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Preliminary study of cetacean depredation on pelagic longline fisheries using passive acoustic monitoring off Reunion Island.

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ABSTRACT

Depredation can be defined as the predation of caught fish or bait by free-ranging animals. Since the 1900s, depredation of Reunion's longline fishery by toothed whales is known to contribute significantly to reduced commercial catch (sometimes destroying 100% of the catch). Describing depredation by cetaceans is a key driver in helping implement non-destructive adaptive fishing solutions. With fishing mainly occurring at night and over long distances, passive acoustic monitoring is a promising method. A preliminary study was launched to determine the technical feasibility accompanied by acoustic analysis of associated with depredation. Over two months (November-December 2014), 3 autonomous hydrophones (HTI-96-MIN) were attached at the extremities and central section of a 30 km longline for 9 fishing operations, 30 miles off Reunion Island. A total of 387 hrs of sound were recorded and analyzed. Biological sounds (clicks and whistles) and physical sounds were quantified over time with two automatic-methods in relation to recorder locations. Whistle samples allowed species identification using a semi-automatic method (ROCCA classifier). Catch data were correlated with cetaceans' presence. Engagement and support from local fishers resulted in a final protocol demonstrating good quality acoustic measurements with reduced physical noise. Whistles and clicks represented 34% of all detections (~12% for clicks). Cetacean sounds were detected during all trials with variable detection rates (between 2.5 to 66% of the recorded duration). Distances between hydrophones enabled the drawing of possible trajectories of groups along longlines. On four fishing trials, cetaceans were detected immediately after the line deployment. Six different species of toothed whales were identified with a predominance of false killer whales (*Pseudorca crassidens*). The presence of the pilot whales (*Globicephala macrorhynchus*) was probably underestimated due to its similarity with *Pseudorca* emissions and the paucity of studied samples. Since few signs of depredation were visible on catches, no obvious correlation was determined between the presence of cetaceans and depredation rates. Further investigations are thus required to build on these preliminary results.

Keywords: Indian Ocean, Passive acoustic, Cetacean depredation, longline fisheries

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 (Romanov et al., 2013). Depredation is usually defined as 'the partial or complete removal of hooked fish or bait from fishing gear... by predators likes cetaceans, sharks, bone fish, birds, squids, crustaceans and others' distinguishing it from predation, i.e. 'the taking of free swimming fish (or others organism) ...' (Donoghue et al. , 2003 ; Gilman et al. , 2006, 2007). As Romanov et al. (2013) suggests 'Depredation observed mostly 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, 2007, Bearzi, 2007) and within aquaculture facilities (Stickley et al., 1992; Coon, 1996; Glahn et al., 1999; Fenech et al., 2004; Kloskowski, 2005). Longline fishing operations probably most suffer from depredation due to its worldwide distribution, stationary nature, long exposure (hours) in the environment, easy access to animal caught and gear fragility. Depredation facts and respective losses of catch are usually not reported in the fishery statistics and are source of 'cryptic mortality' not accounted in the current stock assessment studies, therefore affecting directly fisheries management decision. Economic losses due to catch and gear damage are brought serious concerns for fishers (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) rising conservation issues. There is obvious urgent need for close monitoring of the depredation phenomenon, its quantification, incorporation into the fisheries management schemes and development of mitigation measures.'

Describing and understanding of depredation *modus operandi* by cetaceans is a key driver in helping implement non-destructive adaptive fishing solutions. With fishing mainly occurring at night and over long distances, passive acoustic monitoring is a promising method. A preliminary study was launched to determine the technical feasibility of the method accompanied by acoustic analysis of marine animals sounds associated with depredation.

Fleet and operations mode

The pelagic longline fishery of Reunion Island uses horizontal drifting longlines that are set at night with 300 to 1600 baited hooks to target primarily swordfish. Longlines are hauled in the morning just after the sunrise in attempts to catch – in addition to swordfish – other commercial species such as tunas, marlins and dolphinfish. Reunion's longliners operate in the southwest Indian Ocean mostly between Reunion Island and the east coast of Madagascar. This fishery started in 1991 with a single vessel operating off the coast of

Reunion Island. The fishing fleet grew fast until 2000 with 38 active longliners at that time (Bourjea et al., 2009). By 2014, the number of active longliners was similar (~36) but ratio of small vessels (LOA<12m) to large unities (LOA>12m) increase. During recent years some kind of evolution in the fishing strategy was observed with attempts to target tuna by increasing soaking time: deploying longline earlier and retrieving later in order to overlap tuna late evening/early morning feeding activity at the surface are widely used, in particulars in the areas of tuna aggregations (east coast of Madagascar). Depredation is important issue in local longline fishery. There is common believe among fishermen that attacks level are steadily increasing. Some captains reported associations between their vessels and cetaceans who following the boat in successive fishing operations spread from east coast of Madagascar to Mayotte and back (Romanov et al., 2013). There is common opinion that 'globicephales' (i.e. *Globicephala macrorhynchus*) are mostly responsible on depredation on fish caught, while 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 are also observed. Depredation combined with overall low CPUE observed during several consecutive months of the 2013 provoked a "depredation crisis" that jeopardize longline fishery of Reunion Island. Some vessels ceased operations for several weeks waiting for improvement of the situation. Overall impact related with catch losses and suspension of fishing operations resulted in serious economic losses of the longline fleet based in Reunion Island. In the same one should keep in mind that quantification of overall level of depredation and depredation impact is very difficult. Despite overall detrimental impact of depredation on the fishery and fishery economics there is no system to collect information on depredation on routine basis. Observer coverage is of local fleet is relatively low (~5% of operations) (Romanov et al., 2013).

Passive acoustic monitoring : promising method

To develop an approach to reduce depredation, we need to characterize the phenomenon and know: which species are present in the pelagic environment and implicated in depredation? If presence of certain cetacean species is associated with depredation and lower catches?

Several observation methods have been developed to study biology and understand behaviour of marine mammals. Visual observation is commonly used. However, this method is difficult to use in pelagic environment, with drifting longlines (long soak time, wary species, night-time activity, and longlines drifting for a long distances...).

Another potential method of cetaceans monitoring is tagging. Used for biggest species (humpback whales in Reunion Island), this method is costly, time-consuming, and is difficult to implement on rapid and active toothed whales.

Third complementary monitoring method is passive acoustic monitoring. This method is widely used by scientist more than 20 years for biologic marine studies, in oceans geophysics, and marine engineering. Data collection tool is submerged hydrophones, recording sounds under water. There is a several various types of hydrophones, used in many scientific, military and commercial applications. Marine bioacoustics studies (study of animal sounds) are used in various studies, such as communication and related behaviour, sound production, hearing, environmental monitoring, identification techniques and applications, impact of noise…Studies focused on several groups of marine animals like fishes, crustaceans, pinnipeds, and cetaceans. Biologic sounds detection tools, species automatic recognising, species classifiers and algorithms used to determinate relative abundances or appreciate trajectories turn it into an indispensable tool to observe marine megafauna. Acoustic data are highly useful for creation of a database in order to improve our knowledge on species, their communication system, behaviour, social codes.

Recent studies use bioacoustics to identify presence/absence of marine mammals near infrastructures to be built, for monitoring migratory species (humpback whales, sperm whales), or determination of coastal dolphins habitat. At large scale (South West Indian Ocean basin coupled with year-long monitoring) hydrophone based records may provide a complementary data to ones collected by other methods (visual and telemetric), identify migratory patterns and apply sustainable management measures on pelagic ecosystems. Finally, listening cetaceans is a way to better understanding the poorly known cetacean live patterns in pelagic environment and is a potential key to interpret interaction between longline fisheries and depredation.

This short study has several level of objectives:

- The first one is defined like a ‘listening potentiality’. It focused on feasibility to collect data aboard a longline boat using hydrophone without constraints to fishing operations.
- The second one is defined like a ‘listening quality’. It focused on the development of an evolutive protocol in hydrophone deployment to obtain an optimal listening quality during successive campaigns.
- The third objective is defined like an ‘discriminative listening’. Starting from an optimal listening quality, our aim is to test an ability to differentiate abiotic and biotic sounds by applying two comparative methods and isolate whistles and clicks of cetaceans encountered along longline gear.
- The final objective is defined like a ‘listening to understanding’: testing a potential to identify cetacean species involved in depredation and to set up objective interpretation criteria between presence of cetacean and depredation.

Materials and methods

The study consisted of 9 opportunistic fishing trips carried out between November and December 2014 onboard local fishing vessels. Vessels were selected among voluntary fishermen that accepted to embark acoustic equipment and a scientific observer (Fig.1).

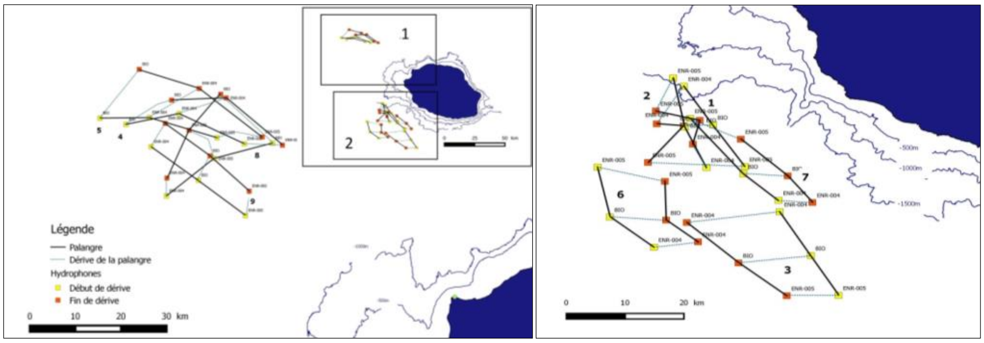


Figure 1: Study area

The autonomous hydrophones (hermetic boxes + recorders) used was constructed by Wildlife Acoustics Inc. Company. Boxes have positive buoyancy, weighing about 8 kg in the air (with 32 batteries) and a length of 80 cm and can be used securely down to 120 m depth. The SM2M recorders have high energetic autonomy (up to two months of continuous recording). They were equipped with SD memory cards (4x32 or 1x128Go) and a microphone “HTI-96-MIN” with a sensitivity of -165 dB re 1V / µPa. It able to record includes a frequency range between 40 Hz and 48 kHz. For each cruise, three hydrophones were attached at even intervals to cover the entire longline. The hydrophones were fixed under a balloon buoy. The hydrophones were set at a depth of 25 m along a rope of 30 m long. This depth was chosen to limit the surface noises. The attachment of hydrophones has evolved constantly to a simplified device to reduce noise. Protection cover of the recorder and handles have been removed, ballast of 6kg to ensure neutral buoyancy were separated. Likewise, the recording settings were adjusted (12dB gain and high-pass filter at 180Hz). Autonomous hydrophones were programmed for recording continuously between 12:00 UTC and 6:00 UTC. Recording rate was adjusted to 96 kHz; bandwidth was 0-48 kHz and the programmed recording time was 3 X 1 min. Recording format was WACO type. In addition to acoustics data collection, supplementary operational data were collected during cruises by scientific observer such as fishing activity, catches, depredation events and other interactions. The acoustics data processing was carried out automatically and manually by means of two analysis methods. The first method relies on energy sounds analysis. For each campaign and each recorder, sound reception was calculated for each third octave band values on duration of a hydrophone signal of 21.8 seconds. This spectral decomposition allows inferring typical sounds level trends such as grinding, shipping, environmental sounds, Ping, bump, whistle and click. A 21.8 second analysis smooth out brief and intensive sound events because the purpose of this study is to obtain trends on a fishing operation scale and to estimate way to improve acoustic records quality towards modifications on hydrophone deployment. To validate this method, a first visual and auditory analysis was carried out on one of three recorders data during the third cruise. The first three minutes on each 10 minutes time recording were systematically analysed, classified and compared with curves of sounds level detection for each typical sound. Concordance between visual results and energy sounds method allows detecting biological impulsive signals and "whistle" signals. The second method is based on a real-time odontocete call detection and classification algorithm. Bioacoustics signal treatment was realized with PAMguard software. PAMguard was developed by the University of St. Andrews, Scotland. Software detects whistles using spectrogram signal (FFT transformation) and differentiate from background noise. Then, whistles are compared with a data stored in reference collection. Detectors and classifiers are specific on dolphin signal encounters and are configured according to environmental conditions of recording. In this study, PAMguard was set up as an automatized detector of whistles and calibrated on 2.7 kHz to 30 kHz sound detection. Detector doesn't work efficiently because of background noises. To validate this method, a visual analysis was carried out on ten minute representative samples. Species identification was realized using a real-time odontocete call classification algorithm (ROCCA) available as a module in PAMguard. ROCCA measures 50 different features from the extracted whistle contour, including duration, frequencies, slopes and variable describing the shape of the whistle. ROCCA distinguishes 7 odontocete species based on data collection from the East Pacific ocean: *Globicephala macrorynchus, Pseudorca crassidens, Stenella attenuata, Stenella longirostris, Steno brendanensis, Delphinus* sp., and *Tursiops* sp. All those species are theoretically present off Reunion Island coasts and study area. ROCCA model was used manually, focusing on high frequentation on odontocetes detected by PAMguard. Ten samples were thus classified. The results of the classification were supported by bibliographical knowledge.

Results

To respond to "listening potentiality" objectives, installation of hydrophones on the longline, their deployment and manipulation, were considered as successful. No damage or loss was reported during the nine cruises with odontocete and shark presence around listening devices. Thanks to an adjusted programming and high energy autonomy, data were recorded along the nine cruises.

Weight and volume of hydrophones used was principal obstacle during manipulations onboard fishing vessels and during deployment operations.. To respond to "listening quality" objectives, we analysed the two automatic detection methods. Capacity of the first method based on energy sounds analysis to estimate presence/absence of animal patterns (impulsive signal and whistles) is globally optimized. It was confirmed by spontaneous visual and auditory verification. Results are presented in table 1.

Environmental signal detected and others typical sounds recorded such as « ping » should be further developed because falses alarms were constantly recognized. It was difficult to differentiate environmental sounds from sound emitted by attachment system. This method doesn't allow discriminating the two typical sounds. Concerning the second method, quality of the whistle detector was validated manually. Overall, 2305 ten minute time samples were identified and detected. 298 samples were checked visually, whether 12.9 % of total data collected. Periods of whistles time were well detected with 42.6% of true positive. Detector is mid-quality with 15% of false negative opposite to 31% of false positive. The software appears to overestimate presence of odontocetes, which can be explained by the presence of background noises. Note that the capacity of the detection is increasing on the sixth campaign with a better definition of presence/absence of whistles. We also note that the capacity to detect absence depends on real number of absence, which had not been the case on our study where the presence of odontocetes was revealed in many campaigns. Generally, capacity of methods to detect presence/ absence was mid to high with an average of 58% of successful. (Table 2).

We note that the detector is more specific in its quantification of the number of whistles from the campaign 6 due to a positive evolution of attachment and recording parameters. During the study, recording parameters were optimized to environmental conditions. Two parameters were changed (Gain and Filter during experimentation. All changes are synthetized in the Table 3.

Table 1: Spontaneous auditory and visual verification from the first detection method by curves of sounds level, by typical sounds level trends, by campaign and by recorder.

Cruise	*Type of noise*	*Hydrophone BIO*		*Hydrophone ENR-004*		*Hydrophone ENR-005*	
		Présence / absence					
		Confirmée	*Non confirmée*	*Confirmée*	*Non confirmée*	*Confirmée*	*Non confirmée*
Campagne01	*Environmental*				*2 instants*		
	Whistle			*4 instants*		*2 instants*	
	Click	*6 instants*		*5 instants*		*6 instants*	
Campagne02	*Whistle*			*3 instants*			
	Ping		*1 instant*				
	Click	*3 instants*		*2 instants*			
Campagne03	*Whistle*	*30 % de la donnée*		*2 instants*			
	Click	*30 % de la donnée*		*3 instants*		*4 instants*	
Campagne04	*Environmental*				*3 instants*		
	Whistle				*3 instants*		
	Click	*4 instants*			*5 instants*	*2 instants*	
Campagne05	*Environmental*				*2 instants*		
	Whistle			*1 instant (19:30:04)*	*2 instants*		
	Clicks			*1 instant (19:30:04)*	*2 instants*		
Campagne06	*Environmental*			*2 instants*			*2 instants*
	Whistle				*2 instants*		
	Click			*2 instants*	*2 instants*		
Campagne07	*Environmental*			*1 instant (19:30:04)*			
	Whistle			*2 instants*		*6 instants*	
	Clicks	*6 instants*		*6 instants*		*4 instants*	
Campagne08	*Clicks*	*6 instants*		*4 instants*	*2 instants*	*3 instants*	
Campagne09	*Whistle*	*5 instants*	*2 instants*	*3 instants*		*3 instants*	
	Clicks	*5 instants*	*3 instants*	*5 instants*	*1 instant*	*3 instants*	*2 instants*

Table 2: Capacity of second automatic method to detect presence of cetacean whistles

		Campagne d'écoute									
		1	2	3	4	5	6	7	8	9	Ensemble des campagnes
Hydrophone ENR-004	Echantillons analysés	105	51	93	89	80	70	69	72	72	701
	Nombre de détections	694	767	487	305	13	32	245	11	759	3313
	Nombre de vérifications	15	14	41	8	11	8	11	5	11	124
	Représentativité des vérifications (%)	14,29	27,45	44,09	8,99	13,75	11,43	15,94	6,94	15,28	17,69
	% de vrais positifs	46,7	71,4	41,5	0,0	0,0	0,0	45,5	0,0	54,5	36,3
	% de vrais négatifs	13,3	14,3	12,2	0,0	54,5	50,0	36,4	80,0	18,2	23,4
	TOTAL de vrai resultats	60,0	85,7	53,7	0,0	54,5	50,0	81,8	80,0	72,7	59,7
	% de faux positifs	20,0	0,0	4,9	100,0	27,3	0,0	18,2	0,0	9,1	15,3
	% de faux négatifs	13,3	14,3	41,5	0,0	18,2	50,0	0,0	20,0	18,2	24,2
Hydrophone ENR-005	Echantillons analysés	74	110	62	107	94	100	105	109	100	861
	Nombre de détections	830	938	226	174	267	1134	164	9	1185	4927
	Nombre de vérifications	12	11	13	16	10	11	11	7	17	108
	Représentativité des vérifications (%)	16,22	10,00	20,97	14,95	10,64	11,00	10,48	6,42	17,00	12,54
	% de vrais positifs	83,3	72,7	23,1	31,3	30,0	18,2	45,5	0,0	58,8	42,6
	% de vrais négatifs	0,0	0,0	38,5	12,5	0,0	0,0	45,5	71,4	5,9	16,7
	TOTAL de vrai resultats	83,3	72,7	61,5	43,8	30,0	18,2	90,9	71,4	64,7	59,3
	% de faux positifs	16,7	27,3	23,1	56,3	70,0	81,8	0,0	28,6	29,4	37,0
	% de faux négatifs	0,0	0,0	15,4	0,0	0,0	0,0	9,1	0,0	5,9	3,7
Hydrophone BIO	Echantillons analysés	92	95	78	71	66	82	79	93	87	402
	Nombre de détections	1740	1062	1311	1167	601	176	464	218	1191	5881
	Nombre de vérifications	17	13	14	12	10	9	9	7	10	66
	Représentativité des vérifications (%)	18,48	13,68	17,95	16,90	15,15	10,98	11,39	7,53	11,49	16,42
	% de vrais positifs	58,8	84,6	64,3	25,0	0,0	33,3	55,6	57,1	60,0	50,5
	% de vrais négatifs	0,0	15,4	0,0	0,0	0,0	11,1	11,1	0,0	0,0	4,0
	TOTAL de vrai resultats	58,8	100,0	64,3	25,0	0,0	44,4	66,7	57,1	60,0	54,5
	% de faux positifs	41,2	0,0	35,7	75,0	100,0	55,6	33,3	42,9	40,0	45,5
	% de faux négatifs	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Ensemble	Echantillons analysés	271	256	233	267	240	252	253	274	259	2305
	Nombre de détections	3264	2767	2024	1646	881	1342	873	238	3135	14121
	Nombre de vérifications	44	38	68	36	31	28	31	19	38	298
	Représentativité des vérifications (%)	16,2	14,8	29,2	13,5	12,9	11,1	12,3	6,9	14,7	12,92842
	% de vrais positifs	61,4	76,3	42,6	22,2	9,7	17,9	48,4	21,1	57,9	42,64264
	% de vrais négatifs	4,5	10,5	14,7	5,6	19,4	17,9	32,3	47,4	7,9	15,31532
	TOTAL de vrai resultats	65,9	86,8	57,4	27,8	29,0	35,7	80,6	68,4	65,8	58,0
	% de faux positifs	27,3	7,9	14,7	72,2	64,5	50,0	16,1	26,3	26,3	31,53153
	% de faux négatifs	4,5	5,3	27,9	0,0	6,5	14,3	3,2	5,3	7,9	10,21021

Table 3: Evolution of recording parameter (Gain and filter)

N° de campagne	Hydrophone ENR-004	Hydrophone ENR-005	Hydrophone BIO
	Gain dB / Filtre Hz		
1 - 2 - 3	24 / 3	12 / 3	24 /3
4 -5	24 / 3	24 / 3	24 / 3
6 -7 - 8 - 9	12 / 180	12 / 180	12 / 180

Best qualities of detection were obtained during cruises 6 to 9 with a 12 dB gain and a 180 Hz pass-high filter. These parameters are adequate to optimized recording sounds from a noisy environment while reducing grinding sounds and low frequencies saturations. In addition, fixation system was adapted to reduce background noise (Figures 2 and 3). We have evolved from a heavy and imposing fixation system to a very simply and optimized system, to reduce undesired sounds, permitting to record sound of high quality in despite of environmental and rigging conditions.

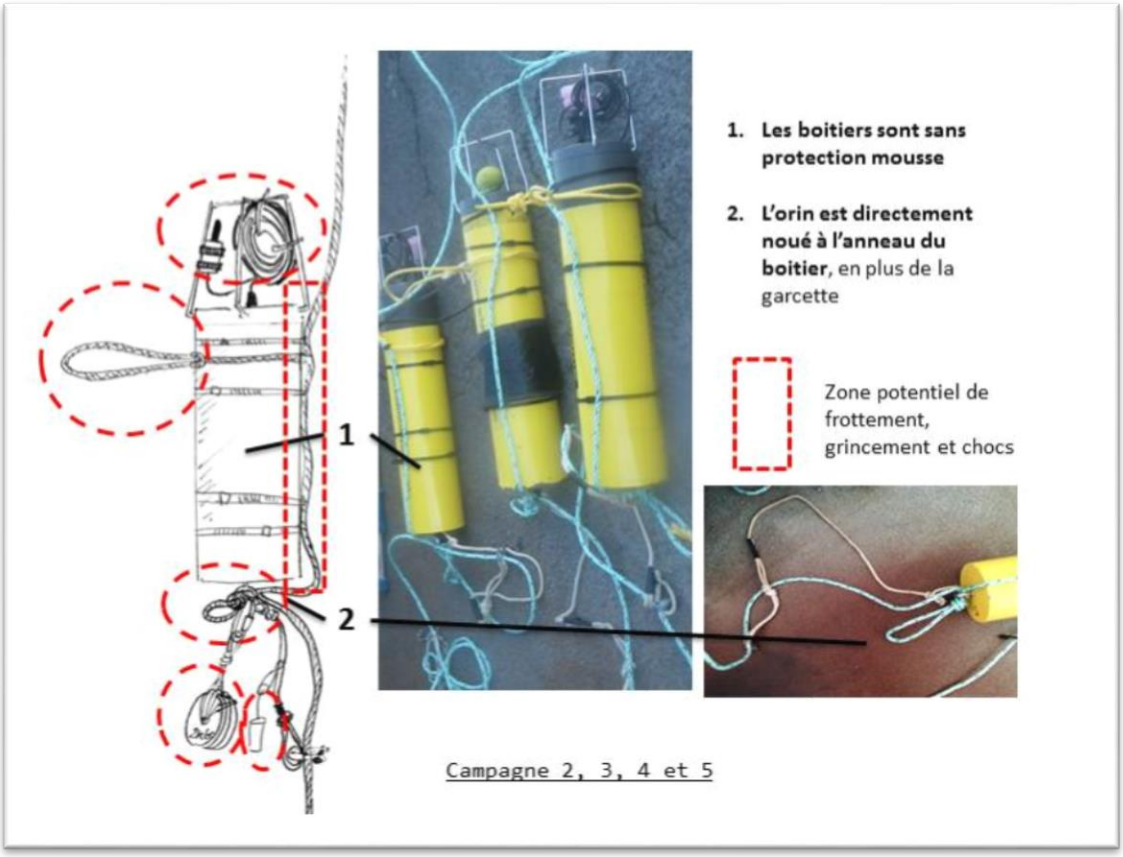


Figure 2: First fixation system deployed during cruises 1 to 5

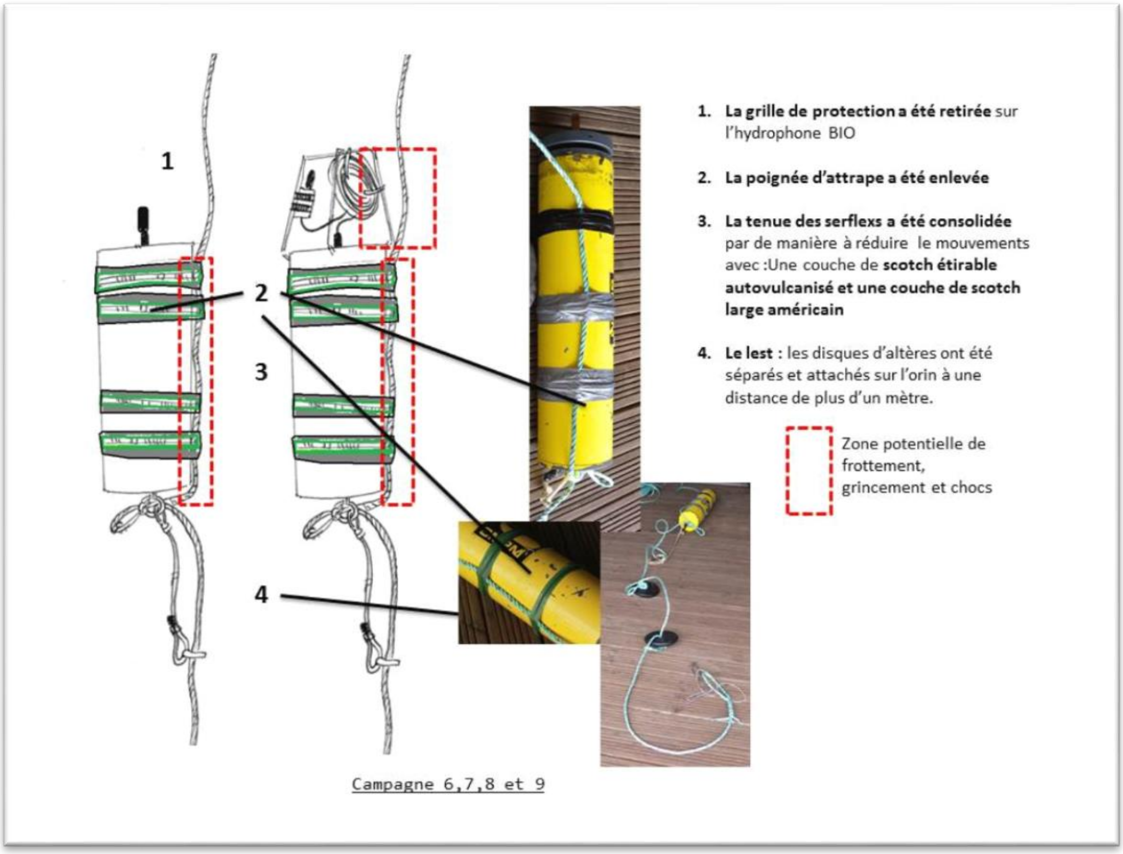
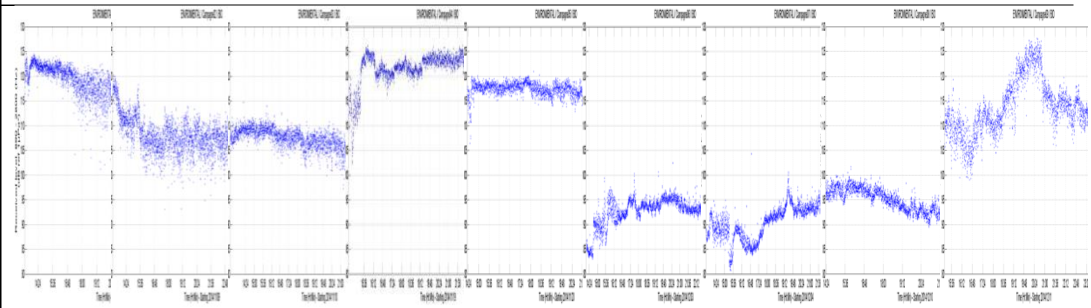


Figure 3 : Attachment optimization of system deployed during cruises 6 to 9

An estimation of the quantity of sound saturated was calculated by campaign and by recorder. (Table 4) Saturated sounds are principally due to bump sound detected on contact with hydrophone.

Table 4: Example of evolution of level environmental sound for the first hydrophone for each cruise

Campaign	1	2	3	4	5	6	7	8	9
Indicator of environmental sounds									

With the modification of the hydrophone attachment and the configuration parameters, saturated sounds decrease in number along the cruises. In addition to modification, the

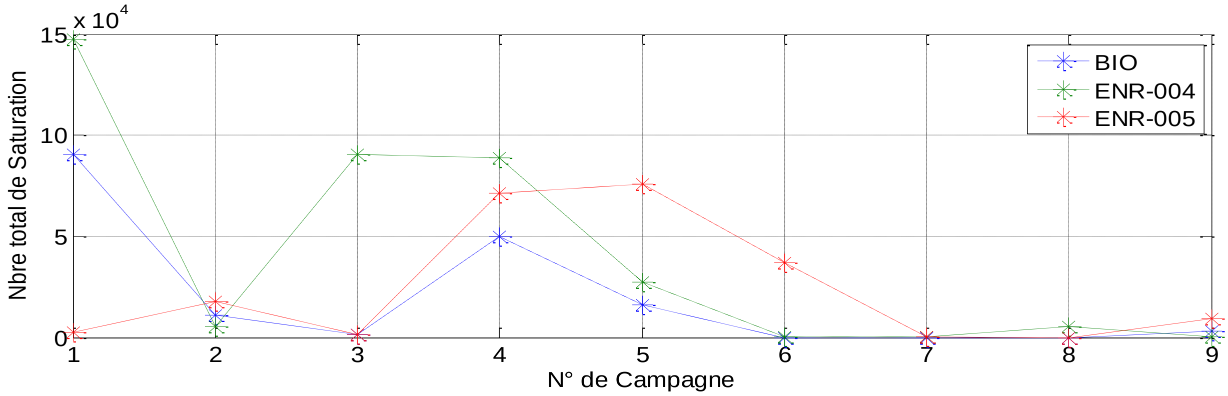


Figure 4: Evolution of the number of total saturated sounds recorded by campaign and by recorder

parameters recording (gain and filter) reduce significantly saturation. The late modifications seem to be adapted to this type of measure. Finally, synthesis of saturating sounds is presented at the Figure 4. Saturated sounds produced by bump sounds on the rigging are decreased along the campaigns.

To respond to “discriminative listening” objectives, we focused on dissociating abiotic sounds from biotic sounds corresponding to whistles and clicks. The evaluation of sound decibel level associates to whistles occurs in signal emission with frequency range 3550 to 11000 Hz. In many cruises, these types of signal were detected with late afternoon recording activity, but not necessarily continue during fishing operation.

More than 50% of the cruises, no whistle has been detected (cruises 3, 4, 5, 6, 8). The evaluation of sound decibel level associates to clicks occurs in signal emission with frequency range 18000 to 44500 Hz. important presence of impulsive biologic signal was detected in 5 cruises (1, 2, 3, 7 et 9), with maximum detection on cruise 2 (entire fishing operation). For the other fourth cruises, results are difficult to use (false alerts on cruises 6 and 8, noise from attachment on cruise 4 and 5). Presence of cetaceans was detected during all cruises. It takes place in two different ways: some short duration presence along longline or long stays. Most of the time marine mammals were detected by all three hydrophones. Presence/absence was evaluated, integrating all clicks and whistles recording by hydrophones (Fig.5).

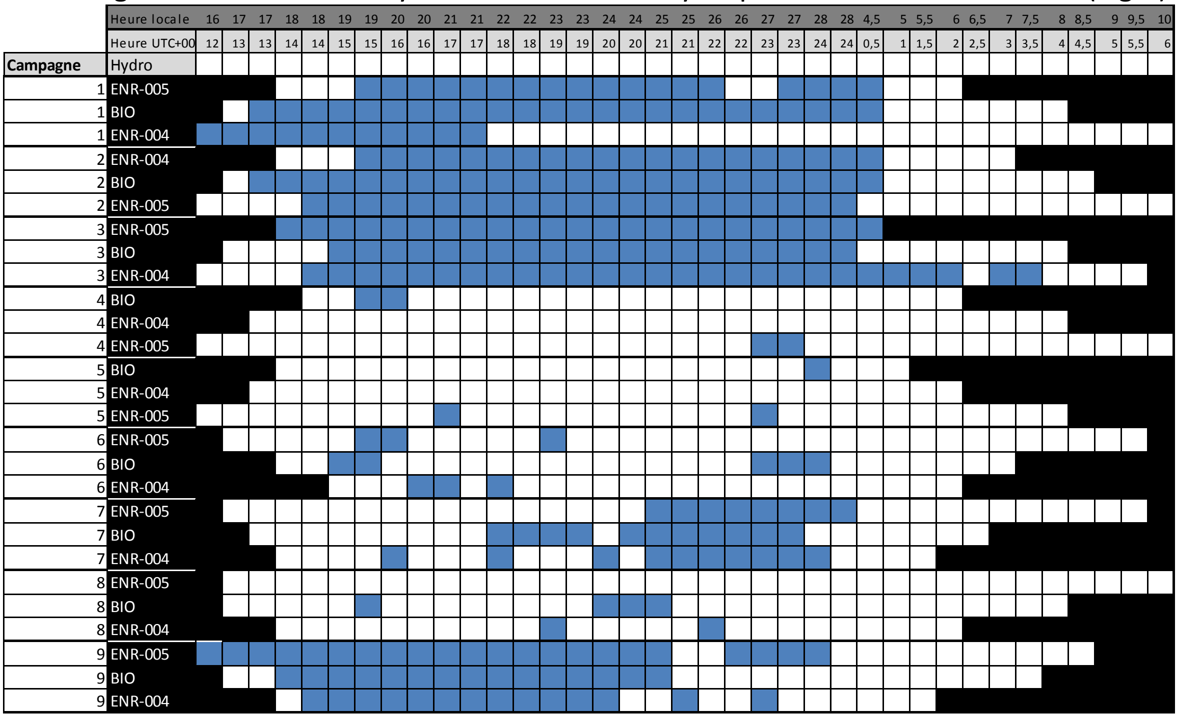


Figure 5: Grid of vocalisation presence (blue box) by campaign and by recorder.

Results indicate that when cetaceans are detected and active around the longline, their presence seems to be extended to part of the night for example: cruises 1, 2, 3, 7 and 9). When aggregate presence rate exceed 50% of the listening effort, early vocalizes were detected quickly after setting. On cruises 1, 3 and 9, cetaceans seems to be present less than 30 minutes after setting. 133 recording hours indicate presence of clicks and whistles against 387.5 cumulative time of recording. Cetaceans are present during 34.5% of monitoring time. Presence rate greatly varies from cruise to cruise, between minimum 2.5% (cruise 5) to maximum 66% (cruise 3). In detailing the analysis of sound energy peaks the signal emission near hydrophones highlight 36 hours of clicks emission, representing 12% of monitoring time.

To respond to “presence of cetacean and depredation” objectives, we analysed presence of cetaceans detected by vocalised sounds with observation data of depredation of catches and baits. In the first campaign, cetacean activities appear permanently around recorders. First contacts were detected quickly. Data seem to indicate cetacean movements along the longline. Peaks activities clearly recorded at dusk near to the first and final hydrophone. In second cruise, central hydrophone picked up signals at the dusk. Then detections are simultaneous on the first and the third hydrophone. That’s movement indicate group separation. During cruise n 3, only the third recorder picks up whistles in the setting. Then, all hydrophones recorded detection (whistles and clicks) successively. Cruises 4, 5 and 8 present a very low detection by only one of three hydrophones during a short time. Cruises 6 and 9, like cruise 1, detections were detected fastly, thirty minutes after launching hydrophones and during setting. Cetaceans were closed to fishing boat and seem to follow it. Cruise 7, activities appear belatedly and travel along the longline with peaks activities on the first and the third hydrophones. Finally, activities of cetaceans are variable. Some cruises record peaks activities early with behaviour of pursuit. Conversely, reduced activity can be identified, with only a few contacts. When cetaceans are present rapidly along the longline, activity is often sustained and long lasting. Successive detection of vocalizations by the hydrophones indicates a movement along the longline (generally the first to the last hydrophone), ending with random movements. Some campaigns seem to indicate arrival through the center of the line with a separation of the group to prospect the entire longline. 5 species were detected by ROCCA method as *Pseudorca crassidens* (False killer whale), *Globicephala macrorynchus* (short-finned pilot whale), *Steno brendanensis* (rough-toothed dolphin), *Delphinus capensis* (long-beaked saddle-back dolphin) *Stenella coreoleoalba* (blue-white dolphin) and 1 species was detected by auditory verification: *Peponocephala electra* (melon-headed whale). We note that *Grampus griseus* (Risso's dolphin) and *Feresa attenuata* (pygmy killer whale) are potentially present in the area but doesn't include in ROCCA classification. Clicks are not considered in this identification analysis limiting identification species. Optimization in clicks analysis is expected to broaden the spectrum of species and the associated level of activity.

Comparing depredation activities and presence of cetaceans along in different cruises allows us to present some tends: cetaceans presence is associated with low catches. Thus, for approximately 60% of unproductive fisheries, the presence time of cetaceans is higher than 60%. However, the negative impact of cetaceans on catch level remains unclear because some correlations have opposite trends at cruise scale (fig. 6). For cruises where highest catch was reported (cruises 1 and 8), cetacean detection rate is very high (> 60%) in one case and very low for the other (<10%). The opposite case is also found in unproductive fisheries where 75% of campaigns (total of 4 cruises) are associated with the presence of more than 50% cetaceans (cruises 2, 3 and 9 / cruise 6 shows a low number of catches and low presence rate).

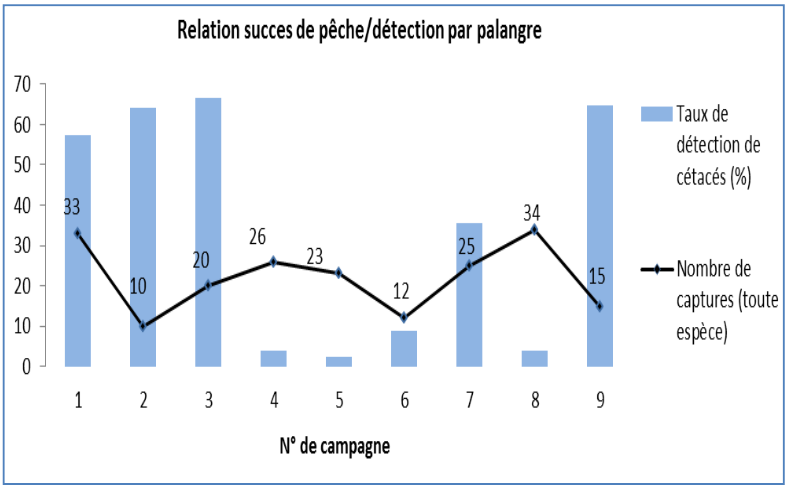


Figure 6: Comparison between presence of cetacean and number of catches for each campaign.

However, we note that the correlations seem to be significant by considering the longline sections covered by the hydrophones. Indeed, significant catches without depredation were found during certain cruises with a very low level of detection of cetaceans: cases 3 cruises for the hydrophone REC-004, case of 4 cruises for the hydrophone BIO, case 3 cruises for the hydrophone REC-005. Finally, a more detailed segregation of sounds could help distinguish behavioral tendencies (clicks and whistles), including explaining the presence of cetaceans in fishing results. Depredation rate (number of individual fish depredated by predators on total catch) was compared with presence of cetacean. During the nine cruises, depredation was caused by large sharks, squid, cookie cutter sharks and marine mammals. As part of this study, a comparison was made specifically between the presence of cetaceans near longline and cases of depredation. Depredation rate was calculated. This analysis incorporates all of depredation and depredation caused by marine mammals (Fig. 7).

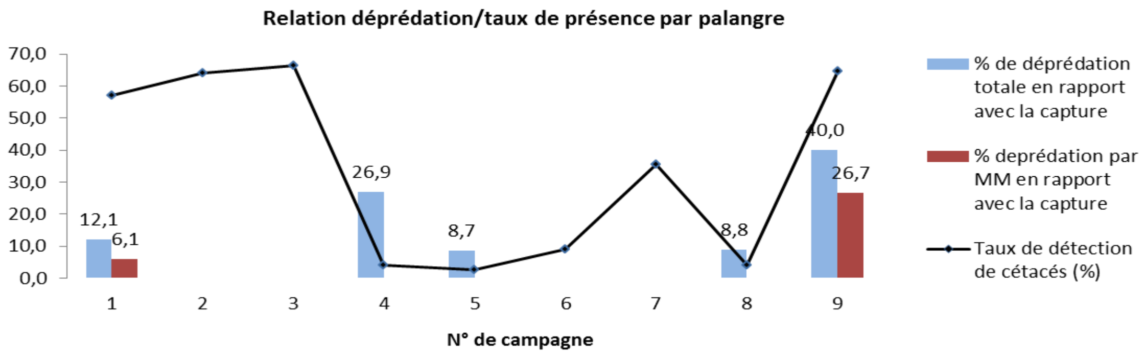


Figure 7: Depredation rate comparison with presence of cetacean by campaign.

Few cases of depredation by cetaceans were found (campaigns 1 & 9). The first and last cruises showed clear signs of depredation by cetaceans with a 6.1% of total catch (N = 2) and 26.7% (N = 4) respectively. These two cases are all both associated with a rate of over 60% detection of cetaceans. Note that the presence of cetaceans does not always associated with for signs of depredation, as was observed during cruises 2 and 3, which nevertheless have similar profiles in the first cruise with a lot of cetacean activity. Given these results and unrepresentative number of depredation rate, no clear relationship was found between the presence of cetaceans and cases of depredation on the longline. However, consideration is to be carried out on certain assumptions as the intensity of clicks that could explain eating behavior and / or hunting.

Discussion and conclusion

The preliminary study of cetacean depredation on pelagic longline fisheries allowed to propose operational system for monitoring marine mammals by professional fishing vessels and confirms the technical feasibility of cetacean's acoustic monitoring on longlines. The equipment \ used (SM2M acoustic box, bandwidth from 2Hz to 40 kHZ) shows its reliability, performance, energy autonomy and its ability to record quality sounds. An operational data collection has been implemented with success, with active participation of fishermen in equipment deployment. Study of acoustic recording allowed to detect physical sounds (vessel, longline …), biological sounds (clicks and whistles) and to classify cetacean species. Cetaceans have been detected on all the monitoring sets, detection time significantly varying up to 66% of fishing time. Some short duration detection indicates passage of transit group. Others detections, on part or over all drift longline, confirm interest of cetacean in longline. On several sets, early vocalizes occur quickly, after 30-60 minutes of recording, and suggest that cetaceans follow the vessel or locate the area on its approach. If study demonstrates efficiency of acoustic recording methods, detection and classification of cetacean species, there is a need to deepen relationship between fishing efficiency and cetacean occurrence. The sampling size is not sufficient to develop the correlation between depredation and presence of cetaceans.

A large-scale study must be done to have a sufficient size sampling, to demonstrate link between cetaceans presence and depredation on baits or catches. In addition to the results, the study highlights technical difficulties of instrumentation at sea. It encourages a longer study to be done to obtain a relevant data sampling to develop simple trends into significant results.

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