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Assessment of the efficiency of the physical protection of fish as mitigation measure to depredation by marine mammals in pelagic longlining

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Introduction

Depredation is defined as the removal of fish from fishing gear by sharks and cetaceans and is opposed to predation, which is the catch of free ranging fish (Donoghue et al., 2003). Reports on depredation by marine mammals on fish caught on commercial longlines indicate an increase both in the frequency of such events and the number of cetacean species involved. Over the past decades, longline fishing has undergone a rapid increase and the scale of interactions between longline fisheries, cetaceans and sharks and longline fishing effort has expanded simultaneously (Donoghue et al. 2002). The problem is documented worldwide and is known in many fisheries (Hückstädt and Antezana, 2004; Hanan et al., 1989; Zollett and Read, 2006; Visser, 2000; Secchi and Vaske, 1998; Dahleim, 1988; Roche et al, 2007). But opposite to bottom longline fishery targeting toothfish (*Dissostichus eleginoides*), pelagic longline fisheries targeting tuna (*Thunnus* spp) and swordfish (*Xiphias gladius*) received less interest from the scientific community regarding depredation issues. In tropical areas, depredation involves mostly false-killer whales (*Pseudorca crassidens*), pilot whales (*Globicephala macrorynchus*) and pelagic sharks. The monitoring of the extent and magnitude of depredation has a great importance since it leads to many negative consequences affecting commercial, biological and assessment aspects. As an impact on assessment, an increase of fishing effort is observed to compensate a fish loss not taken into account in stock analysis (Donoghue et al. 2002). Depredation has biological effects because fisheries give cetaceans access to resources to which they could not access before. Cetacean and shark hunting behaviors are changing as they will get used to search after boats to get easy-to-catch preys instead of hunting common feeding preys (Secchi and Vaske, 1998).

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And last but not least, there are increased risks of injury or mortality of cetaceans and sharks, firstly in a deliberate way due to fishermen who can't stand losing fish anymore, or in an accidental way due to entanglement with the fishing gear. It represents an economic loss to fishermen given that they spend extra money when fixing fishing gears damaged by predators, altogether with an increased fuel expenditure when they move away to avoid areas of high depredation rate (Franse, 2005; Secchi and Vaske, 1998). But the main loss of profits is related to fish loss.

In Seychelles, the overall depredation rate was estimated at 21% and was reported as one of the highest in the world for the longlining fishery. For swordfish only, the economical loss was estimated at 1,000,000 € over the 1995-2006 period (Rabearisoa et al. 2007) Since that it is a serious issue, an action plan was produced in 2007 in order to mitigate depredation. The goal of this project is to mitigate and reduce depredation caused by marine mammals on longline-caught swordfish and tunas in the south-west of Indian Ocean.

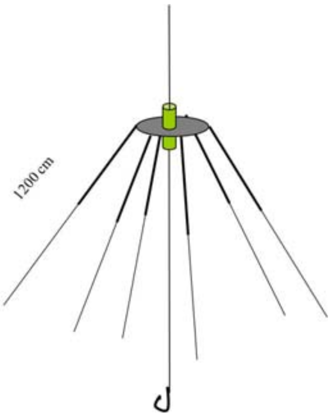
Moreover, in the Indian Ocean, this issue is characterized by a lack of data. Only a few papers deal with this issue (Nishida and Shiba, 2004; Sivasubramanian, 1964; Poisson et al., 2001; Romanov et al., 2007). Number of mitigation measures has been tested so far but none of them proved to be efficient speaking of long term (Jefferson and Curry, 1995). Most research experiments are currently focusing on the use of active and passive acoustic means to deter depredation from cetaceans. They can be efficient at short term but are found to create opposite effect at medium term as they are used as an acoustic attractor by cetaceans (Mooney et al., 2009; Brotons et al., 2008; Franse, 2005).

There are good evidences that cetaceans use their sight to locate the gear and/or the boat, follow them and depredate the fish. Therefore, at the end of the depredation process in order to mitigate depredation events, we propose to develop the physical protection of capture. The goal of this study is to test the efficiency of devices protecting physically catches by covering them. In this context, a first trip was conducted off the Seychelles archipelago onboard a commercial longliner in November 2006. It allowed to study the fishing operation in order to design depredation mitigation devices (DMD) well adapted to the deployment of the fishing gear. Two types of DMD, called “spider” and “sock” were designed and tested respectively in November 2007 and November 2008 onboard the same vessel. Both surveys aimed at checking the efficiency of each DMD and assessing whether they fit the fishing gear and fishing technique parameters and constraints.

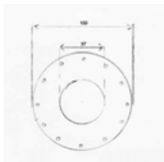
Materials and methods

The "spider"

In November 2007, we tested the "spider" mitigation device, named after its eight strands (Fig 1-a). Trials took place in the north-east of Mahe plateau, during a 13 days-long trip. Designers opted for a dissuasive device made up of a 100 mm diameter plastic disk, with 16 holes in its outer range and a 37 mm diameter central hole (Fig 1-b), four polyester strands inserted in those holes and making eight 1200 mm long hanging legs. The triggering system was made up of a beta pin and an elastic ring (Fig 1-c). The line was inserted in the pin, which was tightened by the ring. The whole system could only be released by a pulling of the hooked fish on the branchline. The device was designed so that the hooked fish was covered by the eight strands, with the disk placed at the level of its bill or its mouth. For each set 327 spiders were set up among 960 hooks, and 26 fishing experiments (2 lines set per day) were operated during the whole survey.



1-a



1-b

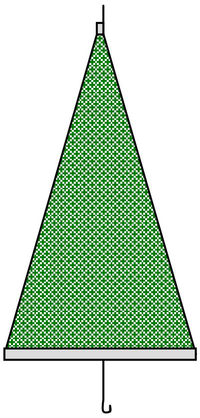
1-c

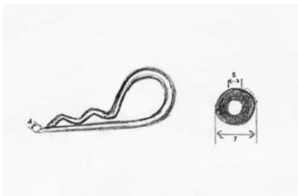
Fig. 1-a : The spider ; Fig. 1-b : Plastic disk ; Fig. 1-c : Triggering system (beta pin and elastic ring)

The "sock"

Based on results obtained during previous trials, a second type of mitigation device called "the sock" was tested in November 2008. The survey was carried out on the same fishing ground (north-east of Mahe plateau) and lasted 17 days. We designed two kinds of devices: one conical net made up of fibreglass mosquito netting and a second one made up of propylene fiber net (Fig. 2-a). A metallic or plastic hoop was set at its base in order to make it rigid and keep it open. The hook was inserted through the upper opening of the device and the device was then fold-up by pulling on the line and inserting it in the beta pin. We added lead weights to increase the diving speed of the device. The same triggering system was used (Fig

2-b and 2-c). As for the spider, the sock was attached above the hook, and the triggering system was released when the fish pulled on the line. Then, the sock slid down the line, covered the catch, and hid it from predators. As they were designed manually, less than 50 socks were ready to be set up for each set. They were set among 850 hooks deployed per set operation, and 13 fishing sets were done (2 portions of line were set per day). We decided to gather the devices on only one line portion.





2-a **2-b** **2-c**

Fig. 2-a : The sock ; Fig. 2b-2c : Triggering system (beta pin and elastic ring)

Experimental procedure and data collection

Initially, the sampling protocol consisted in setting up a device every two hooks. Unfortunately, as the deployment of spider was a time consuming operation, only a feasible frequency of one device per 4 hooks was tested on field. For the second type of depredation mitigation device, as those socks were designed manually, less than 50 of them were ready to be set during the second survey. For the first two sets, socks were attached randomly on the longline. Finally, to increase the odds to obtain significant results on interactions between predators on aggregated catches on the longline, socks were concentrated in the middle of the line, every two hooks.

We collected detailed data during the trials related to every catch (species, weight, depredation type if any) and to the behaviour of all DMD hauled (release status with or without catch, entanglement, deployment quality of the DMD on the fish caught)

Results

Tab 1 Summarization of the total number of sets, hooks and catch for both surveys

	Total nb of sets	Total nb of hooks	Total catch (Thunnus spp + X. gladius)
Survey 1	13	12480	377
Survey 2	13	10920	274

During the first survey, a total number of 12480 hooks were set, and 377 target fish (*T. alalunga, T. obesus* and *X. gladius*) were caught. During the second survey, a total number of 10920 hooks were set, and 274 target fish were caught (Tab. 1).

DMD efficiency

The trigger rate was defined as the ratio between the number of correct deployment of the DMD on the fish caught and the total number of triggered DMD. We considered that a DMD was correctly triggered when it was activated when a fish was hooked and pulled on the line. This rate reached 87% for the spider system, whereas it was about 69% for the sock one (Tab 2).

The untimely triggered rate was defined as the ratio between the number of DMD triggered without capture while hauling and the total number of triggered DMD. This rate was about 9% for the spider and 21% for the sock (Tab 2).

The protection rate was estimated for DMD well deployed on the capture. A good protection corresponds to a DMD covering the whole capture. This rate reaches 80% for spiders and only 10% for socks. (Tab 2).

The efficiency of DMDs regarding depredation was calculated by considering fishing sets affected by depredation due to sharks or cetaceans. This index corresponds to the proportion of fish not depredated and protected by the DMD. It reaches 87.69% for spiders (vs 76,58% for catches without spiders) and 66,67% for socks (vs 89,16% for catches without socks) (Tab 3), suggesting a better efficiency for spiders than for socks.

Tab. 2 Efficiency of the devices regarding their compatibility with the fishing gear (see appendix 1 and 2 for details)

	Spider	Sock
Trigger rate in presence of catch	87%	69%
Untimely triggered rate	9%	19%
Protection rate	80%	10%

Tab 3 Efficiency regarding depredation (we restricted those data to sets affected by depredation)

	Nb fish caught	Nb fish caught without DMD	Nb fish protected by DMD	Nb fish depredated	Nb fish not depredated, protected by DMD	% fish not depredated protected by DMD	Nb fish not depredated without DMD	% fish not depredated without DMD
survey 1	223	158	65	45	57	87,69	121	76,58
survey 2	169	166	3	19	2	66,67	148	89,16

Operational

As for the technical results, we observed a greater entanglement rate on longline equipped with socks than for spiders (respectively 10.95% vs 3.57%). Entanglement with the mainline occurred whether a catch occurred or not. Many factors are involved in entanglement of DMD. First, the hydraulic force produced during the hauling, making the device twirl around the mainline. Sea current was also responsible for this problem and leaded to important knots hard to disentangle. And finally, when a fish was caught, its movements and the tension it applied on the line to escape can produce entanglements. This issue brought the fishing operation to slow down and increase dramatically the hauling time. (Tab. 4).

For both DMD, beta pins were not easy to use, particularly during the setting as they necessitated a strong manual tension to be put in place, and moreover, they rusted as time went by, making them even more difficult to handle. This point leaded to an important loss of time, and that made us set them up every 4 or 2 hooks (Tab. 4).

Tab. 4 Technical results of the devices

	Spider	Sock
Entanglement rate	3.57%	10,95%
Devices loss	12	13
Deployment frequency	1 device/4 hooks	1 device/2 hooks

Discussion

As far as we know, it was the first time that physical protection of fish was tested as a mitigation measure on pelagic longlining. Many scientific teams worked on this methodology in the frame of demersal longline fisheries such as in Crozet and Kerguelen archipelago, Chile and Ukraine, and positive results were obtained regarding the decrease of depredation by sperm whales and killer whales due to DMD deployment (Moreno et al. 2007; Pshenichnov and Zaitsev, 2007). Those nets deployed look more like our socks than spiders and were attached to the mainline. During the hauling, the sleeves slid down the line, protecting the fish caught from killer whales and sperm whales. On the contrary, socks and spiders slid down the branchline once the fish attacks the bait. As depredation on demersal longline fishery mainly occurs during the hauling period, fish caught are rather well protected. This differs from pelagic longline fishery by the fact that depredation occurs mostly during the soak time.

The socks were designed based on the results obtained with spiders. Unfortunately, better results were obtained with the first device (i.e. spiders), particularly with regards to technical results and the easiness of their deployment. More socks were triggered untimely in absence of catch, and less were triggered when a fish was caught. However, without devices such as hook timer to quantify hooking contact, the estimation of this parameter can be biased. Moreover, the entanglement problem could not be solved during the second trial. The entanglement rate was even higher for socks than for spiders. This entanglement issue increased dramatically the time for hauling.

The weak number of devices deployed during each fishing trials does not permit to obtain results on DMD efficiency with a high accuracy. Indeed, whereas from 800 to 950 hooks were set each day, only 327 spiders and less than 50 socks were tested. Therefore, even if some catches were depredated despite their net protection, no definitive conclusion can be obtained as the comparison of the depredation rate of protected hooks and unprotected ones. We need to test more devices before claiming that they failed or not on their dissuasive purpose, and that is an important point which needs to be addressed for the next trial.

But on the other hand, despite their low number, those tests allowed us to check whether the devices fitted both the fishing gear and fishing operations. Both socks and spiders were still too bulky, and their triggering systems required a strong manual tension from the fishermen while setting. Furthermore, their entanglement rate was too important, slowing down the fishing operation when trying to disentangle. Smaller and easier to handle devices are required if we want to keep in mind our idea of physical protection of the catch and if we want to set them up on all hooks in the line.

Another side of DMD must be cautiously examined in the future: do they affect the behaviour of the target fish and then the rate of capture? During the first survey, not such an observation was done, fish being caught either on hooks with or without devices. As for the last survey, data were not sufficient enough to emit a conclusion. However further experiments should be consider this aspect which has consequences on the economic problem of the depredation as well as the depredation behaviour.

An environmental issue was also raised during the second trial since several propylene and fibreglass devices were lost at sea. Next devices should be designed with bio-degradable materials, which would be more costly than predicted. Thus, before investing money in the design of an expensive device which hasn't been yet proved to be effective regarding depredation, the experimental protocol should be enhanced. Next trials should take place in a small scale, on a short monitored longline, before carrying out new fishing trials at large scale.

References

Brotons, J. M., Grau, A. M., Rendell, L., 2008. Estimating the impact of interactions between bottlenose dolphins and artisanal fisheries around the Balearic Islands. Marine Mammal Science 24, no. 1: 112-127.

Dalheim, M. E., 1988. Killer whale (*Orcinus orca*) depredation on longline catches of sablefish (Anoploma fimbria) in Alaskan Waters.

Donoghue, M., Reeves, R.R., Stone, G.S., 2003 (Eds.). Report of the workshop on interactions between cetaceans and longline fisheries, Apia, Samoa: November 2002. New England Aquarium Aquatic Forum Series Report 03-1. 45 p.

Franse, R. Effectiveness of acoustic deterrent devices (pingers). Master Sc of Industrial Ecology. Leiden : Universiteit Leiden, 2005, 31 p.

Hannan, D., Jones, L., Read, R., 1989. California sea lion interaction and depredation rates with the commercial passenger fishing vessel fleet near San Diego. CalCOFl Rep 30: 122-126.

Huckstadt, L., Antezana, T., 2004. Behaviour of Southern sea lions in presence of killer whales during fishing operations in Central Chile. Sci. Mar. 68, no. 2: 295-298.

Jefferson, T. A., Curry., B. “Acoustic methods of reducing or eliminating marine mammal-fishery interactions: do they work?” Ocean & Coastal Management 31, no. 1: 41-70.

Mooney, TA, Pacini, AP, and Nachtigall, PE. 2009. False killer whale (*Pseudorca crassidens*) echolocation and acoustic disruption: Implications for long-line bycatch and depredation. Canadian Journal of Zoology 87:726-733.

Moreno, C.A., L. Mujica. 2007. Modification of fishing gear in the Chilean Patagonian toothfish fishery to minimize interactions with seabirds and toothed whales. *IOTC Workshop on depredation.* Victoria, Seychelles.

Nishida, T., Shiba, Y., 2003. Report of the predation survey by the Japanese commercial tuna longline fisheries (September, 2000 – September, 2002). IOTC Proceedings no. 6. WPTT-03-10

Poisson, F., Marjolet, C., Mété, K., Vanpouille, M. 2001. Évaluation du phénomène de déprédation dû aux mammifères marins. In « L’espadon: de la recherche à l’exploitation durable ». Poisson F., Taquet M. (coord). Programme Palangre Réunionnais, Rapport final, pp. 231-247.

Pshenichnov, L. K., Zaitsev A. K.. 2007. “On the invention of effective and perspective device (protective net) for the mitigation of depredation of fishes in longline fisheries.” *IOTC Workshop on depredation* Victoria, Seychelles.

Rabearisoa N., 2007. Analyse de la déprédation exercée par les requins et les cétacés sur les palangres semi-industrielles des Seychelles. Rapport Master 2 "Méthodes en bioinformatique moléculaire", Université Lyon 1, 45 p.

Roche, C., Guinet, C., Gasco, N., Duhamel., G. (2007). Marine mammals and demersal longline fishery interactions in Crozet and Kerguelen Exclusive Economic Zones: an assessment of depredation levels. CCAMLR Science 14: 67-82.

Romanov, E., Gaertner, D., Bach, P., Romanova, N., 2007. Depredation on pelagic longlines in the Indian Ocean: an analysis of the Soviet historical database (1961-1989) on tuna research . IOTC-2007-DWS-A1-11, 31 p.

Secchi, E. R., Vaske, T. 1998. Killer whale (*Orcinus orca*) sightings and depredation on tuna and swordfish longline catches in southern Brazil. Aquatic Mammals 24, no. 2: 117-122.

Sivasubramaniam, K. 1964. Predation of tuna longline catches in the Indian Ocean, by killer-whales and sharks. *Bulletin of the Fisheries Research Station Ceylon*. 17, no. 2: 221-236.

Visser, I. N. 2000. Killer whale (*Orcinus orca*) interactions with longline fisheries in New

Zealand waters. Aquatic Mammals 26, no. 3: 241-252.

Zollett, E.A., Read, A. 2006. Depredation of catch by bottlenose dolphins (*Tursiops truncatus*) in the Florida king mackerel (*Scomberomorus cavalla*) troll fishery. Fishery Bulletin 104, no. 3: 343-349.

Appendix 1 – Technical results for spiders

	Technical parameters of the DMDs										Catch		
N° set	Nb DMD set	Nb entangled	% entangled	Nb DMD triggered without catch	% DMD triggered without catch	Nb fish with DMD	Nb fish with triggered DMD	% correctly triggered DMD	Nb correctly protected fish	% correctly protected fish	Nb fish caught	Nb Dep cetaceans	Nb Dep sharks
1-1	110	51	46,36	9	8,18	8	6	75,00	3	50,00	20	0	2
1-2	27	15	55,56	3	11,11	3	3	100,00	3	100,00	15	0	3
2-1	30	11	36,67	10	33,33	0	0	NA	0	NA	5	5	0
2-2	30	1	3,33	7	23,33	2	2	100,00	2	100,00	12	0	2
3-1	75	1	1,33	19	25,33	1	1	100,00	1	100,00	1	1	0
3-2	75	2	2,67	21	28,00	2	2	100,00	0	0,00	2	0	0
4-1	89	6	6,74	7	7,87	9	8	88,89	8	100,00	19	5	0
4-2	52	0	0,00	6	11,54	3	3	100,00	2	66,67	16	0	0
5-1	90	2	2,22	5	5,56	5	5	100,00	3	60,00	27	0	2
5-2	60	3	5,00	7	11,67	4	3	75,00	2	66,67	25	0	2
6-1	97	5	5,15	4	4,12	9	5	55,56	5	100,00	29	0	0
6-2	91	3	3,30	4	4,40	10	8	80,00	6	75,00	36	0	0
7-1	107	3	2,80	12	11,21	3	3	100,00	2	66,67	13	0	1
7-2	101	4	3,96	7	6,93	1	1	100,00	1	100,00	10	0	0
8-1	104	4	3,85	2	1,92	4	3	75,00	3	100,00	12	0	0
8-2	114	3	2,63	7	6,14	3	3	100,00	3	100,00	5	0	0
9-1	100	1	1,00	2	2,00	17	13	76,47	11	84,62	26	0	3
9-2	113	5	4,42	4	3,54	3	2	66,67	2	100,00	5	0	0
10-1	95	2	2,11	9	9,47	2	2	100,00	2	100,00	11	4	0
10-2	126	2	1,59	14	11,11	6	4	66,67	4	100,00	9	8	0
11-1	62	5	8,06	2	3,23	8	6	75,00	6	100,00	20	0	1
11-2	58	1	1,72	2	3,45	4	4	100,00	3	75,00	13	0	0
12-1	50	4	8,00	2	4,00	5	3	60,00	3	100,00	20	0	6
12-2	54	3	5,56	1	1,85	4	4	100,00	3	75,00	10	0	0
13-1	30	1	3,33	1	3,33	0	0	NA	0	NA	8	0	0
13-2	30	1	3,33	1	3,33	1	1	100,00	0	0,00	5	0	0
Mean (%)			3,57 *		9,46			87,26		79,98			

* : Mean rate calculated since the 3rd set, after a changing position of the DMD on the fishing gear in order to reduce entanglement rate

Appendix 2 – Technical results for socks

	Technical parameters of the DMDs										Catch		
N° set	Nb DMD set	Nb entangled	% entangled	Nb DMD triggered without catch	% DMD triggered without catch	Nb fish with DMD	Nb fish with triggered DMD	% correctly triggered DMD	Nb correctly protected fish	% correctly protected fish	Nb fish caught	Nb Dep cétacés	Nb Dep requins
1	25	7	28,00	3	12,00	3	2	66,67	0	0,00	23	0	0
2	32	7	21,88	6	18,75	5	3	60,00	1	33,33	31	0	0
3	31	0	0,00	7	22,58	1	0	0,00	0	NA	11	1	0
4	21	2	9,52	3	14,29	2	2	100,00	0	0,00	35	0	4
5	26	0	0,00	11	42,31	1	1	100,00	0	0,00	8	3	0
6	32	3	9,38	17	53,13	1	1	100,00	0	0,00	10	0	3
7	26	1	3,85	4	15,38	1	1	100,00	0	0,00	25	0	3
8	27	6	22,22	2	7,41	2	1	50,00	0	0,00	16	0	0
9	26	2	7,69	2	7,69	2	2	100,00	0	0,00	19	0	0
10	24	2	8,33	2	8,33	1	0	0,00	0	NA	30	0	2
11	26	2	7,69	6	23,08	3	3	100,00	2	66,67	23	0	2
12	21	5	23,81	2	9,52	2	1	50,00	0	0,00	27	0	1
13	22	0	0,00	4	18,18	0	0	NA	0	NA	16	0	0
Mean (%)			10,95		19,43			68,89		10,00			