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Assessment of depredation level in Reunion Island pelagic longline fishery based on information from self-reporting data collection programme

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Introduction

Depredation attracts broad international attention during recent decades with worldwide expansion of fishing by passive gears, in particular pelagic and bottom longlines. Presumed steady increase of depredation level from the early years of fisheries to present (IOTC, 2000a, Donoghue et al., 2003, Gilman et al., 2007) and economic losses associated with this type of interaction (IOTC, 1999, 2000a, Bargain, 2000, 2001; Nishida, Tanio, 2001, Rabearisoa, 2012) were major concerns.

Depredation is usually defined as "the partial or complete removal of hooked fish or bait from fishing gear…" by predators such as cetaceans, sharks, bone fish, birds, squids, crustaceans and others" distinguishing it from predation, i.e. "the taking of free swimming fish (or other organisms)…" (Donoghue et al., 2003; Gilman et al., 2006, 2007).

Depredation mostly occur in stationary (passive) gears like pelagic and bottom longlines (Kock et al., 1996; Gilman et al., 2006, 2008), gillnets (Read et al., 2003), traps, line fisheries (de Stephanis, 2004; Navarro, Bearzi, 2007) and within aquaculture facilities (Stickley et al., 1992; Coon, 1996; Glahn et al., 1999; Fenech et al., 2004; Kloskowski, 2005). However highly mobile fisheries like trolling, trawl and purse seine are also sometimes subject to depredation (often mixed with scavenging) by marine mammals (Zollett, Read, 2006, Zahri et al., 2004), squids (Olson et al., 2006), birds (Baker et al., 2007) or sharks (our unpublished data). Longline fishing operations suffered probably the most from depredation due to its worldwide distribution, stationary nature, long exposure (hours) in the environment, easy access to animal caught and gear fragility.

Possible alternation of predators behaviour resulted from interactions with fishing gears was also suggested based on fact of depredation itself and different reaction to fishing gear among populations of the same species (Matkin et al., 2007). If alteration of predators' behaviour is really take place, potential wide impact on ecosystem scale might be envisaged.

Depredation occurrence and respective losses of catch are usually not reported in the fisheries statistics and are a source of 'cryptic mortality' that is not accounted for in current stock assessment studies, therefore affecting directly fisheries management decisions and practice (Gilman et al., 2007, Romanov et al., 2007).

Economic losses due to catch and gear damage have brought serious concerns to fishermen (Yano, Dahlheim, 1994; Nishida, Tanio, 2001; Donoghue et al., 2003; Rabearisoa, 2012) while harm to marine megafauna either through interactions with fishing gears or with fishermen who attempts to protect their catch (Gulland, 1986; Read, 2008) rises conservation issues.

There is an obvious and urgent need for close monitoring of the depredation phenomenon, its quantification, incorporation into the fisheries management schemes and development of mitigation measures. Here we report preliminary results of depredation affecting the local longline fishery operated from Reunion Island, basing on information from self-reporting data collection programme.

Material and methods

Fleet and operations modes

The pelagic longline fishery of Reunion Island started its activity in 1991 with single vessel involved in the fishing operations (Bourjea et al., 2009). Fleet grew fast until 2000, when 38 active longliners participated in the fishery. By 2013 the number of active longliners decreased to ~29 due to hard operational conditions (high fuel and bait prices, decrease of CPUE, depredation, and low offboard prices for swordfish and tuna) and consequently marginal profit. Details on the fleet operations area, fishing strategy, fishing gear and observation system were described in Bourjea et al. (2009) and Bach et al. (2010, 2011).

It should be noted however that the fishing strategy used by a local fleet are swordfish-targeting: involving night shallow sets, lightstick-equipped branchlines, and squid bait (or mixing squid and fish bait). During recent years some kind of evolution in the fishing strategy was observed with attempts to additionally target tuna species by increasing soaking time: deploying longline earlier and retrieving later than usual in order to overlap tuna late evening/early morning feeding activity at the surface, especially in the areas of tuna aggregations (east coast of Madagascar).

Depredation seems to be an important issue for local longline fishery. There is common believe among fishermen that depredation levels are steadily increasing. Some captains reported associations between cetaceans and their vessels. An anecdotic evidences claiming that cetaceans following the boat in successive fishing operations spread from east coast of Madagascar to Mayotte and back. There is common opinion among fishermen that ‘globicephales’ (i.e. *Globicephala macrorhynchus*) are mostly responsible on depredation on fish caught, while we observed interactions with other predators, in particular cetaceans (false killer whale *Pseudorca crassidens*, dolphins: Risso dolphin *Grampus griseus*, bottlenose dolphin *Tursiops truncatus*), sharks, squids and seabirds. Depredation combined with overall low CPUE observed during several consecutive months of the 2013 provoked a “depredation crisis” that jeopardizes longline fishery of Reunion Island. Some vessels ceased operations for several weeks waiting for improvement of the situation. The overall impact of catch losses and suspension of fishing operations resulted in serious economic losses for the longline fleet based in Reunion Island.

One should keep in mind that quantification of overall levels of depredation and depredation impact is very challenging. Despite overall detrimental impact of depredation on the fishery and fishery economics there is no system to collect information on depredation on routine basis for totality of the fleet. Observer coverage is of local fleet is relatively low (~5% of operations) therefore complementary data collected recently during self-reporting program provides important source of information.

Here we present an attempt to estimate depredation level and its impact on the fisheries based on data collected during self-reporting programme.

Self-reporting programme and data

The pilot self-reporting programme (SRP) developed by IRD and CAP RUN, within activities of the EU “Data Collection Framework” (DCF) was started in April 2011 (test phase dated back to 2009) (Bach et al., 2012). The programme targeting small and medium sector of fishing vessels: 8-12 m and 12-16 m LOA, which are difficult or sometime impossible to monitor with observers. Data collected during self-reporting programme (through the data sheets filled out by vessel’s captains) contain detailed information on fishing operations (date, time, geographic positions of both setting and hauling, gear configuration, maximum fishing depth: the latter obtained with a TDR[1] deployed on the mainline), of catch composition (total catch, retained catch, and discards), of catch fate (conserved on

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[1] TDR – temperature-depth recorder. NKE Instrumentation, Rue Gutenberg, Z.I. Kérandré, 56700, Hennebont, France.

board for sale, conserved on board for crew consumption, discarded alive or dead, depredated …) and interactions with marine mammals, seaturtles and seabirds. Self-reporting sheets contains much more detailed and diverse information than usually required/reported in logbooks of fishing vessels.

All indexes were calculated based on pooled monthly data without any spatial stratification. Quarterly indexes computed as a mean of monthly indexes.

Depredation presented here is a cumulative index for target (swordfish) and non-target but commercially important species (yellowfin tuna, bigeye tuna and albacore, blue, black, stripped marlin and shortbill spearfish, and dolphinfish). Quarterly distribution for '**Depredation Index (DPI)**' (Romanov et al., 2007; Ramos-Cartelle, Mejuto, 2008), were mapped by one-degree squares. DPI is:

$$DPI = \frac{\sum_0^i F_D}{\sum_0^i H} \times 10000$$

Where,

F_D (fish damaged) is the pooled number of marketable fish individuals that were damaged; H is the total number of hooks deployed (pooled nominal fishing effort).

We computed several other indexes, characteristics of depredations, such as:

Attack interval (AI) (Nishida, Tanio, 2001):

$$AI = \frac{\sum O}{\sum O_D}$$

Where,

O is fishing operation (longline set), and O_D (operations with depredation)

Damage rate (DR) (Nishida, Tanio 2001, Romanov et al., 2007)

$$DR = \frac{\sum O_D}{\sum O}$$

O is total number of fishing operations (longline set), O_D (operations with depredation);

Damage intensity (DI) (Nishida, Tanio, 2001, Romanov et al., 2007):

$$DI = \frac{\sum_0^i F_D}{\sum_0^i O_Y}$$

Where,

F_D is fish damaged,
O_Y – operations (either total, positive, affected, affected by specific predator); and

Depredation rate (DPR)(Donoghue et al., 2003, Romanov et al., 2007):

$$DPR = \frac{\sum_0^i F_D}{\sum_0^i F_C}$$

Where,

F_D (damaged catch) is number of fish damaged, F_C (total catch) is number of fish caught, i – number of fishing operations.

Depredation by cetaceans (e.g., globicephalas and false killer whales) and sharks are presented separately. Total depredation is based on actual records of depredated fish, while group-specific cetacean and shark depredation are based on declaration of supposed interactions with the respective predators. Self-reporting forms distributed among fishermen do not allow yet to declare the number of fish attacked by a particular predator group. This approach was chosen to reach maximum simplicity of reporting forms and decrease workload of vessel crew. However such apparent uncertainty in data collected lead us to conclusion on modification of reporting format in order to reach more certainty and a compatibility with depredation data reported by observers.

Results and discussion

A total of 711 fishing operations (=sets) with a total effort of ~869000 hooks has been monitored between May 2011 and June 2013 (Table 1). Coverage rate in terms of total fishing effort (hooks set) / observed fishing effort (hooks observed) varied from ~5% in 2011 to 23% in 2012, representing on average 12% for period where data for total fishing effort were available. In total 432 sets were not attacked, 78 was attacked by cetaceans, 181 by sharks and part of them (44) were attacked by two groups of predators.

The exact position of setting and hauling are collected, therefore fishing polygons that include the line drift can be defined as well as their centre of gravity (Appendix I). Spatial quarterly distribution of all reported sets is presented in Figure 1. The overall spatial coverage of fishing operations spreads from the waters around Reunion Island westward to east coast of Madagascar.

On overall depredation affected 30-40% of fishing effort (both in terms of sets and hooks)(Fig. 2-3). Sharks were responsible for 20-30% of attacks while cetacean' attacks covered about 10% of the fishing effort. Throughout the period of observations the percentage of attacked sets were rather stable for each predator group, while the number of hooks not affected by depredation slightly increased. This could be explained by fishermen compensatory behaviour: a tendency to set more hooks during 'safe' periods and decrease longline length when heavy damage observed.

Spatial distribution of depredation

Predators was found all over the whole area of fishing operations (Fig. 4-6). However at finer scale, depredation occurred in several hotspots while the rest of the fleet only partially affected or was not affected at all. It was suggested (Rabearisoa, 2012) that cetaceans tend to be aggregated in the areas with higher fish abundance. Therefore depredation is most detrimental in the most attractive for fishermen zones. Apparently our observations on CPUE values suggest that it might be true for sharks but not for cetaceans.

CPUE

Overall quarterly CPUE is highly variable with strong seasonality while commercial CPUE (of marketable fish kept) is logically highly dependent on presence/absence of predators attacks and type of predator. The global CPUE vary from 11 to 30, 6 to 36, and 12 to 42 ind./1000 hooks for respectively non-attacked sets, attacked by cetacean and by sharks (Fig. 6). For fish kept these values were: 11-30, 3-36, and 12-40 respectively. It should be noted however that for 6 quarters out of 9 observed, the highest total and commercial CPUEs were recorded in sets that were attacked by sharks. In presence of shark depredation, CPUE (both total and commercial) was always higher than in non-attacked sets! In contrast cetaceans attacks was always (except one quarter of observations) detrimental to fishing success. The median of total/commercial CPUE for cetacean-attacked sets were 10.8/8.6 while these values were 17.6/17.6 for non-attacked sets and 17.9/16.6 for sets attacked by sharks (i.e. almost two times lower). This could be indicator that presence of cetaceans may be a 'fear-factor' for pelagic fish directly affecting the efficiency of longline fisheries.

Discards

As it was shown earlier (Romanov et al., 2007) for each particular set losses caused by cetacean' attacks are usually much heavier than losses due to shark attacks: cetaceans damaged on average 56% of target catch while shark damage 32%. Furthermore damage of individual fish by cetaceans imply almost complete loss of fish while shark-attacked fish are often still marketable.

Our data shoes that within fishing operation (set) number of damaged fish by cetaceans is more than two times higher than by sharks: 5.5 vs. 2.0 (Fig. 7).

Level of discards of target species is also an important indicator of undrawn profit in fisheries. Cetacean-attacked sets are a major source of discards: up to 36% of fish caught are discarded due to damage (Fig. 8). This figure is much lower for shark-attacked sets (not exceed 29%) while discards of target fish in non-attacked sets are very low: less than 1% of the fish caught. It should be noted that level of discards steadily increased from 2011 to 2013. This might be indicator of increased severity of attacks or just better reporting from fishermen who becomes accustomed to data self-reporting forms. We also noted an increase of normalised index of discards: individuals per 1000 hooks, in particular for shark-attacked sets.

Table 1. Self-reporting data program (SRP) coverage over total fishing effort for >12m pelagic longline fishing fleet. Total fishing effort was provided by IFREMER; fishing effort for vessels <12m is not available

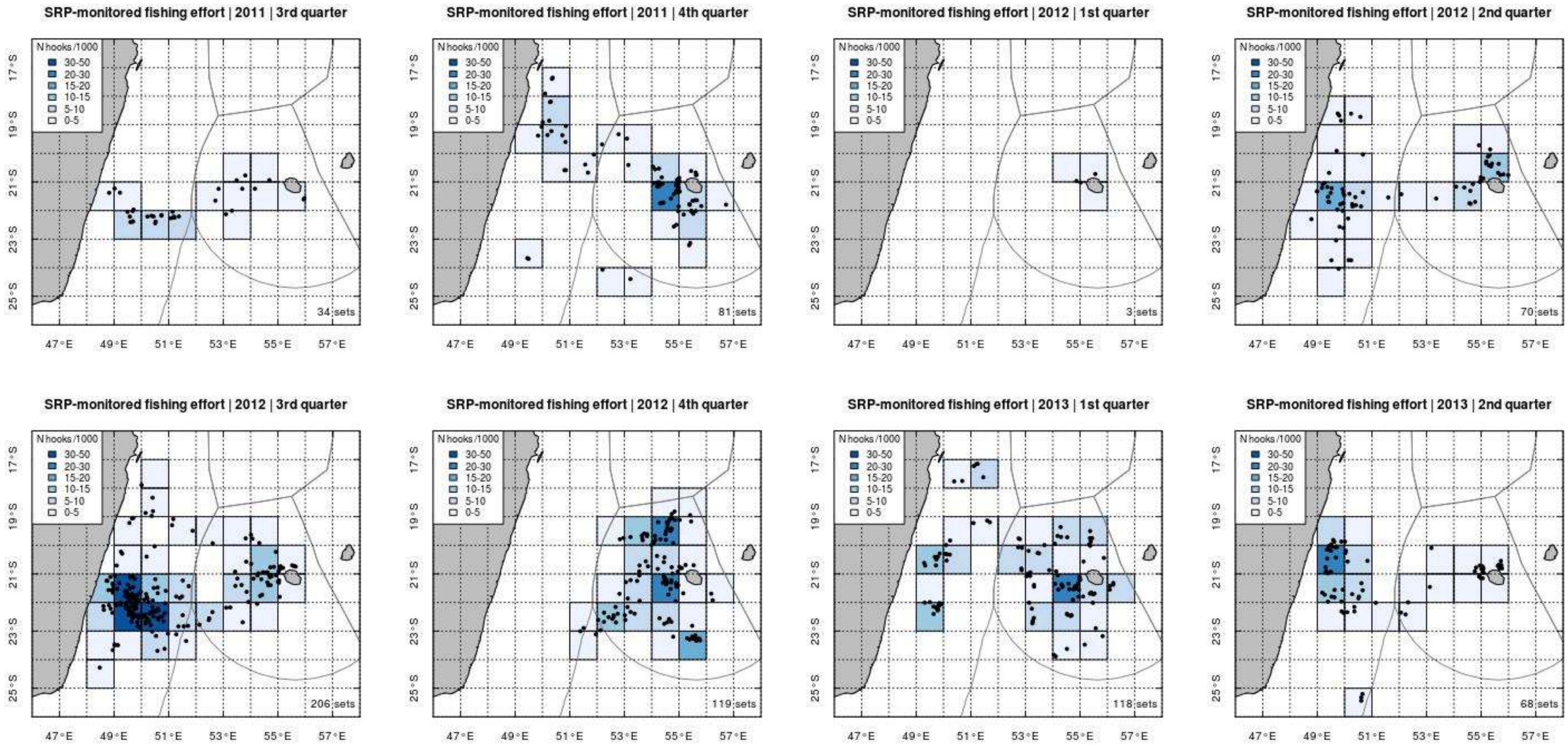
Year	Total fishing effort	SRP-monitored effort*	SRP cover %
2011	3063938	143562	4.7
2012	2141824	501478	23.4
2013	-	218678	-
			12.4**

*Self-reporting program-monitored effort including vessels >12m
**SRP coverage for 2011-2012

Table 2. Major indexes of depredation* on main commercial species (swordfish, tunas, marlins and dolphinfish) for Reunion Island pelagic longline fisheries. N sets is the total number of sets. Depredation rates are given for the total depredation, depredation by cetaceans (c), and sharks (s).

Year	Quarter	N sets	AI	AIc	AIs	DR, %	DRc, %	DRs, %	DI	DIc	DIs	DPR	DPRc	DPRs	DPI	DPIc	DPIs
2011	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	12	6.0	6.0	-	16.7	16.7	0.0	0.6	0.6	0.0	7	58	-	13	13	0
	3	34	2.8	34.0	3.4	35.3	2.9	29.4	0.4	0.0	0.4	1	0	4	3	0	3
	4	81	2.1	6.2	3.9	46.9	16.0	25.9	1.5	0.9	0.4	4	15	2	13	7	3
	Annual	**127**	**2.4**	**7.9**	**4.1**	**40.9**	**12.6**	**24.4**	**1.1**	**0.6**	**0.3**	**3**	**15**	**3**	**10**	**5**	**3**
2012	1	3	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	0	-	-	0	0	0
	2	70	2.3	6.4	4.7	44.3	15.7	21.4	0.4	0.1	0.2	3	9	4	3	1	1
	3	206	2.9	15.8	3.7	34.5	6.3	26.7	0.8	0.3	0.5	4	29	8	6	2	4
	4	119	1.9	9.9	3.1	53.8	10.1	31.9	1.6	0.4	0.6	5	13	5	12	3	4
	Annual	**398**	**2.4**	**11.1**	**3.7**	**41.7**	**9.0**	**27.1**	**1.0**	**0.3**	**0.4**	**4**	**17**	**7**	**8**	**2**	**4**
2013	1	118	2.9	11.8	4.7	34.7	8.5	21.2	1.0	0.3	0.4	7	48	8	8	3	3
	2	68	1.5	4.3	4.0	64.7	23.5	25.0	0.6	0.2	0.3	5	20	13	5	2	3
	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Annual	**186**	**2.2**	**7.2**	**4.4**	**45.7**	**14.0**	**22.6**	**0.9**	**0.3**	**0.4**	**6**	**36**	**9**	**7**	**2**	**3**

*__AI__ is a number of successive sets between attacks,
DR is percentage of sets attacked,
DI is a number of fish damaged per operation,
DPR is a ratio of fish damaged to 100 fish caught,
DPI is number of fish depredated per 10000 hooks set.



SRP-monitored fishing effort | 2011 | 3rd quarter

SRP-monitored fishing effort | 2011 | 4th quarter

SRP-monitored fishing effort | 2012 | 1st quarter

SRP-monitored fishing effort | 2012 | 2nd quarter

SRP-monitored fishing effort | 2012 | 3rd quarter

SRP-monitored fishing effort | 2012 | 4th quarter

SRP-monitored fishing effort | 2013 | 1st quarter

SRP-monitored fishing effort | 2013 | 2nd quarter

Figure 1. Fishing effort monitored by self-reporting program in 2011-2013. Fishing effort is the number of hooks.

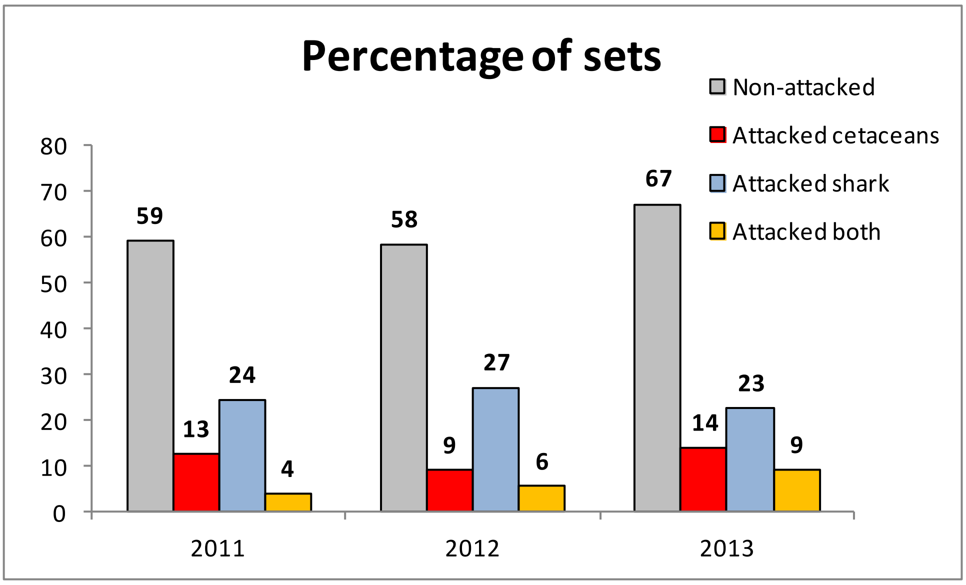


Fig. 2. Percentage of fishing effort (sets) intact and affected by depredation

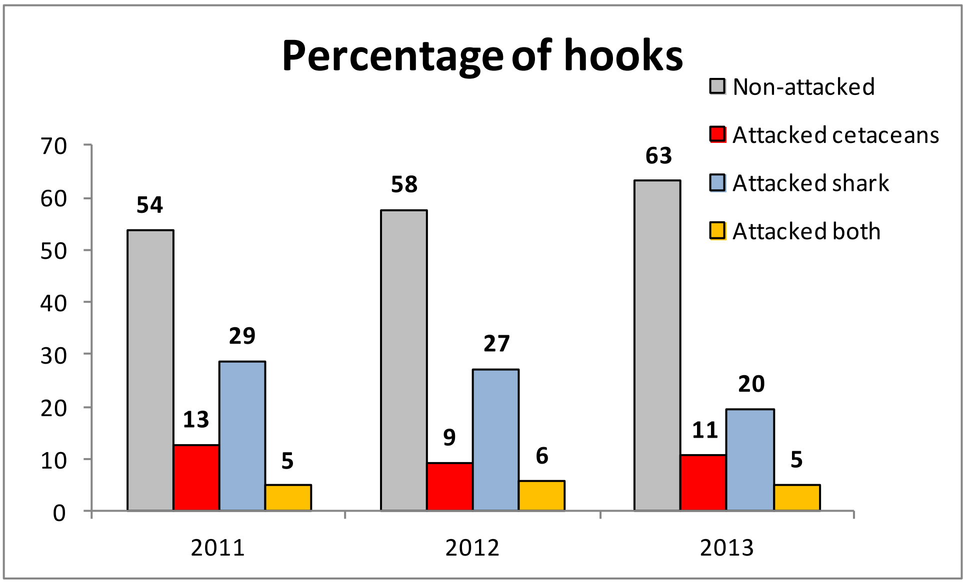


Fig. 3. Percentage of fishing effort (hooks) intact and affected by depredation

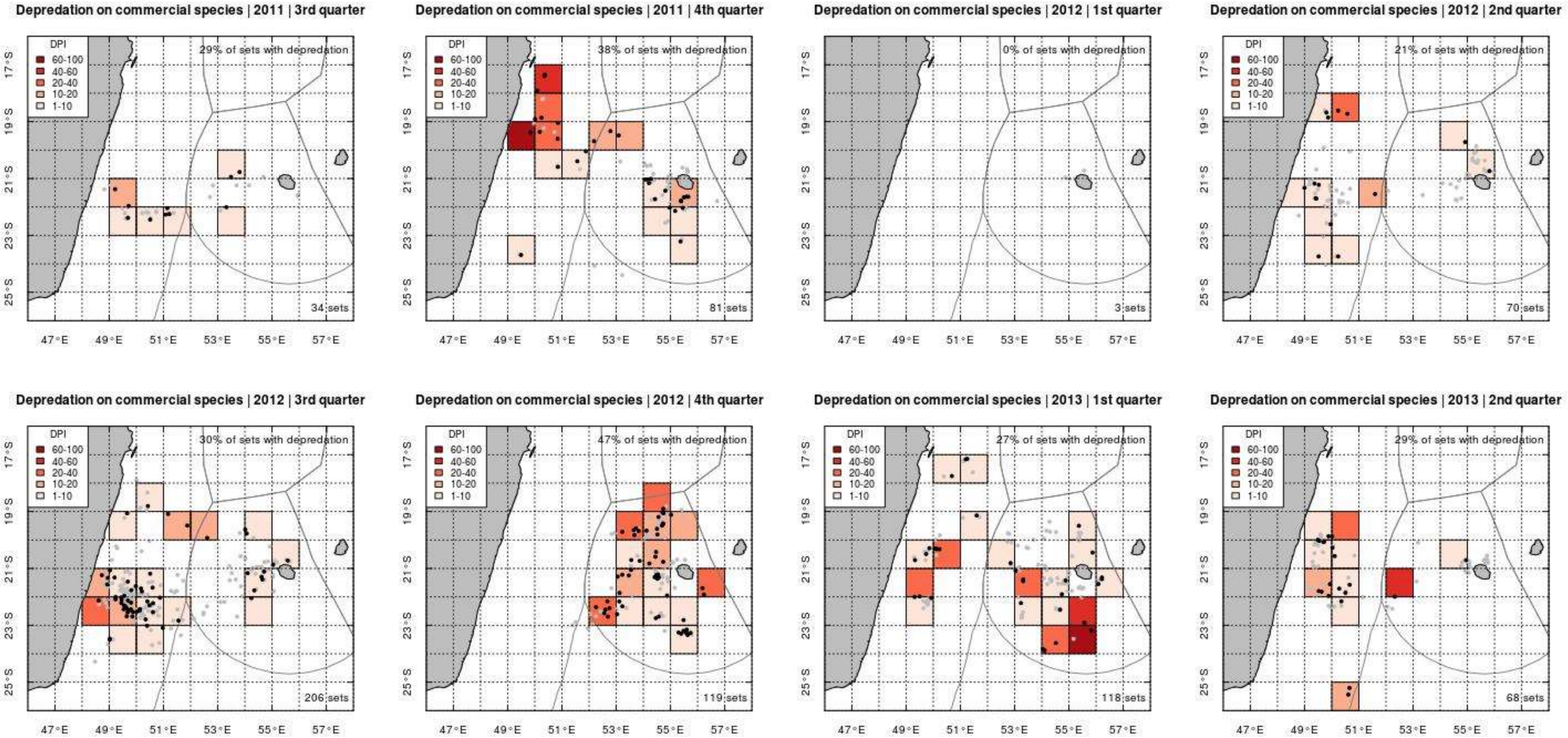


Figure 4. Total depredation index (DPI) 2011-2013. DPI is the number of depredated fish per 10000 hooks including swordfish, tunas, marlins and dolphin fish

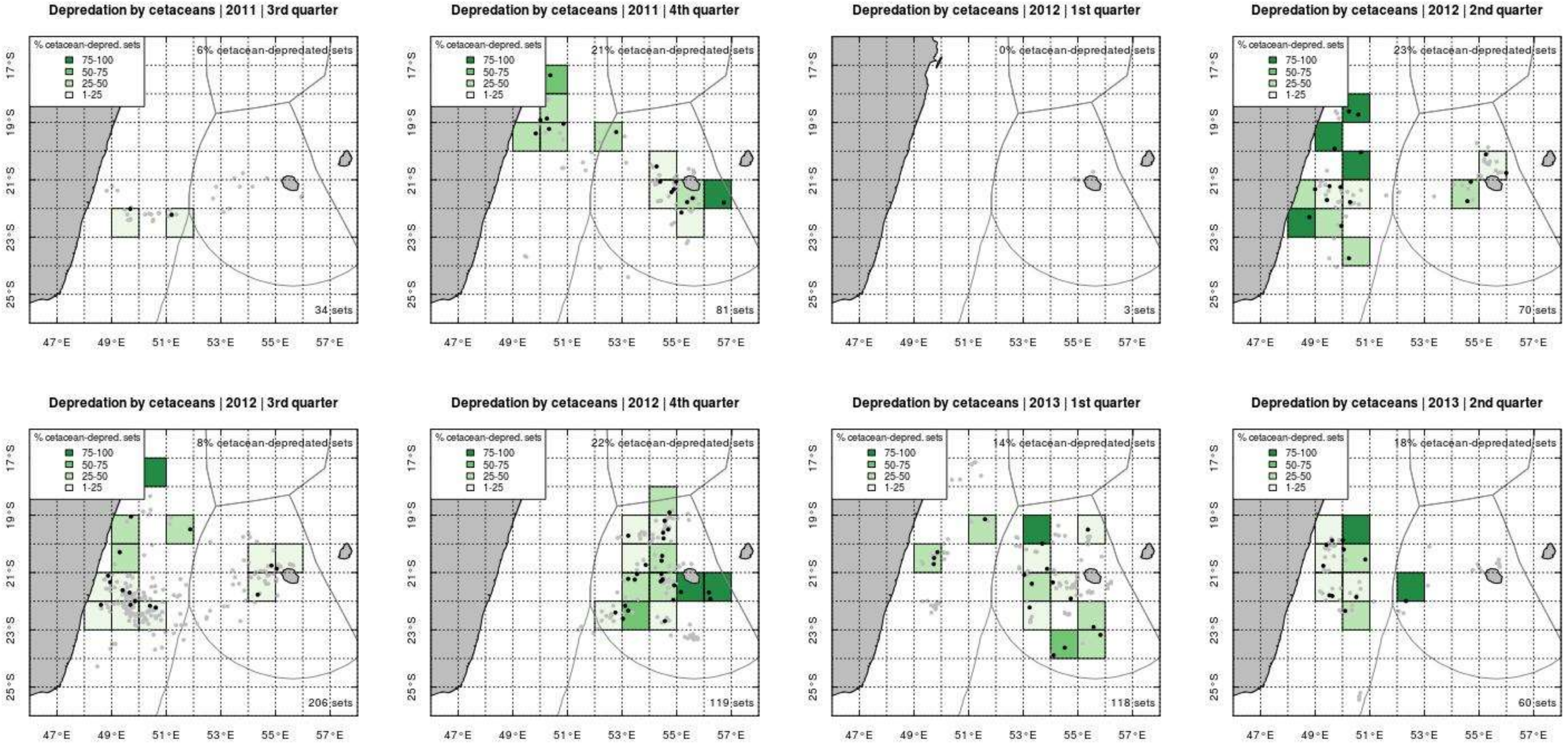
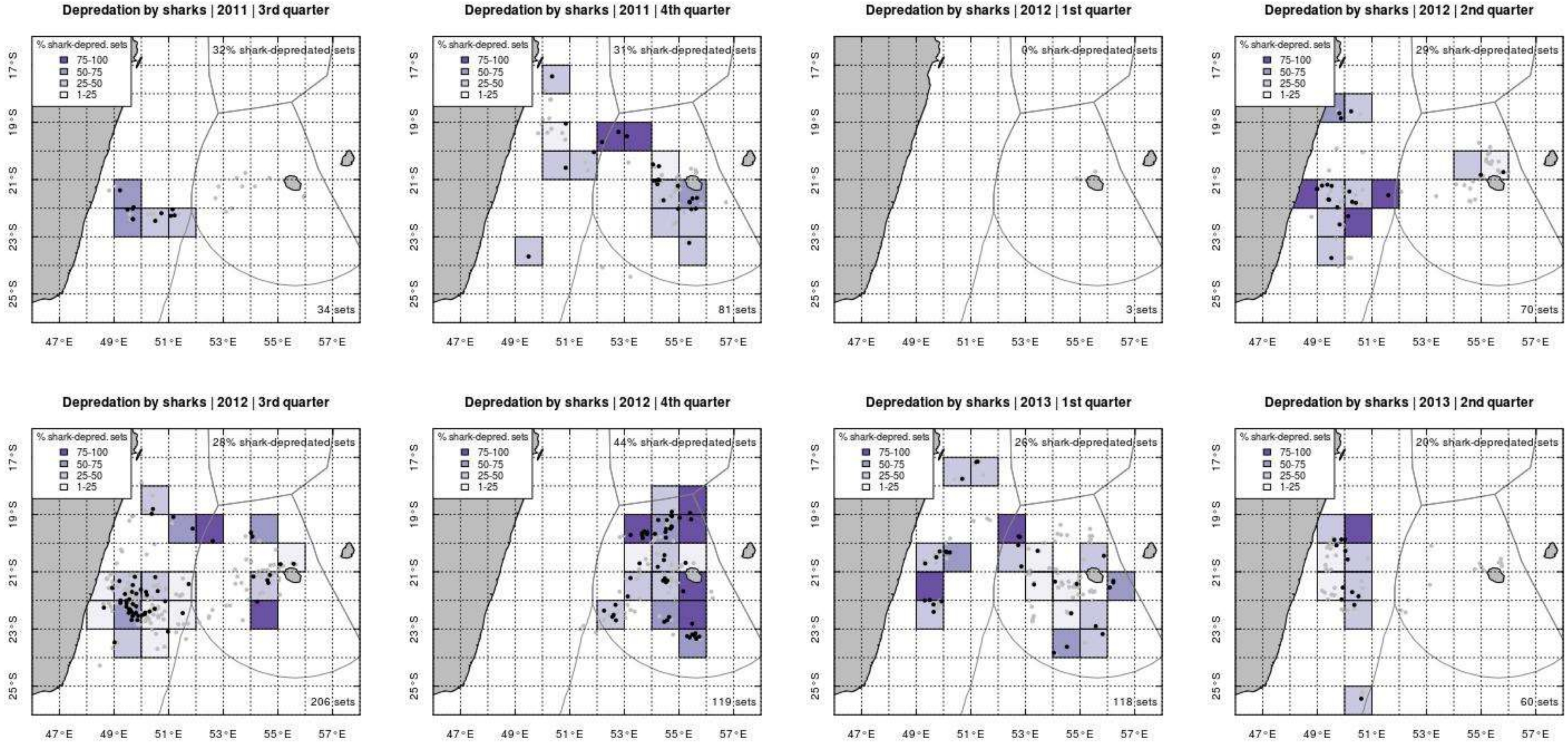


Fig. 5. Depredation by cetaceans in 2011-2013



Depredation by sharks | 2011 | 3rd quarter

Depredation by sharks | 2011 | 4th quarter

Depredation by sharks | 2012 | 1st quarter

Depredation by sharks | 2012 | 2nd quarter

Depredation by sharks | 2012 | 3rd quarter

Depredation by sharks | 2012 | 4th quarter

Depredation by sharks | 2013 | 1st quarter

Depredation by sharks | 2013 | 2nd quarter

Fig. 5. Depredation by sharks in 2011-2013

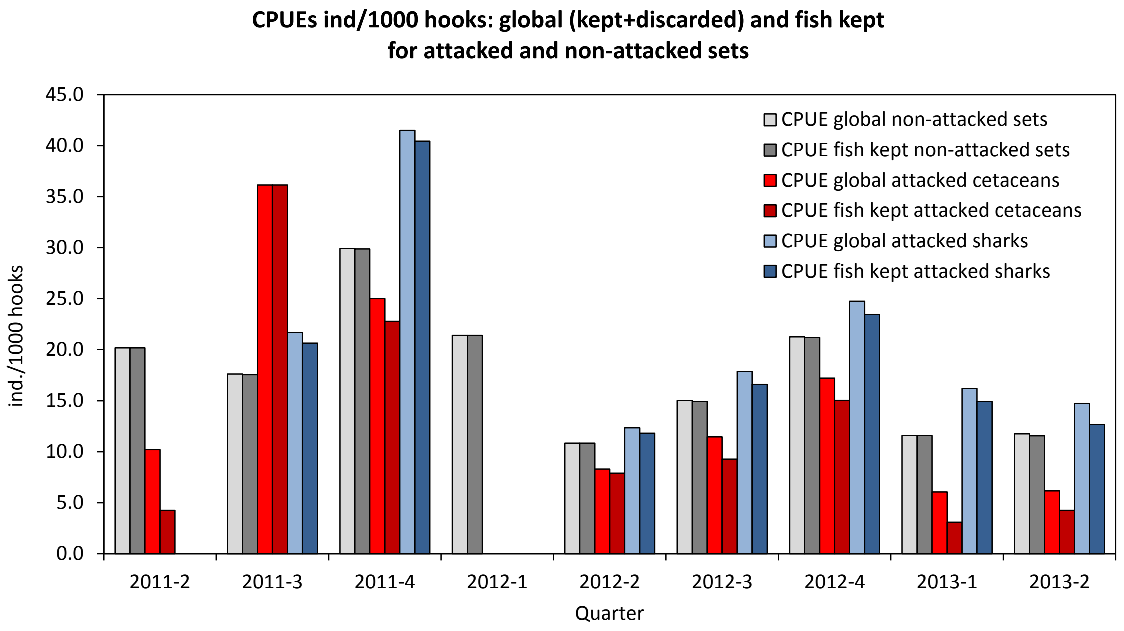


Fig. 6. CPUE of commercial species global (kept+discarded) and CPUE fish kept for non-attacked sets and for set depredated by cetacean and sharks.

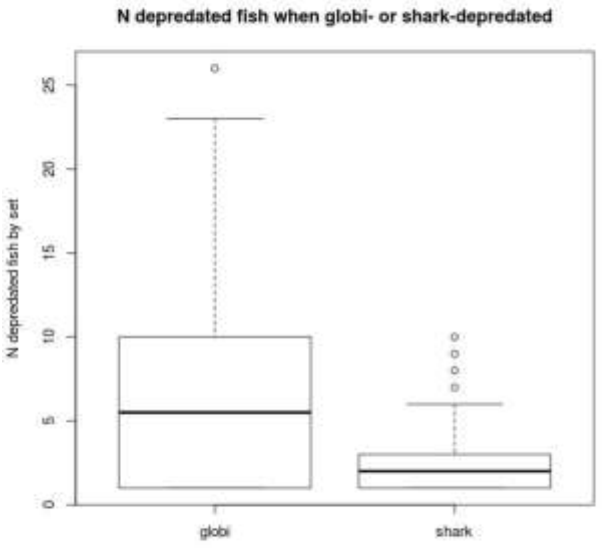


Figure 7. Depredation impact of cetaceans compared to sharks. Number of depredated fish for cetacean-depredated (median is 5.5) and shark-depredated (median is 2) sets.

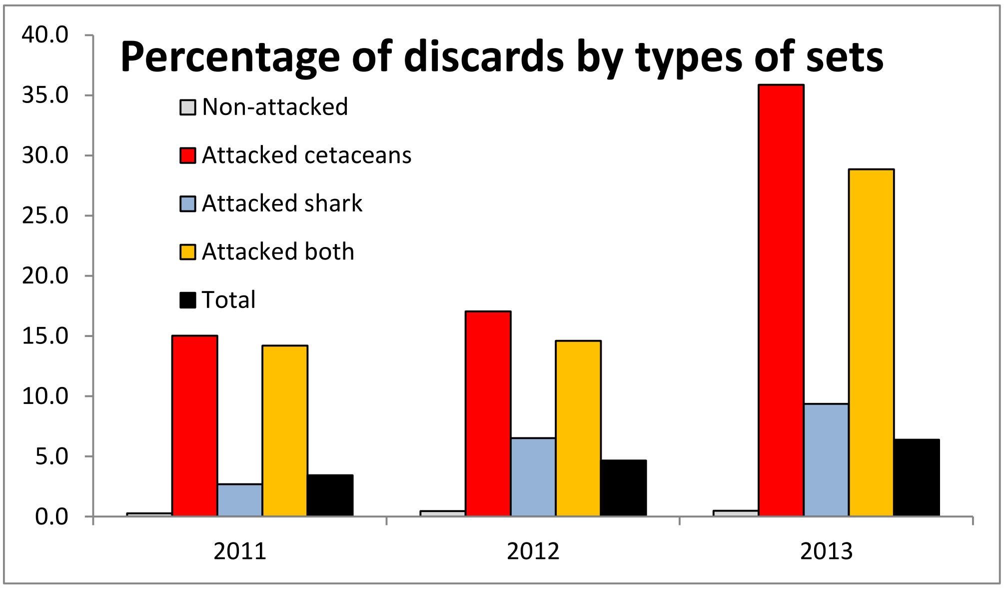


Fig. 8. Annual level of discards (%fish discarded to fish caught) in Reunion Island longline fisheries.

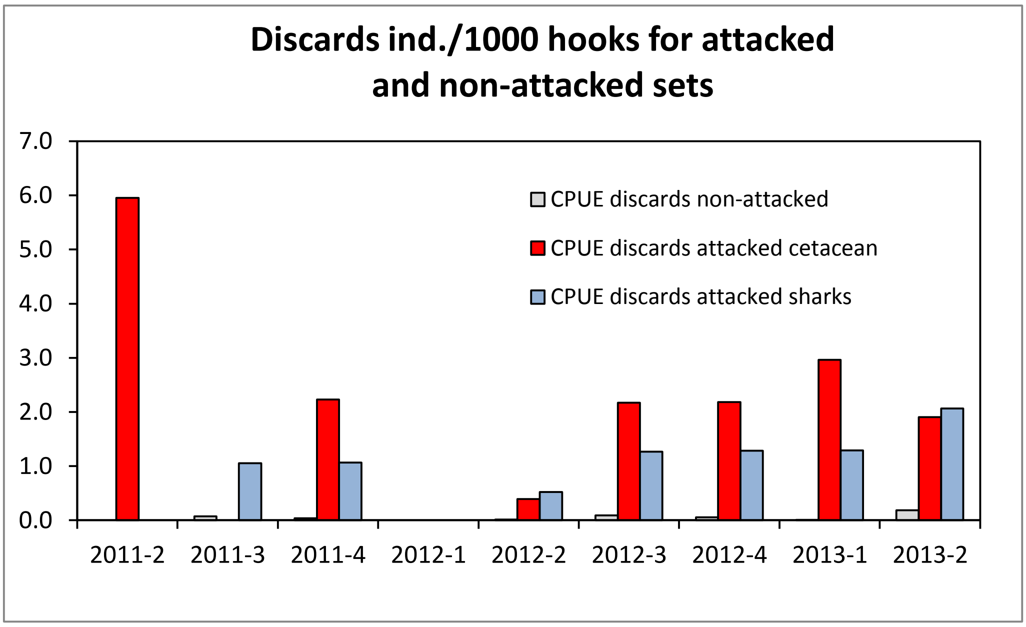


Fig. 9. Level of discards of commercial species (ind./1000 hooks) in Reunion Island longline fisheries.

Impact on the fisheries

Overall losses

Overall detrimental effect of depredation is difficult to challenge. However for better understanding of depredation impact on fisheries, it is necessary to evaluate a balance between retained fish and fish lost in all types of operations (depredated and not). Our results demonstrate that the percentage of discarded commercial fish does not exceed 6.5% of commercial fish caught by the vessels that participated in the self-reporting programme (Fig. 10). This means that the overall impact on local pelagic longline fishery is relatively low. However one should keep in mind that overall profitability of pelagic longline fisheries at the Reunion Island is relatively low due to high running costs and low fish prices. Under such conditions even such minor losses might produce overall disastrous effect on fisheries, which is based on marginal profit. The warning factor is increased percentage of depredation-related discards due to decreased catches and increased severity of attacks (Fig. 10).

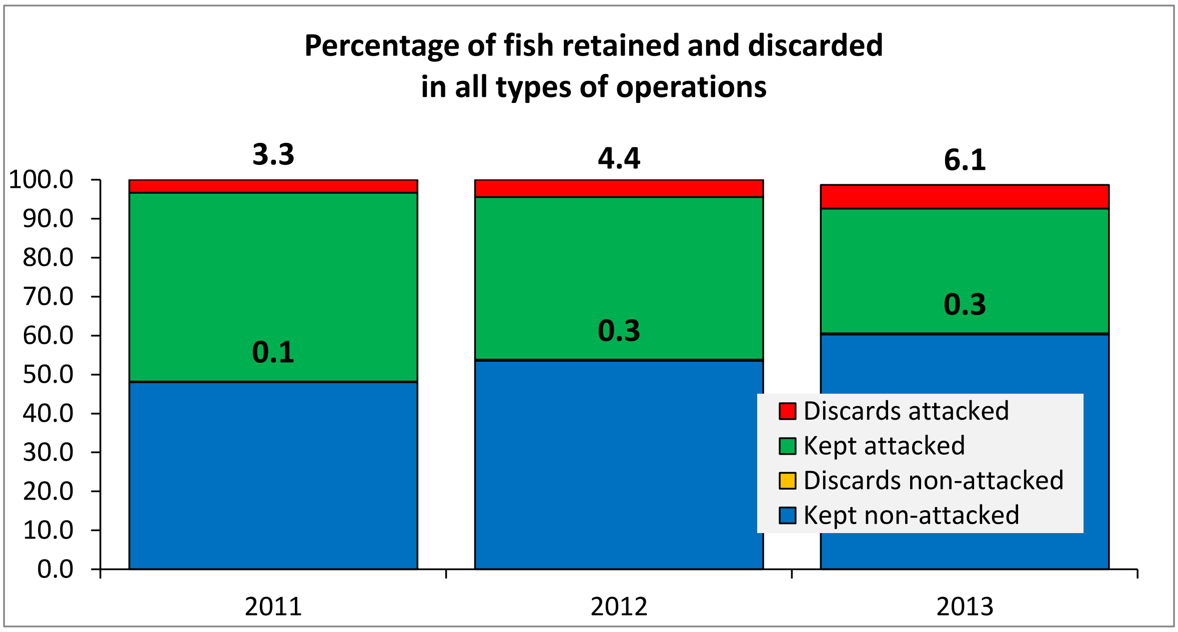


Fig. 10. Percentage of retained/discarded fish in the overall catch of vessels participated in the auto-reporting sampling programme.

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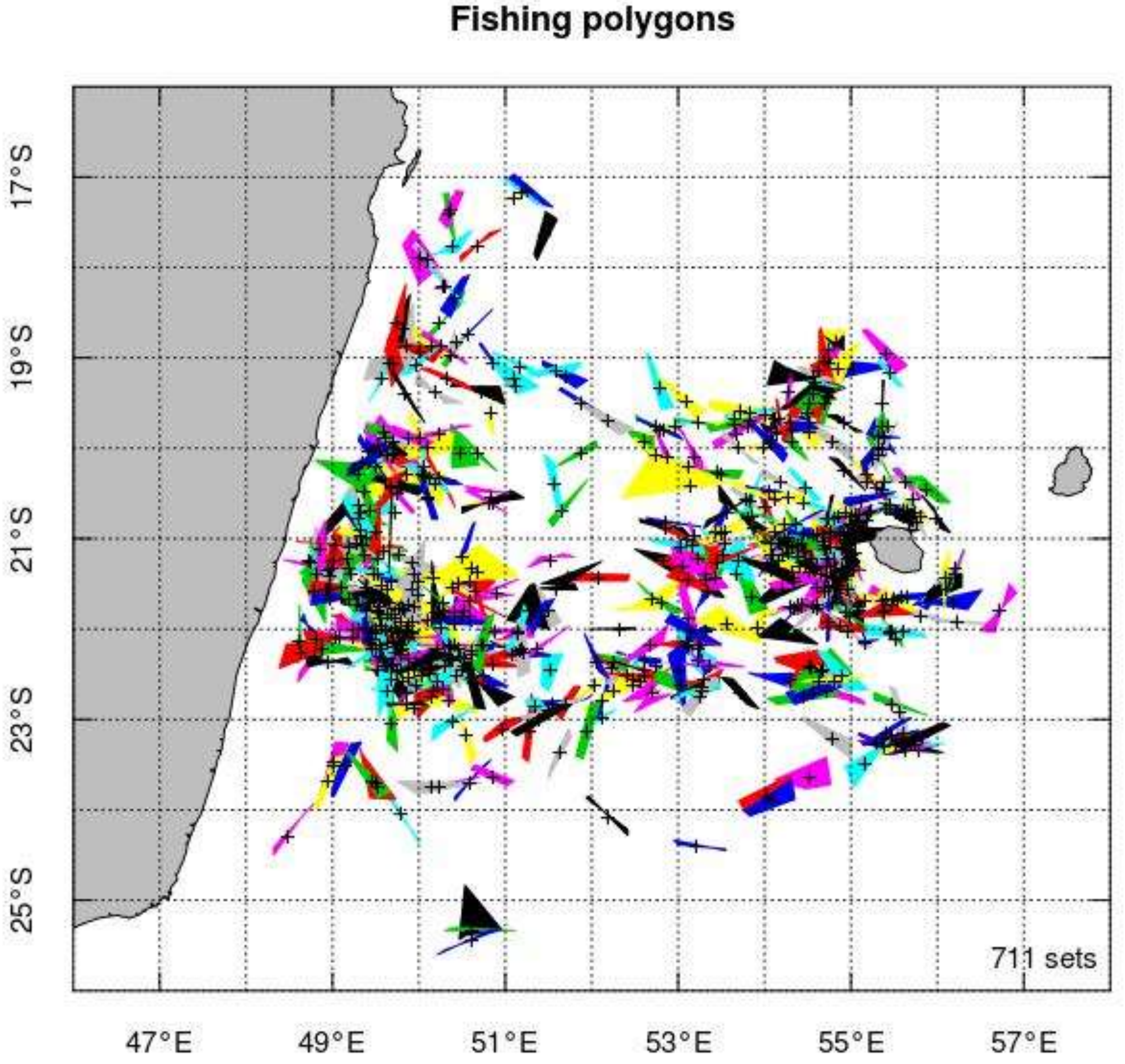

Fishing polygons for the period May 2011- June 2013