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EVALUATION OF A LARGE MESH EXTENSION
IN A BELGIAN BEAM TRAWL
TO REDUCE THE CAPTURE OF SOLE (*SOLEA SOLEA*)

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1 Abstract

A Belgian beam trawler targeting sole (*Solea solea*) carried out a catch comparison experiment with two beam trawls, one with a small mesh and one with a large mesh extension section of the trawl. The aim was to reduce the capture of sole, particularly undersized sole. After 48 comparative hauls, the large mesh trawl reduced total sole catch by 19.7%, and reduced undersized sole (< 24 cm) by 40.3%. Length analysis showed that all sole less than 31 cm were caught significantly more often by the small mesh trawl, and sole larger than 37 cm were caught significantly more by the large mesh trawl, however far fewer of these large-sized fish were caught. Increasing the mesh size of the extension in a beam trawl was shown to be an effective and simple method to reduce the capture of sole, especially sub-legal sized fish.

2 Introduction

The Belgian beam trawl fishery is a mixed-species fishery that primarily targets flatfish in the North Sea, English Channel, Bay of Biscay, and Celtic Sea (Lescrauwaet et al., 2013). Although a mixed-species fishery, sole (*Solea solea*) is the primary target species, providing 35% of the landing value for Belgian vessels (Tessens and Velghe, 2013). For 2015, the European Commission decreased sole total allowable catch (TAC) by 28% in the eastern English Channel (International Council for the Exploration of the Sea (ICES) subarea VII d) and 15% in the Celtic Sea (ICES subareas VII f, g) (European Commission (EC), 2014), prompting the Belgian fleet to seek fishing gear alterations to increase the selectivity of sole, in a desire to increase TAC.

Modifications to the extension section of demersal trawls have led to a reduction of bycatch in many fisheries (reviewed by Glass, 2000; Eayrs, 2007; He, 2010). Typically, modifications to the extension were used to get rid of unwanted catch, usually by adding panels of large mesh, grids, and other sorting devices to separate targeted species from unwanted species by behavioral differences, size, or both (Winger et al., 2010). The extension is the narrowest section of the trawl, making it a logical location within the trawl net to separate fish or include a bycatch reduction device.

Two Belgian commercial beam trawl vessels applied a T90 (diamond-shaped mesh netting turned 90°) extension to a beam trawl to investigate if the mesh orientation change could increase fuel efficiency, reduce the catch of sand, and improve product quality (Depestele et al., 2011). Fuel efficiency effects remained undetermined, but the T90 extension trawl caught less benthic invertebrates and sand, while significantly reducing the catch of Atlantic cod

(*Gadus morhua*), brill (*Scophthalmus rhombus*), and sole (Depestele et al., 2011). Additionally, three extension lengths were tested by Reeves et al. (1992) to increase selectivity of the Scottish whitefish fishery, and extension length was shown to have less of an effect on selectivity than codend mesh size or codend diameter.

Altering mesh sizes in the extension to increase the selectivity of target species has been an uncommon practice, and the impetus to do so is particular to the situation presented to the Belgian beam trawl fleet. Increasing codend mesh size to improve selectivity is a common practice, but was deemed not an effective approach due to the concern of high losses of sole catch. Therefore, an increase in mesh size in the extension section of the trawl was tested with the aim of reducing the capture of sole, but maintaining a commercial capture amount.

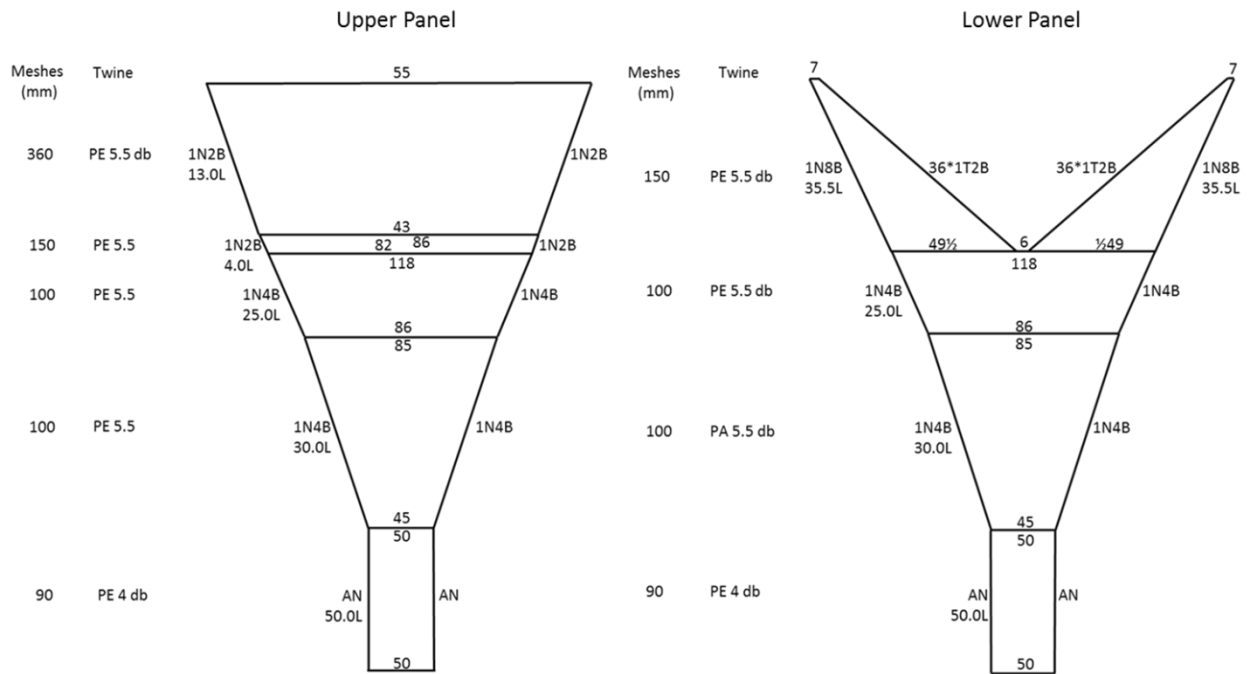
3 Material and methods

Sea trials were carried out in the southern North Sea and eastern English Channel aboard a Belgian commercial beam trawler, F.V. Z 19 “Sonja” (30.7 m L.O.A., 159 GT, 522 kW engine power), from January 3 to 11, 2015. The vessel towed two beam trawls, one on each side, connected by derrick booms as is typical of the fishery. The small mesh trawl (called control) was on the portside, and the large mesh trawl (called experimental) on the starboard. Each net was rigged to a beam, 10 m long, and fished a chain matrix. Each extension was 8 m in length. The control net extension nominal mesh size was 80 mm; the experimental net extension nominal mesh size was 120 mm, however larger mesh sizes were initially used due to concern of mesh shrinking during sea trials, with the desired result intended to be nominal size (for mesh measurements before and after sea trials see Table 1). All other sections of the trawl were identical (additional trawl details can be found at Fig. 1). Haul location and duration was determined by the fishermen, and were typical for commercial operation.

Table 1. Details for the control and experimental extensions, including panel, material, either single or double twine, average of 20 meshes measured at the beginning of the experiment, and the average of 20 meshes at the end of the experiment. Mesh measurements were the inside stretched length (mm) measured by an Omega Gauge.

Mesh Panel	Material	Twine	Measured: beginning	Measured: end
Top Control	PE	Single	87.7	86.7
Bottom Control	PA	Double	81.3	78.5
Top Experimental	PE	Single	140.2	138.5
Bottom Experimental	PE	Double	130.3	122.5

Control Net Plan



Experimental Net Plan

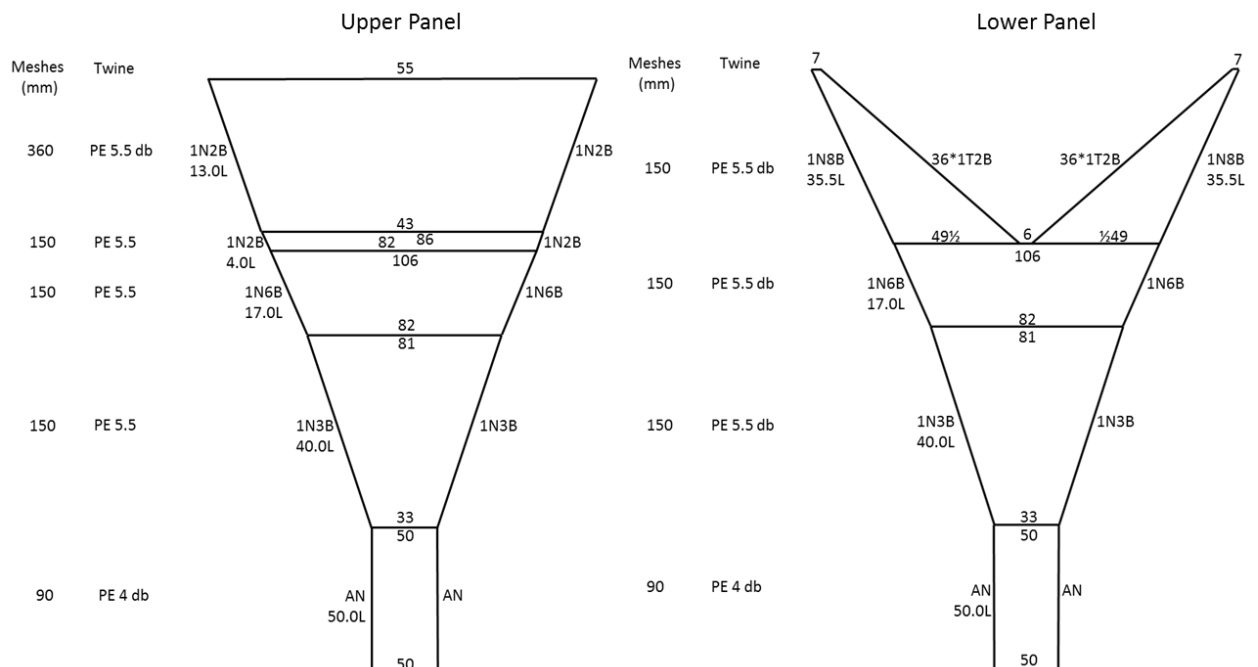


Figure 1. Net plans of trawls used in comparison of a control extension versus a large mesh extension experiment.

Soles were sorted from the catch and measured from the anterior extremity of the fish to the tip of the median rays of the tail to the centimeter below. All soles were measured; there was no subsampling. Other species were not

measured. Differences in catch (by numbers) between the two trawls were analyzed using a Wilcoxon signed-rank test ($\alpha = 0.05$). Catch-at-length was analyzed for sole by comparing the proportion ($\phi(\ell)$) of sole at each length class (ℓ), and was expressed for each length and tow as:

$$\phi(\ell) = N_{\ell e} / (N_{\ell e} + N_{\ell c}),$$

where $N_{\ell e}$ and $N_{\ell c}$ are the number of fish lengths measured for the experimental (e) and the control trawl (c). A value of ($\phi(\ell) = 0.5$) indicates no difference in sole between the two trawls at length (ℓ), whereas, for example, a value of ($\phi(\ell) = 0.75$) indicates that 75% of the total sole at length (ℓ) were caught in the experimental net and 25% were caught in the control.

Catch proportions ($\phi(\ell)$) were analyzed with a generalized linear mixed model (GLMM) following the procedures described in Holst and Revill (2009). The GLMM was implemented using the `glmmPQL` function in the MASS package (Venables and Ripley, 2002) of R statistical software (R Development Core Team, 2009), which used a penalized quasi-likelihood approach (Breslow and Clayton, 1993). A polynomial regression GLMM was used to fit curves for the logit-transformed expected proportions of catch length, and expressed as:

$$\text{logit}[\phi(\ell)] = \log(q_e/q_c) + \beta_0 + \beta_1\ell + \beta_2\ell^2 + \beta_3\ell^3 + a,$$

where q_e and q_c are sub-sampling ratios for the experimental and control respectively, β_0 is the intercept, β_1 is the coefficient of ℓ , β_2 is the coefficient of ℓ^2 , β_3 is the coefficient of ℓ^3 , and a is the random effect that is assumed $N(0, \sigma^2)$ (Holst and Revill, 2009).

Analyses began by fitting the cubic polynomial followed by subsequent reductions of terms until all showed statistical significance ($p < 0.05$) based on Wald t -tests, with removal of one term at a time to determine the best model fit: cubic, quadratic, linear, and constant. The best fit polynomial curve is the lowest order polynomial that both fits (p -value < 0.05) and follows the main trends of the observed proportions (Holst and Revill, 2009).

4 Results

Forty-eight hauls were completed. Mean towing speed was 4.4 knots, mean tow duration was 2 hours and 28 minutes, and fishing depths were between 33 and 52 m. A total of 8462 sole were captured, 4692 for the control (Mean per haul = 97.8, SEM \pm 9.4) and 3770 for the experimental (Mean per haul = 78.5, SEM \pm 8.1), and were significantly different ($W = 368$, $p < 0.001$) (Table 2). For legal-sized sole (≥ 24 cm), 3984 were captured by the control

(Mean per haul = 83.0, SEM \pm 10.3) and 3347 by the experimental (Mean per haul = 69.7, SEM \pm 8.5), and were significantly different ($W = 179.5$, $p = 0.006$) (Table 2). For sole under the minimum landing size (< 24 cm), 708 were captured by the control (Mean per haul = 14.8, SEM \pm 7.1) and 423 by the experimental (Mean per haul = 8.8, SEM \pm 5.6), and were significantly different ($W = 36$, $p = 0.008$) (Table 2).

Soles were captured between 15 and 44 cm. According to the GLMM, sole less than 31 cm were caught significantly more by the control net, and soles larger than 37 cm were captured significantly more by the experimental; a linear curve provided the best fit (Fig. 2; Table 3).

Table 2. Catch summary of the counts of sole (*Solea solea*) captured by 48 comparative hauls between a control net and a large mesh extension experimental net. Measurements include: n (number of soles), percent change (percent difference between the two nets), mean number by haul, standard error of the mean (SEM), and p-value from a Wilcoxon signed rank test.

	<i>n</i>	% Change	Mean	SEM	<i>p</i> -value
All Soles					
Control	4692	-19.7	97.8	9.4	< 0.001
Experimental	3770		78.5	8.1	
Undersized soles (< 24 cm)					
Control	708	-40.3	14.8	7.1	0.008
Experimental	423		8.8	5.6	
Legal-sized soles (≥ 24 cm)					
Control	3984	-16.0	83.0	10.3	0.006
Experimental	3347		69.7	8.5	

Table 3. Generalized linear mixed model parameters for sole (*Solea solea*), where model and parameter are the chosen model (either constant, linear, quadratic, or cubic), estimate is the value of the slope or intercept, SE is the standard error of the estimate, and df is the degrees of freedom; *t*-value and *p*-value are derived from a Wald *t*-test.

Species	Model	Parameter	Estimate	SE	DF	<i>t</i> -value	<i>p</i> -value
Sole	Linear	β_1	-1.259	0.173	841	-7.277	< 0.001

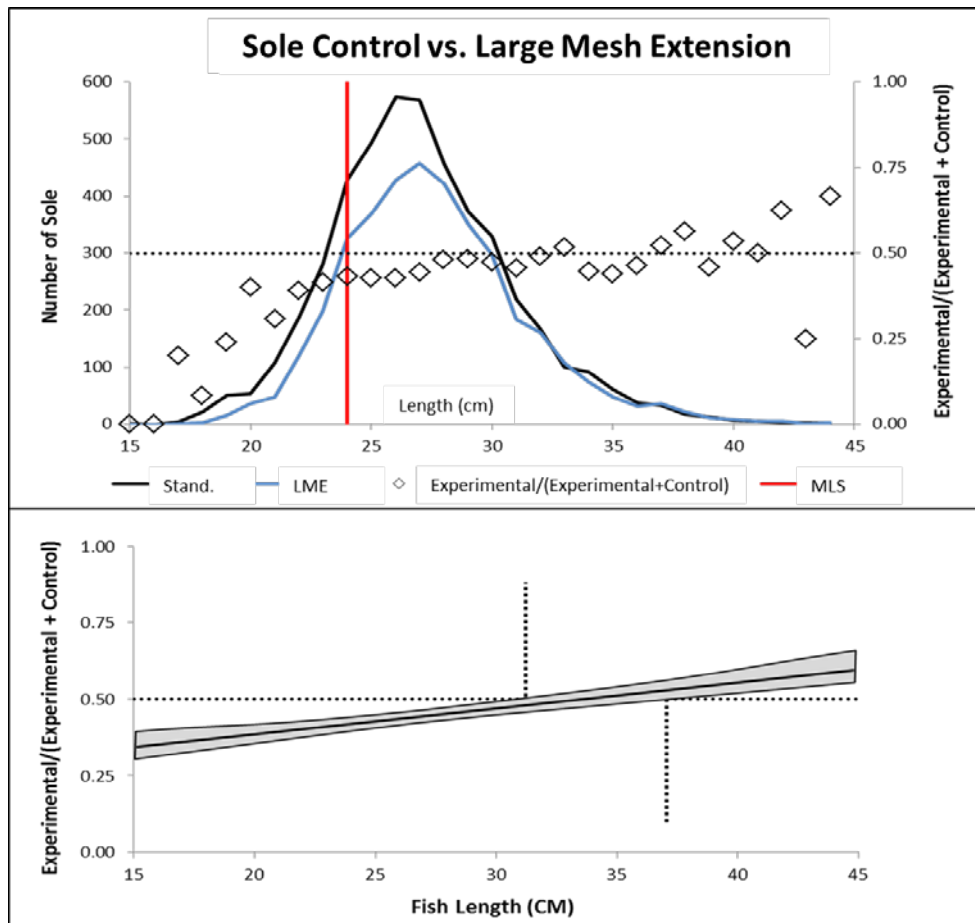


Figure 2. (top figure) Length frequencies of sole (*Solea solea*) and observed proportions (experimental / (experimental + control)) (bottom figure) Generalized linear mixed model (GLMM) modeled proportions of sole at length caught in the trawl with the large mesh extension (experimental). Interpretation: a value of 0.50 indicates an even split between the experimental and the control, whereas a value of 0.75 indicates that 75% of the total sole at that length were caught in the experimental and 25% were caught in the control. The solid line is the mean curve and the shaded areas around the mean curve are the 95% confidence regions. A vertical dotted line displays the length where a significant difference occurs.

5 Discussion

The minimum mesh size in the codend and extension of beam trawls is adapted from the 50% retention length (L_{50}) of sole (24 cm). Considering that the majority of fish that escape from a trawl, escape through the meshes of the codend (Glass, 2000), a method to mitigate a reduction in sole capture, but maintain a commercial quantity of sole, is to increase the mesh size of the extension section of the trawl, while maintaining the 80 mm minimum codend mesh size. An increase in mesh size of the extension was tested, and a reduction of 19.7% of all sizes of sole

was observed, with a 40.3% reduction of undersized fish (< 24 cm). This observed reduction of sole catches, particularly the undersized fish that have no commercial value, can be considered to relieve the reduction of sole quota to the Belgian fleet, which could prove disastrous to a fishery that has already undergone hardships from high fuel prices and other quota reductions.

A clear length relationship was observed for all size classes below 31 cm, as the control extension trawl captured significantly more sole with sufficient totals for each length class ($n > 100$). Very large sole (> 37 cm) were captured more often by the experimental trawl. This result should be considered carefully due to the small number of these sized fish caught, and the general infrequency of these sized fish in the fishery.

The application of the large mesh extension trawl in the Belgian beam trawl fishery can be considered an acceptable method to reduce the capture of sole at a level to meet two needs: reduction of fishing mortality of undersized sole, and maintain the economic viability of the Belgian fishing fleet. Such a large reduction in sole quota from two critical fishing grounds could lead to a failure in the Belgian fleet to maintain a profitable business, which could lead to insurmountable conditions to maintain their commercial operation.

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