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SURVIVAL ESTIMATES OF BYCATCH INDIVIDUALS DISCARDED FROM BIVALVE DREDGES

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ABSTRACT

The fate of released bycatch is an issue of great interest for fisheries research and management. Survival experiments were carried out to assess the survival capacity of animals damaged and discarded during clam dredging operations. Three common bycatch species, two fish (*Trachinus vipera; Dicologlossa cuneata*) and one crab (*Polybius henslowii*), were collected during the sorting of catches from a commercial dredging boat. An arbitrary score scale was used to quantify the type and extent of damage to the organisms. Onboard, damaged individuals were placed in tanks containing seawater which were subsequently transferred to the laboratory. Survival experiments were conducted during the subsequent 48h. *D. cuneata* exhibited the lowest mortality after 48h (54%), followed by *P. henslowii* (65%) and *T. vipera* (81%). Despite the magnitude of the percentage mortalities determined, the average number of individuals estimated to die during a 15 minutes tow (standard commercial fishing time) was relatively small: 1.2, 3.24 and 11 for *D. cuneata*, *T. vipera* and *P. henslowii*, respectively. Nevertheless, when these figures are extrapolated to cover all the dredging fleet the impact of this practice on the populations of the species studied can be significant, particulary for *D. cuneata.*

RESUMO

O destino de capturas acessórias rejeitadas ao mar é uma questão de grande interesse para a pesquisa e gestão das pescas. Foram realizadas experiências de sobrevivência para avaliar a capacidade de sobrevivência dos animais danificados e rejeitados durante as operações com ganchorra, uma draga utilizada na pesca de amêijoa (bivalves). Três espécies capturadas acidentalmente, dois peixes (*Trachinus vipera; Dicologlossa cuneata*) e um caranguejo (*Políbio henslowii*), foram recolhidos durante a triagem das capturas realizadas a bordo de um barco de pesca comercial que opera com ganchorra. Uma escala de pontuação arbitrária foi utilizada para quantificar o tipo e amplitude dos danos inflingidos nos organismos. A bordo, os indivíduos danificados foram colocados em tanques com água do mar, que foram posteriormente transferidos para o laboratório. Experiências de sobrevivência foram realizadas durante as 48h subsequentes. A espécie *D. cuneata* exibiu a menor mortalidade após 48 horas (54%), seguido do *P. henslowii* (65%) e *T. vipera* (81%). Apesar dos valores de mortalidade percentuais determinados, o número médio de indivíduos que morreram durante 15 minutos de arrasto (tempo de pesca comercial padrão) foi relativamente pequeno, 1.2, 3.24 e 11 para *D. cuneata, T. vipera* e *P. henslowii*, respectivamente. No entanto, quando esses números são extrapolados para toda a frota da ganchora o impacto desta prática sobre as populações das espécies estudadas pode ser significativo, particularmente para a *D. cuneata*.

Descriptors: Clam dredge, Survivor experiments, Bycatch, Mortality of discards.
Descritores: Ganchorra para bivalves, Experiências de sobrevivência, Espécies descarregadas, Mortalidade das rejeições.

INTRODUCTION

Fisheries can affect the population recovery or growth of many invertebrate or fish species, both commercial and non-commercial (PAULY; CHRISTENSEN, 1995). Therefore, the ongoing harm to non-target species and damage to marine ecosystems caused by fishing is currently an issue of great concern. According to global statistics (KELLEHER, 2005), almost 10% of global fisheries catches are discarded at sea, often dead or dying. Discarded fish mortality is a critical problem in the management of worldwide fisheries. A huge effort has been made over recent years with a view to a comprehensive reconstruction of wild catch fisheries, based mostly on studies of the discard rates associated with the various kinds of fishing gear (LEITÃO et al., 2009; LEITÃO et al., 2014; HARPER; ZELLER, 2011). Discarding is widely perceived as a waste of resources and an impediment to the recovery of depleted or declining fish stocks. Despite proposals by the European Commission for the implementation of a gradual ban on discards (EUROPEAN COMMISSION, 2009), this practice is still routinely employed by the fishing industry. Accordingly, our ability to assess the status of a stock depends, in part, on our knowledge of the fate of discards. Additional mortality caused by discarding may hamper the sustainable use of marine resources, especially if this is not taken into account in stock assessment (CROWDER; MURAWSKI, 1998; RIJNSDORP et al., 2007) and when long and precise time-series of discard estimates are lacking (AARTS; POOS, 2009). Studies dealing with discards and bycatch have mainly focused on their quantification or on gear modification aiming at the reduction of bycatch (e.g. LØKKEBORG; BJORDAL, 1992; MAHON; HUNTE, 2001; see also reviews by BROADHURST, 2000; BROADHURST et al., 2007; NEGRI et al., 2012). On the other hand, studies of the estimation of discard mortality are scarce (KAISER; SPENCER, 1995; PRANOVI et al. 2000). Bycatch species are subjected to different levels of stress during harvesting and therefore mortality of discarded individuals largely depends on the technical characteristics (e.g. efficiency and selectivity) and mode of operation of the fishing gear. The mortality of discards reflects the different tolerances of species to the cumulative impacts associated with particular catching-sorting-and-discarding procedures. While some bycatch species are able to survive after being discarded, with minimal impacts on their populations, others might not. Special attention must be given to those species captured in large abundances and with reduced capability to survive after fishing operations. These aspects are particularly important in determining the total bycatch mortality associated with a fishing operation, which consists of the immediate mortality observable on-board plus the post-release, cryptic mortality caused by the catch-and-release event (HUETER et al., 2006).

Bivalve dredges are extensively used along the Portuguese northern coast and although they are specifically designed to catch bivalves, they also capture other benthic invertebrates and fish. In this type of fishery, catches are rapidly sorted on board and specimens that are undersized, damaged or of no commercial interest are returned to the sea. Thus, the main issue is to ascertain the chances of survival of the discarded organisms, since some of them may be severely damaged by the gear and may not survive after being returned to the sea. The present study aimed to estimate the mortality of the most abundant and susceptible bycatch species (*Trachinus vipera; Dicologlossa cuneata* and *Polybius henslowi*i) from clam dredges, when returned to the sea, due to the damage they suffer.

MATERIAL AND METHODS

The present study was carried out in July 2009 off the Northwestern Portuguese coast (Aguda: 41º01’00’’N and 08º39’00’’W) in one of the most important fishing grounds for *Spisula solida* (Fig. 1). Fishing was done onboard a commercial dredge vessel. A total of 18 tows were performed at a mean depth of 10m. Dredges were towed for 15min. at a towing speed of approximately 1.7-2.3 knots. The dredge used was identical to the ones used by professional dredgers, consisting of a rectangular rigid iron frame (200cm length x 35cm height) with a toothed lower bar (tooth length 6.5cm; tooth spacing 4cm) and a net bag (25 mm stretched mesh size) to retain the catch (Fig. 1).

Laboratory survival experiments were carried out to test the hypothesis that not all damaged animals necessarily die when discarded or shortly after. Based on their abundance in the catches, economic importance and perceived susceptibility, three *taxa* were selected: one Brachyura (*Polybius henslowii* - crab) and two Osteichthyes (*Trachinus viper* and *Dicologlossa cuneata*). After hauling, the selected species were sorted and a damage score was attributed to each specimen caught (adapted from GASPAR et al., 2001): 1 - individuals in perfect condition; 2 – slightly damaged individuals (fish - loss of scales, small cuts or wounds; crabs 1-2 missing legs and/or small carapace cracks); 3 - badly damaged or dead individuals. Only individuals classed as score 2 were used in the experiments. In the case of the two fish species only juveniles (*i.e.,* individuals under the minimum landing size) were used in the experiments, as the adult fraction is usually landed. For crabs, aggregate juvenile and adult discards mortality was estimated as crabs are not landed. After each tow, all selected specimens were placed in fibreglass tanks (85cm length x 50 cm width x 50 cm height) with fresh seawater. A total of 54 tanks, one per each tow per species (18 tows x 3 species), were used for the experiments. In the case of the fish species the total number of individuals surveyed was 54 (mean n.º ind./per tank = 3) and 36 (mean n.º ind./per tank = 2) for *T. vipera* and *D. cuneata*, respectively. For crabs, a total of 14 individuals were placed inside each of the tanks used (N. total= 252). Onboard, the seawater in each container was continuously renewed in order to maintain water temperature and to avoid oxygen depletion. Once in the harbour, the tanks were immediately transported to the laboratory. In the laboratory the tanks were connected to a fresh seawater supply and maintained under constant aeration. The number of dead animals was recorded every 4 hours for the first 18 hours. Subsequently, counts of all the survivors were made at intervals that never exceeded 8 hours and at the end of the 48h period. It was assumed that individuals which had survived longer than 48h would survive the fishing-sorting-discard process. The criteria used to determine whether an individual was alive followed that proposed by KAISER and SPENCER (1995): fishes were considered alive if respiratory movements were seen, whereas crabs were examined for either general movements or beatings of the maxillipes.

The data from each species in each tank was pooled. The relationship between the number of survivors for each species and time was determined using KAPLAN and MEIER'S method (1958). The graphical result of this method is a curve of the mean cumulative number (replicates being averaged - see LEITÃO, GASPAR, 2011) of specimens surviving during the experiment. The 25%, 50% and 75% (RT 25, 50, 75) average survival time for each species was derived from the curves. For each of the species studied, estimates of the total number of individuals captured (mean ± SD) that would die per 15 minute tow, took into consideration the proportion of individuals that died during the experiments as well as individuals classed as severely damaged during sorting (category 3). It was assumed that all individuals scoring 1 would survive.

RESULTS

For crabs it took more than one day (26h.) for 25% of the individuals to die (Fig. 2). After 33h, 50% of the crabs were dead. No more crabs died after 36 hours, when mortality reached 65%. Immediately after being placed in tanks, fish normally showed accelerated breathing movements and some swimming difficulties. After this initial stage, which normally did not exceed 10 minutes, individuals seemed to recover and to be capable of surviving. Survival curves showed that fish with (*Trachynnus vipera*) and without (*Dicologlossa cuneata*) functional swimbladders differed substantially in their survival rates (Fig. 2). After 17 and 26 hours, 25% and 50% of *D. cuneata* individuals had died, respectively, whereas in the case of *T. vipera* 25% and 50% of mortality was observed after 12 and 33 hours, respectively. Total final mortality of *D. cuneata* was 56%. Despite their robust appearance and smaller initial mortality, *T. vipera* continued to die throughout the experiments, reaching 75% mortality at 36 hours. The survival rate of this species at the end of the experiment was low (19%). Final values for mortality, after 48h, were used to estimate the number of damaged and dead individuals resulting from discarded bycatch, after each fishing tow (Table 1). Despite the relatively high mortalities observed during the experiment, the total number of *D. cuneata* estimated to die in each fishing tow was around 1. For *T. vipera* and *P. henslowii* the estimated number of individuals killed per 15min tow was 3.2 and 11.2, respectively.

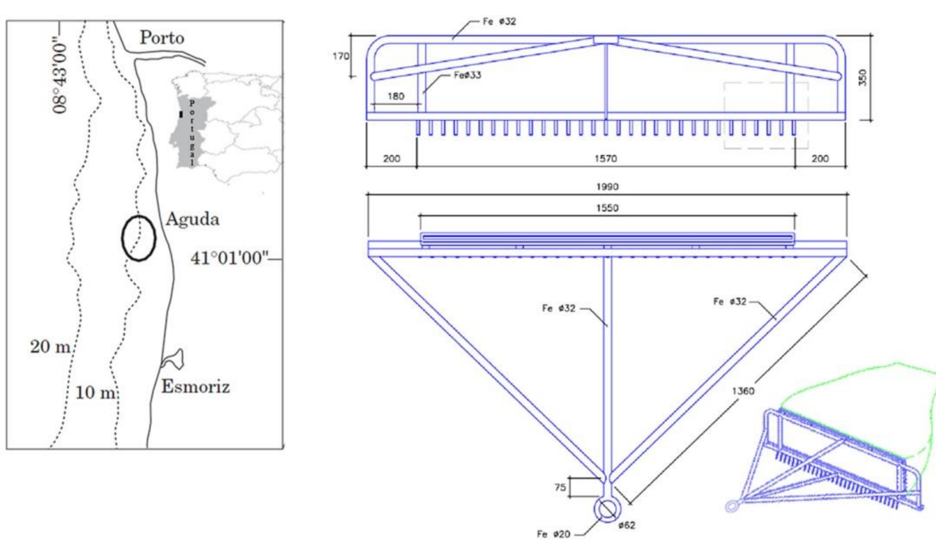

Fig. 1. Sampling area within the ellipse and schematic illustration of the *Spisula solida* dredge used on the North coast of Portugal.

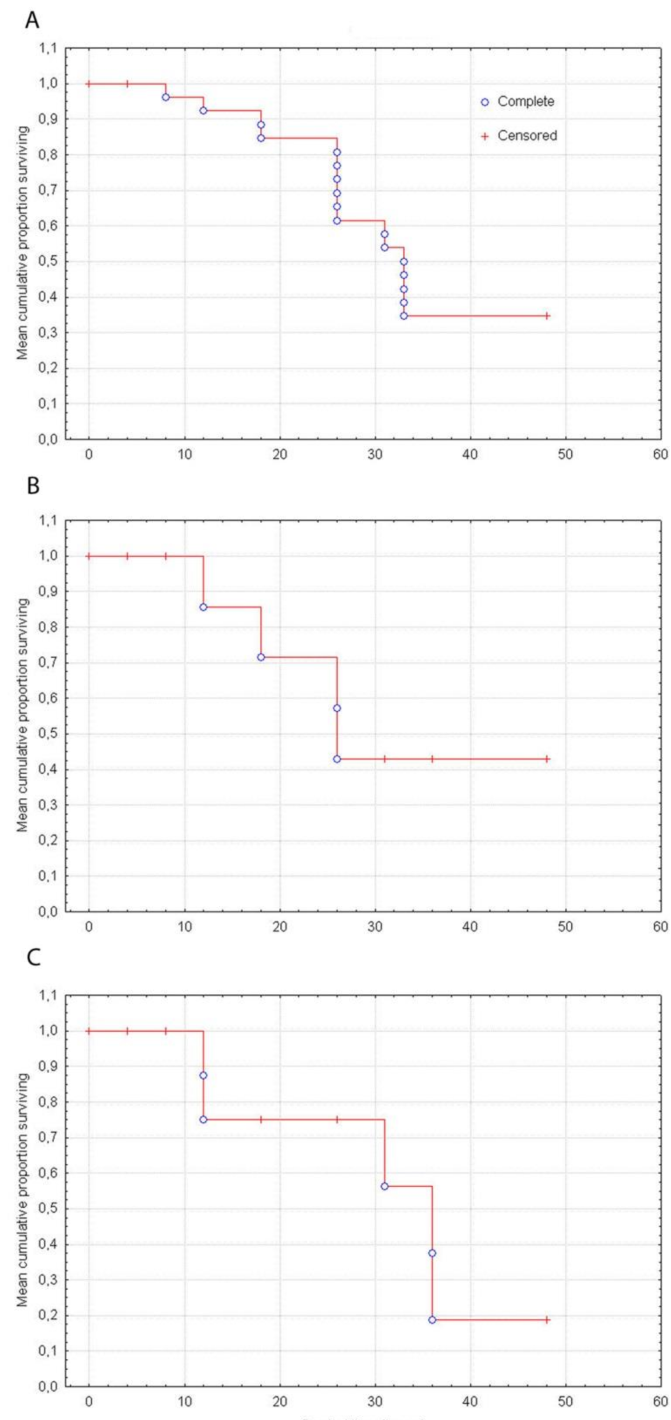

Fig. 2. Mean survival curves for selected fish species after 48 hours. A) *Polybius henslowi*, B) *D. cuneata* and C) *T. vipera*.

Table 1. Estimates for total number of individuals captured (mean and standard deviation), damaged and dead per 15 minutes dredge tow for *Dicologlossa cuneata, Trachinus vipera* and *Polybius henslowii*.

	Mean number of individuals		
	Total	Damaged and dead (%)	Mortality (%)
Dicologlossa cuneata	12.4±0.5	2.2(18%)	1.2(10%)
Trachinus vipera	21±0.6	4.0(19%)	3.24(15.4%)
Polybius henslowii	106±10.3	17(16%)	11.2(10.4%)

DISCUSSION

Despite the relatively large number of studies on bycatch and discarding (see reviews by BROADHURST et al., 2007; NEGRI et al., 2012), there is a lack of knowledge regarding the survival of bycatch species after discarding. Accordingly, the main objective of the present study was to quantify the survival of damaged individuals of the most abundant and susceptible bycatch species (*Polybius henslowii*, *Dicologlossa cuneata* and *Trachinus vipera*) after sorting and discarding operations onboard commercial bivalve dredge vessels. During the fishing trials it was observed that *P. henslowii*, despite its calcareous armour, can be badly affected. In the present study, 16% of the individuals caught were damaged or dead and of these only 35% of the former were estimated to survive after discarding. In a similar experiment, using beam trawl gear, KAISER and SPENCER (1995) recorded mortality rates for swimming crabs (*L. depurator*) ranging between 50 and 57%. Although the values for mortality of crabs are comparable, it should be noted that gear design, depth and duration of towing varied considerably between the two experiments. Gaspar *et al.* (2002) showed that damage and mortality (based on an arbitrary score scale) ranged between 0-36% and 0-67% in number for *D. cuneata* and *T. vipera*, respectively. However, the proportion of those fish that survived after being discarded due to damage was not estimated. The mortality for flatfish recorded for plaice (*Pleuronectes platessa*) by KAISER and SPENCER (2005) was around 61%. In the present study, mortality values for *T. vipera* (81% after 48h) and *D. cuneata* (54% after 48 hours) indicate that the survival of fish varies according to species. Indeed, the sensibility of a given species to fishing disturbances depends on its ability to survive the fishing process and this is directly related to the species' physiology, morphology and behaviour in response to the gear (KAISER; SPENCER, 1995). Determining the cause of death was beyond the scope of our survival experiments. Nevertheless, according to WARDLE (1986), the mortality of finfish caused by towing gear is generally associated with individuals falling back into the net due to exhaustion from swimming at trawl speed. However, considering the amount of sand that accumulated in the net bag during the tows, the most likely cause of death is probably related to individuals' being trapped inside the sand during the tow or to the weight of catches, during sorting, which may induce internal injuries (WASSENBERG; HILL, 1993; KAISER, SPENCER, 1995) leading to death from "non-apparent cause". In addition, although the sorting times of the catch are relatively short, exposure to air inevitably causes stress which may also have contributed to the high mortality observed (NEILSON et al. 1989; GASPAR; MONTEIRO, 1999; see review GASPAR; CHÍCHARO, 2007). The duration of the study was limited and it might, therefore, be open to discussion whether survival up to 48 hrs reflects actual survival of the disturbance due to fishing. Previous studies suggest different monitoring times (DAVIS, 2002; BROADHURST et al. 2006). BROADHURST et al., (2006) indicate that at least 3 days are required for determination of survival rates in beam trawl fisheries. However, Portuguese artisanal dredges are known to have a minor effect on benthic fauna and fish, as compared with beam and otter trawl fisheries, due to shorter tow duration, reduced depth and type of bottom (WASSENBERG; HILL, 1993; PRANOVI et al. 2001; KAISER, SPENCER, 1995; GASPAR et al., 2002, 2003a,b). Furthermore, higher mortalities are usually recorded during the first hours of surveying (KAISER, SPENCER, 1995; GASPAR, MONTEIRO, 1999). We believe, therefore, that our survey was adequate to observe the leveling-off in the survivor function of the species and we are confident that the total mortality associated with the capture and holding process was adequately taken into account.

Overall, mortality of damaged individuals in our study (after 48 hours) was always above 50% for all of the species studied, indicating that most of the injured crabs and fish will die after discarding. Nevertheless, it is of the utmost importance to understand the magnitude of the effects of bivalve harvesting on discarded bycatch species at the scale of the fishery. That requires evaluating the number of individuals that die per fishing day and for the entire dredge fleet. In the present case, despite the large mortalities observed, the estimated number of individuals captured, damaged and killed per 15 minute tow for the selected bycatch species was very small (1.2, 3.2, 11 for *D. cuneata*, *T. vipera* and *P. henslowii*, respectively). Considering that there are 11 dredge vessels operating on the northwestern coast of Portugal and that, on average, 24 tows of 15min duration are carried out per vessel per day, this amounts to an estimated mortality of 317 ind/day for *D. cuneata*, 855 ind/day for *T. vipera* and 2957 ind/day for *P. henslowii*, corresponding to 6kg, 16.8kg and 34kg per day, respectively. Comparing these catches to those of other kinds of fishing gear specifically designed to catch the species investigated, it seems that the dredge fishery may affect their populations. This seems particularly relevant for the populations of *D. cuneata*, given the characteristics of its life-cycle and the decreasing landing trends observed for the species. In July 2009, commercial landings of *D. cuneata* from artisanal vessels (mainly gill-netters) operating in the fishing area where this study took place (Matosinhos and Aveiro) reached 2307 kg (DGRM database). If we consider that in July the dredge fleet fished during 15 days then the *D. cuneata* bycatch caught by dredging would correspond to a meaningful 4% (~90kg) of the total landings recorded. Furthermore, the mortalities estimated relate only to juveniles, whereas only adults are included in the commercial landings. It is difficult to make similar approaches for the other taxa studied, since they are not discriminated in the official statistics. Nonetheless, in the case of *P. henslowii* the impact of discards is probably minimal since, according to the fishermen, during the summer this species is considered a plague due to its anomalous high abundance. It is worth noting that the estimates of mortality presented here should be analysed with caution, since the contribution of different species to bycatch (in number and weight) may change from season to season and in accordance with the fishing area. In dredge fisheries, fishing effort tends to be distributed spatially and seasonally, with fishermen exploiting a particular fishing bed for short periods of time, until catches drop to a nonprofitable yield, after which the clam bed remains unfished for periods of up to 2 years (GASPAR et al., 2002). This leads to a highly patchy distribution of fishing activity, which may reduce its cumulative effects on discarded bycatch species.

Our results indicate that survival studies contribute to increase the accuracy of estimations of bycatch mortality based solely on arbitrary damage scores. Although not investigated in the present study, additional mortality may occur through predation (see review by GASPAR and CHÍCHARO, 2007). Accordingly, the extend of this additional mortality must be quantified if we wish reliably to able to estimate total mortality associated with the discard practice. The fate of discards is a complex issue that should be further studied in order to successfully apply measures to minimize the impacts of this practice and to better understand the effects of fishing gear on the ecosystem.

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