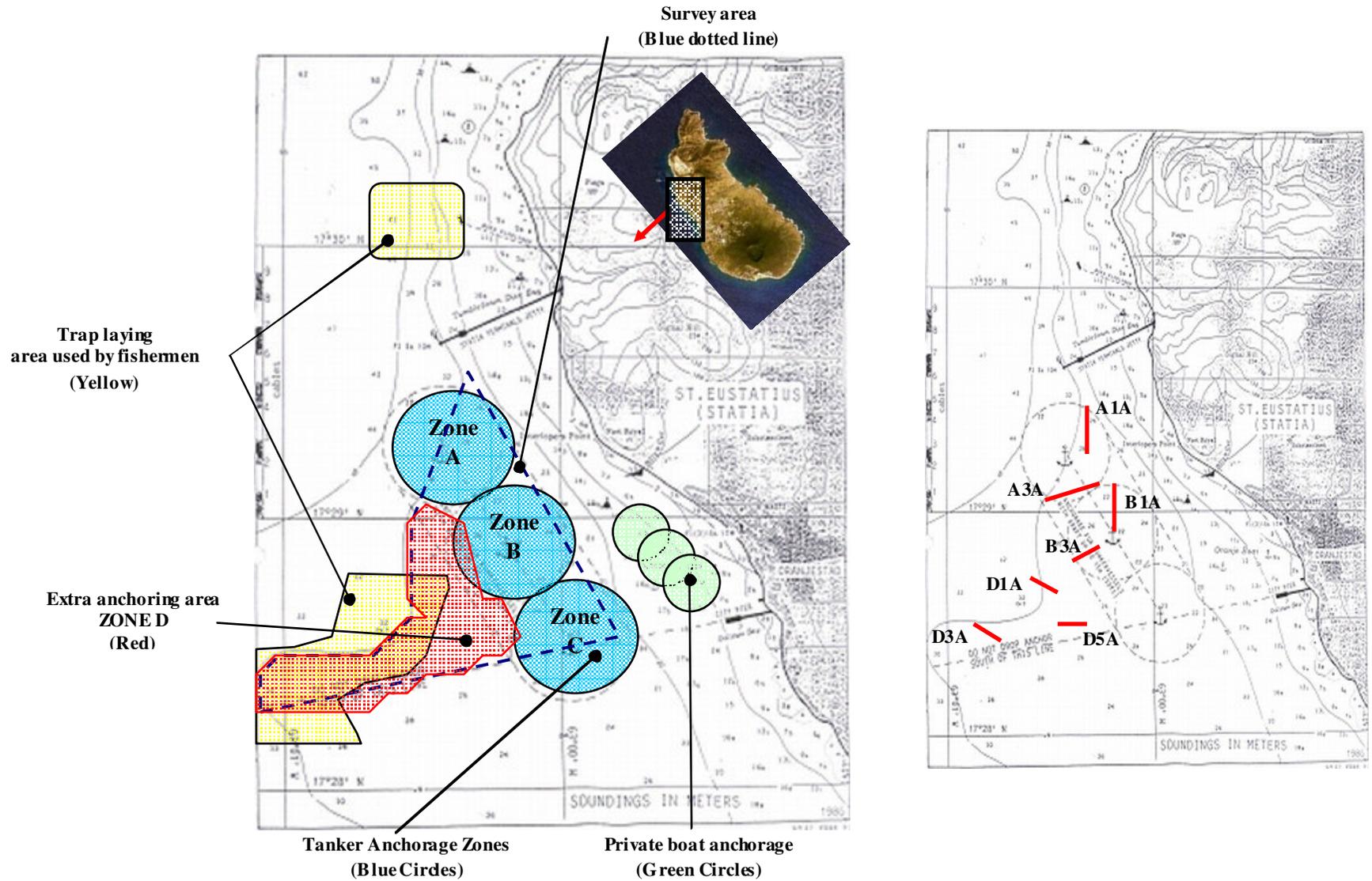


Figure 3 : Areas of use around Statia Terminals NV and Rapid Assessment Survey Dive Locations

The results from the data collection were analysed using Excel software, Table 3: presents a summary of the key results.

Area	Number of dives	Transects	% cover				
			Rubble	Live Coral	Sand	Algae	Other
Zone A	2	7	95	0	5	0	0
Zone B	2	6	95	0	5	0	1
Area D	3	6	45	48	6	2	0
Barracuda Reef <sup>4</sup>	-	-	0	38	0.6	46	15

Table 3: Summary of results

### Substrate composition

Two rapid assessment dives were carried out within anchorage zone A (A1A and A3A shown in Figure 3). During the two dives seven transects were carried out. The observed substrate was 95% rubble, which was covered with algal growth. Two rapid assessment dives were conducted in anchorage zone B, (B1A and B3A shown in Figure 3). During the two dives six transects were carried out within the anchorage zone. The anchorage zone was observed to be 95% rubble, which was covered with algae. Three rapid assessment dives were conducted within anchorage zone D, (D1A, D3A and D5A shown in Figure 3). During these dives six transects were carried out. Transect D1A was found to be composed of mainly rubble, covered with algae, and sand. Transects D3A and D5A were found to be composed of mainly coral formations (see Figure 4).

A nearby reef, Barracuda Reef and data collected during the Reefcheck Survey of 2006 has been used as a control. Barracuda reef is within St Eustatius Marine Park and no anchoring takes place on the reef. The reef is visited by divers. Barracuda Reef has 38% hard and soft coral cover, 46% algae and 15% other organisms which includes sponges.

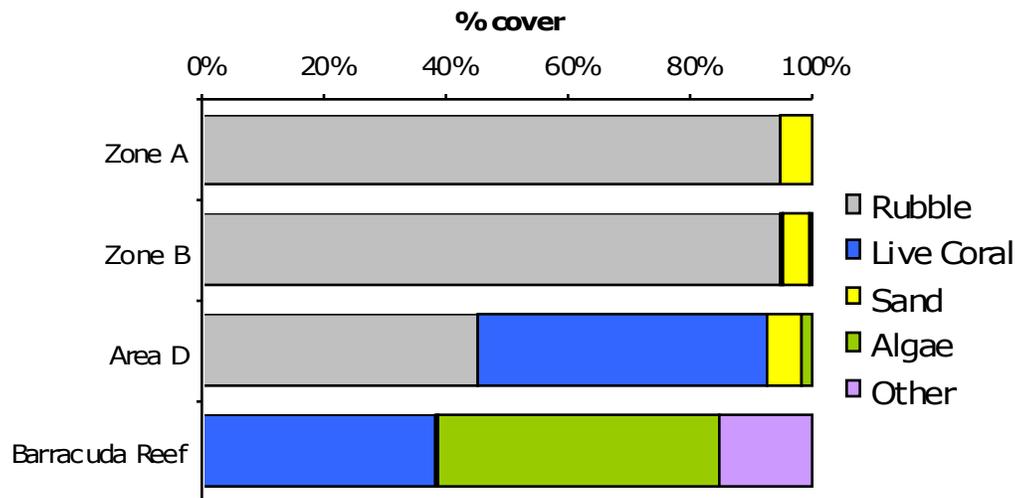


Figure 4: Substrate composition

<sup>4</sup> Barracuda Reef survey dives were carried out during Reefcheck monitoring in 2006

### Anchorage scar observations

In total, 26 anchor scars were observed whilst carrying out the rapid assessment survey of the anchorage zones (See Figure 5). Of these scars 65.4% were found to be located within anchor zone B. Of the total number of scars that were observed, 80.8% were found to be old. These findings were consistent with reports from Terminal staff that Zone B is the most frequently used.

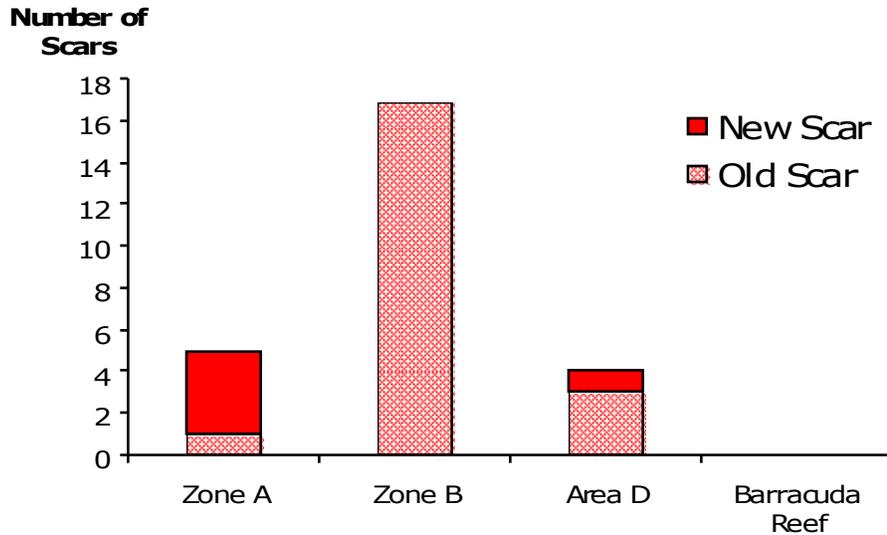


Figure 5: Anchor scars

### Photographs

In addition to the rapid assessment dives two observational dives were carried out to take underwater photographs of the substrate within the survey area. After reviewing the data it was decided that anchorage zones B and D would provide the best examples of the different substrates within the survey area. The rapid assessment dives found that the main substrate within the survey area was rubble covered with algae. Examples of this form of substrate can be seen in Figure 6 of pictures from anchorage zone B. From the rapid assessment survey it was also discovered that anchor zone B showed the greatest examples of anchor damage. Figure 7 provides an example of an anchor scar.

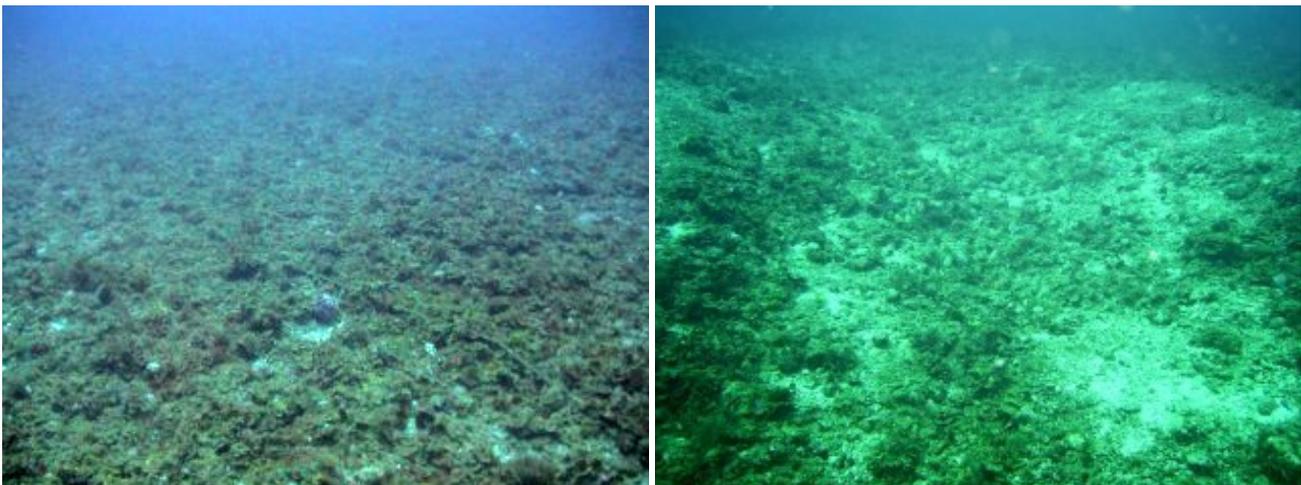


Figure 6 : Rubble Covered with algal growth (Photo: J.White) Figure 7: An anchor scar, (Photo: D.Davis)

These pictures were taken from the end of an anchor scar where the anchor finally came to rest. This is evident due to large depression that has formed in the substrate, which occurred as the anchor chain moved whilst the tanker was stationary. The level of algal growth within the depression leads to the assumption that the scar is not recent. The rapid assessment survey of transects D3A and D5A discovered the presence of coral formations (See Figure 8). These two transects were in complete contrast to what had been found in the previous five survey transects.

There was also evidence of anchor damage within zone D, which can be seen in Figure 8, Figure 9: Coral formations, (Photos: J.White, D.Davis). A clear sand channel can be distinguished that passes through the coral formations. It would appear that this is an old scar as there is a porous sea rod, *Pseudoplexaura sp.*, growing in the centre of the sand channel. Within this sand channel there is evidence of broken and destroyed coral debris, (see Figure 10, Figure 11: ).

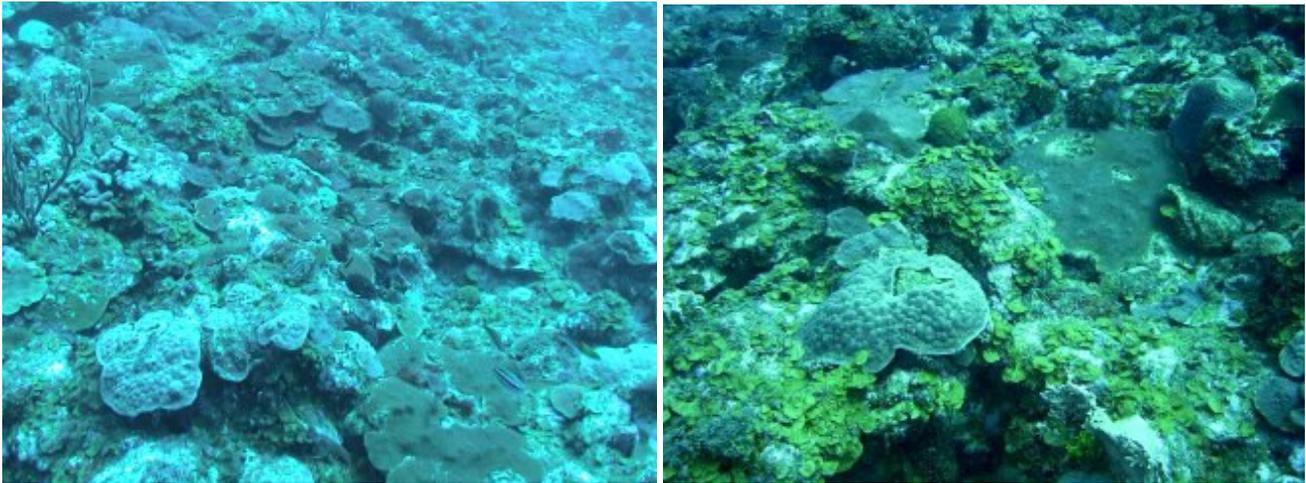


Figure 8, Figure 9: Coral formations, (Photos: J.White, D.Davis)



Figure 10, Figure 11: Anchor damage, (Photos: J.White, D.Davis)

## Discussion

The marine environment of St. Eustatius supports 27.5 km<sup>2</sup> of biologically diverse coral reef, seagrass, sandy seabed and open ocean communities. The Marine Park is one of the top 5 sites in the Caribbean to see healthy coral and fish populations. The St Eustatius Marine Park was established in 1996 to manage these marine resources for the benefit and enjoyment of the people and future generations. The 2 reserves have 43% hard coral cover and the Protected Area is a home, migratory stop over or breeding site for 14 IUCN Red List species, 10 CITES Appendix I species and 98 Appendix II species. St Eustatius Marine Park attracts around 500 yacht visitors and 2500 diving/snorkeling visitors per year contributing to income for the 70% of the islands population employed in restaurants, hotels and other services<sup>5</sup>.

### **Anchor damage in St Eustatius Marine Park**

Anchoring within St Eustatius Marine Park is seriously damaging the coral reefs and the marine resources of St Eustatius. Surveys found very significant differences in substrate between areas where tankers using Statia Terminals NV have been anchoring and areas where they are not. Coral Reefs where anchoring takes place have been reduced to algae dominated rubble. Anchors have been directly damaging the reefs in three main ways (Table 4)

Damage	Explanation	Impact
Broken individual coral colonies	Anchors uproot, scrape and break coral colonies as they are dropped and dragged along a reef searching for a firm hold (Glynn, 1994) Anchor chains rub on coral and damage colonies. (Davis, 1977; Dunstan, 1973)	Dead coral colonies from direct rubbing and breakage. (Halas, 1985) Colonies weakened by anchor damage are more likely to catch disease.
Structural damage to the reefs	Anchors can be dragged around large areas, reducing the height, shape and complexity of the reef (Smith, 1988)	A less complex reef means less habitat for reef organisms e.g. fish have fewer places to hide. Broken corals and rubble can roll down reef slopes, damaging other corals in deeper water. (Smith, 1988)
Sedimentation	Anchors stir up sediments on the seabed as they are dragged around. Anchoring can reduce visibility from 60 metres to 1 metre. (Smith, 1988) Anchors also pulverise the coral they come into contact with, leaving plumes of calcium rich sediment where they are dragged. (Rogers & Garrison, 2001)	Reduced sunlight penetration from cloudy water makes it more difficult for corals to photosynthesise. Smothering leads to damaged coral tissues and weaker colonies, which make a coral more likely to catch diseases such as Black Band Disease and White Band Disease. (Rogers, 1985; Rogers, 1990)

Table 4: Direct damage caused by anchors on coral reefs.

Other important factors to consider relating to anchor damage in St Eustatius Marine Park include:

- The amount of damage caused by anchors is strongly related to the growth form of corals e.g. branching *Acropora* species are more likely to be severely damaged by a falling anchor than more sturdy massive corals such as *Montastrea* species. (Riegl & Riegl, 1996)
- Soft and fragile corals such as octocorals (e.g. *Dendronephthya* species) and plate like corals e.g. *Acropora* species are also easily damaged by anchors (Riegl & Riegl, 1996; Tilmant & Schmahl, 1981)

<sup>5</sup> Central Bureau of Statistics: [www.cbs.an](http://www.cbs.an).

- Deep water communities are damaged more by anchors than shallow water communities. This is because deep water reefs have not evolved to withstand wave action and are therefore more fragile and easily damaged (Riegl & Riegl, 1996).
- After an anchor has damaged an area of reef, the area becomes more sensitive to other ecosystem changes e.g. a die off of the Long Spined sea urchin *Diadema antillarum* will result in a higher death rates of coral juveniles due to overgrowth of macroalgae on an anchor scar. (Rogers & Garrison, 2001)

The direct damage caused by anchors outlined above leads to other problems on coral reefs that last for a very long time. This ‘secondary damage’ is harmful not only to reef organisms but also humans who use the reef. Fisheries, tourism, and coral reef ecology are all affected significantly by secondary anchor damage (Table 5).

Result of damage	Explanation	Impact
Decreased fisheries production for subsistence, commercial and sport fishing.	Loss of habitat means fish and other organisms such as lobsters have fewer places to shelter in an area. Fewer fish means other predatory animals on the reef such as Jacks and Barracuda have less prey to feed on, so they become scarce locally. (Smith, 1988)	Human fish catches will decline in the area as the fish die from lack of food or go elsewhere for hunting. (Edinger <i>et al.</i> , 1998; Ohman, Rajasuriya & Linden, 1993; Rogers, 1985)
Decrease in dive tourism, and related activities.	Fewer fish and overall environmental degradation caused by anchor damage make a place less attractive to visitors. (Jivan Shah <i>et al.</i> , 1997; Smith, 1988). Zone D has several dive sites frequented by local dive centres, such as Neptune’s Locker.	Fewer visitors mean less people staying in hotels and fewer tourists’ spending money elsewhere in an area e.g. restaurants and souvenir shops. Less income for the local and national economy and an increase in unemployment.
Change in community structure	Anchor damage leaves an area bare with no living corals, so there is overgrowth by various algae species especially turf algae (a collection of small hair like plants in clumps around 1-5cm in diameter, brown/red/green in colour) and <i>Dictyota</i> species) (Rogers & Beets, 2001; Rogers & Garrison, 2001; Smith, 1988).	A small change will make the reef less attractive to visitors. A large change or ‘Phase shift’ is nearly impossible to reverse and the coral reef and its associated animals will disappear forever. (Done, 1992)
Ciguatoxic (poisonous) fish	Poisonous algae grows on bare substrate and becomes concentrated in organisms through the food chain. More algae will grow when bare substrate is made available through anchor damage. (Smith, 1988)	‘Edible’ fish become poisonous to humans and other carnivores.
Decreased recruitment and coral larvae survivorship	Low habitat complexity means there are fewer surfaces for young corals to settle on and loose rubble constantly moves around which kills anything that has managed to settle. High macroalgal (large marine plants like <i>Dictyota</i> species) cover means there is lots of competition for resources on the reef and young corals can be out grown. (Rogers & Garrison, 2001)	Slower reef recovery from anchor damage, resulting in long lasting secondary effects of anchor damage.

Table 5: Secondary Anchor Damage

### ***Recovery from anchor damage***

Anchors and anchor chains grind and crush coral, creating a fine and unstable substrate that makes recovery a slower process because young corals cannot settle easily. This is made harder if the area continues to be used by boats as an anchoring site. (Tratalos & Austin, 2001) Rapid stabilization of the sediment and/or sediment removal are important after an anchor has caused damage on a reef. (Rogers & Garrison, 2001) This is to make sure the rubble does not cause any further damage through direct contact with living coral or through sedimentation. If the rubble is left, reef recovery will be very slow, which means the secondary effects of anchor damage will last longer. Coral reef recovery from man-induced impacts is reported to take from a few years to several decades to centuries. Some scientists feel coral reefs damaged by man will never recover. Generalisations are difficult to make since each reef is unique, few studies have been done and, complex variables interact to aid or hinder recovery (Banks *et al.*, 1998).

The nature of the dislodged organisms makes re-attachment difficult. Reattachment of sponges has a rather low success rate. Soft coral reattachment is somewhat more successful, however reattachment must be done soon or survival will be decreased significantly. A dislodged hard coral will likely survive if it remains upright and undisturbed. The greatest loss to the ecosystem may be that of habitat. In low profile reefs soft corals and sponges provide significant habitat especially for filter feeding organisms that live in gaps and holes in the reef. The added elevation of soft corals and sponges is utilized by a number of organisms during nocturnal feeding. The loss of this ecosystem function will likely lead to further decreases in species diversity, directly effecting fisheries.

Without recovery, the loss of reef organisms as well as the habitat value provided by these organisms decreases the value of the reef. The economic and ecological value of these reefs represents a significant monetary interest to the St. Eustatius. It is in the best interest of all parties involved to prevent further degradation of this habitat and to mitigate the damage that has already occurred (Beaver, 2006).

### **Economic values**

The coral reefs of St Eustatius Marine Park have a range of values which come from direct use (fishing etc), indirect use (protection from storms) and existence values - Table 6.

<b>Total economic value</b>			
<b>Use Values</b>			<b>Non-Use Values</b>
<b>Direct</b>		<b>Indirect</b>	<b>Existence</b>
Extractive <ul style="list-style-type: none"> <li>• Capture fisheries</li> <li>• Mariculture</li> <li>• Aquarium Trade</li> <li>• Curio Trade</li> <li>• Pharmaceutical</li> <li>• Other industry</li> <li>• Construction</li> <li>• Genetic Material</li> </ul>	Non-extractive <ul style="list-style-type: none"> <li>• Tourism</li> <li>• Recreation</li> <li>• Research</li> <li>• Education</li> <li>• Aesthetic</li> </ul>	<ul style="list-style-type: none"> <li>• Biological support for other ecosystems and marine organisms</li> <li>• Physical protection to ecosystems, land forms, human settlements.</li> <li>• Global life support; calcium store, carbon store.</li> </ul>	<ul style="list-style-type: none"> <li>• Endangered Species</li> <li>• Charismatic Species</li> <li>• Threatened Reef Habitats</li> <li>• Cherished 'Reefscapes'.</li> </ul>

Table 6: Coral Reef Values (Spurgeon & Aylward, 1992)

A number of valuations based on financial equivalents have been made for specified amounts of coral reef. The United Nations Environment Programme (UNEP) put the annual economic value per square km of reef has been calculated at US\$ 100,000-600,000. In 1984 a ship called The Wedgewood damaged 400ft of reef in John Pennekamp Park Florida. Each foot of reef was valued at \$32,000. This led to a possible in-court settlement of \$20 million to 'mitigate' the effects of the grounding. An out of court settlement of \$6 million was eventually paid. A number of other settlements have been made where coral reefs have been damaged (Table 7). For each m<sup>2</sup> of reef damaged these pay outs are equal to from \$170 to \$11,000 with an average settlement fee of \$2500 per m<sup>2</sup>.

Ship Name	Year	Location	Damage Area (m <sup>2</sup> )	Trustee	Settlement
M/V Wellwood	1984	FL Keys	1,282	NOAA	\$6 mil.
M/V Mini Laurel	1984	FL Keys	N/A	N/A	N/A
M/V Mavro Vetrican	1989	FL Keys	15,800	State of Florida	\$3.3 mil.
M/V Elpis	1989	FL Keys	>3,000	NOAA	\$2.75 mil.
Dredge Long Island	1988	Dade County	>6,006	State of Florida	\$1.1 mil.
USS Memphis	1993	Broward County	1,205	State of Florida	\$750,000
R/V Columbus	1994	FL Keys	338	NOAA	\$3.7 mil.
Iselin					
M/V Firat	1994	Broward County	>1,000	State of Florida	N/A
M/V Sealand Atlantic	1994	Broward County	500-1,000	State of Florida	N/A
M/V Iglee Moon	1996	Biscayne National Park	N/A	US Dept. of Interior	in litigation
M/V Houston	1997	FL Keys	N/A	NOAA, FKNMS, State of Florida	\$6 mil.
M/V Fortuna Reefer	1997	Puerto Rico	7,500	NOAA and PR	\$1.25 mil.
M/V Pacific Mako	1998	Ft. Lauderdale	N/A	State of Florida	not settled

Table 7: Coral Reef Damage Payouts (Banks *et al.*, 1998)

## Recommendations

### **Vessel Monitoring System**

Statia Terminals NV currently records some information about visiting vessels, although this information is far from ideal to apply to the management of the marine park since it cannot be accessed readily and St Eustatius Marine Park staff cannot react to any situations that need to be addressed. To prevent anchoring in certain areas of St Eustatius Marine Park an effective Vessel Monitoring System is required. This will enable real-time reactions to infractions and also provide data for ongoing monitoring and research. A number of options are available for managing and monitoring vessels manoeuvring around and anchoring with St Eustatius Marine Park, these range from marker buoys through to high tech satellite tracking systems. A summary of the different approaches to vessel management is presented in the Appendix of this report.

**The most suitable VMS for St Eustatius Marine Park is a VHF Radio based Automatic Identification System.** Vessels equipped with an Automatic Location Communicator (all vessels over 300 tonnes by law) automatically transmit information, such as location and course, to a coordinating station via VHF and a terrestrial base station. At the coordinating station the information is checked to ensure compliance with management arrangements which are defined within the system. If the system detects a breach of these arrangements it automatically generates a report and can forward an alert to the relevant surveillance authority via e-mail, mobile phone or pager for action. AIS Live ([www.aislive.com](http://www.aislive.com)) provide an internet based service with a range of benefits. Vessel information is collected and presented on a map (Figure 12) with details of the vessels and their status, position etc (more maps with details at different scales can be seen in the Appendix).

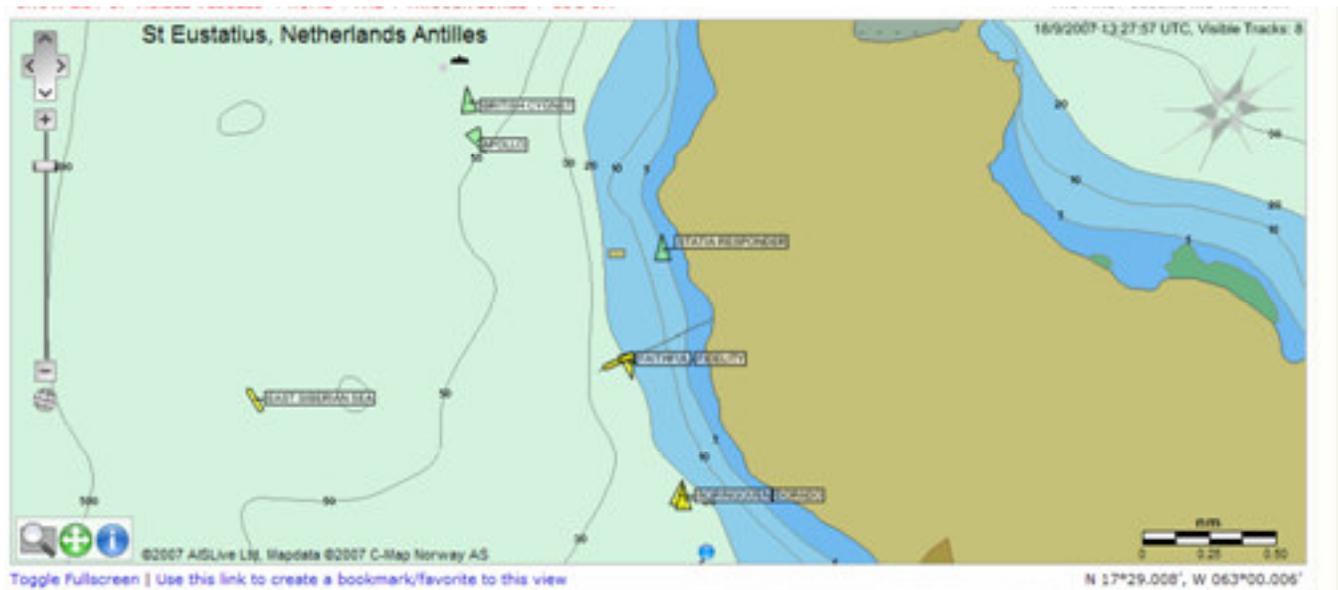


Figure 12: AIS Live graphical presentation (vessels marked as yellow triangles or blocks).

**Subscription costs will be \$1320 per year plus VAT (\$1551).** There will be many benefits to subscribing to such a system. The main use for St Eustatius Marine Park will be to detect likely encroachments on restricted areas through routine monitoring of vessel movement. This will allow rapid reaction to anchor damage and necessary enforcement. There are a wide range of other benefits including; alerts such as SMS text messages and e-mail, ability to define trigger zones (reserves, marine park and area's outside anchoring zones), historical data is recorded by the provider, data can also be used in research and monitoring.

## **Monitoring**

The rapid survey dives carried out for this report highlighted the need for targeted, effective monitoring of the anchoring around Statia Terminals. Three aspects of monitoring should be carried out to increase the data available to decision makers (Table 8)

<b>Monitoring</b>	<b>Justification</b>
Establish the current status of the habitats within and around the anchoring areas	The Use of an established monitoring protocol such as ReefCheck or AGRRA to assess the current status of the reefs will establish good base line data for future data to be compared against. Control sites must be used on near-by reefs where no anchoring takes place
Monitor change in the status of the habitats, establish data for the area of substrate damaged by one anchoring event.	Use specified sites for repeated monitoring to detect change in the habitats, using fixed photo quadrats and other established monitoring protocols. This will allow data to be presented on vessel activity and damage rates. By assessing how much damage is done by one anchoring event, analyses can be carried out on the impact of changes in vessel numbers and anchoring practices. This will also allow some calculation of any mitigation costs.
Research into the recovery rates of the reefs around the anchoring areas	A project to investigate recovery rates will aid planning and management by providing site specific information to decision makers and for lobbying. Information from this research should also influence any restoration projects.

Table 8: Monitoring recommendations

## **Response and Restoration**

Depending on the outcome of any monitoring, restoration may be a viable option for anchor damaged areas. After performing a detailed Damage Assessment and Restoration Plan (DARP), a monetary assessment of damages based on restoration costs should be prepared and a demand for these damages presented to the responsible party. The restoration methodology should be based on the costs of the actions to restore or replace the damaged reef to its pre-disturbance, baseline condition. Replacement costs are the costs of substitution of the resource that provides the same or substantially similar services as the damaged resource. The restoration or replacement alternatives should be evaluated according to the DARP. The damage amount should be the amount to cover all costs related to the injury and not just limited to an amount used to restore the damaged resources, including:

- All emergency response and/or salvage efforts.
- Environmental assessment and mapping of injured resource (damage assessment).
- Implementation of emergency rehabilitation methodologies (reef triage).
- Preparation of the DARP report.
- Implementation and completion of restoration through project success.
- Long-term scientific monitoring studies (both functional and compliance).
- Compensatory restoration for interim loss of services. (Precht, Deis & Gelber, Unknown)

## Acknowledgements

St Eustatius National Parks acknowledges financial assistance from the Dutch Caribbean Nature Alliance towards technical input in completion in this report.

Questions about anchor damage and suitable Vessel Monitoring Systems were posted onto the NOAA coral list server, which has 4000+ members. The following subscribers volunteered useful information:

- Anchor damage; Tegan C. Hofman, Reuven Walder, Richard Unsworth, Paul Erftemeijer, Mizna, Kenneth Banks, Manoj Shivlani,
- VMS; Duncan Vaughan, Dr. Stephen C. Jameson, Jill Zamzow, Peter J. Rubec

Statia Terminals NV were very helpful during preparation and fieldwork phases of this research, in particular Henk Soetekouw and William de Gannes.

The Marine Park wishes to thank a number of volunteers, in particular Joanna White for organising fieldwork and drafting early versions of this report, Peter Esteban for help in preparation and exploratory dives for this study, and Darrell Davis for his help with diving surveys.

This fieldwork based elements of this study was funded by KNAP Fonds Nederlandse Antillen (project K03-09) from the Department of Environment and Nature Conservation (MINA) at the Ministry of Public Health and Social Development of the Government of the Netherlands Antilles in Curaçao.

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## Appendices

### Options investigated for a vessel monitoring/management system

Method	Markers	Radar/ bearings	AIS (Automatic Identification System) - VHF.	Satellite
<b>Area</b>	Local	Local	Local/National	Local/National/Regional
<b>Complexity</b>	Low	Low	Mid	High
<b>Cost</b>	>\$500	<\$200, high cost in terms of work hours.	≈\$1500	>\$2000 plus ongoing costs \$1-\$5 per transmission
<b>Information transmitted</b>	None. Ships use the markers to determine if they are in the safe anchoring area (a visual position fixing method). These would be lit for night operations.	Requirements transmitted to boat captains. Radar ranges and bearings: by the Pilots/Terminal Radio to confirm ships location before anchoring. Ship/Pilot would radio into Terminal Radio when in position to drop anchor to receive permission to drop anchor (ship/pilot uses range markers, GPS, and radar to fix position). Terminal Radio then confirms on his radar that ship is in safe location.	Provide information - including the ship's identity, type, position, course, speed, navigational status and other safety-related information - automatically to appropriately equipped shore stations, other ships and aircraft; receive automatically such information from similarly fitted ships; monitor and track ships; exchange data with shore-based facilities. It utilizes a normal VHF signal to give the vessels GPS lat, long, rate of turn, vessel name etc - the master of the vessel also must enter on the system the status of the vessel location e.g. if it is anchored.	Wide range
<b>Equipment required</b>	Light Buoys, Moorings, land based markers	Radar, radio communications or other for 2 way communications between harbour/enforcement agencies and vessels.	Land base station, computer hard drive to store historical movements. Larger vessels should have transmitters installed. Type B transmitters required for smaller vessels (<\$1500).	Transmitter On vessels, Land base stations, Interpretation software and computers. Access to satellite transmissions on a specified platform e.g. GOES, of INMARSAT.
<b>Issues</b>	Impractical for tankers. Little enforcement capabilities unless the vessels are being directly observed.	Labour intensive, difficult to coordinate between enforcement institutions	Information sent by VHF should be considered in line with the Freedom of Information Act/Human Rights Act/Data Protection Act	Expensive set up and ongoing costs – air time and hardware
<b>Benefits</b>	Low maintenance and set up costs	Direct communication with all vessels, low set up and maintenance costs	IMO (International Maritime Organisation) regulation requires AIS to be fitted aboard all ships of 300 gross tonnage and upwards engaged on international voyages, cargo ships of 500 gross tonnage and upwards not engaged on international voyages and all passenger ships irrespective of size. The requirement became effective for all ships by 31 December 2004. Historical information is a good future data source. Equipment is often already in place (e.g. antenna at a harbour masters). You can also designate no go zones linked to pagers/cell phones etc that will go off if a vessel enters that area and you can respond accordingly.	Details, accurate and a range of information can be transmitted electronically.  Over large areas: detect likely encroachments on restricted areas through routine monitoring of vessel movement., provide information on known vessel activity allowing surveillance missions to quickly identify unknown vessel activity and investigate this more closely, provide near real-time monitoring of vessels during an enforcement or pursuit operation, 2 way e-mail communication between monitoring authorities and fishing vessels.
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N 17°29.614', W 062°59.975'

	MMSI	309215000	Latitude	N 17°28.237'	Last seen at	18/9/2007 13:12:24 UTC
	Name	Rowan	Longitude	W 63°01.142'	Destination	Sint Eustatius
	Callsign	C6JV4	Heading	327°	ETA	17/9/2007 6:00:00 UTC
	IMO number	8814421	Length	181 m	Vessel Type	Tanker
	Status	Anchored	Beam	30 m	Extra Info	N/A
	Speed	0.0 knots	Draught	7.7 m	Retrieved at	18/9/2007 13:14:55 UTC

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	Callsign	C6JV4	Heading	327°	ETA	17/9/2007 6:00:00 UTC
	IMO number	8814421	Length	181 m	Vessel Type	Tanker
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		<b>Name</b>	Rowan	<b>Longitude</b>	W 63°01.142'	<b>Destination</b>	Sint Eustatius
		<b>Callsign</b>	C6JV4	<b>Heading</b>	327°	<b>ETA</b>	17/9/2007 6:00:00 UTC
		<b>IMO number</b>	8814421	<b>Length</b>	181 m	<b>Vessel Type</b>	Tanker
		<b>Status</b>	Anchored	<b>Beam</b>	30 m	<b>Extra Info</b>	N/A
		<b>Speed</b>	0.0 knots	<b>Draught</b>	7.7 m	<b>Retrieved at</b>	18/9/2007 13:14:55 UTC

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