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1.1. Introduction

Research aimed at determining whether aquatic organisms, which have been caught and subsequently returned to the water, survive has been conducted over many decades. Although there have been reviews of the outputs from this work (e.g. Davis, 2002; Broadhurst et al., 2006; Revill, 2012; Uhlmann and Broadhurst, 2013), comprehensive assessment of all the scientific methods and approaches that can be employed in meeting this aim was not started until 2014 by the means of an ICES Workshop on the Methods estimating discard survival (ICES WKMEDS). The impetus for this assessment were the recent changes in European Union fisheries policy, that required for guidance on how to investigate levels of discard survival. Article 15 of the reformed Common Fisheries Policy (CFP) Basic Regulation, which came into force on January 1st 2014, introduced a phased discard ban or landing obligation for regulated species. The policy includes a number of exemptions and flexibility tools. In paragraph 2(b), an exemption from the landing obligation is described for "species for which scientific evidence demonstrates high survival rates, taking into account the characteristics of the gear, of the fishing practices and of the ecosystem". Therefore, to support any proposal for an exemption for selected species or fisheries, clear, defensible, scientific evidence for high discard survival rates are required.

This has generated interest from various stakeholders in understanding the methods to generate discard survival estimates, and in the quality and robustness of the results from survival assessments. There are practical and scientific limitations to all of the methods currently available for estimating discard survival (ICES, 1995, 1997, 2000, 2004 and 2005; Revill, 2012; Gilman et al., 2013). Consequently, there is a need for the provision of guidelines, and identification of best practice, for undertaking discard-survival assessments. These are developed in the ICES Working Group on Methods for Estimating Discard Survival. The studies on survival could be classified into the following categories depending on the length of observations on survival:

1. <u>Short term survival</u>: number of individuals of a chosen species dead or alive after capture (including slipping, if any), prior to discarding.
2. <u>Mid-term survival</u>: number of individuals of a chosen species dead or alive after a few hours in a receptacle with aerated seawater onboard.
3. <u>Long-term survival</u>: number of individuals of a chosen species that are dead or alive after being kept in aquaria for several days.

In a literature review on survival information for Mediterranean species listed in Annex III of MEDREG, carried out by the Scientific, Technical and Economic Committee for fisheries STECF (Sala & Damalas, 2015) it was noted that the availability of this type of data was low for Southern Europe waters. Furthermore, the review aimed to define survival threshold and "high survival" as described under the EU legislative framework was defined as true survival >50% i.e. a greater proportion of fish surviving than dying (STECF 13-23).

Therefore, one of MINOUW tasks (T1.1B) was to review the literature for information on the survival of the species of interest for the project. A summary table was designed and distributed between the project partners as well as a literature review was undertaken. These are summarized for fish and invertebrates, respectively (Tables 1 and 2). It was agreed that to obtain greater publication and communication impact, the literature review could be combined with the experiments to be carried out in the MINOUW Action (Task

2.9) resulting into two publications (one for fish and another for invertebrates). These publications, irrespective of the other possible publications, will carry out a meta-analysis of the available data for invertebrates and for fish. The result of this review work is reported here as Deliverable D1.4.

Survival can be defined as: "The state or fact of continuing to live or exist, typically in spite of an accident, ordeal, or difficult circumstances" (OED, 2014). However, there can be varying states of "survival" where, depending upon the stresses and injuries endured, individuals can be defined as having differing levels of "vitality" (Davis, 2010; Dawkins, 2004). Understanding and measuring these signs of vitality can be useful for predicting the likelihood of survival in fisheries biology (e.g. Benoit et al., 2010; Davis, 2010).

1.2. Discard survival of fish in Mediterranean fisheries: An overview of the relevant scientific literature

In the 1980's the selectivity of the trawling nets was a subject of interest and much work was dedicated to assess the best gear modifications for allowing undersized fish to escape and to reduce unwanted species catch. Unless most of the fish escaping from trawl cod-ends survive, conservation regulations specifying minimum mesh sizes for cod-ends are of little value. Confirmation of the survival of escaping fish was of fundamental importance. Initial work by Main and Sangster (1988), Main and Sangster (1990) and Main and Sangster (1991) suggested that survival rates for haddock and whiting escaping through trawl net meshes could be quite high (80-90%), depending on the mesh size used. Soldal et al. (1991) reported that mortality was less than 10% for haddock and 0% for cod (*Gadus morhua* L.) escaping from a demersal trawl. Jacobsen et al. (1992), in studies with a demersal trawl, indicated that saithe (*Pollachius virens* (L.)) could withstand almost the same sorting through the net as cod, with low mortality. Soldal and Isaksen (1993) further reported that mortality after escape from the Danish seine net was negligible for cod and between 3.2 and 6.8% for haddock. Conversely, *Clupea harengus* L. escaping through a pelagic trawl (Suuronen et al., 1993) indicated a very high trawl induced mortality, in agreement with similar previous work (Suuronen,1991). Robinson et al. (1993) studied the survival rates of groundfish (Atlantic cod, American plaice (*Hippoglossoides plutessoides* (Fabr) and yellowtail flounder (*Limanda ferrugineosa* (Storer)) and concluded that survival rates were extremely variable and very dependent on season.

Thus, immediate and delayed mortalities on fish escaping from fishing gears are very variable depending on the species and the conditions of physical stressors experienced during the fishing process (Chopin and Arimoto 1995). These authors concluded in their review that using fishing gear selectivity as a fisheries management tool without adequate research into the condition of fish escaping from fishing gear may not be the most effective way to protect immature fish. Since these studies most research on fish survival after escaping from the nets has been focused on the North Atlantic and here in particular on demersal species (see WKMEDS 2014 report).

Despite mesh size regulations the proportion of unwanted catches that are brought onto the decks of fishing vessels, together with the target species, can be substantial, in particular in multispecies fisheries. The survival of these unwanted catches, if returned to the sea or discarded, may vary depending on the fish species, the type of fisheries and environmental conditions. Understanding which species experience high survival rates and which factors are influencing fish survival will help decision makers assess when discarding may be a feasible and recommendable from an ecological and management perspective. The main stressors identified to cause discard mortality are gear configuration, handling, deployment duration, body size, water temperature, air exposure, injury, depth, air temperature, gear operation and type, physical condition, season, catch volume, depredation, predation, sex, behavior, dissolved oxygen, light, catch composition, infection, location, catch density, recapture, salinity, sediment type, species, stress, weather and year (Table 7.1 WKMEDS 2014).

It has been demonstrated that most roundfish that are discarded from a vessel deck do not survive and are often taken by seabirds following fishing vessels (reviewed by Chopin and Arimoto 1995; ICES 2000; Suuronen 2005). Further, those fish that escape a trawl codend during a haul may not always survive. Selective fishing can be justified only if significant numbers of escaping animals survive. If most of them die, selective devices are of little conservation value. In towed fishing gears, escape often occurs after the fish have been subjected to a wide variety of stressors and possible damage through contact with other fish, debris or the gear itself. Nevertheless, experiments conducted in Scotland, Norway and Finland have shown high (80–100%) survival likelihood for many gadoid fish (e.g., cod, saithe) that escape from trawl codends (Main and Sangster 1990, 1991; Soldal et al. 1993; Sangster et al. 1996; Suuronen et al. 1996b, 2005; Soldal and Engås 1997; Wileman et al. 1999). For haddock and whiting, observed survival rates have been somewhat lower and more variable; around 60–90% (e.g., Sangster et al. 1996; Ingolfsson 2006). Substantially lower survival rates (10–50%) have been recorded for some pelagic species such as herring and vendace (e.g., Suuronen et al. 1995, 1996a, 1996c). Clearly, the robustness and ability of various species to withstand physical injury and fatigue associated with capture and escape vary markedly. Moreover, the smallest escapees often appear the most vulnerable. There are some indications that escape at night can result in higher mortality than escape in daylight conditions (Suuronen et al. 1995) but this has not been demonstrated conclusively. It is notable that very little is known about the survival of fish that escape during the haul-up of a trawl; survival may not be as high among fish that escape near the surface than among those that escape at the fishing depth during towing because the former are also vulnerable to predation by sea birds. Nevertheless, the survival likelihood of fish escaping from a fishing gear, whether it takes place during the capture or haul-up process is, in practice, always higher than survival of fish that are discarded from a vessel deck (Suuronen and Sardà 2007).

Discard survival of demersal fish has been demonstrated to be dependent on size and composition of catches as well as the sorting and handling once the fish are on deck. The size of the catch in a bottom trawl can negatively affect survival as shown for the spiny dogfish *Squalus acanthias* that was kept for 72 h in holding pens (Mandelman & Farrington 2007). Similarly sorting, handling, deployment duration, sea water temperature and fish size have also been shown to negatively affect survival of Lingcod *Ophiodon elongates* (Parker et al. 2003, Davis and Olla 2002).

1.3. Case Studies

Within the case study areas of the MINOUW project several past studies were performed on the survival of fish species.

European hake discard survival in the Atlantic was studied using fish captured in a special bottom net. The results demonstrated a short term mean survival of 68.2±14.5% and of 63% after 39 h. The main mortality causes were the composition and abundance of by-catch in particular if horse mackerel were part of the catch it had a negative impact on hake survival. Additionally the fishing depth influence catch survival (de Pontual et al. 2003). In a similar study on capture and tagging, the proportion of live hake captured was 58% (Piñeiro et al. 2007). Water temperature and fish condition were shown to be the main determinants in European hake survival (Jolivet et al. 2011), similar to those for cod (Dutil et al. 2006).

In the Algarve case study area, fishing simulation experiments were conducted to predicting the effects of purse-seine capture in sardine fisheries. Experiments were performed using fully acclimated and unstressed fish to monitor fish survival during simulated final stages of purse-seining (Marçalo et al., 2008, 2010). The experiments were designed to assess the role of net confinement (holding times of 10, 20, 40 and 60 min.), temperature (16, 18 and 23 ºC) and fish density on the survival of slipped sardines. Fish were observed for up to 10 days after simulated fishing in a tank. For all the experiments and treatments most mortality was observed within the first five days. Time of confinement was an important stressor, with survival rates decreasing from more than 70% to around 30% with increasing holding periods from 10/20 minutes to 40/60 minutes. Temperature showed an additional negative effect with lower survival at higher temperatures of 23 ºC i.e. 20% less than at lower temperatures of 16 or 18 ºC at any level of simulated fish duration. Density effects were less conclusive. In all these experiments data on the vulnerability of key species were obtained, clearly showing that survivorship is strongly related to good biological condition, higher vitality and low degree of damage. The results indicate that appropriately modified fishing operations and favourable environmental conditions may greatly enhance the probability of survival.

In a review of literature on survival rates on Mediterranean fishes and specially for the species listed in Annex III of the MEDREG (Sala & Damalas, 2015), it was noted that very few information is available. Figuerola et al. (2001) used a commercial otter bottom trawl on the Catalan coast and found relatively high (71.4%) survival of sole after 3 days. Tsagarakis et al. (2015) conducted a pilot experiment in the Ionian Sea trawl fisheries, showing that *Merluccius merluccius, Pagellus erythrinus* and *Trachurus* spp. survival was negligible, whilst seasonal effects were identified for *Diplodus annularis*.

Table 1. Fish survival experiments in the case study areas

Species	Survival	Fishing method	Location	Duration	reference
Sardina pilchardus	52%	Purse-seine	Algarve	2 months	Marçalo et al.2008
Sardina pilchardus	30-70%	Purse-seine	Algarve	2 weeks	Marçalo et al.2010
Merluccius merluccius	0%	Experimental Bottom trawl	Ionian Sea	72 h	Tsagarakis et al 2015
Pagellus erythrinnus	Spring:3.9 % Autumn 0%	Experimental Bottom trawl	Ionian Sea	72 h	Tsagarakis et al 2015
Pagellus erythrinnus	Spring:3.9 % Autumn 0%	Experimental Bottom trawl	Ionian Sea	72 h	Tsagarakis et al 2015
Solea vulgaris	71.4%	Experimental Bottom	Catalan Sea	3 days	Figuerola et al 2001

		trawl			
Trachurus spp.	0%	Experimental Bottom trawl	Catalan Sea	3 days	Figuerola et al 2001

1.4. Discard survival of invertebrates: An overview of the relevant scientific literature

The published literature about the survival of discarded unwanted invertebrate catches appears relatively limited (Broadhurst et al. 2006), in particular with respect to survival experiments in tanks following capture over short or long-term periods, hours and days respectively (see Table 1). More frequent for invertebrates are studies that determine the direct damage caused by the fishing procedures, inferring survival by calculating the percentage of undamaged animals in the catch (Bergmann et al. 2001, Figuerola et al. 2001, Jenkins et al. 2001, Pranovi et al. 2001, Sartor et al. 2006, Leitão et al. 2009). In most cases however, the survival is only implied and is not validated by experimentation. Therefore, most of these studies are likely to have overestimated survival rates.

Survival experiments monitoring survival rates of animals in tanks after capture have primarily been conducted in the Atlantic, either on juvenile species of target species, i.e. juveniles of commercial crustaceans and bivalves (Lancaster & Frid 2002, Castro et al. 2003, Gamito & Cabral 2003) or non-target species (Kaiser & Spencer 1995, Figuerola et al. 2001, Depestele et al. 2014). The only published studies that investigated considerable numbers of non-target species were conducted in the Irish Sea by Kaiser & Spencer (1995), in the North Sea by Depestele et al. (2014) and more recently in the Ionian Sea/Central Mediterranean by Tsagarakis et al. (2015). These studies investigated discard survival of beam trawl and otter trawl fisheries and have the most extensive lists of non-target invertebrate survival with 16, 7 and 5 invertebrate species respectively.

Most papers on bycatch survival focus on otter trawling and beam trawling while few studies have focused on dredging (see Table 2). No published study was thus far sighted describing invertebrate bycatch survival of artisanal fishing methods.

Table 2. Summary of study types of published literature on invertebrate discard survival

Region/Type of studies	**Target species survival in tanks**	**Bycatch survival in tanks**	**Damage assessment**	**Mortality related to air exposure**	**Total**
Adriatic Sea			2	2	4
Bay of Biscay and Iberian Coast	2		1	1	4
Celtic Sea	1	3	2		6
Greater North Sea		1			1
Ionian Sea and the Central Mediterranean		1			1
Western Mediterranean Sea		1	2		2
Total	**3**	**5**	**7**	**3**	**18**

The great majority of papers assesses immediate survival (after transferral of caught animals to tanks strait after capture) and short-term survival of invertebrates (after commercial catch processing, prior to discarding), while few assess long-term survival on the scale of days to weeks (but see Kaiser & Spencer 1995, Bergmann 2001a, b, Depestele et al. 2014, Tsagarakis et al. 2015). In general times of observation vary greatly within and between studies ranging from 17-696 hours.

In the Mediterranean very few studies are available that investigate bycatch survival. The few existing studies to date are focused on the rapido trawl fisheries in the Adriatic (Giomi et al. 2008, Raicevich et al. 2010, 2014) and otter trawling in the Ionian Sea/ (Tsagarakis et al. 2015). Bycatch survival data is thus far lacking for other trawl and dredge fisheries from other regions of the Mediterranean while information from artisanal fishing methods are lacking in general.

Table 3. Summary table of published literature on short and long term survival of invertebrate discards. Short-term indirect studies comprise studies on damage assessments (figure indicates number of studies published).

Fishing gear	**Short-term indirect**	**Short-term**	**Long-term**	**Total**
Beam trawl	3	2	3	8
Dredge	2	1		3
Otter trawl	2	2	3	7
Grand Total	**7**	**5**	**6**	**18**

Evident form the literature is that the length of exposure to air and ambient temperature have the greatest bearing on invertebrate survival apart from the animals morphological composure and type of fisheries (Giomi et al. 2008, Raicevich et al. 2010, 2014). Several studies thus focus particularly on this aspect and investigate the short term survival of invertebrates to different length of air exposure (Gaspar & Monteiro 1999, Giomi et al. 2008, Raicevich et al. 2010, 2014).The combination of thermal shock and air exposure are thought to be the principle factors causing stress and mortality for animals that have survived the capture process. Some fisheries therefore show strong seasonal trends of survival, with survival being greatly increased in winter compared to summer month (Castro et al. 2003, Giomi et al. 2008). Henceforth, fishing in cold seasons can considerably increase bycatch survival.

In summary published information on the survival of unwanted invertebrate catches is scarce in general but in particular for the Mediterranean and Southern Europe waters. Overall there appears to be the need for longer-term survival experiments that are able to more precisely estimate invertebrate survival under different fishing and environmental conditions. If damage scores are used, they should be validated by long-term survival experiments as mentioned above. As thermal shock appears to be one of the main factor driving post catch mortality this factor should be assessed by future studies i.e. sea and air temperatures need to be measured alongside catches.

1.5. Discussion

It is evident that the numerous possible causes of mortality and related mechanisms need to be considered on a case by case basis when determining whether high survival rates may be possible for stocks falling under the landing obligation. The likely uncertainty associated with estimated mortality rates should be taken into account (see differences in survival in Table 1 for fish). The inherent difficulty in the determination of survival is apparent in the few publications available, which are very scarce for the Mediterranean (see bibliography) for both fish and invertebrate species. It appears evident that information on the survival after discarding target and non-target species is lacking for many Mediterranean fisheries. Thus without the collection of more data informed decision making with respect to discarding practices of many fisheries cannot be made with confidence. The current survival experiments conducted within this project therefore will provide important data to close some of the knowledge gaps with respect to Mediterranean fisheries.

However, the main factors affecting survival are:

- The manner in which the fishing operation is carried out: fishing gear type, duration of the fishing operation, movement of fishing gear during capture, hauling speed, catch composition and crowding density, hauling on board, handling, sorting and treatment of catches, experience of the crew.
- Manner in which discards are returned to the sea.
- Environmental conditions such as water and air temperature, and season of the year.

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