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1. Executive Summary

The introduction of a Landing Obligation (LO), under the EU Common Fisheries Policy (CFP), aims to shift harvesting patterns in EU fisheries by reducing the capture of unwanted catches, by banning discarding practices and encouraging more selective capture methods. While there are descriptions and estimates of the magnitude of discarding in Mediterranean and southern European fisheries (e.g. Damalas et al, 2015), there is currently very little information on the fate of the discarded animals, in terms of their likely survival following the stresses of capture, handling and discarding (STECF EWG 15-14). During the introduction of the LO, it will be important to have estimates of the likely survival of the unwanted catch for several reasons, including:

discard survival estimates for regulated species will inform fisheries managers on the likely benefit of the Landing Obligation in terms of shifts in harvesting patterns and resulting changes in fishing related mortality;

Non-regulated and protected species are likely to continue to be released after capture, so data on their fate will also be useful for interpreting the effect of the Landing Obligation across the wider ecosystem; and

Robust data on discard survival will also help identify species that may be applicable for a “High Survival Exemption”, under article 15, para. 4b of the CFP.

This report presents the results of survival assessments conducted as part of Project MINOUW, Task 2.9, and using methods recommended by ICES WKMEDS.

It provides survival related data from a variety of methods, including vitality assessment and time-to-mortality observations, as well as more in-depth survival assessments using captive observation techniques. This has enabled an initial assessment of the vulnerability of over 100 species to the stressors associated with capture in seven different fisheries, from which some inferences can be made on the potential of these animals to survive the discarding process.

This data was collected from nine case-study based assessments, including:

CS 1.2 Algarve deepwater crustacean trawl fishery – bycatch species;

CS 1.4a Catalan sea bottom trawl fishery – *Nephrops*

CS 1.4b Catalan sea bottom trawl fishery – *bycatch species*

CS 1.6/1.8 Ligurian & N. Tyrrenian Sea bottom trawl

CS 2.2 Algarve purse seine – sardine survival after slipping

CS 3.2 Balearic Islands set net fisheries;

CS 3.3 Balearic Islands seine net fisheries;

CS 3.4 Catalonian Trammel nets; and
CS 3.5 Ligurian and N Tyrrhenian Seas trammel net fisheries.

Summary abstracts for each case study are presented at the end of this executive summary.

Synopsis & Conclusions

The nine case-studies conducted as part of Task 2.9 [Assessing and Promoting Survival] have provided much needed information on the post-release survival potential for over one hundred species from a diverse range of taxa (from holothurians, gastropods, and crustaceans to several fish species) caught in a wide selection of fisheries and capture methods.

Most of the studies have focused on assessing the immediate and short-term (i.e. <96 hours) survival potential of the unwanted components of the catch, by monitoring their vitality as they were sorted from the catch and for short periods after that. The main objective of these preliminary assessments was to identify species that have a high potential for post-release survival, and thus inform any prioritisation and scoping of full-scale survival assessments in these fisheries. At the same time, these studies have also identified a list of species for which post-release survival is highly unlikely, in those respective fisheries and operating conditions. These data will be very informative for assessing the ecological consequences of fishing and the effects of any shifts in harvesting practices.

Two studies used captive observation methods to provide scientifically robust estimates of post-release survival estimates for regulated target species: CS 1.4 (Nephrops in the Catalonian crustacean trawl fishery) and CS 2.2 (Sardine in the Algarve purse seine fishery). In both cases, it was demonstrated that under appropriate conditions and handling practices the majority of animals for these two species could survive being caught and released from their respective fisheries. However, it should be recognised that these captive observation techniques cannot account for the increased likelihood of predation following release (e.g. Raby et al, 2013).

The studies described in this report have demonstrated that there are several determinants in the survival of any released animals, including: species, capture method, and their interactions, as well as the environmental conditions and handling practices during the capture and release process.

Species: the ability of an animal to endure the stressors associated with capture and release from fishing operations will be dependent upon key biological characteristics (e.g. de Juan and Demestre, 2012), including: body form and size, integument (skin) form and robustness, presence and form of a swim-bladder, as well as behavioural traits and baseline metabolism. These biological characteristics will make an animal more or less vulnerable to different stressors during the capture and release process, and as such this vulnerability will be dependent upon the nature of the capture method (see below). Thus in case-studies which examined several species in the catch (e.g. CS1.2, CS1.4, CS1.6 and CS3.2), a wide range vitality states were observed amongst different species sorted from the catch. For a more in depth discussion on these points see the separate report: D2.15 Guidance on Promoting Survival of Discarded Fish.

Size: a key biological characteristic that was not explored in-depth as part of these studies, primarily due to small sample sizes, was the effect of individual size upon survival. In the scientific literature, there is growing evidence to support a general hypothesis that large animals within a species have a higher probability of surviving capture and release from fishing gears (e.g. Sangster et al, 1996; Suuronen, 2005). This is an important consideration with regards to the management of a fishery and its discarding practices, because typically it is the undersized animals that are selectively returned to the sea.

Capture Method: Of the 11 broad categories of fishing gear recognised by the FAO International Standard Statistical Classification of Fishing Gear (ISSCFG) (FAO, 1990), this report includes survival data for animals caught in five types: demersal trawls, dredges, surrounding nets (boat & purse seine) and entangling nets (trammel nets). These various fishing methods have quite different modes of operation and thus differing effects on the animals encountering them. Deliverable report D2.15 describes the likely injurious mechanisms in each gear in some detail, and the likely stressors encountered by a captured animal are likely to include: hypoxia, exhaustion, barotrauma, temperature shock, osmoregulatory distress, crowding, physical trauma/injury, light exposure, emersion, displacement and predation.

Typically, it is assumed that the stressors experienced by capture in towed fishing gears are likely to be more severe than those in passive gears (e.g. trammel nets), resulting in lower vitality amongst the capture animals. For example, murex (*Bolinus brandaris*) caught in trammel nets had 100% of individuals with “excellent” or “good” vitality scores (which corresponded to 87% survival at 64 hours), while dredges (“rastell”) only had 65.74% with these vitality levels; due to capture related damage to their shells. However, *Scyliorhinus canicula* caught in demersal trawls in the Tyrrenian Sea had a high proportion of animals with excellent or good vitality states (82.3%), while the same species caught in Balearic trammel nets were typically dead as the catch was brought on board (<20% survival).

Environmental conditions: including the fishing depth, sea state, water temperature, salinity, presence of thermo- and halo-clines, air temperature, etc, can all affect post-release survival (see Deliverable report D2.15 for detailed discussion). In this project, increasing water temperature was noted to have negative effect on survival in two case studies CS1.4 and CS3.3. In CS1.4, survival was best during the Winter, when water temperatures were coolest. In CS3.3, survival was predicted to drop to nearly zero when water temperature was above 15.8 ºC.

Handling of the catch by the fishermen is one of the major determinants in the survival of any released animals. At one extreme, in CS 3.5 [Ligurian coast trammel net fisheries], handling practices are so unsympathetic to the welfare of the captive animals (i.e. long term air exposure, breaking of the body parts to release them from the net) that their post-release survival is highly unlikely. However, in CS 2.2 [Sardines in Algarve Purse Seine], it has been demonstrated that through simple, but well considered, improvements in handling practices (i.e. allowing the fish to swim freely from a purpose-made opening in the net) the survival of these delicate fish can be significantly increased. It is also important to recognise that the survival potential of released fish in both CS2.2 and CS 3.3 [Glass Goby in Balearic Boat Seine] is greatly enhanced by minimising the exposure these animals have to emersion from the water. This simple but profound principle could be generally applied to most fishing practices to generally improve the welfare of the captive animals, both targeted and unwanted catch, and thus improve the likelihood of any released animals. This and other welfare sympathetic handling practices are described and discussed in more detail in a separate report: D2.15 Guidance on Promoting Survival of Discarded Fish.

CS 1.2. Study of by-catch species susceptibilities to discard mortality in Algarve deep-water crustacean trawl fishery

This deep-water multi-species fishery targets the rose shrimp *Parapenaeus longirostris*, the red shrimp *Aristeus antennatus* and the Norway lobster *Nephrops norvegicus*, at fishing depths of between 200 and 700 meters. Up to 80 % of the total weight in each haul is unwanted catch, with a high proportion of non-commercial species, for with there is no information on survival potential. This preliminary work provided estimates of immediate mortality, as well as time to mortality (TTM), for a wide range of species. From this study, it can be concluded that *M. poutassou*, *P. blennoides*, *L. boscii*, *T. lyra*, *M. merluccius*, *M. surmuletus*, *Trachurus spp*., and *H. dactylopterus* are all vulnerable to the stressors associated with capture in this bottom trawl fishery, as well as exposure to air on deck. As such they are likely to have high mortalities (approaching 100%) if discarded in this fishery. However, some species including *G. melastomus* and *Lophius spp*., and especially *S. canicula* and *C. conger,* demonstrated some resilience to these stressors and may warrant further investigation to establish more robust estimates of survival potential.

CS1.4. Survival of discarded *Nephrops norvegicus* from the Catalan sea bottom trawl fishery.

A captive observation survival assessment was conducted in three seasons (spring, summer and winter) from May 2016 to January 2017 in fishing grounds adjacent to Blanes, called “La Malica”, between 250 and 450 meters deep. Sample animals were collected from 10 hauls aboard a commercial fishing trawler, within 10 minutes of the catch arriving on deck, and later transferred to experimental aquaria facilities at the Institute of Marine Science (ICM) in Barcelona. All animals were assessed for vitality (on a four-point categorical scale) at regular intervals during a 2 week monitoring period. High survival was observed for *Nephrops norvegicus* discarded in winter (0.739; CI: 0.699 - 0.781) (January). Significantly lower survival was observed during spring (May) 0.357; CI: 0.309 - 0.412) and summer (August) 0.0575; CI: 0.0367-0.0901). Although it is uncertain whether this is a true seasonal effect or whether it has been biased by elevated water temperatures in the holding tanks during collection and transfer. Analysis of vitality states of animals in this study suggest that vitality assessments could be useful predictors of discard mortality for discarded *Nephrops norvegicus*; which should be investigated further in future studies.

CS 1.4. Catalan sea bottom trawl fishery – Survival of Discarded Bycatch

Two bottom trawl fisheries can be differentiated in Catalonia, a continental-shelf fishery targeting mainly hake, red mullets and octopus, and a deep-water fishery targeting the highly prized crustaceans (red shrimp and Norway lobster). They exploit over 100 demersal and benthic species of finfish, crustaceans, and molluscs; and discards rates are known to be high, particularly for non-regulated and non-commercial species. The objective of this study was to provide a preliminary assessment of the survival of non-regulated invertebrates discarded from trawlers, based at the port of Blanes on the North Catalan Coast. The assessment used vitality assessments conducted at regular periods during a 96-hour monitoring period. Of 22 species observed during the study, only six species had large enough sample sizes to conduct meaningful survival assessments. Of these, three displayed no mortality during the 96 hour observation period: *Antedon mediterranea, Cidaris cidaris* and *Dardanus arrosor (survival 1.0).* While the remaining three species generally had relatively high survival: *Echinaster sepositus (0.938; CI 0.826 – 1), Ophiura texturata (0.789; CI 0.670 – 0.930)* and *Leptometra phalangium (0.724; CI 0.656 – 0.798).* However, the observation period of only 96 hours was too short to observe any stabilisation of mortality for at least two species. Therefore, it is recommended that future assessments of invertebrate discard survival should monitor for longer periods, ideally until any apparent mortality has stabilised.

CS1.6 & 1.8. Preliminary estimation of discard vitality rates in the southern Tuscany otter trawl fishery

The trawl fleet in the Ligurian and northern Tyrrhenian Seas consists of 330 boats, representing about 70% of the fishing capacity in the area; with landings of about 8,000 tonnes. Catch composition is typically fish (58%), molluscs (27%) and crustaceans (15%); with the most important species being European hake, red mullet and horned octopus; the crustaceans Norway lobster, deep-water pink shrimp, and giant red shrimps. These fisheries are also characterised by high proportions of undersized regulated and commercially important species, as well as non-commercial species. The objective of this prioritisation study was to identify species that would be suitable for more in-depth discard survival assessments. This could be justified if species were demonstrated to have a high proportion of animals with high vitality at the point discarding. Survival potential was investigated using categorical vitality assessments of catches under normal fishing conditions. The results of this preliminary analysis indicate that regulated species in this fishery (species included in the Annex III of Reg. EC 1967/2006) generally have a low vitality when discarded. However, five potentially commercially important discarded species were observed with high vitality scores, namely: C. conger, D. oxyrinchus, Scorpaena spp., S. canicula and U. scaber. In addition, 12 non-commercial species had with high vitality scores, including: C. macropus, Galeodea spp., Macropodia spp., O. rufus, Ophiura spp., Pagurus spp., P. cuvieri., P. canaliculata, Serranus spp., S. cabrilla, S. macrochelos and T. torpedo. Although, these species are not currently subject to the Landing Obligation, reliable data on their survival potential could be invaluable for interpreting the effect of the Landing Obligation across the wider ecosystem.

CS 2.2 Algarve Purse seine – survival of slipped sardines

The Portuguese purse-seine fishery targeting European sardine (*Sardina pilchardus*) is responsible for ~50%, in biomass, of fish catches landed in mainland ports. In response to the recent decline of the sardine stock, restrictive fishing measures, including a seasonal “sardine ban”, have been applied to promote the sustainability of the resource. If any sardine is caught during the “sardine ban”, the fishermen are obliged to release the catch via “slipping”. Off Portugal, commercial purse seining operations typically end with complete bunting/crowding of the catch (to enable the fisher to inspect the catch) and thus any slipping would constitute a stressful event, culminating in variable delayed mortality of escapees. The aim of this study was to test methods for minimising mortality of sardines released, or “slipped”, from purse seines off the Algarve coast (Portuguese Southern coast) in two different scenarios, standard and modified. The standard slipping aggregated fish at high densities and made them roll over the floatline, while the modified procedure aggregated the fish at moderate densities and enabled them to escape through an opening created by adding weights to the floatline. Both slipping methods were compared with a control: sardines collected from the loosely bunted pocket of the purse seine. Sub-samples of fish were taken from a commercial purse seine catch and then transferred to observation tanks in an aquaculture centre and monitored for 28 days. For all treatments, most deaths occurred within the first 3-5 days, followed by low rates of mortality in the remaining observation period. Survival at asymptote (with 95% CI) was estimated at 43.6% (CI: 38.0 to 49.3) for the control, 44.7% (CI: 39.3 to 50.1) for the modified slipping and 11.7% (CI: 8.9 to 15.2) for the standard slipping treatments. The results of this survival assessment demonstrate that using a modified slipping technique during purse seine operations may significantly improve survival of slipped pelagic fish.

CS 3.2. Balearic set net fisheries: small-scale trammel netting for the common spiny lobster (*Palinurus elephas*)

Most small-scale vessels in Balearic Islands use trammel nets during some part of the year. Different types and tactics (i.e., métiers) are used, but the trammel nets targeting the common spiny lobster *Palinurus elephas* (Fabricius, 1787) have been one of the most relevant for the 2004-2015 period for the small-scale fleet in effort (21,9%), landings (700 tons) and revenues (25.7 % gross revenues). The target species, spiny lobster (*Palinurus elephas*) which is a regulated species with minimum size of catch 90 cm carapace length (EU Regulation 1967/2006, Annex III) and is thus included in the landing obligation. However, undersized lobsters are frequently returned to sea by the fisherman. The aim of this case-study is to assess the post-release survival of juvenile undersized spiny lobsters (*Palinurus elephas*) and other by-catch species, including: *Leucoraja naevus, Parastichopus regalis, Raja clavata, Scyliorhinus canicula, Scorpaena scrofa* and *Lophius piscatorius*. Undersized *Palinurus elephas* and two by-catch species (*Leucoraja naevus* and *Parastichopus regalis*), had immediate survival probabilities of >0.6, whilst all other species had immediate survival of <0.2.

Spiny lobster (*Palinurus elephas)* were observed to have a relatively high survival (64.2 %; 95% CI: 54.3-76.0%) for up to 7 days after their initial capture. These results suggest that the population of *Palinurus elephas* exploited in Balearic trammel nets could benefit from a "high survival" exemption to the landing obligation (1380/2013, Article 15). Specifically, an obligatory return of undersized spiny lobsters to the sea could provide substantial benefits by reducing unnecessary mortality in undersized lobster. Therefore, it is recommended that an exemption from the Landing Obligation should be sought for spiny lobster (*Palinurus elephas)* in the Balearic trammel net fishery, with respect to article 15, paragraph 4b of the Common Fisheries Policy (EU Regulation 1380/2013).

CS 3.3. Balearic Islands boat seine fisheries: Assessing post-release mortality for the transparent goby fishery in the Balearic Islands

In the boat-seine transparent goby fishery, there is a daily quota for the target species: 30 kg/day/boat for *Aphia minuta* and 50 kg/day/boat for *Pseudaphia ferreri*. If the catch exceeds the quota or by-catch limit (10% of total catch) the cod-end is usually opened and the catch is released. The objective of this study was to assess the survival potential of the target species, *Aphia minuta* and *Pseudaphia ferreri,* after released from the boat seines. The survival of fish sampled from the catch was determined as the fish were taken aboard the vessel, as well as when the catch (held in oxygenated water containers) arrived at port (1 to 9 hours later). The immediate survival when the fish arrived at deck was relatively high with an averaged observed value of 92.4% (estimated Bayesian 95% CI between 46.5 and 100%). However, the averaged observed survival after around 4 hours of captivity was only 27.3% (estimated Bayesian 95% CI of asymptotic survival between 13.5 and 40.2%). A Bayesian model was developed to evaluate the parameters affecting survival, which suggested temperature was a significant explanatory variable, with predicted survival dropping to nearly zero when water temperature was above 15.8 ºC. The depth of capture also influenced survival but to a lesser degree. In addition, the vitality of fish arriving at port was measured, by assessing swimming speed and response to a stimulus, and could be used as a proxy indicator of the survival potential of any released animals. The device developed to measure vitality may result in knowledge transfer and a patent is being considered.

CS 3.4 Catalonian Trammel nets – *Murex (Bolinus brandaris).*

The purple dye murex, Bolinus brandaris, has traditionally been caught by several artisanal fishing gears (trammel nets, basket traps, towed gears), and since the 1980s by a modified beam trawl (the "rastell"). Local authorities are currently drafting a new management plan for the "rastell" fishery, which specifically needs to address the potential post-release survival of undersize individuals. A minimum conservation size of 25 mm (Shell width) is currently in place but "rastell" is not very size selective and catches of undersize animals are up to 50% of total catch. The objective of this assessment was to determine the vitality of purple murex after capture using the two different gears: trammel-nets and "rastell". Samples of undersize murex caught in "rastell" and trammel nets were taken, within 30 minutes of hauling the fishing gear on board (t0), and placed in containers with water at ambient temperatures (24 – 26 ºC). Specimens were assessed for vitality on a 4 point categorical scale (CVA) devised for this study. In addition, murex from the "rastell" were monitored for a further 64 hours in aquariums at the ICM laboratory, with vitality assessments repeat at 12 hour intervals. The condition of murex at t0 was best in the specimens caught by trammel net fishery, where nearly all individuals were in excellent vitality (87%; with the remaining 13% in good condition), while in beam trawl individuals were found to be spread equally among the 3 states (1/3 each, approximately). For “rastell” caught murex monitored for 64 hours, all animals with vitality states 1 and 2 had 100% survival., while only 5 out of 62 vitality state 3 animals died, resulting in an overall estimated survival of 87.1% (95% CI: 79.1 to 95.9%). However, this study only monitored the undersized animals for 64 hours and thus did not describe survival at asymptote. So it is recommended that these captive observations should be expanded in duration in order to describe the asymptotic survival and be replicated at different times of the year.

CS 3.5 Preliminary estimation of discard vitality rates in the Ligurian trammel net fishery

Trammel nets to target caramote prawn (*Melicertus kerathurus*) Ligurian Sea are known to have substantial catches of bycatch and unwanted species (i.e., crabs, hermit crabs, and other invertebrates). A prioritisation study was planned to identify species that would be suitable for more in-depth survival assessment. The planned approach for estimating survival rates was to use vitality assessments of catches under normal fishing conditions (ICES, 2014 & 2017), with a categorial vitality assessment based on Benoit et al. (2010). Further assessment of survival potential could be justified if species were demonstrated to have a high proportion of animals with high vitality at the point discarding. However, handling practices were observed to so unsympathetic to the welfare of the captive animals (i.e. long term air exposure, breaking of the body parts to release them from the net) that their post-release survival is highly unlikely.

2. Introduction

The introduction of a Landing Obligation (LO), under the EU Common Fisheries Policy (CFP), aims to shift harvesting patterns in EU fisheries by reducing the capture of unwanted catches, by banning discarding practices and encouraging more selective capture methods. While there are descriptions and estimates of the magnitude of discarding in Mediterranean and southern European fisheries (e.g. Damalas et al, 2015), there is currently very little information on the fate of the discarded animals, in terms of there likely survival following the stresses of capture, handling and discarding (STECF EWG 15-14). During the introduction of the LO, it will be important to have estimates of the likely survival of the unwanted catch for several reasons, including:

1) discard survival estimates for regulated species will inform fisheries managers on the likely benefit of the Landing Obligation in terms of shifts in harvesting patterns and resulting changes in fishing related mortality;
2) Non-regulated and protected species are likely to continue to be released after capture, so data on their fate will also be useful for interpreting the effect of the Landing Obligation across the wider ecosystem; and
3) Robust data on discard survival will also help identify species that may be applicable for a “High Survival Exemption, under article 15, para. 4b of the CFP.

For more details of the Landing Obligation, in context with the Mediterranean and Southern European waters, see appendix 1

<u>MINOUW Survival Assessments</u>

To address this lack of information on discard survival in the Mediterranean and southern European fisheries Project MINOUW established Task 2.9 in WP2 to collect relevant data using methods recommended by ICES WKMEDS (ICES 2014 & 2017).

T2.9. Assessing and Promoting Survival (from the Description of Actions).

Assess the survival potential of releasable catch (i.e. non-regulated, protected and “high-survival” species) using ICES WKMEDS recommended techniques. Develop innovative solutions to reduce post-catch losses, including: live capture, benign gear design and handling practices. This task will be addressed in the case studies:

1.2 Algarve deepwater crustacean trawl fishery;

1.4 Catalan sea bottom trawl fishery;

1.6* Ligurian & N. Tyrrenian Sea bottom trawl*

2.2 Algarve purse seine;

3.2 Balearic islands set net fisheries;

3.3 Balearic islands seine net fisheries;

3.4# Catalonian Trammel nets# and

3.5 Trammel net fisheries in Ligurian and N Tyrrhenian seas

Survival estimates from each case study will parameterise models in WP3 and be submitted for publication in a peer reviewed journal. Technical reports will provide guidance on innovative gear designs and handling practices to promote post-release survival, and will also be submitted for publication in a peer-reviewed journal.

Responsible and participants: CSIC, DGMRM, CIBM, CCMAR, IMR

* CS 1.6 “Ligurian & N. Tyrrenian Sea bottom trawl” replaces CS 1.7 “Aegean sea bottom trawl” which was originally included in this task.

CS3.4 - Catalonian Trammel nets was included in this task after the beginning of the project.

To coordinate experimental design and methodological approaches for collecting relevant data among the different case studies in this task a seminar was held as part the Second Plenary Meeting in Olhão, Portugal (1st March 2016; session 3.2).

To further support the analysis of the resultant data, using ICES WKMEDS recommended methods, and promote the publication of this work, a MINOUW Survival Analysis Workshop was held as CSIC in Barcelona (13-17th March 2017), with the attendance of the external expert Hugues Benoît from DFO-MPO Canada. The objectives of this meeting were:

- Provide an overview of WKMEDS recommended methods for analysing and summarising the results of discard survival assessments;
- Review methods and data from survival assessments in each case study;
- Plan and conduct analysis of survival data from each case study (with support from Hugues Benoit & Mike Breen);
- Discuss ways of promoting survival of discarded animals, in context with the results from the various case studies; and
- Coordinate the reporting of the survival results from each case study with respect to the deliverables:
  - D2.15: Guidance on promoting discard survival; and
  - D2.16: Data on the survival of unwanted catch.

<u>Report Objective</u>

This report will present the results of survival assessments conducted as part of Project MINOUW, and using methods recommended by ICES WKMEDS, including:

1.2 Algarve deepwater crustacean trawl fishery – bycatch species;

1.4a Catalan sea bottom trawl fishery – *Nephrops*

1.4b Catalan sea bottom trawl fishery – *bycatch species*

1.8 Ligurian & N. Tyrrenian Sea bottom trawl

2.2 Algarve purse seine;

3.2 Balearic Islands set net fisheries;

3.3 Balearic Islands seine net fisheries;

3.4 Catalonian Trammel nets; and

3.5 Ligurian and N Tyrrhenian Seas trammel net fisheries.

3. Case Study Results

CS 1.2. Study of by-catch species susceptibilities to discard mortality in Algarve deep-water crustacean trawl fishery

Ana Catarina Vasconcelos Adão, Mike Breen and Teresa Cerveira Borges

Case study description

Bottom trawling for crustaceans in Portuguese coastal waters constitutes a highly profitable fishery, although it is known to have negative impacts on deep-sea communities and marine ecosystems (e.g. Borges et al. 2001). This deep-water multi-species fishery targets the rose shrimp *Parapenaeus longirostris*, the red shrimp *Aristeus antennatus* and the Norway lobster *Nephrops norvegicus* and concentrates around the Canyons of Lagos, Portimão and Faro (Barlavento or occidental coast of the Algarve), between 200 and 700 meters depth (Campos et al., 2007). Up to 80% of the total weight in each haul is unwanted catch, high in species diversity but few species with commercial interest, so most is discarded (Borges et al. 2001). Survival estimates for discarded and escaping *N. norvegicus* are available for this fishery (Castro et al., 2003; Campos et al., 2015). However, there is no available information on the survival of other discarded species. Discard mortality rates need to be evaluated in order to account for total fishing mortality and in which extent trawling activities affect marine biodiversity. Furthermore, robust scientific data of discard survival may contribute towards exemptions to the Landing Obligation for species with “high survival”.

Objective

In this study, vitality assessments (time-to-mortality or TTM and a categorical vitality assessment, CVA) were used to estimate immediate or short-term mortality of a group of 19 by-catch species, in order to verify and prioritise which species might have the potential for survival for future experiments. These indicators are simple and easy to apply on-board commercial activities and for a wide range of species. The effects of biological traits (e.g. size, presence of gas bladder, scales and injuries) on TTM and CVA were also considered since these determine to a great degree the susceptibility of a species to die after being caught and discarded.

Methods

<u>Fishing operations</u>

Sampling was conducted in December 2016 (during 6 days) and February 2017 (5 days duration) in a commercial fishing vessel along the south coast of Portugal, at a minimum distance of 6 nautical miles off the coast (Figure 1). Positional data (latitude and longitude), depth, fishing operation details and environmental information (air temperature, sea state and light level) were recorded for most hauls. The trawl gear was towed during 4 h (1.75 h minimum and 14.62 h maximum), between 123 and 841 meters depth. Average speed of towing was 2.9-3 knots, and hauling took 20 minutes on average. The cod end was emptied into a container below deck and in most hauls the net was re-deployed prior to catch sorting, which lasted around 7 minutes. Time 0 was defined as when the catch was dropped into this contain container below deck. The crew sorted the catch by hand and samples were taken right after the sorting process started.

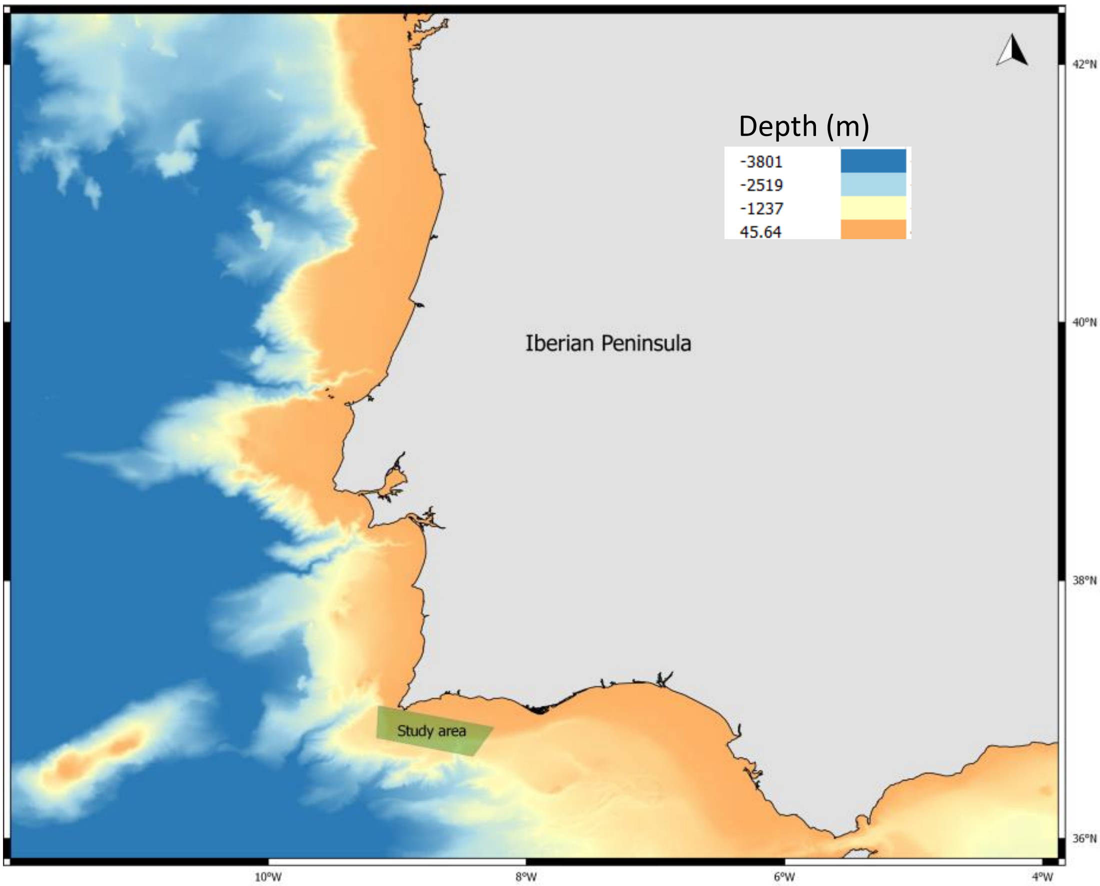


Figure 1. Study area (in green) where the trawls were performed

<u>Vitality assessments</u>

Two vitality assessment methods were applied: a categorical vitality assessment (CVA) with 4 levels characterizing the vitality state and time-to-mortality (TTM), defined as the time required to induce mortality during air exposure (ICES 2014, Benoit et al. 2012; table 1). Additionally, external damage was also recorded for each individual, based on simple descriptions of 4 types of injuries (scored as present, 1, when clearly observed and as absent 0, when not present or when was not obvious its occurrence; table 2).

For practical reasons, samples of 10 to 15 individuals were collected from each of two or three study species for further mortality monitoring. Individuals were repeatedly monitored for 2-3 seconds for vitality assessment and injury evaluation, until there were no signs of life. Immobile individuals were manipulated and tested for reflex responses in order to ensure a dead status (if at least one of the reflexes was present, the individual was considered still alive; table 3). At the end of the monitoring period, total body length was measured and individuals of some species frozen for later observations of the type of gas bladder. Possible explanatory variables with regards to biological traits were scored as present (1) or absent (0).

Table 1. Description of the codes used to score the vitality (Benoit *et al*. 2010)

Vitality state	Score	Description
Excellent	1	Vigorous body movement without stimuli
Good	2	Weak body movement, but responds to touching
Poor	3	No body movement, no obvious response to stimuli, but fish can move operculum/mouth/fins
Dead/moribund	4	No body or opercular movements, no response to touching or grabbing

Table 2. Description of the codes used to score the injuries (Catchpole et al., 2015)

Fish injury	Description
Scale loss	Visible area of scale loss
Bruises	Red bruising visible on the body
Wounding	Visible shallow cuts on the body
Deep wounding	Visible deep cuts on the body

Table 3. Description of the reflex responses tested (Catchpole et al 2015)

Name	Stimulus action	Reflex response
Operculum closure	The operculum of the fish is gently opened with a blunt object	Ability to tightly close/clamp its operculum after being opened within 5 seconds
Mouth closure	The mouth of the fish is gently opened with a blunt object	Ability to tightly close/clamp its mouth after being opened within 5 seconds
Gag response	A blunt object is inserted in the mouth of the fish and touch the throat	Fish gagged/vomit

Data analysis - Time to Mortality

For the statistical analysis, a simple non-parametric Kaplan-Meier model was applied to estimate time to 50% mortality and parametric Weibull models were used to correlate survival (from time-to-mortality estimates) with vitality at first observation and individual size. In addition, the Akaike information criterion (AIC) was calculated to give the goodness-of-fit of each model and likelihood tests were performed to check if there were significant differences in AIC when comparing distinct models.

Biological Traits Analysis

TTM data was collated for five species (*Scyliorhinus canicula*, *Helicolenus dactylopterus*, *Conger conger*, *Lophius spp.* and *Trachurus spp.*) that have distinct combinations of biological traits (table 10) and Weibull models were applied to determine whether these factors have an influence in the TTM results (table 11).

Table 4. Results of censoring, immediate mortality (%) and further statistical analysis for each species. * represents species with small sample size or data coming from only one haul. KM – Kaplan-Meier

Species	Censoring				Immediate mortality (%)	Data analysis
	None	Right	Left	Total		
*Capros aper**	22	0	0	22	15	Excluded
Conger conger	13	27	0	40	3	KM & Weibull
*Citharus linguatula**	2	0	2	4	50	Excluded
Galeus melastomus	14	0	6	20	30	KM
Helicolenus dactylopterus	51	4	8	63	13	KM & Weibull
*Hoplostethus mediterraneus**	4	0	6	10	60	Excluded
Lepidorhombus boscii	13	0	7	20	44	KM
*Lepidopus caudatus**	0	0	3	3	100	Excluded
Lophius spp.	41	0	9	50	18	KM & Weibull
Merluciius merluccius	19	0	14	33	52	KM
Micromesistius poutassou	6	0	24	30	80	KM
Mullus surmuletus	17	0	14	31	45	KM
*Nezumia sclerorhynchus**	0	0	33	33	100	Excluded
Phycis blennoides	6	0	34	40	85	KM
Scyliorhinus canicula	16	24	0	40	8	KM & Weibull
*Setarches guentheri**	4	0	11	15	73	Excluded
*Scomber spp.**	5	0	3	8	38	Excluded
Trigla lyra	13	0	25	38	66	KM
Trachurus spp.	45	0	3	48	17	KM & Weibull

Results

Data on time-to-mortality was collected for a total of 502 individuals, belonging to 19 species, from 40 hauls. For the cases when the exact time of mortality was not observed, observations were considered either left censored, when the individuals were already dead at first observation, or right censored, when individuals were still alive at the time of last observation. For uncensored data, the exact time-to-mortality was observed. Moreover, the number of individuals dead when first observed, or immediate mortality expressed as percentage, was also computed for each species (table 4).

From the group of 19 species, 7 were excluded from the further statistical analysis (species with *) due to small sample size (*Citharus linguatula*, *Lepidopus caudatus*, *Hoplostethus mediterraneus*, *Scomber spp.*) or because the individuals were taken just from one haul (*Capros aper*, *Nezumia sclerorhynchus*, *Setarches guentheri*). Kaplan-Meier models were applied for the rest of the species to calculate time to 50% mortality (figures 2 and 3). For the species with at least 40 individuals whose observations were mainly uncensored or right censored, Weibull models were used to check the effects of vitality and size as explanatory variables (figures 4-8 and tables 5-9).

In figure 2, there are two highly resistant species, *S. canicula* and *C. conger*, with mean times to 50% mortality of over 100 minutes. In fact, these two species together with *H. dactylopterus* were the only that had right censored observations, the remainder died during the monitoring period.

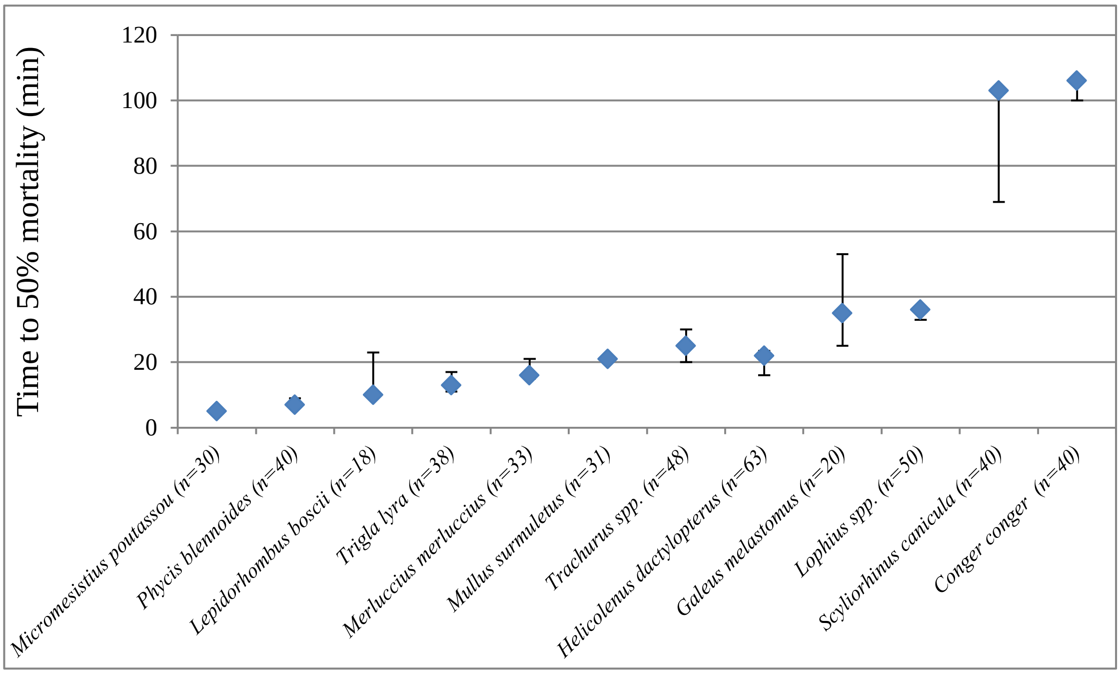


Figure 2. Time to 50% mortality for the species included in the analysis

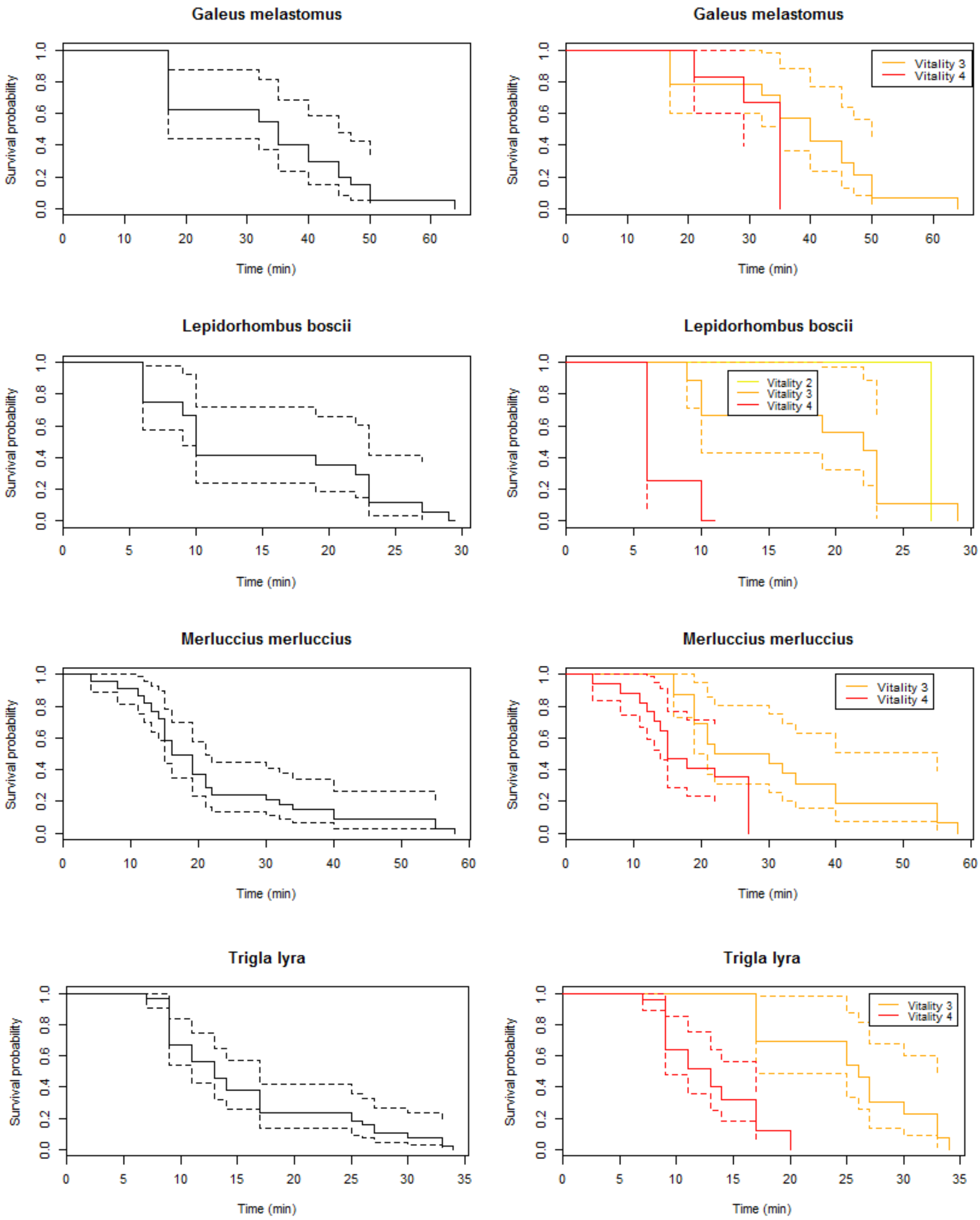


Figure 3. Results of Kaplan-Meier for the species where only this model model was applied. In the left column are shown graphs with the base survival curve and in the right graphs with survival curves separately for each vitality category.

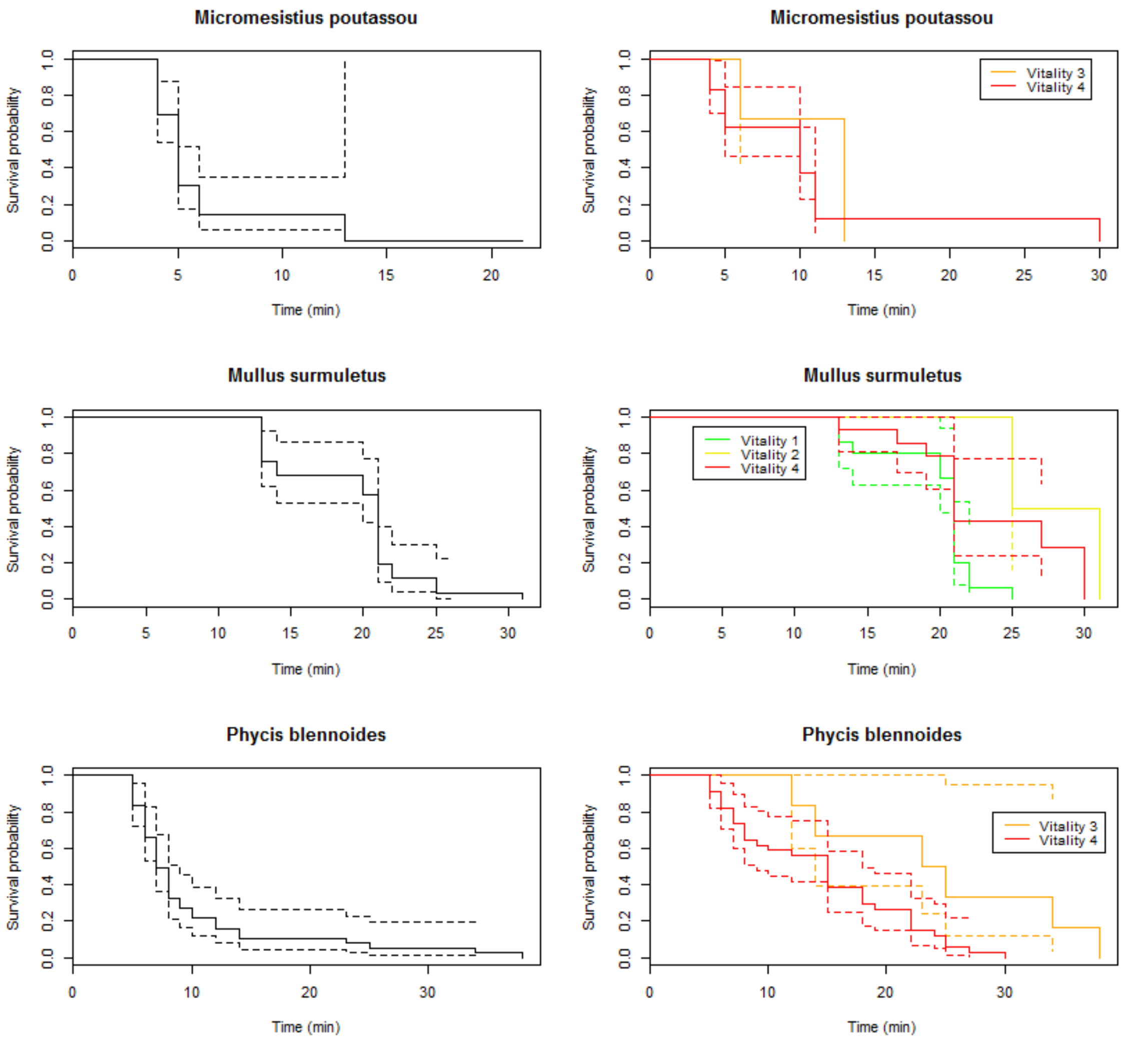


Figure 3 (cont.). Results of Kaplan-Meier for the species where only this model model was applied. In the left column are shown graphs with the base survival curve and in the right graphs with survival curves separately for each vitality category.

Scyliorhinus canicula

Vitality state 1 was not observed in *S. canicula*. Also, vitality categories 2 and 3 overlap, with non-significant differences between them. Vitality state 4 individuals died significantly faster than vitality state 2 and 3 animals. Individual animal size was a significant explanatory variable, meaning that smaller individuals died at a faster rate than larger ones (figure 4 and table 5).

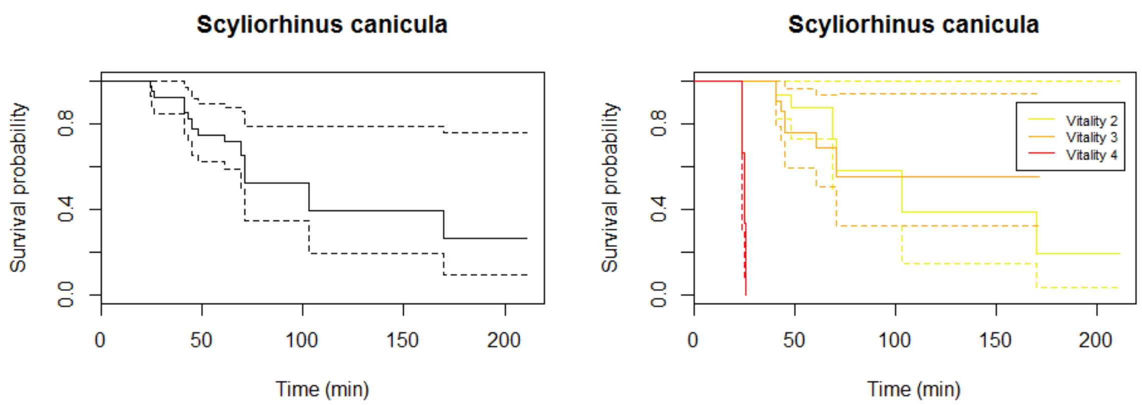


Figure 4. Results of Kaplan-Meier for *Scyliorhinus canicula*, with base survival curve on left and survival curves for each vitality category shown on the right.

Table 5. Results of Weibull models for *Scyliorhinus canicula* – without covariates and with vitality and size as possible explanatory variables.

Parameters/ Models for *S. canicula*	**Base model (without covariates)**			**+ Vitality**			**+ Size**		
	Value	Std. Error	p-value	Value	Std. Error	p-value	Value	Std. Error	p-value
Intercept	4.84	0.16	6.37e-198	5.00	0.188	1.05e-155	2.16	0.55	8.99e-5
Vitality state 3	-	-	-	-0.267	0.255	2.94e-1	-	-	-
Vitality state 4	-	-	-	-1.780	0.324	3.79e-8	-	-	-
Size	-	-	-	-	-	-	0.073	0.018	3.06e-5
AIC		194.230			184.540			174.221	
p-value likelihood test		-			0.0011			2.7126e-6	

Helicolenus dactylopterus

According to the Weibull model, in particular the AIC value, vitality was significantly correlated with TTM (table 6). However, closer examination of the data in figure 5 (right) shows that only vitality states 1 and 4 have significantly different TTM curves, and due to the wide confidence interval around vitality state 4 it is indistinguishable from states 2 and 3. Body size had no significant effect on TTM.

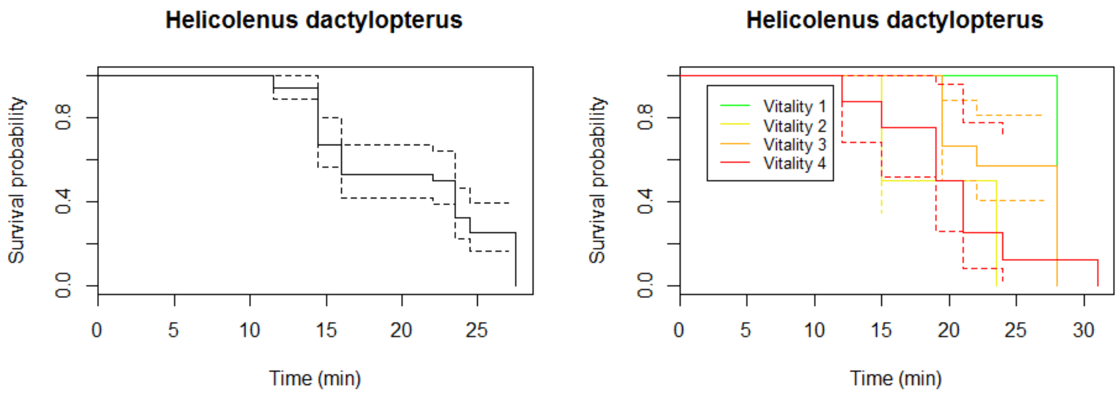


Figure 5. Results of Kaplan-Meier for *Helicolenus dactylopterus*, with base survival curve on left and survival curves for each vitality category shown on the right.

Table 6. Results of Weibull models for *Helicolenus dactylopterus* – without covariates and with vitality and size as possible explanatory variables.

Parameters/Models for *H. dactylopterus*	Base model (without covariates)			+ Vitality			+ Size		
	Value	Std. Error	p-value	Value	Std. Error	p-value	Value	Std. Error	p-value
Intercept	3.13	0.0555	0.00	3.450	0.351	8.91e-23	2.667	0.3433	7.81e-15
Vitality state 2	-	-	-	-0.392	0.365	2.83e-1	-	-	-
Vitality state 3	-	-	-	-0.165	0.360	6.46e-1	-	-	-
Vitality state 4	-	-	-	-1.408	112.63	9.9e-1	-	-	-
Size	-	-	-	-	-	-	0.023	0.0171	1.72e-1
AIC		53.65074			33.8032			53.96227	
p-value likelihood test		-			1.026476e-5			0.1938034	

Conger conger

Vitality has a significant effect on TTM in the Weibull model for *C. conger*. However, only vitality state 4 can be separately distinguished from the other three states, having a significantly more rapid TTM. Size also had a small (0.009) but significant effect on TTM, with larger animals surviving longer.

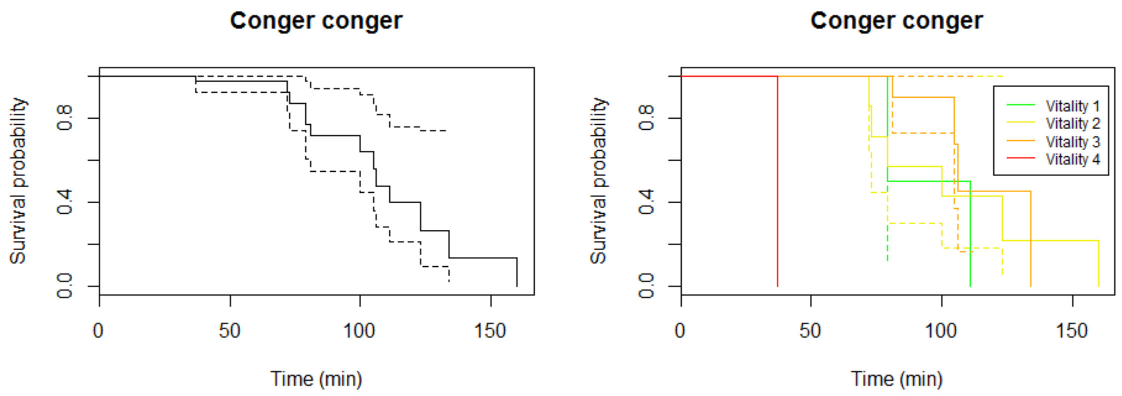


Figure 6. Results of Kaplan-Meier for *Conger conger*, with base survival curve on left and survival curves for each vitality category shown on the right.

Table 7. Results of Weibull models for *Conger conger* – without covariates and with vitality and size as possible explanatory variables.

Parameters/Models for *C. conger*	Base model (without covariates)			+ Vitality			+ Size		
	Value	Std. Error	p-value	Value	Std. Error	p-value	Value	Std. Error	p-value
Intercept	4.78	0.0654	0.000	4.621	0.136	1.1e-253	4.285	0.204	1.33e-97
Vitality state 2	-	-	-	0.198	0.158	2.12e-1	-	-	-
Vitality state 3	-	-	-	0.192	0.169	2.55e-1	-	-	-
Vitality state 4	-	-	-	-1.01	0.235	1.76e-5	-	-	-
Size	-	-	-	-	-	-	0.009	0.004	2.52e-2
AIC	138.5162			134.3772			134.9512		
p-value likelihood test	-			0.0174206			0.01832281		

Lophius spp.

For *Lophius spp.*, only vitality categories 3 and 4 were observed due to its sedentary behaviour when on-board and exposed to air (figure 7 and table 8). Moreover, the estimated value for vitality state 4 did not produce significant differences when compared with vitality state 3 and has a rather large standard error. However, the fit of the model improved compared with the base model, which makes it difficult to correctly interpret these results.

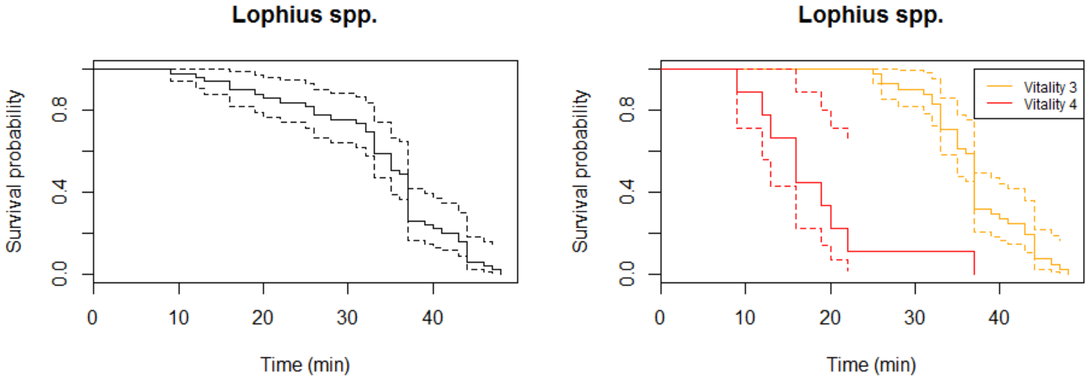


Figure 7. Results of Kaplan-Meier for *Lophius spp.*, with base survival curve on left and survival curves for each vitality category shown on the right.

Table 8. Results of Weibull models for *Lophius spp.* – without covariates and with vitality as possible explanatory variable.

Parameters/Models for *Lophius spp.*	Base model (without covariates)			+ Vitality		
	Value	Std. Error	p-value	Value	Std. Error	p-value
Intercept	3.59	0.0389	0.000	3.67	0.0225	0.000
Vitality state 4	-	-	-	-1.88	87.5579	9.83e-1
AIC		340.1362			264.9406	
p-value likelihood test		-			1.548358e-18	

Trachurus spp.

Although the Weibull model shows a highly significant effect of vitality (at first observation) on TTM (table 9), the relationship is counter-intuitive and not very informative. Figure 8 shows that the KM curves for vitality states 1 and 4 are highly overlapped, while state 3 has the longest TTM. This contradicting relationship is most likely due to the highly active behaviour of healthy animals (vitality 1 and 2) when exposed to air, which thus rapidly exhaust themselves leading to a premature TTM.

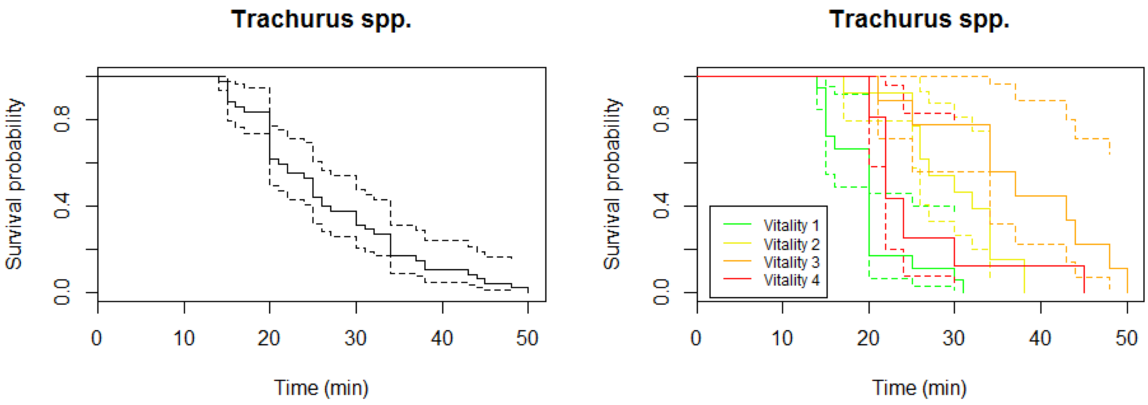


Figure 8. Results of Kaplan-Meier for *Trachurus spp.*, with base survival curve on left and survival curves for each vitality category show on the right.

Table 9. Results of Weibull models for *Trachurus spp.* – without covariates and with vitality as possible explanatory variable.

Parameters/Models for *Trachurus spp.*	Base model (without covariates)			+ Vitality		
	Value	Std. Error	p-value	Value	Std. Error	p-value
Intercept	3.39	0.0518	0.000	3.076	0.0576	0.000
Vitality state 2	-	-	-	0.368	0.0868	2.2e-5
Vitality state 3	-	-	-	0.626	0.0971	1.15e-10
Vitality state 4	-	-	-	0.329	0.1021	1.26e-3
AIC		337.9372			312.4067	
p-value likelihood test		-			6.572296e-7	

Biological Traits Analysis

Of three biological traits (gas bladder, scales and external injuries) observed in five species (*S. canicula*, *H. dactylopterus*, *C. conger*, *Lophius spp.* and *Trachurus spp*.) only the presence of scales (in *H. dactylopterus* and *Trachurus spp.*) significantly effected TTM (effect -0.9385; p-value < 0.0001), where TTM was significantly reduced with this trait. Injuries and presence of a gas bladder appeared to have no effect on TTM for these species.

Table 10. Summary of the biological traits (gas bladder, scales, external injuries) for each species.

Species/Variables	**Gas bladder**	**Scales**	**External injuries**
Conger conger	Yes	No (tough skin)	92.5%
Helicolenus dactylopterus	No	Yes	84.1%
Lophius spp.	No	No	98%
Scyliorhinus canicula	No	No (tough skin)	50%
Trachurus spp.	Yes	Yes	60%

Table 11. Results of Weibull models for 5 species - without covariates and with injuries, gas bladder and scales as possible explanatory variables.

Parameters/Models for 5 species	Base model (without covariates)			Base model + Injuries + Gas bladder + Scales		
	Value	Std	p	Value	Std	p
Intercept	3.696	0.0473	0.000	4.0212	0.1596	5.27e-140
Injuries	-	-	-	-0.0103	0.1599	9.49e-1
Bladder	-	-	-	0.0763	0.0749	3.08e-1
Scales	-	-	-	-0.9385	0.0767	2.18e-34
AIC	955.8255			852.9904		
p-value likelihood test	-			1.95446e-23		

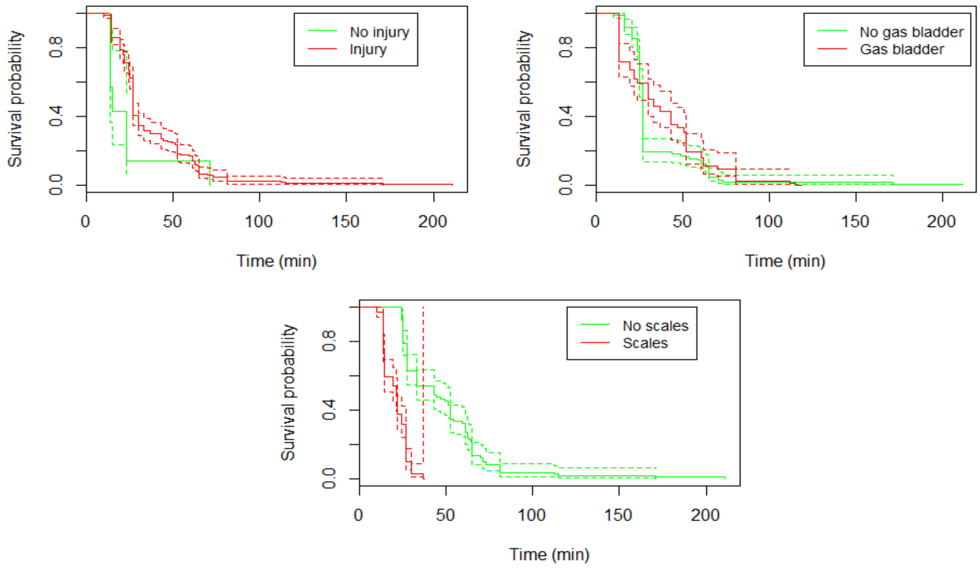


Figure 9. Kaplan-Meier results for the effects biological traits (injury, gas bladder and scales) on time-to-mortality for data pulled from 5 species.

Discussion

This preliminary work provided estimates of immediate mortality, as well as time-to-mortality (TTM), for a wide range of species: *M. merluccius*, *M. poutassou*, *M. surmuletus*, *P. blennoides*, *G. melastomus*, *L. boscii*, *T. lyra*, *Trachurus spp.*, *H. dactylopterus*, *Lophius spp.*, *S. canicula* and *C. conger*. This enabled an initial assessment of the vulnerability of these animals to the stressors associated with capture and exposure to air; from which some inferences can be made on their potential to survive the discarding process.

Time to 50% mortality (50% TTM) and immediate mortality (%) together with the form of the Kaplan-Meier survival curves identify *M. poutassou*, *P. blennoides*, *L. boscii*, *T. lyra*, *M. merluccius*, *M. surmuletus*, *Trachurus spp.* and *H. dactylopterus* as highly susceptible to air exposure; with 50% TTMs of less than 30 minutes, and in most cases less than 20 minutes. However, *S. canicula* and *C. conger* appear to be quite resistant with 50% TTMs in excess of 100 minutes. Furthermore, almost all species were observed with some form of external injuries, mostly scale loss, bruises and shallow wounds. In particular, *M. merluccius*, *P. blennoides*, *T. lyra*, *N. sclerorhynchus* and *S. guentheri* often exhibited evidence of barotrauma, in the form of everted stomach, inflated abdomen or popped eyes.

Based on the results from the Kaplan-Meier and Weibull models, vitality at first observation does not seem to be a good predictor of time-to-mortality. Moreover it appears to be species specific. For some deep-water species such as *Lophius spp.*, *C. conger* and *S. canicula*, this can be explained by their behavioural traits of reduced activity or immobility in response to air exposure, which might represent a strategy to conserve energy when subjected to extreme stress conditions. In contrast, *Trachurus spp.* and *M. surmuletus* display signs of intense activity and jumping movements when brought on deck, and for *Trachurus spp.*, the highest vitality states (1 and 2) also had substantially reduced TTMs. For the most susceptible species, the majority of individuals appear to be almost dead when first observed (vitality states 3 and 4).

The biological traits analysis presented some unexpected results (tables 10 and 11, figure 9). Although individuals with injuries have a decreased TTM, this effect was not significant (effect -0.0103; p-value > 0.1), possibly due to the fact there were very few observations of individuals without injuries. Also, species with gas bladders should have a decreased TTM, which does not equate with the positive but non-significant effect from the model (effect 0.0763; p-value > 0.1). Although, this result is probably biased due to *C. conger* possessing a gas bladder but also representing one of the most resistant species to air-exposure. Species covered with scales appear to have a significant decrease in time-to-mortality, also confirmed visually by the obvious separation of the survival curves in the graph.

Overall, the categorical vitality assessment used in this study does not seem to be a good predictor of time-to-mortality. Moreover it appears to be species specific, so adjustments in this methodology to account for differences in behaviour between species should be considered in future work. Furthermore, more replicates are needed where vitality, size and injuries evaluation are accurately determined, perhaps for a smaller group of species so as not to compromise the quality of information collected on-board.

Conclusion

From this study, it can be concluded that *M. poutassou*, *P. blennoides*, *L. boscii*, *T. lyra*, *M. merluccius*, *M. surmuletus*, *Trachurus spp.* and *H. dactylopterus* are all vulnerable to the stressors associated with capture in this bottom trawl fishery, as well as exposure to air on deck. As such, they are likely to have high mortalities (approaching 100%) if discarded in this fishery. However, some species including *G. melastomus* and *Lophius spp.*, and especially *S. canicula* and *C. conger*, demonstrated some resilience to these stressors and may warrant further investigation to establish more robust estimates of survival potential.

CS 1.4. Survival of discarded *Nephrops norvegicus* from the Catalan sea bottom trawl fishery.

Alfredo García de Vinuesa, Mike Breen, Hugues Benoit and Montserrat Demestre

Introduction

The Norway lobster (*Nephrops norvegicus*) is widely distributed on the continental shelf of the Northeast Atlantic and the Mediterranean, supporting important trawl fisheries (Hrafnkell Eiríksson, 2014). It is an important resource for European fisheries with landings in 2014 of 54,768 tonnes (www.fao.org).

N. norvegicus is exploited by a trawling fleet from 13 ports on the Catalan coast. In 2016, a total of 173,320 kg were landed, representing the 2% of total trawl landings. In particular, the port of Blanes landed 19,348.15 kg, which represents the 4.87% of the total trawl landings (captures-rec.cmima.csic.es/).

In the Catalan sea, *N.norvegicus* is strongly associated with muddy sediment habitats and the bottom temperature (Morfin et al, 2016) and their populations are mainly located in deeper waters on the upper and middle continental slope (300 to 600 m) (Abelló et al, 2002,Cartes and Sardà 1993, Maynou and Sardà 1997, Maynou et al. 1998).

Nephrops fisheries generate large amounts bycatch (Camille et al, 2017). In the trawling vessels of Catalonia the by-catch is composed mainly of commercial species such as *Phycis blennoides, Micromesistius potassou, Merluccius merluccius* and *Lophius sp*. Some species in the catch are discarded due to: low commercial value, e.g. *Scyliorhinus canicula*; because they are smaller than the minimum conservation reference size (MCS), e.g. *Nephrops norvegicus*, (<20 mm CL); or are juveniles of commercial species with no economic value, as, e.g. *Arnoglossus ruepelli*, *Trigla lyra* or *Molva dypterygia*.

Article 15 of the new European Common Fisheries Policy (EU, 2013) imposes a discard ban for all species subject to either quota or MCS and the obligation to land them in port as specified in Regulation (EC) No 850/1998, and thus *Nephrops norvegicus* is affected for this regulation.

Exemptions from the Landing Obligation are possible based on two specific criteria: either when a high survival rate of discards has been demonstrated, or when all potential technical and management measures have been implemented to reduce catches of undersized individuals (EU, 2013: Art. 15).

The aim of this work is to assess the survival of *Nephrops norvegicus* discarded from trawling in the north-western Mediterranean in order to improve the discard management.

Methods

Study area and Fishing characteristics

Animals used in this study were sampled from 10 hauls carried out from May 2016 to January 2017 in the fishing ground adjacent to Blanes, called “La Malica”, between 250 and 450 deep meters (Figure 1). The sampling was conducted on board a commercial trawler; 20.6 meters in length, 600 HP and 64.91 GT. The codend mesh type was 50 mm rhomboid. Towing speed of the trawl was between 2.3 and 2.8 Knots. The fishing schedule of this vessel extended from 8:00 a.m. to 3:00 p.m., the rest of the time is used to travel to and from the fishing grounds. The air temperature was measured on board after each haul. Surface water temperature was estimated from measurements taken at the same time in Barcelona 180 meters away from the coast at one meter depth (marbcn.blogspot.com.es/).

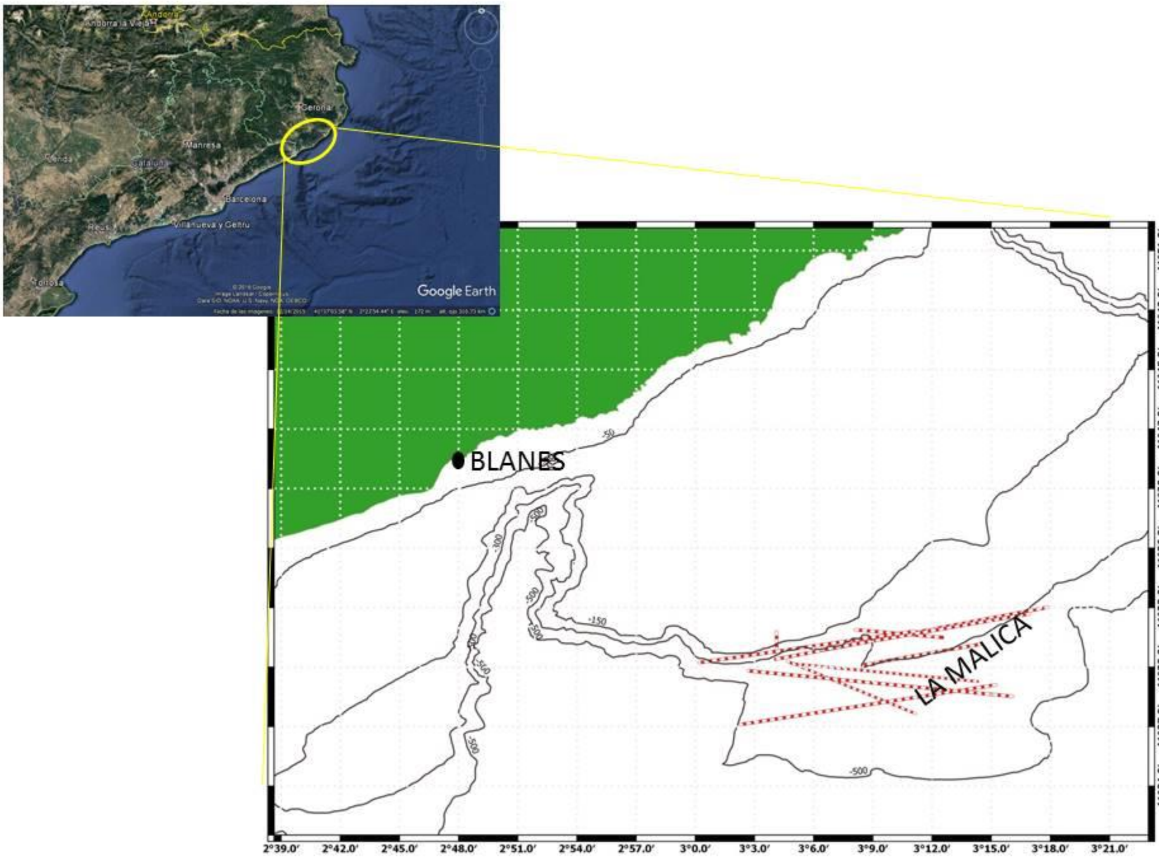


Figure 1. Study area

Experimental design

For the assessment, there were a total of 10 replicate treatment hauls: 4 replicates in winter, 3 in spring and 3 in summer. The towing durations ranged between 120 and 376 minutes.

Due to the challenges of obtaining viable control samples, the survival of individuals who were classified in excellent state of vitality has been taken as pseudo-controls for each haul (table 1).

Sampling Nephrops from the catch was conducted during the first ten minutes of the catch arriving on board. The sample size was constrained to the number of animals (100 approx.) that could be held in a holding tank on the vessel, supplied with surface sea water. A total of 1100 individuals were sampled.

Vitality assessment

As part of the survival assessment, the vitality of each sampled Norway lobster was recorded using a categorical vitality assessment (CVA) method (ICES 2017). This assessment uses behavioural indicators and the presence of injuries to determine the vitality status of each animal with respect to one of four categories: 1 (excellent), 2 (good), 3 (poor) or 4 (dying or dead) (table 1).

Table 1. Criteria for CVA to *Nephorps norvegicus* (ICES-WKMEDS and VIBAM)

State of vitality	Code	*Signals of vitality to Nephrops norvegicus*
Excellent	1	Spasmodic body movements; aggressive position; no external injury
Good	2	Continued body movements; answers to the contact; superficial injury or loss of some pereiopods.
Poor	3	Weak body movements, can move antennas, pereiopods or maxilipeds; loss of some cheliped or deep cuts.
Dying or dead	4	Without movement, does not respond to the insistent contact.

During the 2 week assessment, a total of 13 CVAs were carried out ($T_{0...}T_{12}$) in several situations (Table 2).

Table 2. Location and timing of Categorical Vitality Assessments (CVAs)

Places/CVAs in time	T0 0,5H	T1 6H	T2 18H	T3 30H	T4 42H	T5 54H	T6 66H	T7 78H	T8 90H	T9 96H	*T10* *1WEEK*	*T11* *1,5WEEK*	*T12* *2WEEK*
On-board	x												
Transfer		x											
Aquariums (ICM)			x	x	x	x	x	x	x	x	x	x	x

On-board (T_0)

Immediately after the catch was taken on board, potentially discardable animals were transferred into a plastic holding tank containing surface sea water (figure 2). This process took less than 10 minutes, to avoid the stress which can result from exposure on deck. In the next 30 minutes, the initial vitality assessment (T_0) was conducted and the animals were segregated into seperate white plastic containers according to their state of vitality. The white plastic containers were supplied with running surface sea water, and oxygen producing tablets to prevent hypoxia.

Figure 2. *Nephrops norvegicus* on catch (left) and white plastic containers full of water (right)

Transfer (T_1)

The animals were transferred, in the plastics containers, to the laboratory as quickly as possible (2 hours maximum, from arriving at Blanes port). The first hours of the assessment are the most critical period for survival, so the vitality assessment should be conducted frequently for better resolution. For this reason, one more vitality assessment was performed when the animals were transferred into aquariums (T_1). During this second vitality assessment, animals were segregated into separate aquaria according to their vitality status and animals in vitality state 4 (dead or moribund) were removed and recorded.

At laboratory (T_2…T_9; T_{10}…T_{12})

This phase was conducted in the experimental aquaria of the Institute of Marine Science (ICM) in Barcelona. Eight assessments (T_2…T_9) were conducted with a periodicity of 12 hours, upto 96 hours of the observation period. Later, three assessments were taken after 1 week, 1.5 weeks and 2 weeks from the start of the experiment (T_{10}, T_{11} and T_{12}). No more than 20 individuals were introduced per section.

To simulate the conditions of the natural environment the aquariums had:

- Open circuit seawater.

- Water temperature between 13-14 ° C.

- Photoperiod adapted to the natural luminosity.

- Controls of salinity, nitrates, nitrites and silicates.

- Bricks and rocks to provide artificial shelters in all sections

- Black canvas to dim the light.

The animals were not fed during the assessment.

Analysis of data

Kaplan-Meier analysis was used to describe survival over time, and the effect of season assessed using a log-rank test. In addition, it was noted that there was an initial mortality at first observation, which necessitated the application of a mixed distribution model to estimate asymptotic survival, with an additional parameter to correct for the initial mortality. The analysis of the data using the mixed distribution model is still underway and is not reported here.

Results

Table 3 summarises the survival results (with 95% confidence intervals) for each haul, along with details of season, haul ID, sample size, haul duration, air temperature, surface water temperature. Confidence intervals (95%) for survival estimates were estimated from the Kaplan-Meier analysis.

Table 3. Survival of *Nephrops norvegicus* discards, by haul, from a demersal trawl in the Catalan Sea for three seasons: spring summer and winter.

Season	Haul ID	Sample size	Haul time	Air T (ºC)	Surface Water T(ºC)	Control	Survival	Confidance interval
Spring n=3	MA351	141	350	20	18,5	0,667	0,234	0,174-0,315
	MA364	87	210	18	21,6	0,905	0,506	0,411-0,623
	MA365	111	132	23	21,6	0,826	0,396	0,315-0,499
Summer n=3	MA394	100	127	25	24,8	0,905	0,109	0,0623-0,190
	MA393	101	188	23	24,8	0,826	0,07	0,0343-0,143
	MA3102	112	376	22	23,3	0	0	
Winter n=4	MA3121	115	315	7	15,6	0,917	0,696	0,616-0,785
	MA3122	116	345	5	15,2	1	0,845	0,781-0,913
	MA3011	109	180	7	13,1	0,906	0,725	0,646-0,814
	MA3012	108	120	12	13,1	0,853	0,685	0,603-0,779

Nephrops has a high survival rate in winter, up to 0.845 (CI: 0.781-0.913). Survival was substantially lower in spring and in summer; with 100% mortality in one summer haul.

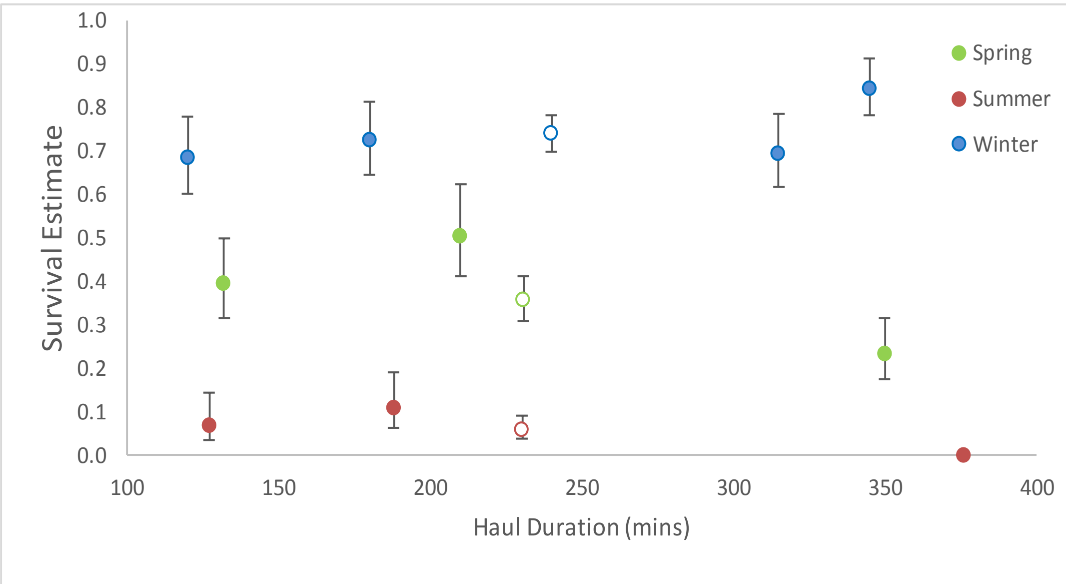


Figure 3. *Nephrops norvegicus* discard survival estimates, by haul (closed circles), in relation to haul duration and season. Mean survival estimates (& towing duration) per season are shown as open circles.

Haul durations appeared to have no real effect on survival; furthermore, the range of towing duration across the seasons was reasonably well balanced (figure 3). However, from season to season, survival generally appeared to decrease with increasing temperature (figure 4). Although, within individual seasons (spring and summer), there is some evidence of a contradictory trend of increasing survival with increasing temperature.

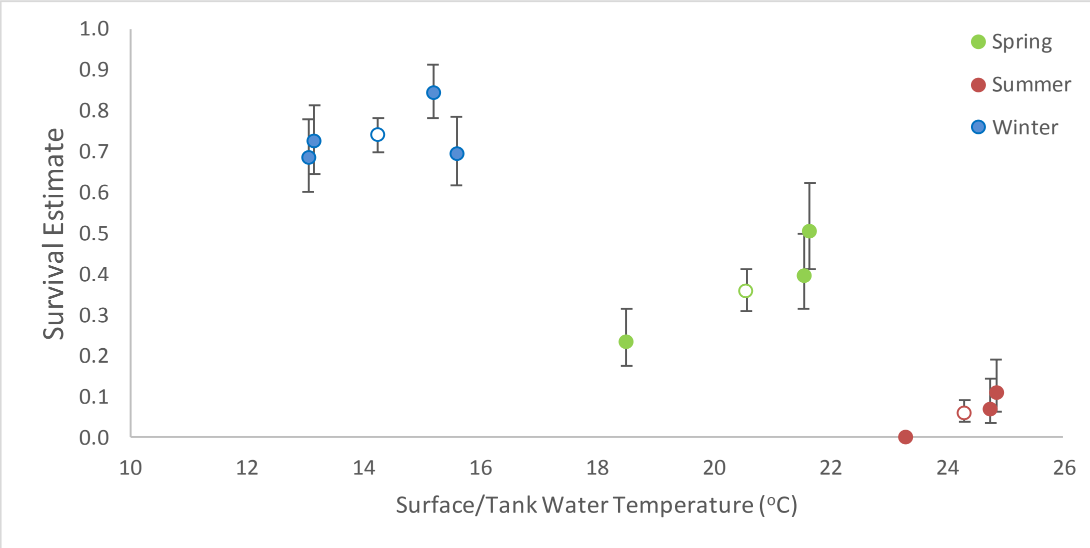


Figure 4. *Nephrops norvegicus* discard survival estimates, by haul (closed circles), in relation to surface/holding tank water temperature and season. Mean survival estimates (& water temperature) per season are shown as open circles.

Seasonal Effects of Survival

To assess the effect of season on survival, analysis was conducted with the data pooled by season (figure 5; Table 4).

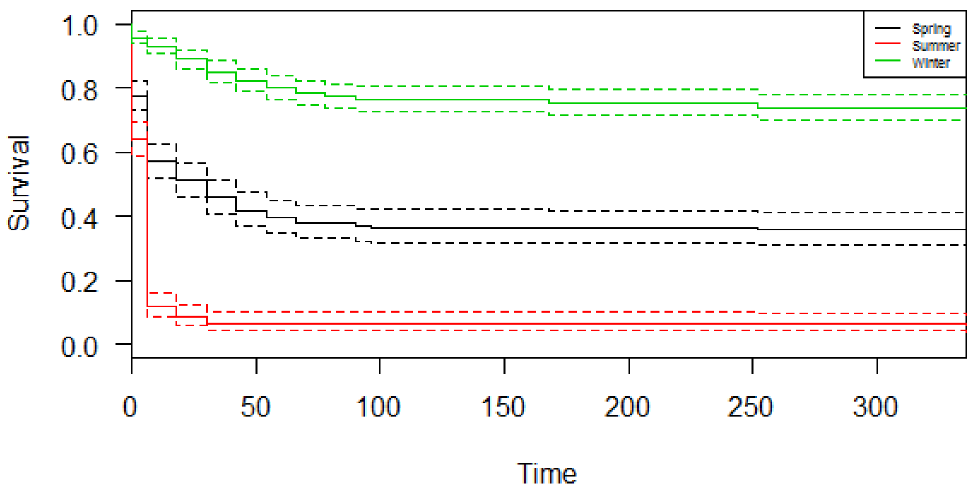


Figure 5. Kaplan-Meier survival curves for *Nephrops norvegicus* by season

Kaplan-Meier survival curves show a substantial difference in survival rates between the seasons (figure 5). Immediate mortality, at the first evaluation of the vitality state (T_0), is significantly higher in spring and especially summer compared to winter.

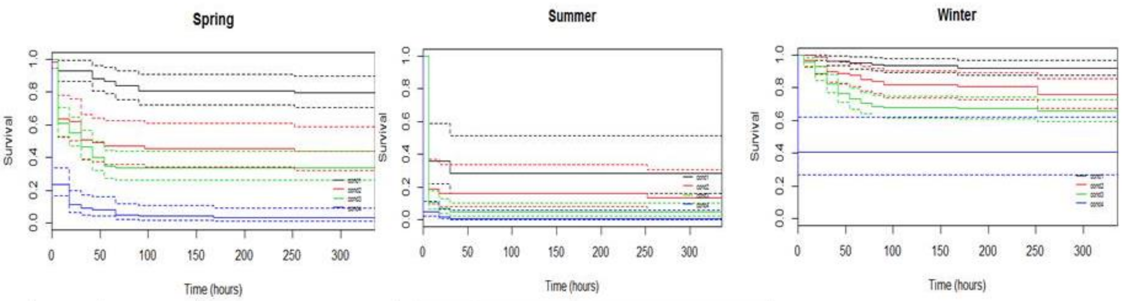
The highest pooled survival is in winter with 0.739 (CI: 0.699-0.781), while in the spring season the value decreases considerably (0.357; CI: 0.309-0.412), and is lowest in summer (0.0575; CI: 0.0367-0.0901) (table 4). A Log Rank test confirmed these differences were highly significant (Chisq(df 2,n=1100)=516; p<0.001).

Table 4. Pooled survival by season with controls and 95% confidence intervals. *n* : number of hauls.

Season	Control	Survival	IC 95%
Winter (n=4)	0.92	0.39	0.699-0.781
Spring (n=3)	0.794	0.357	0.309-0.412
Summer(n=3)	0.214	0.0575	0.0367-0.0901

<u>Vitality Status and Survival</u>

Significant differences exist between the survival associated with different states of vitality for each season (figure 6). In general, although there are seasonal effects (see above), the likelihood of survival is highest for vitality state 1, with the likelihood of survival decreasing progressively for each lower state of vitality (2 to 4).



State of vitality	Survival	Interval confidence 95%	
1	0,794	0,704	0,896
2	0,436	0,323	0,589
3	0,339	0,263	0,436
4	0,0306	0,01	0,0933

State of vitality	Survival	Interval confidence 95%	
1	0,214	0,105	0,436
2	0,135	0,0598	0,305
3	0,0465	0,0213	0,102
4	0,0084	0,00119	592

State of vitality	Survival	Interval confidence 95%	
1	0,92	0,875	0,966
2	0,759	0,674	0,854
3	0,656	0,592	0,727
4	0,4062	0,0868	0,2672

Log rank test
P =0

Log rank test
P = 0

Log rank test
P =6.66e-16

Figure 6. Kaplan-Meier survival curves, with 95% confidence intervals, for each state of vitality [1 excellent (black); 2 good (red); 3 poor (green); and 4 dead or dying (blue)] by season. Final survival estimates at T12 (2 weeks) by vitality state and season are shown with 95% CIs below each figure, along with corresponding p-vaules from the log-rank test.

Discussion

The results show a high survival rate (0.739; CI: 0.699-0.781) during the winter season. Survival of discarded *Nephrops* greater than 50% has already been indicated in some studies (e.g. Castro et al., 2003) however, in our study it was obtained significantly lower survival in the spring and summer, in particular. Although no seasonal effects on survival have been observed for crustaceans, studies have demonstrated seasonal effects for some fish species: skates (Cicia et al., 2010); plaice (Revell et al, 2013) and swordfish (De Metrio et al., 2001; Damalas and Megalofonou, 2009). However, in this study there are concerns that survival in spring and summer may have been underestimated because of the high immediate mortality that occured when the animals were first evaluated on board (T_0) and after the transfer (T_1). These high mortality rates are suspected to be the consequence of the high surface temperature on deck and also the temperature of sea water used on white containers to maintain the animals. For future work, it is recommended that water cooling systems should be used in the plastic holding tanks while on board the vessel and during transfer.

Furthermore, the potential for increased surface temperatures to affect survival emphasises the need for rapid sorting and return to the sea of any discarded animals, where this is permitted under the landing obligation, to reduce the effects of emersion on the discarded animals. The use on-board of sorting tables is recommended to expedite the discard process.

Haul duration did not show a strong correlation with the survival *of Nephrops norvegicus*. This contradicts observations from other crustacean trawl fisheries. For example, Wassenberg et al. (2001) and Uhlmann and Broadhurst (2007) showed that in penaeid prawn trawls, survival probabilities for discarded organisms decreased with longer tow duration. It is possible that small catch sizes and differences in catch composition may have diminished this effect in this case. An additional explanation could be that Nephrops have a stronger carapace compared to shrimps, making them less vulnerable to injury in the codend catch.

Finally, analyses of vitality states in this study suggest that vitality assessments could be useful predictors of discard mortality for discarded *Nephrops norvegicus*. Although there clearly are seasonal effects, which should be investigated further in future studies.

Conclusions

This assessment has observed high survival for *Nephrops norvegicus* discarded at winter (0.739; CI: 0.699-0.781) (January). Significantly lower survival was observed during spring (May) 0.357; CI: 0.309-0.412) and summer (August) 0,0575; CI: 0.0367-0.0901), although it is uncertain whether this is a true seasonal effect or whether it has been biased by elevated water temperatures in the holding tanks during collection and transfer.

Analysis of vitality states of animals in this study suggest that vitality assessments could be useful predictors of discard mortality for discarded *Nephrops norvegicus*; which should be investigated further in future studies.

CS 1.4. Catalan sea bottom trawl fishery – Survival of Discarded Bycatch

Montserrat Demestre, Mike Breen and Alfredo García de Vinuesa

Introduction

Catalonia is an Autonomous Community of Spain where demersal fisheries represent 41% of the total landings and 70% of the value (in 2014), while the remaining fisheries are small pelagics captured by the purse seining fleet. Demersal fisheries are carried out mainly by fleets using bottom trawl, as well as small scale fishery (“rastell”, trammel nets and gillnets and longlines).

The bottom trawl fleet exploits over 100 demersal and benthic species of finfish, crustaceans, and molluscs; and produces 35% of the total landings in weight and 54% of the total landings in value. As in other Mediterranean fisheries, it shows a high rate of unwanted catches that are discarded at sea, consisting of commercially important species under minimum size regulation and marine organisms with no commercial value (Lleonart, 2015; Tsagarakis et al. 2014).

Two broad bottom trawl fisheries can be differentiated in Catalonia, a continental-shelf fishery targeting mainly hake, red mullets and octopus, and a deep-water fishery targeting the highly prized crustaceans (red shrimp and Norway lobster) (Demestre et al., 2000).

The management of the trawl fisheries is based on effort control and technical measures such minimum landing sizes (Demestre et al., 2008; Muntadas et al., 2015). Trawling is forbidden in waters less than 50 m depth (or 3 miles from the coastline) and there are one or two months per year of closure, depending on the ports. The regulation for the minimum mesh size is 50 mm diamond and 40 mm square. Trawl fishing is carried out on soft bottoms and is limited to daily trips from Monday to Friday. The normal effective fishing time is approximately from 8:00 a.m. to 4:00 p.m.; leaving the port at 6:00 a.m. and returning at 6:00 p.m. The trawling speed is typically between 2.3 and 2.8 Knots. During a day, the number of hauls normally varies between 1 and 3 depending on the fishing depth. The fishing grounds and the target species vary according season, and trawl gear can be considered a different metier depending on the selected target species.

The total amount of discards in the trawl fishery is very important and is broadly related to depth and recruitment season of the target species. For instance, in fishing grounds located at depths less than 300 m overall discards are approximately 50% of the total catch, while discards are approximately 20% in deeper waters. An important part of the discarded biomass (30-50%) is composed of species of commercial interest (small sized or damaged specimens) and the rest are species with low or no economic value (Sanchez et al., 2004, 2007).

There is currently very little information on the survival unwanted and non-regulated catch of invertebrates, after the stresses of capture. Some of the non-regulated invertebrates e.g. crinoids, are the basis of essential fish habitats for species such as hake or red mullet (Muntadas et al., 2014). Thus, data on their fate and survival will help in interpreting the effect of the Landing Obligation under Article 15 of the CFP (EU, 2013), and to identify species that may be applicable for a “high survival exemption". More robust information on discard survival will also help to interpret the role of non-regulated invertebrates within the benthic ecosystem. Survival estimates by tagging and biotelemetry of discarded individuals are not possible in this fishery. However, semi-quantitative (categorical) measures of vitality obtained on board prior to discarding can be informative about the survival potential of animals after they are released (Benoît et al., 2012).

One of the objectives of the CS1.4 (as part of Task 2.9 in WP2) was the survival assessments of non-regulated invertebrates discarded from trawlers, based at the port of Blanes on the North Catalan Coast. The assessment has been developed using vitality assessments conducted at regular periods during a 96 hour monitoring period.

Methods

To assess the correlation between vitality state and survival, a categorical vitality assessment (CVA, ICES-WKMEDS) was performed on invertebrates sampled from the unwanted catches from demersal trawls. These animals were then monitored over a 96 hour period, with repeated CVAs at regular intervals.

This CVA uses behavioural indicators and the presence of injuries to determine the vitality status of each animal with respect to one of four categories:

1 (excellent), 2 (good), 3 (poor) or 4 (dying or dead).

A detailed explanation of each state of vitality, for different taxa, is presented in Table1.

During the 96 hour monitoring period, a total of 10 CVAs were conducted (T0…T9) (Table 2).

The first, T0, was conducted on board the fishing vessel, within 30 minutes of the catch arriving aboard. The selected individuals were transferred into a plastic holding tank containing surface sea water. On returning to harbour, the animals were transferred, in the plastics containers, to the laboratory in less than 2 hours, and the water oxygen levels were maintained using oxygen producing tablets.

The second CVA observation, T1, was performed as each individual was transferred into the aquariums at the Institute of Marine Science (ICM) in Barcelona, and animals with vitality state 4 (dead or moribund) were removed and recorded. The remaining 8 CVAs (T2…T9) were conducted in the aquariums every 12 hours up to 96 hours after the animals were first caught. The aquariums were divided into three sections for each vitality states 1, 2, and 3 and no more than 10 individuals were introduced per section.

Natural environmental conditions were simulated in the aquariums, taking into account: open circuit seawater; water temperature between 13-14°C; and photoperiod adapted to the natural luminosity with black canvas to dim the light. Furthermore, water samples were periodically analysed for salinity, nitrates, nitrites and silicates. The animals were not fed during the assessment.

Table 1. Description of vitality levels of different invertebrate organisms for a Categorical Vitality Assessment (CVA) (ICES-WKMEDS and VIBAM)

Vitality levels	**Code**	**Crustaceans**	**Echinoderms (Ophiuroidea and Asteroidea)**	**Echinoderms (Echinoidea)**	**Mollusca**	**Sessile (Ascidians, corals, hydroids, etc.)**
Excellent	1	Continuous movements. No external injury	Continued movement. No external injury	Continued movement. No external injury	Continued movement. No external injury	Shape and size similar to its natural state. No external injury
Good	2	Weak movements; Responds to contact Superficial cuts on the exoskeleton or antennas.	Weak movements; answers to the contact. No external injury or superficial cuts in limbs	Weak movements; answers to the contact. No external injury or superficial cuts in barbed	Weak movements; answers to the contact scraping the shell or moderate loss of tegument.	Size and shape Moderately different from its natural state, cuts or abrasions moderate
Poor	3	Without apparent movement, but can move antennas or maxilipeds. Deep cuts. Or loss of an appendage.	Without apparent movement, but can move tube feet. Cuts deep and loss of all or part of extremities	Without apparent movement, but can move tube feet; external injury and many cuts in barbed.	Without apparent movement, but can move foot, loss of parts of the shell .	Shape and size different to their natural state, cuts, abrasions, surface, serious, or loss of body parts.
Dying or dead	4	Without movement, does not respond to repeated contact.	Without movement, does not respond to the insistent contact. Loss of central parts of the body	Without movement, does not respond to the insistent contact or broken shell.	Without movement, does not respond to the insistent contact, or broken shell.	Loss of central parts of the body.

A total of 22 invertebrate species were sampled: 10 echinoderms; 8 crustaceans; 2 cnidarians; and 2 ascidians.

Table 2. Location and timing of Categorical Vitality Assessments (CVAs)

CVAs/ time	T0 0.5H	T1 6H	T2 18H	T3 30H	T4 42H	T5 54H	T6 66H	T7 78H	T8 90H	T9 96H
On-board	x									
Transfer		x								
Aquariums (ICM)			x	x	x	x	x	x	x	x

The study period was from March to October 2016, with a total of 17 days and 43 hauls. Sampling was performed on board different trawlers in four fishing grounds ("*Garotes*", "*Capets*", "*Planassa*" and "*Malica*") adjacent to the port of Blanes. The range of depth is between 50 and 494 meters deep (Figure 1; Table 3).

Table 3. Number of hauls carried out at each fishing ground, with maximum and minimum depths and target species.

Fishing ground	No Hauls	Min. depth	Max. depth	Target species
Capets	4	70	113	Red mullet, monkfish, hake, Octopus and sea cucumber
Planassa	4	86	318	Red mullet, sea cucumber, hake and monkfish
Garotes	1	55	238	Red mullet and pandora
Malica	19	195	494	Norway lobster
Planassa-Garotes	3	157	285	Blue whiting, sea cucumber and pink cuttlefish

Individuals of each species were selected from the last haul every day, for a period up to 20 minutes after the catch was brought on deck, to avoid long air exposure. The vitality status of each animal was observed and then it was immediately transferred to one of 4 white containers; one for each vitality state. Each container was supplied with running surface sea water to avoid hypoxia. The number of selected animals was the number that could be held in each container without causing stress. A total of 324 individuals were sampled.

<u>Analysis</u>

A Wilson score method was used to calculate the survival estimate and 95% confidence interval of all species sampled. In addition, for species with more than 12 sampled individuals, a Kaplan-Meier (K-M) analysis was performed to assess longitudinal survival data over 96 hours, with respect to the different vitality states.

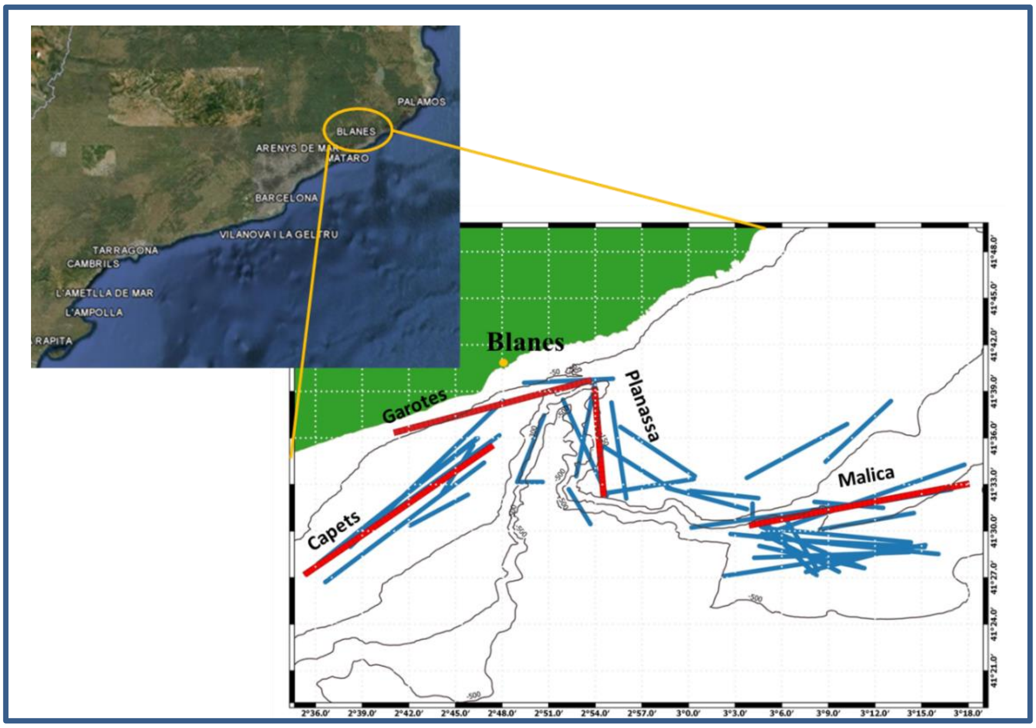


Figure 1. Study area for Case Study 1.4 showing the 4 different fishing grounds, with smpled haul tracks, adjacent to the port of Blanes. The hauls in red were used for the survival assessment.

Results

The majority of species studied, 17 of the 22, showed high survival rates; higher than 0.65 (table 4). However, there are some species, such as *Munida intermedia* and *Alcyonium palmatum, which had very low survival.*

Three of the six invertebrates selected to perform Kaplan-Meier analysis, *Antedon mediterraneum, Cidaris cidaris and Dardanus arrosor*, had 100% survival from T0 during 96 hours of monitoring (Figure 2).

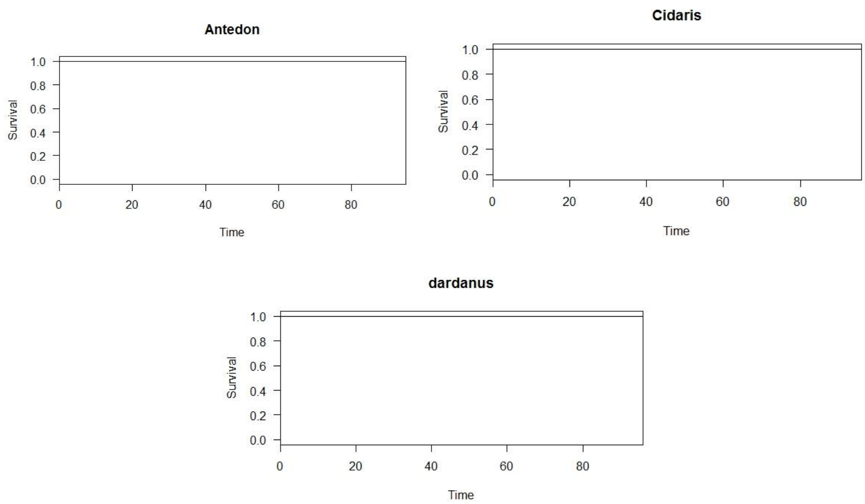


Figure 2. K-M survival curves for *Antedon mediterraneum*, *Cidaris cidaris* and *Dardanus arrosor* . All three species showed 100% of survival.

Table 4. Survival estimates (at 96 hours), with Wilson Score 95% confidence intervals, of non-regulated invertebrate species sampled from trawlcatches on the fishing grounds adjacent to Blanes.. The selected species for Kaplan-Meier analysis are highlighted.

Groups	Species	Number	Dead animals at 96 H	Survival rate	Lower 95% CI	upper 95% CI
Echinoderms	*Anseropoda placenta*	1	0	1.0	0.20654931	1.0
	Antedon mediterranea	29	0	1.0	0.8830302	1.0
	Astropecten aranciacus	6	0	1.0	0.6096657	1.0
	Astropecten irregularis	2	0	1.0	0.3423802	1.0
	Cidaris cidaris	12	0	1.0	0.7575060	1.0
	Echinaster sepositus	16	1	0.9375000	0.7167126	0.9888807
	Echinus melo	23	7	0.6956522	0.4913424	0.8439598
	Ophiura texturata	38	8	0.7894737	0.6365422	0.8892521
	Peltaster placenta	1	0	1.00	0.20654931	1.0
	Leptometra phalangium	152	42	0.7236842	0.6477467	0.7885942
Crustaceans	*Dardanus arrosor*	12	0	1.0	0.7575060	1.0
	Goneplax rhomboide	2	1	0.5	0.094531206	0.9054688
	Liocarcinus depurator	3	1	0.6666667	0.20765960	0.9385081
	Macropipus tuberculatus	6	2	0.6666667	0.2999933	0.9032286
	Macropodia sp.	1	1	0.00	0.00000000	0.7934507
	Monodaeus couchii	2	1	0.5	0.094531206	0.9054688
	Munida intermedia	6	6	0.00	0.00000000	0.3903343
	Partenope macrochelos	4	0	1.0	0.5101092	1.0
Cnidarians	*Alcyonium palmatum*	1	1	0.00	0.00000000	0.7934507
	Pteroide spinosum	1	0	1.00	0.20654931	1.0
Ascidians	*Diazona violacea*	4	0	1.0	0.5101092	1.0
	Microcosmus sulcatus	2	0	1.0	0.3423802	1.0

Leptometra phalangium was observed to have more than 90% survival. However, at vitality state 3 mortality started after 30 hours and did not reach a stable level of mortality (asymptote) within the 96 hour monitored (Figure 3; Table 5). For, state 1 and 2 there was no evidence of mortality (Figure 4; Table 6).

Table 5. Summary of survival and K-M estimates for *Leptometra phalangium (all vitality states combined)*

time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
0	152	12	0.921	0.0219	0.879	0.965
30	140	4	0.895	0.0249	0.847	0.945
42	136	4	0.868	0.0274	0.816	0.924
54	132	9	0.809	0.0319	0.749	0.874
66	123	4	0.783	0.0334	0.720	0.851
78	119	4	0.757	0.0348	0.691	0.828
90	115	5	0.724	0.0363	0.656	0.798

Tabla 6. Summary of survival and K-M estimates for *Leptometra phalangium (vitality state 3)*

T0.0H.=3

time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
30	86	4	0,953	0,0227	0,91	0,999
42	82	4	0,907	0,0313	0,848	0,97
54	78	9	0,802	0,0429	0,722	0,891
66	69	4	0,756	0,0463	0,67	0,852
78	65	4	0,709	0,049	0,62	0,812
90	61	5	0,651	0,0517	0,558	0,76

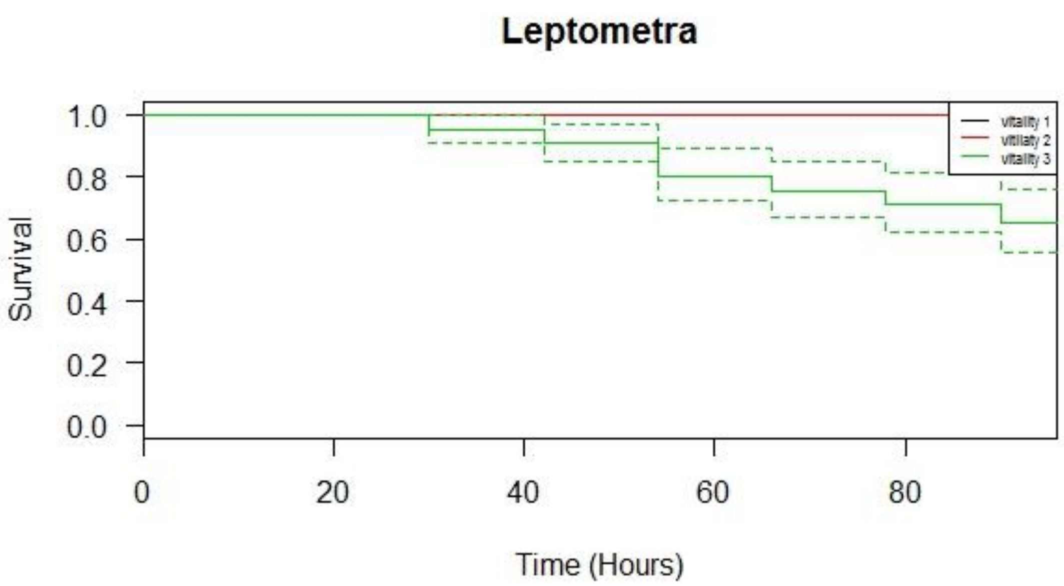


Figure 4. K-M survival curve for *Leptometra phalangium* with three states of vitality 1, 2, 3. Mortality was evident after 30 hours of monitoring for vitality state 3 and no stable level of mortality (asymptote) was achieved.

For *Ophiura texturata* there were similar results. There was no evidence of mortality at state 1 and 2. However, mortality appears at 66 hours for animals of vitality state 3 and although their survival was still high at 96 hours of observation (>79 %), it had not reached asymptote (Figure 5).

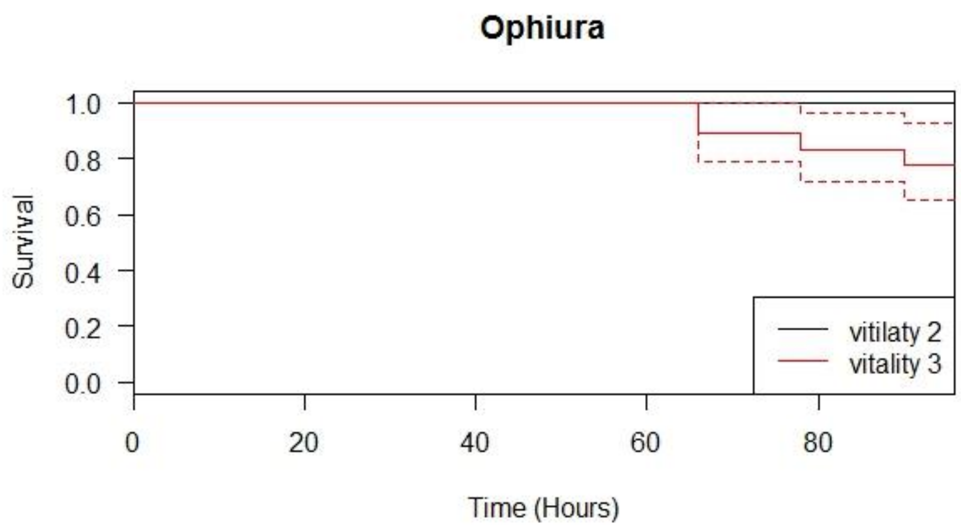


Figure 5. K-M survival curve for *Ophuira texturata* with two states of vitality 2, 3. Mortality was evident at 66 hours in vitality state 3 animals, and no stable level of mortality (asymptote) was observed.

Tabla 7. Results of K-M model to analyse survival of *Ophiura texturata.*

time	n.risk	n.event	survival	std.err	Lower 95% CI	upper95% CI
66	38	4	0.895	0.0498	0.802	0.998
78	34	2	0.842	0.0592	0.734	0.966
90	32	2	0.789	0.0661	0.670	0.930

Table 8. Survival mortality of K-M model of *Ophiura texturata* at States of Vitality 3 at T3

T3.28.5H.=3

time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
66	36	4	0,89	0,0524	0,792	0,998
78	32	2	0,833	0,0621	0,72	0,964
90	30	2	0,778	0,0693	0,653	0,926

In the case of *Echinaster sepositum* only vitality state 3 was observed in capture animals. Mortality at state 1 was observed at 6 hours, but no further deaths were observed and an asymptotic survival of >90% appears at 96 hours (Figure 6 and Table 9).

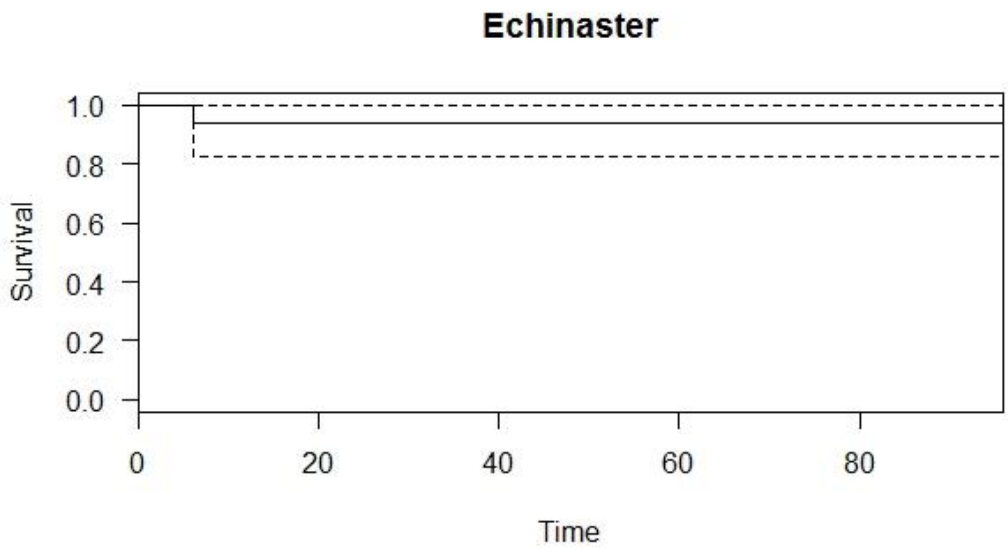


Figure 6. K-M survival curve for *Echinaster sepositus*. Mortality was evident at 6 hours after which a stable level of mortality (asymptote) was observed.

Table 9. Results of K-M model to analyse survival of *Echinaster sepositus*

time	n.risk	n.event	survival	Std.err	Lower 95% CI	Upper 95% CI
6	16	1	0.938	0.0605	0.826	1

Discussion

Survival was generally high for all invertebrate species throughout the assessment; 9 of the 22 species studied show 100% survival. Although, sample sizes were too small to assess whether season or fishing grounds had any influence on survival.

Of the six species assessed by K-M, mortality was only observed in three: *Echinaster sepositus* (Mediterranean red sea star); *Ophiura texturata* (serpent star); and *Leptometra phalangium* (feather star). Furthermore, mortality was only observed in animals with “poor” (level 3) states of vitality, and thus were displaying signs of injury (see table 1). These animals were all echinoderms and thus their body form, particularly brittle stars (*Ophiurida*) and feather stars (*crinoids*), may be more vulnerable to damage during the capture process in trawls, compared to other invertebrates. Although, the other crinoid *Antedon mediterraneum* showed 100% survival. However, the small sample sizes in species from other phylla preclude a thorough exploration of this hypothesis.

Furthermore, the vulnerability of species to trawling related biological factors: behaviour, reproductive characteristics, resilience and habitat conditions; can increase the effect of stressors and injuries on the survival of discarded animals (de Juan and Demestre, 2012). Some of the echinoderms and crinoids form large aggregations creating critical habitats for different demersal resources (Colloca et al., 2004). Therefore, it is of paramount importance to know the survival of the discarded benthic invertebrates to preserve essential habitats and maintain sustainable fisheries.

Emersion from water during sorting (time on deck T0) can be stressful for aquatic animals, as they are exposed to various stressors, including: increased temperatures, desiccation and potentially asphyxia. This assessment deliberately limited sampling times to 20 minutes to limit these effects on the experimental subjects, and thus focus on the effects of capture and handling. However, it would be beneficial for future studies to investigate the effects of prolonged emersion to better understand the effects of handling and sorting practices on the survival and vitality of discarded animals. Furthermore, studies should be made to investigate the benefits of improved handling and sorting practices on survival and vitality. For example, cover the catch with sacking material, soaked and refreshed with running sea water, until all catch has been sorted. With these practices, at least desiccation could be avoided and temperature shock reduced.

Finally, the observation period of only 96 hours was too short to observe any stabilisation of mortality for at least two species: *Ophiura texturata* and *Leptometra phalangium.* Furthermore, it is possible that with relatively sessile animals, with low metabolisms, evidence of fatal injuries may take longer than 96 hours to become apparent. Therefore, it is recommended that future assessments of invertebrate discard survival should monitoring for longer periods, ideally until any apparent mortality has stabilised.

Recomendations

It is recommended that further work should attempt to collect sufficient data on survival and states of vitality to explore the potential for spatial and temporal variation in survival, as well as the effects of body form and size, and other biological factors, on the vulnerability of invertebrate animals to stress and injury during capture in trawls.

Acknowledgements

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CS 1.6. & 1.8. Preliminary estimation of discard vitality rates in the southern Tuscany otter trawl fishery

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Introduction

The trawl fleet in the Ligurian and northern Tyrrhenian Seas (FAO division 37.1.3, Geographical Sub-Area 9, GSA09), in 2012, consisted of 330 boats, with an overall tonnage of approximately 13,000 GT, representing about 70% of the fishing capacity employed in the area. The landings volume produced by trawlers was about 8,000 tonnes. This production features a high proportion of fish (58%), followed by molluscs (27%) and crustaceans (15%). The most important species in terms of landings are European hake, red mullet and horned octopus; the crustaceans Norway lobster, deep-water pink shrimp, and giant red shrimps also play an important role thanks to their high economic value.

The Ligurian and Tyrrhenian bottom otter trawl fisheries are characterised by the problems affecting most of the Mediterranean fisheries: multi-specific composition of the catch and presence of a large number of juveniles of many commercial species subjected to minimum legal size (Caddy, 1993). These characteristics affect the discard practice, and discards may represent a high percentage of the total catch in some periods of the year and in some areas. In particular, the investigated area is characterized by important nurseries for hake, *Merluccius merluccius*, where the concentration of juveniles is among the highest in the Mediterranean (Orsi Relini et al., 2002; Colloca et al., 2004). The introduction of 40 mm square mesh or 50 mm diamond mesh (Council Regulation (CE) No 1967/2006), although contributing to reducing discards, cannot solve the problem by itself due to the characteristics of the fisheries, the demersal communities and the area.

There is currently very little information on the fate of the discarded animals, in terms of there likely survival following the stresses of capture, handling and discarding (STECF EWG 15-14). To address this in case studies 1.6 & 1.8, a prioritisation study was carried out to identify species that would be suitable for survival assessments. The approach to estimating survival rates was to use vitality assessments of catches under normal fishing conditions (ICES, 2014 & 2017), and a categorial vitality assessment was used according to Benoit et al. (2010). Further assessment of survival potential could be justified if species were demonstrated to have a high proportion of animals with high vitality at the point discarding.

Methods

<u>Sampling on board commercial trawlers.</u>

Sampling activities were carried out from November 2016 to February 2017. On a monthly basis, scientific observers performed fishing trips on board commercial vessels. During the fishing trips, there was no interference with the habitual “*modus operandi*” of the fishermen and the fishing (position, duration, sorting, etc.) was decided independently by the crew. For each commercial haul, length of the warps, date, position, depth, and course were recorded. A Simrad system was installed on the trawl net to have information on the geometry of the trawl net (vertical and horizontal opening). The commercial fraction was recorded and weighed at species level. Depending on the quantity, all or a sub-sample of the discarded fraction was collected, and successively sorted and examined in the laboratory. The species composition of the discards was determined and total weight and number of individuals of each taxon was recorded. A scheme of the activity carried out on board is shown in Figure 1.

The trawl gear was deployed, towed and hauled following the normal commercial fishing practises. The cod-end was opened on the aft deck, and the net was re-deployed prior to sorting the catch. This process, depending on the depth, took from 5 to 25 minutes before sorting of the catch began. The crew sorted the catch by hand, and they were asked to place discards into polystyrene boxes, where the vitality of discarded specimens was assessed by the observer. The vitality of fish was assessed using a categorical vitality assessment scale (Benoit et al., 2010; ICES, 2017; see Table 1). Data was recorded using the form shown in Figure 2. A Vitality Index (V_I) was calculated as the ratio between the number of specimens with a vitality from 1 to 3, (V_N) and the total number of discarded individuals (D_N) and expressed as a percentage.

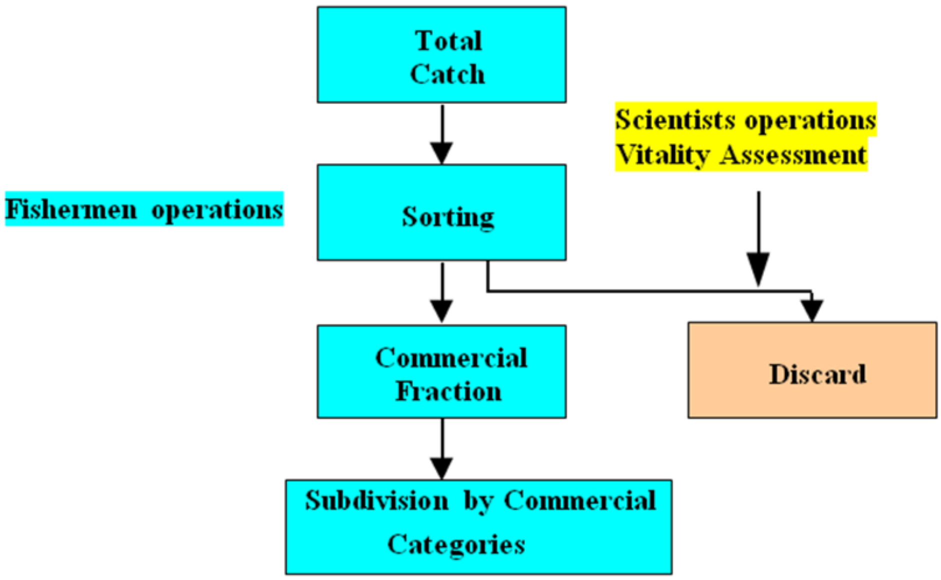

Figure 1. Scheme describing the activities carried out on board.

Table 1. Categorical scale used to score vitality in fish (from Benoit et al., 2010).

VITALITY		DESCRIPTION
EXCELLENT	**1**	Vigorous body movement; lively
GOOD	**2**	Fair body movement; responds to touching/prodding
POOR	**3**	Weak or no body movement; fish can move operculum
DEAD	**4**	No body or opercular movements (no response to touching or prodding)

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Horizon 2020 -Grant Agreement No. 634495

MINOUW

Horizon 2020 European Union Funding for Research & Innovation

Catch Sorting Monitoring: LANDING OBLIGATION & DISCARD SURVIVAL		
Operators: ________________	Sample code: P______-17	Haul N°:
Date: __/__/____	Sorting modality(1): 1 TRADITIONAL	2 LANDING OBLIGATION
Codend boarding time ____:____:____	N° fishermen sorting:	

Sorting	Start Time (T_0)(2)	End Time	Duration	N° of discard boxes(3)
TRADITIONAL	___:___:___	___:___:___	___:___:___	n.____ Traditional
LAND. OBL.	___:___:___	___:___:___	___:___:___	n.____ Traditional n. ____ Annex III

DISCARD SURVIVAL ASSESSMENT (only during Traditional Sorting)												
TIME(4)	(T_0) Codend opening ___:___:___			(T_1) Beginning to 15 min ___:___:___			+15 min to 30 min (T_2) ___:___:___			30 min to end (T_3) ___:___:___		
VITALITY(5)	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*

VITALITY: 1. Excellent; 2. Good/Fair; 3. Poor; 4. Moribund

DATA________________FIRMA_________________________
Inserimento: DATA________________FIRMA_________________________

Figure 2. Form used for data recording.

Sampling and catches

Fishing areas were decided by fishermen taking into account weather conditions and market price and demand (Fig. 3). Twenty-two commercial hauls were carried out in a bathymetric range 85-470 m. The average haul duration was 2.1 hours (min 1.4, max 4.4 hours). Table 2 summarizes the information recorded during each fishing tow.

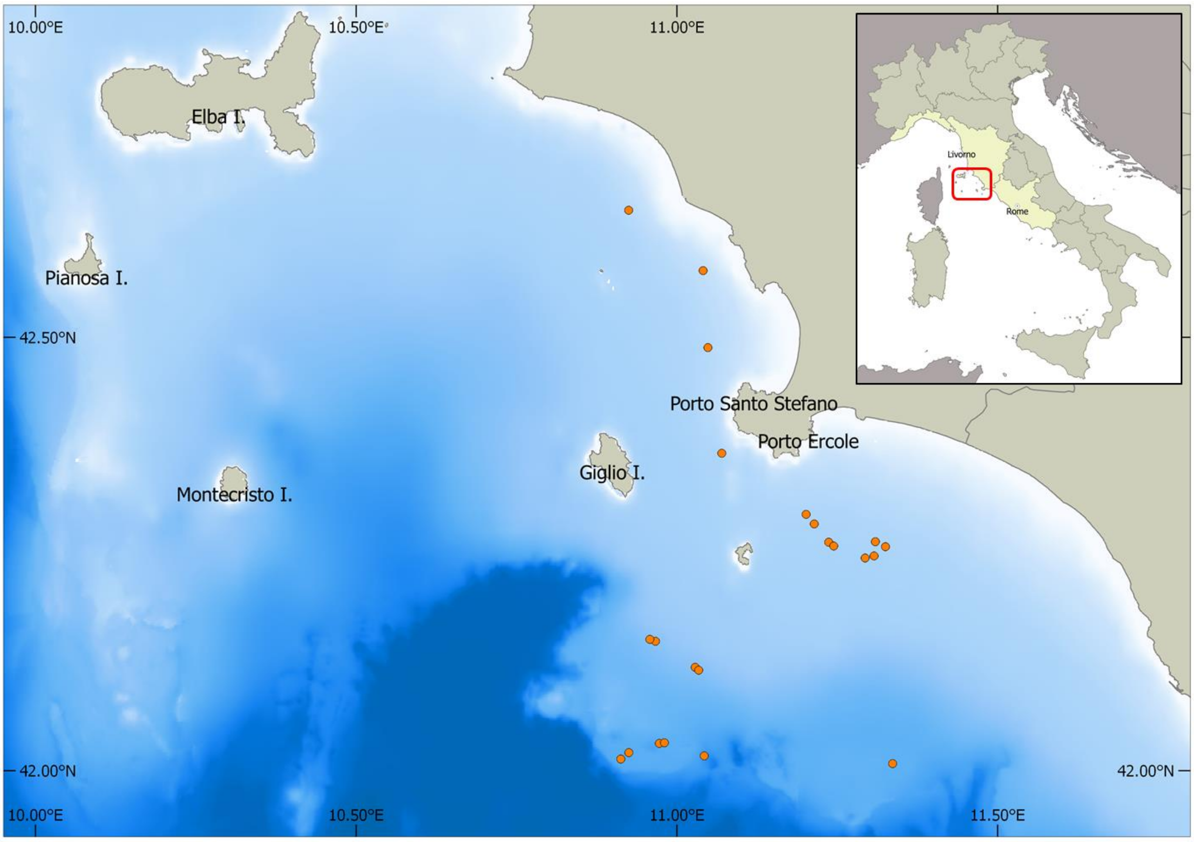

Figure 3. Study area. Each red dot indicates a trawling haul.

Table 2. Trawling hauls carried out during the study.

Haul Num	Date	Haul In	Haul Duration (min)	LATIN	LONGIN	AVG Depth	AVG Velox (nm/h)	WIND DIR	WIND SPEED (km/h)	BOTTOM TEMP °C	WATER SURFACE TEMP °C	AIR TEMP °C	light intensity (W/m$^{2)}$	Swept Area (km^2)
1	30/11/2016	7.30	95.00	42 07 173	11 01 718	230.00	3.4	NE	8.0	14.32	16.40	4.5	50.0	0.22745
2	30/11/2016	10.00	102.00	42 08 978	10 58 001	250.00	3.2	NE	18.0	14.27	16.47	8.0	380.0	0.22568
3	30/11/2016	13.45	90.00	42 15 843	11 14 209	112.00	3.3	NE	10.5	14.89	17.45	12.0	300.0	0.19265
4	30/11/2016	16.00	90.00	42 15 531	11 19 519	97.30	3.4	S	1.8	15.60	17.30	12.0	50.0	0.20658
5	01/12/2016	7.03	97.00	42 06 970	11 02 047	238.00	3.5	E	10.0	14.28	16.40	1.0	0.0	0.22823
6	01/12/2016	9.35	105.00	42 09 113	10 57 476	250.00	3.2	E	6.0	14.24	16.69	5.0	100.0	0.23469
7	01/12/2016	13.25	95.00	42 15 580	11 14 680	112.00	3.2	NE	6.0	14.81	17.40	12.0	100.0	0.19942
8	01/12/2016	15.40	70.00	42 15 876	11 18 576	101.00	3.4	E	5.5	14.93	17.40	12.0	25.0	0.15438
9	14/12/2016	3.30	95.00	42 17 104	11 12 857	112.00	3.3	E	7.0	14.85	17.43	8.0	0.0	0.20336
10	14/12/2016	7.55	85.00	42 01 891	10 58 365	425.00	3.4	E	4.5	14.11	16.20	7.5	30.0	0.18644
11	14/12/2016	10.30	90.00	42 00 804	10 54 763	428.00	3.3	E	1.8	14.10	16.00	12.5	160.0	0.19160
12	14/12/2016	15.15	105.00	42 14 894	11 18 452	109.00	3.4	S	6.5	14.71	16.90	13.0	0.0	0.23157
13	15/12/2016	3.25	105.00	42 17 771	11 12 094	109.00	3.3	E	6.5	14.71	16.95	9.0	0.0	0.22476
14	15/12/2016	10.40	120.00	42 01 249	10 55 510	418.00	3.3	NE	5.0	14.11	16.00	12.0	380.0	0.25547
15	15/12/2016	15.20	100.00	42 14 748	11 17 619	105.00	3.4	N	3.6	14.72	17.00	14.0	20.0	0.23072
16	15/12/2016	8.00	90.00	42 01 933	10 58 840	433.00	3.4	E	7.2	14.11	16.00	9.0	90.0	0.19356
17	26/01/2017	10.05	185.00	42 29 289	11 02 910	84.00	3.1	E	9.0	13.87	14.00	9.0	400.0	0.27143
18	26/01/2017	13.44	204.00	42 21 995	11 04 209	92.00	3.2	S	5.0	13.84	14.10	14.0	300.0	0.31233
19	26/01/2017	1.20	249.00	42 77 830	11 02 800	85.00	3.3	E	10.0	13.47	13.70	3.0	0.0	0.41849
20	26/01/2017	6.09	201.00	42 38 750	10 55 496	84.00	3.1	E	11.0	13.40	13.95	1.5	0.0	0.32450
21	16/02/2017	6.55	259.00	42 00 486	11 20 189	420.00	3.5	E	9.5	14.11	16.10	3.0	250.0	0.58481
22	16/02/2017	12.20	180.00	42 01 024	11 02 563	470.00	3.5	SO	7.2	14.10	16.0	15.0	600.0	0.40643

Results

During the study, 199 species and higher taxa (e.g. Genus) were identified. They belong to the following groups: elasmobranchs (12 species), bony fish (78 species), cephalopods (19 species), crustaceans (35 species). In addition, 55 species and higher taxa belonging to echinoderms, cnidarians, and other invertebrates were identified. The commercial fraction was composed of 58 species, while the discards included a total of 177 species and higher taxa. The species composition of commercial catch and discards is shown in Fig. 4 (in terms of number of species) and Fig. 5 (in terms of biomass).

In the commercial catch, 59.3% of fish species were landed, corresponding to 42.1% of the total landed catch, by weight. Crustaceans represented 31.3% of the commercial fraction, by weight, despite only 8.5% of the species of this group being landed. For cephalopods, 71.4% was landed, corresponding to 22.4% of the landed catch, by weight. Regarding elasmobranchs, they represented only a small fraction of the landed catch (4.0% by weight).

Besides the importance of the above-mentioned groups, species belonging to different groups of invertebrates were collected (e.g., echinoderms, cnidarians, gastropods, etc.). These groups represented around the 20.0% of discards both in terms of numbers and weight.

<u>Vitality assessment</u>

Out of the 177 species and taxa identified in the discarded fraction, 49 only were scored with a “vitality” level (see Annex I and II for details), while 128 species and taxa were not scored because they arrived on board already dead. Tables 3-6 report the number of specimens collected, by category, for regulated species, fishes, cephalopods, crustaceans and elasmobranchs.

During the study, 14 regulated species were caught, and only four were present in the discards and considered for vitality assessment (with MCRS, according to Annex III of the Reg. EC 1967/2006) (Tables 3 and 4). It is worth highlighting that important species for the otter trawl fishery, such as European hake (*Merluccius merluccius*) and red mullet (*Mullus barbatus*), were abundant in the discarded fraction but not scored with a vitality rate because they were already dead when arriving on deck.

Twenty-eight out of the 49 species assessed for vitality are exclusive to the discarded fraction, while 16 were present in both the commercial catch and discards. Considering the regulated species, only horse mackerel (*Trachurus trachurus*,) and Norway lobster (*Nephrops norvegicus*,) showed a vitality index larger than 10% (14.9% and 24.7% respectively). However, the vitality score profile (Fig. 6) shows that the specimens in V_1 were less than 10% of the total.

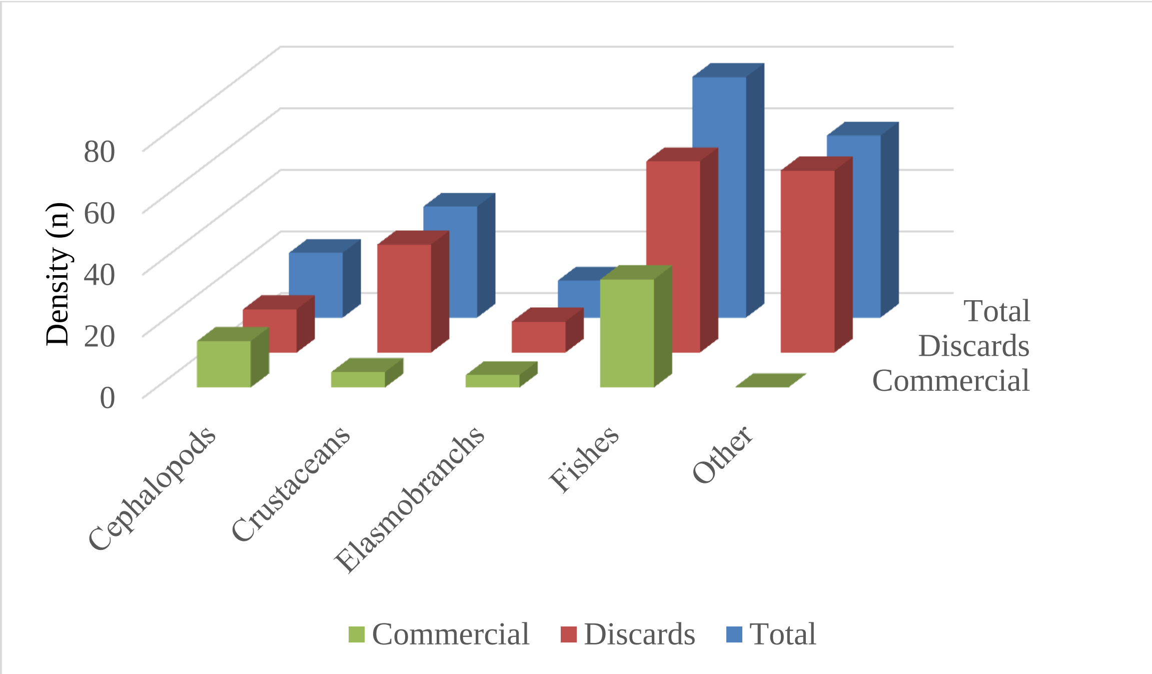

Figure 4. Composition in terms of number of species by taxonomic group of commercial catch and discards.

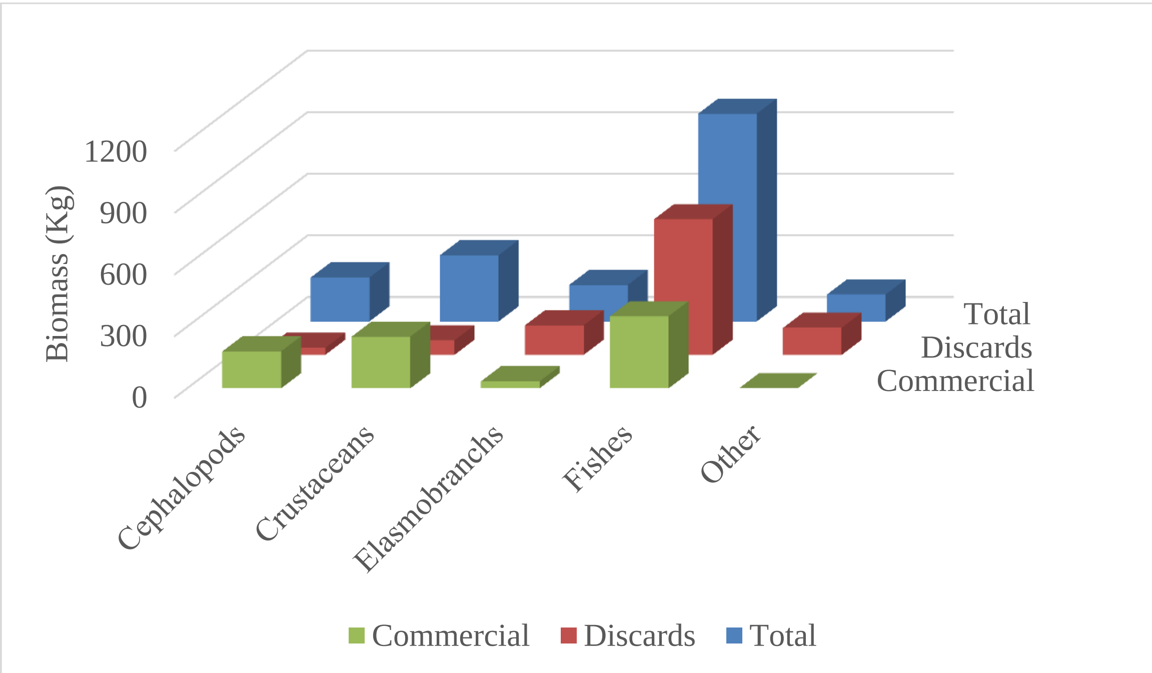

Figure 5. Composition in terms of biomass (Kg) by taxonomic group of commercial catch and discards.

Table 3. Number of specimens collected by category for the species with Minimum Conservation Reference Size. (Disc_Vit= Discarded with a vitality)

Species	Commercial	Discarded	Disc_Vit
D. labrax	1		
E. encrasicolus		3157	
M. merluccius	502	6115	
M. barbatus	1171	533	
M. surmuletus	17		
N. norvegicus	1578	299	31
P. erythrinus	27	42	
P. longirostris	17823	1604	24
S. pilchardus	90	376	
S. colias	2		
S. scombrus	1		
S. solea	41	1	
T. mediterraneus	78	2690	38
T. trachurus		302	40

Table 4. Regulated species. Total number of commercialised individuals (C_N), number of specimens with a vitality from 1 to 3, (V_N), total number of discarded individuals (D_N) and Vitality index (V_I) computed as (V_N)/(D_N)*100.

Species	C_N	V_N	D_N	V_I
N. norvegicus	1578	31	299	10.2
P. longirostris	17823	24	1604	1.5
T. mediterraneus	78	38	2690	1.4
T. trachurus		40	302	13.3

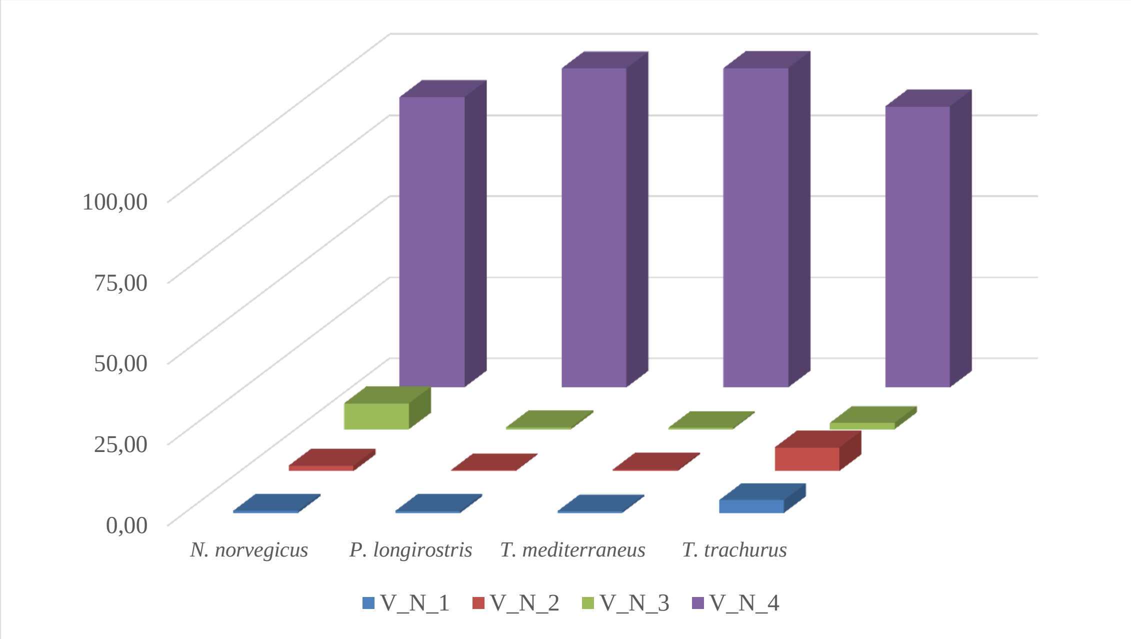

Figure 6. Vitality score profile of regulated species.

Vitality scores for sixteen potentially commercial species observed in the discarded fraction are reported in Tables 5 and Fig. 7. Of these, only 6 species had vitality indexes greater than 50% (Table 5) and a high proportion of animals with vitality states 1 or 2, including: *Conger conger, Dipturus oxyrinchus, Raja* spp., *Scorpaena* spp., *Scyliorhinus canicula* and *Uranoscopus scaber.*

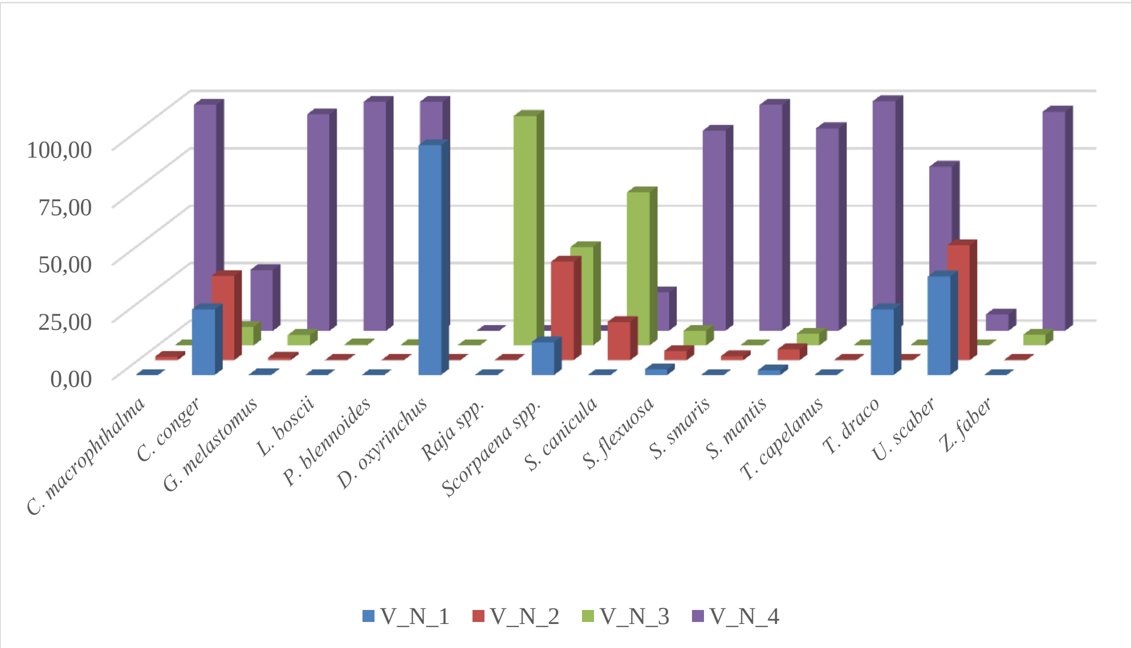

Figure 7. Vitality score profile of the discarded species with potential commercial value.

Table 5. Discards of commercial species. Total number of commercialised individual (C_N), Number of specimens with a vitality from 1 to 3, (V_N), total number of discarded individuals (D_N) and Vitality index (V_I) computed as (V_N)/(D_N)*100.

Species	C_N	V_N	D_N	V_I
C. macrophthalma		3	193	1.6
C. conger		36	49	73.5
D. oxyrinchus	1	1	1	100.0
G. melastomus	1	104	1797	5.8
L. boscii	79	2	632	0.3
P. blennoides	41	2	866	0.2
Raja spp.		24	24	100.0
Scorpaena spp.		21	21	100.0
S. canicula	32	40	48.0	82.3
S. flexuosa		16	125	12.4
S. smaris		4	240	1.7
S. mantis	1073	262	2218	11.8
T. capelanus	698	2	3758	0.1
T. draco		2	7	28.6
U. scaber	8	7	7	100.0
Z. faber	2	2	43	4.7

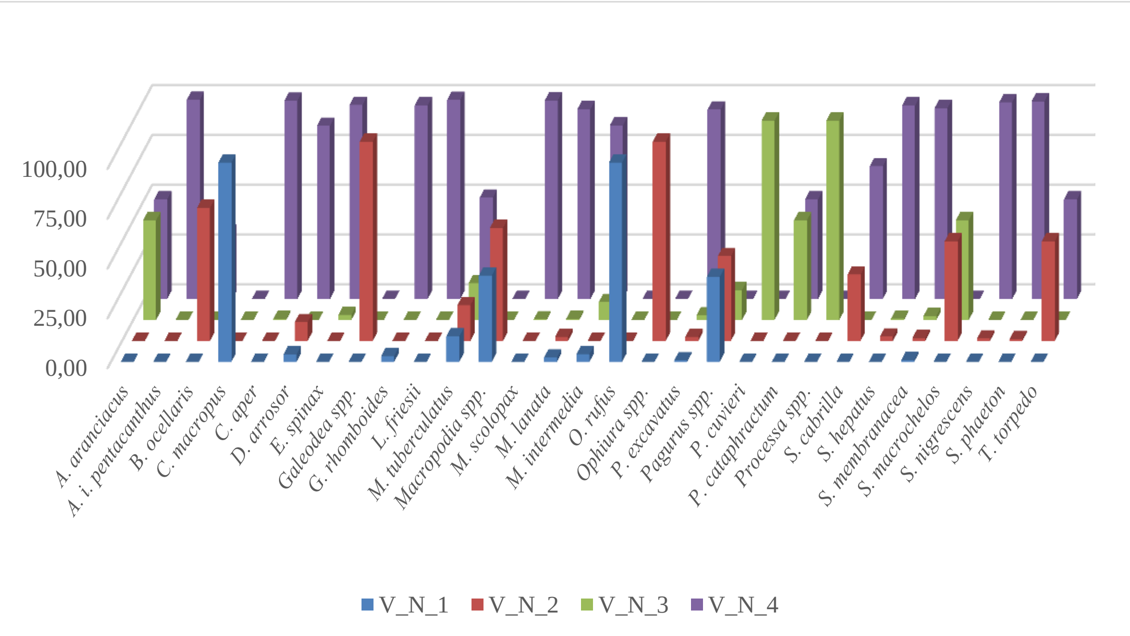

Figure 8. Vitality score profile of non-commercial species.

Table 6. Discards of non-commercial species. Number of specimens with a vitality from 1 to 3, (V_N), total number of discarded individuals (D_N) and vitality index (V_I) computed as (V_N)/(D_N)*100.

Species	V_N	D_N	V_I
A. aranciacus	3	6	50.0
A. irregularis pentacanthus	4	15940	0.0
B. ocellaris	2	3	66.7
C. macropus	3	3	100.0
C. aper	2	394	0.5
D. arrosor	14	107	13.1
E. spinax	2	78	2.6
Galeodea spp.	84	84	100.0
G. rhomboides	7	244	2.7
L. friesii	3	4703	0.1
M. tuberculatus	85	173	48.8
Macropodia spp.	104	104.00	100.00
M. scolopax	4	600	0.7
M. lanata	47	1363	3.4
M. intermedia	5	39	12.8
O. rufus	9	9	100.0
Ophiura spp.	3	3	100.0
P. excavatus	38	795	4.8
Pagurus spp.	40	40.00	100.0
P. cuvieri	2	2	100.0
P. cataphractum	2	4	50.0
P. canaliculata	2	2	100.0
S. cabrilla	1	3	33.3
S. hepatus	12	420	2.9
S. membranacea	409	9655	4.2
S. macrochelos	4	4	100.0
S. nigrescens	9	752	1.2
S. phaeton	3	381	0.8
T. torpedo	2	4	50.0

Vitality scores for twenty-nine potentially non-commercial species observed in the discarded fraction are reported in Table 6 and Fig. 8. Of these, 11 species had vitality indexes greater than 50% (table 5) and a high proportion of animals with vitality states 1 or 2, including: *Blennius ocellaris*, *Callistoctopus. macropus, Galeodea* spp.*, Macropodia spp., Ophicthus rufus, Ophiura* spp.*, Pagurus* spp.*, Paromola cuvieri., Processa canaliculata, Spinolambrus macrochelos* and *Torpedo torpedo.*

Discussion

The objective of this study was to identify species that would be suitable for more in-depth survival assessments. This could be justified if species were demonstrated to have a high proportion of animals with high vitality at the point discarding; i.e. vitality indexes greater than 50% and a high proportion of animals with vitality states 1 or 2. Although, this does not guarantee survival of these animals post-discarding, it would be reasonable to assume that animals without such vitalities at the point of discarding with be unlikely to survive long-term.

The results of this preliminary analysis indicate that regulated species in this fishery (species included in the Annex III of Reg. EC 1967/2006) generally have a low vitality when discarded. However, six potentially commercial discarded species were observed with high vitality scores, namely: *C. conger, D. oxyrinchus, Raja* spp., *Scorpaena* spp.*, S. canicula* and *U. scaber.*

The majority of species that present some vitality were represented by non-commercial taxa, mostly invertebrates, such as crustaceans, echinoderms, etc. Of these, 11 species had vitality indexes greater than 50% (table 5) and a high proportion of animals with vitality states 1 or 2, including: *B. ocellaris*, *C. macropus, Galeodea* spp.*, Macropodia* spp.*, O. rufus, Ophiura* spp.*, Pagurus* spp.*, P. cuvieri., P. canaliculata, Serranus* spp.*, S. cabrilla, S. macrochelos* and *T. torpedo.*

Conclusion

This preliminary analysis did not identify any regulated species that would be suitable for further survival or TTM (Time to Mortality) studies. However, the study did identify 6 commercial species and 11 non-commercial species that did have high vitality scores at the point of discarding. Although, these species are not currently subject to the Landing Obligation, and the associated high survival exemption, reliable data on their survival potential could be invaluable. Firstly, for interpreting the effect of the Landing Obligation across the wider ecosystem, but also for informing fisheries managers on the likely benefit of the Landing Obligation in terms of shifts in harvesting patterns and resulting changes in fishing related mortality.

Annex I: List of discarded species not registered with vitality score.

Group	Scientific name
Cephalopoda	*Alloteuthis* spp.
	Heteroteuthis dispar
	Illex coindetii
	Loligo vulgaris
	Neorossia caroli
	Octopus salutii
	Octopus vulgaris
	Rondeletiola minor
	Sepia elegans
	Sepia orbignyana
	Sepietta oweniana
	Sepiolidae
	Todaropsis eblanae
Chondriychthyes	*Hexanchus griseus*
	Raja asterias
	Raja clavata
	Raja miraletus
	Torpedo marmorata
Crustacea	*Aegaeon cataphractus*
	Alpheus glaber
	Chlorotocus crassicornis
	Liocarcinus depurator
	Maja crispata
	Paguristes eremita
	Pagurus alatus
	Pagurus prideaux
	Pasiphaea sivado
	Plesionika antigai
	Plesionika edwardsii
	Plesionika gigliolii
	Plesionika heterocarpus
	Plesionika martia

	Polycheles typhlops
	Pontophilus spinosus
	Processa canaliculata
	Rissoides pallidus
	Scalpellum scalpellum
Osteichthyes	*Aphia minuta*
	Argentina sphyraena
	Arnoglossus laterna
	Atherina spp.
	Boops boops
	Callionymus maculatus
	Carapus acus
	Chauliodus sloani
	Chlorophthalmus agassizi
	Citharus linguatula
	Coelorinchus caelorhincus
	Deltentosteus quadrimaculatus
	Echelus myrus
	Engraulis encrasicolus
	Epigonus denticulatus
	Gadiculus argenteus
	Gaidropsarus biscayensis
	Glossanodon leioglossus
	Gobius geniporus
	Gobius niger
	Helicolenus dactylopterus
	Hoplostethus mediterraneus mediterraneus
	Hymenocephalus italicus
	Lampanyctus crocodilus
	Lepidorhombus whiffiagonis
	Lepidotrigla cavillone
	Lesueurigobius suerii
	Lophius budegassa
	Merluccius merluccius

	Microchirus variegatus
	Molva dypterygia
	Mullus barbatus
	Nettastoma melanurum
	Nezumia sclerorhynchus
	Ophidion rochei
	Pagellus erythrinus
	Sardina pilchardus
	Scorpaena notata
	Solea solea
	Trigla lyra
Other	*Actiniaria*
	Alcyonium palmatum
	Antedon mediterranea
	Aporrhais pespelecani
	Aporrhais serresianus
	Armina tigrina
	Ascidia spp.
	Astropecten bispinosus
	Bivalvia
	Bolinus brandaris
	Calliactis parasitica
	Calliostoma granulatum
	Cidaris cidaris
	Echinaster sepositus
	Echinus melo
	Funiculina quadrangularis
	Fusinus rostratus
	Galeodea echinophora
	Glandiceps talaboti
	Glossus humanus
	Gracilechinus acutus
	Gryphus vitreus
	Holothuria tubulosa
	Hyalinoecia tubicola

Isopoda

Leptometra phalangium

Leptopentacta elongata

Leptopentacta tergestina

Lophogorgia sarmentosa

Marthasterias glacialis

Microcosmus spp.

Mimachlamys varia

Neopycnodonte coclear

Nucula sulcata

Nudibranchia

Ocnus planci

Ophiuroidea

Ostrea spp.

Panthalis oerstedi

Pennatula rubra

Philine aperta

Phyllophorus urna

Polychaeta

Porifera

Pteroides griseum

Sternaspis scutata

Stichopus regalis

Suberites domuncula

Turritella communis

Annex II: List of discarded species and taxa assigned to a vitality score.

Group	Scientific name
Cephalopoda	*Callistoctopus macropus*
Chondriychthyes	*Dipturus oxyrinchus*
	Etmopterus spinax
	Galeus melastomus
	Scyliorhinus canicula
	Torpedo torpedo
Crustacea	*Dardanus arrosor*
	Goneplax rhomboides
	Macropipus tuberculatus
	Macropodia spp.
	Medorippe lanata
	Munida intermedia
	Nephrops norvegicus
	Pagurus excavatus
	Pagurus spp.
	Parapenaeus longirostris
	Paromola cuvieri
	Processa canaliculata
	Solenocera membranacea
	Spinolambrus macrochelos
	Squilla mantis
Osteichthyes	*Blennius ocellaris*
	Capros aper
	Cepola macrophthalma
	Conger conger
	Lepidorhombus boscii
	Lesueurigobius friesii
	Macroramphosus scolopax
	Ophichthus rufus
	Peristedion cataphractum
	Phycis blennoides
	Scorpaena spp.

	Serranus cabrilla
	Serranus hepatus
	Spicara flexuosa
	Spicara smaris
	Symphurus nigrescens
	Synchiropus phaeton
	Trachinus draco
	Trachurus mediterraneus
Osteichthyes	*Trachurus trachurus*
	Trisopterus capelanus
	Uranoscopus scaber
	Zeus faber
Other	*Astropecten aranciacus*
	Astropecten irregularis pentacanthus
	Galeodea spp.
	Ophiura spp.

CS 2.2. Algarve Purse seine – survival of slipped sardines

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[Extract of a manuscript submitted to ICES Journal of Marine Science]

Introduction

The Portuguese purse-seine fishery targeting European sardine (*Sardina pilchardus*) is responsible for ~50% in biomass of fish catches landed in mainland ports (DGRM, 2016). More recently, in response to the recent decline of the sardine stock, restrictive fishing measures have been applied in order to assure the sustainability of the resource (Silva *et al.*, 2015). To assure economic viability, during the period of the "sardine ban", the purse seine fishing sector targets other important small pelagic in the Portuguese pelagic system, such as chub mackerel (*Scomber colias*) and horse mackerel (*Trachurus trachurus*). However, if any sardine is mixed in these catches, the fishermen are obliged to release the catch via slipping.

The deliberate release of pelagic-schooling fishes at the end of purse seine fishing operations, also referred to as slipping, is a manoeuvre traditionally used to avoid excess or unwanted catch due to regulatory or market demands (Stratoudakis and Marçalo 2002; Hamer et al., 2008). Slipping is a process where part of the catch is released by rolling the fish over the headline (floating line) of the net after partially hauling in, or "drying-up", the net while it is still in the water (Pawson and Lockwood, 1980; Lockwood et al., 1983; Mitchell et al., 2002; Stratoudakis and Marçalo, 2002). This process led to the assumption that the fishery had a low impact on escapees, because the catch never leaves the water before being released. Thus, for most purse seine fisheries, slipping is not accounted for and fish released in such condition are assumed to survive. However, for the last decade, a growing body of research has demonstrated that mortality of slipped fish for several small pelagic species (e.g. sardines, sardinops, herring, mackerel) may be substantial and may result in unacceptably high rates of unaccounted fishing mortality (Lockwood et al., 1983; Mitchell et al., 2002; Stratoudakis and Marçalo 2002; Gonçalves et al., 2008; Marçalo et al., 2006, 2010; Huse and Vold 2010, Tenningen et al., 2012). These studies have shown that mortality of slipped fish is directly related to their treatment within the net, with mortality increasing with increasing crowding densities, crowding time, and scale loss (Lockwood et al., 1983; Marçalo et al., 2010; Tenningen et al., 2012). Consequently, these traumatic events mostly occur at later stages of the fishing event, which coincides with the time at which fishermen have sufficient information on which to decide whether to retain or release the catch. Thus, slipping at an earlier phase in the haul, when the crowding densities are lower, could induce far lower and more acceptable levels of mortality.

The magnitude of slipping in the Portuguese purse seine fishery has been described as high and variable (Stratoudakis and Marçalo 2002). Past research described sardine stress during fishing (Stratoudakis *et al.*, 2003; Marçalo *et al.*, 2006), which led to laboratory studies that revealed that survival rates of released fish are affected by a mixture of operational (*e.g.* holding time and density) and environmental (*e.g.* water temperature) factors. These factors are responsible for affecting primary and secondary physiological stress responses, physical damage and behavioural changes, leading to variable and sometimes high mortality rates (Marçalo *et al.*, 2008, 2010, 2013).

The aim of this study was to test methods for minimising mortality of sardines released, or “slipped” from purse seines off the Algarve coast (Portuguese Southern coast). To accomplish this, the survival of sardines released from three different scenarios were compared: a standard slipping practice; a modified slipping practice and a control.

Methods

The survival assessment was conducted during a commercial fishing trip in late April 2016 at night and in relatively good sea conditions (wave height 0.5 - 1m). Fishing operations followed the typical commercial purse-seine practices (Stratoudakis and Marçalo, 2002). Live sardines were then sub-sampled in three different scenarios:

- <u>standard slipping operation</u>: net totally dried or “bunted”, fish overcrowded and rolled over the float-line;
- <u>modified slipping operation</u>: net partially dried or “bunted”, using weights on the floatline to create an escape window and allow unwanted catch to swim freely out of the net; and
- <u>control</u>: non-crowded sardines collected from inside purse seine.

These sub-samples of fish (table 1) were then transported by sea and land, transferred to observation tanks in an aquaculture centre and monitored for 28 days (EPPO-IPMA, Olhão).

Table 1. Summary information for the field and monitoring/maintenance operations. Mean values and ranges (in paratheses) are provided for transport density at sea, holding temperature, number of fish, length, weight and condition factor.

At Sea								Captivity				
Date of capture	SST (ºC)	Depth (m)	Catch (tons)	Treatment	N Replicates	N fish	Density (kg/m3)	T (ºC)	Length (cm)	Weight (g)	Condition factor	Days of monitoring
29 April 2016	16.9	39.1	1.2	Control	3	106 (89-126)	3.8	19.1 (18.4-22-1)	14.1 (13.2-14.9)	21.7 (15.7-27.6)	7.7 (6.1-9.3)	28
				Modified slipping	3	118 (108-127)	4.2	19.1 (18.4-22.3)	14.0 (12.2-15.1)	21.6 (16.6-28.3)	7.8 (6.5-9.1)	
				Standard slipping	3	143 (134-149)	4.9	19.5 (18.4-22.2)	14.0 (12.6-14.9)	20.7 (15.1-26.8)	7.5 (5.5-11.1)	

<u>Capture and Transfer of Live Fish</u>

To obtain sardines for controls (less crowded fish), drying up of the net was interrupted at its final stage to avoid additional damage. To facilitate fish transfer, crew members and researchers collected fish swimming within the netted area and transferred them from the net directly to the transport tanks of the fishing vessel using 10 l buckets and 15 l vinyl scoops. Following this process, the net was bunted and 4-5 sets of 10 Kg weights were put along the headline in order to allow an escape window to form (Figure 1a). This operation was called the modified slipping operation, and sardines freely swimming out of the net were collected. Next, within 10-15 minutes, bunting was completed and fish were made to roll over the headline and slipped back into the water (standard slipping) and also collected. Fish transfer was fast (~5- 10 min for each treatment) and sardines were collected for each treatment and placed into three 600 l transport tanks (3 replicates per treatment) previously filled with oxygenated sea water (100–150% saturation). Fish stocking densities were visually adjusted and deviations from intended transport densities occurred, but in most cases densities <5 kg m^3 were achieved (Table 1) as suggested in Marçalo *et al.*(2008). On arrival at the port, each tank was transported to the Aquaculture Research Station of IPMA in Olhão (5 min per trip).

Maintenance in captivity.

At the Aquaculture Research Station, sardines in each transportation tank were rapidly transferred into 3000 litre outdoor holding tanks. An open-system water circulation and variable water flow (minimum of 1.8 m^3/h) was used, with an aeration inlet placed at the centre of the tank to facilitate the circular movement of fish. Nets were used to cover each tank to avoid accidental deaths from fish jumping out. In all cases, fish were kept under a natural light regime and photoperiod. The monitoring study period lasted 28 days. Fish were fed with dried pellets at a daily rate of 1–2% biomass (wet mass). Gilthead seabream (*Sparus aurata*) and meagre (*Argyrosomus regius*) eggs when available (in the first two weeks in captivity) at the aquaculture station were also provided and fed to the sardines.

Monitoring

The holding tanks were monitored daily, recording water temperature, fish behaviour and the number of deaths. Dead fish were removed from the tank twice daily (in the morning and late afternoon) to maintain good water conditions, placed in individual plastic bags and frozen for subsequent biological and scale-loss analysis, and to tabulate daily mortalities. In addition, blood samples from a sub-sample of fish from the three treatments (control, modified slipping and standard slipping) were taken immediately after capture at sea, as well as during the monitoring phase,to describe early post-capture evolution of physiological variables. The results of this physilogical analysis is not presented in this report, but is described in a manuscript submitted to the ICES Journal of Marine Science.

Data Analysis

The survival of sardines over time was modelled using a parametric Weibull mixture distribution model that has previously been applied to data for discard mortality (Benoît *et al.*, 2012; 2015). This model has been shown to be well suited to these types of data as it models survivorship as a decreasing function of time for an initial period post release, followed by an asymptote at which the mortality associated with capture and handling is assumed to have been fully expressed. The model is fit to observed times of mortality for individual fish and can accommodate censored observations, in the present case, right censored observations for fish that were removed alive from the experiment when it was terminated at 28 days and for which the time at mortality is known only to occur after the time of censoring.

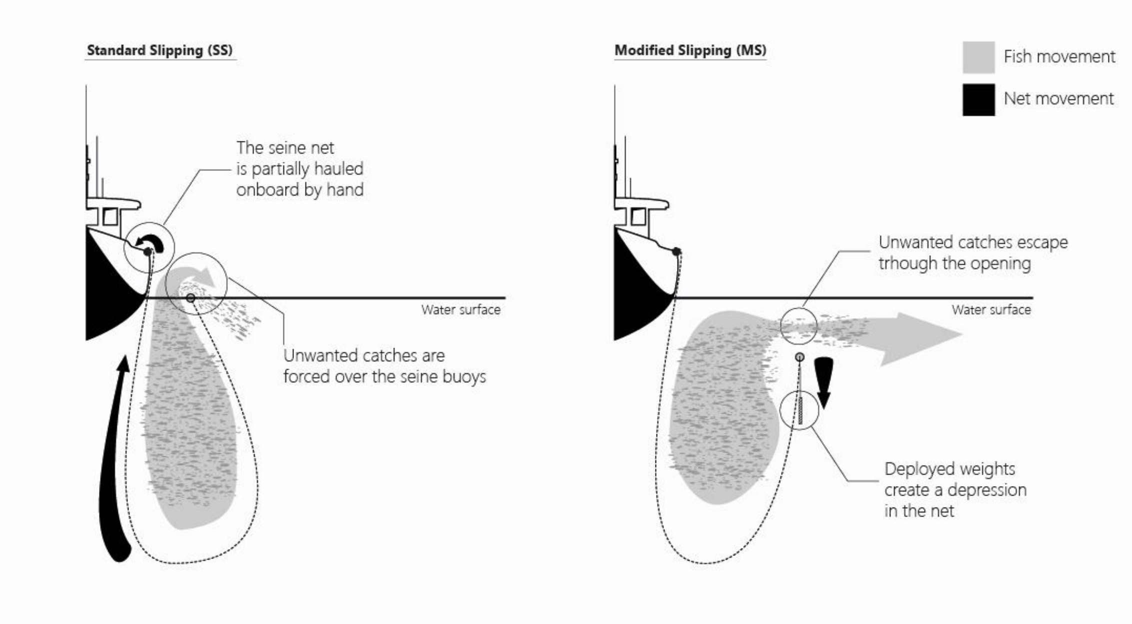

Figure 1. Diagram showing the two slipping methods

Results

The sampled purse seine trip catch contained 1.2 t of, from which 1102 fish (23.5 kg) were transferred alive to the transport tanks onboard the purse seiner. There was little between-treatment variation in sardine size (mean LT = 14.0 cm; mean MT = 21.3 g; Table 1). Sea and land transportation mortality was low for control and modified slipping (MS) tanks (respectively 4.7 % and 3.9 %), and moderate in standard slipping tanks (16.6 %). Unintended fish transportation density differences for each treatment were obtained, due to the fast transfer operation of the fish from the net to the transportation tanks and uncontrolled visual estimation support. However, these differences were small, particularly between the MS and standard slipping treatments and are unlikely to have any pronounced effect on sardine mortality (Table 1). Consistent weight and condition factor gains for all surviving fish in captivity at the end of the observation period in all treatments (Table 2) indicates that conditions in captivity were adequate.

Table 2. Summary of biological data for sardines in survival assessment.

		Day	Length Mean	Length SD	Weight Mean	Weight SD	Condition factor Mean	Condition factor SD	N	Females (%)
Control	Fishing	-1	14.2	0.3	24.8	2.0	8.7	0.5	10	10
	Monitoring	0	14.1	0.4	21.6	2.6	7.8	0.4	10	40
		2	14.3	0.3	22.7	1.6	7.8	0.3	10	33
		7	13.9	0.4	22.9	3.2	8.5	0.6	8	0
		28	14.6	0.3	25.3	2.8	8.2	1.1	15	33
Modified slipping	Fishing	-1	14.3	0.5	24.4	2.2	8.3	0.3	10	30
	Monitoring	0	14.1	0.4	21.2	2.1	7.6	0.3	10	20
		2	14.4	0.5	22.5	2.0	7.6	0.7	10	20
		7	13.6	0.4	20.7	2.0	8.2	0.6	9	0
		28	14.3	0.4	25.6	3.8	8.6	0.8	15	36
Standard slipping	Fishing	-1	14.1	0.4	23.6	2.1	8.4	0.4	10	20
	Monitoring	0	13.8	0.6	22.2	1.3	8.5	1.2	10	50
		2	14.4	0.5	23.3	2.0	7.9	0.5	10	11
		7	13.9	0.4	22.0	2.2	8.3	0.5	6	0
		28	14.3	0.4	25.5	3.3	8.6	0.8	15	50
Post stress	"No stress"	49	15.1	0.4	31.9	3.6	9.3	0.6	20	64
	"High stress"	49	15.0	0.4	28.1	3.7	8.3	1.0	18	50

Survival

Sardine survival for each treatment as a function of observation days are shown in Figure 2. Patterns indicated that mortality had reached asymptote early in the observation period. For all treatments, small between-replicate variation on survival rates was observed (Figure 3), but in all cases most deaths occurred within the first 3-5 days, followed by low rates of mortality in the remaining period in captivity, confirming prior observations made after commercial or simulated fishing (Marçalo *et al.*, 2008; 2010; 2013). The Weibull mixture-distribution survival model fit the observations well for individual replicates (figure 3).

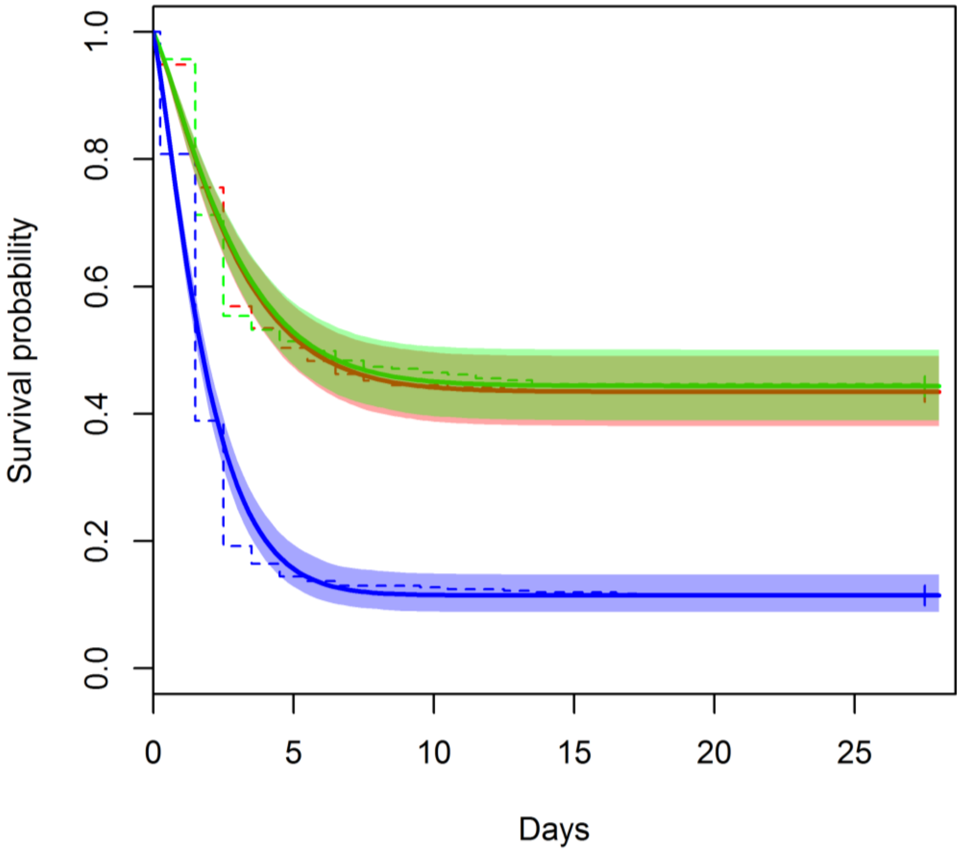

Figure 2. Kaplan-Meier survival curves (dashed lines), overlaid with Weibull mixture-distribution model survival estimates (solid lines with 95% confidence bands) for Sardine in CS2.2 from three treatments: Control (Red), Standard slipping (Blue) and Modified slipping (Green).

Survival at asymptote (with 95% CI) was estimated at 43.6% (CI: 38.0 to 49.3) for the control, 44.7% (CI: 39.3 to 50.1) for the modified slipping and 11.7% (CI: 8.9 to 15.2) for the standard slipping treatments. The estimated time to asymptote was shorter for the standard slipping treatment at 9.8 days (8.9 to 13.0) compared to the other two treatments 14.6 days (10.8 to 16.2), but was well below the study duration of 28 days; confirming that all delayed mortality had been observed.

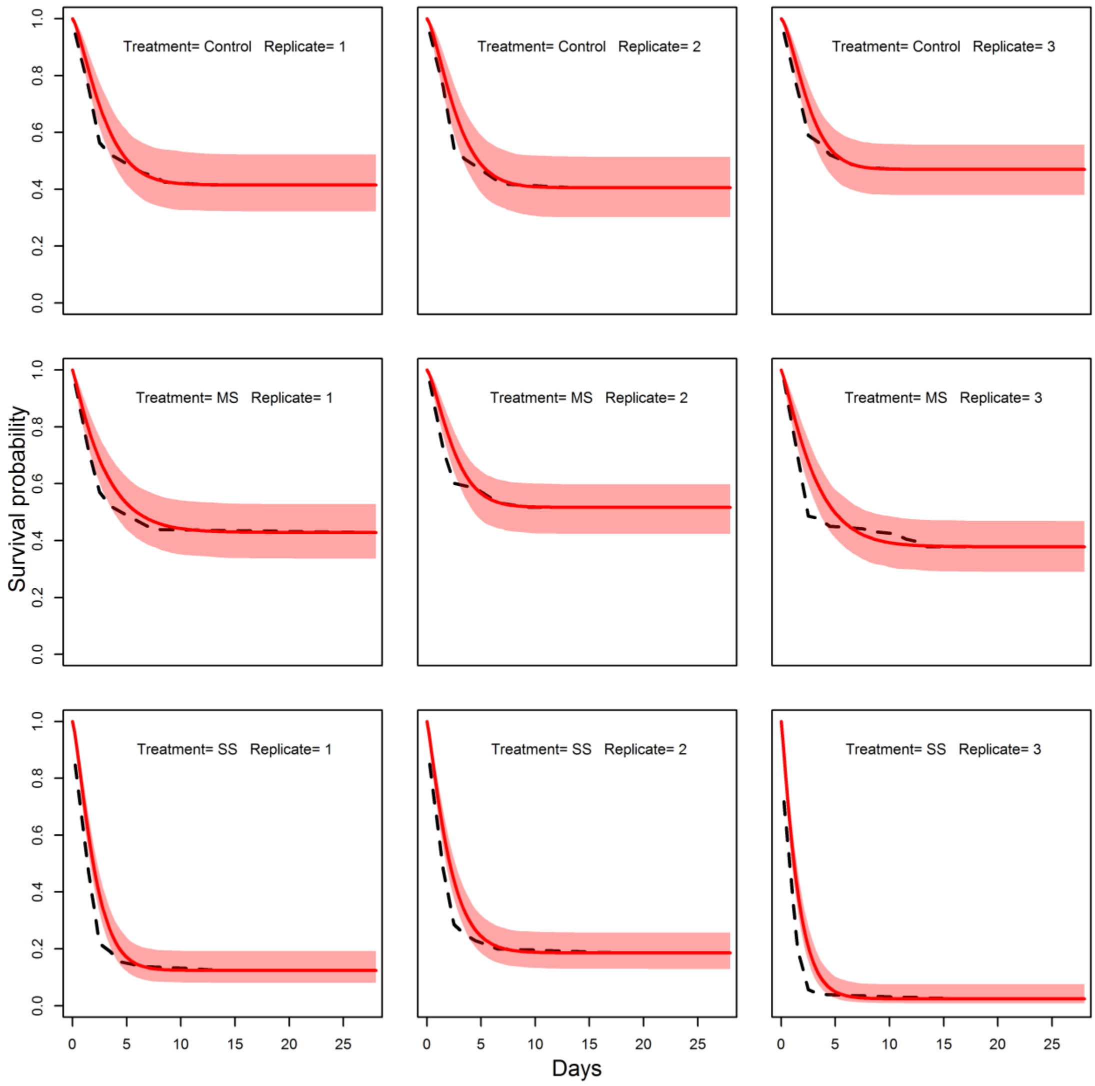

Figure 3. Kaplan-Meier survival curves (dashed line), overlaid with Weibull mixed distribution model survival estimates (solid lines with 95% confidence bands; in red) for Sardine in CS2.2 for individual replicates from three treatments: Controls, Modified Slipping (MS) and Standard Slipping (SS).

Physical Injury

For all treatments, physical damage was associated with the probability of dying after live capture and transport to captivity, with dead fish having significantly higher level of scale loss. Median sardine scale loss for the first two days in captivity for both of the two slipping treatments was of 48.8 and 70.6 % for the modified and standard slipping respectively, with the standard treatment showing significant differences from the control (42.3 %) and modified treatment (Kruskal-Wallis: H =73.3, d.f. = 2, P<0.001; Dunn´s test: P>0.05 for the relevant pair groups.

Discussion and Conclusions

The results of this survival assessment demonstrate that using a modified slipping technique during purse seine operations may significantly improve survival of slipped pelagic fish. Off Portugal, commercial purse seining operations typically end with complete bunting/crowding and thus any slipping would constitute a stressful event, leading to physiological, physical and behavioural alterations, culminating in variable delayed mortality of escapees (Marçalo et al. 2006, 2010, 2013). This assessment showed that mortality and scale loss of sardines slipped using the standard method after fishing operations was significantly higher than the observed in the control (not bunted/crowded) and modified slipping groups. The number of replicates (three replicates for each group) provided consistency in the evidence that the modified slipping method is a reliable technique to reduce substantial and unaccounted mortality, which directly relates to levels of physical damage (scale loss) after crowding when standard slipping is applied (Lockwood et al. 1983; Olsen et al. 2012; Marçalo et al. 2008, 2010).

There are obviously other factors not considered in this work, such as fishing duration, catch size, and environmental variables like water temperature or sea conditions, all important variables that may modify survival because they are known to significantly affect physiological, physical and behavior of escapees (Marçalo et al. 2008, 2010, 2013). However, our results are in line with previous findings using laboratory fishing simulations with sardines (Marçalo et al. 2010). Most importantly this assessment has demonsrtaed that the modified slipping technique not only promotes a quicker and spontaneous escape of unwanted catches after purse seining, but also reduces the likelihood of injury and mortality of released sardines. So, modifications to commercial fishing practices that lead to a higher probability of survival should be adopted and implemented in purse seiners operating off mainland Portugal.

As finding ways to mitigate mortality of escapees due to slipping and to improve release techniques becomes a priority, decisions should take into consideration the functionality of the fishery. Direct guidance from the purse seine fishing sector, which is known to be proactive in collaborating with the scientific community, will greatly facilitate the development of strategies to reduce bycatch and/or discarding (Marçalo et al. 2015). In addition, a code of good practice (CoP) should be adopted, implemented, spread and followed. Future work should rely on delivering the CoP information to the fishing community.

CS 3.2. Balearic set net fisheries: small-scale trammel netting for the common spiny lobster (*Palinurus elephas*)

Gaetano Catanese, Maria del Mar Gil, Miquel Palmer, Elena Pastor, Elka Koleva, Mike Breen, Beatriz Morales-Nin

Case study description

The target species, *Palinurus elephas,* is a large crustacean decapod that reaches 50 cm in length, but rarely exceeds 35 cm. It inhabits the coralline bottoms of the steep coasts, between 20 and 80 meters in depth, although it seasonally migrates to deeper zones. Its geographical distribution covers almost all of the eastern Atlantic, from south-western Norway to Morocco, and all of the Mediterranean, except the extreme eastern and south eastern parts (Holthuis, FAO). The breeding season runs from September to October, in the western Mediterranean, and females reach sexual maturity at 4-5 years (Goñi et al. 2003; Quetglas et al. 2004).

In the Balearic Islands, this species was traditionally caught by pots, but trammel nets have increasingly become the method of choice by fishers because of substantially improved catch rates (Amengual et al. 2016). A variety of regulations have been used to manage *P. elephas* fishing in the Western Mediterranean (Quetglas et al. 2004). For example, in Spain and, with some modifications, the Balearic Islands the regulations include:

- fisheries are closed during the breeding period;
- there is a minimum landing size of 240 mm of total length (90 mm carapace length), which coincides with the size at first maturity;
- prohibition of capture, retention on board and commercialization of ovate females, at any age and size;
- the soaking time of the nets cannot exceed 48 hours, to minimize mortality of discards;
- the mesh size (min. 133 mm) and the total length of trammel nets (5000 m) per vessel are also regulated (BOE 11324/2001; BOIB 38/2001).

On 1st January 2017, the EU Landing Obligation (LO) came into effect in the Mediterranean; and it stipulates that for regulated species undersized individuals are now defined as unwanted catch, and should be retained and brought to port, instead of being discarded as they were before (EU Reg 1380/2013, Art. 15; see appendix 1 for more details). The spiny lobster (*Palinurus elephas*) is a regulated species with a minimum size of catch of 90 cm carapace length (EU Regulation 1967/2006, Annex III) and is thus included in LO. The LO clearly presents a challenge to the spiny lobster fishery because it conflicts directly with national regulations which were aimed at conserving *P. elephas*, specifically regulation c) above. However, there is a mechanism within the LO that enables exemptions to be made, as part of a Discard Management Plan and Commission Delegated Regulation, for "*species for which scientific evidence demonstrates high survival rates …"* (see appendix 2 for more details).

The objective of this study was to firstly, to conduct a preliminary assessment of vitality (as the catch was brought on board) of juvenile undersized spiny lobsters

(*Palinurus elephas*) and other by-catch species, including: *Leucoraja naevus, Parastichopus regalis, Raja clavata, Scyliorhinus canicula, Scorpaena scrofa* and *Lophius piscatorius.* In addition, the survival of undersized lobster was assessed by monitoring in captivity for 7 days.

Methods

A total of 35 fishing trips with lobster trammel nets were surveyed in Balearic waters, off Port d'Andratx and Portopetro harbours, at depths ranging from 10 to 150 m (mean depth 70 S.D. ± 25) from April to August 2015 and 2016. Sampling was conducted on three commercial boats all rigged with two sets of trammel nets. A trammel net set consisted of several (usually between 10 and 30) panels (or netting walls); each approximately 100 meters long and with a mesh size of 160 mm. Soaking time is irregular, but 48 h is the maximum permitted by Law. The mean water temperature in the area, at 50 m depth, during the fishing period is 20.7ºC and at 100 m 12.9ºC. The air temperature rose from an average 13.6ºC in April to 25.1ºC in August (AEMET data), therefore the temperature effect on vitality could vary through the fishing season.

<u>Preliminary Assessment</u>

The aim of this preliminary assessment was to determine the survival potential of animals in the "unwanted catch" at the moment the gear arrived on board. The time that each animal had been retained in the net was not known, being in general less than the maximum soaking time (48 hours). The retrieval of the trammel net is relatively quick and the exposure of the captured animals to air during processing is around 2 minutes. Animals in the "unwanted catch" were identified, measured and their survival status assessed. Unresponsive specimens were considered dead.

The following species were caught in sufficient numbers (>30 individuals) to permit a formal analysis: *Palinurus elephas, Leucoraja naevus, Raja sp.*, *Raja clavata*, *Scyliorhinus canicula*, *Scorpaena scrofa*, *Lophius piscatorius* and *Parastichopus regalis.* The proportion of living animals (at arrival on deck) was estimated from the ratio of living to total observed animals in the unwanted catch, and the Bayesian 95% credibility interval around that proportion was calculated using an ad-hoc R script..

<u>Captive Survival Assessment</u>

To assess survival, small independent samples of undersized lobsters, collected in Port d' Andratx between 26/5/16 and 16/8/16, were transferred in small, aerated and refrigerated tanks to an onshore laboratory (LIMIA facilities). There the lobsters were placed in a 5000 l fiberglass tank, supplied with a continuous flow of 100µm filtered and refrigerated water; temperature was maintained below 18ºC. The tank was also equipped with plastic tub shelters (Fig.1). Individuals were fed once a day with fresh or frozen fish, in general all adapted well to the food. Monitoring for dead animals was done daily for 7 days; the vitality status of the specimens was determined using a four-point vitality scale(Table 1) on days zero, one, two, four and seven.

Table 1. Vitality assessment scale for Palinurus elephas (based on Benoit el al, 2010).

Vitality	Code	Description
'Excellent'	1	Continuous movements. No external injury.
'Good'/fair	2	Weak body movements; Responds to contact. Superficial cuts on the exoskeleton or antennas.
'Poor'	3	No body movement, but can move antennas or maxilipeds. Loss of an appendage or deep cuts.
'Moribund'	4	Without movement, does not respond to repeated contact.

All surviving individuals were then marked with T marks and returned to the sea, the place selected to release them was a protected marine area. The small lobsters were submerged by scuba divers to 40 m deep natural shelters to avoid predation.

Figure 1. Spiny lobsters, sheltering in plastic tube shelters, during the captive observation survival assessment.

Survival data was summarised using a Kaplan-Meier survival function, by combining immediate mortality data from the preliminary assessment with the small dataset from the captive observation assessment. For the purposes of estimating survival probability and 95% confidence intervals, surviving animals in the preliminary assessment were assumed to be censored at day zero. Analysis was conducted using the R package "survival".

Results

Preliminary Survival Assessment

A total of 1216 individuals of 8 species were examined at on board arrival and 353 were found alive (Table 2). Concerning the immediate survival of the most abundant discarded species (n > 30), only *Palinurus elephas, Leucoraja naevus,* and *Parastichopus (Stichopus) regalis* showed immediate survival proportions above 60%.

In contrast, for the other commonly discarded species less than 20% were alive when they came a board (Fig.2).

Table 2. Numbers of animals (alive and total) at arrival on board for differen species from the unwanted catch caught by Balearic Trammel nets. Also given are the surviving proportion, with 95% Bayesian credibility intervals.

Species	Number of observed animals		Proportion Alive	Bayesian 95% credibility interval	
	Alive	Total		2.5%	97.5%
Palinurus elephas	82	127	0.64	0.56	0.72
Stichopus regalis	30	33	0.92	0.80	0.98
Leucoraja naevus	193	296	0.65	0.60	0.71
Raja sp.	5	229	0.02	0.01	0.04
Raja clavata	26	224	0.11	0.08	0.16
Scyliorhinus canicula	12	161	0.07	0.04	0.12
Scorpaena scrofa	4	100	0.04	0.01	0.08
Lophius piscatorius	1	46	0.02	0.00	0.08

Captive Observation

Undersized spiny lobsters (mean carapace length 7.15 ±0.88 cm) (N=16) kept in captivity had one death on the first day of observation, after which survival was stable. The only dying lobster had a carapace length of 7.9cm and was the only specimen with a “poor” vitality status (V3) on day zero; it died (V4) on day 1 (Figure 3). Most surviving animals were classified with a “good” vitality status (level 2) on day zero; only one lobster had an “excellent” vitality status on day Zero. However, all surviving lobsters showed an excellentvitality status on day 1 andfed actively after day 2.

Additionally, a small sample of the holoturian, *Parastichopus (Stichopus) regalis* (N=3), was kept in captivity showing a survival of 66.6%. The other species showing high immediate survival, *Leucoraja naevus*, was not tested due to limited space in the holding facilities.

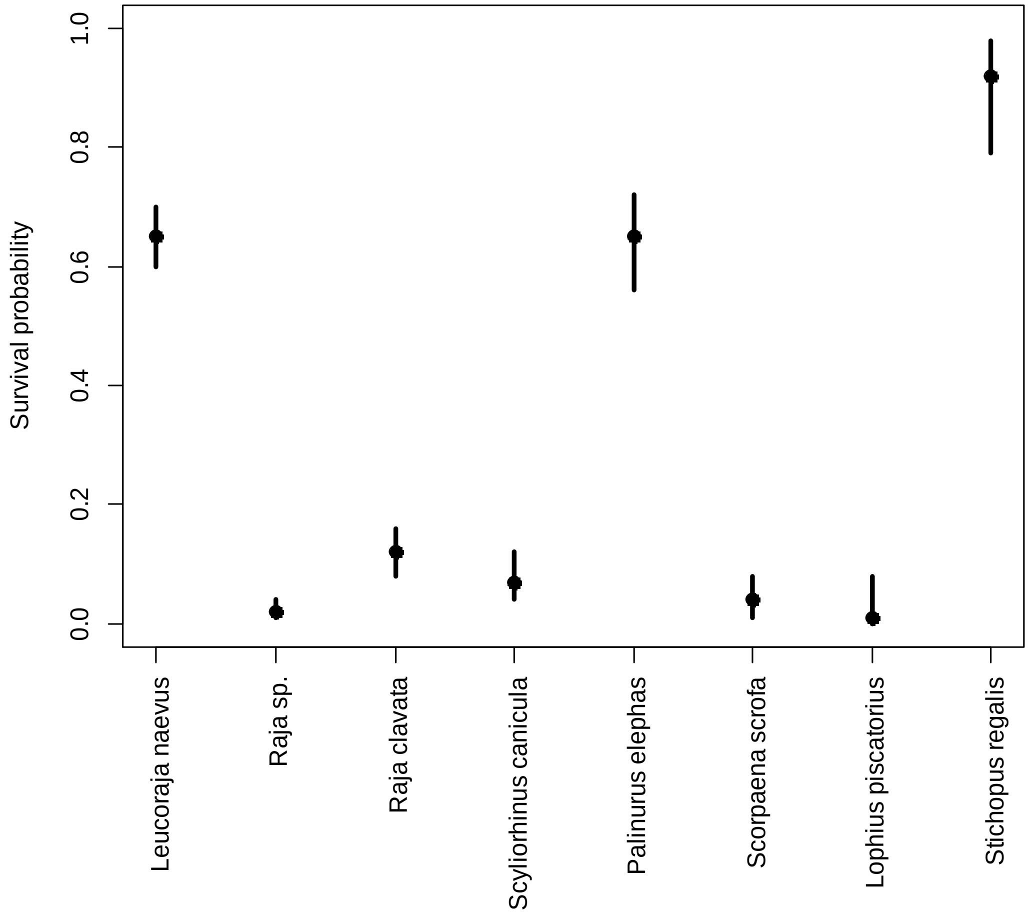

Figure 2. Proportion of living animals in the unwanted catch, by species, (at the moment the catch came on board), with Bayesian 95% credibility intervals.

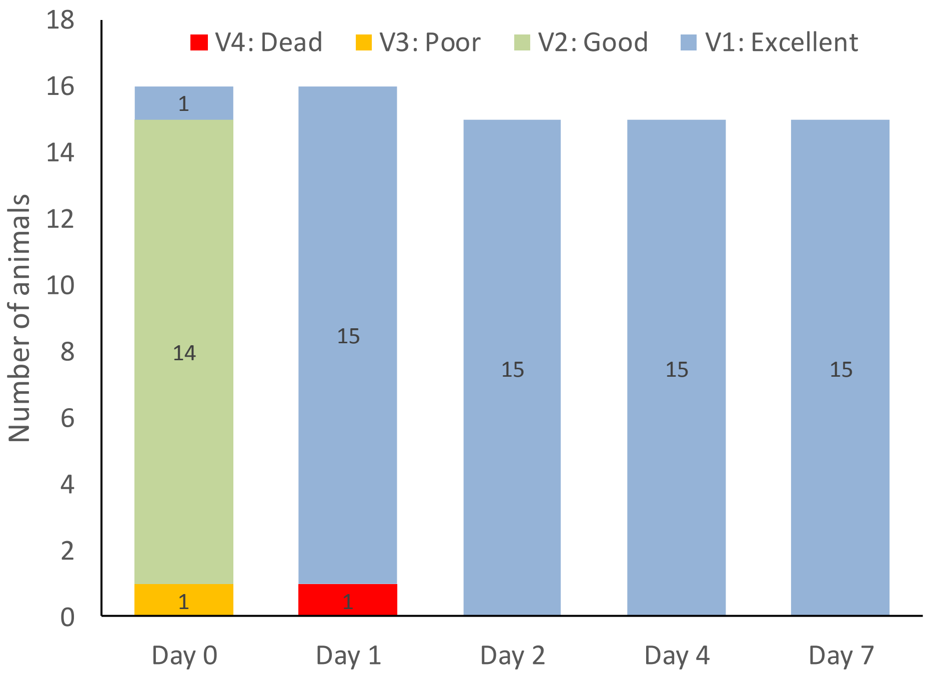

Figure 3. Vitality status of lobsters over time during the captive observation assessment

<u>Overall survival estimates</u>

Overall survival, combining immediate mortality data with the captive observation data, was estimated using a Kaplan-Meier survival function (Table 3; Figure 4). The survival rate clearly stabilises after day 1, implying this data will provide a reliable estimate of survival at asymptote.

Table 3. Kaplan-Meier survival function estimates for spiny lobsters (P. elephas) caught and held in captivity for up to 7 days. [n.risk = total observed; n.event = number dead].

time	n.risk	n.event	survival	std.err	95% CI	
					lower	upper
0	143	45	0.685	0.0388	0.613	0.766
1	16	1	0.642	0.0552	0.543	0.76

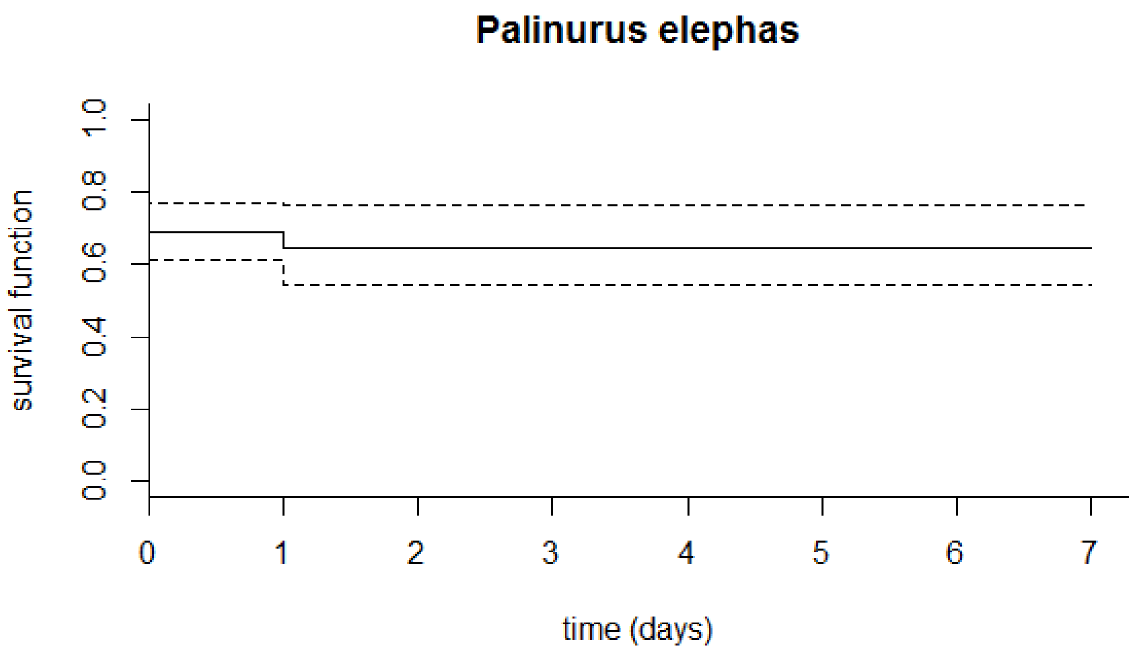

Figure 4. Kaplan-Meier survival curve (with 95% CI) for spiny lobsters (P. elephas) caught and held in captivity for up to 7 days.

Discussion and Conclusions

The vitality assessment of animals in the unwanted component of the catch clearly demonstrated that most fish species were dead, or dying, as they were brought on board the fishing vessel, including: *Raja clavata, Scyliorhinus canicula, Scorpaena scrofa* and *Lophius piscatorius*. This is likely to be due to the prolonged soak times in this fishery, which extend up to 48 hours, and will result in exhaustion, asphyxiation and injury of animals caught in the net, as well as by predation from attracted predators and scavengers (see Deliverable Report D2.15 for more detailed discussion).

These prolonged soak times are a deliberate part of the fishing practice, to capture bycatch species to attract the target species, spiny lobster, to the nets. Therefore, it is recommended that alternative gear configurations and fishing practices should be investigated to attempt to avoid these mortalities amongst the unwanted catch.

In contrast, three species were observed to have relatively high survival (> 60%), as they were brought on deck: spiny lobster (*Palinurus elephas), cuckoo ray (Leucoraja naevus),* and the royal sea-cucumber (*Parastichopus regalis). P. elephas and P. regalis* are both invertebrates which may make them more resilient against asphyxiation and attacks from predators and scavengers. However, it is interesting that an elasmobranch species, *Leucoraja naevus*, also demonstrated a high survival, while other similar species did not. This is worthy of further investigation to determine what the survival mechanism could be. Unfortunately, in this study, there were no suitable holding facilities to assess the continued survival of this species. However, this species may be suitable for using tagging and biotelemetry techniques to monitor the behaviour and long-term survival post-release (Breen & Catchpole, 2017).

Finally, spiny lobster (*Palinurus elephas)* were observed to have a relatively high survival (64.2 %;95% CI: 54.3-76.0%) for up to 7 days after their initial capture. Furthermore, surviving animals demonstrated a rapid recovery in vitality and no mortality was observed after day 1 (post capture), suggesting that mortality had reached asymptote and thus this is a reasonable estimate of post-release survival (excluding any predation effects). Therefore, it is recommended that an exemption from the Landing Obligation should be sought for spiny lobster (*Palinurus elephas)* in the Balearic trammel net fishery, with respect to article 15, paragraph 4b of the Common Fisheries Policy (EU Regulation 1380/2013). Specifically, an obligatory return of ovate female or undersized spiny lobsters to the sea could provide substantial conservation benefits to this exploited population. Such an obligation would also discourage fishermen from keeping undersized or minimum sized lobsters for private consumption and illegal sale.

CS 3.3. Balearic Islands boat seine fisheries. Assessing post-release mortality for the transparent goby fishery in the Balaric Islands

Maria del Mar Gil, Miquel Palmer, G. Morey, Amelia Grau, A. Manjabacas, Elena Pastor

Case study description

The transparent goby fishery is a small-scale fishery that uses a special purse-seine net over sand and gravel bottoms (Iglesias et al 1994). The fishery is economically significant in Mallorca (Palmer et al., submitted). Fishers use a surrounding net that is hauled over sand and gravel bottoms at depths down to 40 m inside bays during winter months. The fishery mainly targets *Aphia minuta* (less than 3 cm long) but other similar sized gobidae (mainly *Pseudaphya ferreri)* are also caught and sold together. Similar fisheries are operating along the Spanish coast and in Italy. The fishery operates with specific licenses, gear controls, and closing seasons. A management plan was set up in 2013, in accordance with the European Union regulations (EU 1967/2006, Article 19), with the specific aim of ensuring a sustainable fishery. The sustainable quotas for this fishery have been set to 30 kg/day/boat for *A. minuta* and 50 kg/day/boat for *P. ferreri*. The by-catch should not exceed 10% of the total catch. Landings can only made to 11 fixed ports and only 35 boats can operate with the specific nets from December 15th to April 30th. In addition, a co-management committee was created with the participation of the public administration, fishermen's associations, researchers and non-governmental organizations (NGO). This committee implements a more restrictive daily quota for sustaining the sale prices, thus the quota is periodically revised throughout the season (Morales-Nin et al, 2017).

Objective

The objective of this study was:

- to assess the survival of the target species, *Aphia minuta* and *Pseudaphia ferreri,* and
- determine the vitality on arrival at port, as a method to evaluate survival potential after release.

Methods

Sampling on board and assessing post release mortality

A total of 19 sampling days were carried out between 15 December 2016 and 30 April 2016 in 5 ports on Mallorca Island (Palma, Port Alcudia, Can Picafort, Port Pollença and Colonia Sant Jordi). Several (up to five, usually 2 or 3) hauls were completed in a given daily fishing trip. They were conducted under normal commercial conditions: the mean duration of the purse seine sets was 35.1 min (21 to 55); and the mesh size in the main body of the net was 40mm, decreasing to 3 mm in the bunt. The number of surveyed sets was 47. The average number of fish sampled per haul was 213.0 ± 144.0 (mean ± sd).

At each fishing trip, both, short-term survival assessments and video recordings for vitality assessments were undertaken. Fish were collected just at the moment the catch was aboard (t_0) by an on-board observer. A mixed sample of fish (including both target species, *Aphia minuta* and *Pseudaphia ferreri*) was placed into a 15 l plastic container with sea water and continuous aeration. Time of day, date, location, set-duration, sea-state, depth and water temperature were recorded. Dead (unresponsive, no mobility, no reflex) fish were counted and separated from those alive at t_0.

At the end of the fishing journey (mean 4 hours, from 1 to 9 hours), the containers with the collected samples were landed at the port. Then (t_f), the dead and alive individuals of each container were counted and separated for later identification and measurement. Time of day, the temperature and the oxygen concentration of each container were recorded at t_f. A random sample of fish remaining alive was video recorded (details provided below). After video-recording, all animals were euthanised and stored with the rest individuals of the same container. Euthanisation was carried out in strict accordance with the recommendations from Directive 2010/63/UE, adhering to Spanish law (RD53/2013, BOE n. 34 February 8th 2013).

a)

b)

Figure 1. Assessing mortality. a) Mortality at port arrival. b) Experiment on vitality.

The swimming speed and reaction to a stimulus of a sample of the individuals that came alive to port were estimated from the video recordings. Ten random individuals per haul were recorded in a circular arena measuring 23 cm in diameter. The entire trajectory of the individuals within the arena was recorded using a GoPro HERO 3 camera (GoPro, Colorado, USA). To avoid any lighting interference, the camera was mounted inside the top of a cylindrical, black, opaque,plastic cover (formerly a disposal bin) (Figure 1). Battery powered LED lights were also mounted around the camera. The reaction to a stimulus was analyzed by dropping a metal weight near the arena. The fishes were given 5 min to acclimatize to the new container, after which the video was recorded for 10 min, and the sound stimulus activated at 5 minutes of recording.

Data analysis: Developing a survival model

The average number of living fish when the haul came on board was 200.7 ± 149.1 and the average number of fish remaining alive after t hours was 67.7 ± 61.3. The averaged ratio of fish remaining alive when $t \geq 4$ hours was only 27.3%.

Preliminary inspection of the variability in the observed survival ratio at different times passed after the gear was aboard, suggest that the survival function *S(t)* achieved an apparently stationary state at a level different from zero when *t* is relatively small (Figure 2). Such a pattern cannot be predicted by either a conventional Weibull model (Benoit, 2012) or a negative exponential model because in those models survival always tends to zero.

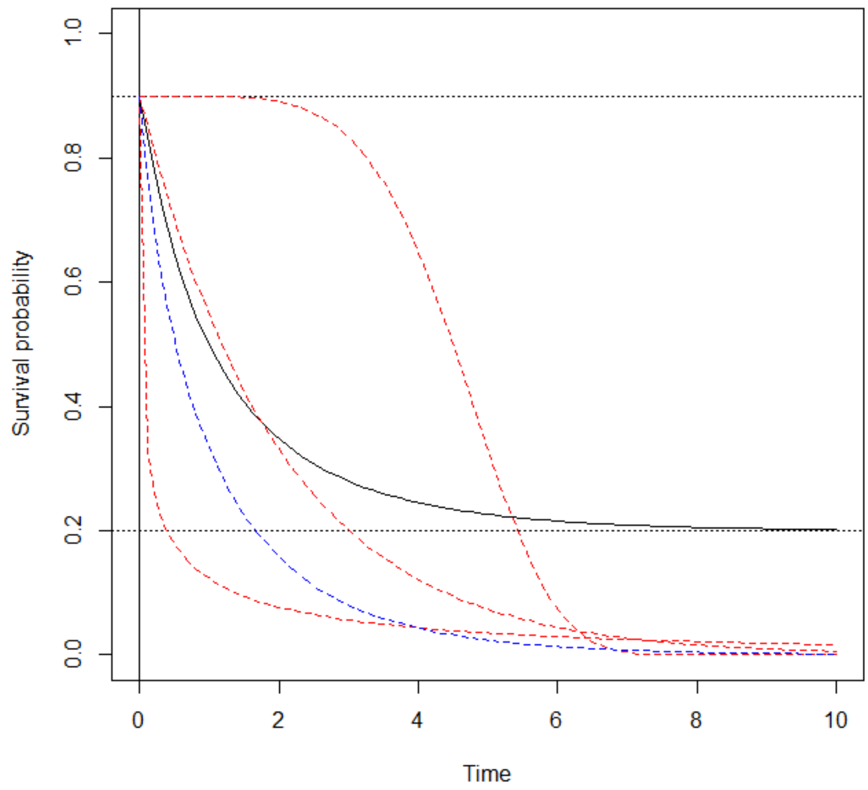

Figure 2. Expected time dependence of Weibull mortality model (the three parameter vectors shown in Benoit, 2012; in red), the special case of negative exponential mortality model (i.e., γ=1; in blue) and the model proposed here (in black).

Specifically, the conventional exponential model assumes constant mortality rate. Conversely, the variation in the number of fish *N* that continue alive after a given time *t* from the moment the gear came aboard may be time-varying:

$$\frac{dN}{dt} = -m(t)N \qquad \text{(eq. 1)}$$

where *m(t)* is the mortality. The expected number of *N* that continue alive after a given time *t* will be:

$$N(t) = N_0 e^{-\int_0^t mt'dt'} = N_0 e^{-M(t)} \qquad \text{(eq. 2)}$$

Certainly, all fish will die at some moment if they were keep at captivity for a very long time, but in this case the estimated mortality was not only related with gear-induced mortality, but it results from the combination of fishing, rearing conditions (e.g., infections or non-natural feeding) and even senescence. According to Gil et al, (2016), time variation for the instantaneous natural mortality rate, *m(t),* could be modelled by:

$$m(t) = m_\infty + (m_0 - m_\infty)e^{-t/\tau} \qquad \text{(eq. 3)}$$

This model seems appropriate for describing the biological process of cumulated mortality related with fishing because it is maximal when fish comes aboard at time t = 0 (m_0) but *m(t)* decreases toward an smaller asymptotic mortality (m_∞) and τ determines the rate of change between m_0 *and* m_∞. We propose that over short periods of time, no other mortality-related process takes action, m_∞= 0 (i.e., stabilization of *N*)*,* thus:

$$m(t) = m_0 e^{-t/\tau} \qquad \text{(eq. 4)}$$

Solving $M(t,t_0)$ from eq. 2 and eq. 4:

$$M(t) = m_0\tau(1 - e^{-t/\tau}) \qquad \text{(eq. 5)}$$

Finally, *N*, the number of fish remaining alive at any time will be:

$$N(t) = S_0 N_0 e^{-m_0\tau(1-e^{-t/\tau})} \qquad \text{(eq. 6)}$$

where S_0 is the survival probability when the gear come aboard (i.e., the number of alive fish from a sample of N_0 individuals). Thus, the asymptotic survival (survival at very large t) will be given by:

$$N(t = \infty) = S_0 N_0 e^{-m_0\tau} \qquad \text{(eq. 7)}$$

Finally, the actual number of surviving fish was expected to have a Poisson distribution with mean *N(t).*

Assuming that the survival patterns may be modulated by different drivers, the lineal dependence of S_0 and m_0 on different covariables was evaluated. Specifically, the covariables considered were:

$$S_0 = \alpha_0 + \alpha_1 \text{Temp}_0 + \alpha_2 \text{Depth}$$

$$m_0 = \beta_0 + \beta_1 \mathrm{Temp_f} + \beta_2 \mathrm{Depth}$$

where *Depth* was the depth at which the gear was operated (that may increase mortality due to barotrauma), and $Temp_0$ and $Temp_f$ were the water temperature at the moment the gear came aboard and at the time when the fish were monitored in port. In addition, a single level of random effects on S_0 and on m_0. Specifically, random (normally distributed with zero mean) variation between the hauls from the same fishing trip was considered.

Model fitting

The unknown parameters of the model were estimated using a Bayesian approach. A nearly non-informative gamma distribution (shape=0.001, scale=0.001) were assumed as priors for τ, and for the tolerance (1/variance) of the two random effects considered (hauls on S_0 and on m_0). Priors for all the parameters of the linear dependences of and all parameters were assumed to be normally distributed with zero mean and a very large variance. Three MCMC chains were run using randomly selected initial values for each parameter within a reasonable interval, and conventional convergence criteria were checked. The number of iterations was selected for each run to obtain at least 1,000 valid values per chain after convergence and thinning (1 out 10). The model was implemented with the library *R2jags*

(http://cran.r-project.org/web/packages/R2jags/R2jags.pdf) of the R-package (at http://www.r-project.org/) that uses the samplers implemented in JAGS (http://mcmc-jags.sourceforge.net/).

Tracking algorithm

A Python (v2.7; https://www.python.org/) code was developed for unsupervised tracking fish and taking advantage of the image analyses functions implemented in OpenCV (v3.0; http://opencv.org/). The code is structured as object-oriented, each track being an independent object, and it is partly inspired by an existing fish tracking algorithm (Marti et al., submitted). RGB color space were shift to HSU for improving blob detection, which was done by applying an unsupervised threshold method. The blobs identified at a given frame may be larger or smaller than the number of objects, thus they were assigned to one of the existing track after applying a series of logic gates based in minimizing the cost in terms of cumulated distance between the observed blob position and the predicted blob position. Missing values (occlusions and failures in the assignment algorithm) were smoothed and filled using a Kalman filter.

Analysing vitality

Speed (*v*, pixels per frame) was extracted from fish trajectories. Speed was modeled as:

$$v_{i,t} = v_{mean} \pm before/after + rnd_i \qquad \text{Eq. 8}$$

where v_{mean} is the average speed of all fish in a trial, *before/after* is the (symmetric) difference around the mean speed of the *i* fish and rnd_i is a fish-specific normally distributed random factor with mean zero and a given variance. The parameters of this model were fitted using a Bayesian approach using non-informative priors and the same settings described above (section 2.4).

The *before/after* difference was then used as a proxy of vitality. Note that at the moment of writing this report, fish trajectories are not yet available for all the hauls sampled, thus, only preliminary result for a single haul are reported here. Nevertheless, two complementary analyses has been planned: (i) to include *before/after* as a new explanatory variable in the model described in section 2.3 and (ii) to explore the correlational patterns between the asymptotic survival (Eq 7) and *before/after*, which may allow to use the latter as a proxy of the former.

Preliminary results

Survival

The observed survival rate (i.e., when the potential effects of covariables are not taken into account, Figure 3) seems to be close to 100% just at the moment at which the gear came aboard, but decreases quickly and seems to converge to a time-independent value after a few hours, thus fitting the conceptual model in Figure 2.

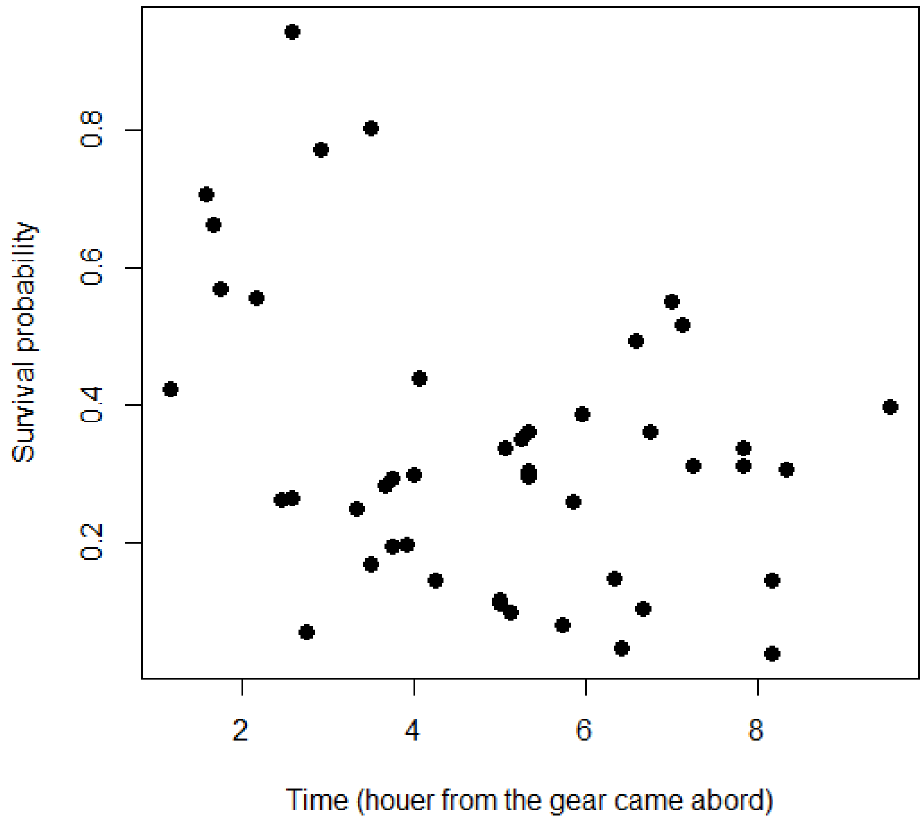

Figure 3. Raw survival probabilty (i.e., before accounting for the effects of covariables) for mixed samples of *Aphia minuta* and *Pseudaphia ferreri*. Each point represents a haul and it is estimated as the ratio between the number of surviving fish and the total number of fish observed.

The median and 95% Bayesian confidence interval of parameters from the model are detailed at Table 1 This model explains reasonably well the observed values (i.e., counts of fish alive/total after t_i hours; Figure 4).

Table 1. Estimates of the survival model parameters.

Parameter	2.5%	Median	97.5%
m_0 α_0 (Intercept)	0.775	1.091	1.522
m_0 α_1 (Depth)	0.004	0.024	0.046
m_0 α_2 (Temperature)	0.098	0.172	0.274
Logit(S_0) β_2 (Intercept)	-0.139	8.020	17.774
Logit(S_0) β_2 (Depth)	0.050	0.094	0.139
Logit(S_0) β_2 (Temperature)	-23.601	-16.452	-11.340
τ	0.842	1.098	1.376
σ_1(random effect on m_0)	0.341	0.508	0.806
σ_2(random effect on S_0)	9.728	16.043	27.068
Derived quantities			
Inmediate survival prob.	0.46	0.99	1.00
Asymtotic survival prob.	0.13	0.29	0.40

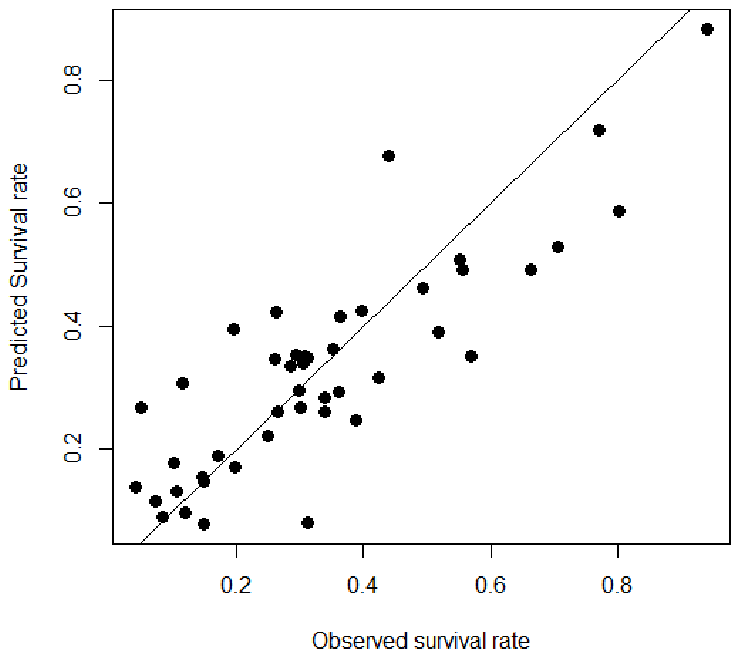

Figure 4. Observed versus expected survival rate (the line has slope = 1 and intercept = 0)

In order to facilitate the interpretation of the relationships between the model parameters and the covariables, the expected values of survival were estimated at different combinations of environmental conditions within the observed ranges (Figure 5). Note to simulate survival at the moment the gear comes aboard, $Temp_f$ was set equal to $Temp_0$. The pattern depicted suggests temperature is highly influencial, with predicted survival dropping to nearly zero when water temperature was above 15.8 degrees Celsius. However, below this threshold, predicted survival was higher at shallower waters and remains above 50% in most scenarios. The survival rate at optimal conditions (<18.5m and <14.9°C) may reach 75%.

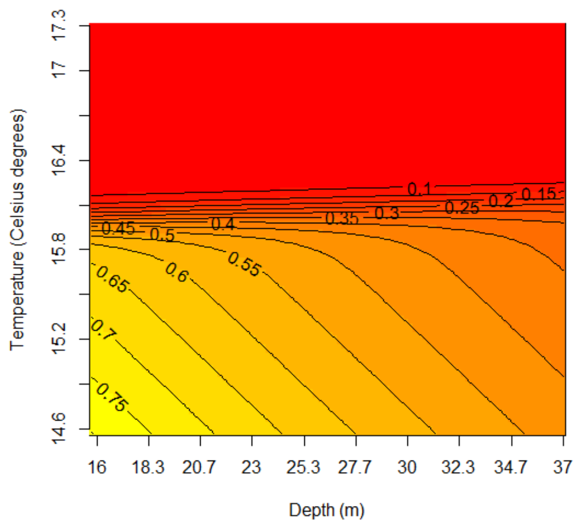

Figure 5. Estimated survival rate at different combinations of environmental variables.

Vitality

The object tracking algorithm successfully estimated the individual trajectories of the fish (Figure 6). Fish seems to increase speed after the stimulus, as suggested by both visual inspection of the tracks and by the results of the mixed effects model (Eq 8). The latter models successfully disentangle fish speed on an individual fish component (averaged speed plus the individual specific random component; Figure 7) plus a before/after component (trial-averaged speed difference between before and after the stimulus). The latter component is expected to be a proxy of fish vitality and, thus, it may be related to survival rate. This hypothesis will be tested when the videos of all the fishing trips are analysed.

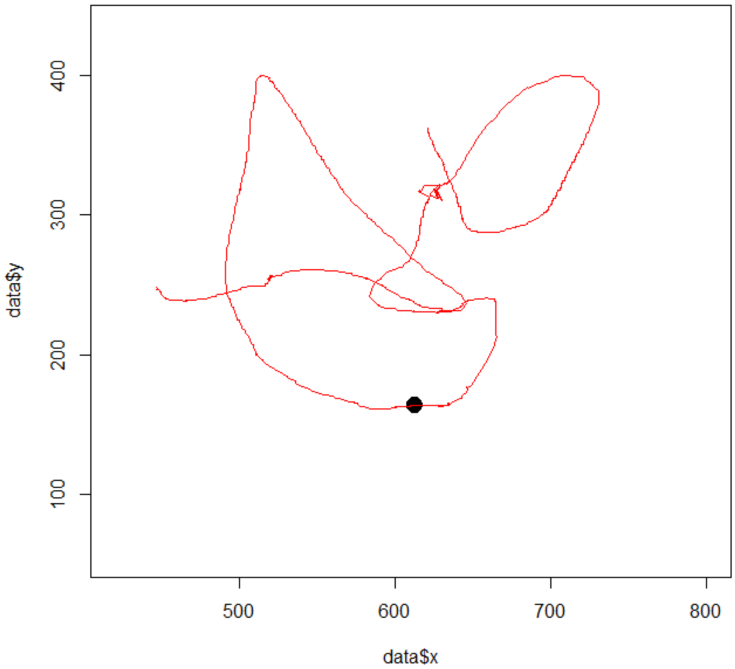

Figure 6. Trajectory of a given fish. The point indicates the moment fish were stimulated.

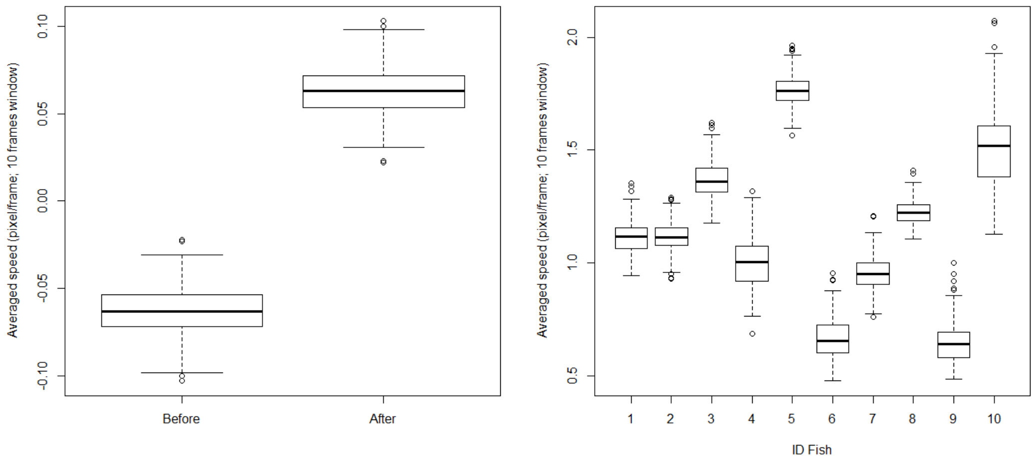

Figure 7. Left panel: Differences between before and after the stimulus in the average speed (pixels/frame) of all fish in a given trial. This difference may be a proxy for vitality. Right panel: average speed (pixels/frame) of each of the fishes in a given trial.

Discussion and Conclusions

Fish from the seine are immediately released into a barrel with water for sorting (the target species tend to remain near the surface, which facilitates sorting). In the case of slipping, transparent goby are directly released to the sea, thus, mortality related with desiccation/air exposure/anoxia or even with on board handling should be considered negligible.

Water temperature seems to have a major effect on survival. Above 15.8^{o}C, most fish are predicted to die. The survival rate is low even at the moment the gear comes aboard. Water temperature was reported to be higher (nearly 17º C) in January, at the opening of the fishing season, reached the threshold temperature toward the end of January and declining to a minimum of around 14^{o}C in March, after which water temperature rises again. The precise physiological process that triggers temperature-related mortality were not investigated, but may be related to elevated metabolic rates (Clarke & Johnston, 1999; Gillhooly et al, 2001) confounded with reduced dissolved oxygen concentrations (e.g. Benson & Krause, 1984).

Depth may play a complementary role with temperature. Morality increases with increasing fishing depth, therefore, the most plausible physiological driver is barotrauma (e.g. Brown et al, 2012).

Concerning management measures that could be deduced from the results obtained, hauling duration is small (around 30 minutes), thus there is no capacity for reductions. Onboard handling is minimal and fish are held water, even when it is kept for sale, thus no clear recommendation can be suggested, other than ensuring the water is well oxygenated and close to ambient water temperatures. Similarly, the gears are typically deployed in depths shallower than 40m and the additional depth related mortality appears to be secondary, thus it would be difficult to reduce barotrauma-related morality.

Concerning technological improvements for reducing discards, selective grid are an impractical option. However, target school identification using multiple frequency hydro-acoustics could be developed for this fishery (e.g. Simmonds & MacLennan, 2005). However, fishers rarely haul a shoal of other species.

The most obvious advice emerging from the results obtained is recommending slipping only when water temperature is below 15.8^{o}C; when survival rate of released fish is likely to be reasonably high (around 50%, depending on depth). This recommendation can be translated into a simpler rule: <u>slipping should be restricted to between the beginning of February until the end of the fishing season</u> because in this period water temperature is typically below the threshold. In December and January, the predicted mortality rate is very high and survival after slipping should be negligible. Therefore, provided that the fishery is managed based in the CPUEs from the previous weeks, more precise fishing mortality will be obtained when keeping and counting fish that otherwise would be slipped.

Vitality metrics related to swimming speeds may open a new way for estimating mortality directly on board, thus negating the need for monitoring fish survival. A very simple device may be implemented for obtaining fish trajectories in a fully unsupervised way and the response to a stimulus may be related with vitality.

The device and algorithms developed to assess vitality in this small fish are now being evaluated by CSIC for a possible patent: "*Insitu* behavioural vitality monitor".

CS 3.4 Catalonian Trammel nets – Murex *(Bolinus brandaris).*

Pilar Sanchez, M. Garriga, Francesc Maynou

Introduction

The purple dye murex, *Bolinus brandaris* is a prosobranch gastropod mollusc, common in the Mediterranean, which inhabits sandy-muddy bottoms at depths between 5 to 50 m. It constitutes a resource of local importance in different zones of its area of distribution.

Traditionally, various artisanal fishing gears have been used for catching this species (trammel nets, basket traps, towed gears). Since the mid-1980s, a new type of gear, locally known as "rastell" and specially designed for catching the murex, began to be used on the Catalan coast. This gear, a small modified beam trawl, is used by around 60 vessels located mainly in Ebro Delta zone.

Before the catch is sold, a selection by size is made in port, and the smallest specimens (<25 mm) are returned to the sea the following day. Co-occurring species in "rastell" include sole (*Solea* spp), prawn (*Penaeus kerathurus*), mantis shrimp (*Squilla mantis*) and cuttlefish (*Sepia officinalis*). In the case of trammel net, murex is a valuable bycatch in trammel nets targeting cuttlefish, prawns and sole.

At the request of the European Commission, local authorities are currently drafting a new management plan for the "rastell", which specifically needs to address the potential post-release survival of undersize individuals. The current local management plan established a minimum size of capture as 25 mm (Shell width) but "rastell" is not very size selective and catches of undersize animals are abundant (fractions of up to 50% of total catch, depending on the season). During the stakeholder consultation process in the Project MINOUW, it became apparent that fishers were reluctant to improve size selectivity because they claimed very high survival of released undersize murex. Our results seem to corroborate this point and will be of importance for the revision of the local management plan that is currently being drafted (2017). The exercise on *Bolinus brandaris* survival also had the objective of testing the methodology for visual assessment of vitality on a type of organisms (e.g. shellfish) that have far fewer external vitality related characteritics to assess than fishes. We adapted the scale proposed by Benoît et al. (2010) with the aim to generalize it to gasteropod and bivalves. Note that Spain as member state should assess the survival of 3 groups of bivalves in Annex III of the Mediterranean regulation (EU 1967/2006), namely *Tapes* spp., *Venus* spp. and *Pecten jacobaeus* for the demersal management plan that will be in force from Jan. 1st, 2019. Our proposed scale for visual assessment could be of use in that context.

Objective

The objective of this assessment was to determine the vitality of purple murex after capture using the two different gears: trammel-nets and a beam trawl ("rastell").

Methods

The material was collected from commercial fishing vessels during August 2016 in the port of Sant Carles de la Ràpita (fig. 1), one of the ports on the Catalan coast where this fishery is of major importance.

Undersize murex were obtained from area "B" in Fig. 1a during a normal "rastell" commercial fishing operation, trawling in a depth of 6-7 m. The "rastell" beam trawl consists of a collecting bag (8 m long) mounted on a rectangular metal frame (2 m wide and 0.4 m high). The upper part of the collecting bag is made of 60 mm netting, while the lower part is made of 40 mm netting of thicker twine. The lower part of the rectangular frame carries 6 to 10 tickler chains (crosswise). Haul duration is approximately one hour, producing 1-3 kg of murex. Several hauls can be made during the maximum 12 working hours. The catch composition is typically 80% or higher murex, i.e. it is a very species selective fishing gear.

In normal commercial operations in the study area, as in other parts of the the Spanish Mediterranean, trammel nets are composed of 50 m wide and 1.2 m high 3-net panels tied together in long gangs of 1250 to 1500 m (in our study, 1400 m). Usually each trammel-netter deploys 3 such gangs during night hours (from 11 pm to 6 am, approximately). The catch composition is extremely varied with dozens of species caught in relatively small amounts each. Murex is a valuable commercial by-catch of trammel-nets, but it is not considered a target species. The samples retained for vitality assessment were from fishing operations in depths of 6-7 m.

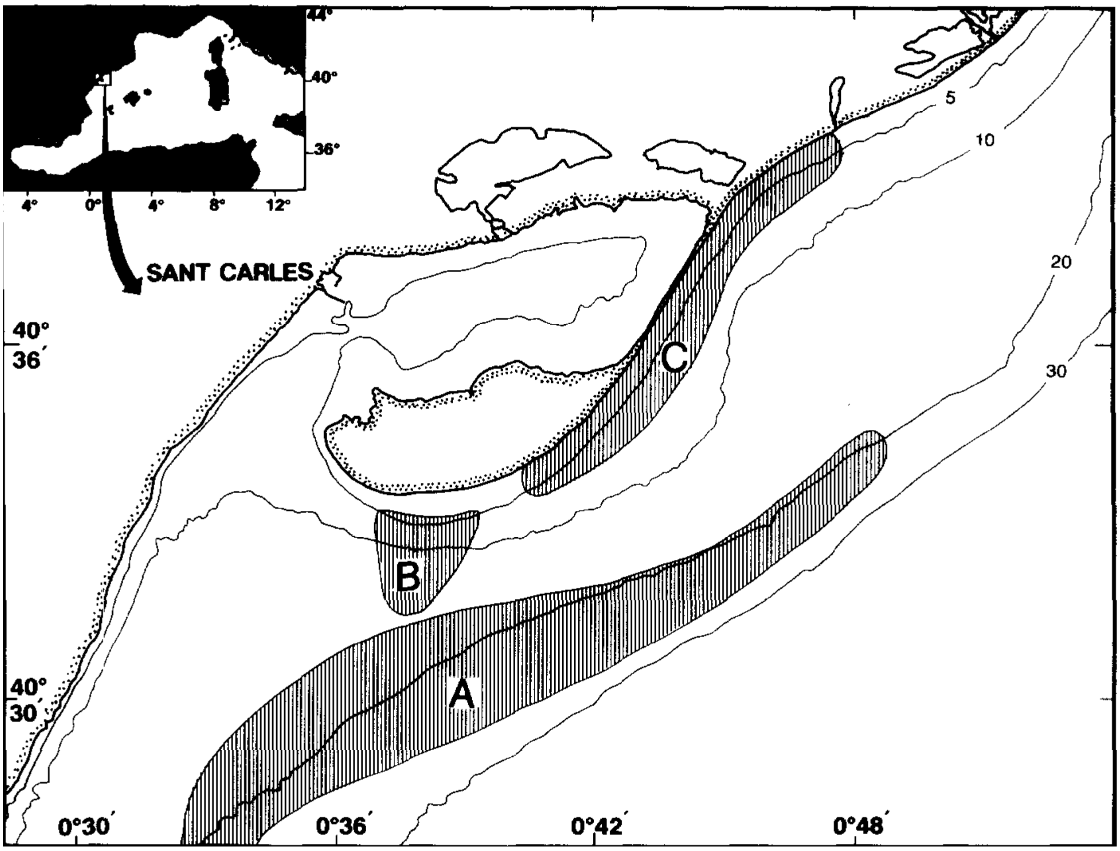

Fig. 1a. General location of "rastell" fishing grounds (from Martín et al. 1995). Our samples were obtained from area marked "B".

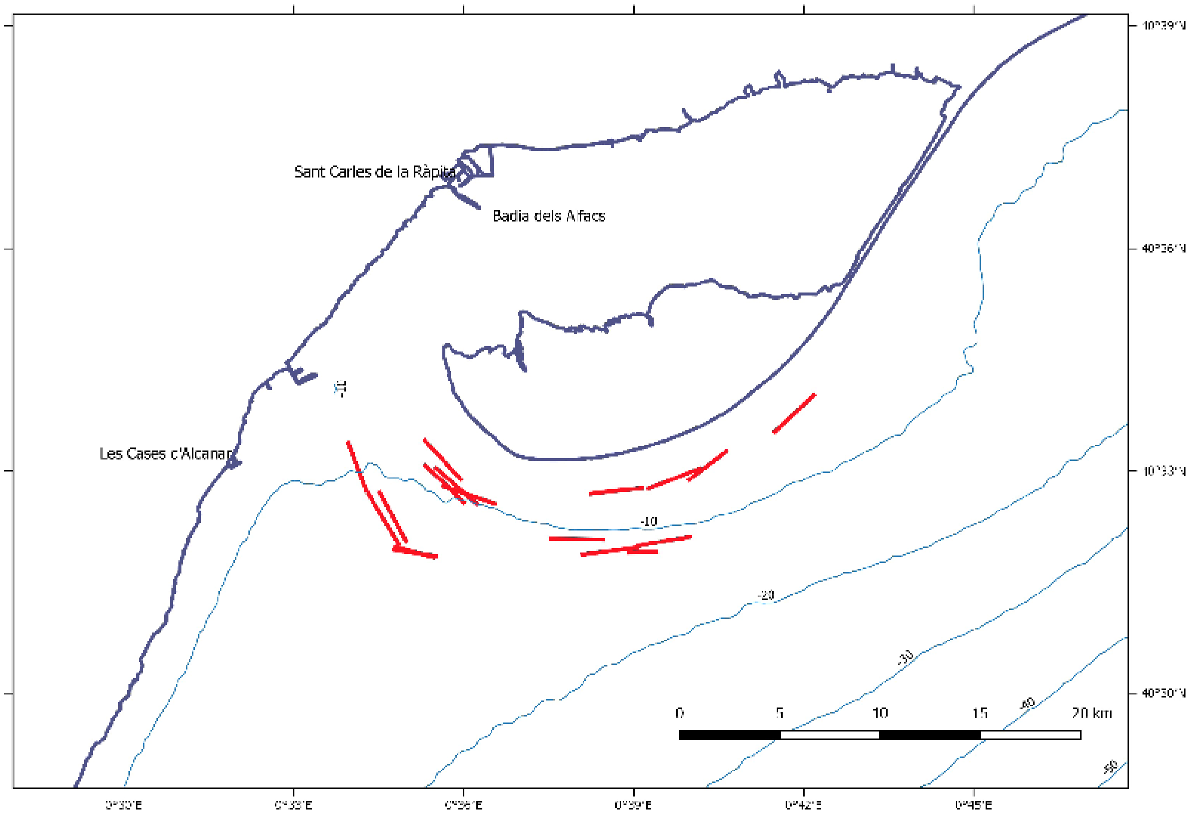

Figure 1b. Study area showing trammel net fishing grounds.

Categorical Vitality Aassessment (CVA)

Samples of murex caught by small beam trawls ("rastell") and trammel nets were taken from the undersize fraction, within 30 minutes of hauling the fishing gear on board, and placed in containers with water at ambient temperatures (24 – 26 ºC). Specimens were assessed for vitality on a 4-point categorical scale (CVA) devised for this study, based on Benoit et al. (2010) and adapted here to shellfish. We defined the different vitality states as follows: vitality state 1: shell and operculum in perfect condition, immediate retractive response to touch (1-2 seconds); 2: Shell or operculum with minor damage (mainly the siphon, <10% broken in length) and responsive to touch; 3: Shell or operculum cracked or with major damage to the siphon (siphon broken >10% in length); 4: Dead/Moribund (operculum not closing and / or major damage to shell or siphon).

The animals from the trammel nets were only assessed for vitality at t0. However, the animals from the beam trawls were monitored for vitality (CVA) every 12 hours for 64 hours (see below).

Survival assessment

The survival assessment was monitored for 64 hours in aquariums at the ICM laboratory. During this time, a total of 7 CVAs were carried out (T0…T6) (Table 1).

The first CVA, T0, was conducted on board within the first 30 minutes of hauling the catch on board, selecting (undersize individuals) and introducing the animals into containers. The second, T1, was performed just after the transferal of the samples to the aquariums in the laboratory. The following 5 CVAs (T2…T6) were made in the aquariums with a periodicity of 12 hours. The transport from the port to the aquariums was a maximum of 3 hours, during which the animals were immersed in seawater in white plastic containers, oxygenated using with oxygen evolving pills.

Table 1. Schedule of the Categorical Vitality Assessments (CVA) carried out on board and at the laboratory of the ICM.

places/SQAs in time	T0 0,5H	T1 6H	T2 18H	T3 30H	T4 42H	T5 54H	T6 64H
On-board	x						
Transfer		x					
Aquariums (ICM)			x	x	x	x	x

Data analysis

A multinomial logit model (Agresti, 1996; http://stats.idre.ucla.edu/r/dae/multinomial-logistic-regression/) was conducted to compare the proportion of individuals in each vitality stage at T0 between the two gear types.

The observed proportion of survivng animals during the captive observation of specimens from “rastell” was described using the empirical Kaplan–Meier function. The Kaplan–Meier survival curve is a function of the data only, and in the absence of censored values, it follows the proportion of individuals alive at each time interval during the holding phase of the experiment.

The statistical analyses was carried out using functions nnet() and survival() in R 3.3.3.

Results

Categorical Vitality Assessment (CVA)

The numbers of animals observed with each of the CVA vitality states, from the two gear types (trammel net and “rastell”), are shown in table 2 , respectively. There was a clear difference in the vitality of animals sampled from the two gear types, with trammel nets showing a far higher proportion of animals in “excellent” condition, and none in poor condition. No “dead” animals were observed from either gear at T0.

Table 2. Number of animals with different vitality states at t0 from trammel net and "rastell" samples.

Vitality	Trammel net	"Rastell"
1	48	61
2	7	58
3	0	62
4	0	0

Multinomial model results

A multinomial moel was fitted to compare the vitality at first observation (T0) between the two gear types. The results show that the difference between gear types was statistically significant (table 3). The condition of murex was best in specimens caught by trammel net, where nearly all individuals were in excellent vitality (87%), while in beam trawl individuals were found to be spread equally among the 3 states (1/3 each, approximately).

Table 3. Results of the multinomial model applied to vitality observed at T0 in trammel net and in beamtrawl ("rastell"): mean estimated proportion and Z-test to compare the difference in proportions between fishing gear.

state	beam trawl	trammel net	Z-test
1	0.34	0.87	<0.001
2	0.32	0.13	<0.001
3	0.34	0.00002	<0.001

Survival Assessment

The Kaplan–Meier survival curve shows the proportion of surviving murex, sampled from the "rastell", at each time interval during the monitoring phase as a function of vitality state (Table 4; Fig. 2). All animals with vitality states 1 and 2 had 100% survival. Furthermore, only 5 out of 62 vitality state 3 animals died, resulting in an overall estimated survival of 87.1% (95% CI: 79.1 to 95.9%) at the end of the monitoring period.

Table 4. Summary results of the survival assessment; with the proportion of surviving murex at time (t), and associated standard error and confidence interval

time (hr)	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
17	181	1	0.984	0.0160	0.953	1.000
42	180	2	0.952	0.0273	0.900	1.000
53	178	5	0.871	0.0426	0.791	0.959

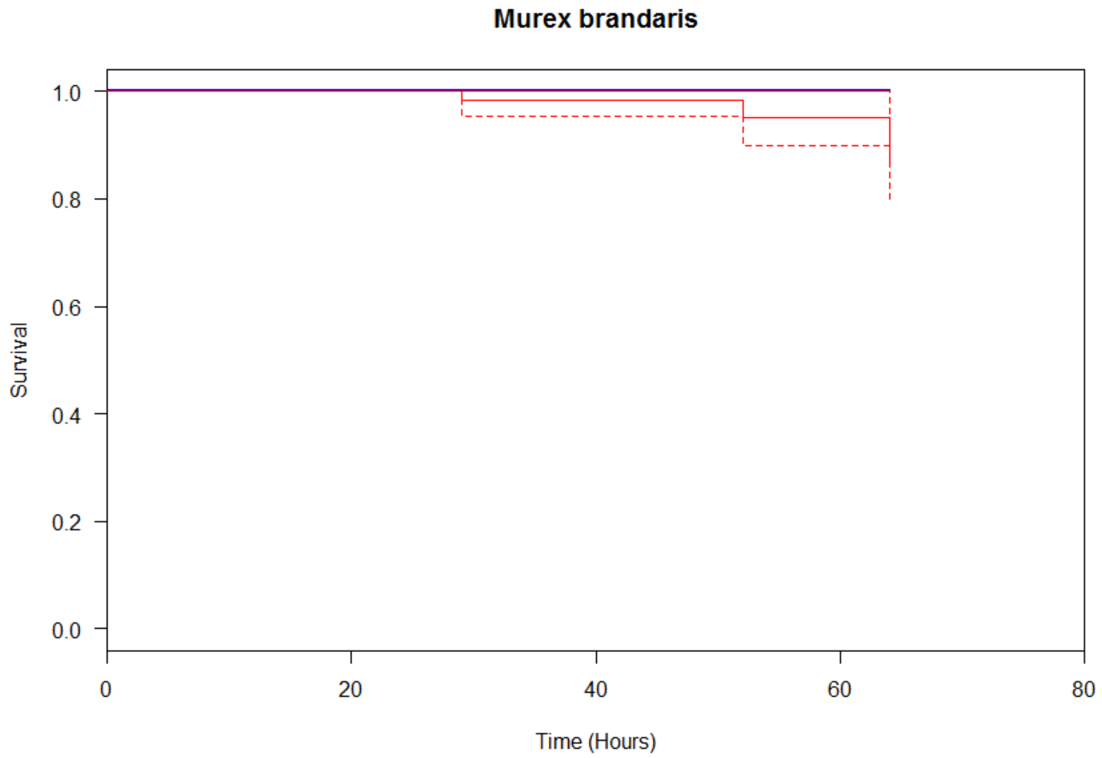

Figure 2. Post-capture survival probability over time (h) for purple dye murex as a function of their pre-holding vitality class score (lines). The broken lines represent the 95% confidence band for the Kaplan–Meier empirical survival curve for each vitality class. Vitality stage 1 and 2: blue; 3: red)

Conclusions

Regarding the undersized *Bolinus (Murex) brandaris* by catch of the trammel net in Catalonia and target of the "rastell" fishery, these preliminary results suggest that undersized individuals returned to the sea potentially have a high probability of survival. However, this study only monitored the undersized animals for 64 hours and thus did not described survival at asymptote. So, it is recommended that these captive observations should be expanded in duration in order to describe the asymptotic survival and be replicated at different times of the year. Although, it is worth noting that our samples were obtained in August at very high water temperatures (24-26 ºC) and the fishery is carried out year-round, so it is expected that thermal-stress related post-capture mortality should be even lower in spring, autumn or winter. Our comparison between fishing gears shows that trammel net is a gentler catching method, producing over 80% of undersize individuals in excellent condition.

Overall, post-release mortality of murex snails is expected to be very low. The methodology tested in this preliminary study could be extended to other shellfish species where high survival exemptions are being considered in the near future (e.g. bivalves in Mediterranean regulation, Annex III).

CS 3.5. Preliminary estimation of discard vitality rates in the Ligurian trammel net fishery

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Case study description

Gears used by small scale fisheries (e.g., set nets, pots, longlines, etc.) are generally considered to be highly selective. However, some gears, such as trammel nets, can have high discard rates; according to investigations carried out by CIBM in the Ligurian and Tyrrhenian Seas (Sbrana et al., 2003, 2004; Francesconi et al., 2005; Rossetti et al., 2006; Sartor et al., 2006). This is the source of some concern, not only from an environmental point of view, but also from a fishing efficiency perspective. Among the small scale fishery activities performed in the area, those using trammel nets to target caramote prawn (*Melicertus kerathurus*) are known to have substantial catches of bycatch and unwanted species (i.e., crabs, hermit crabs, and other invertebrates) (Rossetti et al., 2006).

There is currently very little information on the fate of the discarded animals in the Mediterranean, in terms of there likely survival following the stresses of capture, handling and discarding (STECF EWG 15-14). To address this, a prioritisation study was planned to identify species that would be suitable for more in-depth survival assessment. This prioritisation study would collect vitality data during the field activities of CS 3.5 ("GRECA", Trammel net fisheries in Ligurian Sea).

Methods

The planned approach for estimating survival rates was to use vitality assessments of catches under normal fishing conditions (ICES, 2014 & 2017), with a categorial vitality assessment based on Benoit et al. (2010). Further assessment of survival potential could be justified if species were demonstrated to have a high proportion of animals with high vitality at the point discarding. However, after the first field trials, it was acknowledged that the handling practices in this fishery are so unsympathetic to the welfare of the captive animals that the post-release survival of any released animals was highly unlikely and there was therefore no justification to conduct even a preliminary survival assessment.

Results

A list of species and higher taxa (e.g. Genus) identified during the study is shown in Table 1.

The main reason for this high assumed mortality was due to handling operations observed to be commonly in use among the fishermen in this fishery. While the commercial catch is removed from the net as it is hauled on board, the handling of unwanted species, such as crabs, is performed once in port; usually one hour after the net has been taken aboard. Moreover, the time required to remove crabs, hermit crabs and other invertebrates from the net is considerable. As a result, fishermen do not pay particular attention to removing non-commercial invertebrates from the net while trying to avoid any damage to those organisms. Therefore, fishermen typically break off the crustaceans' appendices and legs to make cleaning the net much faster.

Conclusions

Handling practices in the Ligurian coastal trammel net fisheries are so unsympathetic to the welfare of the captive animals (i.e. long term air exposure, breaking of the body parts to release them from the net) that the post-release survival of any animal is highly unlikely.

In the view of these observations, it was decided to change the target of the planned discard survival assessment. We thus conducted a vitality assessment on board of trawl vessels under the framework of Case Studies 1.6 and 1.8.

Figure 1. Unwanted catch (a swimming crab) entangled in netting.

Figure 2. Target species (caramote prawn) and commercial by-catch (mantis shrimp).

Table 1. List of species present in the commercial (€) and discard fraction (*).

	Category	
Species name	Commercial	Discard
Alosa fallax nilotica	€	
Anadara demiri		*
Aporrhais pespelecani		*
Arnoglossus laterna	€	*
Aspitrigla obscura		*
Astropecten irregularis pentacanthus		*
Boops boops	€	
Buglossidium luteum		*
Conger conger	€	
Diplodus annularis	€	*
Medorippe lanata		*
Engraulis encrasicholus		*
Gobius geniporus		*
Gobius niger	€	*

Deltentosteus quadrimaculatus		*
Hippocampus hippocampus		*
Inachus sp.		*
Inachus thoracicus		*
Oestergrenia digitata		*
Liza aurata	€	
Liza ramada	€	
Macropodia longirostris		*
Macropodia longipes		*
Macropodia sp.		*
Macropipus tuberculatus		*
Liocarcinus vernalis		*
Merluccius merluccius	€	*
Mullus barbatus	€	*
Bolinus brandaris		*
Nassarius mutabilis		*
Oblada melanura	€	
Ophiuroidea indet.		*
Pagellus acarne	€	*
Pagellus erythrinus	€	*
Penaeus kerathurus	€	
Pomatomus saltator	€	
Raja asterias	€	*
Raja clavata	€	
Raja polystigma	€	
Sardina pilchardus	€	*
Sardinella aurita	€	*
Sciaena umbra	€	
Scomber scombrus	€	
Scorpaena porcus	€	
Sepia officinalis	€	
Solea lascaris	€	
Solea vulgaris vulgaris	€	
Sphyraena sphyraena	€	
Spicara flexuosa	€	
Spicara maena	€	
Spondyliosoma cantharus	€	

Squilla mantis	€	
Stromateus fiatola	€	*
Torpedo torpedo	€	*
Trachurus mediterraneus	€	*
Trachynotus ovatus	€	
Trachurus trachurus	€	
Chelydonicthys lucerna	€	*
Umbrina cirrosa	€	
Upogebia sp.		*

4. Synopsis and Conclusions

The nine case-studies conducted as part of Task 2-9 [Assessing and Promoting Survival] have provided much needed information on the post-release survival potential for over one hundred species from a diverse range of taxa (from holoturians, gasteropods, and crustaceans to several fish species) caught in a wide selection of fisheries and capture methods.

Most of the studies have focused on assessing the immediate and short-term (i.e. <96 hours) survival potential of the unwanted components of the catch, by monitoring their vitality as they were sorted from the catch and for short periods after that. The main objective of these preliminary assessments was to identify species that have a high potential for post-release survival, and thus inform any prioritisation and scoping of full-scale survival assesments in these fisheries. At the same time, these studies have also identified a list of species for which post-release survival is highly unlikely, in those respective fisheries and operating conditions. These data will be very informative for assessing the ecological consequences of fishing and the effects of any shifts in harvesting practices.

Two studies used captive observation methods to provide scientifically robust estimates of post-release survival estimates for regulated target species: CS 1.4 (Nephrops in the Catalonian crustacean trawl fishery) and CS 2.2 (Sardine in the Algarve purse seine fishery). In both cases, it was demonstrated that under appropriate conditions and handling practices the majority of animals for these two species could survive being caught and released from their respective fisheries. However, it should be recognised that these captive observation techniques cannot account for the increased likelihood of predation following release (e.g. Raby et al, 2013).

The studies described in this report have demonstrated that there are several determinants in the survival of any released animals, including: species, capture method, and their interactions, as well as the environmental conditions and handling practices during the capture and release process.

<u>Species:</u> the ability of an animal to endure the stressors associated with capture and release from fishing operations will be dependent upon key biological characteristics (e.g. de Juan and Demestre, 2012), including: body form and size, integument (skin) form and robustness, presence and form of a swim-bladder, as well as behavioural traits and baseline metabolism. These biological characteristics will make an animal more or less vulnerable to different stressors during the capture and release process, and as such this vulnerability will be dependent upon the nature of the capture method (see below). Thus in case-studies which examined several species in the catch (e.g. CS1.2, CS1.4, CS1.6 and CS3.2), a wide range vitality states were observed amongst different species sorted from the catch. For a more in depth discussion on these points see the separate report: D2.15 Guidance on Promoting Survival of Discarded Fish.

<u>Size:</u> a key biological characteristic that was not explored in-depth as part of these studies, primarily due to small sample sizes, was the effect of individual size upon survival. In the scientific literature, there is growing evidence to support a general hypothesis that large animals with a species have a higher probability of surviving

capture and release from fishing gears (e.g. Sangster et al, 1996; Suuronen, 2005). This is an important consideration with regards to the management of a fishery and its discarding practices, because typically it is the undersized animals that are selectively returned to the sea.

Capture Method: Of the 11 broad categories of fishing gear recognised by the FAO International Standard Statistical Classification of Fishing Gear (ISSCFG) (FAO, 1990), this report includes survival data for animals caught in five types: demersal trawls, dredges, surrounding nets (boat & purse seine) and entangling nets (trammel nets). These various fishing methods have quite different modes of operation and thus differing effects on the animals encountering them. Deliverable report D2.15 describes the likely injurious mechanisms in each gear in some detail, and the likely stressors encountered by a captured animal are likely to include: hypoxia, exhaustion, barotrauma, temperature shock, osmoregulatory distress, crowding, physical trauma/injury, light exposure, emersion, displacement and predation.

Typically, it is assumed that the stressors experienced by capture in towed fishing gears are likely to be more severe than those in passive gears (e.g. trammel nets), resulting in lower vitality amongst the capture animals. For example, murex (*Bolinus brandaris*) caught in trammel nets had 100% with “excellent” or “good” vitality scores (which corresponded to 100% survival at 64 hours), while dredges (“rastell”) only had only 65.74% with these vitality levels; due to capture related damage to their shells. However, for *Scyliorhinus canicula* caught in demersal trawls in the Tyrrenian Sea had a high proportion of animals with execellent or good vitality states (82.3%), while the same species caught in Balearic trammel nets were typically dead as the catch was brought on board (<20% survival).

Environmental conditions: including the fishing depth, sea state, wáter temperature, salinity, presence of thermo- and halo-clines, air temperature, etc, can all effect post-release survival (see Deliverable report D2.15 for detailed discussion). In this project, increasing water temperature was noted to have negative effect on survival in two case studies CS1.4 and CS3.3. In CS1.4, survival was best during the Winter, when wáter temperatures were coolest. In CS3.3, survival was predicted to drop to nearly zero when water temperature was above 15.8ºC.

Handling of the catch by the fishermen is one of the major determinants in the survival of any released animals. At one extreme, in CS 3.5 [Ligurian coast trammel net fisheries], handling practices are so unsympathetic to the welfare of the captive animals (i.e. long term air exposure, breaking of the body parts to release them from the net) that their post-release survival is highly unlikely. However, in CS 2.2 [Sardines in Algarve Purse Seine], it has been demonstrated that through simple, but well considered, improvements in handling practices (i.e. allowing the fish to swim freely from a purpose-made opening in the net) the survival of these delicate fish can be significantly increased. It is also important to recognise that the survival potential of released fish in both CS2.2 and CS 3.3 [Glass Goby in Balearic Boat Seine] is greatly enhanced by minimising the exposure these animals have to emersion from the water. This simple but profound principle could be generally applied to most fishing practices to generally improve the welfare of the captive animals, both targeted and unwanted catch, and thus improve the likelihood of any released animals. This and other welfare sympathetic handling practices are described and discussed in more detail in a separate report: D2.15 Guidance on Promoting Survival of Discarded Fish.

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Appendix 1. Discard Policy in Mediterranean Sea under Article 15 of EU Regulation 1380/2013

Regulation 1380/2013 of the European Parliament and of the Council of 11 December 2013 introduced articles and provisions that aimed at a gradual introduction of a “Landing Obligation” (LO), as part of a revised Common Fisheries Policy (CFP), with the banning of discarding practices being the intended effect. The provisions on the landing obligation are stated in Article 15 of the regulation, which states that all catches of species managed by quotas/catch limits and Minimum Conservation Reference Size (MCRS) should be landed.

However, there are some important differences between national and European regulation, because in many cases national regulations are more restrictive than European regulation, with a greater number of species regulated using MCRS. Hence, undersized individuals of regulated species with MCRS under national regulations are not covered under the European regulations, and must be returned to the sea. Therefore, the regulation can only apply to species listed in Annex III of Regulation (EC) No 1967/2006, even if other national regulations for minimum size exists for other species.

Implementation Schedule

These provisions are meant to enable member states (MSs) to develop timelines for bringing the different species in a fishery under the landing obligation. A summary of the time schedule for the implementation of the landing obligation in Mediterranean Sea is the following:

- From 1 January 2015:
  - small pelagic fisheries (i.e. mackerel, herring, horse mackerel, blue whiting, boarfish, anchovy, argentine, sardine, sprat);
  - large pelagic fisheries (i.e. fisheries for bluefin tuna, swordfish, albacore tuna, bigeye tuna, blue and white marlin);
- From 1 January 2017:
  - fisheries for target species in the Mediterranean, Black Sea and all other EU waters;
- From 1 January 2019:
  - for all other regulated species in fisheries in all Union waters.

Adopted Mediterranean pelagic and demersal discard plans

Discards Management Plans are to be defined for fisheries characterized by target species. The landing obligation will be applied on a case by case basis, and details of the implementation will be included in multiannual plans or in specific discards plans when no multiannual plan is in place.

At present, the obligations derived from the LO in the Mediterranean are being dealt with through a regionalized approach. The MEDAC (Mediterranean Advisory Council) is actively involved in the development of multiannual plans. For instance, 3 member states are coordinating the discard plan in the Western Mediterranean (Spain, France, Italy) in the working group "PESCAMED" coordinated by MEDAC.

To date, with the aim to obtain the *de minimis* exemption from the landing obligation, three discards plans have been introduced in EU Mediterranean waters:

1. COMMISSION DELEGATED REGULATION (EU) No 1392/2014 of 20 October 2014 establishing a discard plan for certain small pelagic fisheries in the Mediterranean Sea.

This discard plan covers all catches of species which are subject to minimum conservation reference sizes caught in small pelagic fisheries using pelagic mid-water trawl and/or purse seines (i.e. fisheries for anchovy, sardine, mackerel and horse mackerel). It shall apply from 1 January 2015 until 31 December 2017.

***De minimis* exemption:** article 3 defines the quantity of the above species that can be discarded; it varies according to the Mediterranean sub-area.

2. COMMISSION DELEGATED REGULATION (EU) 2016/2376 of 13 October 2016 establishing a discard plan for mollusc bivalve *Venus spp*. in the Italian territorial waters.

Reduction of MCRS from 25 to 22 mm for the species *Venus sp*.. It shall apply from 1 January 2017 until 31 December 2019. A reduction of a minimum conservation reference size from 25 mm to 22 mm in the Italian territorial waters is not incompatible with the length at maturity, so it should not have a significant impact on the protection of the juvenile organisms.

Member State authorities shall determine the vessels subject to the landing obligation.

3. COMMISSION DELEGATED REGULATION (EU) 2017/86 of 20 October 2016 establishing a discard plan for certain demersal fisheries in the Mediterranean Sea.

Survivability exemptions: only for 2017 and for the following species: common sole *(Solea solea)* in GSAs 17 and 18; scallop (*Pecten jacobeus*), carpet clams (*Venerupis* spp.) and Venus shells (*Venus* spp.) in GSAs 1, 2, 5 and 6. By 1 May 2017, Member States having a direct management interest in the fisheries in the Mediterranean Sea shall submit to the Commission additional discard data for further review.

Five species that define the fisheries identified*:* European hake (*Merluccius merluccius*), common sole (*Solea solea*), red mullet (*Mullus barbatus*), striped red mullet (*Mullus surmuletus*) and deep-water rose shrimp (*Parapenaeus longirostris*), with the following criteria: landing obligation for these species shall apply when the total landings per vessel of all species in 2014 and 2015 consist of more than 25 % of the species above mentioned. The demersal discard plan also requires Member States to produce a list of vessels subject to the LO based on specified catch thresholds.

***De minimis* exemption** established for 4 species that define the fisheries, as specified above. Quantities that can be discarded varies according the gear and the zone.

Appendix 2. "High Survival" Exemption under Article 15 of EU Regulation 1380/2013

In Article 15, paragraph 4(b), of the revised CFP 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*".

The primary objective of this exemption is to avoid management scenarios where the introduction of the Landing Obligation (LO) could prove detrimental to the sustainability of a fishery by unintentionally increasing fishing mortality, through the enforced landing of unwanted catch that would otherwise have been discarded and survived.

To support any proposal for a "high survival exemption" (HSE) for selected species or fisheries, therefore, clear, defensible, scientific evidence for high discard survival rates are required. To address this, there are two key elements of this legislation that need to be satisfied: i) obtaining suitably reliable and scientifically robust estimates of discard survival; and ii) demonstrating these estimates are suitably high to justify an exemption in a particular fishery.

<u>Methods for Estimating Discard Survival</u>

From the first implementation of the LO, there was an urgent need for guidelines, and identification of best practice, for undertaking discard survival assessments. In September 2013, a STECF[1] Expert Working Group (EWG 13-16) was tasked with providing this guidance. It concluded that there were three available techniques (captive observation, tagging/biotelemetry and vitality assessment) but that each of these had specific practical and scientific limitations. It was recommended that further work was required to better define best practice in methods for estimating discard survival, as well as defining criteria for critically appraising such assessments.

In response to a request from the EU Commission, the International Council for the Exploration of the Seas (ICES) established a Workshop on Methods for Estimating Discard Survival (WKMEDS) on 1st January 2014. In readiness for the first appraisal of Joint Recommendations by the Commission and STECF (see STECF PLEN 14-02), WKMEDS published its first draft guidance in April 2014 (ICES 2014). Its main recommendations were: i) assessments should be representative of discarded catch and practices, ideally in the metier as a whole; ii) methods should avoid biasing results through observation induced mortality, and ideally demonstrated with appropriate controls; and iii) the monitoring period should be sufficiently long to observe any delayed mortality. A peer reviewed publication of this guidance was published in 2017 (Breen & Catchpole, 2017). Further to drafting this guidance, over a series of six meetings WKMEDS has provided an open forum for researchers and stakeholders

[1] STECF (Scientific, Technical and Economic Committee for Fisheries) is a scientific & economic advisory body of fisheries for the EU Commission.

actively involved in survival assessments to discuss and develop their methods[2]. It has also developed protocols for systematically/critically reviewing survival assessments and analysing survival data (ICES 2015a, 2015b, 2016a, 2016b and 2017).

Selection of a suitable threshold for "high survival".

STECF have emphasised that before considering the implementation of a HSE, it should be remembered that avoidance of unwanted catch, through improved selectivity or other means, is the primary objective of the LO (STECF EWG 16-10). Clearly, determining an appropriate "high survival" threshold for a particular species and metier is complex, which will require an informed understanding of a number of key issues:

- pre-existing status of the stock, and wider ecosystem, with respect to key management criteria (i.e. MSY) and safe biological limits (i.e. recruitment, fishing mortality and spawning stock biomass);
- current discarding rates, including temporal and spatial variability;
- realistic potential for changing the exploitation pattern to avoid unwanted catches;
- potential for reducing the incentive to reduce discarding, if an exemption was implemented;
- potential to undermine compliance to the LO, if an exemption was implemented;
- scientifically validated discard survival likelihood, and its variability across the fishery; and
- likely impacts on the stock, and wider ecosystem, of the LO with and without the HSE.

Finally, STECF have concluded that the selection of a value for "high survival" is subjective and likely to be species- and fishery-specific. Furthermore, they have stated that "the decision to accept or reject an exemption proposal based on the survival value presented is for managers to decide" (STECF EWG 13-16, 13-17, 14-01, 14-11, 15-05, 15-14 and 16-10). This is because the selection of an appropriate "high survival" threshold will involve trade-offs between different management and societal objectives, which will ultimately be driven by the management priority for that fishery at that particular time (e.g. improving stock sustainability; improving financial viability; or avoiding waste).

For further discussion on the policy implications of the High Survival Exemption please refer to MINOUW Deliverable Report D4.1

[2] Details about ICES WKMEDS and meeting reports are available at:

http://www.ices.dk/community/groups/Pages/WKMEDS.aspx

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