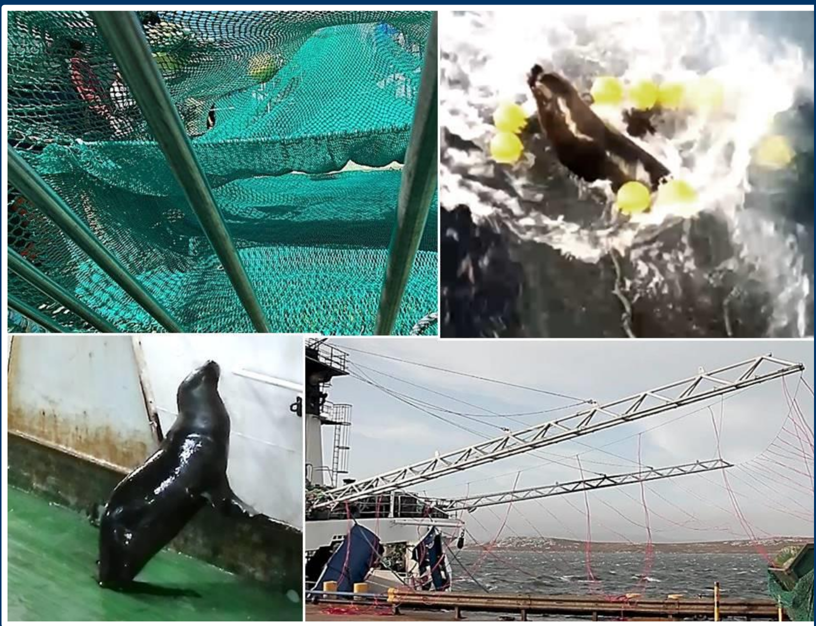
LOL 2020-C MMO Monitoring Program Report



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LOL 2020-C

Participating/Contributing Scientific Staff

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Previous related reports:

Iriarte V, Arkhipkin A, Blake D (2018). License X-2017 Pinniped Bycatch Mitigation Report: Implementation of seal exclusion devices (SEDs) in the Loligo (*Doryteuthis gahi*) fishing fleet during the 2nd season 2017. Fisheries Department, Directorate of Natural Resources, Falkland Islands Government, Stanley, Falkland Islands. 28 pp.

Iriarte V., Pompert J. (2016). Pinniped Bycatch Report: Squid & Finfish Trawlers. Preliminary information on the bycatch of pinnipeds in the Falkland Islands. Fisheries Department, Directorate of Natural Resources, Falkland Islands Government, Stanley, Falkland Islands. 13 pp.

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1. Introduction

The Falkland Islands Patagonian squid (*Doryteuthis gahi*) fishery is currently the only bottom-trawl fishery in the Southwest Atlantic with full observer coverage and Seal Exclusion Device (SED) usage (Iriarte *et al.*, 2020). This aligns with the 2030 Agenda and Sustainable Development Goals of the United Nations, and supports the *D. gahi* (hereafter LOL) product potential eco-labelling and its expansion to new markets.

The Pinniped Observer Program is result of a partnership between Falkland Islands Government (FIG) and the Loligo Producers Group (LPG), with Marine Mammal Observers (MMO) recording South American sea lion (*Otaria flavescens*, hereafter OTB) and South American fur seal (*Arctocephalus australis*, hereafter ARA) abundance, behaviour, net interactions, live deck releases, live SED escapees and incidental mortalities in at least three trawls per day. Secondary MMO duties include monitoring bird scaring lines (BSL) efficiency, recording seabird interactions with the fishing gear, mortalities and carcass collection.

The LOL 2020-C season started on 24th February 2020. Sixteen observers were deployed in the fleet, providing 100% of coverage. MMOs were supplied by MRAG (U.K) and were briefed at the Falkland Islands Fisheries Department (FIFD) on 23rd February, before embarking in their respective vessels. The first part of the briefing focused on the Seabird and Marine Mammal Bycatch Mitigation Program, including an introduction to local otariids (eared seals, OTB and ARA) and seabird species, identification, behaviour, types of interactions with fishing vessels and mortality mitigation methods. The second part concentrated in monitoring interactions, extracting information from carcasses, data gathering and recording, biometrics of LOL and Patagonian toothfish (*Dissostichus eleginoides*, hereafter TOO), and License conditions.

2. Objectives

The objective of this report is to present all the data collected during the 2020-C season regarding marine mammal and seabird interactions with the LOL fleet and to evaluate the mortality mitigation methods in place. Information includes data and samples collected by the MMOs and collated by the FIFD.

3. Methods

3.1 *Manoeuvre monitoring*

MMOs principal duty is to monitor at least three stations per day (one station comprised by a shoot and a haul) to record seal abundance and behaviour and to observe any seal and seabird bycatch. As shoots and hauls represent the most critical moment for both seabird and marine mammal incidental mortality and as seabird bycatch is extremely cryptic and very difficult to detect (Parker *et al*., 2013a; Iriarte & Pompert, 2016; Küepfer, 2016d), MMOs are required to carry out their observations principally from the gantry. Observer monitoring from bridge, bridge wings and deck do not provide enough view to properly assess seabird and seal interactions with the fishing gear; however monitoring from bridge/bridge wings may occur in night hours and unsafe weather conditions.

3.2 *Bird scaring lines monitoring*

The LOL fleet has been directly involved in the development and implementation of both *tori lines* (Sullivan *et al*., 2006; Snell *et al*., 2012) and *fixed aerial array* (Parker, 2012; Parker *et al*., 2013b). Although final *tori line* (TL) requirements are included in the License conditions, specific *recommendations* for the fixed aerial array (FAA) had been produced by the FIFD (Küepfer, 2016c, 2017c, 2018d). As different FAA models have been fitted on vessels, in order to evaluate their performance and to compare them to TL, MMOs are required to carry out one hour of BSL daily observations from the gantry, preferably while the vessel is processing catch and discarding. In vessels fitted with a discard tank observations are carried out even without any factory discharge being made. At the beginning of the observations the MMO estimates the overall vulnerable seabird abundance within 200 m astern, followed by 40 m estimations in 10 min periods and counting seabird presence within 2 m of the warp-water interface during each period. Vulnerable seabirds comprise species with large wing-span, which are prone to fishing gear entanglement (i.e. albatrosses and big petrels). The most common species interacting with the LOL fishery are: black-browed albatross (*Talassarche melanophris*, hereafter DIM), giant petrel species (*Macronectes giganteus* and *Macronectes halli*, hereafter MAX), white-chinned petrel (Procellaria aequinoctialis, hereafter PRO) and Gentoo penguin (*Pygoscelis papua*, hereafter PYP).

3.3 *Seabird and marine mammal bycatch mitigation measures*

MMOs monitor compliance to good practices, bycatch mitigation methods efficiency (i.e. BSL and SED) and discard storage tank usage and functioning. In the LOL fishery incidental mortality of both seals and seabirds occur mostly during shooting, when animals approach the net to forage in catch leftovers (“stickers”) that remain adhered to the net after the previous trawl. In order to mitigate seal and seabird mortality in the fishery, Part 2 of the License conditions mandate the use of BSL, prohibit discarding during manoeuvres (i.e. shoot, turn, haul) and dictate to clean the net thoroughly prior to shooting. Besides, three SED models had been approved by the FIFD, which usage is triggered each season by the Director of Natural Resources, usually after two seal mortalities (Iriarte *et al*., 2020).

3.4 *Mortalities & necropsies*

Observers must report seal mortalities to the FIFD via WhatsApp as soon as they occur, providing photographs of the head and genital area, and possible cause of mortality. If female, observers are instructed to preserve the carcass for posterior necropsy, while male carcasses are usually marked (cut on the left pectoral fin) and dumped overboard.

In the case of seabirds, all carcasses recovered should be preserved frozen for posterior necropsy. Collected individuals are then aged following Prince and Rodwell (1994).

3.5 *Data reporting*

Except BSL monitoring, all collected data by the observers is daily entered in an excel file which is sent to the FIFD, MRAG and the respective fishing companies twice a week (Mondays and Thursdays). BSL data is entered into a separate file and sent once a week (Fridays).

4. Results

4.1 *Manoeuvre monitoring*

Within the total of 1003 fishing days of the first season 2020, 2574 trawls were carried out by the fleet, of which 2572 (99.9%) were monitored in at least one manoeuvre (i.e. either a shoot or haul). Of a total of 2564 shoots observed, 1604 (62%) were monitored from the gantry, 388 from the stern deck (15%), and 572 from elsewhere (23%) (Fig.1). Regarding the 2573 hauls observed, 1789 (70%) were monitored from the gantry, 296 (11%) from the stern deck and 488 (19%) from elsewhere (Fig.1).

Fishing effort concentrated south of 52°S, particularly around Beauchêne Island. The most visited grid square was XVAL, with 470 shoots and 484 hauls, followed by XVAK (290 shoots; 412 hauls) and XVAJ (282 shoots; 341 hauls) (Fig.2). North of 52°S fishing was mostly carried out in XPAP grid square (267 shoots; 289 hauls), followed by XQAP (218 shoots; 170 hauls) (Fig.2).

4.2 Pinniped sightings

A total of 1767 seals [655 OTB, 891 ARA, 221 unknown species (UN)] were seen in 1265 occasions (Table 1). Although 43% of the sightings occurred north of 52ºS and 57% south of 52ºS, the southern region concentrated 84% of the total seal abundance, with ARA representing 56% of the individuals sighted (Table 1).

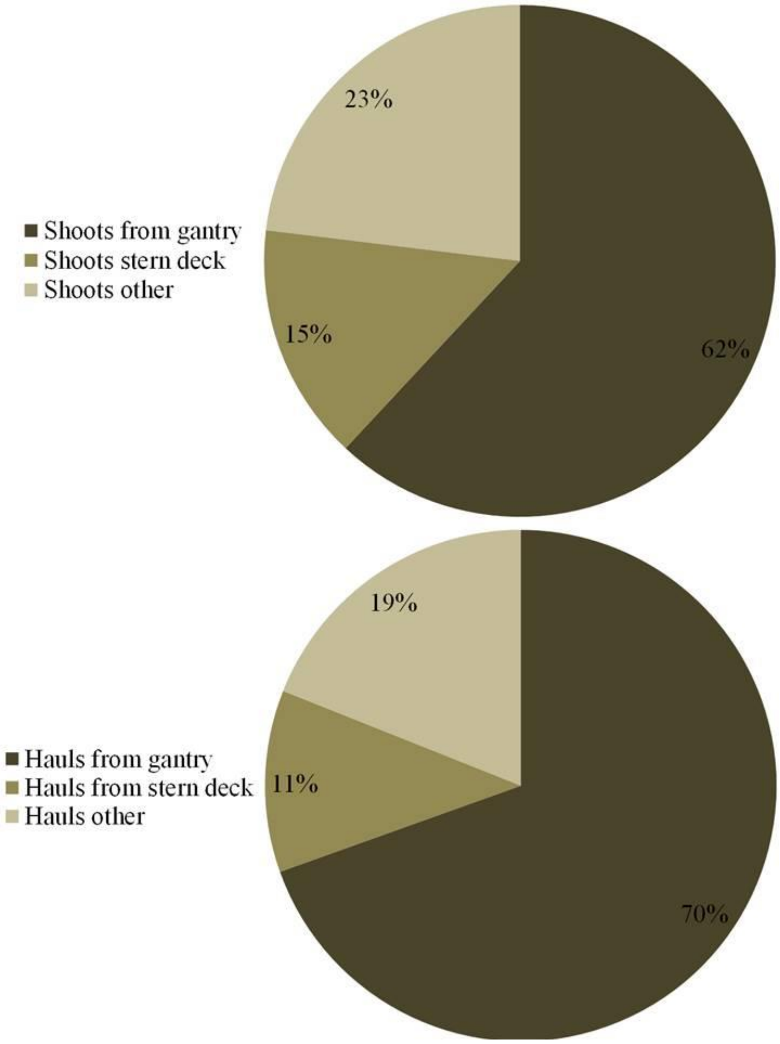

Fig.1. Shoots and hauls monitored from the gantry and stern deck.

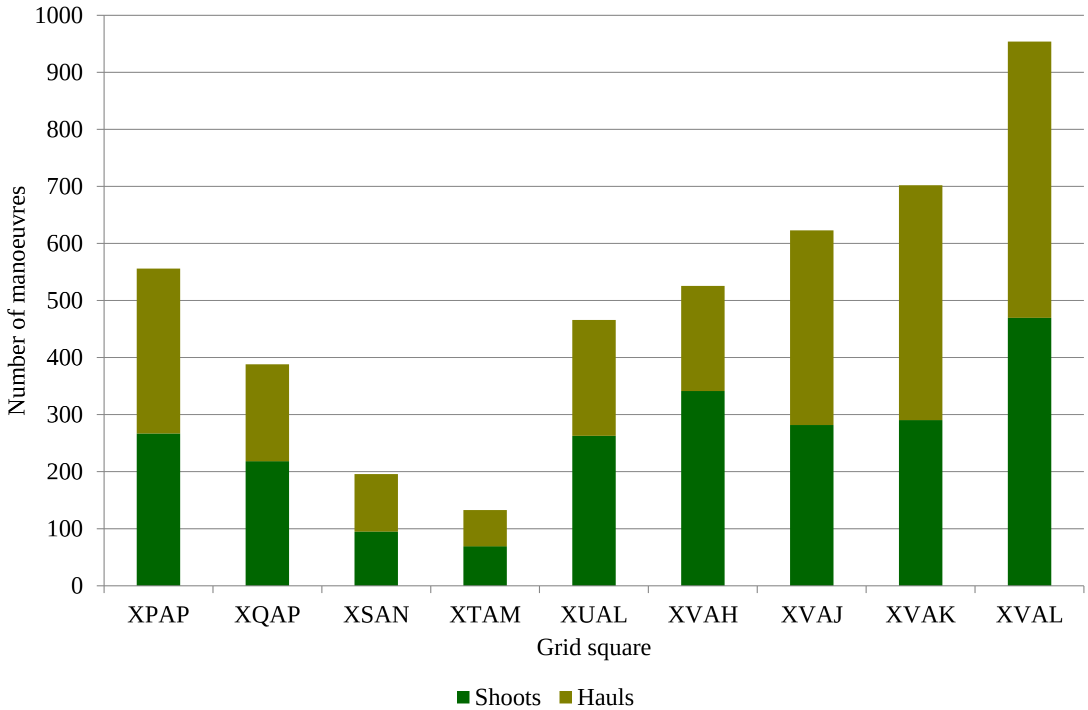

Fig.2. Fishing effort per grid square.

Table 1. Pinniped sighting and abundance per region.

Region	Species	Nº sightings	Nº individuals
North 52ºS	OTB	117	199
	ARA	408	52
	UN	21	31
Sub-total north		546	***282***
South 52ºS	OTB	242	456
	ARA	371	839
	UN	106	190
Sub-total south		719	***1485***
TOTAL		**1265**	**1767**

Seal presence throughout the season constantly increased until the 4th week of the fishery (17-23 March), when a maximum of 311 individuals were sighted (155 ARA, 124 OTB, 32 UN) (Fig.3). From 24th of March until 6th of April the number of sightings decreased, however a second peak in seal occurrence took place during the 7th fishing week (7-13 April), with 219 individuals observed (156 ARA, 48 OTB, 15 UN) (Fig.3).

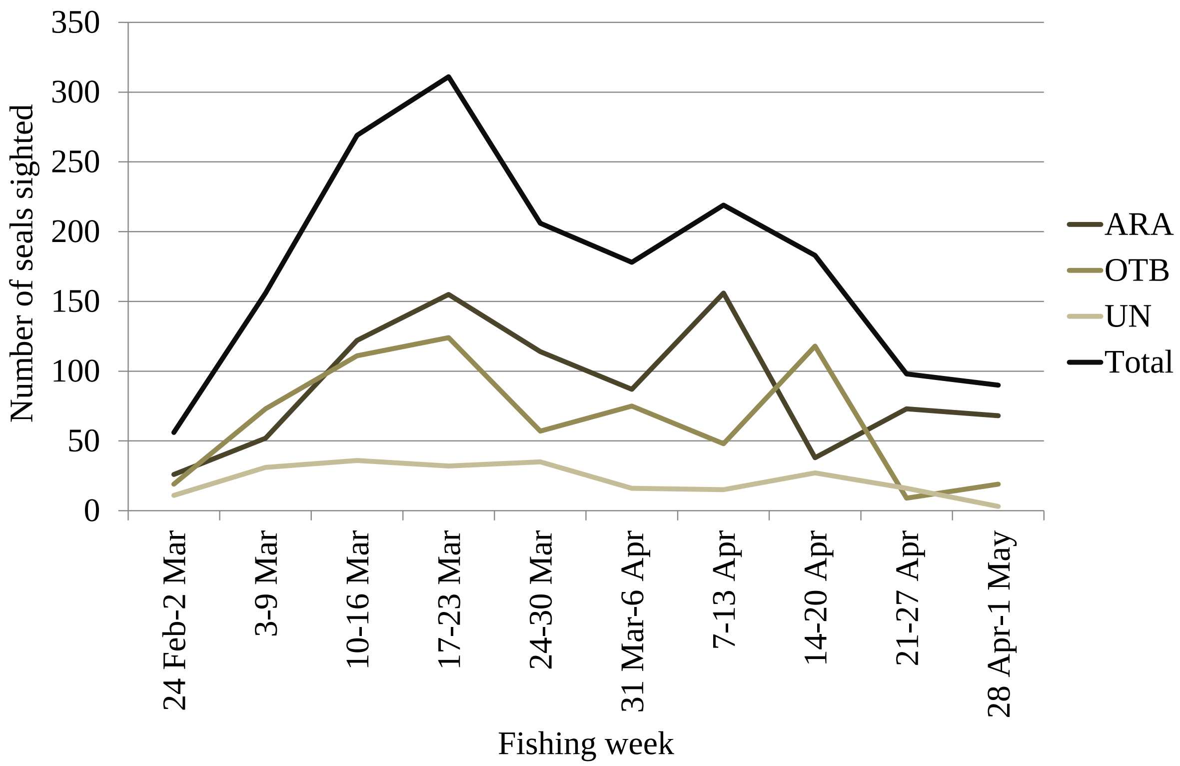

Fig.3. Cumulative pinniped sightings per fishing week.

4.2.1 Pinniped attendance to vessels and behaviour

A total of 1,212 seals (594 ARA, 480 OTB, 138 UN) were observed during hauling, comprising 69% of the individuals sighted. The remaining individuals (555) were seen during trawling (11%), shooting (10%), turning (7%) and steaming/unknown manoeuvre (3%). In 82% of the hauling attendance, seal behaviour was strictly related to foraging, with both ARA and OTB directly eating from the net (43%) or targeting lost catch around the fishing gear (39%) (Fig.4).

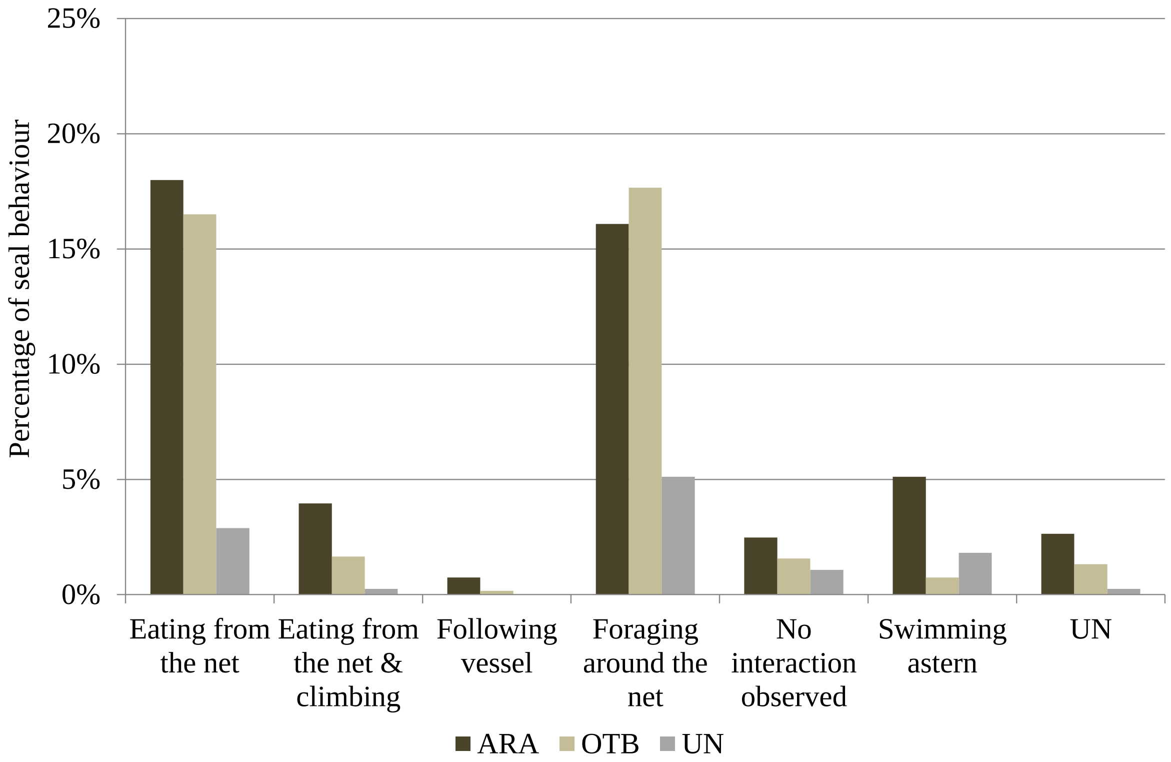

Fig.4. Pinniped behaviour exhibited during hauling.

Furthermore, during both trawling and shooting pinniped vessel attendance was also related to foraging. While trawling, seals were principally seen following the vessel and scavenging from the discard chute, whereas during shooting seals were predominantly seen feeding on stickers both still attached to the net or lost floating ones (Fig.5).

4.3 *Pinniped bycatch*

Following higher fishing effort and seal attendance to vessels south of 52ºS, 79% of pinniped bycatch occurred mostly in the south (XVAK) during hauling manoeuvres (Table 2). A total of 14 individuals were caught, of which five were incidentally killed (1 ARA, 4 OTB), seven were seen escaping through the SED hatch (4 ARA, 3 OTB), and two were released from deck (1 ARA, 1 OTB) (Table 2).

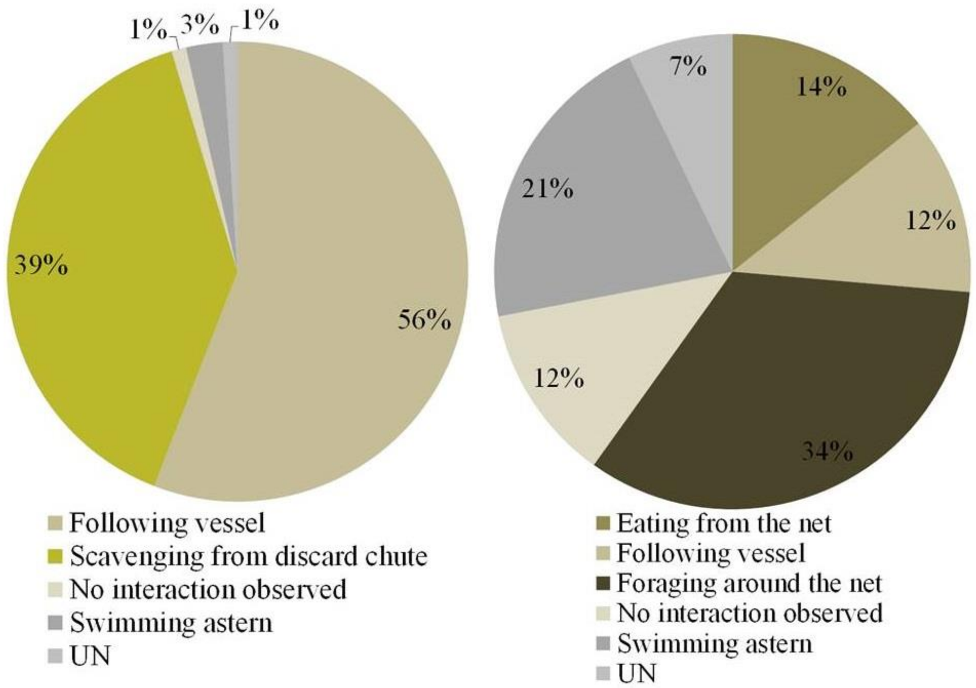

Fig.5. Pinniped behaviour exhibited during trawling (left) and shooting (right).

Table 2. Pinniped bycatch recorded.

Date	Grid	Species	Nº indiv.	Activity	Interaction	Comments
01/03/20	XPAP	OTB	1	Haul	Mortality	Juvenile male, no *rigor mortis*; drowned in haul.
04/03/20	XTAN	OTB	1	Haul	Deck release	Juvenile male inside codend; survived as result of small catch. Retained on top of fish bin grid.
05/03/20	XTAM	OTB	1	Shoot	Mortality	Sub-adult female, drowned in shoot. Carcass frozen for necropsy.
06/03/20	**SED implemented north of 52º30'S**					
09/03/20	XUAL	OTB	1	Shoot	Mortality	Two adult males seen during shooting, one entered the net and drowned. Carcass with *rigor mortis*.
13/03/20	XVAJ	ARA	1	Haul	Deck release	Two individuals eating from the net, one adult male entered the net; safely released by crew.
17/03/20	XUAL	ARA	1	Shoot	Mortality	Eight individuals seen during shooting, one entered the net and drowned. Carcass with *rigor mortis*.
18/03/20	**SED implemented south of 52º30'S (i.e. SED mandatory in the whole LOL Box)**					
19/03/20	XNAP	OTB	3	Haul	Mortality	Four OTB foraging around the net. An adult female (pregnant and lactating) drowned in the haul; no *rigor mortis*. Carcass frozen for necropsy.
22/03/20	XVAK	ARA	1	Haul	SED escapee	Seen exiting the SED while hauling.
23/03/20	XVAK	OTB	1	Haul	SED escapee	Six OTB foraging around the net, 1 seen inside the net and then escaping through the SED.
28/03/20	XVAK	ARA	1	Haul	SED escapee	Safely escaped when SED was at the ramp.
04/04/20	XVAK	ARA	1	Haul	SED escapee	Eating from the net; entered the net and escaped through the SED after crew manoeuvring.
08/04/20	XVAK	ARA	1	Haul	SED escapee	Escaped through the SED after crew manoeuvring.
14/04/20	XPAP	OTB	1	Haul	SED escapee	Two individuals eating from the net; one entered the net and escaped through the SED.
18/04/20	XSAN	OTB	1	Haul	SED escapee	An individual seen inside the net; escaped while SED was still submerged.

4.3.1 *Incidental mortalities and SED implementation*

SED usage was triggered north 52º30'S on March 6th (fishing day 12) after two OTB incidental mortalities (1 juvenile male, 1 sub-adult female) (Table 2). On March 18th (fishing day 24) SEDs became mandatory in the whole *Loligo* Box after two mortalities were recorded in the south (1 ARA, 1 OTB) (Table 2). After SEDs were fully triggered in the fishing area, an additional mortality occurred (Table 2). This last mortality involved an adult female OTB which drowned during a haul, possibly as a result of loss of tension in the fishing gear that led to the blockage of the escape passage. In order to investigate the sexual maturity and reproductive state of the incidentally killed females, carcasses were preserved aboard for posterior necropsy (Table 3). It was confirmed the adult OTB female mortality encompassed also the mortality of both her pup on land and the pre-implanting embryo (Table 3). These increased the LOL 2020-C pinniped mortality numbers to seven individuals (1 ARA, 6 OTB).

Only one carcass recapture was recorded, corresponding to the single ARA mortality (Table 2).

Table 3. Female OTB necropsied.

Mortality date	Necropsy date	Total length (cm)	Axillary girth (cm)	Weight (kg)	Approx. age (y)	Comments
05/03/20	23/06/20	145	99	69.07	4.5	Healthy robust sub-adult individual without previous or current pregnancies; mammary glands without milk. Trachea with foam and edematous lungs.
19/03/20	29/06/20	184	129	~200	20+	Healthy robust fecundus adult female, with ovaries presenting around 15 pregnancy scars. Mammary glands with milk. Enlarged left ovary containing a *Corpus Luteum* (gland that develops after fertilization) and presence of gelatinous secretion in the vagina. Trachea with water and edematous lungs.

4.3.2 *Live deck releases and SED escapees*

Two live deck releases were carried out on the 2nd and 3rd fishing week (1 OTB, 1 ARA), before the SED was triggered (Table 2). Both events took place south of 52º15' S and involved individuals that entered the net during hauling. Although the ARA was inside a net wing and was cut free after discharging the catch into the fish bin, the OTB was inside the cod-end and only survived because the catch was small and the grid on the top of the fish bin prevented the young sea lion to fall into the fish bin (cover photo). It is important to stress that in both cases crew safely handled the seal live releases, both for themselves and the pinnipeds.

Regarding the SED escapees, a total of seven seals were seen safely escaping through the SED hatch while hauling (Table 2). The record of the SED escaping seals was comprised of four ARA and three OTB, being two escapees of the latter observed north of 52ºS (cover photo from grid square XPAP) and the remaining in the south, in grid squares XVAK (4 ARA, 1 OTB) and XSAN (1 OTB).

It should be pointed out that these SED escape events are visible only when the SED is already on the surface of the water. The number of individuals that escaped when the SED was below the surface during both shooting and hauling remains unknown.

4.4 *Seal exclusion device*

Three SED models had been approved by the FIFD which differentiate in the presence of either a small mesh panel (Model B) or a high-speed funnel (Model C) that directs the water flow through the grid and straight into the codend (Iriarte *et al*., 2020) (Fig.6). Within the 2020-C season, two vessels used Model A, eight used Model B, and six used Model C. Of the total of 2574 trawls carried out, 1583 (61%) took place with a SED fitted in the fishing gear, being 31% completed with Model B, 23% with Model C and 7% with Model A (Fig.7).

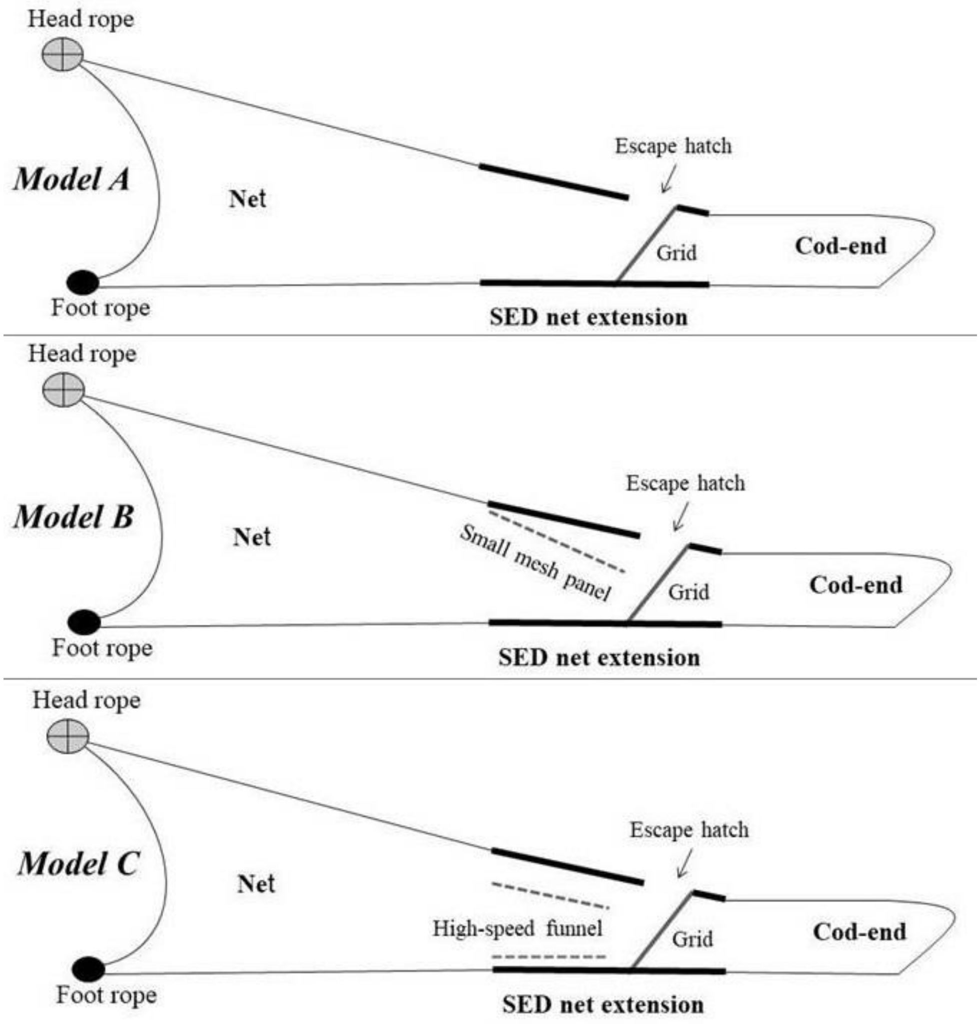

Fig.6. Approved SED models.

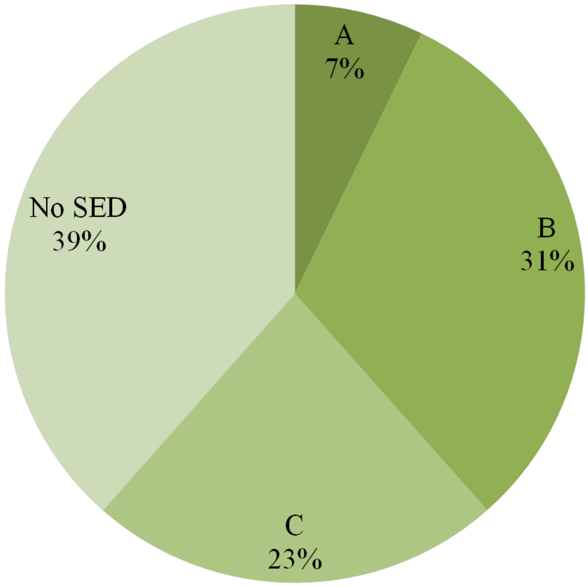

Fig.7. Percentage of stations per SED model.

4.5 *Seabird bycatch*

Alike pinniped interactions, 93% of the seabird interactions took place south of 52ºS, particularly when the vessel activity was either shooting (34%) or hauling (41%) (Fig.8, Table 4). Seventy-four percent of the interactions involved the black-browed albatross (DIM) and 63% occurred around Beauchêne island (grid squares XVAK, XVAL, XVAJ), where fishing effort concentrated (Fig.2). This island comprises the second most important breeding site for DIM in the Falkland Islands (Wolfaardt, 2012). During the fishing season a total of 40 seabirds were incidentally caught, of which 32 were incidentally killed (28 DIM, 2 PRO, 1 PUG, 1 PYP) and 8 were safely released alive (4 DIM, 2 MAX, 1 PRO, 1 PYP). Besides, observers also recorded seabird interactions that were not related to the fishing activity: one DIM landed on the bow with a plastic monofilament in one leg, one storm petrel landed exhausted on deck, and two prions died after colliding with the vessel (Fig.8, indicated as "NA").

4.5.1 *Incidental mortalities*

In coincidence with previous reports, the seabird species with higher agonistic interactions with the fishery was DIM, representing 87.5% of the mortalities. Following the trend of 2017-2018 (FIG, 2019) and 2018-2019 (FIG, 2020), seabird mortalities were mostly related to net entanglements (56%) (Fig.9). These 18 net-related mortalities occurred both during shooting (78%) and hauling (22%). Although entanglements during shooting always result in mortality, during hauling the seabird may be rescued alive. The latter is supported by the eight net entanglements with live releases reported (Table 4).

Table 4. Seabird bycatch recorded.

Date	Grid	Species	Activity	Interaction	Sample	Comments
24/02/20	XVAJ	DIM	Shoot	Net entanglement	Y	5^+ female; brood patch growing; left wing broken.
24/02/20	XVAK	DIM	Trawl	Entanglement in FAA streamers	Y	5^+ male; big gonads; body covered in oil (streamers).
25/02/20	XVAL	DIM	Trawl	Entanglement in FAA streamers	Y	5^+ male; brood patch growing; broken legs and wings; wrapped in oily orange streamers; LOL inside beak.
25/02/20	XVAK	DIM	Trawl	Warp cable	N	Wing recovered in haul.
25/02/20	XVAK	DIM	Haul	Warp cable	N	Lost carcass.
25/02/20	XVAJ	DIM	Shoot	Warp cable/door	N	Wet carcass, lost in haul.
25/02/20	XVAJ	DIM	Shoot	Net entanglement	Y	Necropsy yet to be performed.
26/02/20	XVAJ	DIM	Haul	Warp cable & pulley	Y	5^+ UN; left wing broken and amputated; disconnected legs; exposed organs; broken chest.
27/02/20	XVAL	DIM	Haul	Warp cable & pulley	N	Very strong winds
28/02/20	XVAH	DIM	Turn	Warp cable & pulley	N	Carcass smashed into the winch.
29/02/20	XVAL	PAX	NA	Electric wires	Y	Not related to fishing gear activity.
03/03/20	XUAL	DIM	Haul	Warp cable & pulley	N	Very bad weather.
03/03/20	XUAL	OCO	NA	Landed on vessel	NA	Exhausted individual; safely released.
05/03/20	XVAL	PYP	Haul	Net entanglement	NA	Safely released after cutting the net.
09/03/20	XTAM	PRO	Haul	Net entanglement	N	Broken wings; post-release mortality.
09/03/20	XVAJ	DIM	Shoot/Trawl	Entangled in door	N	Wet carcass; lost in haul.
09/03/20	XVAJ	DIM	Trawl	Entanglement in FAA streamers	N	Carcass seen but lost.
09/03/20	XVAL	DIM	Haul	Warp cable	Y	5^+ male; brood patch present; right wing broken and torn apart; right portion of the body with limbs missing.
09/03/20	XVAK	DIM	Shoot	Net entanglement	Y	5^+ male; grown brood patch.
09/03/20	XVAL	DIM	Shoot	Net entanglement	Y	3y female; brood patch absent.
09/03/20	XVAH	DIM	NA	Landed on vessel	NA	Plastic monofilament on leg; safely released.
10/03/20	XVAL	DIM	Haul	Net entanglement	Y	5y female; brood patch absent.
10/03/20	XVAL	DIM	Shoot	Net entanglement	Y	Recovered in haul; necropsy yet to be performed.
12/03/20	XVAL	PYP	Shoot	Net entanglement	Y	UN sex; fat and healthy individual; right leg broken.
12/03/20	XVAK	PRO	Haul	Net entanglement	NA	Safely released after cutting the net.
14/03/20	XTAM	DIM	Shoot	Net entanglement	N	Carcass lost during trawling.
15/03/20	XTAN	DIM	Shoot	Net entanglement	Y	5y female; brood patch absent; broken bill.
18/03/20	XUAL	DIM	Shoot	Net entanglement	N	Lost carcass.
18/03/20	XUAL	DIM	Shoot	Net entanglement	Y	5^+ male; brood patch growing; left leg broken.
18/03/20	XVAL	DIM	Haul	Fell inside SED	NA	Safely released.
25/03/20	XVAH	DIM	Turn	UN	N	Carcass released itself from the gear.
25/03/20	XVAJ	DIM	Haul	Warp cable & pulley	N	Very strong winds; carcass lost.
27/03/20	XVAJ	PAX	NA	Night collision against vessel	Y	Not related to fishing gear activity.
27/03/20	XVAJ	DIM	Haul	Fell inside SED	NA	Safely released.
27/03/20	XVAK	DIM	Haul	Net entanglement	NA	Safely released.
29/03/20	XVAH	DIM	Shoot	Net entanglement	Y	5^+ female; brood patch growing; LOL sticker inside bill.
31/03/20	XTAM	DIM	Haul	Net entanglement	N	Broken wings; post-release mortality.
02/04/20	XUAL	DIM	Shoot	Net entanglement	Y	5^+ male; brood patch grown.
02/04/20	XTAM	PUG	Haul	Net entanglement	Y	Male; small gonads, possible juvenile or resting adult.
07/04/20	XMAQ	MAX	Haul	Fell inside SED	NA	Safely released.
07/04/20	XMAQ	DIM	Haul	Net entanglement	NA	Safely released after cutting the net.
12/04/20	XVAK	MAX	Haul	Net entanglement	NA	After manoeuvring the bird safely freed itself.
18/04/20	XQAP	PRO	Shoot	Net entanglement	Y	5+ female; brood patch growing.

However, six DIM mortalities were recorded while hauling the warp cables (i.e. haul and turn manoeuvres), representing the second cause of mortality (28%) (Fig.9). In this case rough weather and strong winds deviated FAA streamers, leaving warp cables exposed, against which flying albatrosses collided, stuck, and eventually reached the pulley.

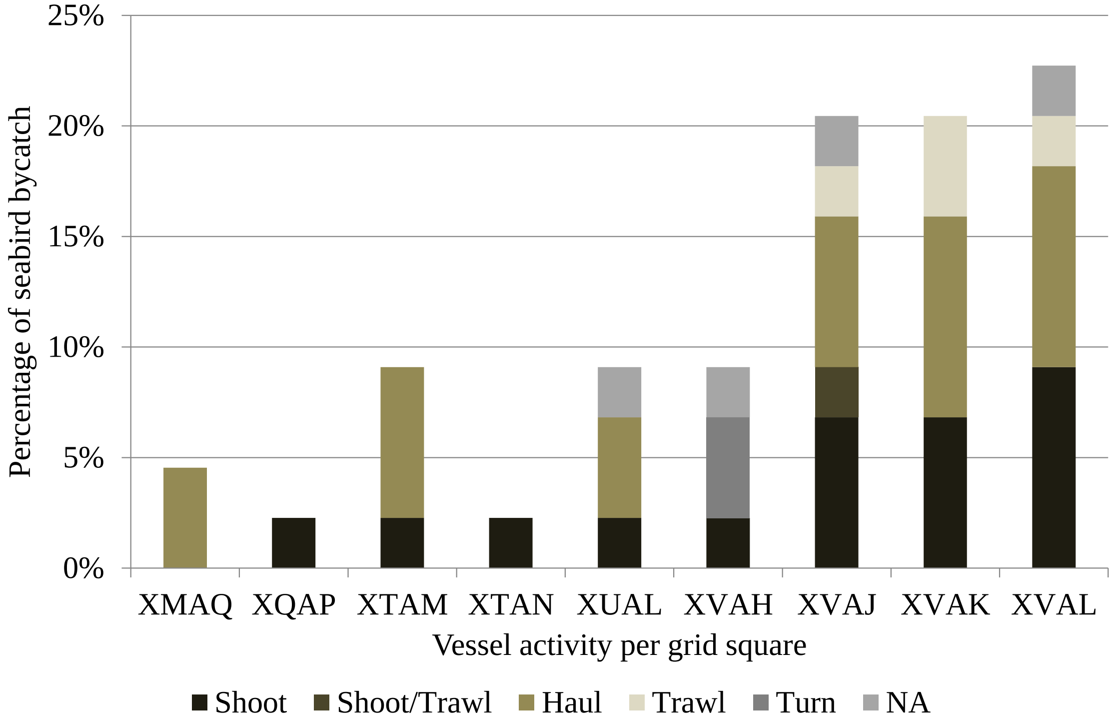

Fig.8. Seabird interactions per vessel activity.

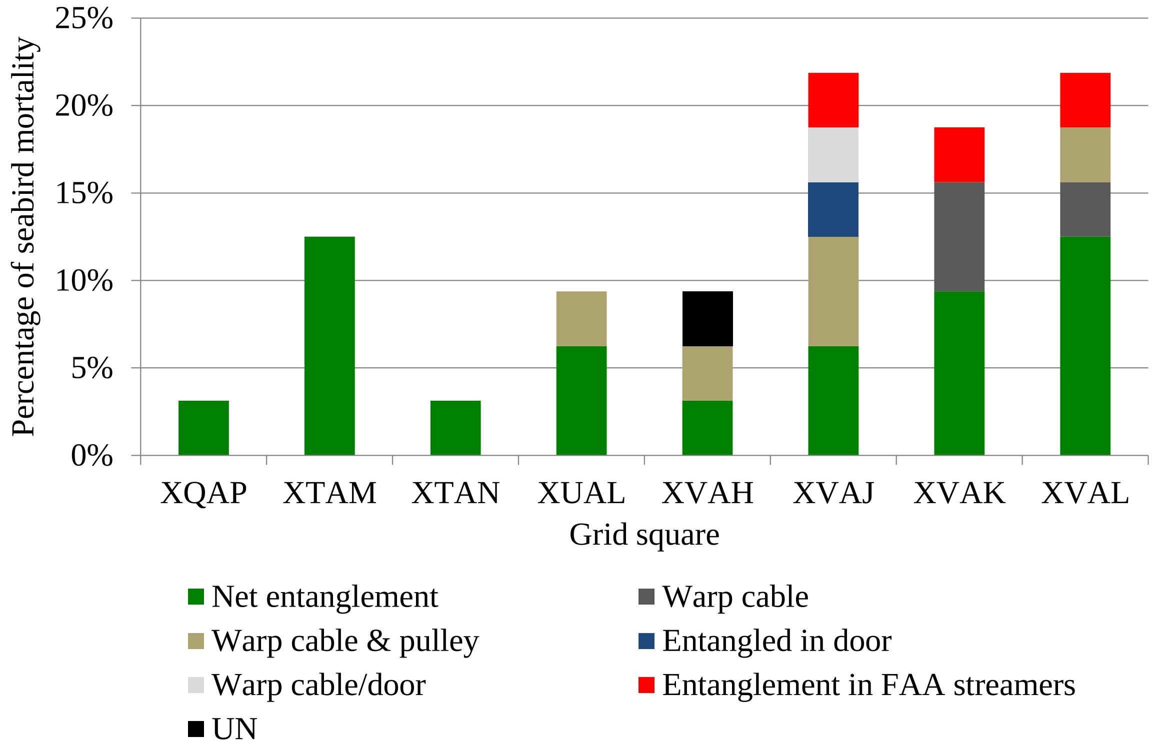

Fig.9. Cause of seabird incidental mortality per grid square.

The third cause of mortality (9%), were entanglements in FAA dirty streamers (i.e. covered in warp cable's oil) (Fig.9). In this specific situation, the oil covering the lower portion of the streamers acted as glue on the albatross' feathers, birds wrapping around the streamers while making efforts to release themselves. As previously reported (Parker, 2012; Snell *et al*., 2012) higher incidence of FAA streamer entanglements was noticed in the orange flexible ones.

4.5.2 *Seabird necropsies*

Of the 32 incidental mortalities recorded, 17 carcasses were preserved (14 DIM, 1 PRO, 1 PUG, 1 PYP) and 15 necropsies were carried out, of which 12 corresponded to DIM (Table 4). Of these individuals, 5 were female, 6 male and 1 unknown (Table 4). Of the females, two were categorised as 5^+ years-old and had a growing brood patch, which indicates they were actually breeding (chicks fledge in April). The rest of the females were immature individuals, one classified as being 3 years-old and two 5 years-old respectively.

Concerning males, all were 5^+ years-old. Regarding their reproductive stage, one had quite developed gonads and three had a growing brood patch, which indicates these individuals were definitely breeding. The remaining two males had a grown brood patch, however it is unknown if they were still immature [sexual maturity on average occurrs at 9.8 years-old (Nevoux *et al*., 2007)] or they were resting adults.

Regarding chick survival, it is unknown wether fledglings were able to live without one of the feeding parents.

4.6 *Fixed aerial array*

During the season 13 vessels had this device fitted on their stern, comprising the use of five FAA different models. Ten of the vessels had a FAA based on the original model 2012 with parallel booms mounted above the warp cables (Parker, 2012) (Fig. 10), while three followed the *recommended* FAA guidelines (Küepfer, 2016c, 2017c, 2018d) and had been fitted with a FAA model with wide open booms (Fig.10).

4.6.1 *FAA performance monitoring*

The FAA 2012 appeared as a novel method to deter seabirds from the warp cable-water interface and the objective was to put an end to several problems TL have: deviation in cross winds; limited warp-water interface protection; entanglements with warp cables; use of streamer inferior quality material prone to tangle and snap; and bird entanglement in streamers, among others (Parker, 2012). However, several consecutive FAA evaluation reports highlighted the same failures as previously mentioned, pointing out that FAA 2012's efficiency had been overestimated (Küepfer, 2012). In consequence, consecutive efforts were

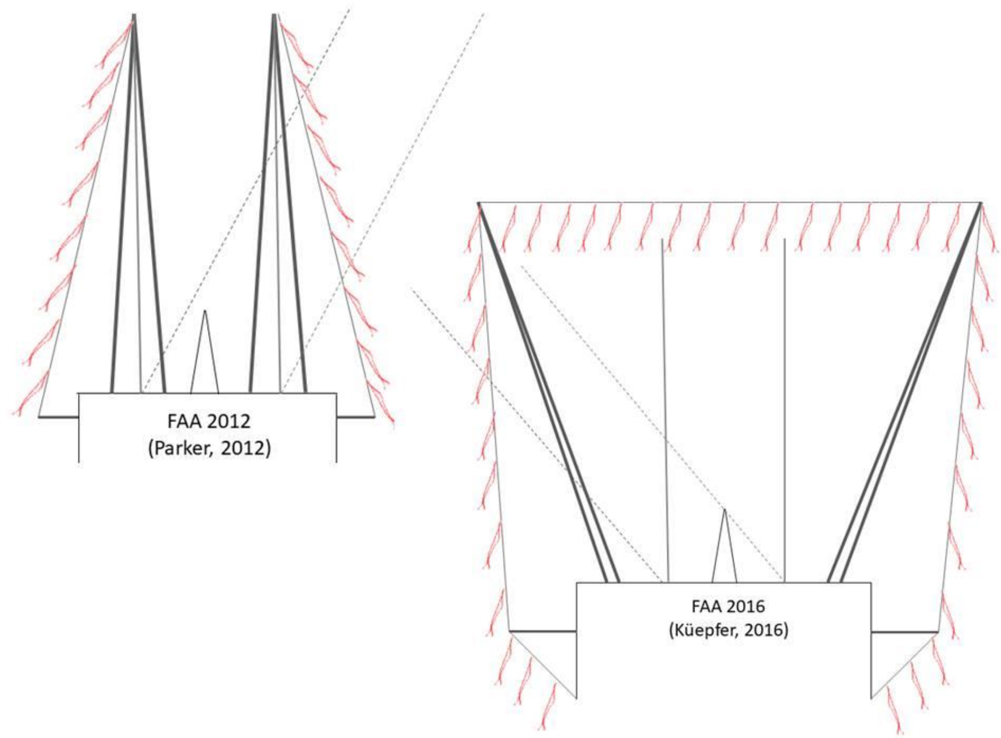

Fig.10. Comparative sketches of FAA 2012 and 2016 models. Note difference in deviated warp coverage in the design with parallel booms right above the warp cables (2012) and the open wide booms located to the outer sides of the warp cables (2016).

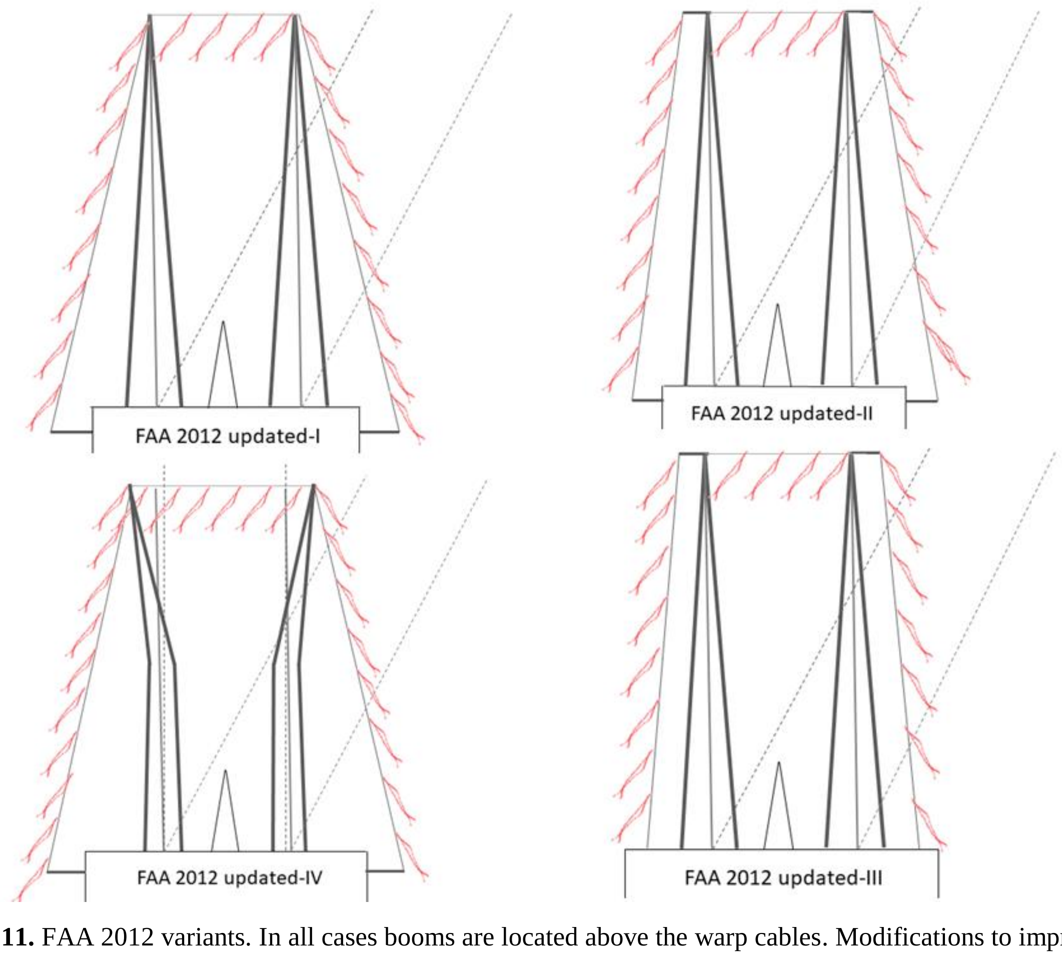

Fig.11. FAA 2012 variants. In all cases booms are located above the warp cables. Modifications to improve efficiency include (clockwise):addition of a distal curtain (I), distal perpendicular small booms (II-III) and distally open booms (IV).

made to carry out FAA modifications –including boom extensions- without success (Küepfer, 2016a,b, 2017a,b, 2018a,b; Iriarte, 2019 a,b) (Fig.11). Based on the field research mentioned above, FAA guidelines with model *recommendations* were produced and shared with industry (Küepfer, 2016c, 2017c, 2018d). Following previous reports, it is important to stress that achieving the perfect FAA to guarantee 100% of warp cable coverage at different depths, weather conditions, cable deviation and cable lateral displacement through moving pulleys is literally impossible. Although the FAA 2016 can exhibit warp exposure when cables deviate, streamers do not entangle and/or snap, requiring less maintenance than the 2012 models (Küepfer, 2018c) (Table 5).

Table 5. FAA performance extracted from MMO 2020-C reports.

FAA Model	***2012-I***	***2012-II***	***2012-III***	***2012-IV***	***2016***
N° of vessels	2	5	2	1	4*
Streamer material	Orange flexible; red semi-flexible	Red semi-flexible; Red weighed semi-flexible; orange flexible	Red weighed semi-flexible; orange flexible	Red semi-flexible; red weighed semi-flexible	Red semi-flexible; red weighed semi-flexible; orange flexible
Streamer contact with warps	Very high	High to very high	Very high	Very high	Moderate
Streamer entanglements	Very high	High to very high	Very high	High	Low
Streamer maintenance	Very high	Very high	Very high	High	Low to moderate
Level of warp exposure	High to very high	High to Very high	High to very high	Very high	Low to moderate

*FAA broken; vessel used TL instead.

Regarding the latter, it should be emphasized that in FAA 2012 models, even when daily cleaned, streamers are permanently covered in oil, adding a threat for seabirds to entangle or become oily at the minimum contact. Due boom disposition in FAA 2012 models, streamers could easily entangle and snap, leaving warps unprotected and incidentally releasing plastic into the ocean. This problem is accentuated if using orange semi-flexible streamers. The low quality and lack of efficiency of this material in TL was noted by Snell and colleagues (2012), which lead to the *recommendation* in License conditions for the semi-flexible red material in 2008. However, the use of the orange flexible material continued (Parker, 2012), even after further *recommendations* to industry were made before the next to LOL 2018-C season.

4.7 *Other bycatch mitigation measures*

License conditions that prohibit discard of unwanted fish and offal during manoeuvres were fully respected. Although there were some instances when net cleaning had low standards, overall adherence was high and it was reflected in less seabird mortalities in comparison to LOL 2019-C. However, the presence of exposed warp splices was detected in at least one vessel, which brings back a problem that was supposed to be resolved. Regarding discard storage tanks, failures were noted and an individual report will be produced evaluating different designs, operational characteristics and performance.

5. Conclusions

- The MMO Program in the LOL fleet comprises a real asset to monitor marine mammal and seabird interactions, supports FIG’s best fishery management, and evidences industry’s contribution to the sustainability of the fishery;

- Both pinniped and seabird interactions with the fleet occurred mostly around Beauchêne Island, where the LOL fleet fishing effort concentrated. These animals attended vessels mostly during manoeuvres to directly eat from the net, forage around the fishing gear and eat from discards. As previously reported, the most dangerous manoeuvre for both seals and seabirds was the shoot, followed by the haul;

- Collected data supports the pinniped bycatch mitigation strategy established in the License conditions and once again highlights the very high efficiency of the SED to mitigate seal mortality;

- The FAA 2016 model represents the most efficient BSL for seabirds to date. The FAA 2016 fitted with a combination of red semi-flexible streamers and red semi-flexible weighed ones provides the best seabird scaring aerial device for trawlers;

- Collected data strongly supports the combination of different methods to mitigate seabird mortality (i.e. FAA 2016, no discarding during manoeuvres, discard retention during trawling, net cleaning).

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