Project Report

Reduction of nurse shark bycatch in the Saba Bank lobster fishery

DRAFT VERSION 1 - December 2021

Project team

The NEV was responsible for project design, supervision and reporting to the Dutch government. The Saba Conservation Foundation/Saba Bank Management Unit acted as local liaison with the fishermen and oversaw the execution of the project on location. Senior shark scientist provided scientific advice on the project and assisted in coordinating the tagging and data analysis.

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Summary

1. This study aimed to find solutions for the bycatch of nurse sharks in the lobster fishery on the Saba Bank, as well as assess the level of bycatch to understand the magnitude of the problem.

2. Fishermen reported high levels of bycatch of nurse shark (*Ginglymostoma cirratum*) in the trap fishery on the Saba Bank, this was problematic because he felt the sharks were damaging the target catch (lobsters) and it was suspected that nurse shark were killed by fishermen.

3. A 3-phase project was set up where the first phase consisted of a pilot project carried out on Saba in 2018 to start collecting data on the nurse sharks and their interaction with the fishery, specifically to see if there was a difference between the two types of traps (swallowtail and square) used in the fishery.

4. During the pilot project 41 sharks were recorded in traps which were subsequently tagged and released with some individuals recaptured within a short time. The duration of the pilot as well as the number of variables to consider was too high to have any conclusions form the project.

5. The second phase was a laboratory setup where different traps and adaptations were trailed under controlled circumstances in a lab in Florida.

6. The results of these lab experiments showed a lower bycatch of sharks in the square traps combined with a higher catch rate of lobsters in comparison to the swallowtail traps. Sharks did not predate on lobster in the traps and only went into traps 10% of the times.

7. Adding ceramic magnets to the opening of the traps had no significant effect on the shark bycatch.

8. One effective alteration to the traps to reduce bycatch was the addition of an escape hatch to the top of the trap. This was effective in allowing a shark to escape from the trap in 60% of the iterations of the experiment.

9. The third phase of the project, where this modification would have been trailed in situ on the Saba Bank had to be cancelled because the Covid-19 pandemic made it impossible to travel to Saba.

10. Monitoring of shark bycatches and recaptures continued throughout the project and we found a high (30%) recapture rate of tagged nurse sharks and it was confirmed that only juvenile and sub-adult sharks end up in traps.

11. We conclude that there is significant bycatch of nurse sharks in the lobster fishery but it is likely to be lower than previously thought because of high instances of recapture. Predation of nurse sharks on lobsters is rare, sharks seem to enter traps for other reasons

12. We recommend starting deploying escape hatches in the traps to reduce bycatch and combine this with further study on their efficacy on both the bycatch as well as the target catch

Introduction

During an expert meeting organised by the NEV and commissioned by the ministry of EZ in October 2016 on Bonaire, it emerged that the fishermen fishing with traps for spiny lobster on Saba Bank frequently have nurse sharks (*Ginglymostoma cirratum*) smaller than 100cm total length as unwanted bycatch in their traps. Research by De Graaf *et al.* (2015) estimated an annual bycatch of between 1712 and 2499 nurse sharks in these traps. More than 95% of these sharks are discarded and there are no data available on post-release survival of these sharks[i] . Fishermen consider this bycatch a nuisance as the sharks can damage the traps and they believe they will dam age the lobsters inside. Anecdotal information from fishermen suggests that sharks revisit the traps, but this has never been quantified. Nurse sharks are known to have a limited home range, so it is possible the same sharks return to the traps and are caught multiple times in the first two to three years of their lives. The possibility of reducing bycatch of sharks in local fisheries was studied in collaboration with local organizations and stakeholders.

Fig 1. *in 2019 a Saban fisherman found over 30 sharks in his traps on a haul of 10 traps*

This project was part of the research for the *Yarari Sanctuary for Sharks and Marine Mammals* in the EEZ of the island of Saba and St Eustatius in the Dutch Caribbean. The first stage of the project was a pilot project in which a protocol was established for tagging these sharks and get a first indication of the (re)capture rates in the fishery. This was followed by experiments in a controlled setup to test different methods to reduce bycatch. The last phase would have been in situ testing of new trap designs to validate the lab research and come up with a clear advice on the best way to adapt the lobster traps to minimise the bycatch of sharks. Unfortunately, due to the Covid-19 pandemic this element could not be completed with in the timeframe of the of the project as it was not possible to travel to Saba for most of 2020. The Saba Bank Management Unit was able to continue the bycatch monitoring and tagging of sharks throughout the project and this gives a clear insight in the frequency of interactions with sharks and especially the recapture rates of sharks in these traps.

Saba Bank Spiny Lobster fishery

The Saba lobster fishery operates through a permit/licensing system, a license gives year-round access to the fishing grounds and there is no restriction on the number of traps that can be put out. There

are currently 10 permits for fishing on the bank but only 7 fishers are active in the fishery at this time. The average number of traps is estimated at 300 per fisherman but according to the fishermen themselves this number is highly variable between fishers. Apart from lobster traps which are placed between 30 to 50m depth most fishers also have traps out in deep water for red fish and other teleost fishes.

The latest assessment of the spiny lobster population by Wageningen Marine Research is that the population is in a healthy state and that the current level of fishing does not have a negative impact[ii].

Information on Saba lobster traps

Fishermen for spiny lobster on the Saba bank use two types of traps, a swallowtail and a square trap. They are fundamentally different in design and fishermen have hypothesized that the square ones have a decreased nurse shark bycatch. All the frames are made of 1/2" rebar and the mesh varies in colour and mesh size. In general, the square trap uses green mesh, and the swallow tail black, green, yellow or silver. Sometimes a combination of different colours, which depends on the availability from the supplier. The preferred mesh size is 1"x2" holes, which is listed under the Visserijwet BES.

Swallowtail trap (Chevron)

A six cornered design with the opening in the middle. Large opening with a short ramp.

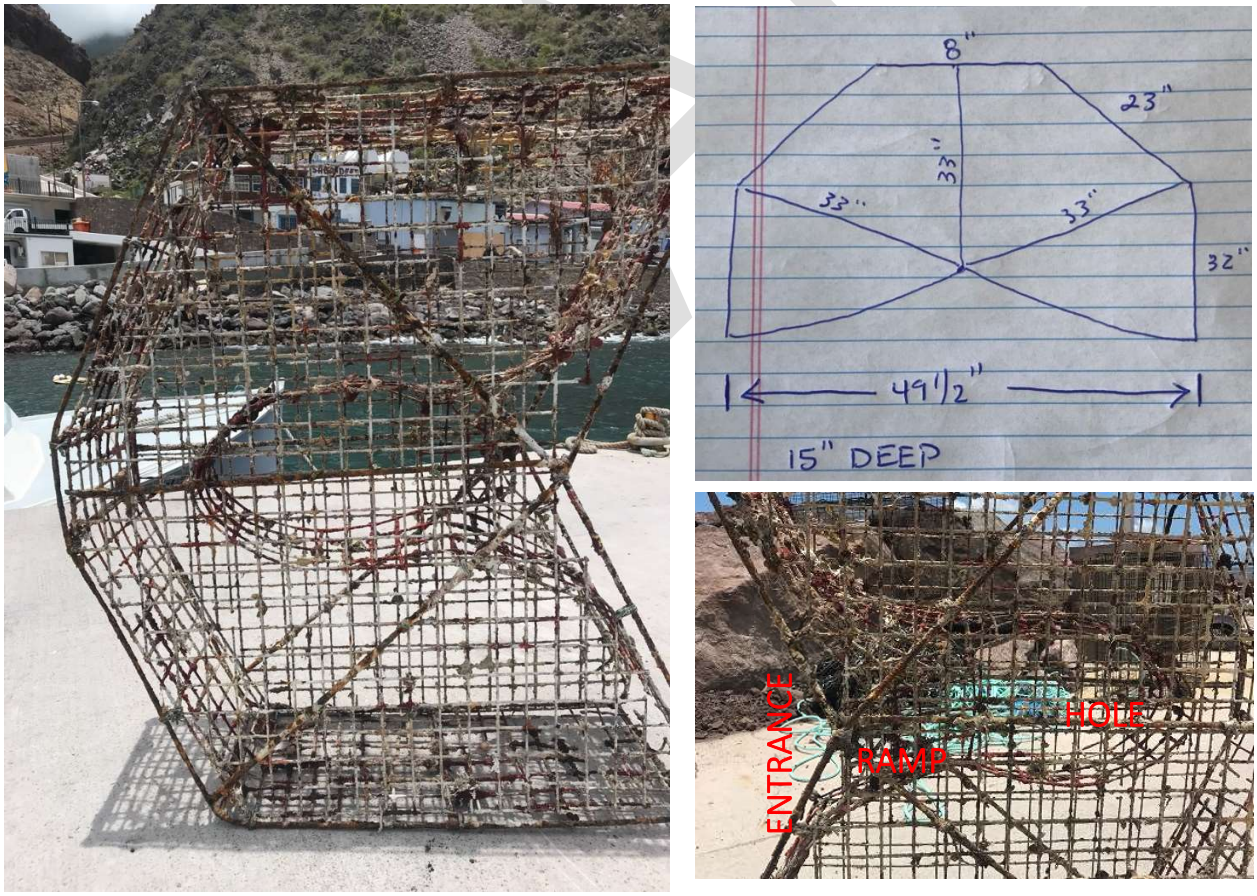


Fig 2. Details of swallowtail traps deployed by the Saban fishermen.

Square trap (box)

A square (rectangular) trap has two openings on across from each other on the long side of the trap. The ramps are longer than those in the swallow tail and the opening (hole) leading to the bottom part of the trap is smaller.

Fig 3. Details of square traps deployed by the Saban fishermen.

The fishermen using the square traps do amongst other things because they believe the shark bycatch in the square traps are less frequent. The traps have two openings opposite each other (the swallowtail has just one) which would allow a shark to swim through without entering the bottom of the trap and getting stuck there.

Phase 1: pilot project 2018

This project was carried out in the course of 2018 and during that time the NEV carried out two site visits, one in April and one in October/November and our junior researcher carried out the field experiment from May to June 2018. The project started in April 2018 when the project team visited the island between April 9th and 13th. During this period the team met with the Saban fishermen to gather information on the fishery and the nurse shark bycatch levels. They trained SCF-staff and fishermen in tagging and data collection and designed a protocol for data collection. Once the fishermen had learnt how to tag sharks, they carried this out independently, this process is ongoing.

During a second site visit at the end of October, the results of the previous six months were discussed with the fishermen and the scientist from SCF.

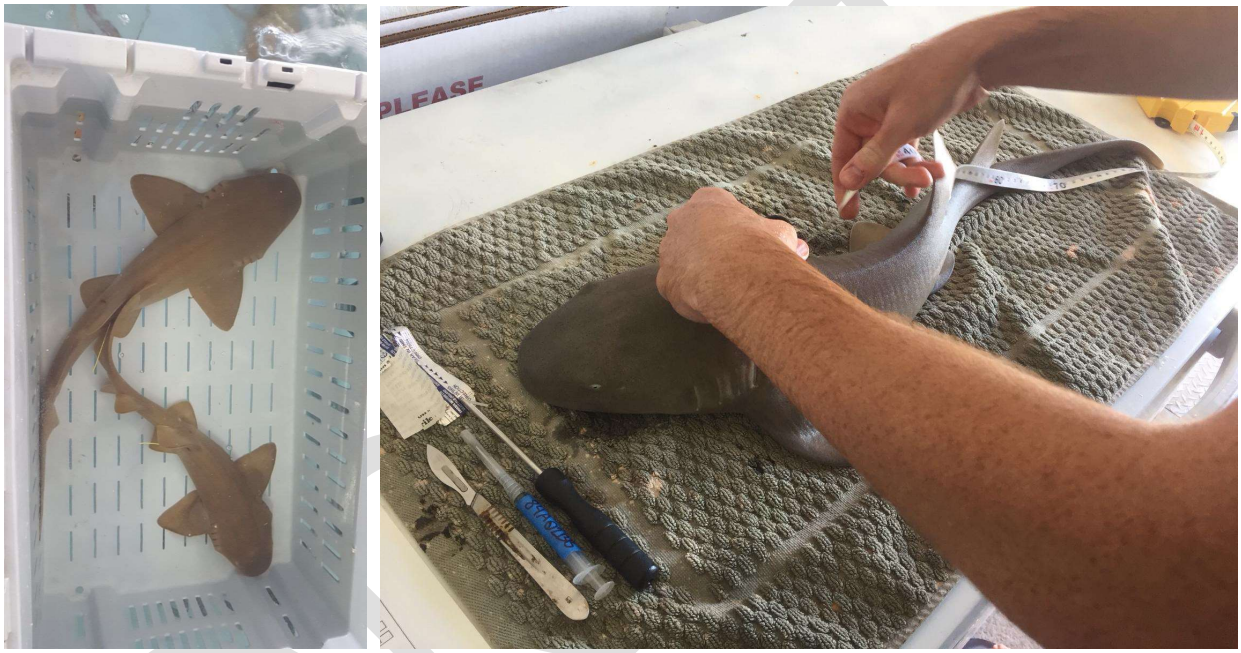
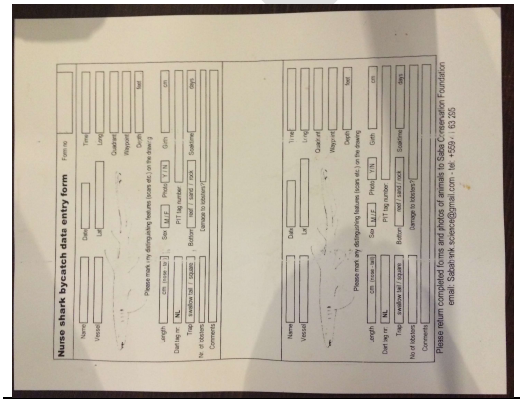


Fig 4: Two tagged nurse shark ready for release & measuring of nurse shark

In the months May and June Guido Leurs Msc stayed on Saba where he oversaw the running of the project. Going out with fishermen on trips for tagging, collecting capture and recapture data and ensuring all data were entered correctly.

Data collection

During the first site visit in April, a sampling protocol and data sheet were developed for the fishermen.


Nurse shark bycatch data entry form

The regular catch of lobsters in the traps is already monitored by Wageningen Marine Research. As for this research, in the detailed shark bycatch datasheet, the amount of lobsters caught (with or without any damage) and the type of trap used was added. This was done to get the CPUE in lobster catch per type of traps as well quantify the bycatch of the two different traps.

Fig 5. Data entry sheet

For the tagged nurse sharks detailed information was gathered using a specially developed data entry form (Figure 4). As collecting this information on an active commercial vessel proved not feasible for fishes, they were asked to only log the number and waypoint of each shark they tagged or recaptured and afterwards an SCF researcher filled in the data sheet with them.

Results

Shark Catches in traps

During the pilot project 41 sharks were recorded as bycatch from traps. The average numbers of sharks caught per trap in each of the two different traps is shown in Figure 5. In this experiment more sharks are caught in the square traps as compared to the swallowtail (2.3 vs. 1.9), but the difference is not significant due to the high standard deviation (2.49 and 1.12 respectively)

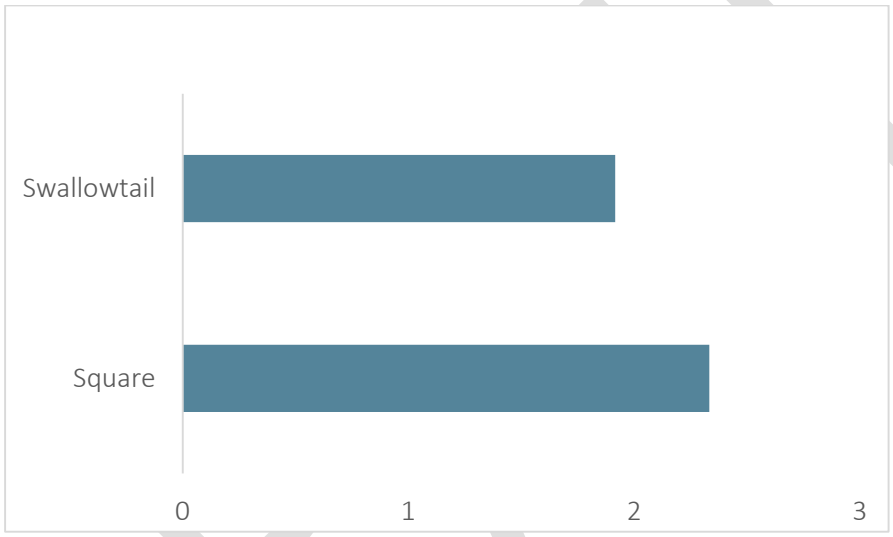


Figure 5. *average number of nurse sharks caught per trap.*

Recaptures

A total of 41 nurse sharks were tagged and there were 13 recaptures. Of these, 7 recaptures were the same shark, number 007, a female of 75 cm which was caught by the same fisherman once a week over the entire summer of 2018. This means that the sharks survive being captured if promptly released.

The results are shown in Table 1. The size range of the tagged nurse sharks is shown in Figure 6.

Table 1. Nurse sharks tagged and recaptured. Data on the type of trap deployed at recapture was not always noted. One of the sharks (No 007) was recaptured 7 times.

	Total	Square	Swallow tail	Unknown	Female	Male	Unknown
Number tagged	41	22	19	NA	17	15	9
Number of recaptures	13	6	2	5	11	2	0
Number of recaptured individual	7	4	2	3	5	2	0

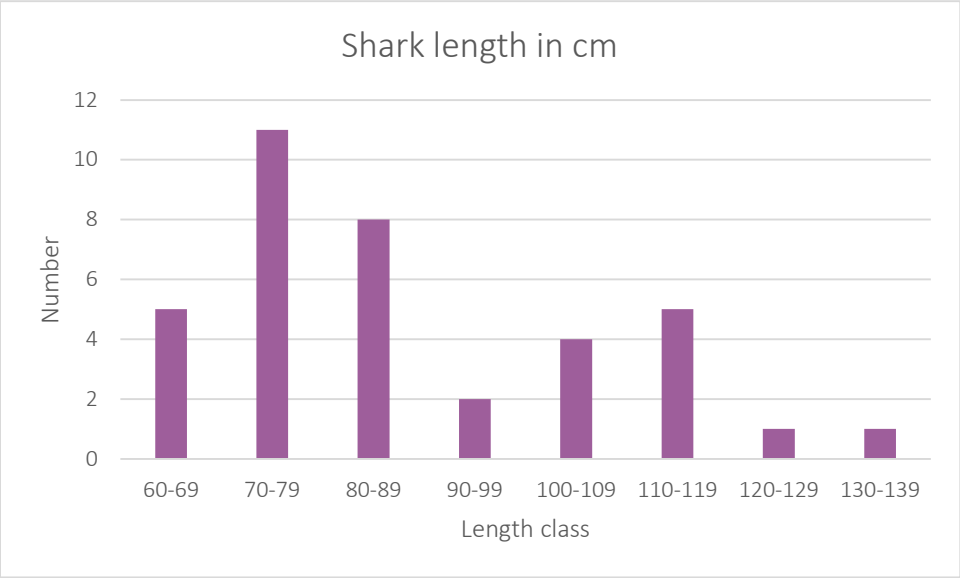


Figure 6. *Length of tagged released sharks. These are all juvenile sharks.*

All sharks caught were juveniles (Figure 6) but none were neonates. Size at birth in nurse sharks is around 30 cm[iii]. Of the smaller sharks (>80cm) many still had spots on their belly indicating these were relatively young sharks as these spots disappear as they age.

Of the 28 cases when the presence or absence of lobsters was reported, there were lobsters present in 8 cases. The numbers of lobsters in the trap ranged from 1 to 6. Damage to the lobsters was reported in two of these 8 cases.

Anecdotal information from fishermen is that the nurse sharks can damage the traps quite extensively when they try to escape, this was not observed in during the field work. There is no information if fishermen believe sharks are more likely to damage a square or swallowtail trap.

Lobsters catches

In the traps in which nurse sharks were found, the numbers of lobsters and if they were damaged or not, were noted. The results show that in most cases, there were no lobsters in the traps and if they were present there was only one case in which damage was seen to the lobsters. Moreover, the swallowtail trap had the lowest number of lobsters caught. See Table 2.

Table 2. Numbers of lobsters seen in the traps in which sharks were also present and the numbers of occasions the lobsters were damaged.

Square trap (n = 14)			Swallowtail trap (n = 13)		
Numbers of lobsters found in trap	Number of occasions damage was seen	Number of occasions no damage was seen	Numbers of lobsters found in trap	Number of occasions damage was seen	Number of occasions no damage was seen
0		7	0		12
1			1		1
2			2		
3	1	2	3		
4		2	4		
5			5		
6		1	6		

Conclusions Pilot project 2018

Based on the field experiment we cannot provide an indication of which trap design has the lowest level of shark bycatch. There was no significant difference between the two trap designs in the experiment.

The very low number of lobsters seen in the traps in which sharks were present, especially in the swallowtail traps, might indicate that the presence of sharks in the traps acts as a deterrent to the lobsters actually entering the traps. Shark do not seem to see the lobsters as an attractive food source as there was only one instance of damage to the lobsters.

The recapture of the same individual, up to five times in one case, shows that the nurse sharks can survive being in the traps, captured, tagged and released. This means that if it is possible to develop a technical measure which allows the sharks to escape, this could be successful in reducing the bycatch if no method can be found to deter sharks from entering the traps.

The observation that sharks survive being captured if promptly released and can re-enter a trap multiple times has implications for the assessments of the amount of shark bycatch in the Saban spiny lobster fishery. This means that a rate of recapture should be factored into the calculations of shark bycatch and the current estimates of around 1700-2500 (de Graaf *et al*., 2015) should be revisited.

The sharks caught in this study were all juveniles and sub-adults, but some fishermen report that large sharks of 9-10ft (up to 3 m) have occasionally gotten into the traps and can severely damage the traps when trying to escape. The composition and relative abundance of the nurse shark population on the Saba Bank has not been studied this should be done to understand the fisheries interactions of this species.

The pilot project did not give a definitive answer on which of the current trap designs has a reduced bycatch level of nurse sharks. In this limited study there is a higher instance of recapture in the square traps than in the swallowtail traps (18% vs 10%), but as sample size is low and not all fishermen participated in the experiment there is the possibility of bias in the data.

Phase 2: Lab experiments 2018-2019

During the limited scope of the pilot project it became clear that there were too many variables to consider to make definitive statements on the options for bycatch reduction. To address this NEV chose to fund a collaborative research project with Mote Marine Laboratory which consisted of tank trials to test shark behaviour towards bycatch reduction measures which ran from September 2018 to March 2019[iv].

The research focussed on 2 distinct research questions:

1) Do trap modifications (ceramic magnets or escape hatches) reduce shark bycatch and do they interfere with lobster catches to ensure any modifications proposed did not reduce target catch.
2) Do sharks behave differently in the 2 different trap types used on the Saba Bank (swallow tail vs square trap)

Experiment set up 1 (magnets)

For this project the researcher remade trap according to the specifications collected on Saba and placed them in a large basis with cameras to observe the behaviour of sharks and lobsters. Both the sharks and lobsters were obtained from the wild (18 lobsters and 9 sharks) and released after the experiment concluded. The traps were baited with cow hide (the same bait used as the fishermen on Saba).

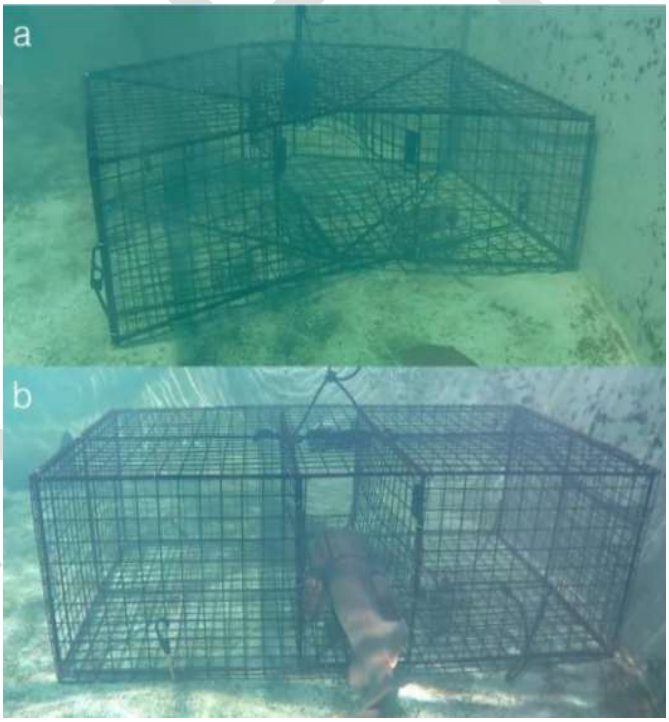


Figure 7. the traps constructed for this experiment (image b has a shark lying in the entrance)

For the first experimental design the researchers attached ceramic magnets to the entrance of the traps as magnets have been shown to deter sharks in other fisheries[v], due to the sensitivity of sharks to magnetism. However, in this experimental set up adding magnets did not have a significant affect on the sharks behaviour, they did not seem less likely to enter traps with magnets on them.

To the researchers surprise the nurse sharks did not seem eager to enter the traps at all, even with live lobsters already present in the traps sharks only entered the traps 10% of the time and when in the traps no predation on lobsters was observed, even though the sharks were starved for 72 hours before they were put in the experimental tank to ensure they were hungry.

By adding small fish (finger mullet) to the traps, the food source provided to the nurse sharks when not in the experiment, the researchers could easily entice the nurse sharks to enter traps to eat these fish, showing that there was no inhibition for them to enter the traps.

When the catches of both sharks and lobsters between the swallowtail and the square traps it was observed less lobsters would enter the swallowtail traps than the box traps and more lobsters would escape from the swallowtail. The reverse was true for the sharks where more sharks would enter the swallow tail traps.

Experiment set up 2 (escape hatches)

In the first experiment the researchers noted that after the entered the trap most nurse sharks swam to the top of the trap to try and find an exit. This led them to consider a new design with an escape hatch of 30x30 cm in one of the top corners of the trap through which a shark could exit. The theory was that a shark could open this hatch with its snout and in this way get out where lobsters would not be able to climb out as they cannot push open the hatch when climbing onto the side of the trap.

The results of this trail were very promising, sharks managed to escape using the hatch in 60% of the trails where without these hatches the managed to get out only 30% of the time (back through the funnel). Additionally escapes through a hath happened a lot faster (average 14.9 minutes) that back through the funnel (avg 34.2 minutes).

Figure 8. Shark exiting trap through escape hatch

No lobster managed to use the escape hatch during the trails. Those that did climb up to the side did not make it out of the hatch but in stead fell back into the trap (figure 9).

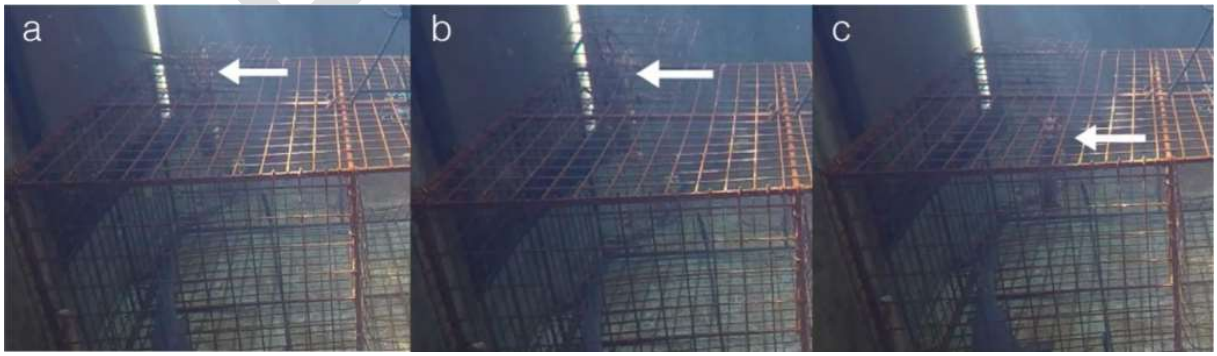


Fig 9. Lobster attempting to climb out of trap through hatch (a+b) but failing to get over the side (c)

Conclusions and Recommendations lab experiments 2018-2019

The following could be concluded from the research carried out by Mote Marine Lab:

1) Magnets have an inconsistent, trap-specific effect on both shark and lobster entry rates.
2) Chevron traps have lower lobster entry rates, higher lobster escape rates, higher shark entry rates, and higher shark escape rates than box traps.
3) Nurse sharks are not heavily motivated to enter traps by the presence of lobsters or cowhide bait alone but may instead enter traps out of a natural tendency to explore nooks and crannies.
4) Low entry rates are not driven by inability to enter traps, as nurse sharks can quickly and easily enter traps when motivated by traps baited with finger mullet.
5) (Nurse sharks rarely engage in aggressive behaviour towards lobsters when they do enter traps, even when hungry.
6) Nurse sharks attempt to escape traps when they enter, but are usually unable to do so, and may instead predate on lobsters in the wild after several days of captivity as hunger increases: and
7) Escape hatches are an effective modification to increase shark escape probability and escape speed, while lobsters are unable to effectively escape using the hatches.

Recommendations

1) Adopting escape hatches into trap designs appear to be a practical solution minimising shark bycatch. Of note here is that the hatches should be modified to keep them shut upon trap deployment in open sea and retrieval.
2) The fishery may consider shifting from chevron traps to box traps in the future (if deck space allows), as these inherently have higher lobster and lower shark catch under controlled conditions;
3) There should be a follow up study to rigorously and quantitatively evaluate the efficacy of escape hatches under field conditions, preferably with trap cameras. This approach would also confirm rates of shark entry and exit and would provide observations of shark/lobster interactions and other bycatch dynamics under field conditions.

The researchers recommend trialling this promising approach in the field by modifying a number of the traps currently used by the fishermen and deploying underwater camera's at the location of the traps for at least a week. This could, prove or disprove the theory that the sharks would rather leave the trap than stay there and consequently damage both the lobsters and the traps while trying to escape.

Fig 10. Nurse shark in entering trap filmed with trap camera

It was planned for these field trail to take place in the spring and summer of 2020. A trap camera was purchased by the NEV and trailed on the Saba Bank in 2019 to help with this research. Unfortunately, the restrictions due to the Covid-19 pandemic made it impossible to travel to Saba for students to carry out the research this s why we could not carry out this part project within the time available.

Monitoring 2019-2021

During phase 1 of the project fishermen and employees of the Saba Bank Management Unit and Saba Conservation Foundation were trained to tag and release sharks, in the years afterwards the tagging was incorporated in the fisheries monitoring of the Saba Bank. Over this period 118 sharks were tagged and released. Not all fishermen participated in the research, only 3 were active throughout the entire phase.

Of the sharks bycaught in the lobster traps the majority, 55%, was female and 45% male of 7 sharks the sex was not recorded. The experiment was not large enough to say if the difference in sex ratio is significant. Even though it was known that sharks would on occasion re-enter the traps the observed recapture rate was unexpectedly high: 34 individuals were recaptured during the project, giving a recapture rate of 30%. Based on these observations the shark bycatch rate calculated on the 2016 data should be revised down. The high instance of recapture also indicates that the survival rate for nurse sharks is high, even if they are not released straight away but kept on board for a couple of minutes for tagging and measuring.

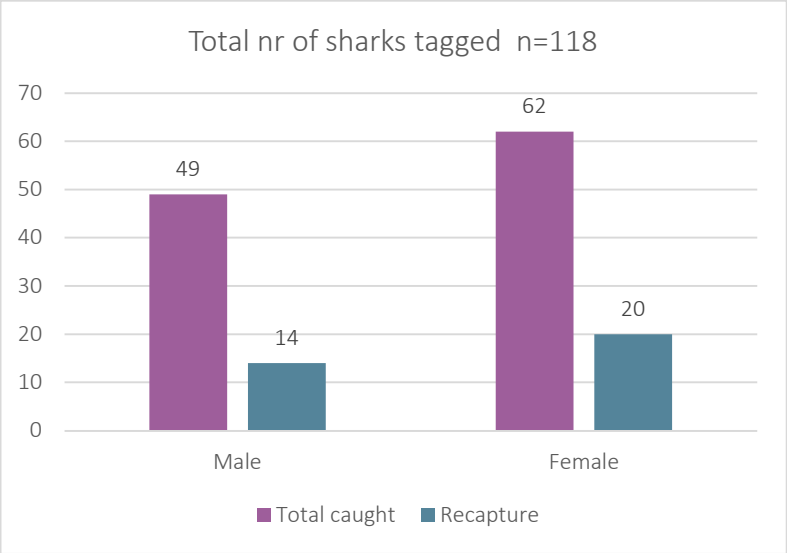


***Figure 11**. bycatch and recapture data of nurse sharks on the Saba Bank*

The majority of sharks caught were small sizes (<85cm) which confirms the observation from fishers that the sharks they find in the traps are for the most part juveniles and sub-adults. The largest sharks (>140cm) caught were all female, with the largest individual measured at 155cm. Size at maturity for this species is estimated between 230-240cm so even this individual was still a sub-adult shark, overall very few large individuals were caught.

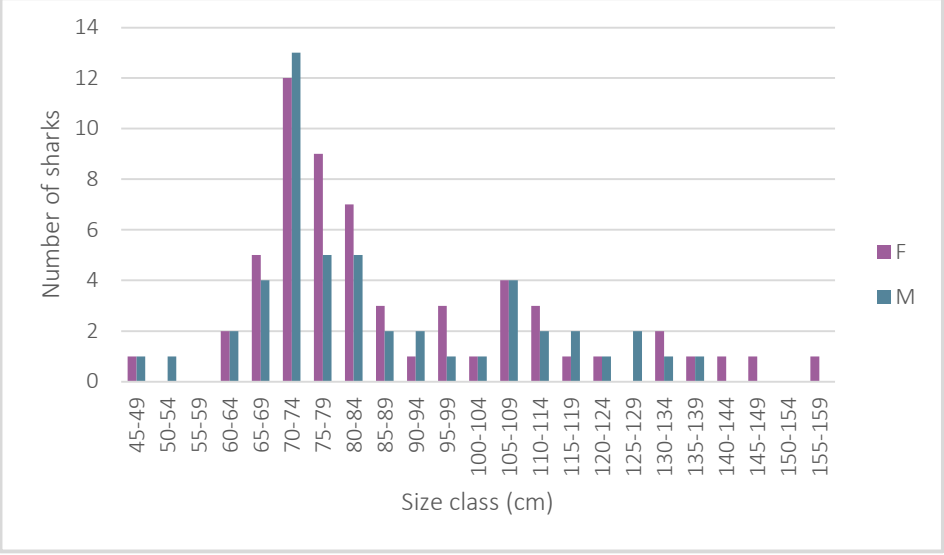


***Figure 12**. overview of length frequencies with males and females separated*

There is a large variance in the days of freedom before sharks end up back in one of the traps. On one extreme of the spectrum a shark was recaptured on the same day (it swam back into a trap the moment it was released) on the other end one female shark was recaptured more than 3 years (1140 days) after she was tagged originally. Most recaptures were registered to have happened within one month (30 days).

During the program 11 individual shark were recaptured multiple times (at least twice) with several distinct outliers. Over a period of 5 months in 2018 a female shark (nr 007) was found in a trap a total of 11 times, and again in 2020, on the same location, a male shark (nr 033) was recaptured 10 times.

Discussion and recommendations

During the project we confirmed that there is substantial bycatch of nurse sharks in the lobster fishery on the Saba Bank. Bycatch events occur year-round with no clear seasonal pattern. The bycatch consists of juvenile and sub-adults only with most animals under 80cm. The frequent recaptures of tagged animals is a clear indication that post release survival for nurse sharks is high and that the population is highly localised and these juvenile sharks have a small home-range. The number of sharks bycaught each year is likely to be lower than first estimated as we saw a recapture rate of 30% in our research.

To get a better understanding of the interactions with sharks we recommend:

- Analysis of bycatch data of all fishers on the Saba Bank to ground the current estimations in actual data and to get a better understanding of spatial patterns of the distribution of sharks.
- We further recommend a fisheries independent study of the nurse shark population to assess population size and distribution, for example through kinship genetics. This could be linked with the ongoing telemetry study[vi] of the Saba Bank sharks to understand connectivity of nurse shark populations between islands.

The escape hatch developed by Mote Marine Lab seems a promising solution to reducing the bycatch in the fishery. It was effective 60% of the time in allowing sharks to leave the trap and no escapes of lobsters were observed in the experiment. We therefore recommend to:

- Start equipping all traps deployed within the Yarari Shark Sanctuary with escape hatches
- Simultaneously start a rigorous in-situ research program to quantify the effect of escape hatches in the field as well as the effect on lobster catches
- Attach the hatches with biodegradable material that dissolves within months to ensure that lost traps do not turn into ghost traps.

ADDITIONAL OBSERVATIONS

Teleosts

During both site visits, the fishermen spoke of the damage that the queen trigger fish (*Balistes vetula*) did to the lobsters in the traps. Trigger, or moon, fish enter the traps and eat the lobsters, sometimes entirely so that there is only an empty carapace left. In some cases, they damage or remove the appendages, making the lobsters worthless on the market. Fishers gave a rough estimate of up to 20% to 25% of the catch damaged by triggerfish when they get into the traps. There was no seasonality observed in triggerfish activity, but they are observed more around the full moon (hence the local name of moon fish).

Figure 13. *Queen trigger fish (Balistes vetula) caught in one of the lobsters trapsr.*

The species is near threatened according to the IUCN Red List[1] and in other regions of the Caribbean and thus a decline in populations has been seen.

Several fishermen reported trigger fish in their traps that killed and/or damaged the lobsters – some reported losing up to 20%-25% of the catch. This species is a problem because it can eat entire lobsters, but can also damages the appendages, making the lobsters worthless on the market. Fishermen made a clear request to look for solutions for the problem with triggerfish. For example, by allowing a targeted fishery for them in their spawning area.

There is no cap on the number of traps allowed by one fishermen to put out on the Bank. Even though the most recent stock assessment does not indicate there is overfishing of the lobster stock, having no cap on the number of traps does present a risk of overexploitation. One suggestion for improved management is that there should be a maximum on number of traps per license linked to a registration process for the traps used. The traps should all be fitted out with a tag with a unique code for registration purposes.

[1] https://www.iucnredlist.org/species/2539/97664057

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