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Survival of discarded *Nephrops norvegicus* after trawling in the Bay of Biscay

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ABSTRACT

The new Common Fisheries Policy may exempt some species from the landing obligation if a high survival rate can be demonstrated among discards. This study focuses on the survival capacity of *Nephrops norvegicus* discarded from trawlers of the Bay of Biscay (France). Three sea trials were conducted on board 3 commercial trawlers and 15 fishing operations were sampled. The vitality of *Nephrops* was classed into three categories (healthy, moribund or dead) before release at sea and samples of healthy and moribund individuals were kept in captivity on *Nephrops* grounds for three days. A Generalised Linear Model was used to examine the variability in the proportion of healthy *Nephrops* discarded, which was significantly influenced by tow duration, duration of air exposure and temperature, as well as individual length. By combining the results on vitality before release at sea with those on survival in captivity following re-immersion, resampled by bootstrapping, it was calculated that 51% [42–60%] of discarded *Nephrops* would survive after three days of re-immersion. We discuss the sources of variability in survival rate, as well as the implications of a potential exemption from the landing obligation for this species.

1. Introduction

The European Union recently modified its Common Fisheries Policy and brought into force the prohibition of discarding catches (European Commission, 2013). Nonetheless, article 15 paragraph 2(b) of the regulation mentions the possibility of exemption from the landing obligation for species for which “scientific evidence demonstrates high survival rates”. Research has thus shown that not all the discarded individuals die and, depending on biological, environmental and technical parameters, their survival rate could be quite high (Revill, 2012). The biological factors potentially influencing animal survival include: species (Broadhurst et al., 2006), size (Davis and Olla, 2002; Benoit et al., 2013) physical injuries (Depestele et al., 2014) and physiological stress (Bergmann et al., 2001). Environmental factors such as temperature, depth and light conditions have also been found to influence an animal's ability to recover after having been thrown back into the water (Davis and Olla, 2002; Giomi et al., 2008). Finally, technical parameters such as catch size (Tenningen et al., 2012), handling practices on deck (Castro et al., 2003; Macbeth et al., 2006), duration of air exposure (Davis, 2002; Broadhurst et al., 2006; Benoit et al., 2010, 2012, 2013) and gear type (Neilson et al., 1989) are amongst those with the strongest effects on organism survival.

In this regard, it is necessary to develop approaches for survival experiments that will provide information about species potential for “high survival rate”. Three methods were identified by the Expert Working Group 13–16 (EWG13-16) from the Scientific, Technical and Economic Committee for Fisheries (STECF, 2013), namely, captive observation (Revill et al., 2013; Depestele et al., 2014), vitality and reflex assessments (Davis and Ottmar, 2006; Humborstad et al., 2009; Davis, 2010) and tagging or biotelemetry experiments (Donaldson et al., 2008; Yergey et al., 2012). These measures of animal survival are especially important as they could be used for stock assessments. Following the implementation of the landing obligation, any individuals that would otherwise have survived the discarding process would thereafter contribute to the overall fishing mortality of the stock. This has significant implications for stocks that include discards in their assessment: determination of discard survival will now influence the assessment process and the setting of total allowable catch (TAC). This is particularly true for stocks simply assumed to have no chance of survival after discarding (either because it is considered negligible or because accurate estimates are not available) or for the few species that already formally have a discard survival factor incorporated in the stock assessment process, such as *Nephrops*.

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For the *Nephrops* fishery in Bay of Biscay, the survival rate of discards from trawlers was studied by Gueguen and Charueau (1975) and by Morizur et al. (1982). These authors concluded that 30% of discarded *Nephrops* could survive, and this rate was later adopted by the International Council for the Exploration of the Sea (ICES) who have since used this figure in the stock assessment procedure. However, the gears used to fish this species have evolved since the 1970s: the codend mesh size has gradually increased from 55 mm in 1975–70 or 80 mm today and, while *Nephrops* trawlers were previously rigged with a single gear, they are now rigged with twin gears, leading to a reduction of the catch volume per codend. The French national fishing committee has also taken restrictive measures in order to reduce the discard rate and preserve the stock: the minimum landing size was set at 9 cm (28 mm cephalothoracic length) and, in 2007, the fishermen had to adopt at least one selective device from the following: a codend mesh size of 80 mm, a flexible grid, or a bottom square mesh panel (CNPMEM, 2010). In 2011, one more selective device, a square mesh cylinder, was added to the legislation. However, despite these technical measures, the discard rates in this mixed bottom trawl fishery remain high, with an average of 49% of the catch discarded in 2013 (Cornou et al., 2015).

The present paper reports a new evaluation of the survival rate of discarded *Nephrops* in the Bay of Biscay using two methods recommended by EWG13-16 (STECF, 2013): vitality assessment and captive observation of captured individuals. We also aimed to determine if this survival rate was influenced by a biological factor (size), an environmental parameter (air temperature) and aspects related to the operational practices (tow duration and duration of air exposure).

2. Materials and methods

2.1. Sampling strategy

The survival experiment was conducted on the *Nephrops* grounds of the Bay of Biscay known as the "Grande Vasière" (Dubrulle et al., 2007), extending from 46°00 N to 47°50 N and 4°50 W–3°00W, on the continental shelf off the Atlantic coast of France at depths between 65 and 113 m (Fig. 1). Three commercial trawlers were used for sampling during the fishing season in July and October 2009 and in July 2010 (Table 1). All vessels were rigged with twin bottom trawls, which are commonly used to target *Nephrops* in this fishery (Macher et al., 2008). The hauls sampled were conducted under normal commercial conditions: the mean duration of the tows was 2.3 h (1.27–3.25), the towing speed ranged between 3 and 4 knots, the codend mesh size was 80 mm (CNPMEM, 2010) and the net extension was equipped with the compulsory square mesh panel (European Union, 1998). The crew was asked to keep onboard handling practices as usual in order to obtain samples representative of normal commercial fishing conditions.

2.2. Survival rate

Survival rate estimation was made using two independent procedures: vitality assessments and field captive observations. Vitality assessments estimated survival as the proportion of individuals alive prior to discarding in a given sample. From field captive observations, survival rate was estimated as the proportion of individuals that survived a re-immersion phase, based on a sample of living individuals at the time of re-immersion. Both estimates were used to compute the overall survival rate of discarded *Nephrops*.

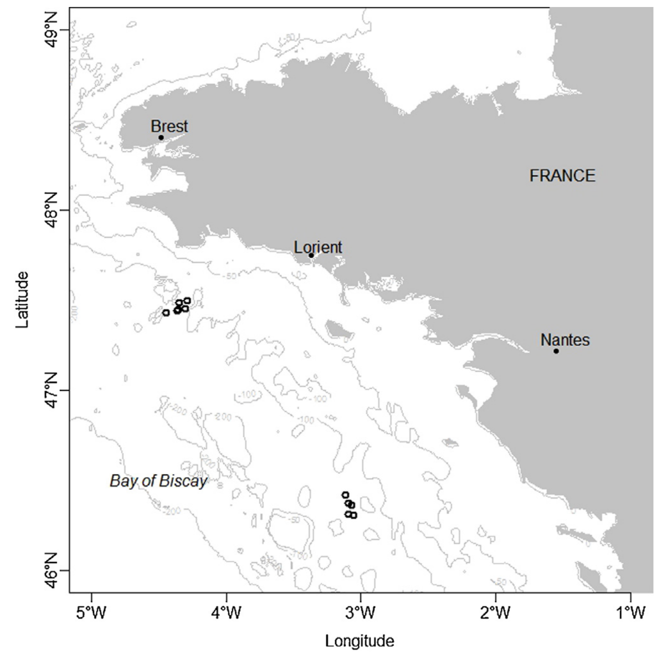

Fig. 1. Map of the study area in the Bay of Biscay presenting the location of sampling sites (black dots) and the 50 m, 100 m and 200 m iso-depth lines (grey lines).

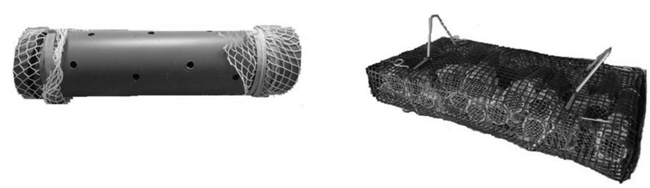

Fig. 2. Tubes (left side) and bags (right side) used for field captive observations. Tubes characteristics: Dimensions = 25 cm length × 5 cm diameter, number of holes = 15, holes diameter = 7 mm, stretch mesh size = 12 mm. Bags characteristics: Dimensions = 70 × 40 × 15 cm, square mesh size = 15 × 15 mm, number of tubes per bag = 25.

2.2.1. Vitality assessment

Thirteen fishing operations were carried out to assess the vitality state (V) of *Nephrops* before discard. Samples of *Nephrops* were taken randomly from the discard heap. Sample size ranged from 72 to 404 individuals (mean = 225), with 2933 *Nephrops* examined in total (Table 1). Cephalothoracic length was measured and vitality state was assessed visually (Gueguen and Charueau, 1975; Castro et al., 2003). Vitality state was rated at three levels: (1) healthy (H): the *Nephrops* was able to do a 'tail-flip' and its body is lively, (2) moribund (M): the *Nephrops* was alive (*e.g.* it moves its legs or antenna) but has no strength in its body (3) dead (D): the *Nephrops* did not move at all and has no strength. Although more detailed vitality state scales were available (*e.g.* Ridgway et al., 2006), this was considered the best compromise between sample size and sample treatment time. Proportions of healthy, moribund and dead individuals were calculated for each fishing operation.

2.2.2. Field captive observations

2.2.2.1. Experimental setup. Living *Nephrops* that were either healthy or moribund, were put into numbered plastic tubes (1 *Nephrops* per tube), which were themselves put in oyster farming bags to be re-immerged close to the site where they were caught. The tubes were made of perforated PVC with dimensions of 25 cm length and 5 cm diameter. They were closed by pieces of net at each extremity (Fig. 2). Each bag contained 25 *Nephrops* tubes, which