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Shark bycatch mitigation project and Scientific activities on Depredation in New-Caledonia

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GOUVERNEMENT DE LA NOUVELLE CALÉDONIE

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**This document was drafted by the Fishery department of New-Caledonia based on unpublished data collected during Fishtek Marine trials in New-Caledonia in 2023 and Margaux Mollier's analysis published in 2024 (Shark and odontocete depredation on the catch of the tuna longline fishery in New Caledonia (South Pacific Ocean)). All authors contributed equally to this paper.*

Abstract

The New-Caledonian longline fleet operates exclusively within the EEZ of New-Caledonia in one of the biggest Marine Protected Areas in the word, the Natural Park of the Coral Sea. These waters are a sanctuary for sharks (Elasmobranchii) and some marine mammals (Mysticeti and some Odontoceti) with which the fishing activity has to cohabit. This can lead to direct or indirect interactions between fisheries and marine predators that can impact one another through accidental catches, predation on baits but also through depredation (damage or removal of target catch by predators). New Caledonia is continuously working in collaboration with the fishing companies to improve practices to limit these interactions and ensure the long-term conservation of these species as well as the economic viability of the fishery.

In 2023, the fishery took part in sea trials testing a novel shark deterrent device developed by Fishtek Marine called SharkGuard®. SharkGuard attaches to branchlines (above the baited hook) and emits a powerful electric field designed to deter sharks and rays from being caught. During these trials an experimental part of the lines was equipped with the device to test its effectiveness and its impact on teleost CPUE. The analysis of the collected data showed no significant reduction in teleost CPUE with the use of SharkGuard and a 57% reduction in elasmobranch catch - noting that this last result wasn't significant due to data power issues. In order to enhance the data power more trials are to be carried out in the future.

These last 3 years, following concerns expressed by local fishing companies about increasing depredation events by sharks and odontocetes, New-Caledonia with the support of SPC-*South Pacific Community* and IRD-*French National Research Institute for Sustainable Development* have launched a project to characterize and assess the depredation phenomenon. So far, the analysis of the available data from 2002 to 2022 showed that while shark depredation occurred more frequently than odontocete depredation (58.5% vs. 9.2% of the longline sets), they damaged a lower proportion of fish (3.9% vs. 12.3%). It also shows a selective depredation of odontocetes on tuna species compared to sharks. These results indicate that depredation in the New Caledonian longline fishery is high compared to other regions and provide essential information on the dynamics and impacts of the issue as a basis for developing effective mitigation solutions.

Table of Content

Introduction

The New-Caledonian tuna fishing fleet has historically been composed of around 20 longliners which mainly targets albacore and yellowfin tuna (16 licenced vessels in 2023). It operates exclusively within the EEZ of New-Caledonia where no other foreign flagged vessels are authorized to fish. Operating within one of the biggest Marine Protected Areas in the world, the Natural Park of the Coral Sea, the local fleet is continuously working toward more sustainability with the local authorities' support. These waters are a sanctuary for many species of special interest, in particular for sharks[1] (Elasmobranchii) and some marine mammals[2] (Mysticeti and some Odontoceti) with which the fishing activity has to cohabit. They mutually impact one another through accidental catches, predation on baits but also through depredation (damage or removal of target catch by predators).

In New-Caledonia, the fishing companies have voluntarily stopped targeting sharks (mainly shortfin mako - *Isurus oxyrinchus*) since 2008 due to production cost issues and fully stopped in 2013 when shark fishing within the EEZ has been strictly prohibited by the law. Since then no branch lines running directly off the longline floats are deployed and no wire traces are used as branch lines or leaders. Nevertheless, accidental catches on baited lines are inevitable therefore vessels use nylon as leaders to allow sharks to easily free themselves by cutting the line.The regulation also prohibits any shark bycaught to be retained on board, therefore all sharks are released in the best practical way by cutting the line as close to the animal as possible to enhance its survival chances as shown by the 2019 *ABNJ joint Analysis of Shark Post-Release Mortality Tagging Results*. This study also shows, in particular for shortfin mako - *Isurus oxyrinchus* and silky sharks - *Carcharhinus falciformis,* that individuals caught on longline and released have a 88% survival rate 3 months after the release. In 2023, the observer program[3] recorded 833 sharks bycaught on longlines out of which 92.3% were released alive. In 2023, As part of its engagement[4] to support research and develop the fishery toward more sustainability, the fleet with the support of the New-Caledonia government, took part in some trials led by Fishtek Marine in order to develop a mitigation device called Sharkguard®. This device aims to deter sharks from preying on bait hence reducing their bycatch rate without affecting tuna catches. The SharkGuard trials are detailed in the first part of this report.

The interactions of the fishery with sharks, but also and especially with marine mammals[5] (odontocetes), also manifest themselves through episodes of depredation. This particular case of Human-Wildlife conflict occurs when large marine predators feed directly on fish that are captured on fishing gears and can have negative consequences on the different components of the marine socio-ecological systems involved. According to the fishing companies the depredation phenomenon is getting more and more significant jeopardizing to some extent the catch rates of the fleet. The issue slightly differs according to whether the interactions occur with sharks or with marine mammals. In 2023, 100% of the observed sets have shown at least one shark depredation event and 7% have shown at least one marine mammal depredation event. Overall the observed loss accounted for 6% of the total observed catches in 2022 and 9.3% in 2023. Relatively to the total catches of the fleet, the loss can be estimated at 150 mt in 2022 and 210 mt in 2023.

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[1] Decree n° 2013-1007 of 23rd April 2013 relating to the exploitation of sharks in the maritime area of New Caledonia.
[2] Resolution n°397 of 13th August 2003 relating to the creation of a whaling sanctuary.
[3] 8.1% set coverage in 2022 and 8.8% in 2023.
[4] Every vessel owns a responsible fishing label.
[5] Observed accidental catch of marine mammals are infrequent : 2 released alive in 2022 and 1 dead in 2023.

Depredation by sharks appears more common but generally only affects a limited number of catches on a set. On the other hand, depredation by marine mammals, which is less frequent, has a greater impact since it can affect all catches of a set. In addition, as the presence of marine mammals can be persistent, vessels are obliged to apply an avoidance strategy by moving away to other fishing areas. Since 2020, representatives of the fishery sector (FPH - *Fédération des pêcheurs hauturiers*) have been raising awareness on this issue and asked for the support of the government to address it. In the first instance the government sought SPC support to analyze the phenomenon using the existing available data. Following the preliminary study held by SPC, a joint agreement was signed between New-Caledonia government, SPC, IRD (*French National Research Institute for Sustainable Development*) and FPH to characterize and evaluate the depredation conflict within New-Caledonia longline fishery in order to adapt fishing strategies to reduce its impact on the catch and address potential conservation issues with involved species. This project is described in the second part of this report.

I. Shark bycatch mitigation device trial for the development of Fishtek Marine's SharkGuard®

1.1) Context and objectives

In 2023, the observer program's data showed the following catch composition : 78% of retained catches (tuna, marlin, opah, wahoo, etc.) and 22% of descarded species (non-commercial species, damaged individuals, species of special interest and sharks). Sharks account for 5.5% of the total catch with 18 species identified. Generally, no sharks are brought back on board the vessels and each year almost 95% of the sharks caught by longlines are released alive.

New Caledonia is continuously working in collaboration with the FPH to improve practices to ensure the long-term conservation of sharks in its EEZ. This is why the request for participation in trials for the Sharkguard device development project from the company Fishtek Marine was positively received. SharkGuard is a shark repelling device deployable on longline leaders. The device developed by Fishtek Marine, placed one meter from the hook, emits electric fields which rays and sharks are sensitive through their electro-receptor organs called Ampullae of Lorenzini. This technological innovation offers an interesting response to the local and regional problem of accidental catch of sharks. It could both reduce the impact of tuna fishing on shark populations while providing solutions for optimizing longline fishing activity: better availability of bait for targeted species, less handling to release sharks and to rebuild the lines where the hooks are cut or even reduce material losses and therefore reducing associated costs.

In 2022, a first round of trials carried out by Fishtek Marine with the French Mediterranean bluefin tuna (*Thunnus thynnus*) fishery showed encouraging results with some evidence of the effectiveness of the SharkGuard device (Doherty et al., 2022). In 2023, after undertaking a desk review to determine where would be the top priority areas to further trial and enhance SharkGuard, New Caledonia came out as one of the top candidates in regard to the key factors : high tuna CPUE and shark capture, proactive fisheries management towards sustainability, track record of undertaking trials in bycatch mitigation, meet all science criteria. And after a first round of informational meetings held with the support of SPC, New-Caledonia and the local longline fishery decided to engage with the project and took part in the SharkGuard trial.

The main objectives of the trials carried out in New-Caledonia were :

- to explore any impact of SharkGuard on target catch and add further evidence of the technologies effectiveness at reducing elasmobranch capture rates.
- to collect information on the operational practicality of SharkGuard in order to further adapt the device and ensure future design iterations did not interrupt commercial fishing operations.

FISHTEK MARINE — University of Exeter — Fédération des Pêcheurs Hauturiers Nouvelle-Calédonie — Gouvernement de la Nouvelle Calédonie

1.2) Materials and methods

In July and August 2023, with the collaboration of FPH and assistance from the New-Caledonia Fishery department, two longliners took part in two different at sea trial trips with Fishtek Marine. Table 1 describes the characteristics of these two trips during which close to 35,000 hooks were observed and monitored by a fishery observer and one of Fishtek Marine's fishery scientists.

The longlines were set and divided in three parts as follow for 2,200 hooks (Figure 1) :

- The first 550 hooks were set as controls;
- The 1,100 following hooks were set alternatively with an active SharkGuard, no SharkGuard (control), an inactive SharkGuard and no SharkGuard (control);
- The last 550 hooks were set as controls.

Every fish and shark and the hook on which they were caught as well as the hook treatment (active, inactive or control) were recorded both by the observer and the fishery scientist. Preliminary analysis of this data was then carried out by the University of Exeter.

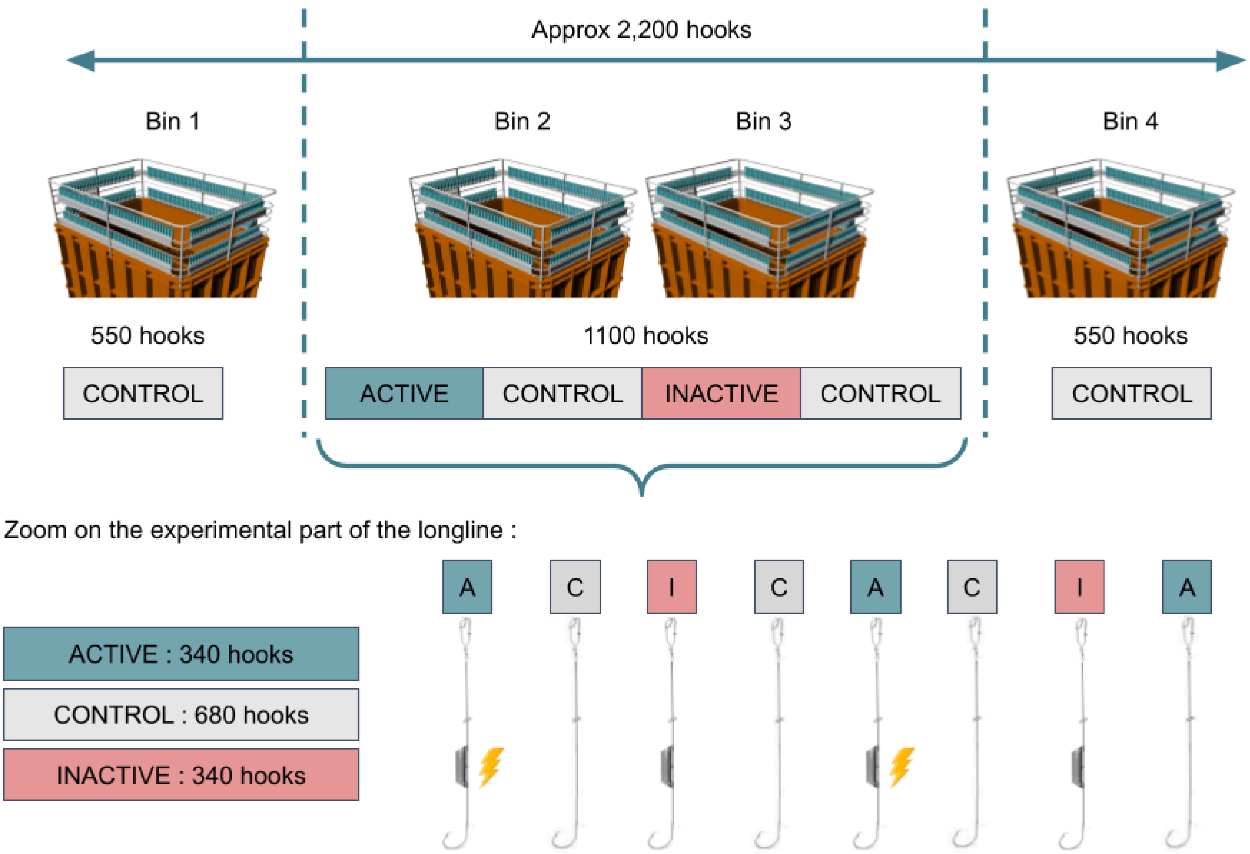


Figure 1 : Experimental longline setup (*from Fishtek Marine*)

1.3) Results and Perspectives

A total of 18 experimental hauls and 34,539 hooks were observed (Table 1). The data collected during both trial trips (NC01 and NC02) are summarized in Figure 2 distinguishing the longline parts with a normal fishing treatment and with the experimental treatment, and indicating each hook on which a shark (elasmobranchs) or a fish (teleosts) was caught .

Table 1 : Trial trips information

	Vessel name	*Dates*	*Number of sampled hauls*	*Number of hooks shot*	*Number of shark bycaught*	*Number of fish caught*
TRIP 1	F.V. SAINT MICHEL	10th-23rd July 2023	8	15,444	77	676
TRIP 2	F.V. SAINT RAPHAËL	1st – 15th August 2023	10	19,095	117	1,142

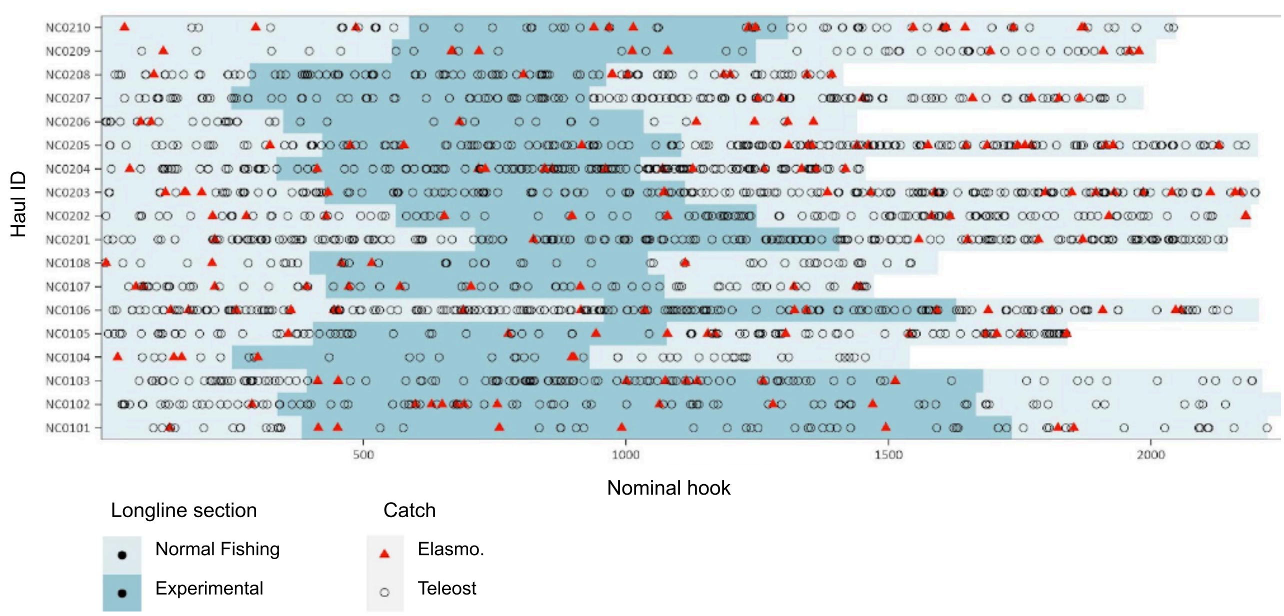
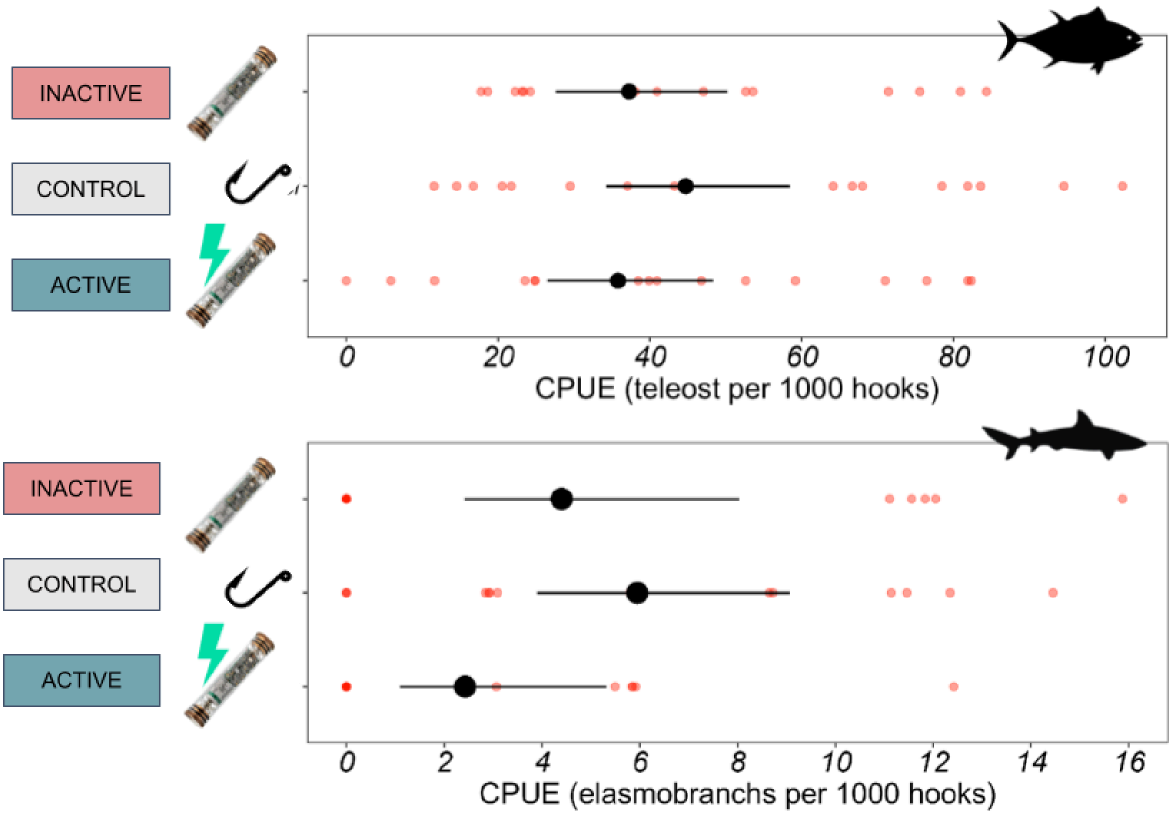


Figure 2 : Catches recorded for both trial trips (*University of Exeter, T. Horton*)

For each haul and for each treatment, CPUE per 1000 hooks were calculated for elasmobranchs and for teleosts (Figure 3). The results show no significant reduction in teleost CPUE between control and active SharkGuard®, giving some evidence that SharkGuard seems to have no impact on target catches. The reduction in the number of catches compared to the control was -19% for inactivated SharkGuard® and -21% for active SharkGuard but is not statistically significant.

Initially, SharkGuard was attached 10 cm above the baited hook (as per Doherty et al 2022). The close proximity of SharkGuard to the hook (either with active or inactive devices) significantly reduced tuna catches compared to branchlines without SharkGuard attached. Given that both active and inactive SharkGuard branchlines saw similarly reduced tuna catches when 10 cm away from the hook, it was hypothesized that the physical presence of the device itself acted as a visual deterrent to the tuna being caught rather than any effect caused by the electric field. To this end, active and inactive SharkGuards were moved away from the hook to a distance of 100 cm for the remaining hauls. Tuna catch rates went back to normal rates after this adjustment according to the fishing crew. Subsequent analysis (Figure 4) confirms the negative impact of the SharkGuard (active or inactive) on teleosts CPUE when placed too close to the hook. It should, however, be noted that catches of both sharks and teleosts vary in space and time. Low catch rates were also documented on other hauls where the device was 1 m from the hook (e.g. NC209). This together with other results indicate sample-size challenges and highlight the benefit in further trials.

Regarding elasmobranchs, the results show a 57% reduction in elasmobranch catch between control and active SharkGuard but these results are not statistically significant (Figure 3). The average active SharkGuard hooks deployed per trip (180) might have been too low (in France trials the mean was 428) reducing the power in the data in a variable system, thus limiting inferences that can be made. The analysis on the adjustment of the SharkGuard position shows that no significant reduction to the performance of the active SharkGuard occurred when placed 1 meter above the hook (Figure 4).



<u>Figure 3 :</u> CPUE per 1000 hooks calculated for teleosts (top) and elasmobranchs (bottom) (*University of Exeter, T. Horton*)

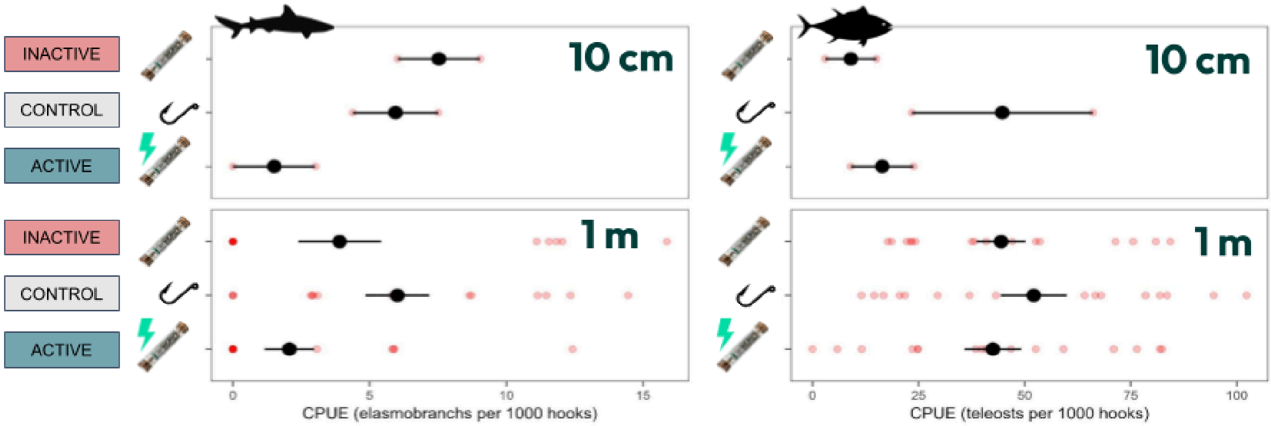


Figure 4 : CPUE per 1000 hooks comparison for different SharkGuard positions above the hook (*University of Exeter, T. Horton*)

Fishtek Marine is currently carrying on with the development and enhancement of its device taking into account the results of these trials and the feedback received from the fishing crew and observer. In order to address the data power issue, the idea would be to increase the number of experimental hooks by carrying out more trials in the future.

II. Shark and odontocete depredation on the catch of the tuna longline fishery in New Caledonia

2.1) Context and objectives

In 2023, according New Caledonia's observer program data, 9.3% of tuna catches had been discarded due to depredation by marine mammals and sharks. In relation to the total fleet activity, the loss can be estimated at around 210 tonnes over the year (150 tonnes in 2022).

In 2020, as concerns about the increasing presence of marine mammals in areas commonly frequented by fishing vessels was growing, FPH (fishing companies representative) sought the support of the New Caledonian Fishery department to better understand and address this issue. While the phenomenon of depredation on fishing gear is well known in other parts of the world, particularly in longline fisheries, it is very poorly documented in the western and central pacific region, and even more so on a territorial scale. SPC has therefore been tasked to provide expertise on this issue, to help analyze the phenomenon and develop strategies to reduce the impact of depredation. New Caledonia's historical fishing data, derived from fishing companies reporting obligations and from the observer program database, were used to carry out a preliminary analysis on the evolution of the situation over the last few decades.

In 2022, following this first phase New Caledonia drew up a collaboration agreement involving four stakeholders: the government of New-Caledonia, FPH, SPC and IRD. The aim of this agreement was to characterize and assess the depredation phenomenon, with a view to reducing its impact on catches from New Caledonia's longline fishing industry. To this end, the data collection system has been optimized to better integrate depredation data. New input fields have been added to fishing paper logbooks and to the Onboard E-reporting application used by captains to ensure better recording of depredation events. Then, in 2023, existing and newly collected data were further analyzed and the acquisition of new data in the field was developed as part of a PhD on marine megafauna-fisheries interactions (IRD Sète - UMR MARBEC). Ultimately, the study aims to formulate recommendations to reduce the impacts of marine megafauna-fisheries interactions.

2.2) Materials and methods

Data collection and in-depth analysis of historical data

In 2021, as a first step, SPC identified sources and types of depredation data available for the New Caledonian longline fishery. The data sets from fishing logbooks and from the observer program, hosted in the SPC regional database, were analyzed to determine the nature of the information that could be used, taking into account its degree of representativeness in terms of fishing activity coverage.

Data collected through New Caledonia observer program and fishing logbooks were used to monitor fishing activities and catches. These data were collected between 2002 and 2022 by fishermen (for 100% of the fishing trips) and fishery observers (for 4.2% of the trips) and were extracted from the SPC database for the study. For each longline set, the following data were recorded: vessel ID, longline set ID, time at the start and end of setting, time at the start and end of hauling, geographic position (latitude and longitude) of the start and end of the longline set, the number of hooks per set, the catch by species (in number of individuals), and its fate, including the number of fish per species, that were non-depredated and retained, depredated by sharks or odontocetes and retained, depredated by sharks or odontocetes and discarded.

The fish were assigned a depredated fate when partially consumed by sharks or odontocetes. Accordingly, results were aggregated at species group level (i.e. sharks and odontocetes) rather than species level. Bite marks were used to differentiate between shark and odontocete depredation. Sharks generally leave crescent shaped cuts with clean-cut edges and the overall damage to the fish is often represented by few or single bites (Figure 5, left). Odontocetes leave torn-off pieces of flesh, ragged edges of wounds with traces of conical, widely spaced teeth. Odontocetes also often predate the whole fish leaving only hard parts of the head or up to the position of the hook in the fish mouth (Figure 5, right). Fishing captains can easily determine if the depredation was from a shark or an odontocete from this distinction.

Figure 5 : Bite marks for depredation type identification. Left : shark bite. Right : remains of damaged fish after odontocete bite (*New-Caledonia Observer program*).

Data analysis

Assessment of depredation levels

The frequency at which depredation occurred, here defined as the interaction rate (IR) by sharks (IRs) or odontocetes (IRo), was calculated as the number of longline sets hauled with at least one depredated fish (DT) over the total number of longline sets monitored (TS). The depredation rate (DR) was defined as the number of fish damaged by sharks (DRs) or odontocetes (DRo) over the total catch (TC). The catch per unit of effort (CPUE) was calculated as the number of fish caught (TC) per 1,000 hooks. The depredation per unit of effort (DPUE) was defined as the number of fish depredated (DC) per 1,000 hooks. Unless otherwise stated, means are provided with their standard deviation (±SD).

Selective depredation of fish species

In order to assess if sharks and odontocetes selectively depredated specific fish species among all species captured on longlines, the resource selectivity index of Ivlev[6] was calculated for each set with depredation. Ivlev's index values range between −1 and 1. Values from 0.6 to 1.0 were considered as indicating positive selectivity; values from −0.6 to −1.0 were considered as indicating negative selectivity (i.e. avoidance); and values from −0.6 to 0.6 were considered as indicating

[6] Krebs CJ. Ecological Methodology. New York, NY: Harper and Row, 1989, 654pp.

neutral selectivity. The relative frequency distribution of positive, negative, and neutral selectivity by sharks and odontocetes was determined for the main commercial fish species only (albacore, dolphinfish, skipjack, wahoo, and yellowfin tuna).

Economic value of depredated fish

The economic value (EL) of the amount of fish lost to shark and odontocete depredation was calculated only considering the depredated fish that were discarded and for the three main commercial species of tuna (albacore, yellowfin, and bigeye tuna), using the mean weight (in kg) of the fish landed per fishing trip times the number of fish depredated and the sale price of the fish per kg. The mean weights of albacore, yellowfin, and bigeye tuna were estimated as 17, 31, and 38 kg, respectively. The mean prices used were 12 USD/kg for albacore, 23 USD/kg for yellowfin, and 29 USD/kg for bigeye tuna (2020 market prices). The economic value of the amount of depredated fish per fishing trip (ER) was calculated by dividing the total economic value of the depredated fish by the number of sampled fishing trips.

Influence of temporal, spatial, and operational variables on depredation

Generalized linear models were used to assess the influence of spatial, temporal, and operational variables on the probability of shark or odontocete depredation to occur and to examine differences in this probability among vessels. The models best explaining the occurrence of depredation, with one model fitted to the occurrence of shark depredation, and one to the occurrence of odontocete depredation, were selected from the full models containing all explanatory variables.

2.3) Results and Perspectives

Depredation levels from the observed data

Data was analyzed from a total of 2,864 longline sets (5,558,418 hooks) deployed by 31 vessels during 370 trips between 2002 and 2022 within an area encompassing 16°–25°S and 157°–172°E. The mean fishing effort per set was 1,945 ± 307 hooks and ranged from 45 to 2,600 hooks. A total of 190,586 fish were caught over the study period [58.3% albacore, 12.3% yellowfin tuna, 6.8% long-snouted lancetfish, 5.3% dolphinfish, 4.1% skipjack tuna, 1.5% wahoo, 1.2% bigeye tuna, and 10% other species].

The overall CPUE was 27.9 fish/1,000 hooks. CPUE was lower for non-depredated sets (25.3 fish/1,000 hooks) compared to those with at least one fish depredated by sharks or odontocetes (39.3 fish/1,000 hooks) and sets with shark depredation only and odontocetes depredation only (40.4 and 32.4 fish/1,000 hooks, respectively). Table 2 shows the fishing effort and déprédation indicators.

Table 2 : Summary of the fishing effort, the catch, and the shark/odontocete depredation levels, considering either all fish species captured or the three tuna species only between 2002 and 2022 (*Mollier et al. 2024*).

		Fishing effort					*Depredation indicators*				
		TT	TS	TH	TC	CPUE	IR	DC	DR	DR per set (mean ± *SD*)	DPUE
No dep	All species	27	1061	1 992 605	50 351	25.3	0	0	0	0	0
	Tuna only					19.0					
Sharks	All species	340	1676	3 319 957	134 227	40.4	58.5	5196	3.9	4.3 ± 3.6	1.6
	Tuna only					30.8			3.2	3.9 ± 3.2	1.4
Odontocetes	All species	168	264	522 923	16 939	32.4	9.2	2076	12.3	13.1 ± 18.8	4.0
	Tuna only					24.5			11.7	15.7 ± 18.4	3.9
Total depredation	All species	343	1803	3 565 813	140 235	39.3	63.0	7272	5.2	6.4 ± 9.3	2.0
	Tuna only					29.9			4.5	6.0 ± 9.2	1.8

TT: total number of fishing trips, TS: total number of longline sets deployed, TH: total number of hooks deployed, TC: total catch (in number of fish), CPUE: the catch per unit effort (in number of fish/1,000 hooks), IR: the interaction rate of sharks or odontocetes (in % of all longline sets deployed), DC: the total number of fish depredated, DR: the depredation rate by sharks or odontocete (in % of the total catch), and DPUE: the depredation per unit effort (in number of fish depredated/1,000 hooks).

Over the whole time period, sharks depredated 1.6 fish/1,000 hooks (1.4 fish/1,000 hooks for tuna) and odontocetes depredated 4 fish/1,000 hooks (3.9 fish/1,000 hooks for tuna). Most of the depredated fish were discarded (91.6% of all fish depredated by sharks; 99.1% of all fish depredated by odontocetes).

Depredation levels by fish species

Albacore tuna and yellowfin tuna were the two most depredated species with 4,627 and 1,604 individuals depredated, respectively (63.6% and 22.1% of all depredated fish respectively), followed by dolphinfish (4.5%), skipjack tuna (3.2%), and wahoo (2.1%), which represent 95.5% of total depredated fish. Figure 6 shows the relative proportions of fish species depredated by sharks or odontocetes.

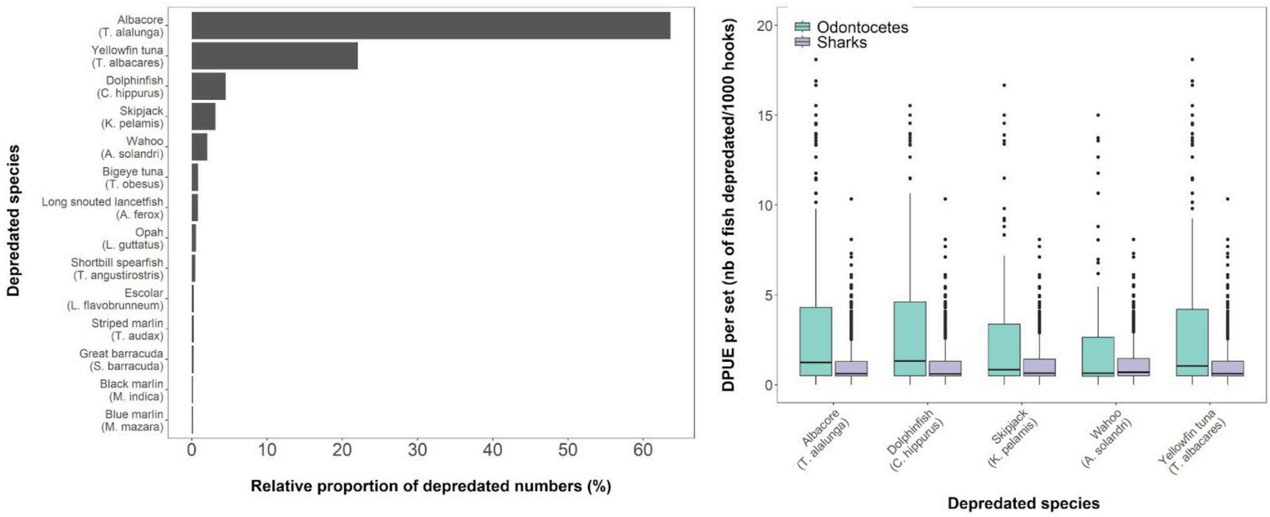
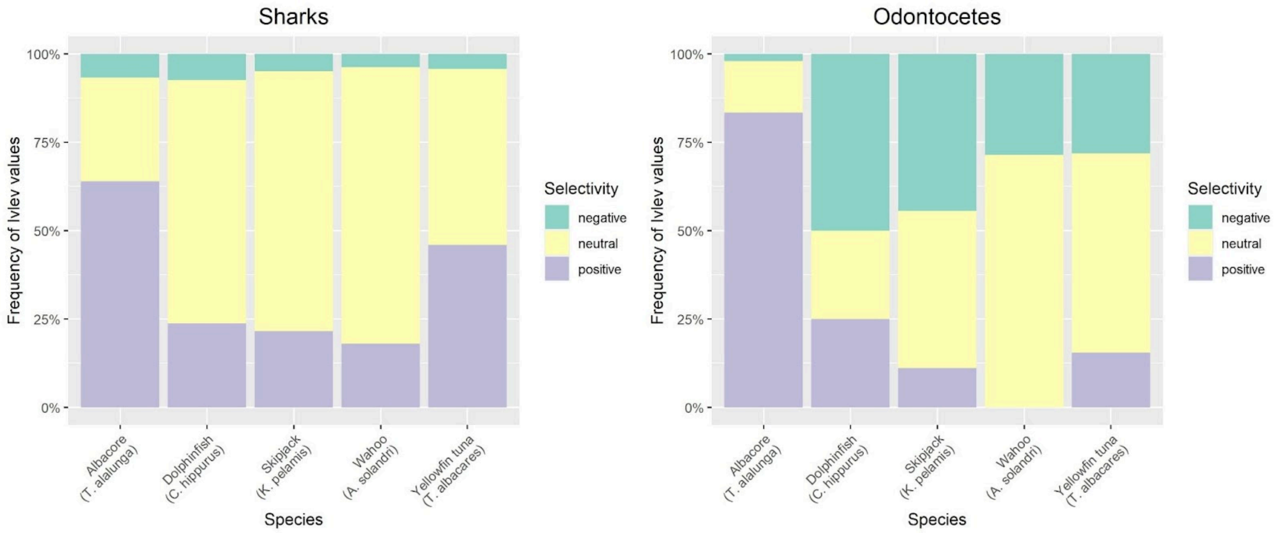


Figure 6 : Left - Relative proportions of fish species depredated by sharks or odontocetes (% of the species out of all fish depredated). Right - Boxplots of the DPUE (number of depredated fish per 1,000 hooks, calculated per set using depredated sets only) for the main five fish species depredated by sharks (light purple) and odontocetes (green) (*Mollier et al. 2024*).

The results showed that when odontocetes find longline sets, they appear to be selective in the fish species they depredated, with a preference for *T. alalunga*, *C. hippurus*, and *T. albacares* (Figure 7). Unlike odontocetes, sharks did not appear to be selective in the fish species they depredated with a higher proportion of the fish species caught than odontocetes (41% vs. 27% for odontocetes) and even if the Ivlev selectivity index suggested a preference for *T. alalunga*, sharks did not seem to avoid certain species of fish on the line.



<u>Figure 7 :</u> Relative frequency (in % of the depredated longline sets) of the values of Ivlev selectivity index of resources by species that indicate: positive selectivity (Ivlev = 1.0 to 0.6), neutral (Ivlev = 0.6 to −0.6), and negative selectivity (Ivlev = −0.6 to −1.0). The left panel shows selectivity by sharks and the right panel represents selectivity by odontocetes (*Mollier et al. 2024*).

A total fish biomass of 121,805 kg was estimated as depredated, with 85,263 kg by sharks and 36,542 kg by odontocetes from 2002 to 2022, including 74,528 kg of albacore (61%), 45,415 kg of yellowfin tuna (37%), and 1,862 kg of bigeye tuna (2%). Based on the sale price of fish in 2020, the value of this amount was 2,099,016 USD for the whole fleet during the study period (4.5% of the total value of the landed non-depredated fish) and USD 5,719 per fishing trip. The total value of the amount of depredated fish was the highest in 2019 with USD 252,174 and the lowest in 2007 with USD 3,325.

Factors influencing levels of depredation

Figure 8 shows that the frequency at which shark depredation occurred significantly increased between 2002 and 2022, from <10% of the sets before 2008 to >40% since 2009 and reaching 66% in 2017. Several factors, acting alone or together, might explain such a trend. First, vessels stopped catching/retaining sharks in 2008 within the EEZ, ahead of a ban on shark retention in the EEZ in 2013 and the implementation of a ‘Shark sanctuary’ in 2013. Second, the probability of sharks encountering fishing vessels may have changed, as a consequence of changes in their natural distribution, feeding patterns, and behavior, which may include ‘learnt’ behaviors influenced by opportunistic feeding on large fish provided by a fishery. It is also important to note that improved data collection can lead to a better assessment of the frequency of depredation, which could have potentially been underestimated previously.

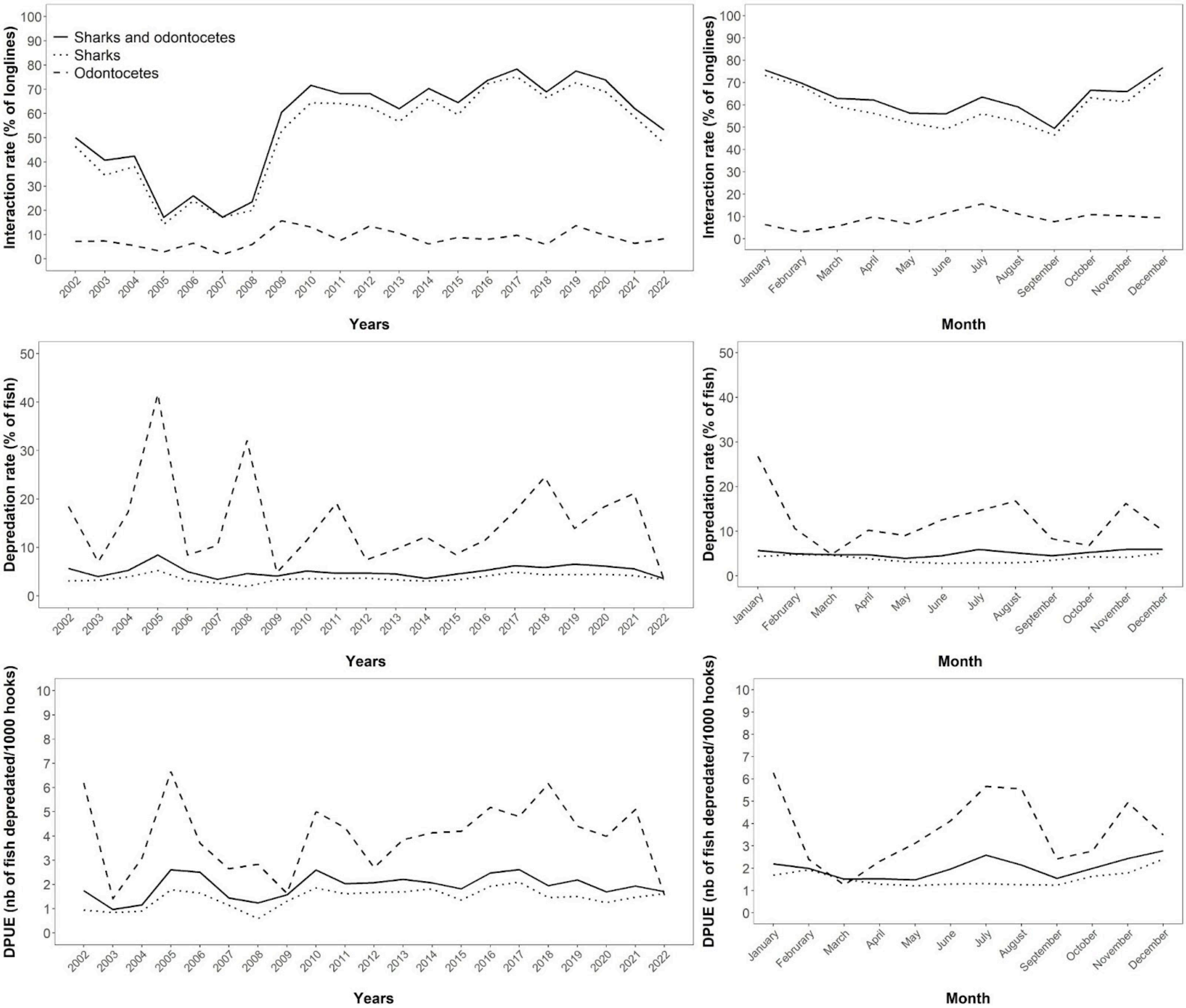


Figure 8 : Interaction rate (% of sets with depredation out of all sets), depredation rate (% of fish depredated out of the total catch), and DPUE (number of fish depredated/1,000 hooks for sets with depredation) per year (left) and per month (right). Solid lines and dots represent the depredation by sharks or odontocetes; dotted lines represent depredation by sharks; and dashed lines by odontocetes (*Mollier et al. 2024*).

Depredation occurred year-round but was significantly higher in December for sharks and July for odontocetes. For odontocetes, this seasonal variation is consistent with that of the tuna catch rates of the fishery.

Unlike for sharks, no trend in the frequency at which odontocete depredation occurred could be detected but fishermen report that the volume of fish they removed from longline sets did increase in recent years. This result suggests that odontocetes may be increasingly effective at removing fish when depredating, and this could explain why fishermen feel that odontocete depredation has become more and more problematic over the years.

The models did not show any significant influence of the spatial variable on the occurrence of depredation by sharks and odontocetes. However, further analysis of the spatio-temporal distribution of depredation is needed to assess the co-occurrence between species distribution and fishing activities.

Depredation levels in New Caledonia compared to other regions

Results show relatively high levels of shark and odontocete depredation on the catch of the pelagic longline fishery of New Caledonia compared to other regions and fisheries facing a similar issue. With 63% of all longline sets with at least one fish depredated by sharks or odontocetes (IR) (*Mollier et al. 2024*), depredation occurs as frequently or more frequently than in the pelagic tuna longline fisheries of the Seychelles (63% of the set)[7], Reunion Island (41%)[7], tropical western Atlantic Ocean (29.7%)[7], southwestern Atlantic Ocean (6.2%)[7] and in the Azores (3.6%)[7], and the north-eastern region of Brazil (3.3%)[7].

The proportion of fish depredated by sharks and odontocetes (DR) in the New Caledonian fishery (2.2% of the total catch between 2002 and 2022, *Mollier et al. 2024*) is consistent with depredation rates reported in other longline tuna fisheries (0.2–15%)[7]. Depredation rates for sharks only, were similar to those estimated for the Reunion Island fleet (2%)[7]. However, odontocete depredation rates (12.3%) were much higher than those observed in the Reunion Island and Seychelles (0.5%)[7].

While the depredating odontocete species have yet to be confirmed, it is likely that they are primarily false killer whales as the species most often documented depredating on catches in other tuna longline fisheries operating in tropical/subtropical waters. The results support this assumption since false killer whales were reported also preferentially taking tuna species when depredating in these other fisheries.

Most (>90%) of the fish affected by depredation were too damaged to be retained, with 58.9 ± 79.8 kg worth of fish per trip being lost. For the entire period, the total volume depredated was 121,805 kg (4.5% of the total catch, equivalent to USD 99,953 per year). This could be considered lower than the volume of fish depredated by killer whales and sperm whales in some demersal Patagonian toothfish longline fisheries of the Southern Ocean (e.g. >30% of the catch, equivalent to USD 15 million per year)[7]. The depredated volume and associated value for the New Caledonian fishery is also smaller than around the Seychelles (130,000 metric tonnes between 2004 and 2010; USD 500,000 per year)[7].

Perspectives

The estimates of depredation levels should be considered as minimum estimates due to the nature and the extent of the data available for the study. The use of logbook and observer data can lead to bias that comes with self-reporting and the relative low coverage of fishery observers. Nevertheless, these initial results can be used to better understand the socioeconomic impact of depredation.

In September 2023, a longline fishing trip was conducted in order to gather information on to better characterize the phenomenon observed by the offshore industry in New-Caledonia. To this end, a data collection protocol was set up to collect a wide range of biological and environmental information using underwater cameras, hydrophones, accelerometers and genetic samples deployed to complement the usual observation data collection carried out by the observer program. New-Caledonia intends to continue these experiments in collaboration with local fishing companies in the coming years. Further work is required, particularly on species ecology and fishermen's strategies, in order to draw up recommendations for reducing the impact of the interaction between marine fauna and fisheries.

[7] References for these figures can be found in *Mollier et al. 2024*

Finally, as New Caledonia accounts for only a small proportion of Pacific longline catches, the topic of depredation and its impact seems interesting to consider at a regional scale.

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