Lobster trap detection at the Saba Bank

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Summary

According to previous studies and anecdotal evidence there are a lot of lost lobster traps at the Saba Bank. One study estimated the loss to be between 210 and 795 lobster traps per year. The Saba Bank is an approximately 2,200 km^2 submerged area and spiny lobster (*Panulirus argus*) is one of the main fisheries with an annual economic value over USD 1 million.

The traps get lost due to a combination of bad weather moving or damaging traps and marker buoy lines, ship traffic running into and cutting marker buoy lines and removal of marker buoy or theft of traps by vandals. Lost traps are a concern for the Saba Bank fisheries management, because of the potential impact of ghost fishing by lost traps and the damage to the benthic environment.

IMARES was commissioned by the Ministry of Economic Affairs, Agriculture and Innovation to advise on a method to detect lost lobster traps. The objective of this desk study was to provide information for the sustainable management of the lobster fisheries and the conservation of the Saba Bank.

In this report we investigate the most efficient method for the detection of lost lobster traps from a small vessel in water between 15 and 50 meter depth. We not only address methods for the location of traps, but also recommend methods for the retrieval of traps and measurement of ghost fishing.

Side scan sonar in combination with a magnetometer is recommended as the best, most efficient method to locate lost lobster traps in order to retrieve them.

This is not necessarily the most cost-efficient method to respond to the problem of future traps loss, as preventive measures tend to be more effective and less costly than curative measures. However, a detection survey can be used to better estimate the magnitude of the problem of already lost traps. It is not realistic that a detection survey can locate all lost traps that are present on the Saba Bank.

1 Introduction

The Saba Bank (17°25′ N, 63°30′ W) is a roughly rectangular undersea elevation with a flattened top, located 3-5 km Southwest of Saba and 25 km West of St. Eustatius in the Dutch Caribbean (figure 1). With a length of 60-65 km and a width of 30-40 km the total surface area is approximately 2,200 km^2, as measured to the 200-meter isobath.

The Saba Bank is raised about 1000 meter above the general depths of the surrounding sea floor. The bathymetric map (figure 2) shows the surface slopes gradually from the shallower southeastern part to the deeper northwestern part. On the eastern and southeastern edges, where a prominent and actively growing coral ridge of 55 km long runs along the platform, depths vary between 7 and 15 m. On its western rim depths are around 50 m and without actively growing coral reef this rim should be considered a drowned fringing reef. The largest part of the Saba Bank is between 20 and 50 m depth, but a substantial eastern part (approximately 225 km^2) is between 10 and 20 m depth (Macintyre et al. 1975; Van der Land 1977).

The Saba Bank lies completely within the Exclusive Economic Zone of the Netherlands. Part of the Bank is within 12 nautical miles of Saba and falls under their island authority (figure 1). The Saba Bank has been declared a protected area by the Dutch Government on 15 December 2010. The coordinates of the Saba Bank designated protected area are given in table 1. Two applications for an international special status of the Saba Bank are pending: to IMO to request for a Particularly Sensitive Sea Area (PSSA) status and in March 2012 to CBD to request for an Ecological or Biological Significant Area (EBSA) status.

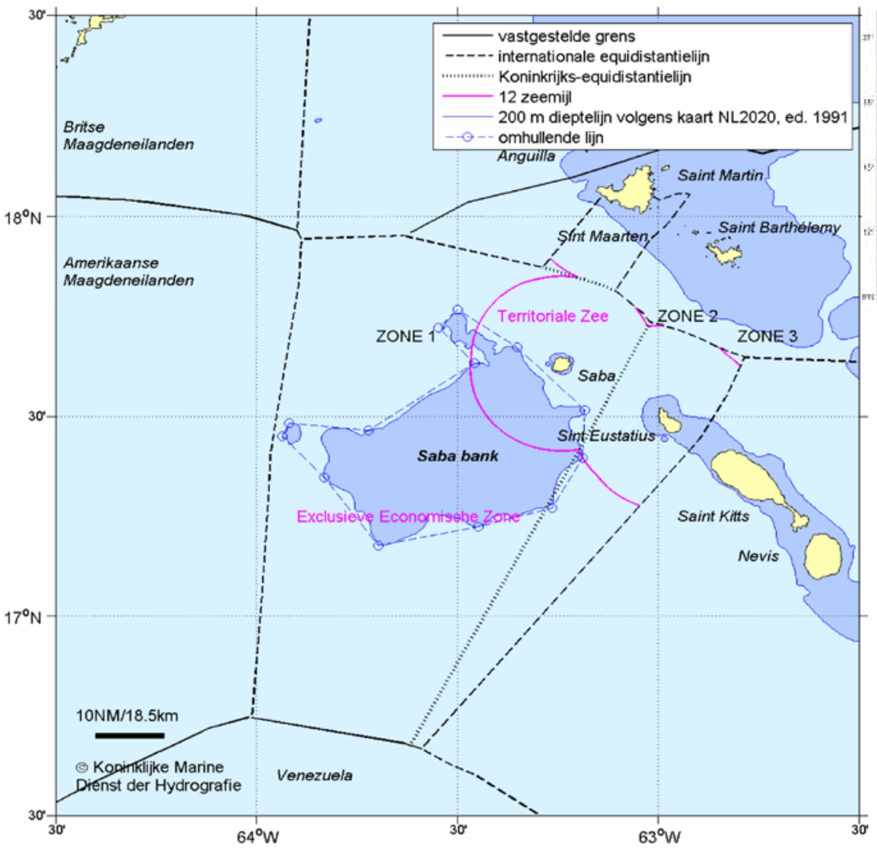

Figure 1. Location and zonation of the Saba Bank, Exclusive Economic Zone and Territorial Sea (Staatscourant 2010 no. 20424)

Latitude	Longitude
17° 27′ 03.4669 N	63° 56′ 08.2227 W
17° 29′ 00.0843 N	63° 55′ 05.1235 W
17° 27′ 56.1354 N	63° 43′ 19.2013 W
17° 38′ 01.5182 N	63° 27′ 24.8261 W
17° 43′ 20.9030 N	63° 32′ 44.2657 W
17° 45′ 58.6584 N	63° 29′ 58.6303 W
17° 40′ 20.5639 N	63° 21′ 06.2309 W
17° 30′ 52.9201 N	63° 10′ 54.9575 W
17° 23′ 47.8041 N	63° 11′ 14.6760 W
17° 16′ 16.0527 N	63° 15′ 50.7350 W
17° 13′ 26.5665 N	63° 26′ 53.2765 W
17° 10′ 33.2692 N	63° 41′ 48.4962 W
17° 20′ 50.9049 N	63° 49′ 53.5713 W

Table 1. Geographical coordinates of the Saba Bank protected area in WGS84 reference coordinate system (Staatscourant 2010 no. 20424). The designated protected area is marked with the dashed blue line in figure 1. Geographical coordinates match the circles on the dashed blue line.

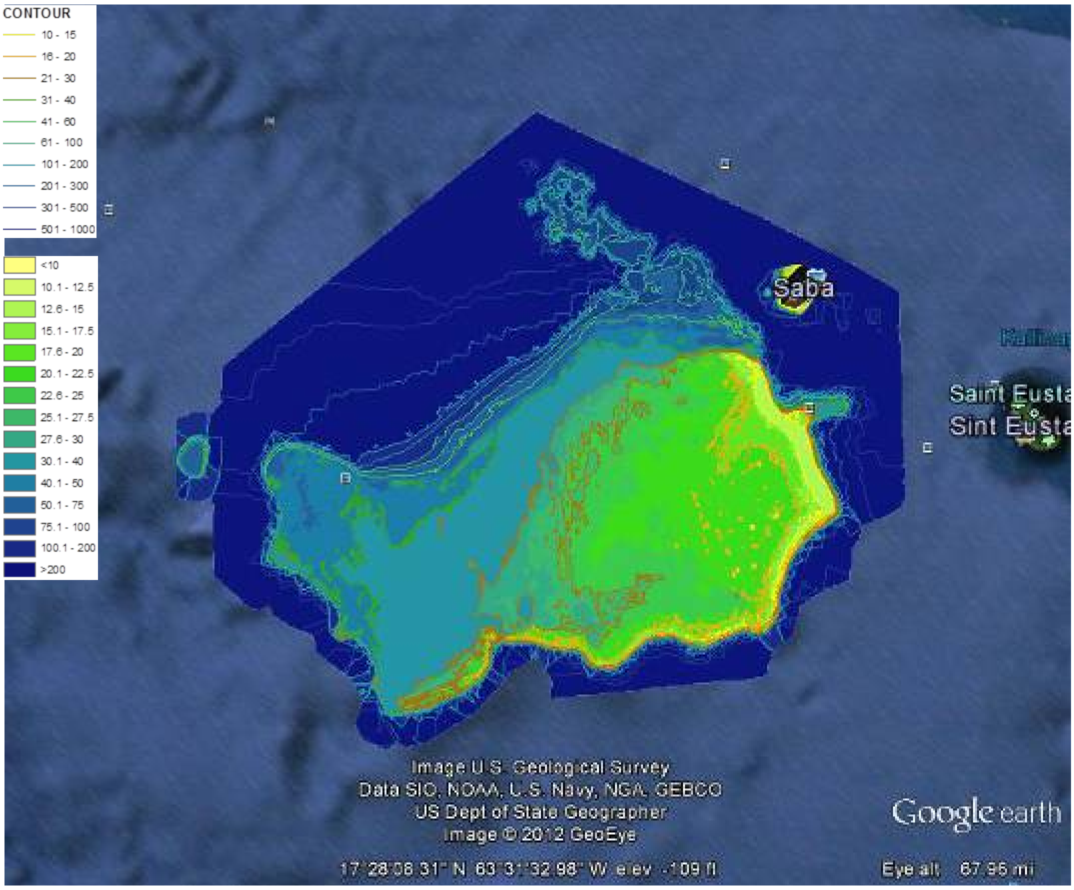

Figure 2. Bathymetry of the Saba Bank with isobath depth contour lines (Netherlands Hydrographic Service)

The main fisheries on the Saba Bank are the spiny lobster (*Panulirus argus*) fishery and the 'redfish' fishery targeting a number of snapper species (*Lutjanus spp.*) The lobster fishery uses traps, made of a rebar frame covered with plastic coated wire mesh of approximately 120 cm long, 120 cm wide and 60 cm high. The redfish fishery uses a variety of methods, including traps since the beginning of 2000, which have a similar design as the lobster traps. Other methods used in the redfish fishery are hand lines, bottom long-lines and snapper reels (Dilrosun 2000; Toller and Lundvall 2008).

In the 1980s and 1990s the fisheries on the Saba Bank was over-exploited by foreign vessels, which resulted in declined catch and a reduction of the Saban fisheries to 4 fishing boats and 8 professional fishermen. When the coast guard of the Netherlands Antilles started to patrol the Bank in 1996, illegal vessels were expelled and the Saban people were encouraged to expand their fishing industry. This resulted in a viable semi-industrial fishery with 14 fishing boats in 2000 of which 12 were based on Saba and 2 on St. Maarten (Dilrosun 2000). In 2007 there were still 12 fishing boats on Saba with a permit to fish at the Saba Bank, although only 10 were operational in the commercial fisheries while 2 were used in recreational fishing (Toller and Lundvall 2008). At present there are 10 permits, but only 9 boats are fishing (M. de Graaf, pers. comm.).

The lobster fisheries is relatively stable in terms of total landings, economic value and fishing methods (Toller and Lundvall 2008) with an annual catch of around 85 metric tonnes (mt). This is based on two fisheries studies: a 12-month fishery assessment running from April 1999 to May 2000 recorded a lobster catch of 89.2 mt with a value of USD 1.1 million (Dilrosun 2000); a 6-month fishery assessment from June to November 2007 estimated the annual lobster landings at 83.6 mt with a value of USD 1.3 million (Toller and Lundvall 2008). The fishing effort measured by the number of boats was stable too, however measured by trap haul rate per trip the fishing effort was 31% higher in 2007 compared to

1999-2000. Based on this increase of 31% the study of Toller and Lundvall (2008) estimated an increase in the number of lobster traps used on the Saba Bank from 1,426 in 1999-2000 to 1,862 traps in 2007.

1.1 Problem definition

According to Dilrosun (2000) during the 1999 hurricane season close to 1000 lobster traps were lost. In addition to bad weather a considerable number of traps are lost every year due to ship traffic. According to the Saban fishermen removal of marker buoys or theft of traps by vandals also occurs regularly (Toller and Lundvall 2008, Paul Hoetjes, pers. comm.). Toller and Lundvall (2008) estimated the annual loss between 210 and 795 lobster traps and between 50 and 193 fish traps. This is based on an estimated trap loss rate (numbers of traps lost per fishing trip) of 0.21-0.80 for lobster traps and 0.16-0.62 for fish traps. Fish traps are more likely to get lost since they lie on ledges on steep drop-off and can easily slide off the slope with the current (Dilrosun 2000). This does not appear from the above-mentioned trap loss rates of Toller and Lundvall (2008), which are slightly lower for fish traps.

Dilrosun (2000) reported that ghost fishing by lost traps had become a concern for both the Saba Island Government and the Central Government of the Netherlands Antilles. Ghost fishing is defined as the ability of fishing gear to continue fishing after all control of that gear is lost by the fisherman (Smolowitz 1978). Trap loss and the potential impact of ghost fishing became a concern for the following reasons. First, traps loss was expected to continue due to the repeated exposure of the Saba Bank to hurricanes (Dilrosun 2000). Second, ghost fishing by lost traps was expected to increase with traps made from long-lasting, corrosion resistant materials that take several years to disintegrate and form an escape opening (Dilrosun 2000). Third, none of the traps used on the Saba Bank were fitted with a biodegradable escape opening in 2000 (Dilrosun 2000). A biodegradable escape opening is a timed-release mechanism designed to release animals caught in a lost trap (Breen 1990), not to be confused with a sublegal escape opening to allow lobsters under the legal minimum size to escape (Smolowitz 1978; Breen 1990). The first forms an escape opening after a certain time thereby reducing the duration of ghost fishing, while the latter has a permanent smaller escape opening.

The regulation that traps are fitted with a biodegradable escape opening, as stated in article 2 of the National Fishery Ordinance (official bulletin 1992, no. 108), was not complied with in 2000, even though the importance was emphasized in various fishery meetings and enforcement by the coast guard was announced in a press release (Dilrosun 2000). Compliance remained low in 2007 according to Toller and Lundvall (2008). At the time of this research in May 2012 biodegradable escape openings were still either not installed or not made of biodegradable material (G. van Laake, pers. comm.), except for one fisherman who reportedly uses biodegradable panels (P. Hoetjes, pers. comm.).

According to Toller and Lundvall (2008) the issue of lost traps and potential ghost fishing continued to be an issue for the Saba Bank fisheries management in 2007 and had been debated without resolution for at least seven years. In their report they state this was due to general disagreement, between scientists and resource managers on the one hand and the fishing industry on the other hand, on the magnitude of impacts caused by lost traps and the efficacy of the biodegradable escape panels as legally mandated management solution. Toller and Lundvall (2008) proposed to address the issue by first getting a better understanding of ghost fishing in the context of the Saba Bank trap fisheries, and second identifying and implementing realistic solutions to reduce ghost fishing by having resource managers work directly with the Saban fishing industry.

The magnitude of impacts caused by lost traps on the Saba Bank is not known, because there is no quantitative information on ghost trap mortality by lost lobster traps on the Saba Bank (Toller and Lundvall 2008). Also the magnitude of trap loss on the Saba Bank is not precisely known, as the estimated loss of 210 to 795 traps per year by Toller and Lundvall (2008) gives a rather wide range. Besides during their 6-month study, trap losses are not reported nor recorded (P. Hoetjes, pers. comm.;

G. van Laake, pers. comm.). Trap loss locations are not known, but information is available based on anecdotal evidence (G. van Laake, pers. comm). To put the issue of the Saba Bank in a broader perspective, a summary of relevant research on lost fishing gear and its potential impacts is given below. Where possible this is put in the context of the Saba Bank trap fisheries.

Ghost fishing by derelict fishing gear refers to the ability of abandoned, lost or otherwise discarded fishing gear (ALDFG) to continue to fish (Macfadyen et al. 2009). Derelict fishing gear is not necessarily ghost fishing and can have a variety of possible impacts other than ghost fishing (Matsuoka et al. 2005). The problem of ghost fishing was first recognized in gillnet fisheries and a major topic of discussion at a FAO meeting in Rome in 1960 (Smolowitz 1978). Ghost fishing in pot or trap fisheries, two terms used interchangeably, became a concern in king crab fisheries in the early 1960s. This concern was based on the evolving trap design from wooden traps to highly durable traps of steel frames covered with synthetic material, slowing down the process of deterioration to the point where fish can escape (Smolowitz 1978).

On a global scale ALDFG is an increasing concern. UNEP and FAO conducted a study (Macfadyen et al. 2009) to raise awareness of the extent of the problem and to give recommendations for international organisations, regional fisheries organisations and flag states to mitigate the problem. The impacts of ALDFG are not only the continued catch of target and non-target species, but also impacts to the benthic environment, navigational hazards, beach debris/litter, introduction of synthetic material into the marine food web and introduction of alien species transported by ALDFG (Macfadyen et al. 2009). In general, gillnets and traps are most likely to ghost fish. Other gear, such as trawls and long lines, are more likely to cause habitat damage and entanglement of marine organisms including endangered and protected species (Macfadyen et al. 2009).

Because the Saba Bank lobster fisheries uses traps, ghost fishing is a potential concern. Navigational hazards and beach litter are unlikely to be a problem, because of the depth of the seafloor (20-50m) and the distance of the Saba Bank to shore (km). Introduction of synthetic material is not considered an issue as the wire traps are not made of synthetics apart from the PVC coating, nor is the introduction of alien species as it concerns a local fisheries.

Scientific evidence of the impacts on target and non-target species and on the benthic environment is lacking quantitative data in the Wider Caribbean according to Macfadyen et al. (2009). For this desk study some studies in this region have been identified, using three literature reviews on ghost fishing (Smolowitz 1978; Breen 1990; Matsuoka et al. 2005) as starting point. General observations are there is no consensus on impacts of ghost fishing and outcomes vary depending on the study design and trap design used. Some studies used outdated traps made of wood instead of metal (Munro 1974; Pecci et al. 1978), while others concern fish traps instead of lobster traps (Munro 1974; Renchen 2011). Also differences in baited and unbaited traps and closed traps or traps with escapes result in different outcomes. Some outcomes were based on infrequent observations (Parrish and Kazama 1992), while other traps were monitored on a daily basis for 6 months (Renchen 2011). Therefore below results need to be interpreted for the Saban lobster trap fisheries with care.

Munro (1974) studied wooden and metal, baited and unbaited fish traps in Jamaica. Steel framed traps captured 22% less fish than wooden traps and baiting a trap temporarily increased the rate of ingress. Furthermore catch escaped with increased soak time with 50% escapement after 14 days and catch stabilised with daily ingress equal to daily escapes. Pecci et al. (1978) did the first quantitative study in Maine, USA with simulated lost, wooden lobster traps and reported 30% escapement of American lobster (*Homarus americanus*) and 25% mortality. According to Parrish and Kazama (1992) this was due to the conventional wooden trap design. Parrish and Kazama (1992) studied retention of the Hawaiian spiny lobster (*Panulirus marginatus*) and slipper lobster (*Scyllarides squammosus*), which were entrapped on purpose in simulated lost, unbaited traps. Numerous escapes as well as entries and little in-trap mortality

were observed, so the conclusion was unbaited traps are short-term artificial shelter (Parrish and Kazama 1992). A comprehensive experimental *in-situ* study in the Caribbean on biological and physical impacts by derelict fish traps was carried out in 2010 in the U.S. Virgin Islands (Renchen 2011). This study revealed that ghost fishing mortality is 5%, while 95% of the fish escaped. Experiments were done in closed traps and traps with an opening, whereby all mortalities except one occurred in the closed traps. Of all fish, 5% got skin wounds or abrasions. The fish traps used in the experiment had a similar design as Saban lobster traps, except for a slightly bigger mesh width of 2 inch.
Summarizing, ghost fishing efficiency depends on the design and state of the gear, species behaviour and seasonality. Not all lost traps become ghost traps due to destruction of traps by storms (Breen 1990), although steel traps are stronger and have a longer ghost fishing lifespan. Catching efficiency of traps depends to a large extent to the bait and declines when bait has been eaten or degraded (IEEP 2005; Macfadyen et al. 2009). However, ghost fishing goes through cycles of autorebaiting or rebaiting by other species, when scavengers attracted by the bait become entrapped and die, becoming new bait for other scavengers (IEEP 2005). Ghost fishing also occurs in unbaited traps, by attraction by conspecifics or by the trap alone for example for shelter (Breen 1990). The trap may kill through starvation, cannibalism and predation. Certain species may repel conspecifics and prevent or reduce ghost fishing this way (Breen 1990). A distinction should be made between permanent entrapment and temporary occupation of a trap for feeding or shelter (Parrish and Kazama 1992). Several studies indicate that catch rates decline with increasing soak time due to escapes after the bait has gone, although ghost fishing may occur on the long term despite short-term escapes (Breen 1990). Bio-degradable escape mechanisms built in traps limit ghost fishing due to higher escapements.

The physical impact on the benthos depends on the type of habitat and the occurrence of these habitats relative to the distribution of traps. Sea grass beds and coral reef habitats are more sensitive to lobster traps compared to sand and mud-bottom habitats (Macfadyen et al. 2009). The effect depends on frequency and intensity of physical contact, hence actively fishing traps with more frequent trap deployments may have more impact than lost traps (Jennings and Kaiser, 1998 in Macfadyen et al. 2009). The smothering effect might be more for lost traps (Guillory, 2001 in Macfadyen et al. 2009). Lost traps can also have a positive effect on the benthos, because they may function as artificial reefs or nursery habitats for juveniles, especially in areas with low structural complexity (Renchen 2011).
According to a marine debris study in the Florida keys (Chiappone et al. 2002) 49 percent of all marine debris, mostly originating from hook-and-line fishing gear (55%) and lobster traps (35%), caused mortality, tissue abrasion or other damage to sessile benthos. Effected benthos consisted of gorgonians (37%), sponges (28%), fire coral (19%), scleractinian or stony corals (9%) and colonial zoanthids (8%). Debris causing the greatest damage were hook-and-line gear (68%) and lobster traps (26%), especially lobster trap ropes (21%). Lobster traps and ropes caused most damage to stony corals (64% of the above 9%) and less damage to sponges (29% of the above 28%) and to gorgonians (22% of the above 37%). Injuries to stony corals, octocorals and sponges can occur from wind-driven trap movement due to hurricanes and lesser wind events (Lewis et al. 2009). Hydrological factors (tides and currents) at the specific location are also of influence. Locations susceptible to strong currents damage the benthic environment most.

A variety of measures are in place to reduce ALDFG, which are either preventive - *ex-ante* – or curative - *ex-post (Macfadyen et al. 2009)*. This desk study looked into a curative measure to locate and retrieve lost lobster traps on the Saba Bank.

1.2 Research question and objectives

This research has been commissioned by the Dutch Ministry of Economic Affairs, Agriculture and Innovation (EL&I). The research question posed by EL&I was to:

Investigate what is the best, most efficient method to locate lost lobster traps in order to retrieve them, using a small vessel (approximately 11 meter).

The objective is to provide information to resource managers and the fishing industry for the sustainable management of the lobster fisheries and the conservation of the Saba Bank.

Figure 3. The vessel that is available for lobster trap detection at the Saba Bank, the “Queen Beatrix” (H. Verdaat, 2012)

1.3 Scope

This research explored methods to locate and retrieve lost traps. It gives a general introduction of the Saba Bank lobster trap fisheries and the magnitude and causes of trap loss on the Saba Bank. It does not study the impacts of ghost fishing on target and non-target species and on the benthic environment at the Saba Bank. Only in the introduction reviews and studies on these impacts outside the Saba Bank are briefly addressed.
Although the research question concerns the lobster trap fishery on the shallow part of the Saba Bank, this report also provides some information on the redfish trap fisheries located in deep water at the edge of the Saba Bank. The main differences between lobster and redfish trap fisheries are addressed, to ensure the selected detection method and survey area are first of all appropriate to locate lobster traps. Redfish traps may be located and retrieved if they are within an accessible depth range.

1.4 Acknowledgements

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2 Methods

In this desk study reports and publications on the Saba Bank fisheries were used to describe the lobster and fish trap fisheries. Because the most recent fisheries report dates back to 2008, this was completed with information on current practices in the trap fisheries. Information was collected from the park ranger at the Saba Marine Park and the EL&I policy coordinator nature of the National Office for the Caribbean Netherlands, using standard questionnaires.
Reports from various international and intergovernmental organizations were analysed to get an overview of applied methods in ghost trap detection and to get selection criteria to choose the best detection method for the Saba Bank. Best practices of other trap fisheries in the region were consulted, using the NOAA workshop report on derelict trap detection (NOAA 2009). After selecting a short-list of detection methods, expert interviews with two suppliers of detection equipment in the Netherland were held, to investigate operational use and limitations of the short-listed detection methods. Based on all of the above, recommendations were made for the best, most efficient method to locate and retrieve lost traps.

3 Results

This chapter starts with a detailed description of lobster and redfish trap design, fishing grounds and fishing methods as well as information on trap loss. This answers the question what to detect and where to detect it. How to detect lobster traps is answered in the following chapters. Chapter 3.2 gives an overview of available detection methods and the selection criteria applied to advise side scan sonar in combination with magnetometer as the best, most efficient method. In chapter 3.3 other considerations in derelict trap detection are addressed.

3.1 Description lobster and 'redfish' trap fisheries

Traps are the primary gear used by professional Saban fishermen on the Saba Bank. Traps target two different fish stocks: lobster and 'redfish'. Lobster traps target the Caribbean spiny lobster (*Panulirus argus),* but capture also mixed reef fish such as grunts, groupers and triggerfish. Redfish traps target a number of snapper species or 'redfish', particularly silk snapper (*Lutjanus vivanus),* blackfin snapper (*L. buccanella)* and vermilion snapper (*Rhomboplites aurorubens)* (Toller and Lundvall 2008). The differences in fishing gear and methods are sufficiently large, and catch characteristics sufficiently distinctive, to consider lobster and redfish two different types of fisheries (Toller and Lundvall 2008). Besides the different target catch, the main difference is the location where traps are set. The lobster trap fishery is concentrated on the shallow part, while the redfish trap fishery is located in deep water at the edges of the Saba Bank. Because the research question concerns lobster trap detection only, the redfish trap fishery will not be discussed in detail. Only those differences between lobster and redfish fishing gear and fishing grounds are described, which are relevant to ensure fish traps are not mistakenly identified as lobster trap nor included in the survey area.

3.1.1 Fishing gear

Lobster traps (figure 4) and fish traps (figure 5) are made from a welded iron rebar frame covered with a wire mesh with a funnel entrance. Lobster traps and fish traps are similar in design and size. The length of a lobster trap is either 3, 4, or 5 feet (90, 120, or 150 cm), the 4 feet trap being preferred by most Saban fishermen. The width of a lobster trap is 3 or 4 feet (90 or 120 cm) and the height is 45 or 60 cm. The funnel entrance is 22.5 cm wide and 20 cm high. The funnel has a parabolic shape and has a total length of 125 cm (Dilrosun 2000).

Figure 4. Lobster trap (P. Hoetjes, 2012)

Figure 5. Fish trap (P. Hoetjes, 2012)

The main difference between a lobster trap and a fish trap is the funnel entrance and the mesh material. The funnel opening of a fish trap is much narrower than the funnel opening of a lobster trap. Fish traps used to be constructed from uncoated chicken wire, while for the lobster traps plastic coated wire mesh is used. The colour of the plastic coating is either black or green. Most lobster traps have a mesh width of 1,5 inch (3.8 cm), the minimum size as required by law. An anode is attached to the wire mesh in order to slow down corrosion. As long as the anodes are changed regularly a lobster trap can last at least 5 years (Dilrosun 2000). Some traps are fitted with the obligatory biodegradable escape panel (G. van Laake, pers. comm., P. Hoetjes, pers. comm.).

3.1.2 Fishing grounds

Lobster traps are set on the Saba Bank between 11-50 meter depth. Fish traps are set on the drop-off at the edges of the Saba Bank between 70-180 meter depth (Dilrosun 2000) and may exceed 245 meter depth (Toller and Lundvall 2008). It is therefore easy to exclude fish traps from the survey area, as fish traps are located in distinctly different area (figure 6).
Suitable lobster fishing grounds cover an area of 1,850 km^2, based on the 50 meter isobath (Toller and Lundvall 2008). According to the Saban fishermen, commercial exploitation of spiny lobsters began on the North-Northwestern of part of the Saba Bank, the area closest to Saba, but presently lobster traps are set all over the Saba Bank (Dilrosun 2000). Figure 5 and 6 show lobster trap locations in 1999 and 2007, with highest concentrations still in the Northeastern and Northwestern part.

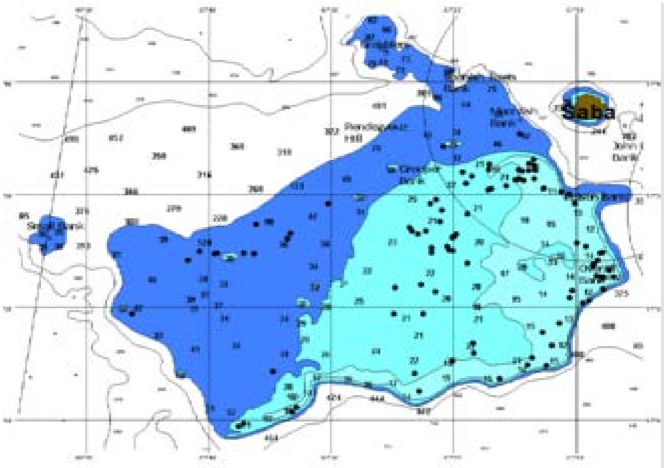

Figure 6. Lobster trap locations in ***1999-2000*** *(Dilrosun 2000)*

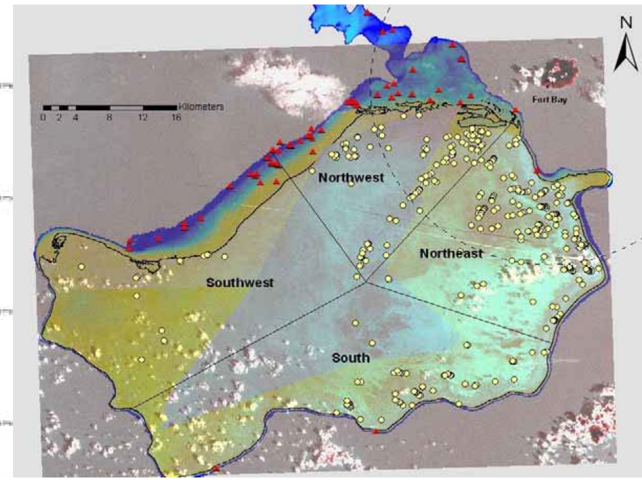

Figure 7. Lobster trap (yellow circles) and fish trap (red triangles) locations in ***2007*** *(Toller and Lundvall 2008)*

3.1.3 Fishing method

Fishing boats are equipped with a hydraulic winch and davit for hauling traps, a Global Positioning System and a deep water echo sounder (Toller and Lundvall 2008). Each fishing boat has between 100-300 lobster traps. All traps are marked by a buoy that is attached to the trap. The fishing or soak time, the time gear remains in the water, for a lobster trap is commonly 7 days. In general the effectiveness of a lobster trap does not improve after 5-12 days in the water (Dilrosun 2000). The lobsters are harvested and transported alive and kept in holding cages (traps without funnels) in the harbour of Saba until they are sold (Toller and Lundvall 2008).
Lobster traps are baited with pieces of cow skin. Lobster traps catch a variety of non-target reef fish and invertebrates that are discarded at sea as by-catch or used for other purposes. This can be as bait for the traps, as feed for the lobsters in the holding pots, as food for personal consumption by the fishermen or for sale (Toller and Lundvall 2008). The bycatch is largely unquantified, except for some landing data.

White grunt, queen triggerfish and red hind account for three quarter of the landings (Toller and Lundvall 2008) and are preferred to be landed and sold (Dilrosun 2000). Invertebrates account for less than 1% of the landings and include slipper lobster, common octopus, spider crab and batwing coral crab, used for personal consumption or for sale (Toller and Lundvall 2008). Species used as feed in holding cages are the small or inedible species (Toller and Lundvall 2008) and species used as bait in lobster traps are nurse shark, parrotfish, jack, surgeonfish, cowfish, angelfish and coney (Dilrosun 2000). Nurse sharks are a common bycatch and a nuisance to fishermen as they consume catch and bait and damage traps. They are either moved, killed or retained for personal consumption (Toller and Lundvall 2008).

3.1.4 Trap losses

The precise magnitude and locations of lobster and fish trap losses are not known, because there is no central reporting and registration system in place. The only quantification of lost traps was done in the two Saba Bank fisheries studies. Dilrosun (2000) reported loss of close to 1000 lobster traps during the 1999 hurricane season. Toller and Lundvall (2008) estimated the annual lobster trap loss to be between 210 and 795 traps per year, based on an estimated trap loss rate (number of traps lost per trip) of between 0.21 and 0.80. The maximum estimate was based on reported trap loss, but due to inconsistencies in interpreting the fishermen's reports, a minimum estimate was added. This conservative estimate is comparable with finding of other studies. Studies on blue crab trap fisheries in Chesapeake Bay, USA (NOAA 2009) and Virginia, USA (Havens et al. 2008 in Clark et al. 2012) estimated trap loss at 20% and 30% respectively and estimated loss in the trap fisheries in Florida is between 10% and 20% (Lewis et al. 2009). A recent study on fish and lobster trap fisheries in the U.S. Virgin Islands (Clark et al. 2012) estimated trap loss at 8% to 10%, with most loss occurring at depths ranging between 20 and 40 meter and lobster trap loss being correlated with effort.

Table 2. Estimation of the number of intact lost lobster traps at the Saba Bank that still have the potential to ghost fish and are more difficult to detect if they lost their distinct shape.

Lost lobster traps Saba Bank	**Annual trap loss [1]**	**Lifespan trap [2]**	**Total lost traps [3]**
Minimum (conservative) estimate	210	1 year	210
Maximum (reported) estimate	795	3 years	2385

[1] (Toller and Lundvall 2008)
[2] Lifespan of traps to continue to fish according to various studies in the review of Matsuoka et al. (2005)
[3] For calculation example of the maximum estimate of 2385 traps refer to table 3

Table 3. Estimation of the total number of intact lost traps. This stabilizes at 2385 traps (a) after 3 years if estimated trap degradation occurs at once and (b) after 19 years if estimated trap degradation occurs at a rate of 1:3 years=0.33

(a) Trap degradation all at once	**Year 1**	**Year 2**	**Year 3**	**Year 4**		
Traps at the start of year	0	795	1590	2385		
New lost traps during the year	+795	+795	+795	+795		
Degradation trap after 3 years	-0	-0	-0	-795		
Total lost traps at the end	795	1590	**2385**	**2385**		
(b) Gradual trap degradation rate	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5-18**	**Year 19**
Traps at the start of year	0	795	1325	1678	...	2384
New lost traps during the year	+795	+795	+795	+795	+795	+795
Trap degradation=0.33 x traps at start year		-262	-438	-556	...	-794
Total lost traps at the end	795	1325	1678	1914	...	**2385**

The trap degradation rate needs to be considered to estimate how many of the lost traps are still intact (table 2). This is important as degraded traps do not have the potential impact to ghost fish and are more difficult to detect if they have lost their distinct shape. As long as anodes are changed regularly a lobster trap can last at least 5 years (Dilrosun 2000), so the maximum lifespan is 5 years. The lifespan to continue fishing is shorter and estimated to be between 1 and 3 years (table 3). In the review of ghost fishing by Matsuoka et al. (2005) some studies mention lost traps can continue fishing for 1 or more

years with a declining efficiency, while other studies indicate shallow water traps continue ghost fishing as long as 3 years or even more in deep water where traps are less damaged by waves. Some lost traps never become ghost traps if they were damaged immediately when they got lost or destructed by storms (Breen 1990). Based on the estimated trap loss ranging from 210 to 795 traps and the estimated lifespan ranging from 1 to 3 years, it is expected there are between 210 and 2385 lost traps on the Saba Bank that have a potential to ghost fish (table 3).
Given the large size of the lobster fishing grounds it is important to know the locations of trap loss to identify a smaller area for the detection survey. If no accurate information on locations of trap loss is available, the use of modelling techniques, local knowledge and anecdotal information to identify potential hotspots is essential in order to better target the survey (Macfadyen et al. 2009). There is anecdotal information on individual locations and concentrations of lost traps (G. van Laake, pers. comm.). Prior to starting a detection survey this information should be gathered by means of interviews on gear lost, date, depth, coordinates and reason for loss.

3.2 Selection of detection methods

A variety of trap detection methods are available, which are side scan sonar, multibeam sonar, side imaging, video, surface visual, aerial visual, diver tow (NOAA, 2009), diver survey and magnetometry (H. de Vries, pers. comm.). Not all of these detection methods are applicable for the Saba Bank. Selection criteria for the best, most efficient method have been collected. Based on this a shortlist of three detection methods has been made, which are side scan sonar, multibeam sonar and magnetometry. A description of the target and survey environment characteristics is given in chapter 3.2.1. Based on these characteristics and the selection criteria listed in chapter 3.2.2 the choice for side scan sonar is justified. Chapter 3.3.3 describes side scan sonar and magnetometry as other method to support side scan sonar and make detection more efficient. Chapter 3.4 discusses other considerations in trap detection, such as methods for retrieval, preventive measures, costs and benefits.

3.2.1 Target and survey environment characteristics

The selection of the best detection method can be divided in two steps: step one to select the technology and step two to select the survey protocol (NOAA 2009). Technology refers to the technical equipment required to detect the traps given the target and survey environment characteristics. The survey protocol refers to the appropriate survey depth or elevation above the seafloor, survey range and frequency and survey vessel speed given the survey environment characteristics. In order to select the technology and survey protocol, the following questions as formulated in the NOAA workshop on derelict trap detection (2009) were answered, to describe target and survey environment characteristics.

Step one: selection of technology

- *How large is the area of study?*
  The potential lobster fishing grounds are 1,850 km^2. The maps of lobster trap positions (figure 5 and 6) show the actual fishing grounds are more concentrated and smaller, so the study area can be considerably reduced. If anecdotal evidence on individual locations and concentrations of lost traps is collected, the study area can be further reduced. On the other hand storm-induced currents may move traps from their original position, which increases the study area. Because the study area is large the swath coverage or area width of the detection method should be as large as possible and the vessel speed should be as high as possible.
- *What level of target detail is required?*
  The target objects have a distinct, rectangular shape of approximately 1 m^2. The detection method should be able to recognize this distinct shape amidst the surrounding environment of sediment, rubble and (patch) reef.

- *What data is required from processing of survey results?*

  Since the objective is only the quantification of lost traps, the detection method should provide data on trap location only. If the quantification of ghost catch rates would have been included in the objective, the detection method should also provide data on entrapped species.

Step two: selection of survey protocol

- *What is the depth of the water to be surveyed?*

  Lobster traps are set at 11-50 meter depth or even deeper. Traps may move to deeper area by storm-induced currents.

- *What is the expected size of the smallest object necessary to be discovered?*

  Traps have an approximate size of 1 m^2. The maximum resolution of the detection method should therefore be 1 m^2.

- *What is the bottom topography?*

  The surface of the Saba Bank almost completely consists of carbonate rock and carbonaceous sediments. Geologists believe that a composite volcanic island is buried under these more recent formations. There are no volcanic rocks, just some black sand of volcanic origin on the southwestern part (Van der Land 1977). The bottom classification map in appendix A shows that the substrate of the Saba Bank largely consists of bedrock, pavement, sediment, rubble, patch reef or combinations thereof and of algal and coral reefs at the edges of the Saba Bank. This classification has not been groundtruthed, however a small area has been studied in detail by Toller, Debrot et al. (2010). In this study they distinguished different zones and habitat types (figure 7) for which they quantified depth, substrate (percentage hard bottom, rubble and sand), vertical relief, rugosity and slope. Within the study area the bottom rise and fall is negligible at most parts with slopes <1% in the lagoon zone and on the reef flat and small on fore reefs with slopes between 5-10%. Vertical relief is a measure for structural complexity and a good indicator if there are obstructions that make detection of lost traps difficult. Vertical relief was < 0.5 meter in the lagoon zone, 0.5-1 meter at the reef flat and either 0.5-1 meter or >1 meter at the fore reef (Toller et al. 2010).

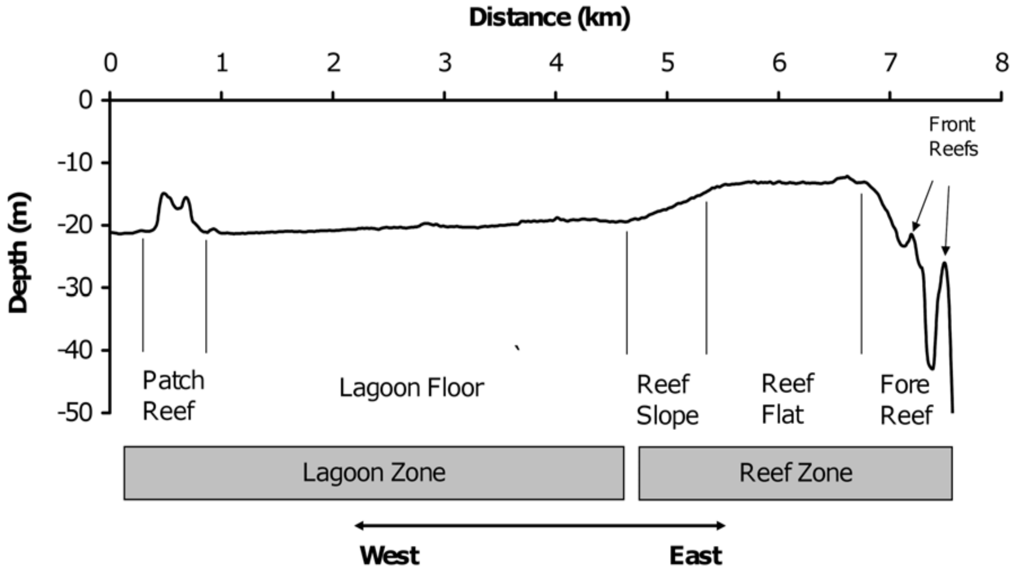

Figure 8. Depth profile of the study area at the edge of the Saba Bank (as marked on the map in Appendix A) and names of habitat types and zones used by Van der Land (1977) (Toller et al. 2010)

The ridges on the Saba Bank must be considered reefs. They are characterized by a quite irregular surface, very steep slopes and sharp summits. All channels between the reefs lie at the same level as the adjoining lagoon floor. In the lagoon there are large area of calcareous bedrock (Van der Land 1974).

Lobster traps are mainly set on flat surfaces with substrate composed of hard bottom pavement, rubble or sediment with or without patch reefs (Appendix A). For the choice of the detection method this implies there are no major obstructions to be expected which can cause acoustic shadowing, not from large rocky boulders and sea mounts nor from large coral reef structures with vertical relief > 1 meter.

- *What is the bottom habitat?*

  The main habitat types used in the study of Toller, Debrot et al. (2010) where hard bottom lagoon (pavement and rubble), soft bottom lagoon (sand and rubble), fore reef (hard bottom with high coral cover), outer reef flat (hard bottom with low coral cover and large rubble fragments) and inner reef flat (hard bottom with very low coral cover and rubble). For pictures of the different habitat types is referred to appendix B. Macroalgae were the dominant benthic group in all habitat types (roughly 30-50%), but the height of this aquatic vegetation is not larger than the trap height of 45 to 60 cm. Gorgonian height may exceed trap height, but only areas with high gorgonians and very high density may cover traps and obstruct trap detection. At the fore reef gorgonian density was medium to high with heights ranging from 0.25-1 meter to over 1 meter. At the outer reef flat gorgonians were moderately abundant and 0.25-1 meter high (Toller et al. 2010). Based on these observations it is not expected that traps are covered and hidden by benthos.

- *What is the degree of accuracy required for geo-referenced positions of traps?*

  Accuracy must be high, because the retrieval of traps relies entirely on the recorded GPS position of the traps.

3.2.2 Selection criteria for detection methods

In the NOAA workshop report on submerged derelict trap detection methods (2009) an overview is provided of detection methods and selection criteria. These selection criteria are based on characteristics of the survey environment, such as water depth, bottom composition and structure. Table 4 presents different survey protocol variables to consider in the selection and table 5 presents detection system applicability in different survey environments.

Table 4. Detection methods and their different survey protocols (NOAA 2009). Green highlights which criteria are considered important for the Saba Bank and which detection method is compliant with a (relevant) criterion and red highlights which shortlisted detection method is not meeting a (relevant) criterion.

Detection method	Survey protocol				
	Water Depth	**Elevation above sea floor**	**Frequency**	**Swath Coverage Area Width**	**Speed**
Side Scan Sonar	2 – 600 m	10% of range of sonar	300 – 600 kHz	20 – 50 m	4 – 5 kts
Side Imaging	1 – 10 m	n/a – hull mount	455 kHz	20 – 25 m	4 – 5 kts
Multibeam Sonar	> 2 frequency dependent	n/a – hull mount	240 – 455 kHz	3.5 x elevation	4 – 5 kts
Diver Tow	2 – 15 m	Topography dependant	n/a	Visibility dependant	4 – 5 kts
Video	2 – 6000 m	Visibility dependant	n/a	Visibility dependant	< 1 kts
Surface Visual	Location dependent	Visibility dependant	n/a	Visibility dependant	< 1 kts
Aerial Visual	0 m	n/a	n/a	Visibility dependant	85 – 110 kts

Table 5. Detection methods and their applicability in different survey environments (NOAA 2009). Green highlights which criteria are considered relevant for the Saba Bank and which shortlisted detection method is compliant with a criterion and red highlights which shortlisted detection method is not meeting a criterion. SAV is the acronym for Submerged Aquatic Vegetation

Detection method	Survey environment								
	Flat bottom	**Sandy / Muddy**	**Rocky < Pebbles**	**Rocky > Boulders**	**Sea mounts**	**High relief bottom**	**SAV> trap height**	**SAV< trap height**	**High turbidity**
Side Scan Sonar	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes
Side Imaging	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Multibeam Sonar	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Diver Tow	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Video	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No
Surface Visual	Yes	Yes	Yes	Yes	No	No	No	Yes	No
Aerial Visual	Yes	Yes	Yes	No	Yes	No	No	Yes	No

Based on the above selection criteria and the description of the survey environment characteristics in the previous chapter a shortlist of three detection methods was identified. The most important characteristics of the Saba Bank and the lobster trap fisheries that determine the effectiveness of the detection method are the water depth at and the large size of the fishing grounds. Therefore water depth has been used as first selection criterion and swath coverage as second selection criterion. Based on this side scan sonar and multibeam sonar were identified as the best detection method as explained below.

Water depth limitations (first highlighted column in table 4) make only three detection methods suitable for the Saba Bank: side scan sonar, multibeam sonar and video (ROV or tow). Most lobster fishing grounds are at water depths ranging from 11-50 meter, which excludes side imaging, diver tow, surface and areal visual.

Swath coverage is another important selection criterion given the large survey area (second highlighted column in table 4) with the most efficient detection method having the largest swath coverage. Swath coverage is twice the range of the detection device, the range to port plus the range to starboard. Range refers to the distance from the detection device to the outer edge of the recorded data. Swath coverage is related to the frequency of the sonar, so the higher the frequency of the sonar the higher the resolution of the recorded data and the smaller the range.
Based on swath coverage side scan sonar and multibeam sonar qualify as the best detection methods. Side scan sonar surveys detecting traps or pots typically use 600 kHz sonar to detect one meter target objects and have a 50 meter range (NOAA 2009; Fenn 2012) meaning a 100 meter swath. Multibeam sonar has a variable range depending on the elevation, which would be 3.5 times 11 meter is 35 meter swath at the shallower sites and 3.5 times 50 meter is 175 meter swath at deeper sites. Video has a variable range depending on the visibility which is generally not more than 20 meter. Therefor it is considered not suitable for the large area of the fishing grounds on the Saba Bank.

Side scan sonar and multibeam sonar both meet all criteria related to the survey environment (table 5) that are relevant for the Saba Bank. Multibeam sonar has the advantage that it can also be applied in the presence of seamounts, which is not relevant for the Saba Bank. Both side scan sonar and multibeam sonar are not able to detect traps in a survey environment with rocky boulders causing acoustic shadowing and aquatic vegetation higher than the trap height covering the trap. Both criteria are not a concern on the Saba Bank, as the substrate does not contain rocky boulders nor algae of that height. Only large coral structures can cause comparable acoustic shadowing as boulders do and dense and high gorgonians can cover traps. However, coral cover with vertical relief >1 meter and dense gorgonians > 1 meter only occur at fore reef habitats (Toller et al. 2010) which are located at the edge of the lobster fishing grounds. So there may be an issue with traps at the edge of the lobster fishing grounds, reason why magnetometry is added to the shortlisted detection methods.

Magnetometer and diver survey are not listed in the NOAA tables (tables 4 and 5). Magnetometer is included in the shortlist, because based on expert advice (H. de Vries, pers. comm.) it can complement and overcome the above-mentioned shortcomings of sonar detection. This is discussed in more detail in the next chapter. Diver survey is excluded because of the water depth where lobster traps are placed and limited diver bottom time at these depths (approximately 15 minutes at 30 meter) and a maximum depth limitation of 40 meter for recreational diving. Diving beyond this depth limit and with longer bottom time requires technical diver skills and equipment. Another limitation of diver survey is the small area that can be covered.

3.2.3 Shortlisted detection methods

Multibeam sonar

A multibeam sonar or multibeam echosounder is a device that transmits acoustic pulses from the ocean surface and listens for their reflection (or echo) from the seafloor. Multibeam sonar is typically used by hydrographic surveys to determine the water depth and the nature of the seabed. Other survey applications include search and locate, route survey, habitat mapping, and seafloor characterization (DeKeyzer et al. 2002).

Differences with side scan sonar are that the multibeam sonar is attached to the hull of the vessel instead of towed in the water column. The resulting imagery is not as sharp as the imagery from a towed side scan sonar (DeKeyzer et al. 2002). The multibeam provides a 3D scan which shows depth as third dimension, while the side scan is a 2D scan that produces a flat image that does show elevated objects on the seafloor (figure 9), but does not show relief and depth relative to the surroundings. With side scan sonar data viewing can be done as the data are being collected (Fenn 2012), so it is theoretically possible to combine location and retrieval in one boat trip. With multibeam sonar data analysis is more complex and time consuming. Furthermore multibeam sonar is much more expensive than side scan sonar, because the equipment is roughly ten times more expensive than an Imagenex Sportscan of approximately EUR 20.000 (K. Kersting, pers. comm.) and more acoustic pulses are transmitted which requires more data storage and data processing time (H. de Vries, pers. comm.). Because of all of the above, multibeam sonar has too many limitations compared to side scan sonar to be selected as the best, most efficient detection method for lost trap detection.

Side scan sonar

Side scan sonar also transmits acoustic energy (sound) from two transducers on the so-called towfish, a torpedo shaped device that is submerged. The acoustic energy that travels through the water reflects off the seafloor or items on the seafloor and returns to the transducers. The sonar data received at the towfish is sent up the tow cable into a Central Processing Unit (CPU) or data acquisition system, which enables viewing of the sonar data as it is being collected (Fenn 2012).

According to the report of NOAA (NOAA 2009) side scan sonar provides a cost effective means to survey a large area and detecting, accurately identifying and locating lost traps. The report also provides examples of crab trap detection with side scan sonar in Maine and Chesapeake Bay, USA. Traps can be easily detected with side scan sonar, because of their distinct shape (figure 9) and the steel frame that gives a strong signal compared to the surrounding environment. A recent report (Clark et al. 2012) experimentally evaluated fish trap detection efficiency of side scan sonar in a coral reef ecosystem with a variety of habitats (seagrass, sand and reef) in the U.S. Virgin Islands, which was not studied before. Their test survey with 50 traps revealed that detection on sandy and rhodolith (crustose benthic red algae) substrates was highly successful with a detection rate of 90% to 100%, while the detection rate at patch reefs and aggregated reefs (fore reefs) was considerably lower at 50% to 66% due to high vertical relief. The study did not quantify vertical relief, so it is difficult to compare their results to the topography of the Saba Bank, with vertical relief of 0.5-1 meter at the reef flat and either 0.5-1 meter or >1 meter at the fore reef (Toller et al. 2010). Furthermore their fish traps are slightly smaller in size (0.83x0.63x0.45m) than those on the Saba Bank (chapter 3.1.1) and lobster traps on the Saba Bank are generally set on flat surfaces with sandy or rubble substrates with or without patch reefs (chapter 3.2.1).

Side scan sonar can be employed from a small boat (10 meter) or can be incorporated in an Autonomous Underwater Vehicle (AUV). Other materials required for the side scan sonar system apart from a boat with GPS antenna are a handling system made up of towfish, tow cable, winch, deck cable, string block and davit and a data acquisition system (CPU) including software to analyse the data. The towfish is a weighted hydrodynamic torpedo-shaped towed vehicle that houses, protects and provides a stable platform for the transducers. There are different types, such as heavy towfish suitable for deep water and neutrally buoyant towfish suitable for rough water (Fenn 2012).

Before starting the field operation a survey protocol needs to be prepared with survey track lines, range setting, elevation setting, adjustment gain or attenuation to produce the desired images and georeferencing of the sonar (Fenn 2012):

- Range setting mainly depends on the target characteristics and the frequency of the sonar. The higher the frequency the better the resolution, but the smaller the range and swath. The 1 m^2 trap requires a resolution of at least 1 m^2 for which a 600 kHz sonar is commonly used with a 100 meter swath coverage (NOAA 2009; Fenn 2012).
- Survey track lines must overlap slightly with 10-20% overlap (H. de Vries, pers. comm.), which reduces the effective swath coverage. To increase the detection probability of traps hidden between two obstacles it is advised to also run track lines perpendicular to the initial track lines (H. de Vries, pers. comm.).
- Elevation setting of the towfish above the seafloor is 10% of the range of the sonar, which would be 5 meter above the seafloor when the range is 50 meter. It is important to use a single beam echo sounder to detect changes in the depth of the seabed and in large obstacles higher than 5 meter, if applicable. The boat available for lobster trap detection (figure 3) will be equipped with such an echo sounder.
- Georeferencing of sonar data to be able to locate the lost traps with is done by determining the position (layback and offset) of the towfish in relationship to the GPS antenna on the boat. In water deeper than 30 meter layback and offset data are calculated by acoustically tracking the towfish. In shallow water =< 30 meters a simple calculation can be used (figure 10). If vessel speed or cable length changes than layback changes too.

The survey protocol should prioritize areas with highest fishing effort based on historical fishing effort data (Fenn 2012). Assuming a 100 m swath coverage with 20% overlap and a 4 knots (rounded down to 7 km/hr) vessel speed it is possible to cover an area of approximately 2.8 km^2 in an on average 5-hour survey day, excluding a travel time to and from the harbour on Saba to the survey site of 1 up to 4 hours (5hr x 7 km x 0.08km (100-20m) = 2.8 km^2). Because of the large area of 1,850 km^2 it will take almost two years (1,850 km^2 / 2.8 km^2 / 365 dy = 1.8 yr) to survey the entire lobster fishing grounds!

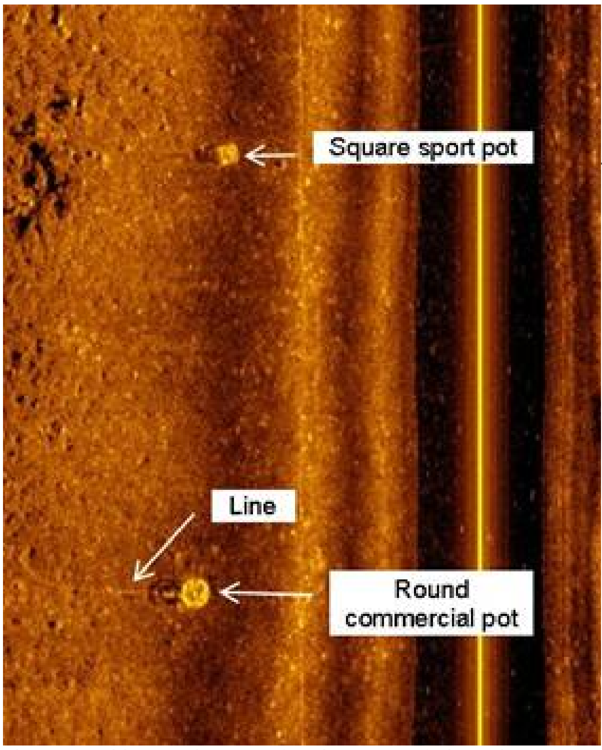

Figure 9. Side scan images of crab pots, a 2ft (0.6m) square pot and a 3 ft (0.9m) round pot on silt/mud substrate (Fenn 2012)

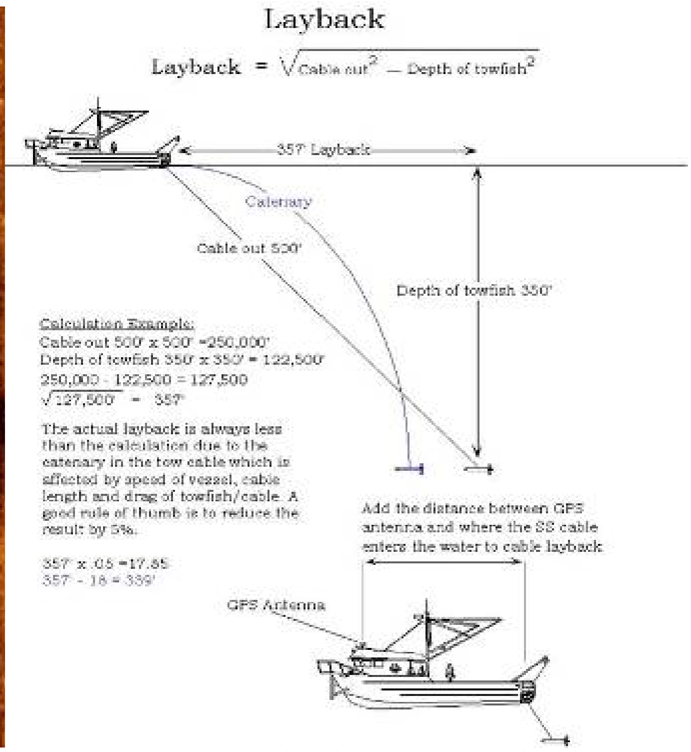

Figure 10. Layback calculation for georeferencing of the sonar in the towfish (Fenn 2012)

Other limitations of side scan sonar and suggestions how to overcome them are the following:

- Traps can be difficult to detect if they are (partially) buried in the substrate or destroyed by storms and currents (Smolowitz 1978) or if they are overgrown with brown algae and over time possibly also with fire coral, although this will be limited with plastic coated traps (P. Hoetjes, pers. comm.). Detection is still possible as long as the rectangular shape is visible in relation to its environment. Hard overgrowth by corals makes detection easier as it makes the acoustic signal stronger. Soft overgrowth by algae is not a problem if the frequency is high enough to detect the rectangular shape underneath (H. de Vries, pers. comm.).
- Results with side scan sonar vary dramatically depending on the skills of the operator and the ability of the captain to stay on course (Fenn 2012). Smooth tows, with a stable flying height of the towfish, are important for the quality of the images, but are difficult in the open sea and at deeper depth (FANTARED2 2003; IEEP 2005). There is a probability that the towfish collides with elevations or obstructions on the seafloor. Experience with analysing images in tropical ecosystems with specific benthos is another important skill, to be able to accurately identify the target object and distinguish it from its environment (H. de Vries, pers. comm.). Noise in the data can be produced by for example unintended objects such as schools of fish or gas-charged objects such as vegetation that act as bubble curtain. Thermoclines and haloclines change sound velocity which will degrade the data and reduce the effective range of the sonar. All this requires operational adjustments, for example of the range of the sonar and the spacing of the survey track lines (Fenn 2012). Operating side scan sonar and detecting, accurately identifying and locating traps requires training, some trial and error practice and experience.
- Difficulties to distinguish between lost traps and those that are in use and fishing on the bottom (FANTARED2 2003) is a problem that can be overcome with viewing data while they are being collected and looking for cut marker buoy lines on the image (figure 9) or missing marker buoys at the surface. The latter may be a problem as parts of the Saba Bank are covered with lobster pots and marker buoys. During the bathymetric survey of the Hydrographic service of the Royal Netherlands Navy in 2007 'the side scan sonar got entangled in the small floating devices marking the lobster pots. These floating buoys could only be seen during day time and the area was covered with hundreds of lobster pots which made towing any equipment almost impossible. The magnetometer was towed only a few days after which the instrument got damaged beyond repair' (A. Meurink, pers. comm.).
- Steep slopes and high elevations or obstructions cause acoustic shadowing which makes it difficult to detect traps. The slopes at the lobster fishing grounds are mostly negligible and 5-10% at the margins, which is not a problem for the side scan sonar. The slopes at the redfish fishing grounds are larger as fish traps lie on ledges on steep drop-off and can easily slide off the slope with the current (Dilrosun 2000).
- The towfish carrying the transducers is connected with a tow cable to the CPU on deck of the vessel. A limitation of certain brands and types of side scan sonar is the maximum cable length. The cable length should be 2-3 times the depth of the towfish, because of the layback of the towfish behind the boat (figure 10). Of the two experts consulted for this research one deploys the Imagenex Sportscan with a maximum cable length of 65 meter and the other also the Imagenex Yellowfin with a maximum cable length of 600 meter [1]. The Sportscan is not suitable for this detection survey, given the maximum water depth of 50 meter and towfish depth of approximately 45meter

Magnetometer

A magnetometer is a device that measures the strength and direction of magnetic fields or magnetic objects. A magnetometer is different from a metal detector which detects metal objects by detecting their conductivity. Also the range is different which is rarely more than 2 meters for a metal detector, while magnetometers are able to detect objects at tens of meters. A magnetometer can only detect ferromagnetic metal [2] which is the material the steel frame and wire of a trap are made from.

Limitations of the magnetometer according to expert knowledge (H. de Vries, pers. comm.) are as follows:

- A magnetometer is a 'blind' sensor so it is not known if the detected object is in or on top of the seafloor. It therefore cannot be used as the only detection method, but is best used in combination with side scan sonar or video.
- Anomalies, which are abnormal (diurnal) variations in the Total Earth Magnetic field over small distance, compared to the common ambient Total Earth Magnetic field, can cause deflections of the magnetometer. Whether or not this is a concern in trap detection depends on the strength and frequency of the anomalies. The strength of the ambient Total Earth Magnetic Field at the Saba Bank is approximately 37.000 nanotesla (nT) or 37.000 gamma or 0.37 Gauss (figure) as read from the map in appendix C.
  No specific information on the occurrence, strength and frequency of anomalies was found during data collection. The Hydrographic Service of the Royal Netherlands Navy provides software to calculate magnetic declination and inclination for any geographical coordinate position (option 5.9 in application PCTrans to be found at http://www.defensie.nl/marine/hydrografie/nautische_applicaties/) (A. Meurink, pers. comm.). More information about anomalies may be available at the nearest Earth Magnetic Base station (for example the NOAA Space Weather Prediction Center [3] which has not been further explored. Also users of a magnetic compass at the Saba Bank can be a source of information whether deflections of the compass occur in small local area when moving at slow pace, which is an indication of anomalies. If the carbonate surface of the Saba Bank is thick enough, anomalies over short distances are not expected or homogenous enough to not cause deflections (H. de Vries, pers. comm.).

3.3 Other considerations in derelict trap detection

3.3.1 Retrieval of detected and located traps

The research question was to advise on the best, most efficient method to locate lost lobster traps in order to retrieve them. If location of lost traps takes place by side scan sonar in combination with magnetometry, it is important that the vessel stays on course in the survey track line and that the vessel speed is constant to have a smooth tow and keep the towfish with sonar at a stable flying height. Therefore retrieval of located traps can only take place after the survey has been done.
Sidescan sonar surveys produce detailed location information that allows return to within 2 to 3 meter of the trap location to conduct removal operations (NOAA 2009). The traps can be hauled by a boat equipped with a hydraulic winch and davit for hauling traps, but first a line needs to be attached to the lost trap. Such fastening of the trap for removal by recreational divers has similar disadvantages as trap location by divers (chapter 3.2.2), being maximum depth limitation (40 meter); maximum bottom time limitation (10 minutes at 40 meter, 20 minutes at 30 meter); and minimum surface interval between dives (at least 2 hours). Finding and fastening of the trap can also be done using an Autonomous Underwater Vehicle (AUV), Remotely Operated Vehicle (ROV) or drop camera with hook (H. de Vries, pers. comm.). The differences are that a ROV and drop camera are physically connected to the boat by a cable and the AUV is not. A ROV can be independently operated and a drop camera has a fixed position from the boat and is therefore more difficult to position precisely at the location of the lost trap (K. Kersting, pers. comm.).

3.3.2 Movement of lost lobster traps by currents

Lost lobster traps can be moved over great distances by storms, swells and resulting strong currents (P. Hoetjes, pers. comm.). This is why lost traps can cause potential damage to the benthic environment (Macfadyen et al. 2009). Movement of lost traps is also important to take into consideration in the selection of the survey area and how far downstream from the fishing grounds the survey should take place. Furthermore it is important information for the positioning of the towfish in the water column and for the likelihood that located traps are moved before they are retrieved. Based on the map with mean current velocities in the Caribbean Sea (figure 11) current velocity at the Saba Bank is comparatively low (approximately 1-3 cm/s). According to the experience of Rijkswaterstaat with side scan sonar detection of objects in the Dutch Waddenzee these lost frames do not move in current velocities as strong as 4 knots, which is 7.4 km/hr or 200 cm/s (B. Valstra, pers. comm.). Therefore the chance lost traps are moved far away from the position where they got lost can be considered negligible. A factor that may need to be taken into account are the so-called winter “swells”, water movements originating from Atlantic winter storms causing long period waves that enter the Caribbean from the North every winter. According to the fishermen these swells severely affect the bottom of the Saba Bank, causing loss of traps, presumably by causing the traps to roll on the bottom, submerging the marker buoy lines. It is unknown if or how far such swells could move these lost traps (P. Hoetjes, pers. comm.).

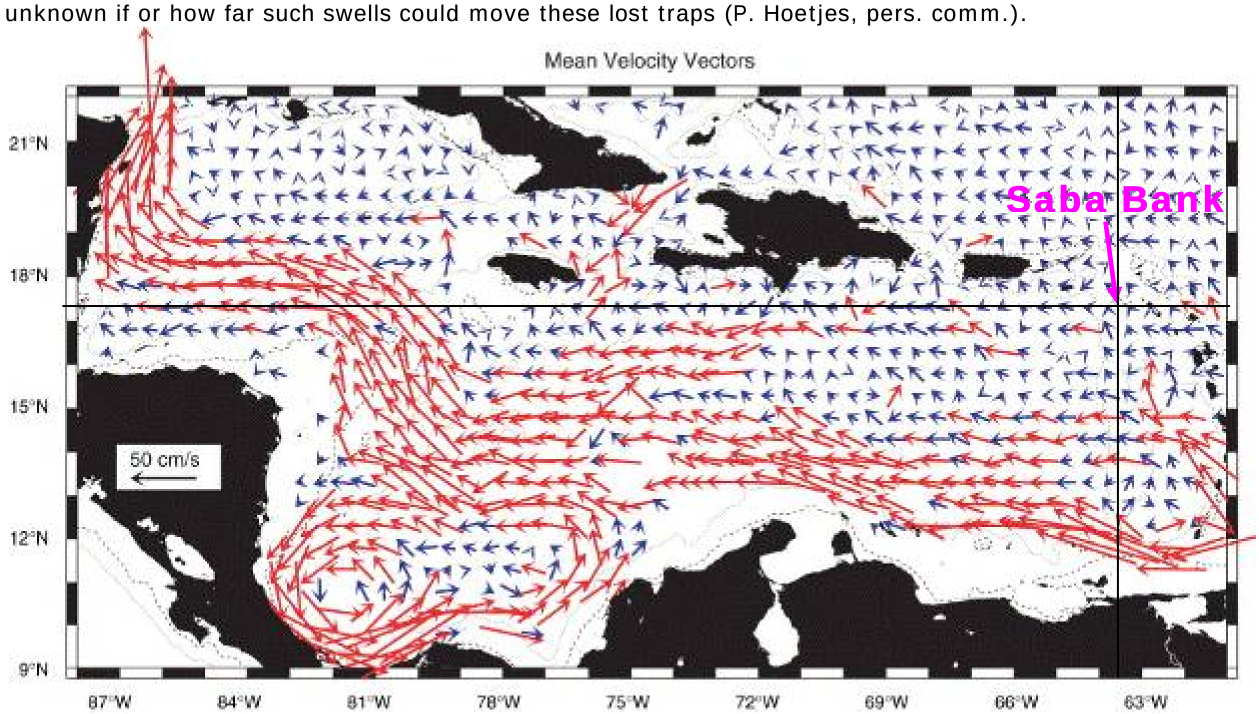

Figure 11. Mean current velocity grouped into ½-degree by ½-degree bins. The strong Caribbean Current is shown by red arrows (>25 cm/second) and the location of the Saba Bank is marked at the intersection of the black lines at 17°25′ N and 63°30′ W (Adapted from Richardson 2005).

3.3.3 Costs and benefits of location and retrieval

Curative measures such as a trap location and retrieval program tend to be less effective and more costly than preventive measures. In environmental terms prevention is certainly better than cure, and based on a limited number of cost-effectiveness studies (Wiig (2005) and Brown and Macfadyen (2007) in Macfadyen et al. 2009) this also seems to be true in economic terms. However, curative measures can still be cost-effective when considering the cost of ghost fishing when leaving ALDFG *in-situ.* (Macfadyen et al. 2009). A cost benefit analysis can provide important information whether the costs per trap retrieved do not exceed the benefits. Costs include not only the costs of the detection survey itself, but also the opportunity costs of time for fishermen who are engaged in the location and retrieval program. The latter refers to the loss of earnings from reduced fishing time. Benefits include having no replacement costs for lost gear and no loss of earnings from ghost fishing mortality, because fish get entrapped and die instead of being landed and sold.

A lost lobster trap including rope and buoys costs approximately USD 100 in materials and labour according to the fishermen (Dilrosun 2000). This is low in comparison with the cost price of a lobster and fish trap in the U.S. Virgin Islands of USD 144 and 271 respectively (Clark et al. 2012). The annual replacement costs for gear based on the estimated annual trap loss at the Saba Bank (table 2) are thus between USD 21.000 and USD 79.500.

How much fishing takes place by ghost traps requires 1) estimates of the number of traps used in the fisheries and the loss rate 2) an assumption about the percentage of lost traps that ghost fish instead of being destroyed 3) estimates of the rate of mortality in ghost fishing traps and natural mortality rates and 4) an estimate of the lifespan of a ghost fishing trap (Breen 1990). Estimates of point 1, 2 and 3 for the Saba Bank lobster fisheries were provided in chapter 3.1.4 (table 2). Renchen (2011) estimated point 3, the annual loss from ghost fishing mortality, for the U.S. Virgin Islands at USD 26 per trap per year. Applying this to the estimated number of 210 to 2385 lost traps that are still intact and able to ghost fish at the Saba Bank (table 2) the annual loss from ghost fishing mortality ranges between USD 5.460 and USD 62.010. Obviously this is a very rough estimate, because of uncertainty in trap loss at the Saba Bank and because of inaccuracy in the ghost fishing loss. USD 26 loss per trap per year is likely to be different for the Saba Bank, as it depends on the ghost fishing rate, ghost catch species composition and the market value of the catch. Renchen estimated 5% ghost fishing mortality and catch was composed of reef fish only. A more accurate cost benefit analysis would require better information on trap loss, ghost fishing duration and ghost fishing mortality at the Saba Bank. The costs of a trap detection program have not been investigated in detail either. The fixed costs are likely to include equipment purchase of approximately EUR 25.000 or rental of EUR 900 per day plus travel costs of a side scan sonar expert to Saba, and the variable costs are approximately EUR 70-133 per hour for an expert plus accommodation costs and operational costs like petrol. A rough estimate is that a 2-week survey will cost between EUR 25.000 and EUR 50.000 depending on the consultant fee and rental or purchase of the side scan sonar (table 6). Obviously this is only a preliminary estimate based on a hypothetical equipment choice and survey duration. If the staff of the Saba Marine Park can be trained on the job in the operational use of the equipment and in data analysis of the images, the consultancy fee might be less.

Table 6. Preliminary estimated costs of a 2-weeks detection survey when (a) renting or (b) purchasing the equipment.

	Unit	Unit price in EUR	Number of units	Equipment	
				(a) Rental	**(b) Purchase**
Imagenex Yellowfin	Day	565	14 days	7.910	25.600
Magnetometer	Day	323	14 days	4.520	4.520 (rental)
Petrol	Day	100	14 days	1.400	1.400
International travel	Flight	1000	1	1.000	1.000
Food accommodation	Day	100	14 days	1.400	1.400
Consultant fee	Hour	70 - 133	14 x 8 hours	7.840 – 14.990	7.840 – 14.990
			Estimated costs in EUR	**24.070 – 31.220**	**41.760 - 48.910**

3.3.4 Sample design

It is not reasonable to survey the entire lobster fishing grounds, so a pilot is recommended. Based on the number of traps detected in the pilot a decision can be made to expand the survey. It is recommended to start with a pilot survey in the area with expected high concentrations of lost traps, to investigate how the magnitude of lost lobster traps relates to the estimated range of 210 to 2385 traps. Matsuoka et al. (2005) designed a methodology to calculate the number of ghost fishing gear with the formula: $E_g = n_l$ x

r_e x A, whereby n_l is the number of lost gear remaining in a unit area, r_e is the ratio of functioning gear of lost ones and A is the total area of ghost fishing ground. In a detection survey, the ratio of functioning gear of lost ones can only be established upon retrieval. Nevertheless the above equation can be used to get a more precise estimation of the magnitude of lost lobster traps. Matsuoka et al. (2005) also came up with an equation to calculate ghost fishing mortality, but this requires a field experiment similar to the one of Renchen (2011) to collect data on species entering and escaping gear over a longer period of time and the mortality rate. It is questioned if this is worth the time and investment.

The sample design for the pilot should be a stratified random sample to get a statistically sound quantification of trap loss (and ghost catch rates). Since it is recommended to focus on the area with expected high concentrations of lost traps, it is best to stratify the survey area into 3 groups and within each group take random samples. This results in the following sample design:

- Divide the pilot in 100 survey track lines of 100 meter wide and 1 km long. This means the total survey area is 10 km^2 which can be surveyed in 14.2 hours (100 x 1 km / 7 km/hr). This equals 3 survey days, as effective survey time is no more than 4-6 hours per day, taking into account travel time to and from the survey area. A survey area of 10 km^2 is 0.5% of the total potential fishing grounds (1,850 km^2). Depending on the available resource the area of the pilot can be increased. The advantage of taking survey track lines instead of survey squares (eg 300 x 300 meter) is that swatch overlap of 20% is avoided and it is easier to keep track rather than navigate in U turns. In addition, it is not a big problem if the survey track is not a straight line, when the boat needs to navigate around the (presumably many) marker buoys on the survey track in order to avoid entanglement of side scan sonar or magnetometer.
- Stratify the survey area in 3 area: A) area with expected high concentrations of lost traps based on anecdotal evidence B) area with high fishing effort and C) area with moderate fishing effort. Area A can coincide with area B and C. In case anecdotal information is incomplete or incorrect and stratum A does not contain many lost traps, it is still likely to find most lost traps in highly fished area, stratum B. Stratum C represents the area outside area A and B. The ratio of samples per area can be 40:40:20, to put more effort in area with expected high trap loss and high fishing effort.
- Divide each stratum in 1km x 1km grid cells and randomly select the samples according to the sample size of 40:40:20.

A consideration is to focus on the eastern part of the Saba Bank (approximately 225 km^2) which is between 10 and 20 m depth. Justification is that this area is not too deep for divers to conduct removal operations, in order to avoid the use of AUVs or ROVs which require special equipment and operational skills, the latter being available at the Saba Marine Park (P. Hoetjes, pers. comm.). In addition, the pilot can take place in a more confined area that is closer to Saba, in order to avoid travel time to and from the survey site and in between survey tracks. The sample size would than increase from 0.5 to 5% (10 km^2 / 225 km^2). Another consideration is to practise with an experimental setting and identify traps that are put in the water (FANTARED2 2003) in the vicinity of Saba. This training will ensure the accuracy of lobster trap identification from the sonar images.

It is recommended to collect available anecdotal information on individual locations and concentrations of lost traps to determine stratum A. From literature it appears interviewing fishermen is the most efficient way to get information about lost gear and detection surveys without these interviews are very inefficient (FANTARED2 2003; NOAA 2009). Collecting this anecdotal information can be done through structured interviews (asking for gear lost, date, depth, coordinates and reason for loss) amongst representatives of the Saban fishermen or through a participatory mapping approach. Such a method was used by Renchen (2010) whereby locations of fishing effort were divided up into 1km x 1km grid cells and geographical coordinates were given to locations where they lost traps in past.

3.3.5 Prevention of trap loss and ghost fishing

Comparatively intensive trap location and retrieval programs may be undertaken initially as curative measures to solve the immediate problem of lost traps, but this should be supported by measures to prevent the recurrence of trap loss. Preventive measures include prevention of trap loss and prevention of ghost fishing when trap loss does occur. A detailed understanding of why gear is lost is needed to take effective preventive measures. A measure to prevent trap loss due to bad weather is to avoid setting gear or haul gear that is in use if extreme weather is predicted. A measure to prevent trap loss due to gear conflicts is better spatial management to avoid conflict for example by setting up a zoning scheme which allocates sections of the fishing grounds to different fishermen (Macfadyen et al. 2009). A measure to prevent trap loss due to breaking lines of marker buoys by vessels is to further limit boat traffic or to better mark the buoys. Other measures to reduce operational trap loss include effort reduction measures such as limits to the amount of traps used, limits to the soak time (FANTARED2 2003; Macfadyen et al. 2009) or seasonal closure. A measure to prevent ghost fishing is regulation and enforcement of the use of biodegradable escape panels in traps. Other measures to support location and retrieval programs are trap marking with pingers and a reporting system of lost trap when trap loss occurs (Macfadyen et al. 2009).

4 Conclusions and Recommendations

Side scan sonar in combination with a magnetometer is recommended as the best, most efficient method to locate lost lobster traps in order to retrieve them.

Side scan sonar is recommended, because with a frequency of 600 kHz the resolution of the images can be small enough to detect 1 m^2 traps, while the swath width (100 m) and vessel speed (7 km/hr) are high enough to cover a reasonable area (5 km^2) in a 8-hour survey day. In general, the survey environment at the Saba Bank is suitable for side scan sonar, as most lobster traps are located on flat surfaces with substrate composed of hard bottom pavement, rubble or sediment with or without patch reefs (Appendix A). Detection problems due to so-called acoustic shadowing are not expected there, as slopes are negligible, vertical relief of rock and coral formations is low enough and aquatic vegetation and gorgonian height and density are low enough. Acoustic shadowing can occur for lobster traps located at the edge of the lobster fishing grounds, where fore reef coral cover has vertical relief >1 meter and dense gorgonians > 1 meter. To ensure detection of these trap locations as well, a magnetometer is recommended to complement the side scan sonar. A magnetometer will also detect (partial) buried, damaged or overgrown traps that lost their distinct rectangular shape necessary to accurately identify traps from the side scan images.

It is recommended to retrieve located traps separately, after the detection survey has taken place, as it is essential to operate the side scan sonar with a smooth and stable tow, whereby the boat stays on course and travels at a constant speed. The three suggested methods for retrieval are Autonomous Underwater Vehicle (AUV), Remotely Operated Vehicle (ROV) and drop camera.

Since it is not reasonable to survey the entire potential lobster fishing grounds of 1.850 km^2 a pilot is recommended. Based on the number of traps detected in the pilot a decision can be made to expand the survey. The pilot can be accompanied by a cost benefit analysis to advise decision makers if the costs per trap retrieved do not exceed the benefits. A preliminary estimate of the costs of a detection survey and the benefits of ghost fishing mitigation has been made in this desk study.
The costs for a 2 week pilot survey (covering 2.8 km^2 x 14 days = 40 km^2) range between EUR 20.000 and 40.000 (table 6), depending on whether the equipment is purchased or rented and whether the survey is outsourced completely or not. The costs of retrieval are not included yet in this estimate.
The annual benefits of traps location and retrieval include the value of the avoided ghost fishing catch, estimated to be between USD 5.460 and USD 62.010 and the value of the retrieved fishing gear, estimated between USD 21.000 and USD 79.500. These estimates needs to be considered with care for three reasons. First, it assumes all lost traps are located and retrieved, which requires a survey of more than a year to cover 1.850 km^2. Second, trap loss is based on one 6-month study with inconsistencies in interpreting the fishermen's reports, resulting in the large ranges. Third, the ghost catch value of USD 26 per trap per year is based on one study in the U.S. Virgin Islands using fish traps. The ghost fishing rate, ghost catch species composition and their market value for lobster traps at the Saba Bank are likely to be different due to different trap design. It requires further research to determine these values for the Saba Bank and to better quantify the impacts on target and non-target species and on the benthic environment.

It is recommended to introduce a reporting and registration system on gear loss to collect more comprehensive data on gear lost, date, coordinates, depth (unless this can be easily retrieved from coordinates data) and reason for loss. This can be incorporated in an existing fisheries landings registration system. Data on gear loss not only provide useful information for curative measures such as trap detection. It also provides information for preventive measures, as a detailed understanding of why gear is lost is needed to take effective preventive measures. They can be split in measures to prevent loss and measures to prevent ghost fishing. One measure to prevent ghost fishing is already in place, which is the use of biodegradable escape panels in the lobster traps. However, this regulation of 1992 has not been implemented properly due to lack of enforcement and compliance.

A lobster trap detection survey at the Saba Bank is possible using side scan sonar and magnetometer. However, it is not necessarily the best, most cost-efficient method to respond to the problem of traps getting lost. Preventive measures tend to be more effective and less costly than curative measures such as a trap detection survey. However, preventive measures do not resolve the problem of the traps that already have gone lost and their potential impacts. A detection survey can be used to estimate the magnitude of the problem of lost lobster traps using the methodology of Matsuoka et al. (2005) to extrapolate the number of lost gear in the surveyed area to the total area. It is not realistic that a detection survey can locate all lost traps on the Saba Bank.

5 Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 57846-2009-AQ-NLD-RvA). This certificate is valid until 15 December 2012. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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[1] (http://www.metaldec.nl/sidescan.html)

[2] (http://en.wikipedia.org/wiki/Magnetometer)

[3] http://www.swpc.noaa.gov/SWN/index.html)

Justification

Report number C091/12
Project Number:43.08.701.010

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

Approved: Dr. M. de Graaf
Researcher

Signature:

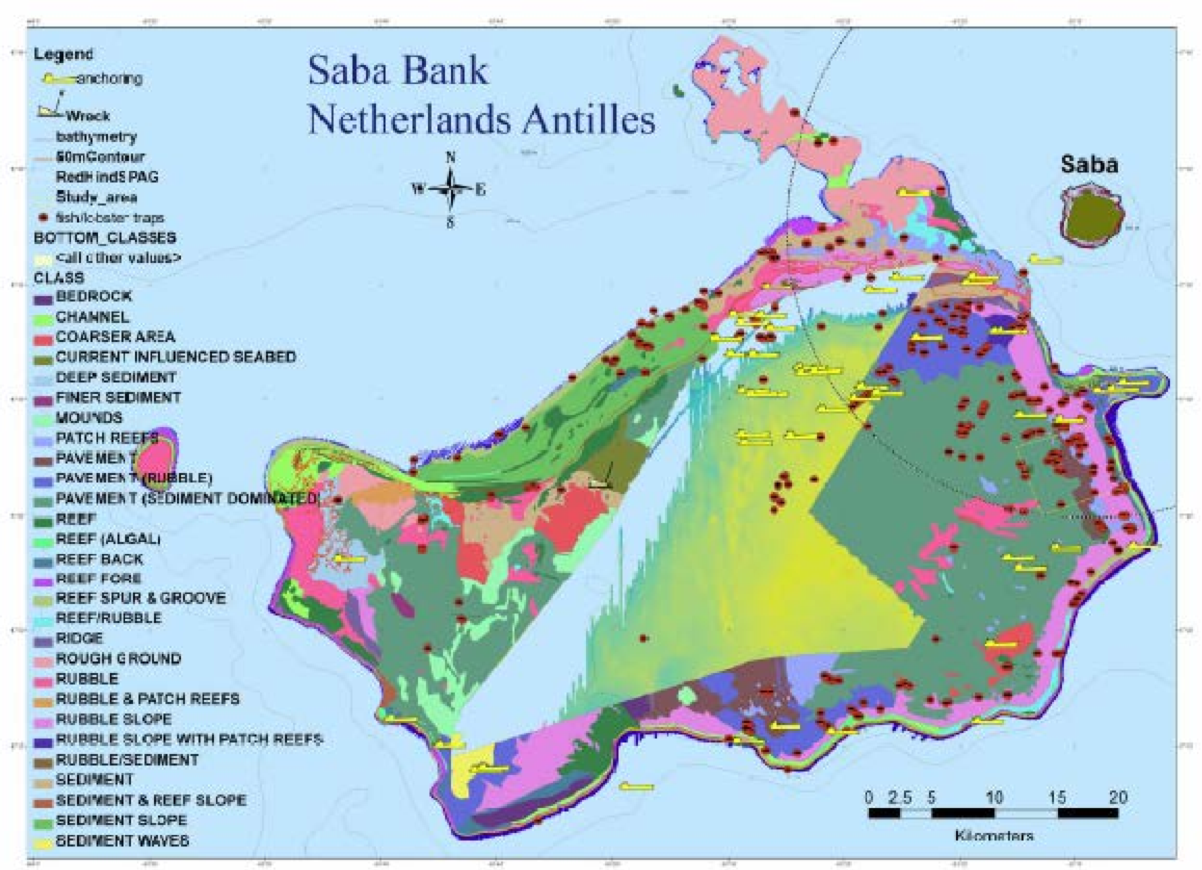
Date: July 23th 2012

Approved: Drs. F.C. Groenendijk
Head Department Maritime

Signature:

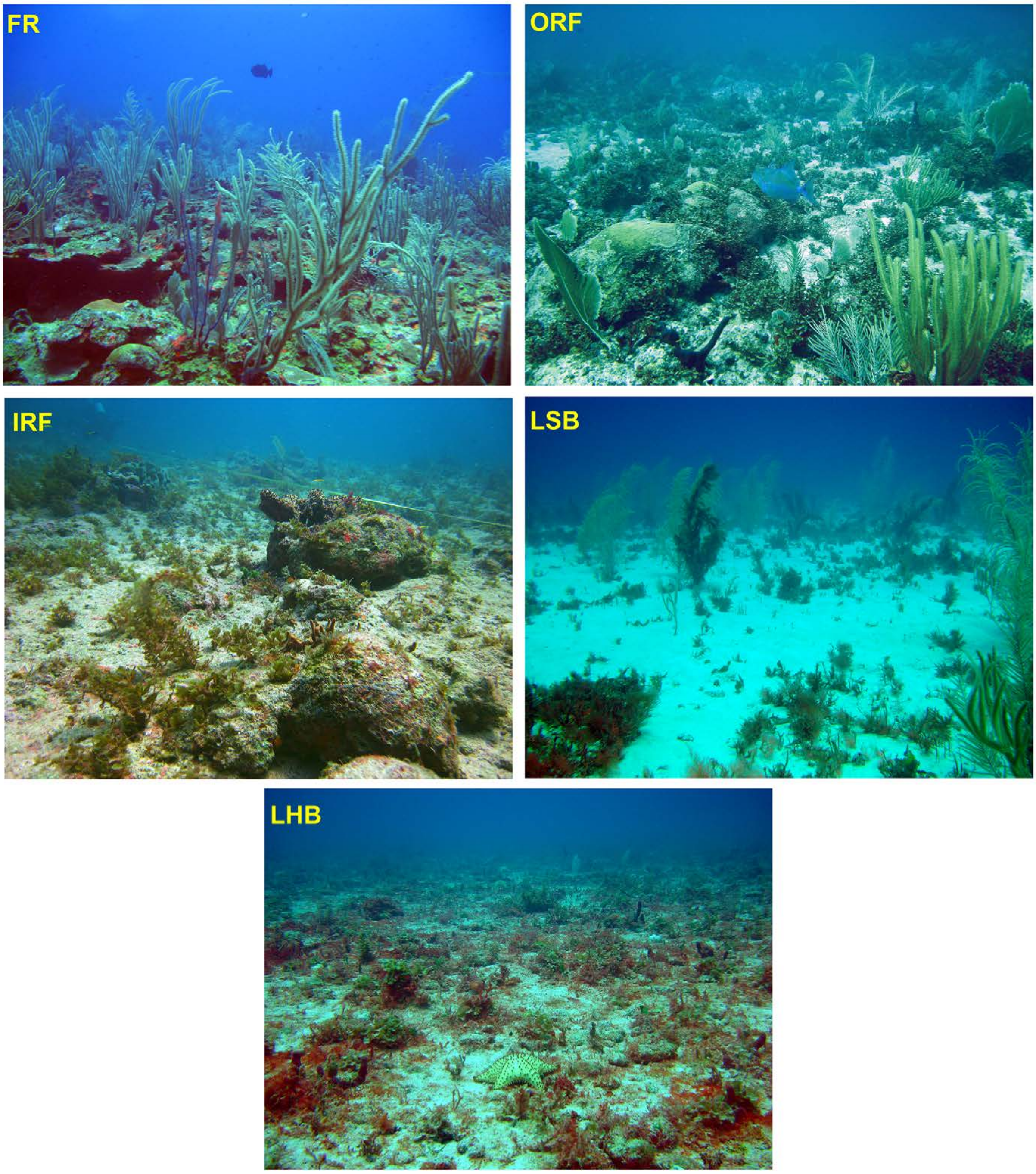
Date: July 23th 2012

Appendix A. Saba Bank bottom classification map



Bottom classification of the Saba Bank, which is based on data from the Hydrographic Service of the Royal Netherlands Navy collected in bathymetric surveys in 2007 with high resolution multibeam echosounder (the most detailed area) and between 1988-1996 with single beam echosounder (the central yellow and green area). The light blue area is lacking digital bathymetric data (Toller et al. 2010). The classification has not been based on ground truthing, but gives a good indication of the different bottom types. Lobster fishing grounds are mainly found on rubble and sediment, with or without patch reefs and with or without slopes.

Appendix B. Saba Bank pictures of habitat types



General impression of the five habitat types found in the study area of Toller, Debrot et al. (2010) as marked on the map in Appendix A: (FR) Fore reef habitat; (ORF) outer reef flat habitat; (IRF) inner reef flat habitat; (LSB) soft bottom lagoon habitat and (LHB) hard bottom lagoon habitat.

Appendix C. Total Earth Magnetic Field map