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Survival of trawl-caught Norway lobster (*Nephrops norvegicus* L.) after capture and release—Potential effect of codend mesh type on survival

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ABSTRACT

Survival estimates were obtained for the Norway lobster, *Nephrops norvegicus*, retained and escaping from a standard 70 mm mesh size diamond and a modified 55 mm square mesh codend, on board a commercial vessel in fishing grounds off the Portuguese south coast. Ten hauls were carried out, five with each experimental codend, plus three creel sets for the capture of a control group in an adjacent non-trawled area. A total of 571 lobsters were sampled upon arrival on vessel deck, either captured in the codend or retained in the codend cover. In addition, a total of 25 individuals were caught with creels. They were assessed for physical damage and vitality and subsequently placed in cages which were deployed in the same adjacent area for 48 h. Average survival rates were 0.18 and 0.17 for retained individuals and 0.17 and 0.30, for individuals escaping through diamond and square meshes, respectively, and 0.84 for creeled individuals. A discussion is carried out stressing the difficulty in disentangling the influence of the different factors contributing to condition and mortality of individual lobsters.

1. Introduction

Survival and full recovery of individuals escaping from codends or other trawl areas is a central question regarding the usefulness and justification of improving gear selectivity for management purposes (Chopin and Arimoto, 1995; Sangster et al., 1996; Suuronen, 2005). Fish may die as a result of injuries associated with capture and escape, from impairment due to physiological stress or increased vulnerability to predation, decreasing the potential benefits of adopted selective measures. The assessment of survival rates for escapees is thus of utmost importance to validate the choice of gear based management measures, particularly in areas where the fishing pressure is high.

Recently, a discard ban associated to a landing obligation has been implemented by the Commission, to be introduced as a precautionary management strategy within the new CFP (e.g. STECF, 2013). The first step to address the discard problem is to draw up a long-term policy to encourage the reduction of bycatch and elimination of discards. The adoption of gear-based management measures can thus become a reality in a number of European fisheries. Within such a framework, one of the issues deserving special attention is survival of fish escaping from gear.

Studies of survival of escapees during the trawl capture process have been undertaken for many different species in the north Atlantic and worldwide (reviews in Suuronen, 2005; Broadhurst et al., 2006), showing great variability in species survival and reflecting differences in robustness and ability to withstand physical stressors and fatigue during the different phases of the capture process. High survival rates for escapees have been observed for gadoids and flatfishes (Soldal et al., 1993; Sangster et al., 1996; Suuronen et al., 1996a; Soldal and Engås, 1997; Wileman et al., 1999), while for small pelagics substantially lower values have been recorded (Suuronen et al., 1996b). However, considerable variability may be observed even within-experiments, associated with different degrees of exposure to particular stressors during the capture and escape process. Particular conditions associated with the fishing grounds, such as the type of bottom, water temperature and catch composition (Suuronen et al., 2005), as well as operational factors related to the type of gear and the way it is used (Suuronen et al., 1996b,c; Soldal and Engås, 1997) are known to influence survival. Furthermore, interactions between these stressors and their impact on survival are still poorly understood (Davis and Ryer, 2003; Ridgway et al., 2006a,b).There is some evidence that a higher survival probability can be expected for individuals escaping

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through a selective device that promotes an easy escape (*e.g.* Main and Sangster, 1990; Broadhurst et al., 2006). Nonetheless, Wileman et al. (1999) found only slightly higher survival for Norway lobster that escaped from a 60 mm square mesh codends compared to 70 mm diamond mesh ones. On the other hand, nearly 100% survival was observed for small gadoids (haddock, whiting, *Merlangius merlangus*, and cod, *Gadus morhua* excluded from a shrimp trawl by a Nordmøre grid placed in front of the codend (Soldal and Engås, 1997)), while Ingólfsson et al. (2007) found no differences in mortality between haddock escaping from codends and excluded by a grid.

Invertebrates have a higher chance of survival when compared to fish since their shells or exoskeletons provide an increased protection against abrasion and compression (Kaiser and Spencer, 1995; Wileman et al., 1999; Broadhurst et al., 2002). Most studies have focused on discard mortality of commercially important crustaceans (see Broadhurst et al., 2006 for a review), where survival rates were typically higher than 50% (Symonds and Simpson, 1971; Gueguen and Charuau, 1975; Wileman et al., 1999; Harris and Ulmestrand, 2004; Depestele et al., 2014). Norway lobster is a high-valued species widely distributed within EU waters, however there is an acute lack of information on survival of individuals escaping from trawls. In the two studies where the escape survival of Norway lobster was addressed (Morizur et al., 1982; Wileman et al., 1999), mean survival rates were 70% for 45 mm diamond mesh codends escapees (Morizur et al., 1982), while in Wileman et al. (1999) survival was over 80% and 85% for individuals escaping from 70 to 100 mm diamond mesh codends and 60 mm square mesh ones, respectively.

Castro et al. (2003) found average survival rates of 35% in a study addressing Norway lobster discarded by the Portuguese crustacean trawl fleet. These results proved the capacity of Norway lobster to withstand the stress and physical injury associated with typically long hauls carried out on muddy grounds, changes in water temperature during haul-back and exposure to high air temperatures during sorting on deck.

Codend mesh size selectivity studies, including changes in mesh configuration were carried out for this fishery (Campos et al., 2002, 2003; Fonseca et al., 2007). These studies highlighted the potential of changes in mesh configuration to improve the fishing pattern of Norway lobster and reduce fish bycatch. However, the adoption of any change within a gear-based management approach, is only justifiable if escapees survive.

The present study was designed to obtain comparative estimates of survival for Norway lobster escaping from the standard 70 mm mesh size *versus* 55 mm square mesh codends, previously tested in this fishery with proven selective properties, providing support for an informed decision on the introduction of modifications in the gear and fishing practices. Another objective of the project was to better understand the relationships between survival and physical damage with biological and operational factors.

2. Materials and methods

2.1. Experimental design

Within the last two decades, a number of methodologies have been developed for monitoring survival *in situ*, aiming at reducing increased mortality due to handling and stressors during collection, transport and monitoring. These consist in detachable remotely operated covers, allowing underwater transfer of cover escapees to sea bed cages where they stay immersed for monitoring (Wileman et al., 1999; Sangster et al., 1996; Suuronen et al., 1996a–c; Soldal and Engås, 1997; Ingólfsson et al., 2007). These methodologies were not available and besides they have never been tested at the depths fished in this study, where the Norway lobster grounds are located in the continental slope. Thus, the escapees were collected in small mesh covers attached to the codends and were hauled up on board at the end of the tow. Upon arrival on deck, lobsters were measured, evaluated for their vitality and were checked for damage undertaken during the fishing operation. They were then put into cages which were deployed to the seafloor at depths ranging between 625 and 650 m and subsequently brought back to the surface to check for survivors.

The need to bring individuals on board introduces mortality causes otherwise not present. This experimentally-induced mortality resulting from hauling, air exposure, catch handling and sorting was tentatively accounted for by using a control group caught by creeling, using a set of 47 mackerel-baited creels. From the time of arrival on deck onwards the different groups had similar treatments.

The experimental work was carried out from 20 to 25 July 2007, in Norway lobster fishing grounds off the Portuguese south coast between Portimão (8.5 °W, 37.1 °N) and Sagres (8.9 °W, 37.0 °N), at depths between 330 and 480 m (Fig. 1), on board F/V 'Calypso', a 25 metres Loa 600HP stern trawler licensed for crustacean fishing. Two 5-m long double-braided knotted polyethylene 3.5 mm twine thickness codends were tested, one with a standard 70 mm diamond mesh (the legal mesh size for Norway lobster according to the present regulations) and the other with a 55 mm square mesh designed for the experiment. The choice of this mesh size was based in previous selectivity results from Campos et al. (2002, 2003) and Fonseca et al. (2007), with higher L_{50} associated to 55 mm square mesh codends when compared to 70 mm diamond ones. This was observed mainly for the Norway lobster and the hake, *Merluccius merluccius*, with round body sections that fit particularly well in a square mesh opening. The covers were made in knotted polyamide twine 1.0 mm and 25 mm mesh size, with overall dimensions 1.5 times the width and length of the codends (Stewart and Robertson, 1985). Two PVC hoops were fitted outside the covers to minimise their collapse over the codends (Main and Sangster,1990).

The summary of fishing operations and cage deployments is presented in Table 1a and b. Thirteen valid trials out of a total of 16 were carried out, 10 hauls and 3 creel sets. After each fishing operation the individuals sampled were placed in holding trays until they were transferred to cages that were deployed to the sea floor at the end of the day. During the six days of experiments, a total of 5 cage deployments was carried out (Table 1b). During towing and cage deployment, water temperature and depth were recorded at 10-min intervals by sensors (VEMCO 8-bit TDR minilogs) attached to the trawl headline and cage mainline.

The fishing experimental procedures were as follows: the creels to collect controls were set every other day and two daily one-hour trawl tows were carried out at about 3 knots. Creels and trawl were hauled up at approximately the same speed (average 12 and 14 m/min respectively). The time interval between the end of haul-back (net on board), and placement of cover catches at the sampling table was of 5–10 min. Codend catches were kept in an adjacent under-deck compartment, where they were continuously wet with pumped sea water during 20 to 30 min before reaching the sampling table.

The experimental protocol for collecting and monitoring Nephrops was similar to the method described by Castro et al. (2003), with some modifications. After each tow or creel hauling, at arrival on deck, the Norway lobster sampled (from the codend and cover in the case of tows), were observed for data collection (size, sex, vitality and physical damage) and each individual was assigned an identification number. Since cage deployment was done only