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Research Paper

Survivability of discarded Norway lobster in the bottom trawl fishery of the Bay of Biscay

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ABSTRACT

In the context of the landing obligation set by the new Common Fisheries Policy (CFP), Norway lobster *Nephrops norvegicus* was identified as a species likely to have high survival rate when discarded in the bottom trawl fishery of the Bay of Biscay. Previous studies in this area reported a survival rate between 30% and 51%, but the experiments were done on a limited monitoring period and the seasonal variations were not investigated. This study was designed to obtain a reliable value for survival rate after a 14-day monitoring period in onshore tanks allowing considering delayed mortality. The study also tested the effect on the survival rate of using a discarding chute system, a sorting device that was made mandatory on the 1st of January 2017 for *Nephrops* trawlers in the Bay of Biscay. This device, which enables fishermen to discard undersized *Nephrops* back to the sea while sorting, led to an increased average survival rate (51.2%) compared with the standard sorting practice (36.9%). The impact of biological, environmental and fishing operation related variables on survival from the first day of captivity to the end of the monitoring period was examined using a generalized linear model. The results of the GLM indicate that injuries, season and duration of the air exposure, significantly influence the survival from the 1st day of captivity to the end of the monitoring period. The survival rate was higher for non-injured *Nephrops* as well as for *Nephrops* that have undergone short air exposure, in summer and autumn.

1. Introduction

The new Common Fisheries Policy (CFP) brought into force the 1st of January 2014 gradually established a landing obligation to encourage the long-term reduction of discards. However, according to article 15 paragraph 4(b), exemptions to the landing obligation can be obtained for species in which "scientific evidence demonstrates high survival rates, taking into account the characteristics of the gear, of the fishing practices and of the ecosystem" (European Commission, 2013). In particular, Norway lobster *Nephrops norvegicus* was identified by the ICES Workshop on Methods for Estimating Discard Survival (WKMEDS) as a species susceptible of a high survival rate (ICES, 2015). Previous studies investigated the influence of biological parameters on *Nephrops* survival rate after discard and found that size, sex and physical injuries all had a significant influence (Campos et al., 2015; Méhault et al., 2016; Milligan et al., 2009; Valentinsson and Nilsson, 2015). Environmental parameters, such as air temperature (Giomi et al., 2008) and salinity (Harris and Ulmestrand, 2004), have also been shown to influence survival rate. Light, of the intensity level found at the sea surface, damages *Nephrops*' eyes, but no impact on their survival has been demonstrated (Chapman et al., 2000; Gaten et al., 2013). Variations in ability to recover and survive across the seasons are acknowledged (Albalat et al., 2010; Castro et al., 2003; Lund et al., 2009), but the causes of such differences remain unclear and probably involve biological and environmental factors such as moult status, size (Milligan et al., 2009) or air temperature. Finally, trawling characteristics such as catch composition, tow duration, speed, the type of selective device used on the fishing gears (Campos et al., 2015; Valentinsson and Nilsson, 2015) or handling practices on deck (Bergmann and Moor, 2001), for instance duration of air exposure (Méhault et al., 2016), also have a major effect on survival.

The *Nephrops* catches are of particular importance in the North of the Bay of Biscay, where it accounted for 28% of the total landings in term of weight for the *Nephrops* bottom trawl *metier* in 2015 (Cornou et al., 2016). In 2012, 191 trawlers targeted *Nephrops* and generated more than €30 million in market value (Leblond et al., 2012). However, this mixed fishery has a historically high level of bycatch, composed of undersized *Nephrops* and other commercial species such as hake (Vogel

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et al., 2017). To improve the selectivity of this fishery, in 2008, the French national fishing committee made it mandatory to use one of the following selective devices: codend mesh size of 80 mm (instead of the 70 mm used up to 2008), flexible grid or bottom square mesh panel (JORF, 2008). In 2011, a square mesh cylinder was added to the list (JORF, 2011). In addition to these devices, the use of a 100 mm top square mesh panel for hake escapement has been mandatory since 2006 (European Commission, 2006). Furthermore, the minimum landing size was set at 9 cm (total length) to preserve the stock. Despite these improvements, discard rates remained high, accounting for about 30% in weight of all the *Nephrops* caught in 2015 (Cornou et al., 2016). The discarded *Nephrops* that survive can contribute to stock replenishment, making it particularly important to favour their survival. In this context, the European Commission incited initiatives that improve discarded *Nephrops* survival. The use of a discarding chute system was proposed by fishermen to decrease air exposure and injuries since these factors are known to be amongst the main drivers of *Nephrops* survival (Campos et al., 2015; hault et al., 2016,b; Ridgway et al., 2006a,b; Wileman et al., 1999). This device is joined to the sorting table and makes it possible to discard individuals back to the sea throughout the on-board sorting process. This minimises the duration of air exposure as well as the possibility of being injured during the time spent on the deck, compared with the standard sorting practice that consisted in discarding *Nephrops* back to the sea at the end of the sorting process. The use of this sorting device became mandatory on the 1st of January 2017 (JORF, 2016).

To measure survival rate, two methods were chosen for this study among the three identified by the Expert Working Group 13–16 (EWG13-16) of the Scientific, Technical and Economic Committee for Fisheries (STECF, 2013): vitality assessment and captive observation. Previous studies on discarded *Nephrops* survival in the Bay of Biscay that used a captive observation method in open water reported a survival rate between 30% and 51% (Gueguen and Charuau, 1975; Méhault et al., 2016). However, these earlier studies were too short (3 days) to allow the asymptote of the survival rate to be reached, or to investigate variability between the different fishing seasons, or consider different sorting practices.

This study was designed to obtain a reliable value for survival rate, including its potential variations across seasons and different sorting practices. Individuals were sampled in three different seasons and two sorting practices were simulated: (1) the standard scenario, which consists of discarding the unwanted catch back into the sea at the end of the sorting process; and (2) the discarding chute system scenario, with individuals being discarded back to the sea during sorting. This study therefore investigated the influence of an environmental parameter (season), fishing operation characteristics (sorting practice, duration of air exposure, composition of the haul) and biological parameters (length, sex and injury) on *Nephrops* survival from the first day of captivity to the end of the monitoring period.

2. Materials and methods

2.1. Sampling strategy and material

Sampling was conducted on the “Grande Vasière” *Nephrops* ground in the North of the Bay of Biscay (Fig. 1), in depths of 78–110 m, on board two commercial trawlers. The sampling was done in three different seasons, in April, June and September 2016 (hereafter named spring, summer and autumn, respectively). The hauls were conducted under regular commercial conditions: the duration was set at 3 h, with a speed around 3.5 knots and both vessels were rigged with a twin bottom trawl equipped with a codend mesh size of 80 mm and a 100 mm top square mesh panel. On-board handling practices were kept as usual to obtain data representative of this fishery. The main characteristics of each fishing operation were recorded: the air temperature at the sorting time, the duration of air exposure, as well as the catch composition defined here by the ratio between the weight of *Nephrops* caught and the weight of the total catch.

2.1.1. Control group sampling

To disentangle the part of the mortality caused by the catch from any caused by captivity, control samplings were also made. Sampling of control individuals was conducted on separate fishing trips at each season, before the test group was sampled. Tow duration was set at 1 h to prevent physical damage (Milligan et al., 2009). Living *Nephrops* were sampled among the undersized *Nephrops* and put in trays with individual cells (35 mm × 35 mm × 200 mm) (Fig. 2) in on-board tanks. Once landed, these *Nephrops* were kept in onshore tanks until stabilisation of mortality was observed. Then a set of individuals with a sex ratio of about 50:50 were selected and these were placed in the on-board tanks during the sampling of the test group and have undergone the same protocol as the test group sampling.

2.1.2. Test group sampling

Nephrops were randomly sampled among the discarded individuals following two different sorting processes: (1) to simulate the standard sorting scenario individuals were collected at the end of the sorting process and (2) to simulate the discarding chute system sorting scenario (Fig. 2), individuals were sampled every 10 min. Both sorting processes were implemented during each fishing operation. *Nephrops* were placed in the trays and immerged in the on-board tanks. When a sampled individual was found to be dead, the corresponding cell in the tray was left empty. Cephalothoracic length (mm), sex and presence of injuries (cuts on the tail, smashed *Nephrops*, broken rostrum, necrosis stains and holes in the carapace) were recorded at the death of the *Nephrops* or at the end of the monitoring period. Environmental variables and characteristics of the fishing operation were recorded at each haul (Table 1).

2.1.3. Experimental set up

The on-board tanks on both sampling vessels were approximately 2 m^3 and were equipped with bubbler systems. The water flowing in was pumped close to the surface and cooled to reach the temperature measured on the seabed at the sampling sites location. The onshore holding facilities were located in the port of Lorient, so air exposure during the transit from the vessel to the onshore tanks only lasted a few minutes. In the onshore facilities, control and test trays were randomly distributed between two tanks of 0.7 m^3 each, whose temperature was set to the value recorded at the sampling sites. Salinity, temperature and nutrient concentrations were checked on a regular basis to ensure no variations could impair *Nephrops* survival. In addition, tanks were filled with pumped seawater that was bio-filtrated and recirculated during the experiment. They were equipped with a bubbler system and a cover to maintain *Nephrops* into the dark. *Nephrops* were not fed, based on their demonstrated ability to endure a monitoring period without food (Valentinsson and Nilsson, 2015) and the potential stress induced by an inadequate alimentation.

2.2. Vitality assessment

Vitality was assessed visually, based on the three vitality levels defined in Méhault et al. (2016), developed based on unstressed *Nephrops* reactions: (1) healthy: the *Nephrops* has some strength in its body, moves without stimulus and is able to do a ‘tail-flip’; (2) moribund: the *Nephrops* moves slowly or only if stimulated, only its appendages move; (3) dead: the *Nephrops* does not move at all and shows no reaction to stimuli. The vitality state of each *Nephrops* was recorded on a daily basis over 14 days. Individuals that were not moving were gently stimulated with long curved tweezers and if they did not react, they were put into a water-filled tray with large cells for further examination. Dead individuals were removed from the trays.