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What can be expected of a T90 extension piece to improve selectivity in bottom trawl multispecific fisheries in the Bay of Biscay?

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Abstract :

In the Bay of Biscay, the selective properties of otter trawls have mainly been studied with regard to single species. However, for bottom trawl multispecific fisheries targeting fish, it remains challenging to find a selective device capable of limiting catches of small individuals of several species without commercial losses. The present study focuses on an innovative technical solution to reduce catches of undersized individuals in a multispecies bottom trawl fishery in the Bay of Biscay. We tested a cylinder made of 100-mm diamond meshes turned at 90°, namely T90 inserted in the extension piece. We present the selectivity results obtained for six commercial species. This device allows the escape of small *Solea solea*, *Trachurus trachurus* and *Spondyliosoma cantharus* individuals. No commercial losses of *Sepia officinalis* were recorded. Patterns for *Dicentrarchus labrax* and *Mullus surmuletus* require further investigation due to limited fish size ranges in the dataset.

Keywords : Gear technology, Covered codend, Turned mesh, Escape, Discard ban

1. Introduction

In 2013, the European Union reformed its Common Fisheries Policy (CFP) and approved the landing obligation, prohibiting the discard of any individual of the species under quota (Official Journal of the European Union, 28 December 2013). *De minimis* exemptions to this landing obligation could be granted on the condition that scientific evidence indicates that increases in selectivity are very difficult to achieve (Council of the European Union, 2013). Thus the landing obligation serves as motivation for fishermen to implement selectivity measures to reduce discards. Among these measures, improving gear selectivity was identified as one way to reduce unwanted bycatch such as commercial species under specific legislation or individuals below the Minimum Conservation Reference Sizes (MCRS) (Graham 2006).

Gear selectivity can be improved by i) adding a selective device (e.g. Lomeli and Wakefield 2016), ii) changing mesh size and shape (e.g. Sala et al. 2008; Aydın and Tosunoğlu 2010) or iii) by combining both approaches (e.g. Lövgren et al. 2016; Vogel et al. 2017). Bycatch reduction devices, such as grids (Fonseca et al. 2005), horizontal separator panels (Ferro et al. 2007) or topless trawls (Revill et al. 2006) have already proven to significantly reduce discards in fisheries. However, the diversity of species caught in multispecies fisheries, their corresponding morphologies and behaviours, as well as the variability in their MCRS may impede the overall efficiency of a given selective device (Bullough et al. 2007; Ryer 2008; Krag et al. 2014; Santos et al. 2015). Improvements of fishing gear selectivity in multispecies fisheries remain challenging and experimental testing of various selective techniques continues in Europe (e.g. Ordines et al. 2006; Sala et al. 2008; Bayse et al. 2016; Lövgren et al. 2016; Krag et al., 2016; Vogel et al. 2017).

The T90 mesh based techniques, i.e. a diamond mesh turned 90° and remaining wide open throughout the fishing process, was first introduced in the early 1990s in the Baltic Sea (Moderhak 1997). It was later tested in the Bay of Biscay (Meillat and Morandeau 2001) and in other European ecoregions (Madsen et al. 2012; Tokaç et al. 2014; Bayse et al. 2016). Conclusions on its selective properties vary, depending on whether roundfish or flatfish species are considered (Madsen et al.

2012; Herrmann et al. 2013; Bayse et al. 2016). Compared to equivalent diamond mesh sizes, enhanced selectivity in the codend is found for roundfish with T90 netting whereas T90 decreases selectivity for flatfish like plaice. So far, T90 meshes were mainly tested in the codend (Madsen et al. 2012; Herrmann et al. 2013; Bayse et al. 2016) while other parts from the trawl might be relevant to increase fishing gear selectivity. The present study focuses on an innovative technical solution to reduce catches of undersized individuals in a multispecies fish-directed bottom trawl fishery in the Bay of Biscay, France. No selective studies have been reported to date on this fishery and there is a need to provide fishermen with selective devices adapted to multispecies catches, which can be extended to other demersal fisheries or areas. The experimental selective device we present, a cylinder composed of 100 mm T90 meshes mounted in the extension piece, is innovative since to our knowledge, T90 netting has never been tested in the extension piece of the trawl.

2. Materials and methods

2.1. Selective device and collection of escaping fish

The experiment was conducted onboard the commercial fishing vessel *Déesses de l'Océan* (NO 930 461) using a single otter trawl with semi pelagic rig, with a 22 m ground rope and 18 m headline. The codend was 25 meshes deep, 140 free meshes in circumference and made of double-twine PE with a stretched-mesh size of 74.6 ± 3.1 mm (70 mm nominal). The selective device was mounted in the extension piece, between 22 meshes in the anterior part and 10 meshes in the posterior part (Fig. 1). Fish were prevented from escaping these two sections by: i) a flapper (70 mm mesh) in the anterior part, ii) an overlapping net (100 mm mesh) used as connection with the inner bag in the posterior part (Fig. 1). To avoid escape from the codend, a fine mesh inner bag of 37.2 ± 0.8 mm mesh size (20 mm nominal) was inserted there. The selective device used was a cylinder composed of 113.9 ± 1.8 mm (100 mm nominal) meshes mounted in the extension piece with a netting orientation turned at 90° (T90 ; Fig. 2) with a 72 mesh circumference and 40 mesh length polyethylene (PE). The selective performance of the T90 extension piece was estimated using the covered codend method (MacLennan 1992), held open by kites as developed by Madsen et al. (2001). The cover was made of polyamide netting with a 20 mm nominal mesh size, a circumference of 1370 meshes and a length twice as long as the extension piece and codend combined. A combination of kites, floats and chains was used to keep the cover away from the test extension piece (Madsen et al. 2001) (Fig. 1). Prior the sea trials, the kite cover and the selective device were tested and validated in the flume tank at IFREMER Lorient, using a half scale model. All mesh measurements of gear parts were made on 30 meshes with the Omega mesh gauge.

2.2. Field data collection

The sea trials were conducted in the fishing grounds of the Bay of Bourgneuf (Bay of Biscay, off France, 47°02N; 02°10W) in June 2016 (Fig. 3). Nine hauls were performed during daytime at a mean (± SD) depth of 11 ± 4 m. Haul speed was 3.5 knots as under commercial conditions and tow duration was set at one hour. After each haul, the total catches from the codend (i.e. the fine mesh-size inner bag) and from the cover were sorted separately and by species. The weight of all individuals from a given species was recorded and the total length of each individual was measured. When the total catch was too large to allow measurement of every individual (e.g. for horse mackerel), sub-sampling was performed by randomly dividing the species catch into two baskets, repeating this operation until reaching a manageable and representative sample size. Resultant sampling ratios were used to elevate numbers at length used in the subsequent modelling process. The species investigated in this study were black seabream *Spondyliosoma cantharus*, cuttlefish *Sepia officinalis*, horse mackerel *Trachurus trachurus*, red mullet *Mullus surmuletus*, European seabass *Dicentrarchus labrax* and common sole *Solea solea*.

2.3. Data analysis

The size selectivity of our device was assessed by comparing the distribution of individual total length between the codend and cover fractions. Length–frequency curves were plotted for the six species in the codend and the cover. Proportions of fish retained per length class, $P(l)$, were calculated according to:

$$P\,(l) = \frac{N_{l,t}}{N_{l,c} + N_{l,t}}$$

where $N_{l,t}$ is the sum of fish of length l in the codend and $N_{l,c}$ the sum of fish of length l in the cover, across all hauls.

For each one of the six species, the proportions $P(l)$ were analyzed using Generalized Linear Modelling (GLM), with the logit link function. The aim was to examine whether the retention and escape of the different species was length related. A logistic model, whose parameters a and b were estimated by maximum likelihood, was adjusted to the observed retention proportions $P(l)$ (Fryer 1991; Millar and Fryer 1999).

In the case of the covered codend method, the logistic model is reduced to

$$logit\big(P(l)\big) = \ln\left(\frac{P(l)}{1 - P(l)}\right) = a + b.l$$

where $P(l)$ is the probability that a fish of length l will be retained in the test codend given it enters the trawl. The goodness of fit of the model to data was evaluated by plotting the deviance residuals *vs* the fitted values. When a pattern was observed from GLM residuals, polynomial of second order GLM was tested.

Finally, the selectivity parameters L_{50} (50% retention length) and *SR* (selection range) were calculated from the 1st order polynomial model parameters (Wilemand et al. 1996):

$L50 = \frac{-a}{b}$ and $SR = \frac{2\log(3)}{b}$

All statistical analyses were performed in R (R Core Team, 2017).

3. Results

Catches per length classes displayed contrasting retention patterns for the different species (Fig. 4). Sole from 5 to 24 cm were able to escape the fishing gear, but this trend steadily decreased from length 25 cm and upwards. For black seabream, individuals between 15 and 23 cm escaped, while individuals below 15 cm and over 23 cm were mostly retained and those above 28 cm were always captured in the codend. On the whole range of length classes observed (most of the catch was made up of individuals below 18 cm), cuttlefish was always more numerous in the codend than in the cover. It is worth noting that, even though no size related differences in seabass retention rates could be detected by the model, there was a slight increase in the catch proportion in the codend. Red mullets escaped on the whole length range observed. For horse mackerel, more individuals of 10-15 cm long were recorded in the cover than in the codend.

GLM of first order polynomial was fitted to cuttlefish, horse mackerel, red mullet, seabass and sole data and polynomial of second order GLM was fitted to black seabream data. For all species, graphics of deviance residuals versus fitted values did not display any special pattern and less than 5% of the values were found outside the 95%-confidence interval. GLMs identified significant size related differences in retention rates for cuttlefish, sole, black seabream. L_{50} for sole is 26.1 cm with associated *SR* of 55.7 cm. The L_{50} for cuttlefish is 0.7 cm, showing a poor selectivity of the device for this species (Table 1). Associated prediction curves correctly pick up the retention profile of the T90 cylinder for cuttlefish and black seabream (Fig. 4), while it is less evident for sole. No size related differences in retention rates could be shown for horse mackerel, red mullet and seabass based on the GLM procedure, leading to the absence of L_{50} (Table 1).

4. Discussion

Our experiments demonstrate that, for coastal trawlers from the Bay of Biscay, a T90 cylinder mounted in the extension piece let escape part of the unwanted catch such as horse mackerel though selection of other commercial species are mixed and discussed hereafter.

Results for sole showed a L_{50} of 26 cm with most of the individuals from 5 to 24 cm escaping when using the selective device. However, a wide *SR* of 55.7 cm is observed, which leads to both escapement of commercial size individuals and retention of unwanted individuals. Bayse et al. (2016) observed a smaller selection range of 3.5 cm when using a 80 mm T90 codend. Such difference suggests that the position of the selective mesh in the trawl has an effect on fish contact probability, which is supported by Graham et al. (2003) who found that a square mesh panel provides better escapement rates when placed close to the codend than in the extension piece. Fish behaviour combined to the contact probability of the device are known to have an effect on selectivity patterns (Ryer 2008; Krag et al. 2014, 2016; Santos et al. 2016), which may explain wider *SR* from extension than from codend selective device.

Sole falls under the new PCP legislation and the landing obligation. Given that its MCRS is set at 26 cm in the Bay of Biscay, the escape of individuals under MCRS is beneficial to both fishermen and the stock, as escaping individuals would not account for TAC but would contribute to stock dynamics. The implementation of the T90 cylinder would lead to less discards. Moreover, according to Suuronen (2005) and references therein, mortality observed for escaped individuals may be relatively low for flatfish; for example, a survival probability of nearly 100% was estimated for escaped white flounder (DeAlteris and Reifsteck 1993).

The three-part pattern observed for black seabream could be explained by two independent processes. While large individuals (> 23 cm) are mechanically retained, smaller individuals seem to be under physiological constraints; thus individuals smaller than 15 cm are retained in the codend whilst individuals 15-23 cm are able to escape. Based on Breen et al. (2004), we hypothesize that larger individuals are able to swim for a longer time whereas smaller ones drop back rapidly into the codend.

Our experiment revealed that nearly the whole fraction of horse mackerel under 15 cm total length escaped from the T90 cylinder, which is the species MCRS. As this species constitutes the third most discarded species (in tons) in the coastal bottom trawl fisheries of the Bay of Biscay (Cornou et al. 2016), this escape would allow fisherman to avoid lengthy sorting periods while later discarding the fish. Moreover this species shows particularly low survival probability when exposed to air on deck (Morfin et al. 2017); their direct escape at sea from the gear would be highly beneficial for the species stock. Finally, because the catch is mostly composed of individuals below 15 cm, these immature fish (Mahé al. 2007) may further contribute to the stock replenishment. Moreover, schooling behaviour characterise horse mackerel aggregations (Masse et al. 1996) and may be responsible for the high escapement rate observed during our experiment. Although the phenomenon provides a particularly interesting demonstration of escapement from the T90 cylinder, the dominance of the 10-15 cm size-class compared to the whole size range of the species impairs the model ability to pick up an overall pattern and flattens the shape of the retention curve.

The T90 cylinder does not let cuttlefish escape from the trawl; almost the whole species catch is found in the codend. Given that there is no MCRS for that species, status quo is preserved: no discard reduction or commercial loss are observed. Further work would need to be carried out on the financial implications for fishermen, as potential economic losses on other associated demersal species may be compensated for by cuttlefish catches.

Concerning European seabass, it is worth noting that, while the model detects high escapement rate and a weak size effect on retention, the length range observed in the experimental hauls does not cover the whole size range of the species in the wild nor the MCRS set at 42 cm in the Bay of Biscay. Therefore, no conclusion can be drawn on commercial size retention though, based on a small number of individuals, our experiment suggests that retention is initiated from 32cm.

Finally, from the sea trials, it appears that the T90 let escape a majority of red mullet individuals across the observed size range. However, the small number of individuals captured during the trial limits our understanding of the effect of the T90 cylinder on this species. Even if the landing tonnage of this species is rather small compared to the other commercial species caught, its high market value (around 10€/kg in 2014) (Coupeau et al. 2016) and its low legal minimum landing weight (40g; Council Regulation (EC) No 2406/96) renders the cylinder detrimental in terms of financial outcomes for fishermen. Red mullets reach sexual maturity above 15 cm total length (Mahé et al. 2013) and from a stock management point of view, the escape of immature individuals by the implementation of the T90 cylinder would be beneficial for further fish reproduction and subsequent stock recruitment.

To the best of our knowledge, this is the first time that the T90 mesh configuration has been tested in a cylinder located in the extension part of the trawl, although the T90 codend has been frequently tested (Moderhak 1997; Digre et al. 2010; Herrmann et al. 2013; Bayse et al. 2016). Also, it is expected that the gear configuration we tested enhances escapees' survival potential by giving unwanted fish the opportunity to escape before entering the codend and preventing them from swimming related exhaustion in the trawl body. It may also help preserving the physical integrity of escapees since they do not face compression in the codend nor are in contact with abrasive objects within the catch bulk such as crustacean pincers or bivalve shells. The large size of the mesh (100 mm) as well as the mesh orientation (i.e., not classical diamond mesh but T90 open meshes) prevent escaped fish from injuries due to skin and scale loss as already observed for round fish passing through a T90 codend (Digre et al. 2010).

To conclude, based on the multispecies approach we present, the proposed 100 mm T90 cylinder mounted in the extension part of a coastal otter trawl provides fishermen with a selective device relevant to reduce discards. The device appears especially efficient when by-catch is made of high proportion of pelagic species displaying schooling behaviour, as demonstrated for horse mackerel in our experiment. Such a selective device may therefore be of interest for other multispecies demersal fisheries facing by-catch of anchovy, sardine and sprat in the Bay of Biscay, and herring in the Channel and North Sea areas.

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Table 1 Results of the selectivity analysis. Numbers of fish escaped and caught, *p*-value corresponds to the significance of the length/length² parameters in the GLM, L_{50} and *SR* are presented only when the length parameter is significant in case of first order polynomial model

Species	Number escaped	Number caught	*p*-value	L_{50}	*SR*
Black seabream	31	86	0.012/0.006	-	-
Cuttlefish	50	472	0.000	0.7	8.1
Horse mackerel	5037	172	0.917	-	-
Red mullet	76	35	0.828	-	-
Seabass	109	31	0.384	-	-
Sole	88	66	0.034	26.1	55.7

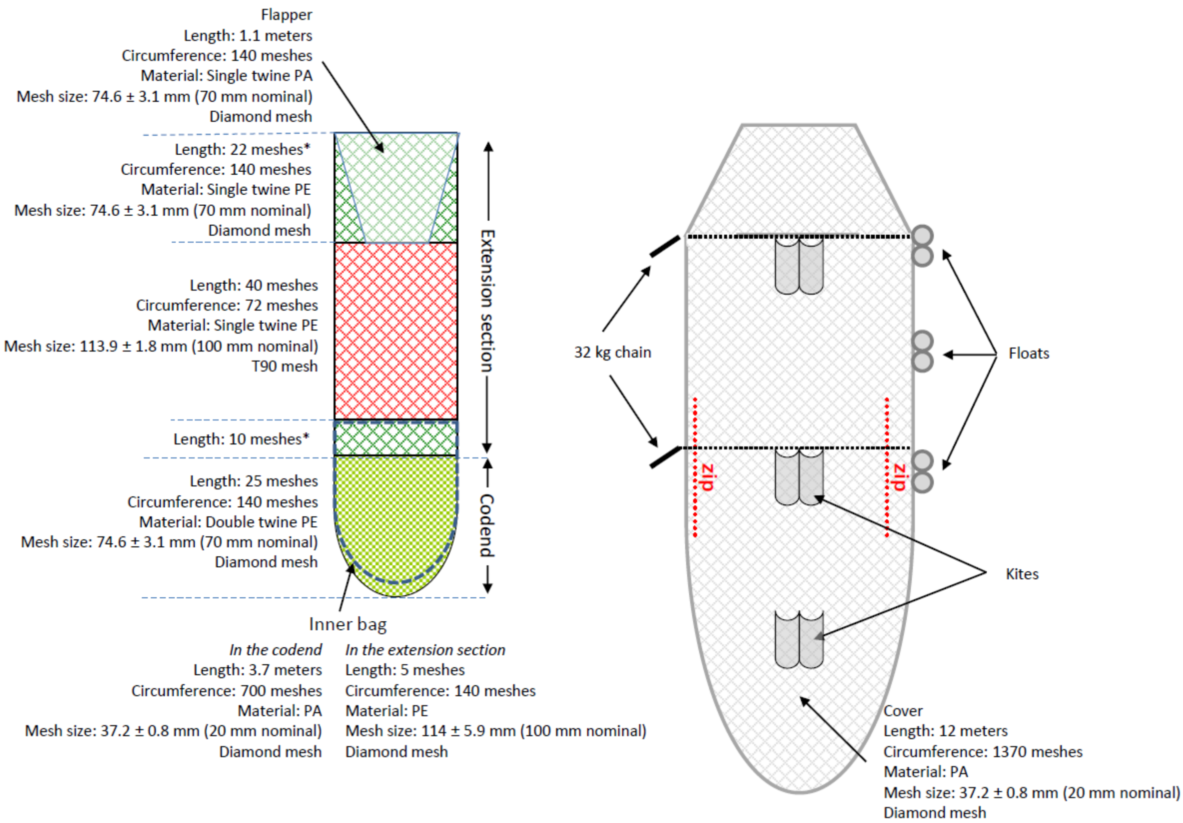
Figure captions

Fig. 1 Diagram of the selective device with location details within the trawl body (left side) and of the covered codend (right side)

Fig. 2 a- standard netting used onboard commercial vessel, b- the turned mesh T90 netting used in this study in the extension piece

Fig. 3 Map of the study area in the Bay of Biscay presenting the location of sampling sites (black dots)

Fig. 4 Selectivity curves for fish including 95% confidence intervals (grey shaded areas). Black dots represent experimental retention proportions. Solid black lines represent the catch size frequency distribution in the cover and dotted black lines represent the catch size frequency distribution in the codend



Flapper
Length: 1.1 meters
Circumference: 140 meshes
Material: Single twine PA
Mesh size: 74.6 ± 3.1 mm (70 mm nominal)
Diamond mesh
Length: 22 meshes*
Circumference: 140 meshes
Material: Single twine PE
Mesh size: 74.6 ± 3.1 mm (70 mm nominal)
Diamond mesh
Length: 40 meshes
Circumference: 72 meshes
Material: Single twine PE
Mesh size: 113.9 ± 1.8 mm (100 mm nominal)
T90 mesh
Length: 10 meshes*
Length: 25 meshes
Circumference: 140 meshes
Material: Double twine PE
Mesh size: 74.6 ± 3.1 mm (70 mm nominal)
Diamond mesh
Extension section
Codend
Inner bag
In the codend
Length: 3.7 meters
Circumference: 700 meshes
Material: PA
Mesh size: 37.2 ± 0.8 mm (20 mm nominal)
Diamond mesh
In the extension section
Length: 5 meshes
Circumference: 140 meshes
Material: PE
Mesh size: 114 ± 5.9 mm (100 mm nominal)
Diamond mesh
32 kg chain
Floats
zip
zip
Kites
Cover
Length: 12 meters
Circumference: 1370 meshes
Material: PA
Mesh size: 37.2 ± 0.8 mm (20 mm nominal)
Diamond mesh

Figure 1

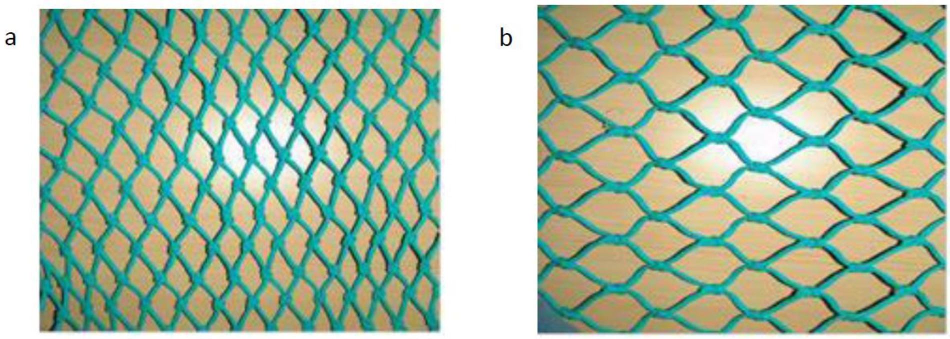


Figure 2

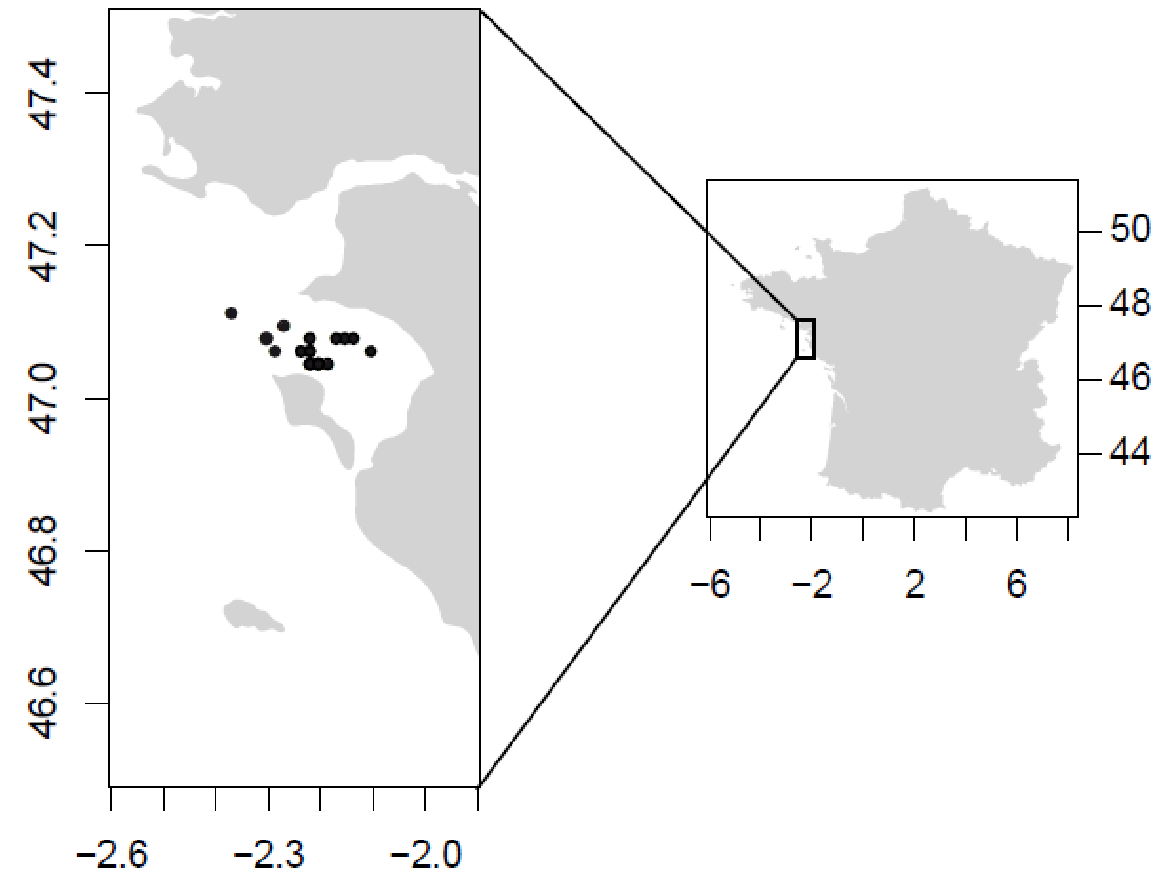
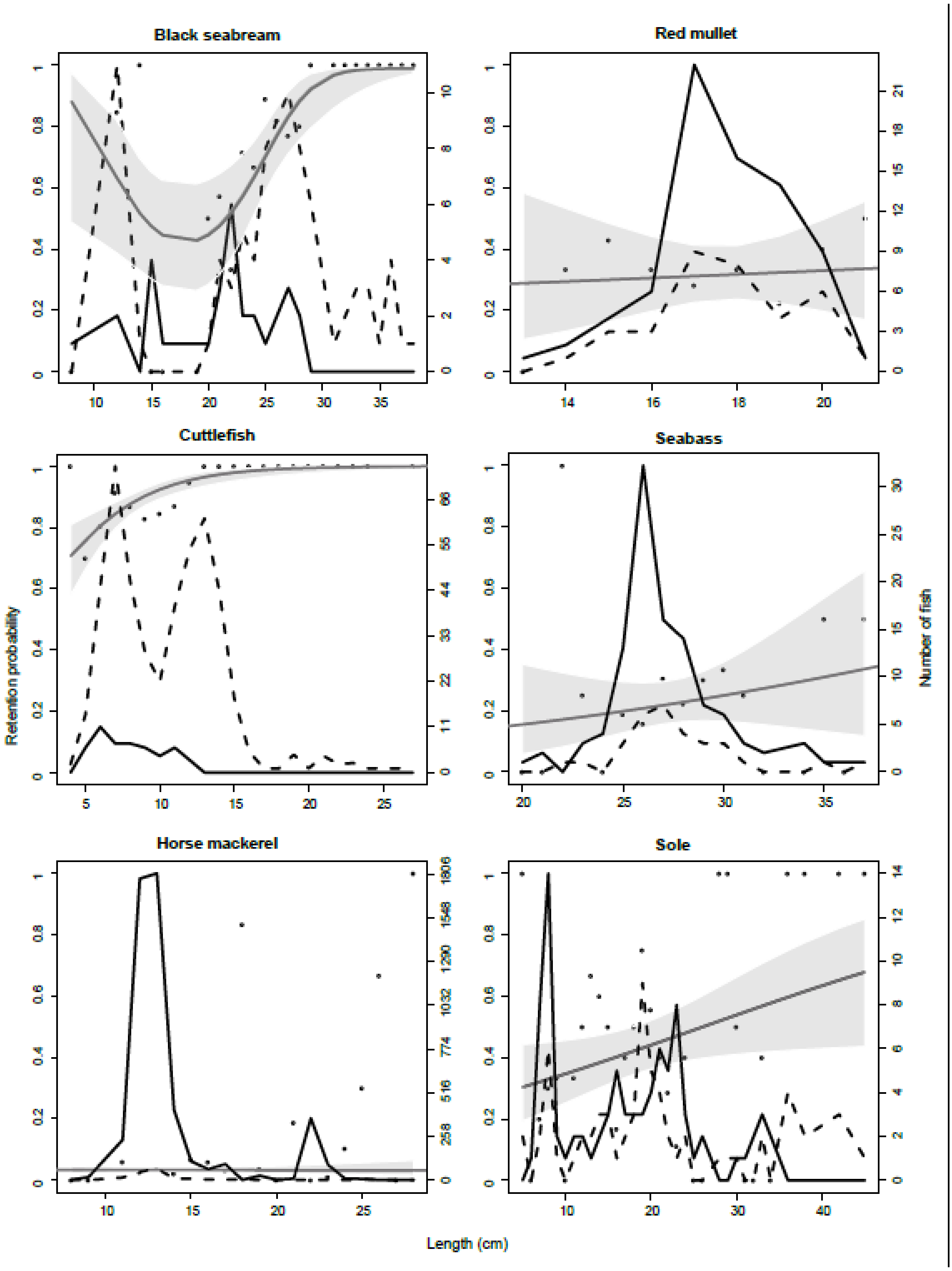


Figure 3



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