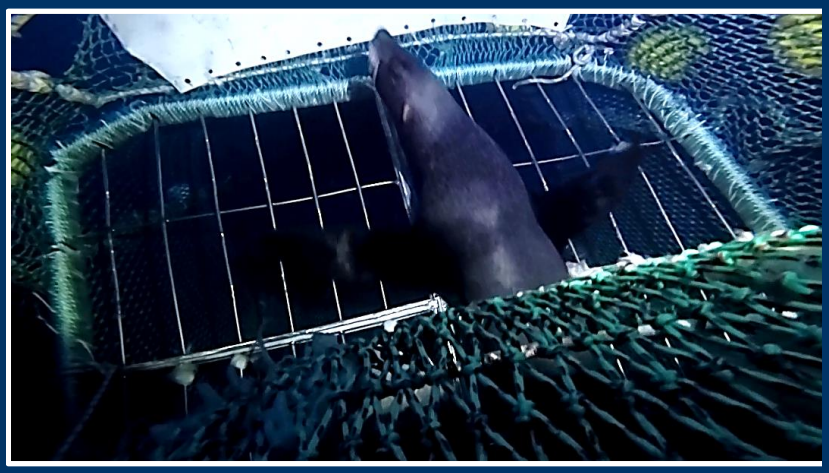
Pinniped Bycatch Mitigation Report License X-2017

Implementation of seal exclusion devices (SEDs) in the Loligo (*Doryteuthis gahi*) fishing fleet during the 2nd season 2017



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31 May 2018

License X-2017

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Acknowledgements

To all captains, engineers and crew of the fleet for giving their bests to build and improve SEDs in order to mitigate pinniped mortalities. To the LPG for contributing to the sustainability of the fishery. Haseeb Randawa and Alastair Baylis carried out the necropsies.

For citation purposes this publication should be referenced as follows:

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.

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1. INTRODUCTION

Interactions of marine mammals with fisheries have been recorded worldwide, causing impacts and putting these animals at risk by entanglements and direct bycatch in the nets (Pauly *et al*., 1998; De Master *et al*., 2001; Kovacs *et al*., 2012; Franco-Trecu *et al*., 2017). Efforts have been made to minimize these interactions, particularly in industrial fisheries, including the introduction of codes of practice and gear modifications. However, compliance strictly relies on fishing companies and captains, sometimes causing difficulties for the conservation of megafauna and sustainable management of the fisheries (e.g. Cox *et al*., 2007; Cleal *et al*., 2009). The use of exclusion devices have been proved effective in mitigating mortalities of sea turtles and seals in trawlers fishing for shrimp, finfish, krill and squid (e.g. Steele *et al*., 2002; Hooper *et al*., 2005; Lyle & Willcox, 2008; Cleal *et al*., 2009).

The Falkland Islands are part of the distribution and reproductive area of several pinniped species, including the South American fur seal *Arctocephalus australis* (~20,000 individuals), the South American sea lion *Otaria flavescens* (~9,000 individuals) and the southern elephant seal *Mirounga leonina* (2-3,000 individuals) (Strange, 1992). Periodically, other seals migrate to Falkland Islands waters, such as the subantarctic fur seal *Arctocephalus tropicalis*, the Antarctic fur seal *Arctocephalus gazella* and the leopard seal *Hydrurga leptonix* (White *et al*., 2002). These pinnipeds are top predators of the shelf ecosystem feeding on a variety of abundant fish species such as hakes *Merluccius hubbsi* and *M. australis*, southern blue whiting *Micromesistius australis*, hoki *Macruronus magellanicus* and squid, including the Argentine short-finned squid *Illex argentinus* and the Patagonian squid *Doryteuthis gahi* (Thompson *et al*., 1998; Aguiar dos Santos & Haimovici, 2002; Romero *et al*., 2011; Baylis *et al*., 2013; Thompson *et al*., 2013). While foraging, pinnipeds may interact with fishing fleets targeting commercial fish and squid by directly scavenging from the discard chute or the trawl nets during hauling. Usually, seals enter the trawls during hauling, and are brought to the main deck of a vessel alive in either net wings or the codend. To release a live-captured animal, the crew must cut the net to free the seal and sometimes force it to escape from the deck by water jet. There have also been incidents of mortalities when seals have drowned after entering the net during shooting or in the first stages of a haul.

In the past, mortalities of pinnipeds in Falkland Islands' fisheries were quite rare events, with only few animals estimated to be killed every year. However, in 2015-2016 the number of bycaught individuals by trawl fisheries increased. In 2016, 119 individuals were estimated to

be incidentally caught by the trawl fleet, with about 2/3 of that number presumably dead (Iriarte & Pompert, 2016). Even if estimated numbers are less than 1% of the total amount of seals in the Falkland Islands waters, it was recommended to treat them with caution as little is known about the survival rates and recruitment numbers of seals from the local colonies (Iriarte & Pompert, 2016). The majority of interactions involved the South American fur seal, followed by the South American sea lion.

2. THE PROBLEM

Unusual high presence and incidental mortality of seals *A. australis* (ARA) and *O. flavescens* (OTB) was first revealed during the regular pre-recruitment biomass survey of *D. gahi* (LOL) in 13-28 July 2017 (Table 1). In the north, interactions involved mostly OTB, while in the south ARA were predominant. These interactions took the form of *porpoising* behind the vessel between trawls, and directly feeding on discards from the discard chute and sometimes directly from the codend during hauls. Incidental live catches and mortalities were also recorded. In the south, high mortality (up to 4 individuals in a single trawl) was possibly due pinnipeds foraging on high LOL biomasses (Fig.1, 2). Efforts to mitigate interactions were put into practice in manoeuvres, however they resulted non-effective (Table 2). The Falkland Islands Fisheries Department (FIFD) informed all the company members of the Loligo Producers Group (LPG) about the situation and new requirements were established for the incoming fishing season.

Table 1. Pinniped bycatch along the pre-recruitment survey.

Date	Position	Station	Species	N°of individuals	Sex	Mortality
15/07/17	50.87 S 57.00 W	906	OTB	2	M	Y
18/07/17	52.18 S 57.67 W	921	OTB	1	M	Y
21/07/17	52.98 S 59.01 W	933	ARA	1	M	N
23/07/17	52.77 S 60.36 W	941	ARA	2	M	N
24/07/17	52.94 S 59.97 W	942	MIL	1	M	Carcass
25/07/17	53.01 S 59.33 W	948	ARA	1	UN	Y
25/07/17	52.99 S 59.10 W	948	ARA	1	UN	N
26/07/17	52.69 S 58.46 W	949	ARA	1	M	Y
26/07/17	52.88 S 58.90 W	951	ARA	4	UN	Y
26/07/17	53.01 S 59.29 W	Commercial	ARA	1	UN	Y
28/07/17	51.81 S 57.33 W	960	ARA	1	M	N
28/07/17	51.41 S 57.07 W	Commercial	OTB	1	UN	N

3. BYCATCH MITIGATION ALONG THE COMMERCIAL SEASON

3.1 First mitigation measures

In order to avoid high bycatch of seals in the area where highest mortalities had been observed during pre-recruitment survey, an exclusion fishing zone (EZ) was established around Beauchêne Island for 5 days (29 Jul-2 Aug). The EZ included grid squares XUAK, XUAL, XVAK, XVAL, XWAK, XWAL (Fig.3). Furthermore, all ships were required to include seal bycatch numbers (both dead and alive) in their daily catch reports. It is notable that initial mortalities were mostly reported by just four vessels: those that had a FIFD scientific fisheries observer aboard. Total daily reported incidental live catches and mortalities were calculated and communicated to all LPG members. During the first 12 days of the fishery (29 Jul-09 Aug), LOL trawlers worked exclusively in the southern area of the Loligo Box to the west of the Exclusion Zone, having extremely good catches of squid (average 65t per day per vessel). From 1 August all vessels were required to manufacture either metal bars or a mesh grid over the fish bin to prevent seals (dead or alive) being deposited into the fish bin when the catch was discharged (Fig.4, 5).

3.2 Total closure of the Exclusion Zone

After initial five days of the fishery, it was decided that four vessels with observers aboard (*Venturer*, *Beagle FI*, *Robin M. Lee*, *Igueldo*) should enter the EZ around Beauchêne for three days of fishing (3 to 5 August) to assess whether the seals had dispersed within the Exclusion Zone. The vessels encountered high abundance of squid and unfortunately large numbers of seals as well. Within the first day of fishing, only one mortality was reported inside the EZ. However, as vessels stayed in one area, seals were increasingly attracted by the fishing activity, some exhibiting curious behaviour towards the gear, and others seen directly scavenging from the discard chute. Within the EZ and west of it a total of 50 ARA were incidentally killed (41 in the EZ; Table 2) and as a result, on the 5 August at midday, the four trawlers were instructed to leave the Beauchêne Exclusion Zone immediately, without finishing their afternoon trawls.

Table 2. Mitigation measures and outcomes during the second fishing season 2017.

Period	2nd Pre-recruit survey 2017		2nd Commercial season 2017						
Section	**2**		**3.1**	**3.1**	**3.2**	**3.3**	**5.1**	**5.2**	**5.3**
Mitigation	Shoot on the turn; haul with net mouth closed; high speed steaming 1-2 nm before shoot		Exclusion zone: XUAK, XUAL, XVAK, XVAL, XWAK, XWAL (Fig.3)	Mandatory grid/net on the top of pantano; 4 vessels with observers fishing in EZ; mortalities both within and outside EZ	No fishing allowed in EZ; vessels with observers + rest of the fleet west of EZ; first SED trial west of EZ on the 8th with an observer (Table 3)	Total closure of fishing grounds south of 52°30' (Fig.6)	Compulsory usage of SED only south of 52°30'; 3 vessel with *Panther* trials (Table 4)	Compulsory usage of SED in entire LOL Box; on Aug 29th ropes inside SED banned; from Sep 3rd 8 vessels with observer coverage; from Sep 5th 11 vessels with observer coverage	Compulsory usage of SED in entire LOL Box; 100% observer coverage
Mitigation efficiency	Non-efficient		EZ non-efficient, individuals incidentally caught outside of the EZ	Grid efficient to avoid seals falling into the pantano, however mortality was not addressed	EZ + manoeuvring non-efficient; SED efficient (Table 3)	Non-efficient, transfer of mortality from ARA to OTB; efficient SED trials in EZ (Table 3)	SED efficient; *Panther* with high mortality (Table 4)	90%	100%
Area of LOL box	N 52°	S 52°	S 52°, west of EZ	Exclusion zone; west of EZ	West of EZ	North of 52°30'	All LOL box available for fishing	LOL Box	LOL Box
Species	OTB	ARA	ARA, OTB	ARA	ARA, OTB	ARA, OTB	ARA, OTB	ARA	ARA, OTB
Abundance	~12	~70	Medium-high	High	ARA high, OTB low	Medium	High	High	High
Behaviour	SDC	SDC, NF	SDC, FS, AS	SDC, FS, AS	SDC, FS, AS	SDC, FS	SDC, FS, AS	SDC, FS, AS	SDC, FS, AS
N° of casualties reported	3 OTB	7 ARA	7 ARA, 2 OTB	50 ARA (41 in EZ)	43 (41 ARA, 1 OTB, 1 UN)	8 (3 ARA, 5 OTB)	7 (6 ARA[a], 1 OTB[b])	8[c] ARA	1 ARA[d]
N° of live individuals reported	1 OTB	5 ARA	5 ARA, 1 UN	16 ARA (5 in EZ), 1 OTB	25 (24 ARA, 1 OTB)	6 (4 ARA, 2 OTB)	54 (53 ARA, 1 OTB)	86 ARA	77 (76 ARA, 1 OTB)

SDC=scavenging from discard chute; NF=net feeding; FS=following ship; AS=approaching ship. a=5 individuals killed (2 in shoot, 3 in haul) while trialling a foldable SED that collapsed; another individual possibly an old carcass. b= killed in the north, where SEDs were still not compulsory. c=1 head entangled in net wing/broken neck; 1 possibly killed on turn; 1 drowned during haul; 5 unknown. d=inside SED but with clear signs of being killed by propeller.

3.3 Total closure of the fishing area S52°30'

The situation west of the Exclusion Zone was also becoming graver, as in between 6-9 August the seals accumulated there as well. Sixty-eight bycatch events were recorded, with 43 mortalities reported (Table 2). To prevent further seal mortalities, on the 10 August the whole southern area of the Loligo Box was closed to fishing up to the 20th (Fig.6). It was hoped that the closure would allow seals to disperse and maybe migrate to forage for southern blue whiting (*M. australis*) which were expected to appear as spawning aggregations west of the Loligo Box. Unfortunately, this closure of the southern area had a large negative impact on the commercial performance of the LOL fleet, as the densities of squid in the northern part of the fishing area were quite low (Winter *et al*; 2017).

3.4 Fishing in the North

From 10-20 August, the whole LOL fleet worked north of 52°30'S having an average of 10-15t of squid per day per vessel. No ARA concentrations were observed in this area. In spite of that, 5-10 OTB were commonly following the vessels and foraging from discards. However, there were few interactions between sea lions and fishing vessels. These animals were more cautious than fur seals, waiting for discards and generally not entering the nets neither during shooting nor hauling. During this period 14 incidental pinniped catches were reported, six of them consisting of live releases (4 ARA, 2 OTB) and eight mortalities (3 ARA, 5 OTB) (Table 2).

4. MORTALITY MITIGATION

4.1 Fishing gear trials

During one of the early joint meetings of the FIFD and the LPG, it was communicated that the captain of *Golden Chicha* had a proposal to build and test a seal exclusion device (SED). In consequence, an observer was assigned to the vessel. After *Golden Chicha*'s first five trials (Table 3), the *Hermanos Touza* also started fishing with a SED built following the design of *Golden Chicha*; in this case the SED efficiency was also monitored by another FIFD observer. In the meantime, other fishing companies proposed testing another modified net, the *Panther*, built by EuroRed, a Spanish fishing gear enterprise. Trials with observer

monitoring the *panther* performance were carried out aboard the vessels *Argos Vigo*, *Castelo*, and *Sil* (Table 4).

4.1.2 Seal exclusion device (SED)

The SED was originally designed and built aboard the *Golden Chicha*, following SED models used for different fisheries elsewhere. The general concept of the SED is to introduce a solid grid barrier at the codend's mouth to prevent seals entering it. This physical barrier (a metal grid) should easily direct the seal to an escape hatch, located on the top of the trawl. In order to do so, the grid bars must be vertical and its angle should be around 45-50 degrees (Fig.7). On *Golden Chicha* a small mesh size (*calcetín*, Fig.8) high-speed funnel was also installed just before the SED to direct the water flow and squid into the codend (Annex II, SED-C). During the trials (starting August 8th) it was noticed that modifications needed to be made as initial SED designs were inadequate in terms of efficiency and strength, as squid was lost through the sides of the trawl (Fig.9). In consequence, after several adjustments the SED proved to be efficient enough to both mitigate pinniped mortality and maintain successful LOL catches (Table 2). During the 14 *Golden Chicha* trials, a total of 30 incidental ARA catches were recorded, 27 live and 3 mortalities (carcasses retained inside the SED), of which one died after its head became stuck between the grid bars during the haul (Fig.10). While incidental mortalities were minimized by introducing further SED modifications (e.g. grid's bar distance ≤15cm; no attaching ropes inside SED, Fig.11), a special fishing-gear haul manoeuvring protocol was also established aboard in order to allow the seals to escape through the SED's hatch while the net was still in the water, which would also prevent stress and injuries both to seals and crew. Furthermore, between 16 -19 August nine SED trials were also carried out in the EZ by the *Hermanos Touza*. Instead of the high-speed funnel, their SED used a small top mesh panel to direct the catch towards the grid (Annex II, SED-A). Similar to *Golden Chicha*, catches by *Hermanos Touza* averaged 17 t, suggesting no difference of using either a funnel or mesh panel inside the trawl. On the *Hermanos Touza*, a total of 18 live ARA were caught and safely released.

4.1.3 EuroRed's Panther

The general concept of the *panther* was to prevent the entrance of pinnipeds in the net, however the design proved ineffective and a number of seals became entangled in the net and

drowned. It consisted of a square mesh with the side of 150 mm located over the net's mouth (Fig.12, 13).

Table 3. **SED trials** aboard the *Golden Chicha*[1].

SED Trials	**F/V *Golden Chicha***					
Location	S52°:XVAJ, XVAH	EZ: XVAK, XVAL	EZ: XVAL, XVAK	EZ:XVAK, XVAL	S52°: XVAJ, XVAH	S52°: XVAH, XVAJ
Date	08 Aug 2017	15 Aug 2017	16 Aug 2017	17 Aug 2017	18 Aug 2017	19 Aug 2017
Mitigation	SED-C	SED-C	SED-C	SED-C	SED-C	SED-C
N° of trawls	3	2	2	2	2	3
Problems encountered	High speed funnel broken; squid lost; bent grid; seal inside SED on deck	Grid bars unwelded; still losing squid, so for 2nd trawl "calcetín" funnel widened 40cm to increase flow of water; seals either inside SED or net wing (freed on deck)	None in first trawl; grid bent a bit in 2nd trawl	Grid bent more; grid's bar space too big (17cm)	None	Ropes that attach funnel to the grid
SED Efficiency	100% for seals but very small squid catches	100% for seals; 1st catch 7t, 2nd trawl of 16.5t	90%; 1st catch 31t and 2nd 41t	90%; 1st catch 21t and 2nd 31t	100%, 1st catch 19t, 2nd 7t	90%, 1st catch 4-5t, 2nd 16t, 3rd 13.5t
Species	ARA	ARA	ARA	ARA	ARA	ARA
N° of casualties	0	0	1	1	0	1[a]
Cause of casualty	NA	NA	UN[b]	Head in between SED bars (Fig.10)	NA	Tried to exist through dead space of lateral rope inside SED
N° of live captures	1	5	1 (net wing)	7 (after especially manoeuvring escape through SED while still in water)	2 (after especially manoeuvring escape through SED while still in water)	11
Modifications to be made	Funnel with smaller mesh; rebuild grid: stronger material + vertical bars	Rebuild grid; widen funnel to allow flow in higher trawling speeds; manoeuvre to make seals escape through SED when it still is in the water	Manoeuvre to make seals escape through SED when it still is in the water	Rebuild grid stronger and with smaller inter bar space (12cm)	None	Change ropes for flexible material or eliminate ropes

1= *Hermanos Touza* also doing trials on 16-19August, however built the SED following modifications already introduced by the *Golden Chicha*; a= pregnant and lactating; b= possibly killed by tension in the net wing (41t).

Although a similar system has been used to mitigate seal bycatch in the krill midwater fishery in CCAMLR waters (Hooper *et al*., 2005), the features of the LOL fishery that use the bottom trawl with higher trawling speed (up to 4.5 knots) are quite different. There is also bycatch of

bottom species (rays and finfish), that become entangled in the *panther* net making it non-efficient. Even in the presence of high concentrations of squid (Fig.13) the amount of squid caught was low. In consequence, the *panther* appeared unattractive for fishing. Seventeen trawls performed by three fishing vessels (*Argos Vigo*, *Castelo*, *Sil*) were carried out using *panther*, all in the southern portion of the LOL Box. While the average catch of all trawls combined was of 5.5 t, 20 ARA incidental catches were recorded (11 live and 9 mortalities, with at least 4 killed during the haul). As the individuals were all wrapped in the *panther* net, releasing them on deck was not a straight forward process, besides putting on risk crew in front of a stressed wild animal. Consequently, after these trials the usage of *panther* net was not allowed in the LOL fishery.

5. IMPLEMENTATION OF GEAR MODIFICATIONS

5.1 SED mandatory south of 52°30' S

As the SED trials (Table 3) aboard the *Golden Chicha* and the *Hermanos Touza* proved positive for both LOL catches and seal mortality mitigation, it was recommended that all *Loligo* trawlers manufacture and install a seal exclusion device in their nets *ad hoc*, which from 20-28 August was compulsory only to south of 52°30'S.

5.2 SED mandatory in the whole LOL Box

After OTB casualties in the north, and in order to avoid transferring the problem from one species to another, SEDs were made mandatory in the whole LOL Box from 29 August (Table 2). Furthermore, throughout the fishing season SED modifications were introduced in order to prevent further seal mortalities: it was recommended to decrease the spaces between metal bars to 12-15 cm, and to increase the width of the internal hatch to match that of the top side of the metal grill. Since these measurements were implemented, mortalities became almost negligible (Table 2). Up to the end of the season (5 October), 233 seals were incidentally caught (217 alive, 16 dead) (Table 2). Mortalities included an OTB that was caught in the north before the SED became compulsory, 5 ARA were killed on the trial of an EuroRed foldable SED that collapsed in the shoot and prevented the individuals from escaping (2 killed in shoot, 3 in haul), 3 entangled on ropes that connected the internal mesh funnel/pannel to the SED grid, 1 had its head entangled in the net wing and died during the haul (broken neck), 2 drowned (1 possibly in a turn), 1 was killed by a propeller and caught

dead, while the possible cause of mortality for the others was not described by the observers (Table 2).

5.3 Observer coverage

In addition to the implementation of SEDs, the fishing industry made an urgent effort to bring external observers (MRAG & CapMarine) to monitor the whole fleet. On 3 September four of these observers were placed on vessels, followed by others on 5 September and reaching 100% of coverage from 10 September to 5 October.

Table 4. *Panther* trials.

Panther Trials	F/V Argos Vigo					F/V Castelo	F/V Sil
Location	S52°: XVAJ	S52°: XVAJ, XVAH	S52°: XVAJ, XVAH	S52°: XVAL, XVAJ	EZ:XWAK, XVAL	EZ: XVAL	EZ: XWAK
Date	20 Aug 2017	21 Aug 2017	22 Aug 2017	24 Aug 2017	25 Aug 2017	27 Aug 2017	25 Aug 2017
N° of trawls	2	3	3	3	3	1	2
Catch	T1: 4t, T2: 14t	T1: 7t, T2: 5t, T3: 4t	T1: 3t, T2: 2t, T3: 4t	T1: 3t, T2: 9t, T3: 8t	T1: 6t, T2: 6t, T3: 3t	4t	T1: 7t, T2: 5t
Problems encountered	Low catches; RAY clogging	Abundance interactions of seals with net; clogging	Low catches; RAY clogging; seal cryptic mortality	Low catches; RAY clogging; seal cryptic mortality	Low catches; RAY clogging; seal cryptic mortality	Low catch; high seal bycatch and mortality	Low catches; high bycatch, injuries and mortality; cryptic mortality; net clogging
Species	NA	ARA	NA	ARA	ARA	ARA	ARA
N° of casualties	0	0	0	0	0	5	4
Cause of casualty	NA	NA	NA	NA	NA	Entanglement in panther	Entanglement (wrapped) in panther
N° of live captures	NA	2	0	1	1	4	3

6. SED EFFICIENCY MONITORING: UNDERWATER FOOTAGE

At least four vessels within the fleet were fitted with underwater cameras to monitor SED effectiveness (*Sil*, *New Polar*, *Robin M. Lee* and *Golden Chicha*). Analysis of shooting and

trawling events was carried out for a total of 77,252 sec (1,287.53 min), of which 71,375 sec (1,189.583 min) corresponded to SEDs (Table 5) and 5,877sec (97.95min) to *panther* recordings. With respect to the *panther*, during the only shoot video recorded ARA were seen swimming around the net (Fig.13), but no entanglements were detected. However, the haul brought 4 carcasses and 3 live individuals. Within the SED data examined, 305 min corresponded to shoots and 889 min to trawls; no underwater footage for hauls was available. ARA was seen entering the net only during shoots, which confirms that both shooting and hauling are critical periods for pinniped mortality. In total, 11 ARA escaped safely and 2 died due gear entanglement while the net was submerging (Table 5). All escaped seals were in good condition, staying inside the SED just a few seconds and actively swimming out through the escape hatch; however entanglement with the internal ropes was seen twice (Fig. 15, 16). Three individuals were seen entering the SED through the escape hatch, and exhibiting curious behaviour towards the camera/light, before spending a few more seconds inside the SED (17, 32 and 72 sec) but far from their breathing limits (around 7 min). Although contacts with the grid were observed, as the gear was stationary no impacts occurred. In the majority of the cases, fur seals touched the grid with their limbs in order to propel themselves out of the SED (see cover image). Furthermore, the SED allowed both the escape of sharks (1 *Schroederichthys bivius*, 1 *Squalus acanthias*) and helped to identify 3 black-browed albatross mortalities (*Thalassarche melanophris*) (Table 5).

With respect to the shoot where 2 ARA mortalities occurred, the tunnel to the SED started to close and after 5 min of the gear being deployed it was 100% blocked. In the footage it is clearly seen when the seals tried to find a way out, as it trembled several times. Footage shows that immediately after the path suddenly opens one of the carcasses is visible, staying pinned against the grid during the whole trawl. In the haul both individuals were still inside the SED when it was hauled on deck.

The underwater footage also contributed to the detection of problems in SED configuration in one of the ships, with an outward current observed from inside towards the escape hatch that allowed a proportion of squid catch to escape through the hatch. This problem was partially solved after the installation of a narrow “wing” attached to the base of the top escape hatch, which created a counter-current into the net and weakened the outgoing water stream and therefore decreased the loss of squid.

7. NECROPSIES

Fifteen individuals were necropsied (14 ARA, 1 possible *Arctocephalus gazella*). Of those, 4 (30%) were pregnant and lactating females. Despite the sample being small and information incomplete, if we take into account that for the whole season 143 mortalities were reported, 43 of those would be female, which mortality implied also the mortality of a pup on land, plus the foetus in advanced stage of development. From the stomach contents we can infer that pinnipeds were foraging in the area, presumably on dense LOL concentrations (Fig.2, 3).

8. CONCLUSIONS

During the whole second fishing season 2017 a total of 143 pinniped mortalities were reported (131 ARA, 12 OTB), of which an estimated number of 43 individuals (30%) may have been pregnant and lactating females, that raises the total number of reported mortalities to 229 individuals, however, many more mortalities may have actually occurred, as before 100% observer coverage in the fleet was implemented, reported seal mortalities came mostly from vessels with scientific observers aboard;

✓ After the SED was implemented, only 16 mortalities were reported, validating the usefulness of this device for mitigating seal mortality, however high numbers of unmarked carcasses could suggest mortality of post-traumatic stress of live caught released individuals;

✓ Data obtained showed that the usage of SEDs in nets did not affect the probability of having big catches, however if a loss of squid occurred, it was negligible;

✓ SEDs were efficient for allowing entering seals to safely escape both during shoots and hauls;

✓ No seals were seen entering the net during trawling.

Table 5. Underwater SED footage analysed from F/V *New Polar* and *Sil*.

Callsign	Date	Trawl N°	Phase	Footage length (s)	Escaping megafauna	Species	N° individuals	Time in SED (s)	Behaviour	Grid contact
ZDLR1	24/08	2	S/T	7161	Y	ARA	2	#1=1; #2=12	#1=AS; #2=GI	#1=NC; #2=PF
ZDLR1	26/08	3	S/T	6062	Y	ARA	2	#1=3; #2=3	#1=AS; #2=AS	#1=FL; #2=SN + FL
ZDLR1	26/08	5	S/T	7016	N	_____	_____	_____	_____	_____
ZDLF2	27/08	4	S/T	5704	N	_____	_____	_____	_____	_____
ZDLF2	28/08	1	S/T	1473	N	_____	_____	_____	_____	_____
ZDLF2	29/08	2	S/T	735	Y	ARA	4	#1=2; #2=1; #3=5; #4=2	#1=AS; #2=AS; #3=RE + AS; #4=AS	#1=SN; #2=NC; #3=RC; #4=NC
ZDLF2	29/08	1	S/T	5711	N	_____	_____	_____	_____	_____
ZDLF2	30/08	1	S/T	2188	Y	ARA	1	72	RE+AW+EH+CB +AW+EH+SG+AS	AW+SG
ZDLF2	30/08	2	S/T	7045	CARCASS	DIM	1	_____	_____	_____
ZDLF2	30/08	3	S	451	N	_____	_____	_____	_____	_____
ZDLF2	31/08	2	S/T	3483	Y	ARA	1	3	AS	NC
ZDLF2	31/08	3	S	651	Y	ARA	2	#1=17; #2=32	#1=EH+CB+AS; #2= EH+CB+AS	#1=NC; #2=NC
ZDLF2	02/09	1	S/T	5446	MORTALITY	ARA	2	_____	_____	_____
ZDLF2	03/09	1	S/T	5699	N	_____	_____	_____	_____	_____
ZDLF2	04/09	2	S/T	6361	N	_____	_____	_____	_____	_____
ZDLF2	05/09	1	S/T	6189	CARCASS	DIM	2	_____	_____	_____

S=shoot; T=trawl; AS=active swimming; GI=grid inspection; PF=pectoral fins; FL=four limbs; SN=snout; NC=no contact; RE=rope entanglement; RC=rope contact; EH=entering SED through hatch; AW=actively "walking" on grid; CB=curious behaviour towards camera; SG=stands on the grid.

Table 6. Pinniped necropsies from 2nd LOL season 2017.

Callsign	License	Date	SED	Species	Sex	Length (cm)	Weight (kg)	Mortality	Stomach contents	Comments
ZDLP1	A	04/07/17	N	ARA	F	--------	----------	Drowned in shoot	E	P/L
ZDLE1	E	26/07/17	N	ARA	M	142	82.05	Drowned in shoot	2 PAR, 28 LOL	----------
ZDLE1	E	26/07/17	N	ARA	M	145	85.10	Drowned in shoot	FIN	----------
ZDLY	X	01/08/17	N	ARA	M	--------	----------	UN	42 LOL	----------
ZDLC1	X	02/08/17	N	ARA	F	147	60.5	Drowned in shoot	FIN, LOL	P/L
ZDLY	X	03/08/17	N	ARA	F	---------	----------	UN	31 LOL	P/L
ZDLE1	X	04/08/17	N	ARA	M	150	72.20	Drowned in net	11 LOL	----------
ZDLC1	X	16/08/17	Y	ARA	M	----------	----------	Smashed by net pressure	61 LOL	SED trial
ZDLC1	X	19/08/17	Y	ARA	F	----------	----------	Entangled in rope/dead space inside SED	10 LOL	P/L; SED trial
EHIS	X	----------	UN	ARA	M	----------	----------	UN	17 LOL	----------
--------	X	----------	UN	ARA	M	179	111.70	UN	72 LOL	----------
-------	X	----------	UN	ARG	M	177	90.20	UN	E	Spp. to confirm
----------	X	----------	UN	ARA	M	126	50.20	UN	6 LOL	----------
----------	X	----------	UN	ARA	M	160	85.40	UN	66 LOL, 1 PAR, 1 WHI	----------
----------	X	----------	UN	ARA	M	152	75.85	UN	2 LOL, 24 WHI OTO	----------

P/L=pregnant and lactating; E=empty; PAR=*Patagonotothen ramsayi*; FIN=finfish; ARG=*Arctocephalus gazella*; WHI=*Macruronus magellanicus*; OTO=otoliths.

9. RECOMMENDATIONS

- Increase haul speed and diminish it after doors come up, in order to give time to seals to reach the SED and escape through it when the net is still in the water;

- It is of paramount importance for the deck bosun/officers to pay attention during hauls in order to see if live seals are present in the net wings, in the proximate area to the SED. In order to avoid seal post-traumatic stress deaths, crew must try to force the seals entrapped in

the trawl to exit through the escape hatch by retrieving and shooting cables/bridles- several times during hauling;

- Underwater cameras allow vessels to prove the functionality of SED;
- It is important to exchange information about experience in improving the SEDs between the vessels, companies and the Fisheries Department;
- To continue with 100% seal observer coverage in the fleet;
- Honest reporting of incidental mortalities/carcasses retrieval is fundamental to ensure the sustainability of the fishery;
- In the case of a mortality, it is important to mark the carcass before dumping (e.g. cut the tip of one pectoral fin) and if freezing it, record vessel's call sign, date, trawl number, time and position.

10. PERSPECTIVES

It is still unknown whether pinniped mortality will repeat in the 2nd season 2018, however besides continuing monitoring, trials of new mitigation practices would be welcome:

i) A combination of net binding with sisal and adding weight to the cod-end;

ii) Net binding with hydrostatic release;

iii) Net with hydrostatic release and SED with an acoustic transponder release gate (transponder in the hull of the vessel);

iv) Modified SEDs for finfish vessels.

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ANNEX I: FIGURES

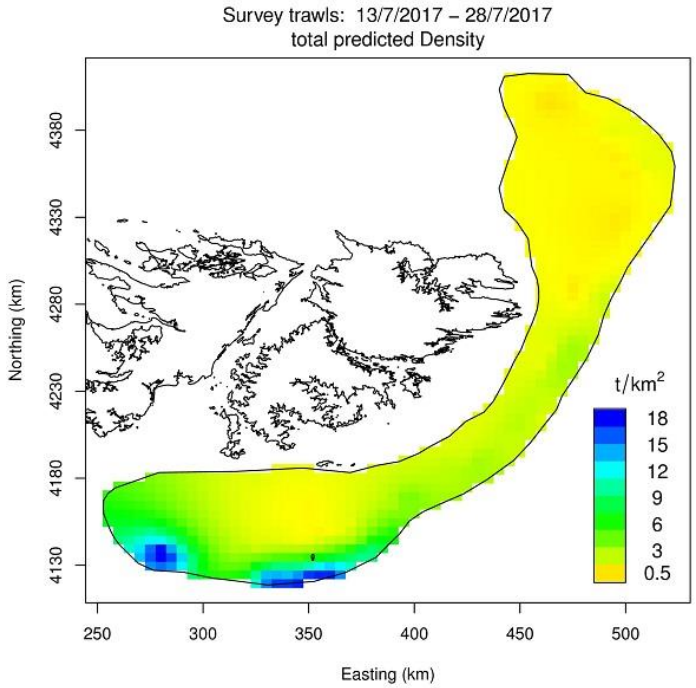


Fig.1. Predicted LOL density from positive catch (pre-recruitment survey 2nd season 2017). Extracted from Winter *et al*., 2017.

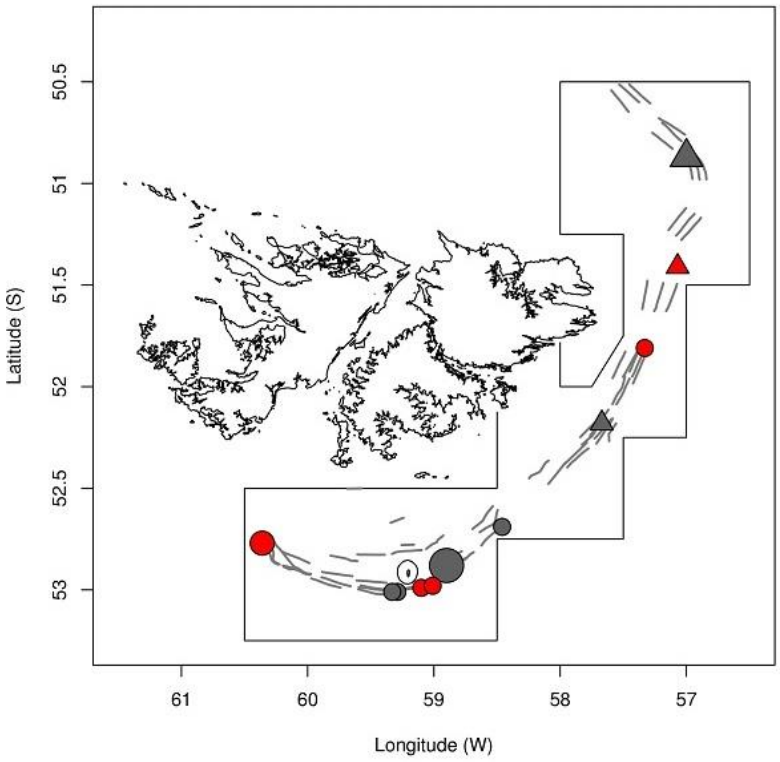


Fig.2. Pinniped bycatch during the 2nd season 2017 pre-recruitment survey. Triangles: OTB; circles: ARA. Black: mortalities; red: alive individuals. Grey lines: survey tracks. Extracted from Winter *et al*., 2017.

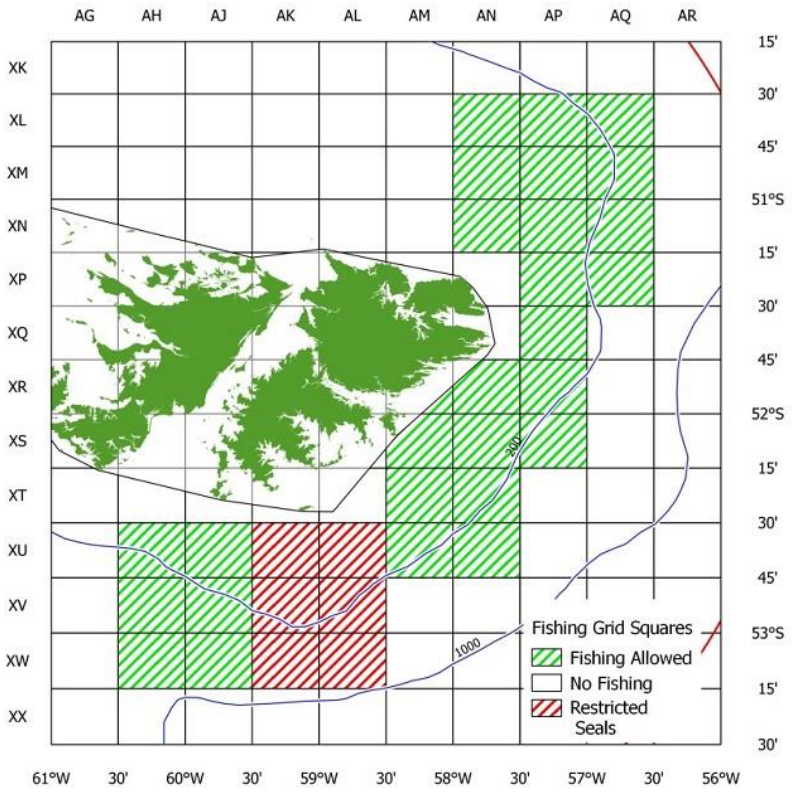


Fig.3. Beauchêne Island Exclusion Zone.

Fig.4. Mesh pantano grid aboard the F/V *Golden Chicha*.

Fig.5. Inox steel pantano grid aboard the F/V *Venturer*. The distance in between bars is 20cm.

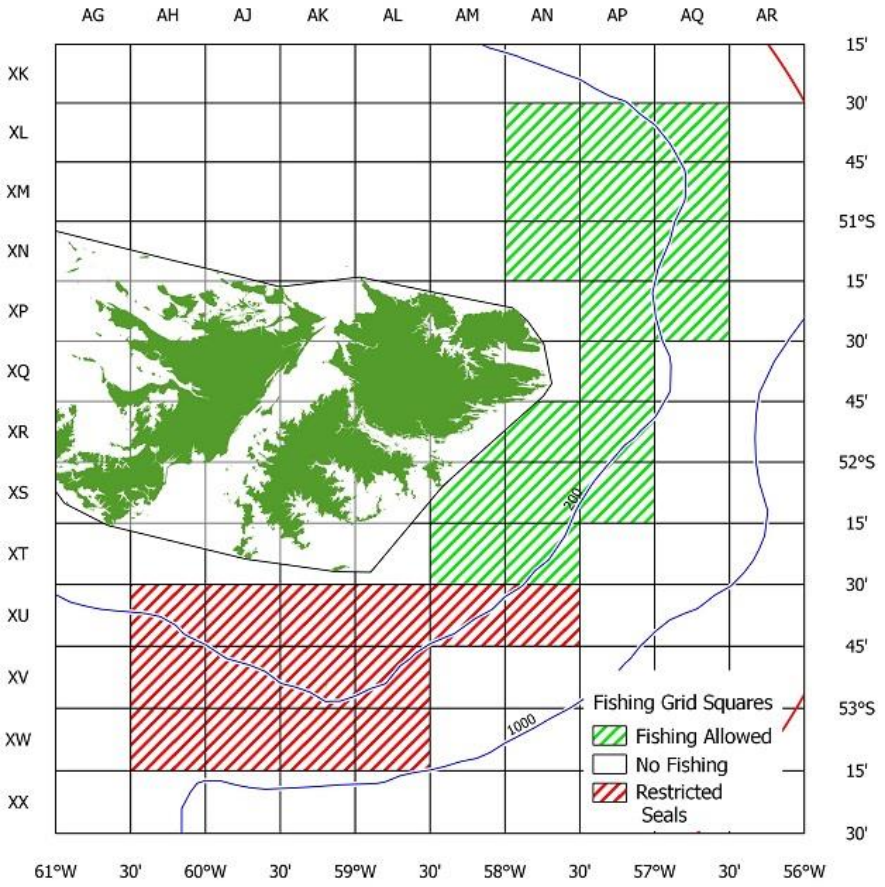


Fig.6. Total closure of the LOL BOX south of 52°30'S.

Fig.7. Final SED trialled version aboard the F/V *Golden Chicha*. The grid is made of inox steel, 150cm width and 200cm height. The inox bars have a diameter of 16mm, enforced with two horizontal bars with a diameter of 22mm. The grid's border is also enforced with a 30mm inox frame. The SED's bottom is protected by a thicker mesh; ropes attached used to while retrieving the gear during hauls. Note ropes also attaching the internal speed funnel towards the grid. From 29 August internal ropes were forbidden.

Fig.8. SED's high-speed internal funnel.

Fig.9. Loss of catch in the first day SED trial aboard the F/V *Golden Chicha*.

Fig.10. *Arctocephalus autralis* mortality recorded in a 19 cm bar spacing.

Fig.11. Final SED configuration aboard the F/V *New Polar*. Note the small mesh panel is attached to the sides of the net by a rope inside a PVC tube. Image extracted from underwater footage of the vessel.

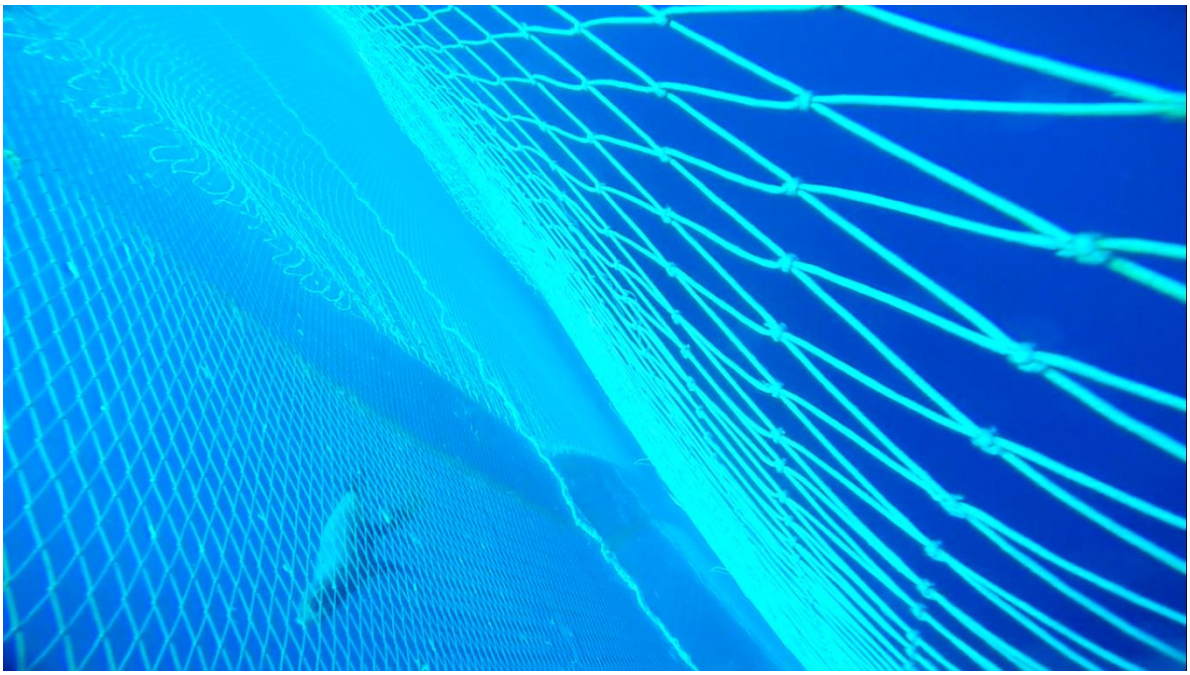


Fig.12. Second *panther* trial aboard the F/V *Sil*. The image shows the gear after being shot and an *Arctocephalus australis* swimming around. It is important to mention 4 seal carcasses were retrieved in the haul, plus 3 live individuals. Image extracted from footage of the vessel.

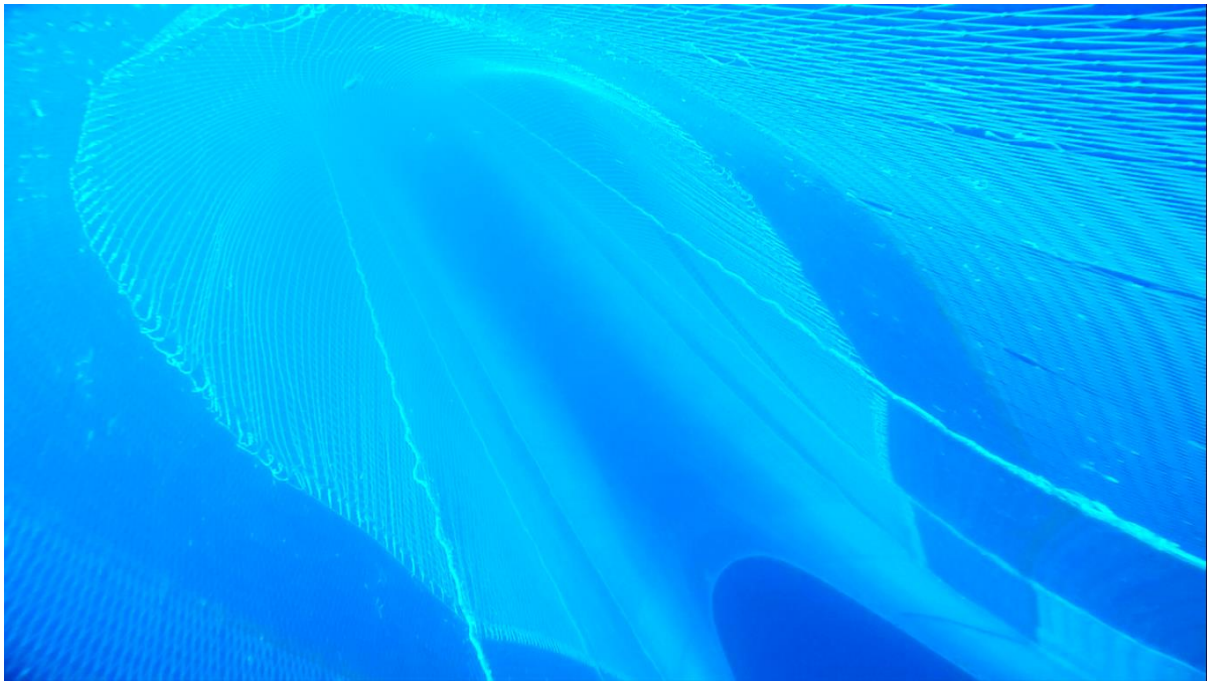


Fig.13. *Panther* close-up.

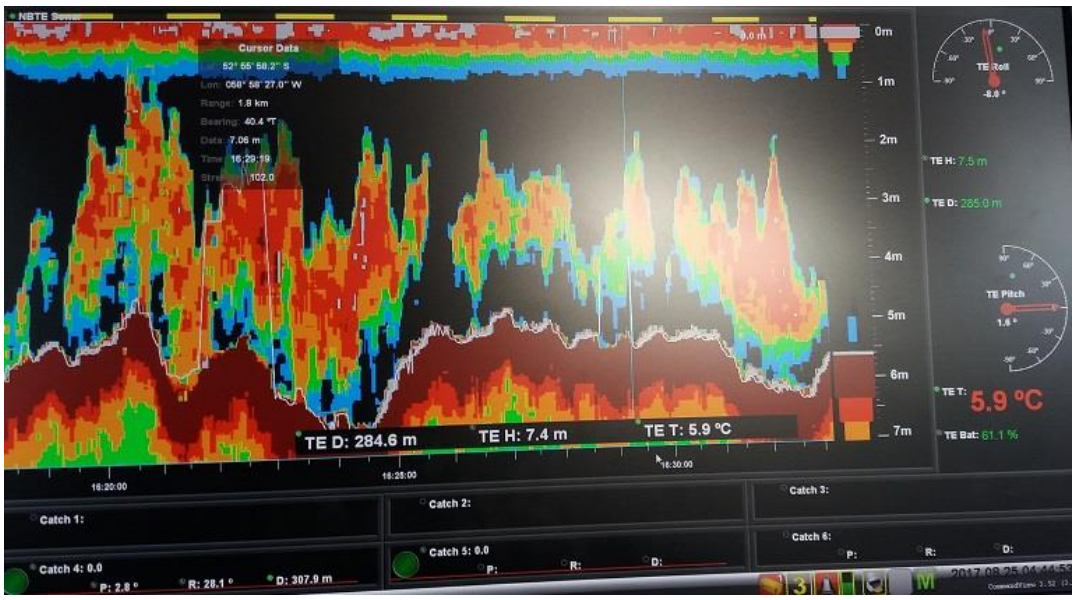


Fig.14. High squid aggregation detected aboard the F/V *Sil* during the 2nd *panther* trial, however the catch was only 5t.

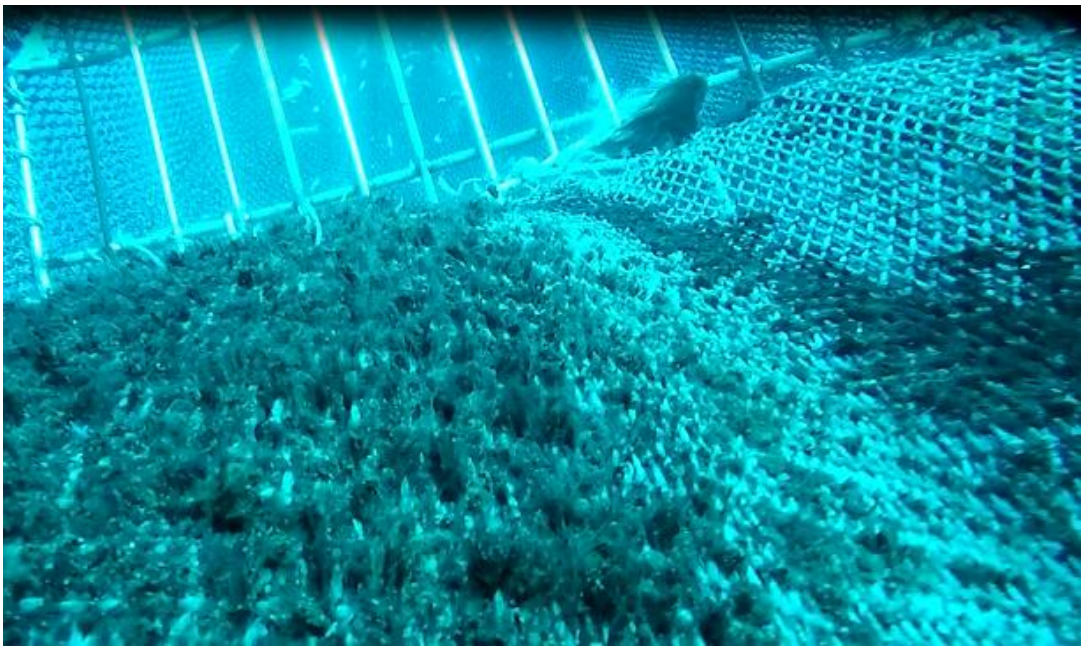
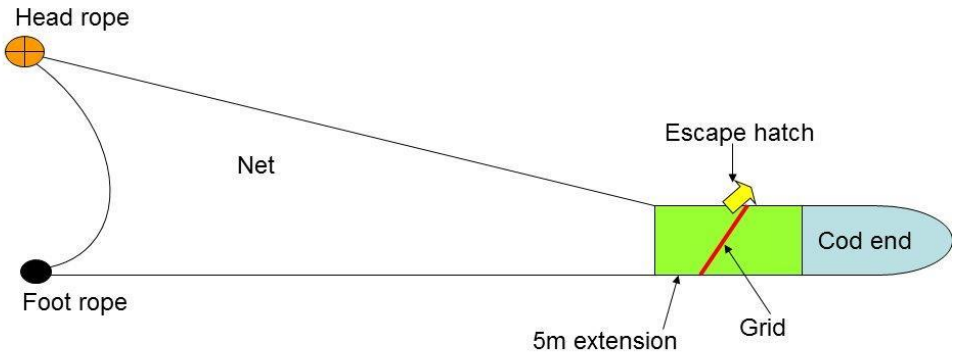


Fig.15. *Arctocephalus australis* hitting an internal rope of the SED that connected a small mesh panel to the grid. From August 29th those ropes were forbidden. Image extracted from footage obtained aboard the F/V *New Polar*.

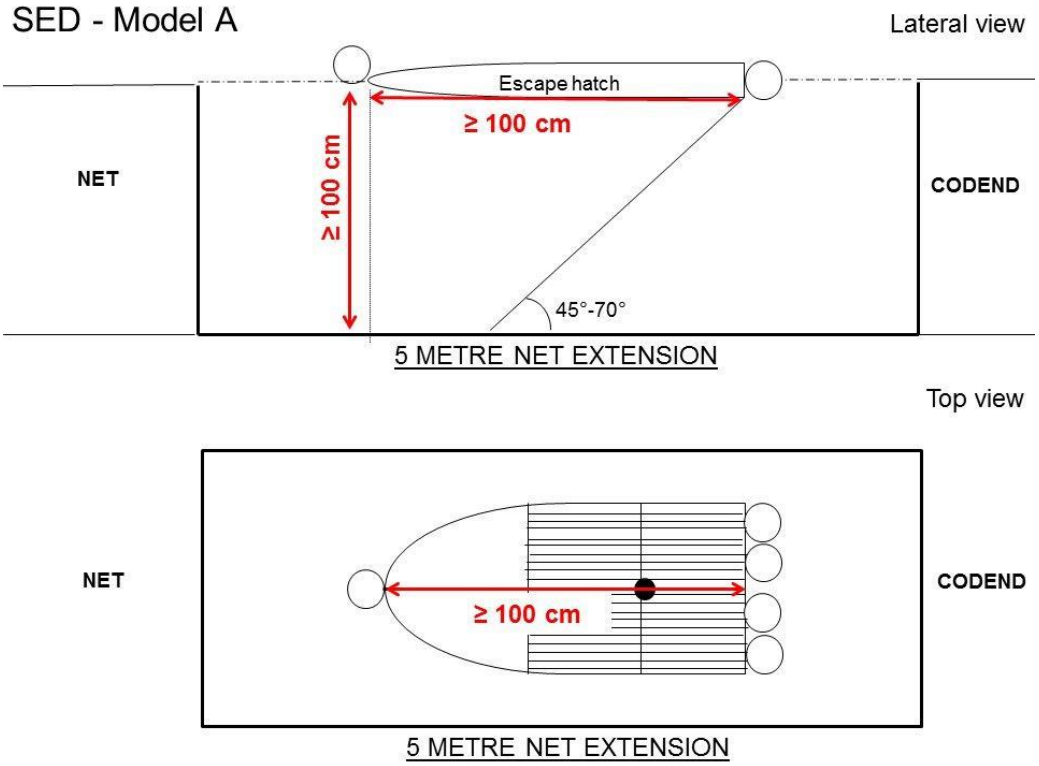
Fig.16. Same individual as previous image, with bent body and coming out of the SED with a second individual. Note rope touching its body.

ANNEX II: APPROVED SED MODELS

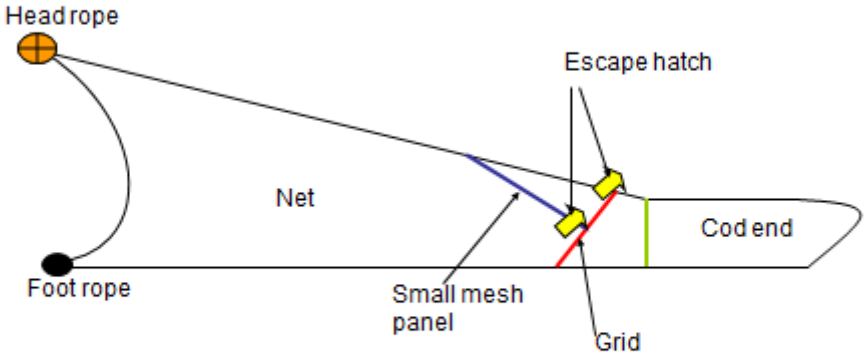
SED – Model A



SED - Model A

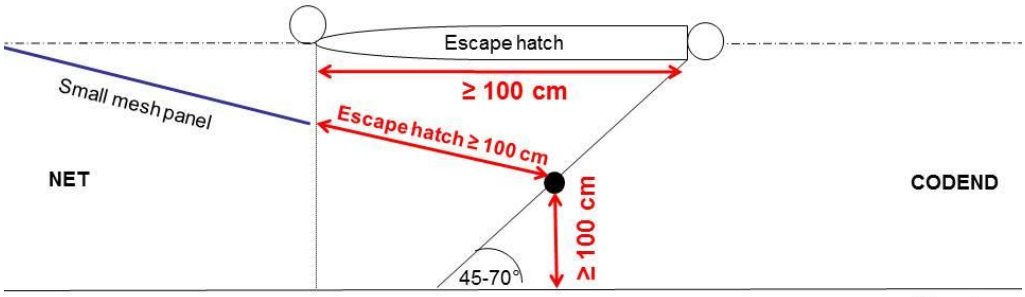


SED – Model B

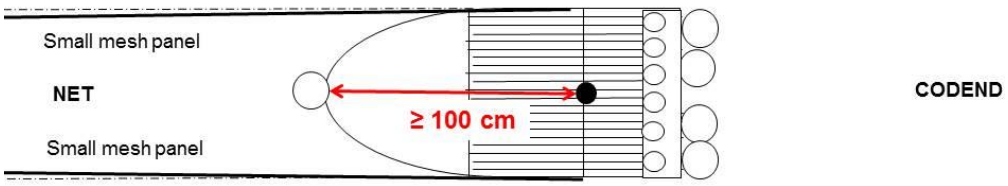


SED - Model B

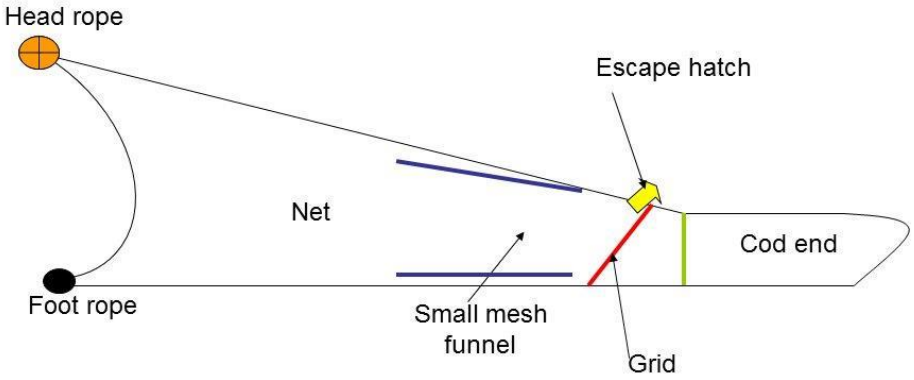
Lateral view



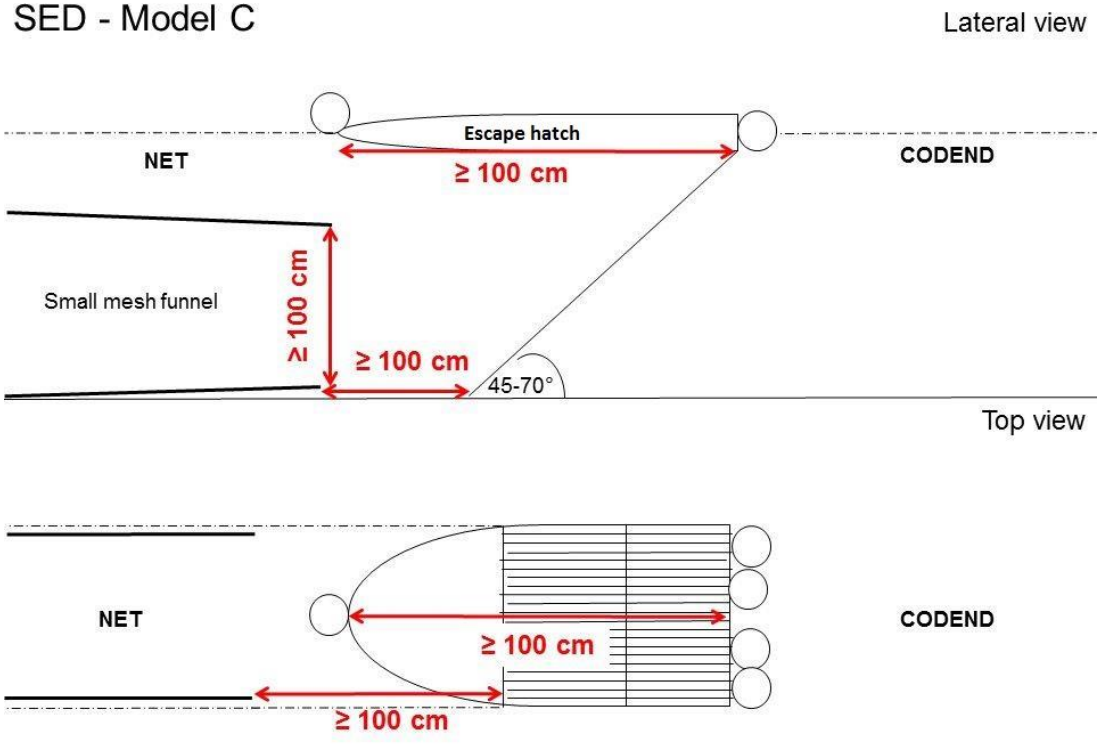
Top view

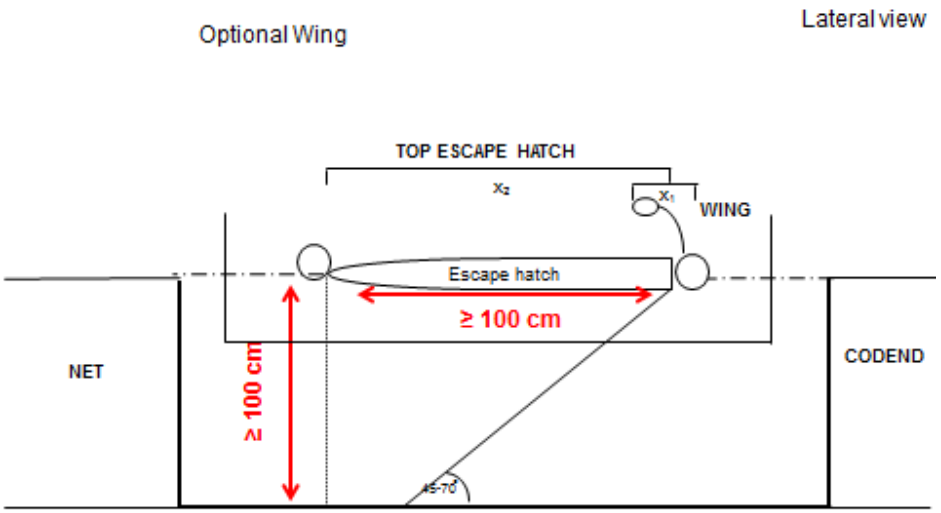


SED – Model C



SED - Model C





5 METRE NET EXTENSION