Population status and reproductive biology of the Queen conch (*Lobatus gigas*) in the waters of Anguilla

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A research on the distribution of the population, abundance and reproductive biology of the Queen Conch (*Lobatus gigas*) in the waters of Anguilla – British West Indies

A 3rd year's internship period of 20 weeks for Coastal and Marine Management at Van Hall Larenstein, for the Institute of Marine Resources and Ecological Studies and the Department of Fisheries and Marine Resources in Anguilla.

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Abstract

The queen conch (*Lobatus gigas*) is herbivorous, molluscan gastropod found in the shallow seagrass beds throughout 20 countries in the Caribbean. The Queen conch is commercially valuable since it forms an important food source for many local communities for many years. The demand for the *L. gigas* increased and the pressure on the population led to the listing of the Queen conch under Appendix II of CITES in 1992. Appendix II includes species that are at risk of becoming endangered. Despite the decline in abundance, the *L. gigas* is still harvested throughout the Wider Caribbean region. Therefore, stock assessment has become very important to sustain fisheries in the region. Until last year, Anguilla did not have any history of research on the Queen conch and no data was present on the sustainability of the conch fisheries on the island. Many of the fished conchs on Anguilla are exported to neighboring islands. Any regulations present on the island regarding the fisheries of the conch is stated as: the minimum shell length should be 18cm and a minimum weight of 225 grams of conch meat (cleaned). There is no quota nor a minimum for lip thickness. The queen conch stock has been estimated as low in the waters of Anguilla. The mean adult conch/ha is 26 and is nearly half of what CITES recommend. A total of 2,350,015 *L. gigas* is estimated to be found in the 80,900 ha submerged plateau with an estimate mean annual catch of 139,496. This number represents 6% of the estimated queen conch stock, which is just below the recommended fishable biomass of 8% of the Queen Conch Expert Workshop. The abundance of the *L. gigas* depends on the habitat and depth. The abundance of conch is higher in medium depths ranging from 15 – 29,9 meter. The recorded population consists of thick lipped adults with an average of LT 12,6 mm, which is above the minimum for the reproductive behavior (9 mm) (Stoner *et al*., 2012). Management strategies should focus on setting quota based on lip thickness instead of the current shell length, marine parks and reserves of Anguilla should be revised on their goals and criteria, and management on the CITES permits should take place for the exportation of conchs to the surrounding islands. Concluding, a small scale fishery can sustainably operate in Anguilla, however, judging by the few locations with high densities of adult conch the fishery should be closely monitored. Any expansion of the fleet is not recommended.

Contents

1 Introduction

The Queen conch (*Lobatus gigas*) is a large gastropod that can be found in the waters ranging from the Gulf of Mexico, up to Bermuda and down through the Caribbean, further to Brazil (Figure 1) (Stoner, 2003; Davis, 2005). Out of the six conch species, the *L. gigas* is one of the largest, herbivorous, molluscan gastropod found mainly in shallow seagrass beds. Throughout 20 countries in the Caribbean, the Queen conch is commercially valuable since it forms an important food source for many local communities (CFMC & CFRAMP, 1999). It has been traditionally fished for many years, but has come under increasing strain as an export market has developed similar to that of the spiny lobster (*Panulirus argus*). The increase of fishing pressure and exports in the last two decades resulted in a diminished population density (National Marine Fisheries, 2014). Additionally, the decline of the *L. gigas* population in the wider Caribbean is most likely accelerated by (illegal) harvesting of immature conchs (Stoner *et al*. 2012b).

Figure 1. An overview of the occurrence range of L. gigas in the Wider Caribbean

The queen conch is commonly fished by two methods, either by scuba diving (or hookah gear) or snorkeling (freediving) (Theile, 2001; Doerr & Hill, 2013). The meat of the marine snails is removed either on board or on shore (Aiken *et al.* 2006). By cleaning the meat on board it allows the divers to carry more meat per dive trip and the dive crew to transport higher volumes of meat per fishing trip since the weight of the shell is removed (Theile, 2001). The remaining shells are either sold or dumped on a near- or on shore location to prevent fishing for empty shells (Aiken *et al.*, 2006). The demand for the *L. gigas* increased in the United States of America and the pressure on the population led to the listing of the Queen conch under Appendix II of the Convention on the International Trade of Endangered Species of Wildlife Flora (CITES) in 1992 (CFMC & CFRAMP, 1999; Stoner et al., 2012a). Appendix II of CITES includes species that are at risk of becoming endangered.

Since the listing of the Queen conch in the Appendix II, management measures were set for the fishery industry (Theile, 2001). The minimum size restrictions are generally based on the shell measurements of the queen conch. The commonly used measure for the minimum size restriction is the shell length and the lip thickness of the individual, assuming that sexual maturity occurs at a certain size (Theile, 2001). However, animals with a shell length of an adult conch may still be immature but legal to harvest (Theile, 2001). The general measurements of an adult queen conch have a minimum shell length between ± 180 – 250 mm and a lip thickness of 5 mm (Apeldoorn, 1988; Theile, 2001). However, average shell length and lip thickness may vary per region due to ecological factors (Kemp & Bertness, 1984; Roy, 2002; Stoner, 2012b). Furthermore, before sexual maturity is reached, the growth in shell length ceases and the flared lip starts to form (Figure 2) (CFMC and CFRAMP, 1999). Further shell growth mainly occurs on the thickening of the shell and the lip. In terms of shell growth, the life-history is divided in two stages: juvenile and adult. This has a profound impact on assessing age, growth and mortality using size based techniques. Length-frequency of the adult L. *gigas* is used for juveniles and for adults the lip-thickness is used (CFMC and CFRAMP, 1999). Their reproductive season is from April until October where it peaks in July and August (Stoner et al., 1992). During the reproductive seasons, *L. gigas* usually migrate to shallower waters between the 10 and 20 meters, on sandy and near reef habitats when temperature start to inrease in March (Stoner & Ray-Culp, 2000; Prada et al., 2008). The population density is crucial for the reproduction of the *L. gigas*. Observation done by Stoner & Ray-Culp (2000) and Stoner *et al.* (2011 and 2012a) showed that copulation and egg laying intensity is related to the density of mature conch. The critical density for conchs was 56 adults per hectare. Below the critical density of 56/ha no mating was observed during their study. *L. gigas* are known to move about 0,5 miles per month (Davis, 2003; Glazer *et al*. 2003), which is a crucial movement to find other individuals for internal fertilization. Females produce large egg massess measuring up to 12 cm long (Randall, 1964) and lay about 100.000 eggs per egg mass, which usually occurs

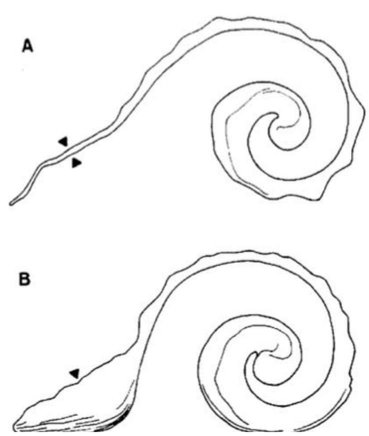

Figure 2. Cross-section of a shell from a juvenile (A) and an adult Lobatus gigas showing the growth in lip thickness. Arrows show the position where lip thickness is measured (CFRAMP, 1999)

several weeks after copulaion. Adult *L. gigas* are found in depths ranging down to a depth of ± 60 m (Randall, 1965) on rubble substrate and seldom on reef habitats (Acosta, 2006). The habitat utilization differs dramatically trouhgout their life history (Doerr & Hill, 2013).

The abundance of the *L. gigas* has varied greatly over the past 130 years (Berg jr et al., 2012), which may be attributed to natural environment conditions that affect recruitment process, and in more present day, the influence of overexploitation by man and habitat degradation. Despite the decline in abundance, the *L. gigas* is still harvested throughout the wider Caribbean region (Stoner et al. 2012b). Therefore, stock assessment has become very important to assess fished stocks in the region. Conch fisheries possess some characteristics, which makes stock assessment difficult. In particular, the growth and biology of the queen conch makes it difficult to establish management strategies (CFMC and CFRAMP, 1999).

In 2013, the head of the Department of Fisheries and Marine Resources (DFMR) of Anguilla requested the Institute of Marine Resources and Ecological Studies (IMARES) conduct in 2013 a study on the Queen conch of Anguilla. Prior to this, Anguilla did not have any history of research on the Queen conch and no data were present on the sustainability of the conch fisheries on the island. Most of the fished conchs on Anguilla are exported to neighboring islands, mainly St. Maarten/Saint Martin, and a small portion is consumed locally on the island. Regulations present on the island regarding the landing of queen conch are the following: the minimum shell length is 18 cm and a weight of 225 grams of meat (after the removal of the digestive gland) (Fisheries Protection Act, 2000). No regulation on quota or minimum lip thickness is defined. The unknown status of the queen conch stock in Anguilla can lead to an overexploitation of the population found in the Anguillan waters. Since the 14th of February 2014, the foreign office has extended CITES to Overseas Territories, including Anguilla (Government of UK, 2014). However, with the lack of management and regulations, and without the advice of a CITES Management Authority of the State, Anguilla cannot determine if the current fishery on the queen conch is detrimental or not (FAO report, 2012). Besides, local fishermen of Anguilla depend on the queen conch fishery for their livelihood. To determine if the Anguillan conch population can support a small-scale commercial fishery, a survey to assess the size structure, abundance and distribution of the queen conch population was initiated in 2014.

The objective of this study was to evaluate the sustainability of the current small-scale conch fishery in Anguilla. To achieve the objectives, the following research questions were set:

[1] What is the current distribution, abundance and population structure of the *L. gigas* in Anguilla?

[2] Which habitat characteristics determine the abundance and size of the conch around Anguilla?

[3] What is the current status of the conch fishery in Anguilla?

2 Materials and Methods

2.1 Study area

Anguilla, an overseas British territory, is one of the most northerly islands in the Lesser Antilles. Anguilla is located east of Puerto Rico and the Virgin Islands and directly north of Saint Martin. The main island of Anguilla totals 91 km^2, approximately 26 km long by 5 km wide at its widest point (Stanley, 2009), and its highest point is 65m. Anguilla was created by volcanic eruptions, the southern part of Anguilla is flat and low-lying, as are most of the small cays which occur to the north and west of the main island (Christman, 1953; Mitchell, 2009a). Many of the offshore cays are marine protected areas: [1] Dog island (10 km^2), Prickly Pear (33 km^2), Little Bay (1km^2), Shoal Bay/Island Harbour (19 km^2), and Sandy island (5 km^2) (Figure 3) (Hoggarth, 2001). Each marine park is managed under the same regulations with no specific (sub)zones defined besides the anchoring areas with the corresponding buoys (Hoggarth, 2001). Under the Fisheries Protection Act in Anguilla, only residents are allowed to spearfish within the Anguillan waters and/or use SCUBA gear to take any marine product (Hoggarth, 2001; DFMR, 2015). Anguilla's Exclusive Fishing zone (EFZ) is one the largest of the Caribbean, stretching 200 nautical miles to the north covering approximately 85,500 km^2 (DFMR, 2014). Due to its geographical location, the northern part of Anguilla does not share its Exclusive Economic Zone (EEZ) with any other country. The island is also known for its ecologically important coral reefs. Most of the surveyed coral reefs lay in a 2,000 km^2 shelf with an average depth of 22m (Figure 4) (Green, 2001; DFMR, 2014). As for the seagrass beds, it covers approximately 34 km^2 (Olsen & Ogden, 1981). North of Anguilla there is 17 km long reef along the coast, Putney (1982) considered as one of the most important reefs in the eastern Caribbean. Today, the reef is heavily degraded and much of it is broken up (Wynne, 2015).

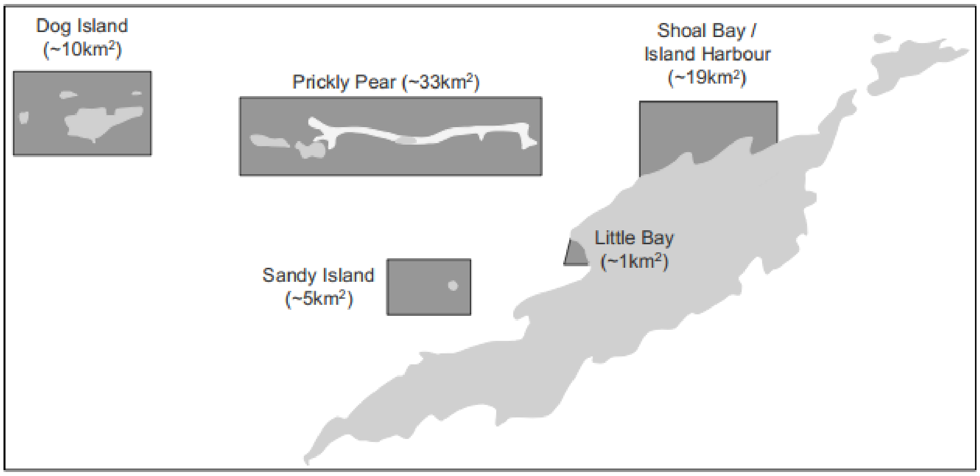

Figure 3*. Offshore cays with marine protected areas and the surface area of the marine park (Wynne, 2013)*

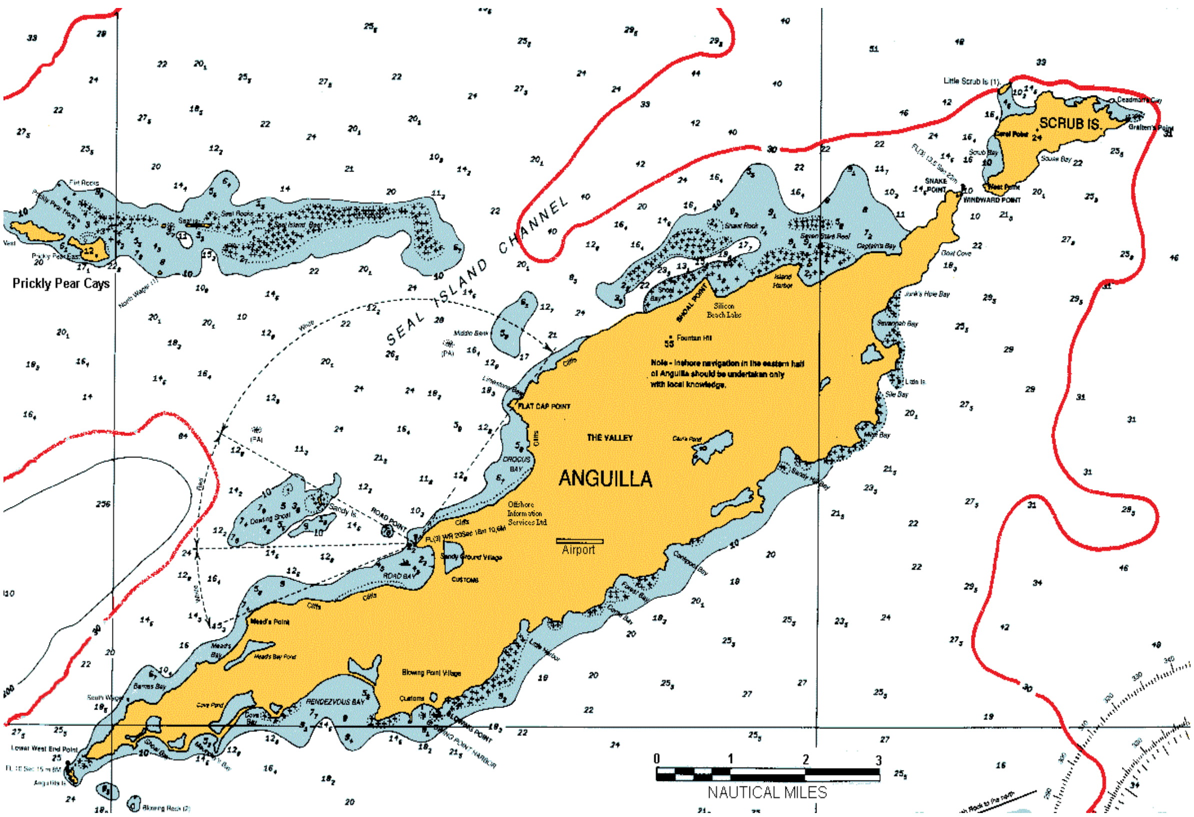

Figure 4*. Red line represents the 2,000 ha of submerged shelf of Anguilla within a depth of 22m.*

This study covers the coastal waters of Anguilla from the coastline up to de maximum depth of 54 meters. A total of 126 locations were selected on a habitat map, by placing randomly three points in a grid of 5 by 5 km within the Anguillan waters (Figure 5). For the dive survey, 32 sites were randomly selected to collect data by SCUBA. For the towed video array survey, substrates consisting of coral reefs, rocks, any fragile or large objects were avoided. Any other type of substrate (sand, rubble and seagrass) were surveyed.

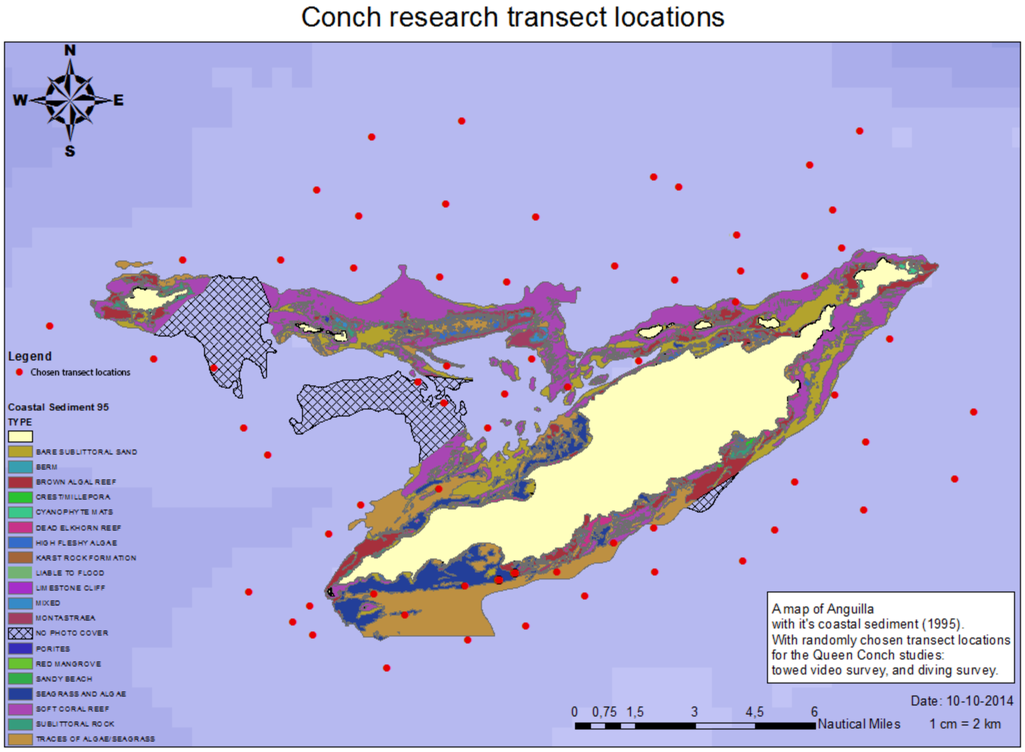

Figure 5. *Queen conch research locations for the transects randomly selected within a 5 by 5 km grid.*

2.2 Towed Video Array

The towed video array was based on the design by Stevens (2003) and Sheehan et al. (2010). The methodology was used based on a study done by Boman *et al.* (2016). Successful results from the study by Boman *et al.*, (2016) showed that the towed video method was accurate in identifying live adult conchs in different habitats and to estimate densities for adult queen conch down to a depth of approximately 50m (Figure 6). The towed video array consisted out of polyvinyl chloride (PVC) (Boman *et al.* 2016). Two air-filled PVC pipes, firmly sealed, were attached on top of the array to keep the array positively buoyant.

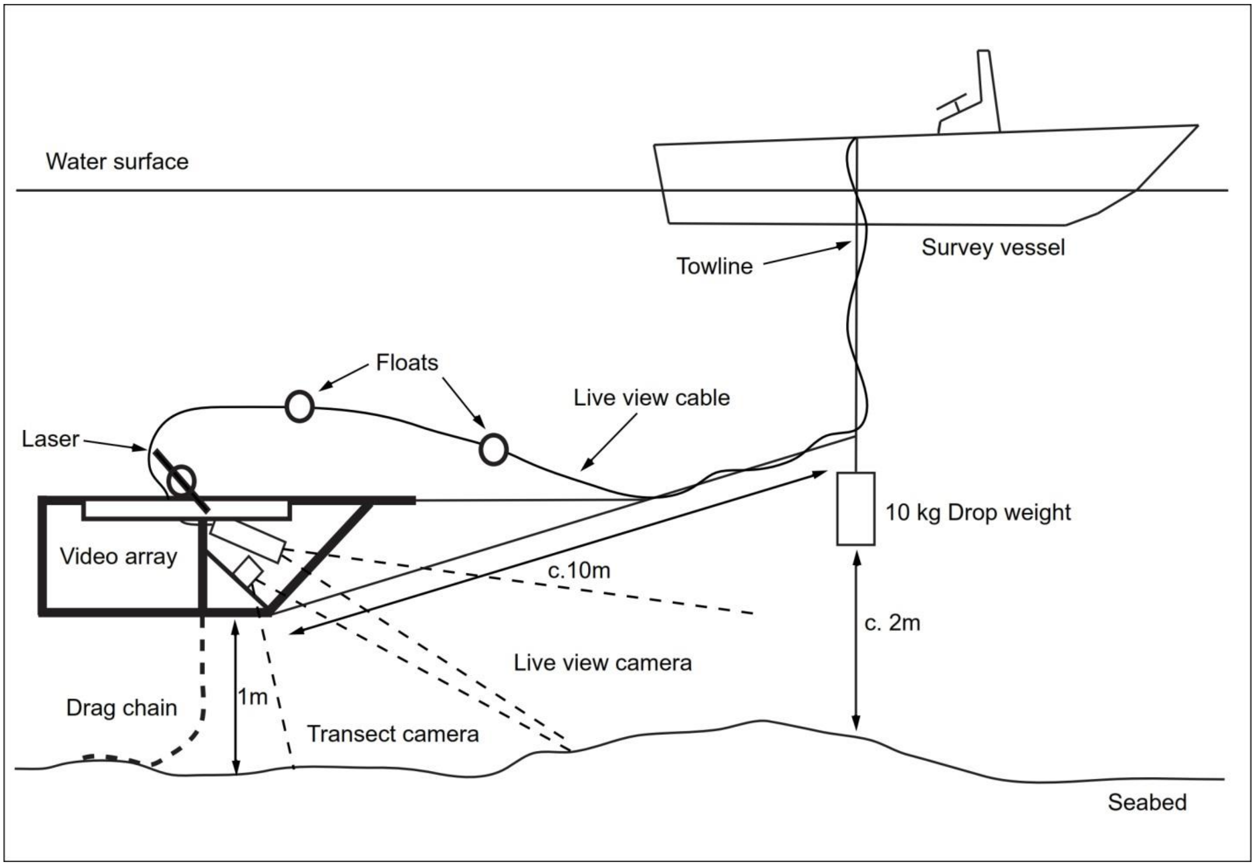

Figure 6. *An schematic overview of the setup of the methodology used for the towed video array (Boman et al., 2016)*

Two laser pointers (Z-Bolt, SCUBA-1, Underwater green laser; Beam of Light Technologies Inc., Happy Valley, OR, www.z-bolt.com) were placed at 1 m width of each other to indicate the transect (Figure 6). Transects were recorded with a waterproof HD action camera (GoPro Hero4 Black, dive housing, GoPro battery backpack and 64GB SD cards) (GoPro, San Mateo, CA, www.gopro.com). The action camera was placed at a downward 40^{o} angle at the center of the array to capture the lasers of the transects and for an optimal angle for the video analysis. A live view camera (Seaview Super mini; Seaviewer Cameras Inc., Tampa, FL, www.seaviewer.com) was attached in a downward 30^{o} angle (Figure 7). The live view camera provided continuous real-life feed to the operator on the boat through a cable to avoid high-relief habitats, objects and to adjust to the changes of depth.

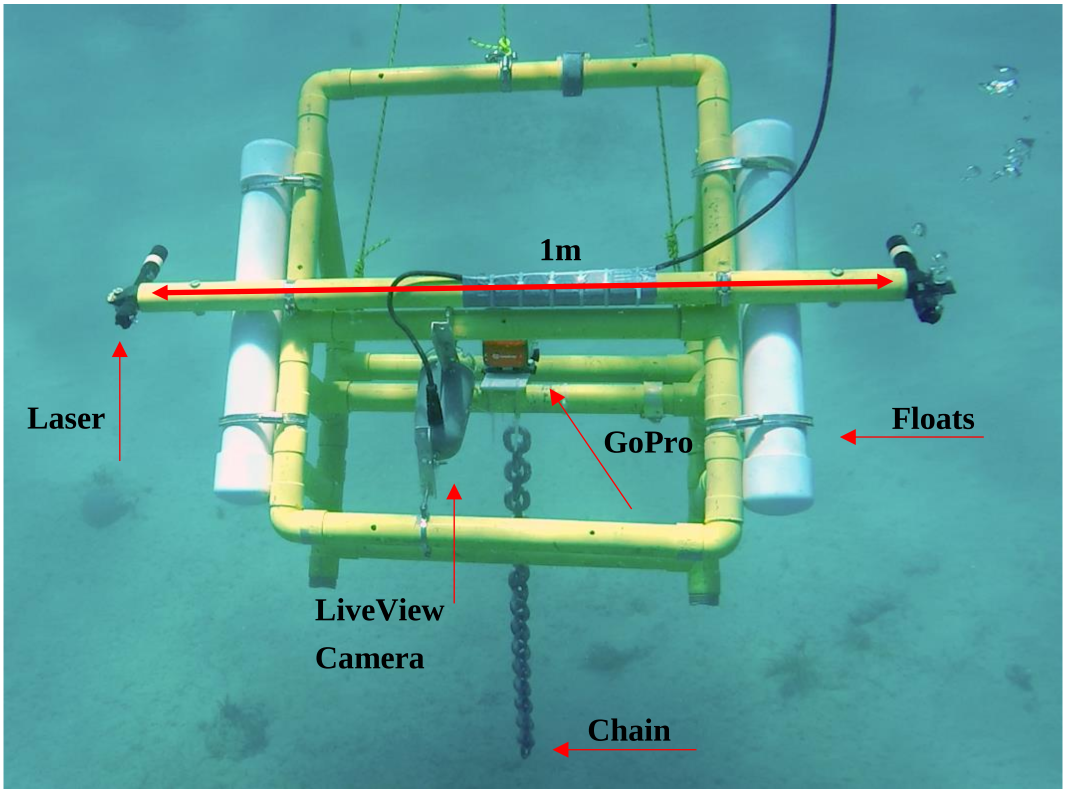

Figure 7. Towed Video Array under water and the equipment used to collect data

The video array was towed behind a boat with the engines turned off and carried by the currents and wind. Find the protocol in Appendix I for more detailed information. The chain (± 1,5 m and ± 5-6 kg) provided stability and kept the array in balance to hover it over the sea bottom. A drop weight (± 10kg) was attached to the towline 10 m in front of the array to ensure that the array was kept at a forward and horizontal position. The drop weight was held at a height of 1-2 meters above the seafloor. It also provided some stability from the up and downward movements by wave action at the surface. The tow line, power and video cable were attached to each other at several points with tie-wraps. To prevent entanglement of the cables with objects or substrate. The power and video cable were given some slack together with small floats, to prevent bending in the power cable and video transfer failure. Depending on the depth the length of the towline was adjusted manually (Boman *et al.*, 2016).

At the start and end of each transect the date, location, depth and time were registered. The distance and coordinates of each transect were recorded with a Garmin GPSmap 78 (Garmin GPSmap 78, Garmin Ltd., Olathe, KS, www.garmin.com) by making a waypoint for each start and end point of a transect. Figure 8 illustrates the on field layout with the required equipment's on board for the live view. The settings of the GPS were set to track every 20 seconds for an accurate length of each transect. With the programs MapSource all transects were revised again to see the tracking trails. The exact time and date of the GPS and action camera were synchronized with each other.

Figure 8. *Live SeaView screen setup on the boat*

Video analysis

The recordings of each transect were converted into one AVI-format file using Xilisoft video converter (Xilisoft Corporation, San Diego, CA, www.xilisoft.com). After converting the videos, they were analyzed using TransectMeasure (SeaGIS Pty. Ltd., Bacchus Marsh, VIC, Australia, www.seagis.com.au 2014). For the software TransectMeasure an attribute table containing all species of conch, reproductive information, substrate type, benthos and several other specifications (Appendix I). All analyzed from start until end to identify all conchs within the lasers. Each conch inside the transect was marked and correct information from the attribute table was added. After completion of all transects, all information of each conch was transferred into Excel for further analysis.

Habitat analysis

After the analysis of conch species and count, the same video was used to do the habitat analysis. The habitat analysis was done in TransectMeasure. The start time of the transect was subtracted from the end time. This would give the total length of the transect in the movie. Each movie was divided in 20 sections, where each section contained 10 dot points. Every point was analyzed and substrate type and benthos were determined.

2.3 Frame survey

The frame survey was done to register all conch fishing vessels to keep track of the conch fleet. Every month the list for the survey was updated with the name of the vessel, owner's name, home port of the vessel, type of fishing gear, length of the vessel, number of crew members, man or machine powered, out- inboard engines, the number and horse power of each engine and if a depth finder and GPS were present onboard (de Graaf *et al*., 2012; de Graaf, 2014).

2.4 Boat activity survey

The Boat Activity Survey referred as the Boat Activity Coefficients (BAC) represented the probability that a fishing vessel was active on any day of the month. The BAC consisted of the fishing vessels that were registered in the frame survey. Daily monitoring took place where the date, vessel name and activity was noted for each boat. A second sheet was used to register the date, home port, number of conch vessels within the port and how many of the fishing vessels were out fishing.

2.5 Short interview

A short interview was done to collect fisheries catch data. A series of questions were asked about their daily catch when the fishermen returned to shore. The fishermen were approached in an informal way, and the conversation was adapted to the atmosphere to make the fishermen feel more at ease. The questions were related to the location of fishery activity, number of tanks used (if SCUBA), depth of fishing area, estimated weight (kg) of both cleaned and uncleaned meat, amount of conchs caught and if any other species were caught (de Graaf *et al.*, 2012: de Graaf, 2014).

2.6 Fisheries catch survey

The fisheries catch survey was used to gain information (lip thickness, shell length and sex) of each conch caught by a fishing vessel. The fisheries catch survey was done three times a month within study period of 2015. Usually, the fishing boats are manned by two crewmembers and fishing occurred using SCUBA gear with a dive limit of approximately 30 m (100 ft.) (DFMR, 2014). Onboard a random sample was measured in the instance that the total catch was not able to be measured. Most of the conch shells were measured for the lip thickness and shell length with a small (150 mm HEGATEX) and big caliper (usually used to measure turtles). The shell length was measure from the apical of the shell to the siphonal groove (Figure 9). The lip thickness was measured in line with the spikes where the caliper was held flat. After removal of the meat, the sex for each conch with its corresponding shell measurements was determined (Figure 10). Occasionally, an individual showed both sexes and thus both were noted. The shells that were not measured on board were counted as numbers from the total catch. Afterwards a percentage was drawn of the measured conchs from the total catch.

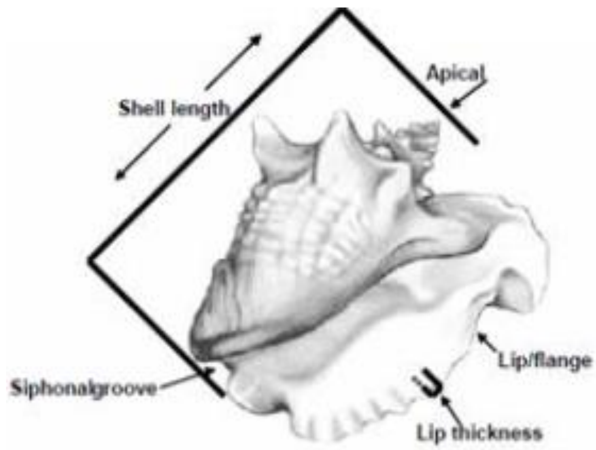

Figure 9. *places on where queen conchs are measured for the shell length and lip thickness*

Figure 10. *Pictures of (left) a female egg groove and (left) a male verge*

2.7 Data analysis

The data used for the analysis were from the study period September 2014 until December 2015. In total 126 surveys were done using the towed video array and 32 surveys by SCUBA diving. Transects varied in length from 73 m to 619 m and depth ranged from 3 m to 54 m. The number of *L. gigas* were calculated per hectare, only the live adult queen conchs with a flared lip were analyzed. The abundance per habitat was analyzed by habitat and depth categories used by Meijer zu Schlochtern (2014). The habitat types were categorized by the estimating the highest percentage of benthos coverage and substrate type. This resulted in three different substrate categories: soft bottom (if Sand >0,8%) hard bottom (If Sand <0,2%) and mix bottom (if Sand >0,2 - <0,8%). The three benthos groups were [1] 'Algae', which included the following species: red algae, green algae, brown algae, sargassum, *Dictyota spp*., *Lobophora spp*., *Halimeda spp*. and *Udotea spp.* The category [2] 'Mix' consisted of soft coral, hard coral and sponges [3] 'Seagrass' consisted of the following: seagrass, *Thalassia spp.*, *Syringodium spp*., *Halophila spp*. Native and *Halophila spp.* Invasive. These were added together to the higher groups and were analyzed together with the average density of adult conch/ha with a 95% CI. Finally, there were three benthos categories: seagrass (seagrass cover >0,49%), algae (algae cover >0,49%) and mix. For depth the following categories were given: <15m = 'Shallow', ≥ 15 – ≤ 29,9 = 'Medium', and >29,9m = 'Deep'. Analyses were done using the software environment R (R Development Core Team, 2016) with all data normalized.

3 Results

3.1 Distribution and abundance

The distribution of *L. gigas* was mapped to provide an overview of the adult conch densities around Anguilla (Figure 11). During the study period an area of 9,43 ha was covered in which a total of 126 points were surveyed with the towed video and 32 points by a dive survey. The overall mean density of *L. gigas* in Anguilla is 29,05 ± 5,49 (CI 95%) conchs per hectare. Results showed four locations (dark red) with the highest density of 200.1 – 350 conchs per hectare (Figure 12). Two of these areas were found in the northern part of Anguilla within the protect areas of Shoal Bay and Island harbor. The other two were found in the southern part of the island. All points were within the depth of 12 and 27 meters. Densities of 100.1 – 200 per hectare (red) were found at six locations of which four were found north and two south of the island. All within a depth of 12 to 22 meters. Five locations had a density of 50.1 – 100 conchs per hectare (brown) between the depths of 16 – 30 meters. Densities of 25.1 – 50 conchs/ha (light brown) were mainly found on the north and north-west of the island. Densities between 0 and 25 conchs per hectare (yellow) were mainly found north of the island. In 80 different sample sites no conchs were found within the transect.

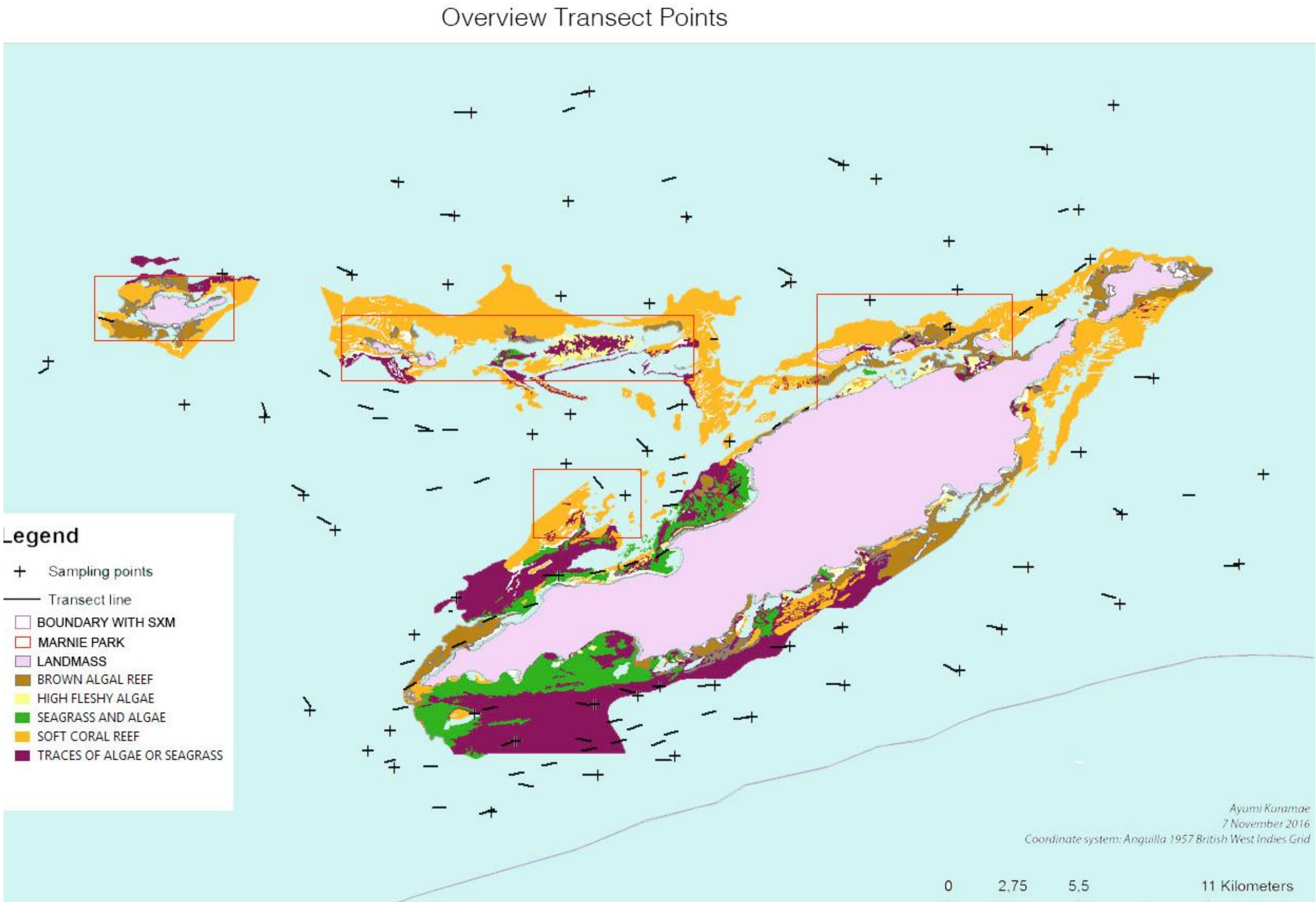

Figure 11. *Crossess represent the pre-set sampling points for the queen conch transects. Transect lines represent the transects done with a total length of approximately 500 meter and a width of 1 meter.*

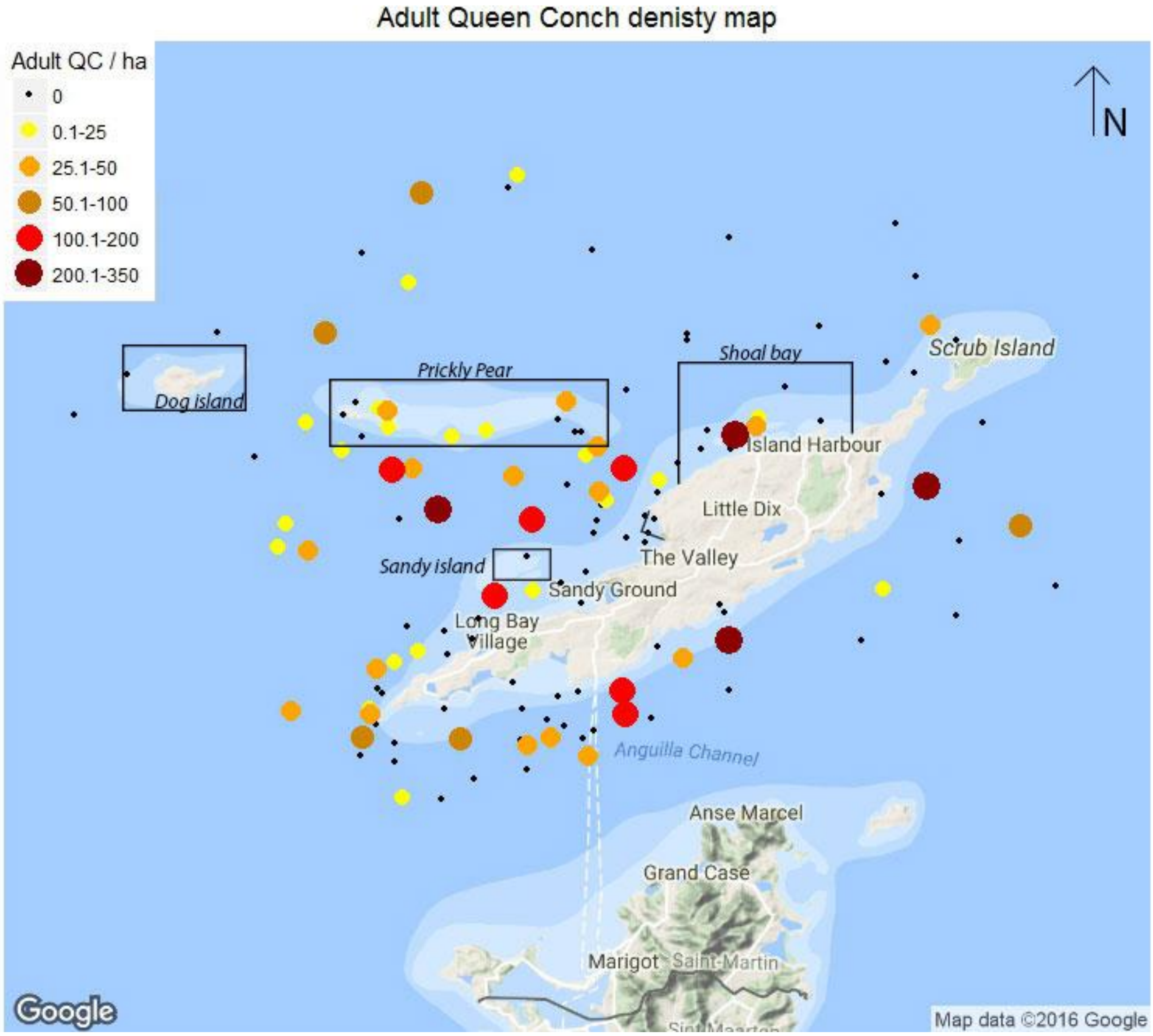

Figure 12. *A density map illustrating the live adult queen conchs on the sampled locations around Anguilla.*

3.2 Abundance per substrate, benthos and depth

Substrate and benthos

An abundance estimation of live adult queen conchs per substrate was done for the video survey measurements. The highest mean density of *L. gigas* was found on 'mixed bottom' 27.35 ± 7.43 (mean ± se). The second highest was on 'soft bottom' 25.59 ± 7.43. 'Hard bottom', consisting mainly of rock substrate showed the lowest density of *L. gigas* with 13.91 ± 4.80 (Figure 13). An analysis was done on three benthos groups found during the study (Figure 13 - A). Results showed that the highest average density occurred on seagrass beds with a mean density of 32,27 ± 11.08 (mean ± se) adults/ha. Second highest was found on 'Mix' benthos category with a mean density of 20,79 ± 5,74 adults/ha. Lowest density was found on ‘Algae’ habitats with a density of 17,44 ± 5.99 adults/ha.

A separate analysis was done to specify substrate types conforming reef, rock, rubble and sand (Figure 14) versus the density of adult conch/ha. Reef substrate cover results showed that higher reef cover resulted in a decrease of live adult conch/ha, whereas the highest densities were found at a reef cover of 0% (Figure 14 - A). Highest densities of adult conch/ha were found at rock covers ranging between 0 – 0.25% (Figure 14 – B). Results of the rubble substrate showed that adults conchs found during the study were frequently found on rubble cover of ≤ 50% with densities of *L. gigas* ranging between 0 – 350 per ha (Figure 14 – C). A high diversity of live adult conch/ha on sand substrates where the high densities were found over the 0.75% of sand cover.

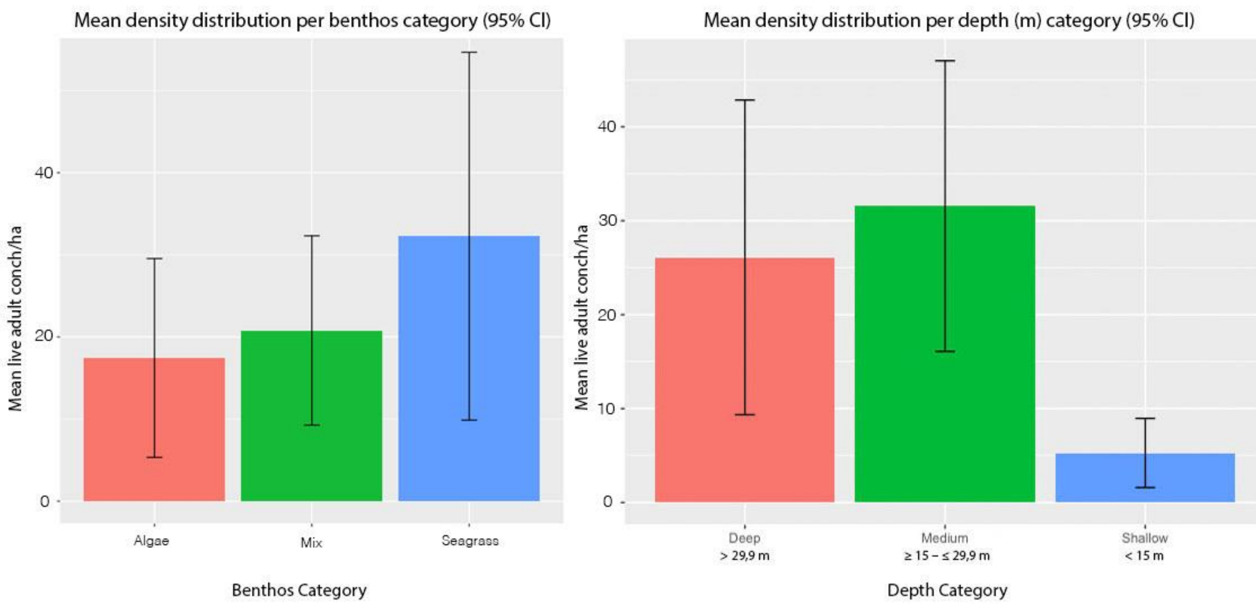

Figure 13. A*: Distribution of queen conch in three different benthos category. Highest densities were found on seagrass benthos.* ***B****: Distribution of the queen conch in three different depth categories. Highest densities were found in 'shallow' areas*

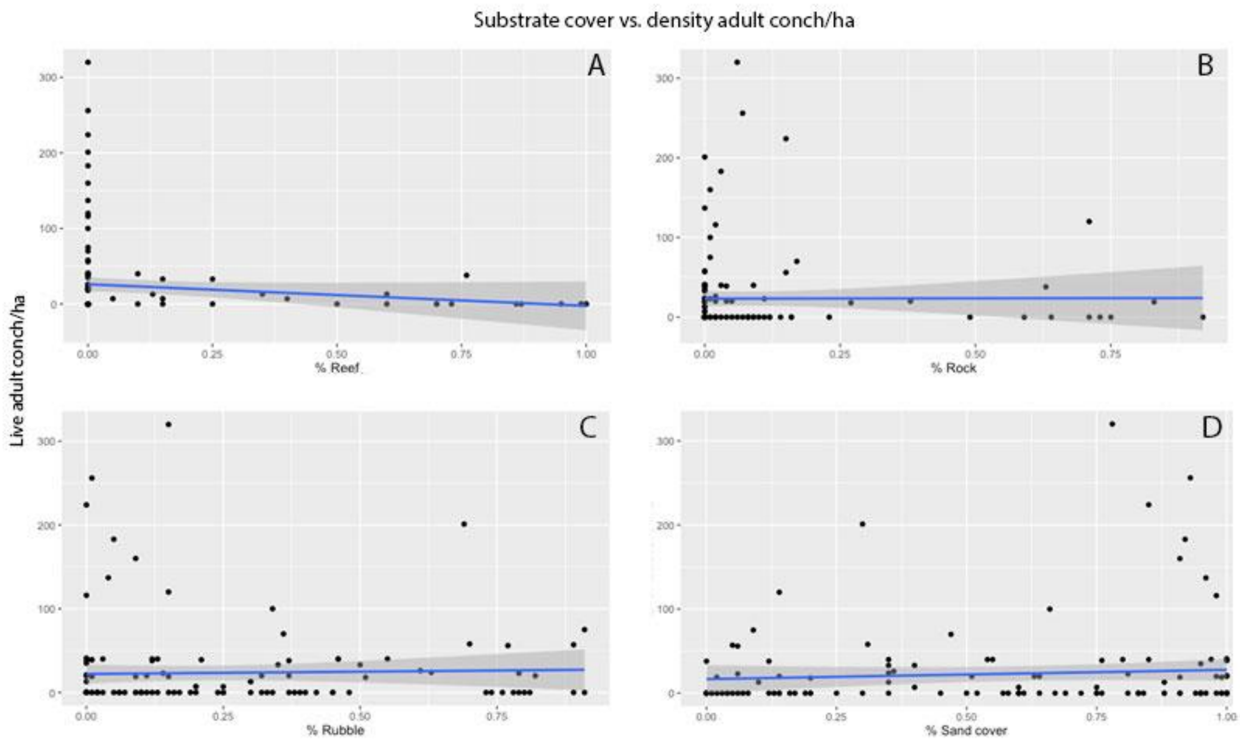

Figure 14. Densities of adult conch/ha shown on four substrate types recorded during this study (95% CI). **A**: low percentages of reef cover ranging between 0 – 0.25% showed the highest density of queen conch. **B**: high densities of adult conch of 0- 325 were found at rock cover ranging between 0 to 0.25% and between 0.62% and 0.75% with a density of 50 – 125 conchs per ha. **C**: Results showed a high densities of conchs/ha between 0 – 0.37% and from 0.70% - 0.90%. **D**: Highest densities of 100 – 350 adult conch/ha were found at sand cover ranging between 0.60% up to 1.00%.

Depth

Figure 13 - B shows that the majority of the adult live Queen conchs were found at a 'Medium depth' with a mean density of 31,56 ± 7.75 (mean ± se) conch/ha. In the category 'Deep' a mean density of 26,10 ± 8,19 conch/ha was found. 'Shallow' showed the lowest density of conchs/ha of 5,28 ± 1,81. A positive correlation was found between the density of conch with increasing depth (Figure 15). A linear model shows a weak positive correlation between the increasing depth and the abundance of conchs found. With the majority of the *L. gigas* found in depths between 20 – 35 meters.

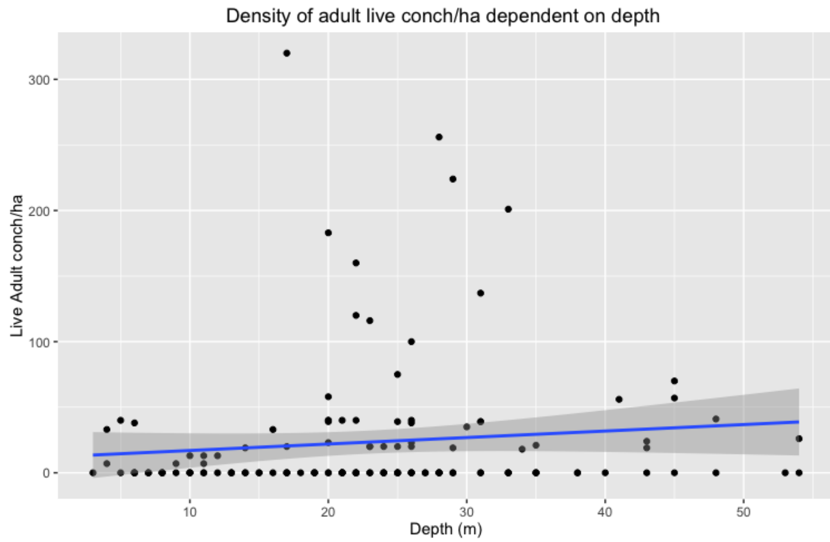

Figure 15. *Linear model of density of live adult queen conchs/ha dependent on depth*

3.3 Population size structure

Size frequency

The data used for the size frequency of *L.* gigas in this study were derived from fisheries landing. In total 554 females and 440 males were measured on their shell length (SL) and lip thickness (LT). Unknown sexes and individuals that showed both sexes were excluded from these measurements. Figure 16 - A shows the frequency of SL per sex. Female *L. gigas* showed an average of 22,42 ± 0,05 cm (mean ± se) and males showed and average of 22,32 ± 0,07 cm. In terms of LT, female *L. gigas* showed an average LT of 12,85 ± 0,24 mm (mean ± se) and males showed an average LT of 13,21 ± 0,27 mm (Figure 16 – B).

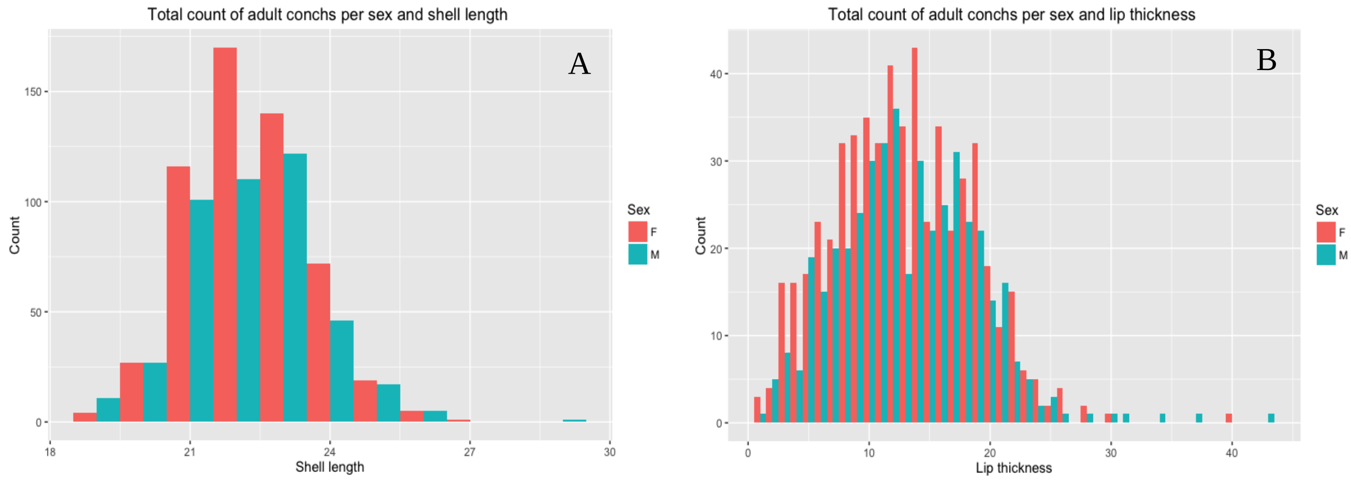

***Figure 16. A**: count of adult conchs per gender of female (F) and male (M) in shell length. **B**: total count of different genders of conchs in different lip thickness categories.*

Catch effort

The conch fishing fleet was observed daily on boat activity, except for the weekends. Two of the nine fishing vessels were the most active of which one would go out for fishing for approximately four days a week. With each SCUBA tank a basked that fits approximately 20-25 conchs were filled. Most fishing activity occurred at the southern side of the island towards St. Maarten and a couple of other fishing trips took place towards Dog Island. Two fishermen were recorded to be actively fishing on *L. gigas*. The fishing trips were recorded through the research period from which the catch was measured and recorded. A single trip of a fisherman resulted in an average of 275 conchs per fishing trip. Results of the boat activity count (BAC) were used to estimate an average fishing activity through the study period. Results showed an average boat activity of 19,00 ± 2,15 days per month (mean ± SD), this is 228 days of fishing activity by all boats in a year. The total annual catch of conchs would be 139,496 conchs.

The submerged plateau of Anguilla is 200 000 ha. We removed the reef areas and all landmasses including the offshore cays from the total submerged plateau. The resulting surface area of the submerged plateau is 80 900 ha. If we would extrapolate the average conch found per hectare through the remaining submerged plateau, this would result in a conch stock of 2,350,015 in total. The total catch yearly is estimated to be 139,496 conchs. Meaning that the estimated annual catch of the fishermen is 6% of the total estimated mean adult conch stock. With a low confidence interval, the conch stock would result in 1,906,061 and an estimated annual catch of 7% of the total stock. A high confidence interval results in a conch stock of 2,793,969 with an estimated annual catch of 5% of the total stock.

4 Discussion

QUEEN CONCH DENSITY AND DISTRIBUTION

The queen conch density in Anguilla is lower compared to other study sites in the region. For example, St. Eustatius showed a mean density of 56 conchs/ha in their diving data and 115 conchs/ha in their towed video data (Meijer Zu-Slochtern, 2014). However, Stoner & Ray-Culp (2000) showed that no mating nor spawning was recorded at means densities of less than 56 adults/ha. Whereas in Anguilla, 29 adult conchs/ha are found which is almost half of the recommended minimum density of 56 adult conchs/ha by CITES and Stoner & Ray-Culp (2000), and mean density of 100 adult/ha or higher (QCEWR, 2012). This indicates that in many locations the conch population of Anguilla is too low to ensure successful reproduction which can replenish the stock. In Antigua and Barbuda, Tewfik *et al.* (2001) found even lower densities of adult conchs/ha, of 17.2 conch/ha (78.4% were juveniles) and Valles & Oxenford (2012) found densities of 4.3 - 14.4 conch/ha differing per west or south coast of the island, in comparison to Anguilla. Furthermore, in St. Eustatius more sites with densities of 200 – 350 conchs/ha and Cuba showed densities of 520 conchs/ha (Cala *et al*., 2013). While in this study, four sites were found with the highest density of *L. gigas* (200 – 350/ha), meaning that these are the areas that queen conchs are able to successfully reproduce and will be important to maintain for the future of the stock. It is known that the sites of high density in Anguilla are not targeted by fishermen in Anguilla (pers. com.). One site was found within the marine park area of Shoal Bay/Island Harbor. Shoal Bay marine park could be addressed as an important spawning area of queen conch. The other three areas of high density were found in the North of Anguilla, and two other sites in the South of Anguilla. These sites are also known to be outside the fixed fishing grounds of fishermen. Fishermen in Anguilla tend to keep targeting their ‘own’ fishing areas. Although these areas with high densities are not targeted by local fishermen, they are highly important for the reproductive success of the queen conch population in Anguilla. The high density of adults per hectare are very important, since queen conch can only move approximately 0.8 km per month (Ehrhardt & Valle-Esquivel, 2008), which is a critical movement in order to find possible mating individuals during mating season. Because *L. gigas* have slow movement and need physical contact for copulation and egg production, maintaining populations at high densities is necessary for successful reproduction. As for Anguilla, at low densities, reproductive opportunities are lost to the time necessary searching for mates (CFCM, 1999). Areas with 50 – 350 conchs per hectare should be carefully treated since if they occur in shallow waters, the conchs are easily targeted by fishermen using scuba gear of freediving techniques. Making the species more vulnerable to exploitation. Given the distribution of the queen conch are relatively low in shallow waters in comparison with ‘medium’ and ‘deep’ waters, could mean that the shallow areas have been already overexploited by fishermen.

Density distributions are influenced by depth and habitat (CMCF, 1999). In this study the highest densities of conchs/ha were found on seagrass beds communities. The abundance of *L. gigas* was higher in ‘mix substrate’ followed by ‘soft substrate’. This can be related to the type of benthos growing on the substrates on which the queen conch fed on. High sand cover showed a higher density of queen conch per hectare, as rubble cover increased queen conchs were found at relatively high densities up until 30% of rubble cover. The type of substrate found in this study corresponds with the substrate seagrass species prefer to grow on (Randall, 1964; Duarte, 1991; Delgado, 1999). Furthermore, seagrass beds are known to be influenced by nutrient input, sea temperature changes and algae cover (Orth, 2006; Barbier, 2011; Duarte, 2013). For example, the increased nutrient input or sedimentation in Trinidad (Appeldoorn & Bakker, 2013), habitat destruction in Montserrat (Posada *et al.*, 1997) which all lead to a decline in seagrass were related to the lower conch densities (Stoner, 2003). The adult conch densities found in deeper areas in Anguilla can be explained by the limited distribution of seagrass meadows (Schweizer & Rosada, 2002) since light penetration is limited at certain depths. The exclusion of reef systems for this research has little to no impact on the population structure since reef habitat are usually not preferred by the queen conch (Acosta, 2006).

POPULATION SIZE STRUCTURE

How is this in relation to other locations and how is that important to reproduction? Which sites with lowest do you recommend with lowest density for harvesting?

In this study the average size of females was slightly bigger than males, the same was observed during other studies done by Randall (1964) in the US Virgin Islands and Appeldoorn (1994) in the Bahamas. The average SL of ♀22,42 cm and ♂22,32 cm and an average LT of ♀2,85 mm and ♂13,21 mm is slightly smaller than the measurements of the study done by van Rijn (2013) in St. Eustatius. Van Rijn found the average SL of the queen conch in St. Eustatius were 25 cm and an average LT of 22 mm. Meaning that the fishermen in Anguilla are targeting the mature conchs aging older than three years (Figure 17) (van Rijn, 2013) (Meijer Zu-Slochtern, 2014). The morphology of *L. gigas* are known to be influenced by the habitat they occur in (Alocado, 1976; Meldey, 2008). In this study the majority of the conchs were found in a mixed bottom consisting of sand and rubble, which could influence the erosion rate of the shells (Medley, 2008).

Life stage	Siphonal length (cm)	Flared lip	Age (years)
Juveniles	<10cm	no	1-2
Intermediates	>10 cm	no	2-3
Adult	>19cm	yes	>3

Figure 17. *Classification of three different life stage of L. gigas classified by siphonal length and the corresponding age (Stoner and Davis, 2010).*

A small number of juvenile conchs were found during the study from the catch data. This is explained by the sizes that fishermen target conchs that are commercially attractive. From the towed video data only a few juveniles and intermediate conchs were determined. Medley (2008) reported that juvenile conchs are buried in soft sand during their first years and through daytime (Randall, 1964), therefore, making them undetectable during the study. Moreover, their sizes are less than 10 cm (Stoner and Davis, 2013) which makes it difficult to analyze the on the video data. Study done by Schweizer & Posada (2002) recorded more adults rather than juvenile or intermediate sized conchs. The low amount of juvenile conchs possibly indicates low recruitment of young conch. *L. gigas* are known to reach mature size in lip thickness however it does not necessarily mean that the mature adults are ready to mate. Meaning that although fishermen are targeting mature conch it does not mean these conchs had or are able to reproduce. Moreover, the mean age and size at when the flared lip starts to form, varies within regions. In St. Kitts and Nevis it is estimated that maturation starts between 2.3 – 2.8 years (Wilkins *et al.*, 1987), whereas in Bermuda and Belize the maturation is only between 3.5 - 4 years (CFCM, 1999). It should be also taken into account that currently due to ocean acidification, the shells of *L. gigas* are more porous or weaker than before (Doney, 2006; National Marine Fisheries Service, 2014), thus more sensitive to erosion, which may create a bias in the lip thickness measurements to estimate mature size.

Because of the rate of shell erosion, as Medley (2008) has reported, it is hard to differentiate the dead queen conch shell from the complex structure on high complexity habitat (Boman *et al.* 2016). Growth of periphyton and epiphyte on the shells makes it even more difficult to differentiate the shells from their habitat or to establish if individuals are still alive. It is highly important to be able to distinguish between live and dead conch to produce reliable density estimates for the queen conch management (Ehrhardt & Valle-Esquivel, 2008). However, newly published research (van Rijn, 2013; Boman *et al.* 2016) on the towed video methodology used in this study proved to be accurate enough and does not lead to overestimation.

CATCH EFFORT

Total catch effort was based on mainly two fishermen that cooperated with the study. Other fishermen that are part of the conch fishing fleet have been reported to be active in fishing but not necessarily targeting queen conchs. There was a difference in boat activity, the number of divers and the number of dive between fishermen. This could have led to an underestimation of the fisheries since only two fishermen provided the study with data and it is unknown if the remaining fishermen were also targeting the queen conch. However, the data derived from the landings showed higher numbers of queen conchs caught with a shell length of approximately 23 cm (Figure 16). It should be taken into account that fishermen target thick lipped conchs of approximately 13 mm which are commercially more attractive. Fishermen from Anguilla seem to be targeting conchs with a relatively smaller lip thickness in comparison with conch fish data from St. Eustatius with an average lip thickness of 26 mm (Meijer zu-Slochtern, 2014). This could be attributed to the fact that St. Eustatius has a greater stock numbers with different size classes in comparison to Anguilla. Therefore, fishermen in St. Eustatius are able to for bigger individuals as seen in the study from Meijer zu-Slochtern. For an additional project, during the study data of gonad samples were collected. Thick lipped shells above the category of 24 mm in lip thickness were not found. Moreover, the higher numbers in females found in this study can be related to the shell size of females to be bigger than males which are in turn targeted by fishermen. Size differences between sexes has also been reported by Randal (1964).

An average of 278 conchs per fishing trip was recorded with an annual catch estimated to be around 2,350,015 in total. The estimated annual catch represents an average of 6% of the estimated conch stock, twice as much as from the study done by Meijer zu-Slocthern in St. Eustatius (2014). Compared to a study done in the Bahamas by Stoner & Davis (2010) where a stock was estimated to be 2,11 million adults in an area of 31,353 ha, which is still in higher densities than Anguilla. The estimated annual catch is just below recommended fishable biomass of 8% for sustainable fishing yield set by the Queen Conch Expert Workshop (2012). Meaning that the conch fishery of Anguilla shows a sustainable yield based on the estimated mean stock.

MANAGEMENT

Since Anguilla is part of CITES since 2014, the export of any specimen listed in Appendix II requires the prior grant and presentation of an export limit. An export permit shall only be granted when conditions have been met listed under Article IV. This includes that a Scientific Authority of the State of export has advised that the export of the species is not detrimental for the survival of that species. In the case of Anguilla, the current fishing pressure on *L. gigas* is close to being detrimental. A revision of export permits should take place, since it has not been recorded that any of the fishermen showed a permit for exportation to the surrounding islands (pers. comm., 2015).

The current regulations set by the Department of Fisheries and Marine Resources should be revised in order to support the conch population in the Anguillan waters. To ensure maturity, studies (Avila-Poveda & Baqueiro-Cardenas, 2006; Aranda & Frankiel, 2007; Mueller & Stoner, 2013) have shown that lip thickness is the proper way, or management tool, for assessing the maturity of a conch. Currently, the management regulations set by the DFMR are based on shell length and total weight of meat. However, by retrieving the meat of the conch the animals are already killed and too late to be assessed if the individual is within the measurements set within the regulations. Moreover, shells are not landed nor are any officials present on the boat during fishing, therefore making it hard to monitor. Besides, fishermen will not target undersized queen conchs since they are not economically attractive.

Hoggarth (2001) mentioned in the Anguilla Marine Parks Management Plan that: "*No clear statement has been defined outlining the goals and objectives of Anguilla's marine park system."* When the five marine park boundaries were set, their main goal was to protect the sensitive benthic communities from anchorage damage while access was still granted to tourists and fishermen and other recreational use. The same report stated that: *"...protected areas may serve two main objectives: (1) conservation of biodiversity (both for nature in its own right, and for its potential use to humankind), and (2) for increasing productivity. If fishery productivity is the main objective, a marine park may be best set in the most highly degraded area or in a spawning site. If biodiversity is to maintained, the most pristine and diverse habitats may be best protected."* As for the conch conservation of Anguilla, objective number 1 would be the most suitable since during the study it was observed that close to Meads Bay at a depth of approximately 3 to 5 meters many juvenile queen conchs were spotted during a snorkeling trip in the months of September – October 2015 (pers. obs.).

5 Conclusion

The queen conch stock is low in the waters of Anguilla. The mean adult conch/ha is 26 and is nearly half of what CITES recommend and much lower than recommended by other studies in the Caribbean (Stoner & Ray-Culp, 2000; QCEWR, 2012). A total mean of 2,350,015 ($1.91 \times 10^6 - 2.79 \times 10^6$), *L. gigas* is estimated to be found in the 80,900 ha submerged plateau of which an annual catch of 6% of the total stock has been estimated. These number are just below the recommended fishable biomass of 8% of the Queen Conch Expert workshop. The low density numbers found during this study should have fishery management strategies to focus on setting quota for fisheries or harvest restrictions on adult conchs based on lip thickness instead of the current shell lengths of 180 mm, since lip thickness has been proved to be the most effective way to assess maturity in conch. Moreover, the biology of conch suggests that it takes more than 3 years to reach maturity size. The effective fishery management tool is the establishment of networks of marine reserves and reinforcement (Kay & Alder, 2005), in which high density areas are protected to maintain and support population densities. The current MPA's established in Anguilla were not established as a queen conch management tool. However, the persistent depletion of low density areas will result in a low recovery rate of the population on those areas due to the limiting numbers of adult conchs for possible mating. Quota will help the population to stay in balance and prevent the decrease on size and sexual maturity. Effective enforcement is essential and requires patrolling of national waters, especially since Anguilla is a member of CITES and special permits are applicable for the export of conchs to other countries (e.g. St. Maarten which is part of the Dutch Caribbean). Assistance from external agencies, or DFMR, is needed to strengthen the fishing regulations that Anguilla currently holds. The current MPAs established in Anguilla were not established as queen conch management tool other than to prevent the anchoring damage of sensitive habitats, thus, should be revised for effectiveness, goals and criteria. The abundance of *L. gigas* depends on the habitat and depth since the conch abundance is higher on the sand habitats with seagrass beds. Additionally, the abundance of conch is higher in medium depths compared to deeper or shallower areas, which can be explained by the fishing pressure or depletion on shallow waters which are easily accessible by fishermen by SCUBA gear. The recorded population consists of thick lipped adults with an average of LT 12,6 mm, which is above the minimum for the reproductive behavior of 9 mm for males and 12 mm for females (Stoner *et al.,* 2012). More research is necessary to qualify the fisheries catch data from fishermen and precise monitoring of boat activity needs to take place. It should be taken into account that the establishment of temporal closures should be considered in order to support the queen conch abundance in Anguilla. Closure of the conch fisheries for a certain time frame has proven to have a positive effect on the conch population abundance per hectare in Mexico in 1995 (Vasquez, 1995), and should be considered for Anguilla in order to keep the population numbers high to support overall population. Therefore, monitoring conch population densities is vital to the long term sustainability of the species around Anguilla. The results of this study suggest that a small scale fishery can operate sustainably in Anguilla. However, due to the relatively few locations with high densities of adult conch, which would allow for successful reproduction, the fishery needs to be closely monitored to ensure that a decline in population density does not occur. Furthermore, any expansion in the current fishery is not recommended. Identification of reproductive peaks, nursery and spawning areas throughout the year would allow for a more in depth knowledge of the population characteristics. With increased knowledge of the population characteristics of L. gigas in Anguilla, management policies can be adapted and applied to prevent overexploitation of the species and to maintain a sustainable small-scale fishery on the island.

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7 Appendix

7.1 Appendix I – Protocols

7.1.1 Protocol for video array and additional equipment and programs

Protocol video transects

This protocol is written by *L. Ayumi Kuramae Izioka* based on the latest project carried out in the period of July-December 2015, which resulted in 126 successful transects for the research or the Population status and reproductive biology of the Queen conch *(Lobatus gigas)* in the coastal waters of Anguilla. Supported by previously written protocols by *van Rijn* (2013), *Koenen* (2014) and *zu Slochtern* (2014). The most recently used equipment for the research is the SeaViewer model Super Mini with a cable line of 200 metres. GPSmap78 Garmin, GoPro Hero4 Black Edition.

Everyday checklist

- ☐ **Array** with the live-view **cable** and the **towing line** attached to it
- ☐ **Drop-weight** (concrete block of 20kg) and the **drag chain** (approximately 1.5m)
- ☐ **GoPro camera** in waterproof case (including all extra batteries, SD cards, red filters, the anti-fog pads and fishing line)
- ☐ **Live-view** camera surface console case
- ☐ **GPS**
- ☐ **Fresh water** (to rinse) and a **towel** to dry off the lasers and GoPro before changing batteries
- ☐ **Fishing line (X-WEIGHT BEING ABLE TO CARRY)**
- ☐ **Notebook**
- ☐ **Spare batteries** for the GPS and lasers
- ☐ **Pencils**

Preparation (either on board or at the office) *highly recommended doing this before loading all equipment on the boat*.

1. Lines of the array should be checked for robes and if everything is still good and firmly connected (e.g. the cable output from the camera on the array). If the towig rope is attached to the cable, there should be enough slack in it.
2. Check the GoPro holder if both mounts fit and if there is still a clear "click" sound when the GoPro is being attached. If not, replace one of the mounts that is causing the problem.
3. Check all the duct tape on the array, where loose replace it.

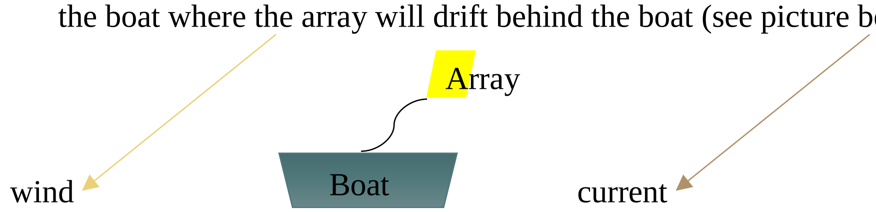
4. Double check checklists and make sure enough spare batteries are brought along.
5. Check if fishing lines on the chain are still strong enough; it should not have any dents in it. If the fishing line is in any odd shape it should be replaced immediately. The same thing should be done for the GoPro security lines. There should be at least 2 fishing lines as security for the drag chain for preventing it from getting stuck and losing the whole array. The line must be strong enough to hold the chain, but "weak" enough to snap when the array gets stuck and is pulled up.
6. Make sure the attachments of the SeaView are still firmly screwed onto the array, if not adjust it. The position of the SeaView should be just on the left side (when facing the back of the array) of the GoPro and be able to see the left laser on the screen. A test with the live-view should be carried out in order to see if the GoPro is just on the right side of the live-view. This will provide an image where the GoPro is visible and has not gotten loose from the array.

Transect *(this part is based on a teamwork of 2 people)*

1. The chain should be attached to the shackle by using the loops of the fishing line. (ADD PICTURE).
2. The SeaView should be attached to the live-view. The connection cables are in a small transparent box with a bleu lid. Make sure to always have the box closed at all times and away from splashes of seawater. It may **never** get wet.
3. Before placing the GoPro make sure it is set to the right settings (see 'Protocol for GoPro'. The GoPro should be attached on the mount placed on the array with the safety fishing line in the shackle (together with drag chain). Be sure to check that the fishing line is not stuck between the GoPro housing to prevent it from getting water damage or flooding.
4. The GoPro should be pulled to the back, where 1 finger will still fit between the array and the float. This will give the GoPro the perfect angle to the seafloor.
5. Both lasers should be checked on sharpness and brightness. If one of them seems weaker than the other, the batteries should be replaced. Preferably they should be at the same height, if one is a little diverted this should be fine, however, the right laser should still visible on the live-view (when the cameras are facing you). If lasers are being displaced too much by the water movement they can be secured with cable ties in a cross-form.
6. The live-view camera should in the meantime be attached to the SeaView and the view of the SeaView should be checked if correctly placed *(see 'preparation – point 6')*
7. The following data should be written on the notebook:

SD #	Date	Location	Transect #	Waypoint Start	Waypoint End	Time Start	Time End	Depth Start	Depth End

8. The captain should drive the boat upwind of the coordinate made on the GPS. In this case, depending on which side of the boat the array will be towed, the captain should turn the boat where the array will drift behind the boat (see picture below.



9. Check the depth before you start preparing the array. Do not tow in areas where the depth is any deeper than 60m *(this is the maximum depth for the GoPro)* or reef areas.
10. Turn on the GoPro and check if it is set to the video/recording mode.
11. Start recording, double check if the GoPro is recording by lifting up the array and the red indication light for recording is blinking.
12. Make sure to check all the lines before putting the array in the water. Any entanglement will cause the array to lopsided resulting in a failed transect.
13. Carefully lift up the array with the drag chain and make sure the chain does not damage the boat when lifting over the side into the water. Check the lines if they are not tangled or wrapped around one of the lasers. When the array is put in the water it should fill itself with water and slowly start to sink.
14. Give rope and let the array sink. Once the rope has reached the attachment for the drop-weight, make sure it is secured properly with (preferably two) shackles. Lift it over the side and carefully let it sink in the water. *DO NOT THROW*.
15. Let the drop-weight sink till it reaches the sea bottom; often this will be visible on the live-view. When it reaches the bottom, pull it back up for about 1m.
16. Check if the array is on the correct height from the bottom by using the laser mark on the live-view screen. If the laser is too much to the middle of the screen; lower the array down, the opposite has to be done if the laser is too much to the side of the screen.
17. When the live-view provides a good view, with the lasers at the correct position on the screen and correct habitat; transect could be started by making a GPS waypoint. Note this down as mentioned in point 7.
18. Let the boat drift during transect, if needed drive the boat with a speed of 0.5 knot.
19. Monitor the live-view camera during transect, if needed adjust the height of the array by pulling it up or lowering it down. Be careful with reef structures, this will cause the chain to get stuck, loose the chain or damage the array.
20. If any rocks or small patch reefs is approaching, make sure to pull the frame a few meters up to avoid getting stuck with the drag-chain, the array can be lowered down when these have passed.
21. If the array gets stuck, the captain will turn the boat in such a way that it should give a bit of slack in the rope to give the array a chance to free itself. In worst case the fishing line of the drag-chain will snap and the array will slowly float to the surface.
22. Monitor the GPS by placing the arrow on top of your 'Waypoint_Start' and on the top-left of the GPS screen it should give how far you have drifted away. When reaching approximately 500m the transect can be ended by making a new waypoint. Make sure to check the depth and the time the transect had ended.
23. Take your time to pull up the array. When the drop-weight and the array are at the surface, carefully lift it up on the boat.
24. Stop the recording of the GoPro. Check how much life the GoPro batteries still has and how long many hours/minutes are left to record. Turn off the lasers and camera between transects to save the endurance of the batteries. Where needed the batteries should be replaced. **Always** rinse with fresh water and dry the object it is being replaced with new batteries.
25. Move to the next transect and repeat from step 8.

- If reaching a habitat with hard substrate with sponges, it should be considered that you are either drifting away or towards a reef. Make sure to avoid damaging the sponges by lifting the array up on time. To continue transect you can lower the array down again.
- DO NOT tow in either a complex reef habitat or intermediate (patch) reef. If the array is almost at the bottom and it seems to be a reef habitat, it should be pulled back up. The captain can drive a few meters away to a habitat, which is favourable for transects.
- When the boat is driving to anywhere, make sure that the topside of the live-view case is down to prevent it from getting either wet or slam down.

Finalisation

1. When the captain decides to head back to shore, make sure that all of the electrical equipment has been turned off properly.
2. Disconnect the SeaView from the live-view and store the small electrical box safely away.
3. Rinse with fresh water the SeaView, lasers, GoPro and all other metal parts of the array.
4. Store all equipment together in a way that it is safely on the boat and preventing anything to fall down when the boat is moving.

Home/office

1. Charge all batteries follow the steps on *'Protocol for GoPro, GPS and lasers'*.
2. Make a copy of all the GoPro videos on the external hard drive before formatting the SD card. Make sure you always have a back up by copying the GoPro movies to another hard disk.
3. Copy the GPS waypoints to the external hard drive and import the tracks on MapSource program. Calculate the length of transect in the same program *(see 'Protocol for MapSource')*.
4. Read from the GoPro movies what time they have been created and the duration length of the movie by right click on the movie, followed by 'settings' where you will find the information needed.
5. Fill in all your data in the excel sheet provided.
6. Set the GoPro movies to be converted to AVI movies by using Xilisoft (see 'Protocol for Xilisoft'). Let this run overnight since it may take up to several hours to finalise convertion.

Recommendations

- Check the cable of the SeaViewer, once in every 2 days put WD40 on the cables and wipe it off gently with a dry kitchen paper towel. Try to get the rust and any other dirt off as much as possible.

- Check the small cable box, which is the connection between the live-view once every week or two to make sure that not too much corrosion has taken place. If needed replace the screws as soon as possible to prevent them from being difficult to get out.

7.1.2 Protocol for GoPro, GPS and lasers

This protocol is based on the GoPro Hero 4 Black edition with 9 rechargeable batteries, 5 SD cards (class 10), battery backpack, float, red filter and fishing line.

The GPS is a Garmin GPSmap 78 with 2 batteries in it and 2x4 extra AA batteries provided.

Lasers are (Z-Bolt, SCUBA-1, Underwater green laser; Beam of Light Technologies Inc., Happy Valley, OR, www.z-bolt.com). The same batteries for the GPS can be used for the lasers.

Always bring fresh water to rinse all electronical devices.

GoPro

1. Make sure all batteries are fully charged by using the dual chargers. Each of the batteries in the charger will have its own indicator lamp and should be ready to use when the light is green. If one of the batteries is low or empty the indication lights will show either orange or red. The GoPro batteries can also be charged in the GoPro itself by using the cables provided.
2. Make sure the GoPro is set to the correct time corresponding to the time given by the GPS. This should be as precise as possible to be able to make the video analysis more efficient.
3. There are a few anti-fog pads provided, 4 of the anti-fogs should be put in the housing of the GoPro (one on each side) to prevent blurring the recording.
4. The fishing line should be attached as an extra safety measure to prevent from losing it. The fishing line can be attached onto the backdoor and should be long enough to reach the shackle where the drag chain is attached to it. If any odd dents or whatsoever occurs on the line; it should be replaced.
5. The GoPro must have a (white) locking plug, which can be pressed in, to ensure that the mount piece is prevented from getting loose by friction and water movements.
6. The float should be attached to the back door and be able to stay without moving.

*The GoPro settings should be as the following: **1080p** with **60** frames/s, **Medium** view, **Spotmeter** on, **Protune** off, **Low Light** on.*

GPS and lasers

1. Batteries for the GPS, if rechargeable, should be charged with the charger provided.
2. The **2** batteries for the GPS should be good enough for **one** to **two** weeks (3 mornings of transects), this highly depends on how long and how often you go out for the transects.
3. Make sure that the batteries are for long endurance and, if possible, new ones should be bought from **Duracell**.
4. A set of battery for each laser should take long enough for a morning of transects. But make sure that they are replaced after **6** transects.
5. **Always** make sure to have at least **6** spare batteries with you on the boat in case one of the lasers or GPS may need earlier replacement.
6. Make sure to have a map printed with the remaining coordinates and the ones completed for transects. This way the captain will be able to discuss where to go and which one are/are not accessible. The map can be made with **Google Earth**.
7. Make sure that the same coordinates as on the Google Earth map is also on the GPS in order to track down the way to that point.
8. **Remember**: GPS should be synchronised with the GoPro!

*The settings of the GPS should be as the following: position format **hddd°mm.mmm'**, Map datum **WGS 84**, Map Spherold **WGS 84**, **WAAS**, correct **battery** indication (full), Recording interval: Most often (should be every 10sec).*

Home/Office

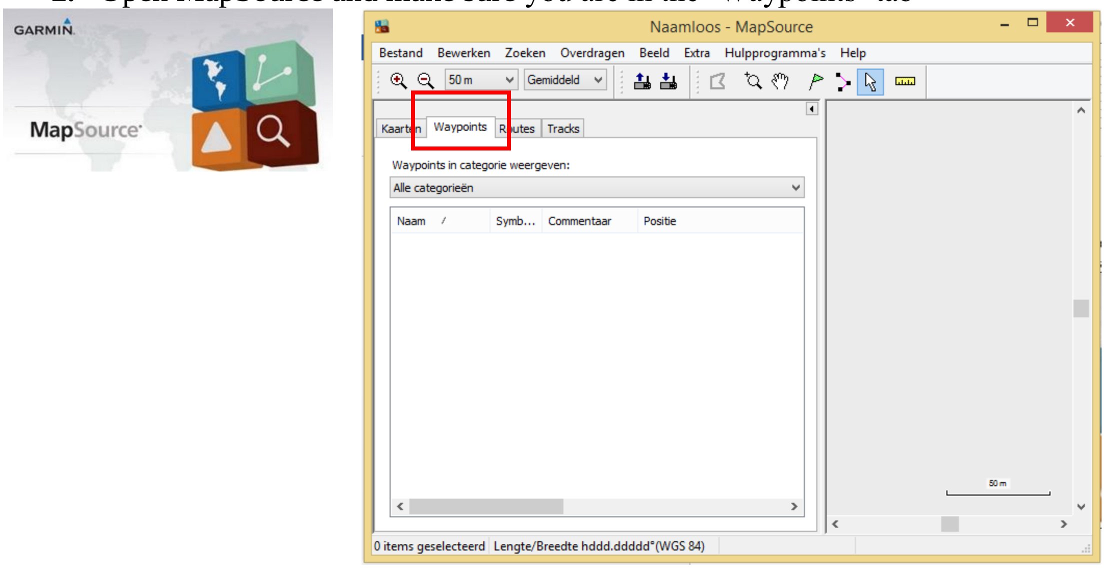
When all the equipment has been brought back to shore, the GoPro, GPS and SeaViewer should be taken back home.

1. Rinse the GoPro thoroughly in freshwater (e.g. sink).
2. If there are some remains of salt on the case of the GPS gently get a damp kitchen towel and wipe off the salt.
3. Transfers all GoPro video to the external hard disk by copy-pasting them. After all the GoPro videos have been transferred successfully, they need to be **checked** on the **quality** and **successfulness** of transects. If the videos are either of bad quality, transect failed or any kind of error, the movies need to be transferred again. If transects are either not good enough they should be classified as **failed** and be redone again. Only erase the videos from the SD card once all videos are transferred correctly.
4. After deleting the videos make sure to empty your trash and proceed by formatting the SD card.
5. **Always** eject the SD card safely.

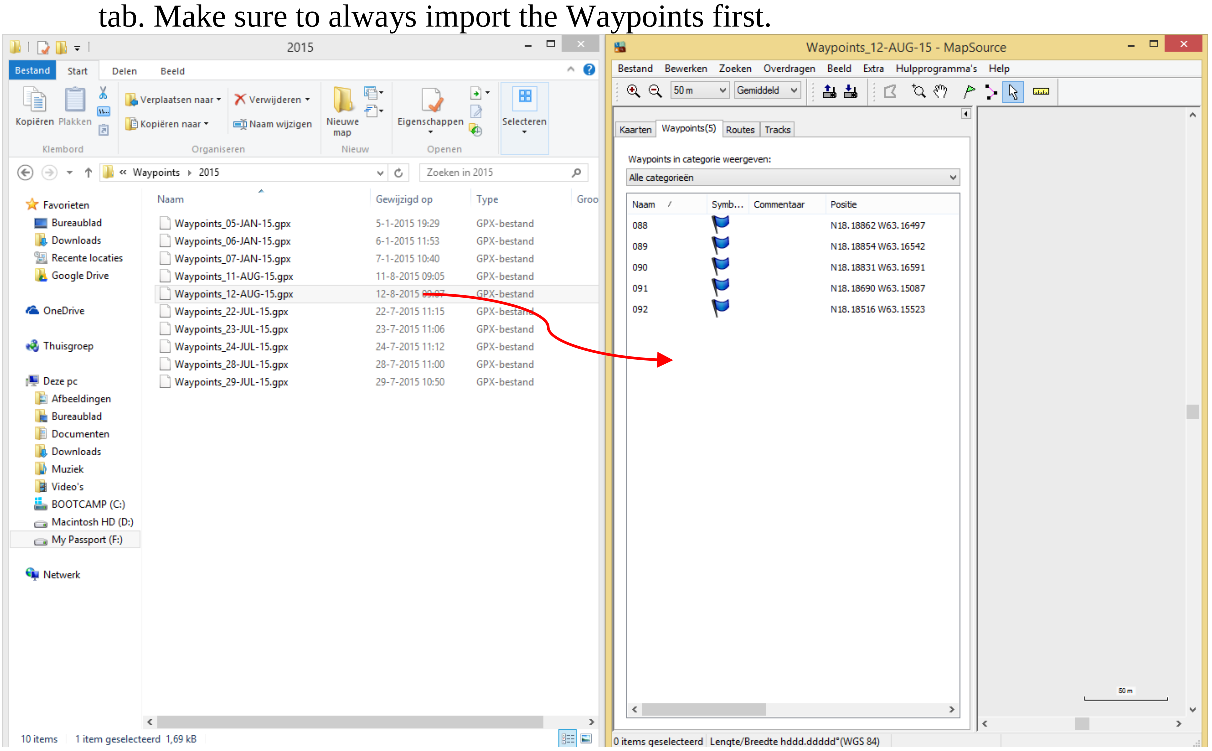
7.1.3 Protocol for MapSource

MapSource can be either downloaded form an external hard drive or by the website: http://www8.garmin.com/support/download_details.jsp?id=209.

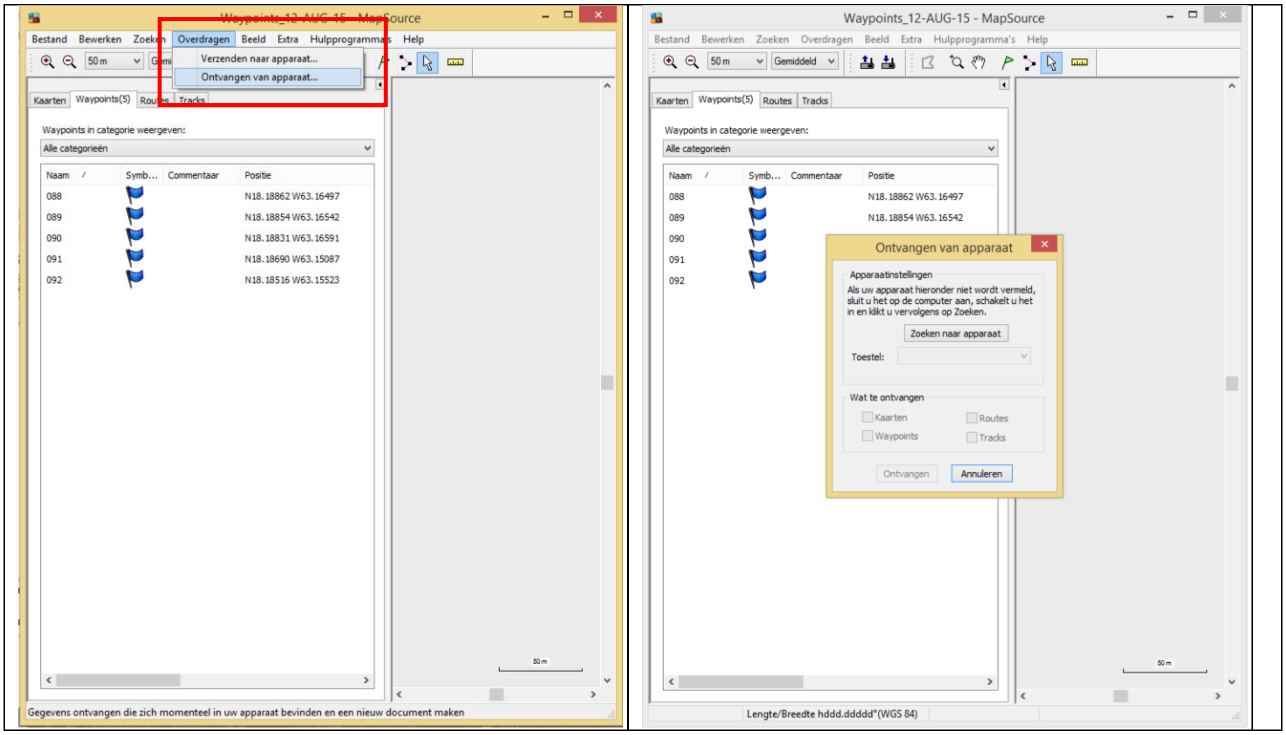
1. Plug in the GPS in the computer → open GARMIN → GPX
2. Open MapSource and make sure you are in the 'Waypoints' tab



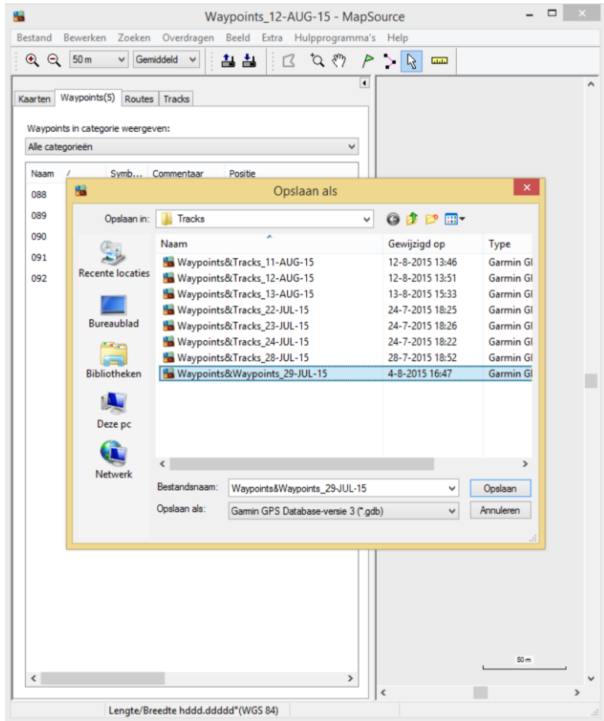
3. From the GPX map click and drag the GPX-file with the correct date to the Waypoint tab. Make sure to always import the Waypoints first.



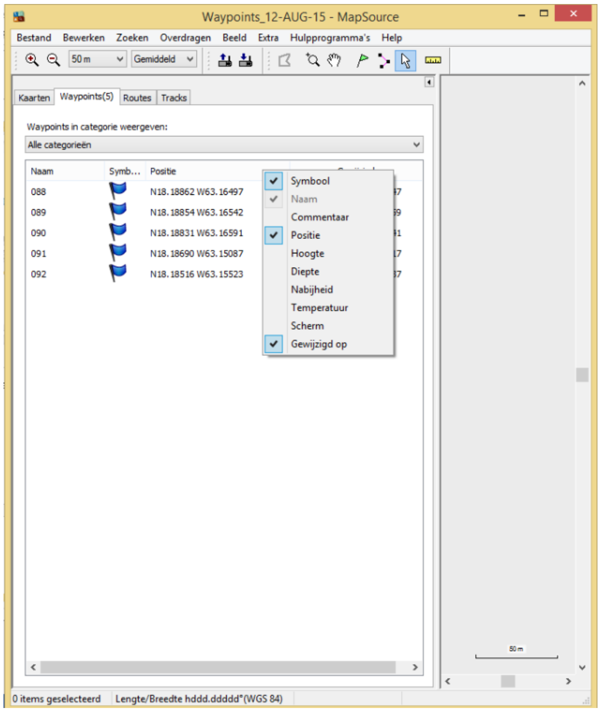
4. Switch in MapSource from Waypoints tab to Tracks. Go to ‘Transfer’ and choose for ‘Transfer **from** device’. If a new window pops up, click on ‘Ok’ and another windows should show up as on the right picture below. Make sure the ‘Tracks’ is checked and hit the button ‘Transfer’.

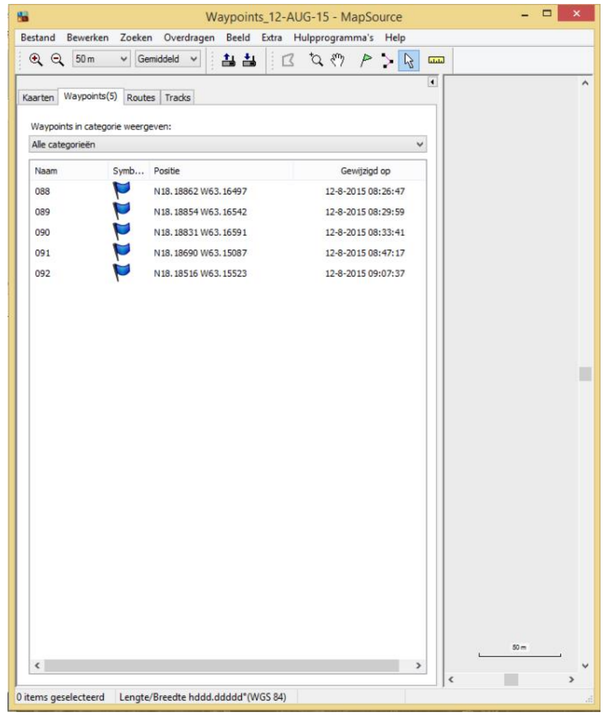


5. Make sure to save the tracks on the hard disk. Go to ‘File’→ ‘Safe File As…’→ External hard drive → the map where it should be put in→ name the file as the following ‘Waypoints&Tracks_DATE’ → ‘Safe’.

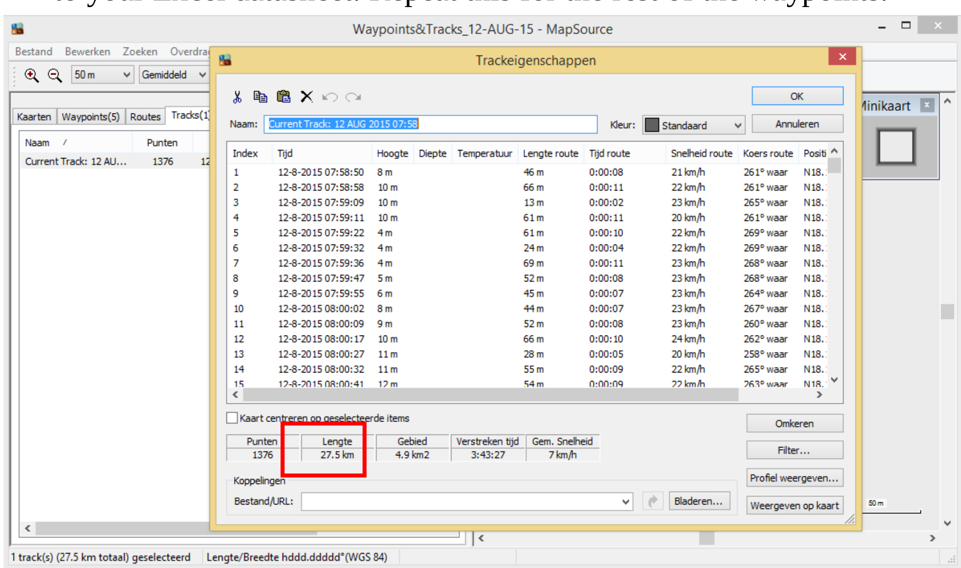


6. Going back to the ‘Waypoints’ tab, right click on the upper bar where the titles are given and make sure to have only the following checked: ‘Symbol’, ‘Position’ and ‘Last edited’ (see left image). This should give the same image as the right picture and from there the GPS coordinates and the time of the waypoints can be read and copied into the Excel datasheet.





7. **7.** Once your data for the coordinates, time of start-end has been filled in, use MapSource to read how long each transect was. Do this by going to the 'Tracks' tab and double click on the track with the corresponding date of your waypoints.
   a. A new window should pop-up with a title 'Track options'.
   b. Find the start time of your transect and select all of the other points till you reach at the end time of the transect.
   c. At the bottom of the pop up screen you will be able to read the 'Length'. Add this to your Excel datasheet. Repeat this for the rest of the waypoints.



7.1.4 Protocol for conch counting on board of fishing vessels

Checklist for equipment

- ☐ ***Datasheets*** *at least 2,* with the following:

Date: Boat:			Sorted/Unsorted: % Sampled of total catch:	
Sex	***SL_cm**	****LT_mm**	*****Flared Lip (1/0)**	******Landed (1/0)**

*SL = Shell Length

** ST = Lip Thickness

*** Flared lip = *1* Yes *0* No

**** Landed = *1* Yes (brought on board and not thrown back in the sea), *0* = No (brought on board but for any kind of reason thrown back into the sea)

- ☐ ***Vernier caliper***: used to measure the lip thickness
- ☐ ***Large sized caliper/ruler***: to measure the shell length

On board

This protocol is based on *three* people working as a team on board a fishing vessel. Tasks should be divided between the people to optimise the working efficiency and not slow down the fisheries process of the fishermen.

1. Once the pot with conch has been pulled up, one of the crewmembers will put them on the floor of the boat. At this point everyone should have its task and be ready to start measuring and positioned itself in a way you will not be obstructing the others.
2. As the conch shells are lying on the floor the second person measuring the lip thickness can start measuring and speak out loudly the size so the writer can note it down.
3. The third person will be at stand-by when the measurement of the lip thickness has been carried out, he/she can start reading the shell length and speak out loudly as well.
4. The measured conchs should be put in a chronological sequence in order to be able to write down the sex after they have taken out the conch out.

5. When all collected conch for the first pot has been measured one of the crewmember will start opening the shells and taking the conch out, this is where the sex will be revealed and spoken out loudly to the one who is writing.
6. Repeat all the steps mentioned above for the next catch.

Home/Office

When getting back home or to the office cleanse everything thoroughly in fresh water and spray with WD40 and take the remaining rust as much as possible off. This will make the caliper slide better and make measuring faster and easier.