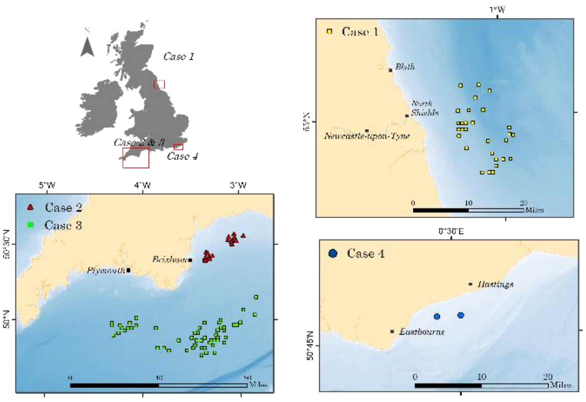
Estimating the discard survival rates of selected commercial fish species (plaice - *Pleuronectes platessa*) in four English fisheries (MF1234)







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Executive Summary

Discarding fish back to the sea that are caught during commercial fishing is often considered to be wasteful as many species are returned dead or dying. On 1st January 2014, the latest reform of the EU Common Fisheries Policy (CFP) (1380/2013) came into force and with it a discard ban or landing obligation for regulated species (EU 2013). The discard ban is being phased in and will cover all quota stocks in EU waters by January 2019. The principle of the new CFP is to incentivise fishers to avoid catching unwanted fish.

Research has shown that some discards survive and that in some cases, the proportion of discarded fish that survive can be substantial. As such, the new policy includes the possibility of exemptions 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* …'. In these cases it may be beneficial to return a proportion of the catch to the sea to support the stock biomass and the profitability of the fishing industry.

Some survival data on discarded fish has been published but the results are highly variable and available for only a few selected species and fisheries. Many factors, including biological attributes, environmental conditions and technical elements of the capture process, have been identified as affecting the survival rate of discarded species. There is an immediate demand for scientific evidence on fishery specific discard survival rates, which consider the specific characteristics of the gear and fishing practices.

To meet this requirement, this project had three main aims:

(1) To assess the potential survival rates of quota species in different English fisheries and areas and complete a prioritisation process to select four case study species and fisheries.
(2) To deliver four case studies to quantify discard survival for prioritised fisheries under normal commercial fishing operations.
(3) To identify the factors that most influence discard survival rates with the aim to identify mechanisms to improve survivability.

Four case study fisheries were selected through a prioritisation process based on biological susceptibility to post-capture mortality, state of the fish population, levels of discarding in the fishery, gear used in the fishery, and economic value of the stock. The selected fisheries were the North Sea mixed demersal otter trawl fishery, the Western Channel mixed demersal otter trawl fishery, the Western Channel mixed demersal beam trawl fishery and the Eastern Channel trammel net fishery. For these fisheries, only the highest priority species could be investigated, which was plaice (*Pleuronectes platessa*) in all cases, with the exception of the trammel net fishery in which it was also possible to investigate rays.

The structure of the project dictated the method that could be used to assess discard survival rates, and this was developed within the project and in parallel with the ICES' Workshop on Methods to Estimate Discard Survival (WKMEDS). The approach selected was to assess the health and vitality of fish at the point at which it would have been discarded during a representative range of conditions and combine this with survival rates of fish held in captivity, also selected from the catch with a representative range of vitality conditions, and combine these data to generate an overall weighted mean discard survival estimate. Electronic tags were used on a limited scale to assess the survival of discarded rays.

The project generated both experimental estimates within a pre-defined observation period, and modelled results, to account for predicted mortalities beyond the observation period. The experimental results gave mean discard survival estimates for plaice of:

- 42% for the North Sea otter trawl fishery (observation period 105-120 hrs);
- 64% for the Western Channel otter trawl (66-133 hrs);
- 37% for the Western Channel beam trawl (38-72 hrs) and
- 73% in the Eastern Channel trammel net fishery (168-342 hrs).

The models predicted discard mortality had virtually ceased during the observation period in two studies; the modelled survival estimate for the Western Channel otter trawl was 47-63% and 71-72% for the trammel net fishery. In the other two studies, the models indicate that further mortality was likely beyond the observation period, predicting discard survival estimates of 19-20% for the North Sea otter trawl fishery and 4-15% in the Western Channel beam trawl fishery.

All estimates included avian predation but excluded other marine predation. Furthermore, the stressors exerted on the fish from the method applied, including temperature differences, handing, confinement, proximity with other fish, dissolved oxygen depletion, were likely to have induced some experimental mortality. Therefore, the results presented here should be interpreted as minimum estimates of discard survival, excluding marine predation.

Some initial analysis of the factors that influence survival showed that lower survival was associated with higher wind strength and longer catch sorting times. There were many factors measured that had the potential to effect survival. The number of fish that could be retained meant that it was difficult to determine the relative influence of these factors. In general, the findings from this project indicated that gear type, handling, air/water temperature and exposure are likely key variables. For example, there was a lower incidence of abrasion, net marks and scale loss in plaice caught with the trammel net compared with towed gears, with scale loss associated with increased mortality. Changing the gear type, operational practice and sorting practices offer methods to potentially increase the survival rates of discarded fish.

The survival estimates generated here are representative of the observed trips. Assumptions must be made in order to extrapolate the data to vessel and fleet level. However, this evidence is considered to provide scientifically robust estimates of discard survival and will inform fisheries managers of the appropriateness and potential to develop proposals to gain exemption from the landing obligation under the high survivability provision in European Regional Discard Plans.

1. Introduction

2.1 Background

Discarding fish back to the sea that are caught during commercial fishing is often considered to be wasteful by fishers, conservationists and fisheries managers alike as many discards are returned dead or dying. On 1st January 2014, the latest reform of the EU Common Fisheries Policy (CFP) came into force and with it a ban on discarding (also known as a landing obligation) for regulated species (EU 2013). This discard ban is being phased in, beginning with pelagic fisheries in 1st January 2015. It will cover all quota stocks in EU waters (and those with a Minimum Landing Size in the Mediterranean) by January 2019. The principle of the new CFP is to incentivise fishers to avoid catching unwanted fish.

There are a number of exemptions and flexibility tools to help the landing obligation work in practice. One exemption which can be granted is 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 discarding process can be separated into three phases: i) capture by fishing gear, ii) handling at the surface, and iii) release back to the sea. Research has shown that some discards survive the process. In some cases, the proportion of discarded fish that survive may be substantial, depending on the species, the characteristics of the vessels and other operational, biological and environmental factors. In these cases it may be justifiable, and even beneficial to continue discarding these species.

The European Commission's Scientific, Technical, Economic Committee for Fisheries (STECF) concluded that selection of a value which constitutes "high" survival is subjective and likely to be species- and fishery-specific. The value will be based on "trade-offs" between the benefits to the stock of continued discarding and the potential removal of incentives to change exploitation pattern and how this contributes to the minimisation of waste and the elimination of discards (STECF 2014). Central to any proposal for an exemption for selected species or fisheries, is the requirement for clear, defensible, scientific evidence on discard survival rates.

Details of agreed exemptions will be included in regionally formulated Discard Plans in the short term and ultimately Multi-Annual Plans. These exemptions will be based on scientific studies that have been independently reviewed by STECF before the plans are adopted by the EU Commission. There are some published discard survival data but the results are highly variable and available for only few species and fisheries. Many factors, including biological attributes, environmental conditions and technical elements of the capture process, can affect the survival rate of discarded species. Article 15 notes that consideration must be given to the specific characteristics of the gear, fishing practices and of the ecosystem. Therefore, there is an immediate demand for scientific evidence on fishery specific discard survival rates.

2.2 Project objectives

To support any proposal for an exemption for selected species or fisheries, there is a requirement for clear, defensible, scientific evidence for discard survival rates. To meet this requirement, this project was structured with three main aims; namely, to:

1. assess the potential survival rates of quota species in different English fisheries and areas and complete a prioritisation process to select four case study species and fisheries;
2. deliver four case studies to quantify discard survival for prioritised fisheries under normal commercial fishing operations; and
3. identify the factors that most influence discard survival rates with the aim to identify mechanisms to improve survivability.

In order to prioritise and select the case studies for survival studies for English fisheries the following information was evaluated:

i) known fishery-species discard rates;
ii) existing knowledge of survival rates;
iii) the relative importance of a species/stock to the English fishing fleets; and
iv) industry opinion on expected survivability derived from a series of fishing industry meetings conducted in the Defra/Cefas ASSIST project.

To undertake four practical case studies to quantify discard survival, three approaches to define survivability were proposed, with the appropriate combination of approaches applied to achieve confidence in the result and reduce the assumptions:

i) immediate mortality estimates (vitality assessments and predation observation);
ii) captive observation (retaining and monitoring commercial caught fish in holding tanks); and
iii) biotelemetry/tagging (tagging and releasing discarded fish with the means to quantify survival rates).

All the fieldwork was to be conducted on-board commercial fishing vessels in a partnership approach with industry and the findings were to be representative of normal fishing operations. We aimed to estimate the survival rates across the full length range of the catch, under the assumption that fish at any length could be discarded and an exemption, if awarded, would not apply to specific lengths only.

The project aimed to use the data from the three experimental approaches and combine this with descriptive data on the technical, biological and environmental characteristics of the fishing operation to identify factors that most influence discard survival.

These data would be used as variables in a statistical model to identify factors influencing health and mortality. The results from the analyses would be used to identify, where possible, which factors might potentially influence and increase in discard survival rates.

3. Methods

3.1 Case study selection

The first work package identified the species and fisheries that were suitable candidates for the survivability case studies. We developed a set of selection criteria based on biological susceptibility to post-capture mortality, state of the fish population, levels of discarding in the fishery, gear used in the fishery, and economic value of the stock. Using these criteria we developed a scoring system using a 'productivity and susceptibility' approach to assign a score to each fishery against each criterion, while also providing an opportunity for input from the project steering board. This "productivity and susceptibility" type scoring method has had wide application in ecological risk assessments (Patrick et al. 2009) and was used to synthesise all available information and provide an objective scoring system to base decisions on suitable case studies.

These criteria broadly fell into two categories: 1) Feasibility of the species having substantial survival - including physiological characteristics of the fish such as the presence of a swim bladder and size of the fish (Davis 2002, Benoit et al. 2013), and the 2) fishing gear used (e.g. trawl, nets), including mesh size, tow duration and soak time influence survival, and the desirability of seeking exemption for the species from the landings obligation - including consideration of the state of the fish population, levels of discarding and economic value of the stock to the fishery.

A score, from 1-3, was assigned to each criterion (Annex 1), derived from the available literature, data or expert knowledge and a confidence rating based on the certainty of that knowledge was also assigned. Where more than one attribute was in place for a criteria type, the mean of these score was used.

To generate an initial list of species, areas and fisheries we first considered the species subject to total allowable catch (TAC) limits in the 2013 TAC and Quota Regulation (Council Regulation No. 39/2013). Landings data from the Marine Management Organisation annual fisheries statistics for 2012 (MMO 2014) was then used to assign a landings volume (t) and value (£) for each species in each of the following areas: (a) the North Sea and Eastern Channel (ICES Subarea IV and Division VIId), (b) the Celtic Sea and Western Channel (ICES Divisions VIIbc, e-k) and (c) the Irish Sea (ICES Division VIIa).

In order to reduce the list, any species/area combination without landings in 2012 by English vessels were removed. Fisheries were described according to the Data Collection Framework métiers definitions relating to gear type, target species and vessel size. Based on landings disaggregated to the fishery level for the species-area combinations a final list of 241 species-area-fishery combinations was produced, after starting with 45 species in 192 stocks.

An overall rank for each species and fishery was produced (Annex 2). There was a common group of species identified as likely to have good survival chances based on their biological traits, which also have high discard rates and value to English fisheries: plaice (*Pleuronectes platessa*), skates and rays ,undulate ray (*Raja undulata*), thornback ray (*Raja clavata*) and sole (S*olea solea*). These species are caught in trammel net, otter trawl and *Nephrops* trawl fisheries. These species are also caught in the same fisheries as each other allowing for the potential to undertake case studies that could include more than one species.

We then considered the practicalities of the case studies (e.g. timing of fishery, availability of vessels) to finalise a list of fisheries and species. The outcome of the analysis was presented to the project steering group which consisted of Cefas scientists and Defra policy officials and the final selection of case studies was made. Species associated with the top ranking species/fisheries were ranked in order of priority (Table 1).

Table 1: Selected species-fisheries case studies with ranked priority species.

Case Study	ICES' Subarea and Division	Gear	Species rank 1	Species rank 2	Species rank 3	Species rank 4
1	IV	Otter trawl	Plaice	Sole	Lemon sole	Rays
2	VIIb,c,e-k	Otter trawl	Plaice	Sole	Monkfish	Rays
3	VIIe (inside 12nm)	Beam trawl	Plaice	Sole	Monkfish	Rays
4	IVc/VIId	Gill/trammel nets	Plaice	Sole	Dab	Rays

3.2 Methodological approach

Research aimed at determining whether aquatic organisms survive, which have been caught and subsequently returned to the water, has been conducted over many decades. Although there have been reviews of the outputs from this work (Broadhurst et al. 2006, Revill et al. 2013), at the commencement of this project there had been no assessment of the scientific methods and approaches that can be used to meet this aim.

Around the same time as the start of this project an ICES (International Council for the Exploration of the Sea) group on Methods to Estimate Discard Survival (WKMEDS) was initiated. The ICES workshop was initiated to develop and describe the methods of best practice to quantify the survival of aquatic organisms caught and returned to the water. The catalyst for creating the WKMEDS was the change in European Union fisheries policy, generating a need for guidance on how to investigate levels of discard survival, which was absent at the beginning of this project. The co-chair of ICES WKMEDS provided the scientific advice for this project.

Therefore, during the course of this project, the methods of best practice to derive estimates of discard survival have been developing. The outputs from ICES WKMEDS have been applied to this project, moreover, the experiences from this project have been used to improve the guidance on how best to conduct discard survival assessments as reported by WKMEDS.

3.2.1 What is survival?

The opposite of survival is death, which is a more definitive state to identify. So typically when we measure the “survival” of organisms, after they have experienced a particular treatment, for example being caught and discarded, we in fact quantify the number of individuals that died, based on a measurable definition of death. More precisely, we usually measure mortality rates, which is the number of individuals that die over a defined period of time. The inverse of the mortality rate is the survival rate.

Death is not normally an instantaneous process and some time will elapse between an initial exposure to a fatal stressor and the eventual cessation of life. Conversely, if observed long enough, any individual will die. Therefore, the timeframe over which observations are made will have an important influence on the estimated survival rate. There is no standard time frame for conducting a survival assessment, as it depends upon the species in question and the nature of the fatal effects, as well as the logistical limitations of the investigation. It is recommended that survival estimates should be presented with reference to the timeframe over which they were derived (e.g. “40% mortality, equating to 60% survival; 6 days observation”).

3.2.2 What influences survival?

A fish or other animal will experience an array of different potentially injurious events, or stressors, throughout each phase of the capture process:

i) capture by the fishing gear;
ii) handling at the surface;
iii) release back to the water

In this context, an array of factors that could potentially influence discard mortality can be identified. These can be classified into three broad categories: biological (e.g. species, size, age, physical condition, occurrence of injuries), environmental (e.g. changes in: temperature, depth, light conditions) and technical (e.g. fishing method, catch size and composition, handling practices on deck, air exposure). Each stressor and the additive effects of multiple stressors will influence the survival of an individual.

3.2.3 How do you estimate discard survival?

There are three main approaches to conducting a discard survival assessment with the aim to estimate discard survival (ICES 2014):

(1) Vitality Assessment: where the health status of the subject to be discarded is scored relative to any array of indicators (e.g. activity, reflex responses and injuries) that can be combined to produce a vitality score. Where these scores have been correlated with a likelihood of survival they can be used as a proxy for survival likelihood;
(2) Captive Observation: where the discarded subject is observed in captivity, to determine whether it lives or dies; and
(3) Tagging and Biotelemetry: where the subject to be discarded is tagged and released, and either its behaviour/physiological status is remotely monitored (via biotelemetry) to determine its post-release fate, or survival estimates are derived from the number of returned tags.

In isolation each of the outlined methods has limitations which can restrict the usefulness of the survival estimates they produce. However, when two or more of these methods are combined there is clear potential for considerable benefits. The benefits from this integrated approach include: reducing resource requirements, increasing the scope of the investigation, as well as improving the accuracy and application of the survival estimates.

Table 2 outlines the combination of approaches which are needed to meet different survival assessment objectives (ICES 2014). The outputs from each approach range from providing estimates of the proportion of discards that appear dead or impaired at the point of discarding (referred to as “survival potential”) (option 1), to generating a discard survival rate for a population that is representative of a fishery (option 6). In general, the resources and time needed to meet the objectives increase from option 1 to 6.

The resources and, more critically, the time available in this project dictated which of the approaches was used. The approach selected was to use vitality assessments on-board commercial vessels during a representative range of conditions combined with captive observation of individuals with different vitality levels to generate an overall weighted mean survival estimate. It was decided that added to this we would provide estimates of avian predation. This approach would provide an estimated discard survival rate, excluding marine predation, which is representative of the fishery.

It is practically difficult and expensive to use the captive observation method so that fish are sampled from the full range of conditions experienced in a fishery. In contrast, the vitality of fish can be derived with relative ease from multiple fishing operations. A fishery-based discard survival estimate can be derived by using vitality as a proxy. The proportion of fish surviving with different vitality levels, observed from captive observation, can be applied to the proportion of fish at each vitality in all fishing trips. This technique also gives the relative influence on discard survival of measured variables.

3.2.4 The limitations and assumptions of the selected approach

1. The captive observation approach excludes predation and therefore may overestimate survival. The inclusion of estimates of avian predation in this project meant that it is only marine predation that is not accounted for, but the levels of this are unknown. To account for marine predation requires the use of data storage or acoustic tagging techniques but these could not be delivered within the time and cost structure of this project.

2. When using captive observation, the period of observation will dictate the context of the survival estimates (e.g. 60% survival after 6 days). Ideally monitoring should continue until mortalities cease or at least slow down. However, in practice, the duration of monitoring has to be a trade-off between ideal scientific needs, the available resources (sea time, budgets and available tank time) and occurrence of confounding mortality not associated with the process of discarding. Therefore, if the observation period is too short, the survival estimates might be overestimated. Models to project forward from a survival probability curve were used to inform whether a longer observation period would have generated lower survival estimates (see Analytical Methods section 3.5).

3. It must be assumed that retaining fish in holding tanks does not have a recuperative effect and artificially increase survival. This was considered unlikely in this project - see below (4).

4. Holding wild animals in captivity can induce stress, which can potentially increase mortality in addition to the treatment effect. Moreover, physical damage from being held in tanks on-board a moving vessel, changes in salinity, light, pressure and temperature, and being held in close proximity with other fish, all exert stress on fish. When these stressors occur, they will likely have additive effects to the treatment stressors and reduce observed survival rates.

5. For survival estimates to be representative of the fishery vitality data should be generated for fish discarded during all conditions of a fishery. However, because conditions are constantly changing, without a continuous vitality monitoring programme the survival estimates may be representative only for the trips from which vitality data have been collected. To extrapolate the results to a fishery, it must be assumed that the combination and strength of stressors on the discarded fish are the same on all trips as those from which vitality data were collected.

6. To be able to use the assessments of fish vitality as a proxy for survival when combined with captive observation results, two assumptions have to be made:
a) Scientific fieldworkers need to be able to assess the vitality of fish consistently, in time, in different conditions and between different workers. All the fieldworkers collecting data during this project underwent training in handling live fish and performing vitality assessments. To have as much consistency as possible in the vitality assessments two case studies were assigned each to two scientists. The North Sea otter trawl and Eastern Channel gill net fishery were managed by one scientist; the Western Channel otter trawl and beam trawl studies were managed by another scientist.
b) Most importantly, to be able to use vitality assessments as a proxy for survival, there must be a significant relationship between survival and vitality score. Therefore, the protocol used to generate vitality scores must deliver scores that can consistently predict survival likelihood. The results from the captive observation will determine whether assessed vitality is a good predictor of survival.

Table 2: An overview of possible objectives for a survival assessment and the recommended approaches (ICES 2014).

Objective (for the selected species, variables & management unit)	Suggested approach	Resource Implications
1. To estimate discard survival potential for particular conditions	**Vitality assessment** on-board commercial vessel(s), with targeted observations of the factors that affect mortality.	**Personnel:** Trained observers & fishers **Specialist equipment:** None **Time frame:** hours to days for field trials
2. To estimate discard survival potential that is representative of the management unit	**Vitality assessments** on-board commercial vessels during representative range of conditions	**Personnel:** Trained observers & fishers **Specialist equipment:** None **Time frame:** hours to days for field trials
3. To estimate discard survival rate, excluding predation, for particular conditions	**Captive observation** of individuals under particular conditions	**Personnel:** Experienced researchers & fishers **Specialist equipment:** Containment facilities (e.g. aquaria & sea-cages) **Time frame:** days to weeks for monitoring period
4. To estimate discard survival rate, excluding predation, representative of the management unit	**Vitality assessments** on-board commercial vessel(s) during a representative range of conditions combined with **captive observation** of individuals representing the various vitality levels to generate an overall weighted-mean survival estimate	**Personnel:** Trained observers, Experienced researchers & fishers. **Specialist equipment:** Containment facilities **Time frame:** days to weeks for monitoring period
5. To estimate discard survival rate, including predation effects, for particular conditions	**Tagging/biotelemetry** on-board commercial vessel(s) under particular conditions	**Personnel:** Experienced researchers & fishers. **Specialist equipment:** Tags **Time frame:** days to months/years for monitoring
6. To estimate discard survival rate, including predation effects, representative of the management unit	Option 1: **Vitality assessment** on-board commercial vessel(s) during representative range of conditions combined with **tagging/biotelemetry** of individuals representing the various vitality levels on-board commercial vessel(s) to generate an indirect survival estimate	**Personnel:** Trained observers, Experienced researchers & fishers. **Specialist equipment:** Tags **Time frame:** days - months/years for monitoring
	Option 2: **Vitality assessment** on-board commercial vessel(s) during representative range of conditions combined with **captive observation** (to estimate short term mortality) and **tagging/biotelemetry** (to estimate conditional long-term mortality) of individuals representing the various vitality levels on-board commercial vessel(s) to generate an indirect survival estimate	**Personnel:** Trained observers, Experienced researchers & fishers. **Specialist equipment:** Tags, Containment facilities (e.g. aquaria & sea-cages) **Time frame:** days to months/years for monitoring

3.3 Survival assessment method

The principle method used to conduct the survival assessments was the same for each case study. This sections describes the method applied to all case studies. There is more detail on the methods used in the recent report from ICES WKMEDS (ICES 2014). Owing to the characteristics of the fisheries, the vessels and the locations, there were operational differences between the case studies which are detailed in the following sections. All field studies were conducted on-board commercial fishing vessels performing representative fishing operations so that the fish were exposed to the normal stressors and combination of stressors associated with the capture and discarding process.

The participation of fishing vessels for this work was sought through an open tendering process in accordance with government procurement procedures, with the opportunity advertised in a national industry publication (Fishing News). One vessel was selected based on predefined evaluation criteria from the applicants for each case study. All four vessels were paid a daily rate for each day of fishing from which survival data were generated.

The approach selected was to use vitality assessments during a representative range of conditions combined with the captive observation of individuals with a different vitality levels. The proportions surviving at each vitality level were applied to the proportions of fish at each vitality level in all observed fishing trips to generate an overall weighted mean survival estimate. This was supplemented with estimates of avian predation where possible to provide an estimated discard survival rate, excluding marine predation, which is representative of the fishery.

3.3.1 Developing the vitality assessment protocols

The health or vitality of fish was assessed using two methods; a semi-quantitative assessment of the vigour of the individual fish and a semi-quantitative reflex and injury scoring method. The vigour assessment was based on four ordinal classes that are defined, at one extreme characterising very lively and responsive fish (1, excellent) and at the other extreme unresponsive (4, dead) individuals (Table 3). This was adapted from several previous studies, e.g. Benoit et al. (2010).

Table 3: Description of the categories used to score the pre-discarding vitality of individual fish for the semi-quantitative activity method (from Benoît, et al., 2010).

Vitality	Code	Description
'Excellent'	1	Vigorous body movement; no or minor [a] external injuries only
'Good'/fair	2	Weak body movement; responds to touching/prodding; minor [a] external injuries
'Poor'	3	No body movement but fish can move operculum ; minor [a] or major [b] external injuries
'Moribund'	4	No body or operculum movements (no response to touching or prodding)

[a] Minor injuries were defined as 'minor bleeding, or minor tear of mouthparts or operculum (≤10% of the diameter), or moderate loss of scales (i.e. bare patch)'.

[b] Major injuries were defined as 'major bleeding, or major tear of mouthparts or operculum, or everted stomach, or bloated swim bladder'.

A protocol for the vitality reflex and injury assessment was developed from the outputs of the ICES WKMEDS 2014 report and from working directly with fish of the selected species in the Cefas laboratory. A list of identified reflexes from the literature (Davis 2010, ICES 2014) were tested with aquarium kept (unstressed) plaice. A series of behavioural reflex tests was identified that consistently produced unimpaired responses in both free swimming and restrained fish, and could be scored rapidly in a replicable manner (Table 4). In November 2014 at the second ICES WKMEDS meeting, the opportunity was taken to "harmonize" the methods of a number of European survival studies in an attempt to ensure comparability and maximize the collective science from them. As part of this process the most useful reflexes for same species (*Pleuronectes platessa*) were identified and it was agreed that all studies would include mostly the same reflexes. In the end all studies had observations on four reflexes including the righting (orientation) reflex with either tail grab or startle, or either the body flex or the startle reflex (more details in (ICES 2014).

Table 4: Vitality reflex and injury assessment protocol developed for plaice (*Pleuronectes platessa*) and applied to all case studies.

Name	**Stimulus action**	**Reflex response**
Startle touch	Fish is underwater and hand approaches to touch fish	Actively moves away before or at first touch
Tail grab	Fish is held gently by its tail and held between two fingers	Actively struggles free and swims away within 5 seconds
Orientation/Righting	Fish is held on the palm of two hands on its back at the surface of the water and then released.	Actively righting itself underwater within 5 seconds
Body flex	Fish is held outside the water on the palm of a hand with its belly facing up	Actively trying to move head and tail towards each other within 5 seconds
Operculum	The operculum of the fish is gently opened with a blunt object.	Ability to tightly close its operculum after being opened within 5 seconds
Name	**Injury description**	
Bulging Eyes	Eyes distended outwards abnormally from head	
Corneal gas bubbles	Air bubbles present in eye or membrane covering eye.	
Subcutaneous gas bubbles	Air bubbles under tissue (fins, body surface).	
Prolapsed Cloaca	Intestine protruding out of anus	
Fin fraying	Fins damaged, with slight bleeding	
Wounding	Nicks or shallow cuts on body	
Deep wounding	Obvious deep cuts or gashes on body	
Bleeding	Obvious bleeding from any location	
Mucus loss	Obvious area of mucus loss	
Scale loss	Obvious area of scale loss	
Abrasion	Haemorrhaging red area from abrasion	
Predation by 'lice' or another e.g. seal, crabs etc	Predation event observed with lice actively present or notable predation damage (e.g. area of fish body eaten, bite mark).	
Internal organs exposed	Internal organs exposed with wounds	

A reflex action was scored as unimpaired (0) when it was strong or easily observed, or impaired (1) when it was not present or if there was doubt about its presence. An injury was scored as absent (0) when it was not present or there was doubt about its presence, and present (1) when clearly observed. Therefore, when reflex and injury scores were summed, the least stressed fish had the lowest scores. Injury types, specific to the fishery of interest, were also defined and scored in the field.

To maintain consistency in the vitality scoring all scientists assessing vitality underwent training at the Cefas laboratory to become familiarised with the fish, and the levels of activity and reflexes expected of healthy (aquarium kept) fish of the selected species. The measurements and vitality assessments were carried out by the same individuals throughout each case study, and two scientists were each assigned two case studies to manage, to further mitigate against any observer effect. A step-by-step guide was also issued to all fieldworkers, describing a 12 step procedure to conduct the survival assessments to ensure consistency across case studies (Annex 3).

3.3.2 At sea data collection

All caught fish of the species selected for study were recorded by length (to the nearest cm below). When catches were high a sample of fish were measured and raised to the total catch. The catches of all other species were recorded by weight or volume so that the full catch composition from each haul could be quantified.

Positional data (lat/long; depth) and environmental information (air temperature, sea surface temperature, wind speed, sea state and light level) were recorded for all hauls. Light levels were measured using a Reed Instruments' ST-1301 digital light meter, placed at deck level. The specification of the fishing gear used in for each haul was recorded along with the times the fishing gear was shot and hauled. The times that the sorting process started and finished were also recorded.

The catch was sorted by the crew as per normal commercial practice. Fish were selected for vitality assessments and for holding for captive observation at the point the fish would normally be discarded. Fish were assessed, using the vigour assessment score, to have excellent, good, poor moribund and dead health states and were scored by the presence or absence of specific reflexes and injuries.

After the vitality assessments, some fish were selected for retention in on-board tanks. The selection of fish for the on board tanks was based on the need to identify each individual throughout the experiment; only fish of different lengths were put together in each of the numbered on-board tanks. To enable application of the captive observation results to the larger sample of vitality assessed fish, fish were selected to ensure the full length range of the catch and the full range of assessed vigour vitalities were represented in the captive observation experiments.

In order to minimise captivity stress and to remove potential interspecies interactions, the stocking density of the on-board tanks was set at a maximum of six individuals (as supported by the control experiments, section 3.3.10). This was based on the control experiments conducted at the laboratory (see Control section 3.3.9). The tank number was recorded against the data for each individual fish (haul number; species; length; vigour category) to ensure that each fish stored in the on-board tanks was uniquely identifiable.

3.3.3 On-board tanks

In three of the four case study fisheries (Western Channel otter trawl, Eastern Channel gill net and North Sea otter trawl) the vessels took part in day fishing, landing catches daily. Therefore, fish were kept on-board for a period of less than 12 hours before being transferred to onshore holding tanks. The on-board tanks comprised of a vertical stack of six numbered grey polypropylene holding tanks secured to the deck. A constant supply of seawater was supplied to the tanks in a flow to waste circuit from the vessel's deck wash system. The flow of seawater to the tanks was adjusted to maintain a flow rate of 2-4l/min. The seawater supply entered the stack through an inlet pipe in the top tank and flowed through the vertical stack by gravity-fed drainage through interconnecting overflow pipes, exiting the through an overflow pipe in the bottom tank (Figure 1).

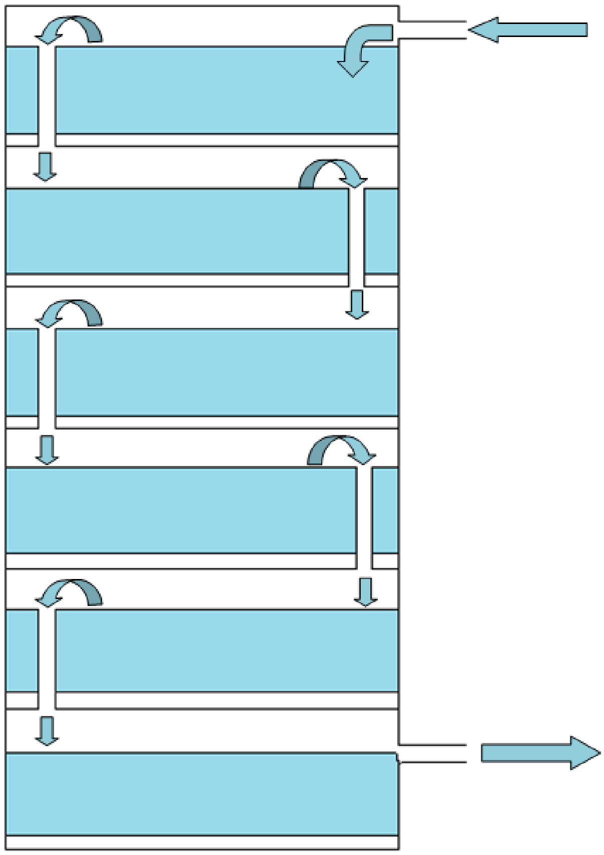


Figure 1: Diagram illustrating the design of the on board tanks with a gravity fed flow to waste seawater supply fed in series to all tanks.

In the Western Channel mixed demersal beam trawl case the vessel remained at sea for 6-8 days. The holding tank system used in this case study differed substantially and is described fully in section 3.4.3.

3.3.4 Transit from sea to shore

In three case studies (Western Channel otter trawl, Eastern Channel gill net and North Sea otter trawl) the vessels returned to port each day with selected fish in the on-board tanks. The pump supplying the stack of tanks with seawater was turned off when the vessel reached an appropriate distance from the port entrance to avoid subjecting the fish to substantial changes in salinity. As quickly as possible after docking in port, the fish in the on-board tanks were transferred to six identically numbered buckets for transportation to the onshore tanks. Fish were not mixed with individuals from other tanks. The precise process used to transfer the fish from on-board to onshore tanks for each case study is outlined in section 3.4.

Fish in the numbered buckets were transferred to the numbered onshore holding tanks by hand and the tank number was recorded. At the point of transfer any fish that died in transit were measured, identified, recorded and removed from the experiment.

3.3.5 On-shore holding tanks designed and built

Four purpose-built on-shore holding tank rigs were designed and built as part of the project. The holding tanks were designed with the following considerations (based on WKMEDS Guidance):

- There should be sufficient water exchange within the tank to ensure that oxygen levels are not depleted or that bio-waste products accumulate. Insufficient oxygen and elevated toxins can kill the experimental subjects, but even at sub-lethal levels, the stress induced by these factors is likely to affect any subsequent survival.
- The water exchange in tanks should be designed in such a manner, that inter-tank contamination is avoided with each tank receiving its own independent water supply.
- The tanks must be suitable to hold the study species, in this case plaice. The conditions in the containment facilities should correspond to biological and behavioural needs of the species. For example, it has been noted that flatfish require a non-abrasive bottom surface area to rest on, as opposed to a large tank volume.
- To minimize captivity stress, the holding conditions should attempt to simulate natural illumination levels and patterns. Many aquatic species are adapted to light intensities much lower than will be experienced at the surface. Moreover, the subject's natural light will have a periodicity and spectrum that will be specific to its natural habitat.
- The two units need to be transportable and be used continuously for periods of several weeks in remote locations outside. The pump unit should be able to utilise filtered seawater pumped from a quay or marina and be supplied from local electrical power or independently with a generator.
- The tanks need to be safe to operate by scientists and not be a hazard to the public if left unattended for long periods.

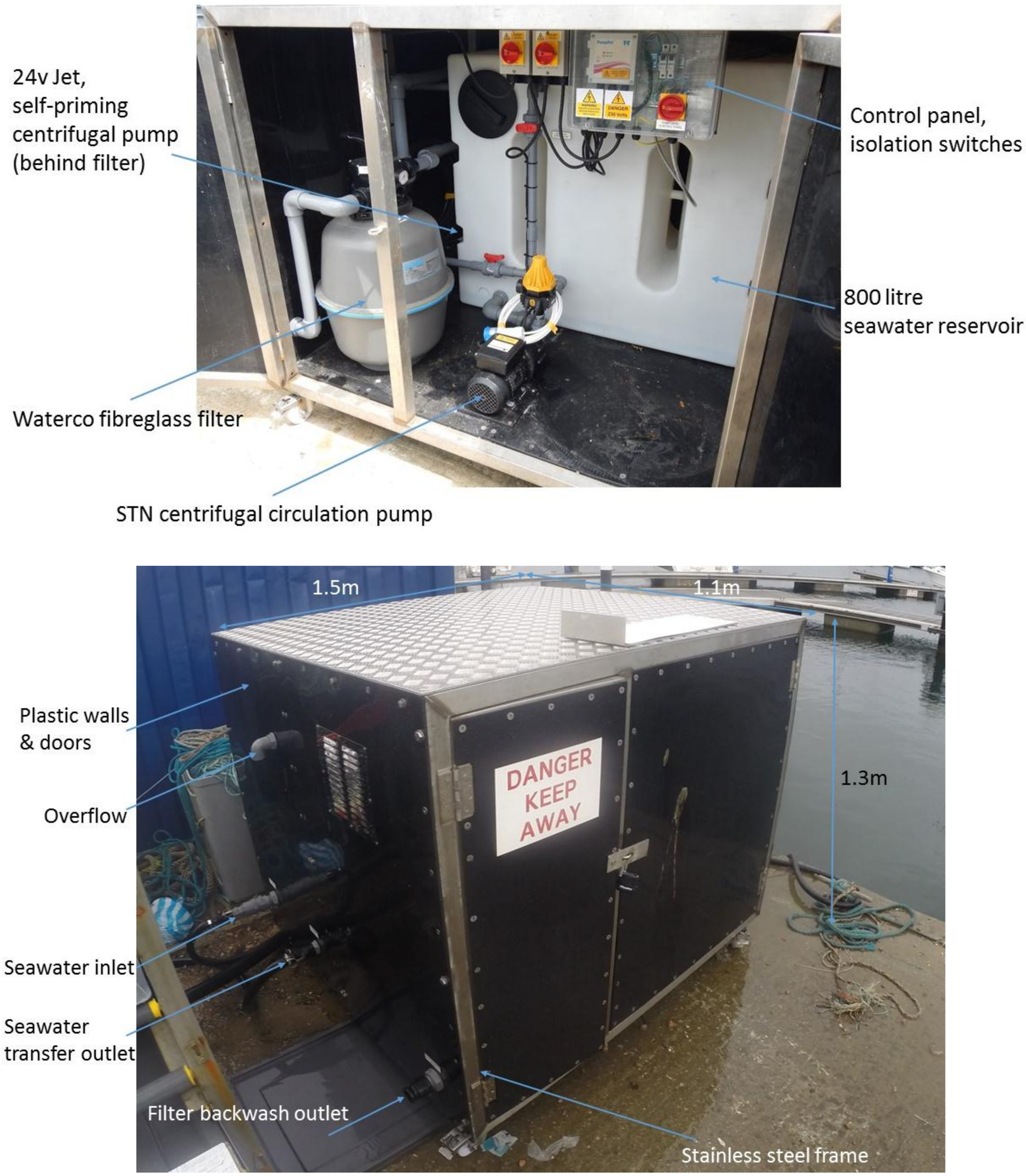
To meet these criteria the development and construction of the tanks took longer than originally anticipated and more of the project budget was spent on this phase than planned. The onshore rig was composed of two units; the holding tank unit (Figure 2) and the pump rig (Figure 3).

The pump rig constituted a stainless steel frame (dimensions are 1.5 m wide x 1.1 m deep x 1.3 m high) with plastic walls. This unit contained an 800 litre seawater reservoir supplied with water using 24v Jet, self-priming centrifugal pump via a Waterco fibreglass filter. Seawater was drawn via either a 2.5 cm or 5 cm, 10m flexible hose from source with a non-return valve at the submerged end. The water level within the reservoir tank was controlled using a water-pump float-switch fluid level controller. This was to ensure that there was a constant supply of water to the tanks from the reservoir. The seawater was transferred to the holding tank unit using a STN centrifugal circulation pump via a plastic hose. The pump rig also contained a control panel with isolation switches to power the seawater pump and the circulation pump.

The holding tank unit was composed of a stainless steel tray shelving unit 2 m wide x 1.25 m deep x 1.6 m high. The frame was divided into 3 columns with 4 shelves each. Each of the 12 shelves housed a grey plastic holding tank (80 cm x 60 cm x 20 cm high). Water was delivered to the front of the tank & drained from the rear of the tank to ensure a flow and exchange of water. Each individual tank drained via hosepipe to a sewer pipe from where all combined waste water flowed via flexible hose back to the sea. The flow of water to each of the twelve separate holding tanks was independent and could be individually controlled using integral flow meters; the flow rate was set and monitored at a constant rate of 2l/min. The tanks sat on rollers to enable the scientists to pull them forward and inspect the fish. Each tank had a dark lid which minimised light entering the tanks and prevented fresh rainwater and debris from entering the tanks. A thin layer of aquarium silica sand was placed on the bottom of each holding tank to provide a familiar substratum for the plaice and minimise captive stress.

Figure 2: On-shore aquaria, holding tank unit, front aspect above, rear aspect, below (in situ Case Study 1).

Figure 3: Onshore aquaria, pump unit, open (above) and closed (below) in situ.



3.3.6 On-shore data collection

A series of observations was performed on the fish in the onshore holding tanks. Fish were examined every 12 hours; those that responded to a tail grab were declared alive and fish that produced no response were examined for opercular movement. Fish that showed no visible response (body or opercular movement) to touching or prodding were classified as dead. Any fish assessed to be dead were removed from the tank, measured, identified and recorded. At the end of the observation period all fish were individually removed from the holding tanks, measured, identified and their vitality was assessed and recorded and the fish were terminated.

The total captive observation period varied between studies (see Results section 4 below).The onshore holding tanks held up to a maximum of 72 fish. As the on-board tanks held fewer fish it took more than one day of fishing to fill the onshore holding tanks. Only when all the fish had been removed from an onshore tank were new fish added. The onshore observation period was balanced against the number of replicates and the fishing opportunities, as well as the real-time monitoring of mortality rates.

3.3.7 Monitoring conditions in the holding tanks

The temperature, salinity and dissolved oxygen concentration were regularly monitored in both the onshore and on-board holding tanks using an Oxyguard Handy Polaris 2 dissolved oxygen meter and an Aquamarin refractometer.

3.3.8 Avian predation

To evidence avian predation of discarded fish, individuals of known species, size and vigour category scores were released back to the sea, in a manner consistent with normal discarding during commercial fishing on that vessel. These fish were then tracked visually by the observer and the presence or absence of sea birds and the subsequent fate of the fish was recorded. The following information was recorded:

- Fish observed to swim below surface
- Bird(s) interested
- Bird species
- Birds fighting or competing
- Picked up but rejected
- Eaten
- Lost sight of fish

3.3.9 Control

Including controls within a survival assessment informs on the sources of observed mortality. Where survival is less than 100%, unless a control is employed, it cannot be determined whether it was the treatment (having gone through the catch and discard process) or the method (having been contained) which caused those deaths. The lower the observed survival rate, the higher the potential for method related mortality. In cases where 100% of the treatment subjects survive, it can be concluded that there was no mortality associated with the method. Investigators will therefore want to know that test subjects can be observed without killing a substantial proportion of them (ICES 2014).

The acquisition of good controls is one of the most challenging aspects of a survival assessment. The aim should be to use specimens that are as representative of the treatment group but without having undergone the catch and discard process. The test and control subjects should be identical, or at least comparable, with respect to key biological variables that could affect mortality, e.g. length, age, physical condition, sexual maturity, feeding status, parasite/disease loading and genotype. In reality it is difficult to select two identical groups of experimental subjects (ICES 2014).

In other studies there are examples of survival estimates being adjusted or "corrected" with respect to estimates of survival from controls. This has been done by either: i) subtracting the method control mortality from the observed treatment estimate; or ii) by dividing the observed treatment survival estimate by the method control survival estimate. The rationale behind this is to remove any biases introduced by mortality associated with the method (e.g. captive observation). While in principle this appears to be a rational "correction", unfortunately this has the potential to introduce errors and biases itself. Simply subtracting one proportion from another is mathematically incorrect, because proportions are bounded by 0 and 1. This can lead to impossible "corrected" estimates of survival, i.e. negative proportions. For example if 50% of control subjects died and 40% of treatment subjects died, the subtraction method would give a corrected survival rate of -10%. More mathematically acceptable approaches can be argued, however, these approaches assume there is no interaction between the treatment and observation effects, which in reality is unlikely to be true (Pollock et al. 2007).

To date, there is no satisfactory method to adjust the treatment data using the control data and it is currently recommended that control mortality is not used to adjust the treatment survival values. The magnitude of the control mortality can only be used to indicate the suitability of the method, e.g. where control mortalities are close to zero it suggests a more valid method for accurately estimating discard survival. In the absence of controls, valid conclusions can still be reached, but these must make reference to the uncertainty in the level of method related mortality (ICES 2014).

In this project there was limited use of controls. Controls were used to investigate method induced mortality associated with the onshore captive observation holding tanks (details below). No other controls were employed for the following reasons:

1. Each of the four case studies would have required a unique control population from the fishery under investigation.
2. There is no known capture method for plaice that does not induce stress. Therefore, any control fish caught at the same time and location as the experimental subjects would have undergone capture stress with unknown associated mortality.
3. Fish caught and held for sufficient period to recuperate from a capture process would be acclimatised to holding facilitates and be subject to a different feeding regime effecting condition. Moreover, only fish surviving a capture process and the holding period could be used as controls, and these fish individuals would then be a selection of the fittest from the original population, creating bias in the control group.
4. The limited space on the small vessels meant that had control fish been taken to sea, the number of replicates for the treatment fish would have been halved, reducing the number to below what was considered a sufficient number per haul (less than 10).

5. The fisheries investigated were remote from any aquarium facilities making the holding and transport of control fish logistically difficult.
6. With current analytical methods, there is no mechanism to use control survival to adjust the treatment survival results. Death of control fish indicate only that there is some unknown level of method induced mortality. Even when all controls survive, unless control fish are genuinely representative of the treatment fish, it only indicates that the method induced mortality is likely to be small.

Given the logistical and practical constraints on the use of control fish; it was decided that the benefits of not using controls in the experiments outweighed the disadvantages. This meant that the results the discard survival rates could be interpreted only as a minimum survival level, with an unknown component of experimental mortality. However, the series of experiments using the same method enabled inferences to be made about the potential for method induced mortality when discard survival estimates varied between vitalities and between case studies.

3.3.10 A control experiment with the onshore tanks

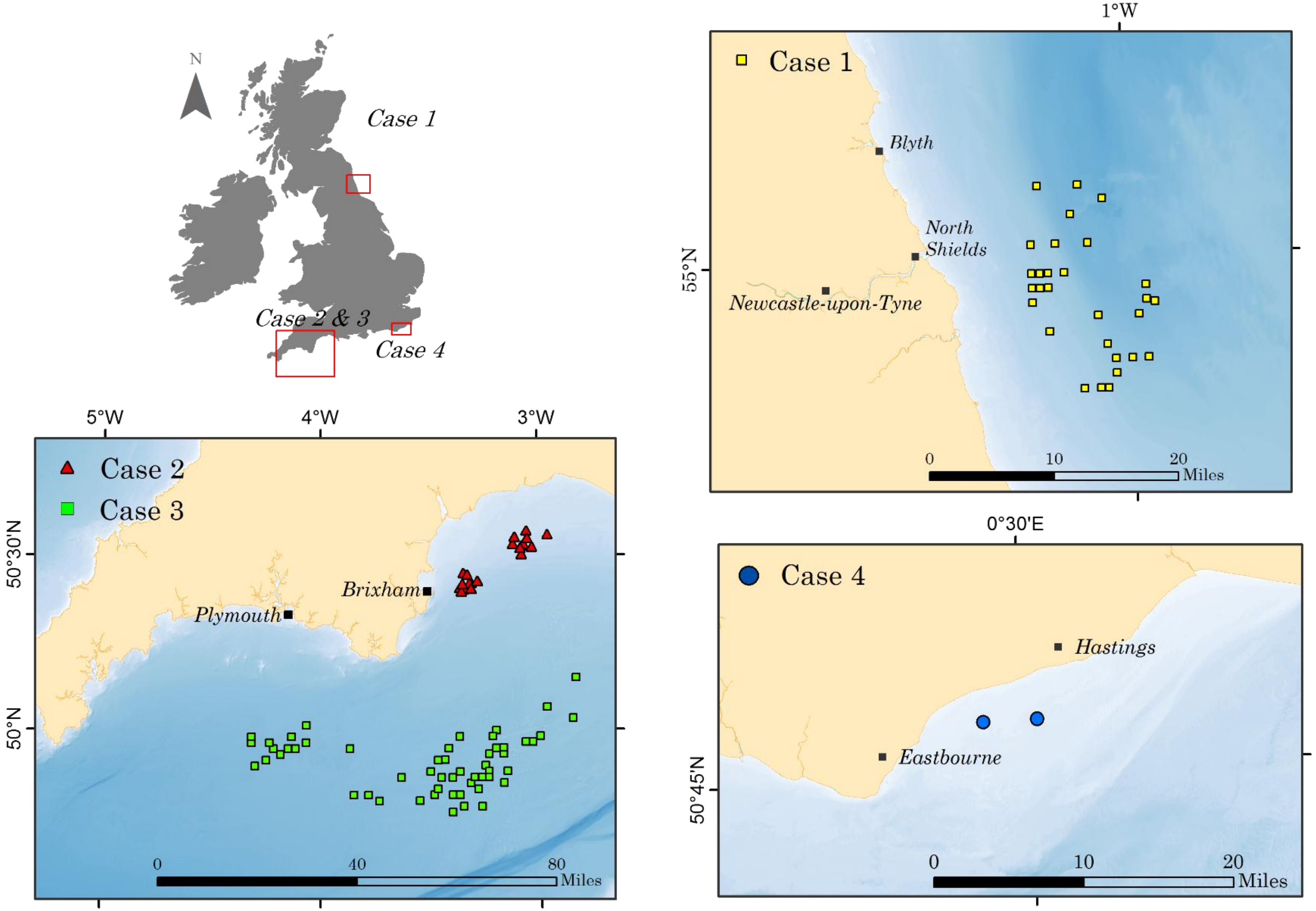
On build completion the onshore tanks were tested in a control situation. One of the four holding tank rigs was set up at the Cefas laboratory Lowestoft. The inbuilt electric pump was run and the inlet hose fed by the laboratories underground seawater tanks. The tank rig was primed and run for 48 hours. Aquarium acclimatised plaice were introduced into four of the individual holding tanks in the rigs at different stocking densities. Stocking densities of 3, 4, 5, and 6 plaice were observed. An assessment of both activity and reflex and injury were performed on each plaice before being introduced to the tanks. Water temperature and salinity were the same in the aquarium and the holding tanks. The tanks were checked for any mortalities every 24 hours, for 72 hours, along with the dissolved oxygen within the tanks. At the end of the observation period the plaice were re-assessed for activity and reflex and injury before being returned to the aquarium facilities.
There were no mortalities nor any discernible reduction in vitality of the control fish or increase in injury when plaice were held in the on-shore holding tanks at the laboratory for 72 hrs (Table 5).

Table 5: Summary results from control experiment of the onshore tanks at Cefas Laboratory.

Tank Number	Number fish in each tank	Number ‘Excellent’ fish at 0 hrs	Number ‘Excellent’ fish at 72 hrs
1	3	3	3
2	4	4	4
3	5	5	5
4	6	6	6

3.4 Specific case study methods

Figure 4: The locations of the fishing haul positions from each case study from where estimates on the survival of discarded plaice were generated (the hauling was a continuous process from the first net in case study 4 and started from only two different locations).



3.4.1 Case study 1 - North Sea mixed demersal otter trawl fishery

Vessel & port of operation

The vessel used in this trial was the MFV LUC SN36 (Figure 5) (17.8 m 69 t steel stern trawler powered by a 171 kw engine) operating from North Shields on the north-east coast of England (Figure 4).

Fishing activity of the vessel

All tows took place in the North Sea at the southern edge of the Farne Deep fishing grounds (ICES Division IVb, ICES rectangles 39E8 or 38E8), in depths of 49-90m. The vessel used a 73m footrope otter trawl, with codend mesh sizes of 99mm and 90mm, on muddy sand to target mixed demersal species but the main target catch was whiting (*Merlangius merlangus*). Catches from two or three tows, of three hours duration, were landed daily representing the normal activity of the fleet working this area (Annex 4).

Vitality assessment

When the net was brought to the surface, hauling was performed by a net drum until all fish could be seen to have descended to the cod end. This was then closed and slack net was paid off allowing the weight to be transferred to the lifting gear which raised the cod end from the water into an aluminium reception hopper. The cod end was opened and the fish dropped into the hopper where they remained until the trawl was redeployed. This process took about 10 minutes before sorting of the catch began. A door in the hopper was opened allowing a small quantity fish to move onto an aluminium sorting table. The crew sorted the catch and at the point when the plaice would normally be put in a basket for landing or discarded it was presented to the observer. All plaice were assessed for vitality and some fish were selected for the holding tanks.

The vitality assessments were conducted in a two-thirds filled, 40 litre Flexitub. The tubs were circular, made of semi-rigid yellow plastic with moulded handles and were frequently but not continuously refilled by the deck hose. Fish were selected for holding tanks on the basis of needing fish representing the full range of vitalities and different lengths, so that they could be individually identified. Immediately after the vitality assessment, each plaice was transferred to one of six 40 litre Flexitubs. Six fish were put into each of the Flexitubs. At the end of each haul, usually about 30 minutes after they had entered the reception hopper, the fish in the Flexitubs were transferred to the holding tanks (all fish from each tub were put into one on the six on board holding tanks).

On-board holding tanks

Each on-board holding tank was constructed from grey rigid plastic 80 cm by 60 cm by 20 cm holding approximately 75 litres of sea water. The water in each tank flowed into the one below when full, water being introduced to the top tank only, the bottom tank vented onto the vessel's deck (Figure 1). Seawater was supplied via the vessel's pumping system through phosphor bronze pipes leading to a plastic connection hose and valve. This allowed the flow rate to be adjusted but not metered. Tanks were filled with fish from the bottom upwards and fish remained in these tanks until the vessel approached the port.

Transporting the fish

When nearing port the fish were removed from the on-board holding tanks into large plastic bags filled with seawater, which were put inside the flexi tubs. Tanks and tubs were numbered the same so that the batches of six fish were not mixed. Immediately on docking the tubs were offloaded into a van and transported to the onshore holding tanks located 10 miles away at the RNLI Blyth boat station in the town of Blyth. Here they were offloaded and seawater introduced to each plastic bag. Initial dissolved oxygen readings were usually in excess of 80% at the port and between 40% and 50% on arrival at the onshore holding tanks. After the water was refreshed the fish were transferred in the same batches into each of the holding tanks.

Onshore holding tanks

A suitable site for the onshore holding tanks could not be found at the landing port (North Shields) due to the freshwater influence of the River Tyne. As such the onshore tanks were located adjacent to the RNLI Blyth boat station, in the town of Blyth, Northumberland, 10 miles from the port. The tanks where sited on a small pier within the river Blyth a few hundred metres from the sea. Water from the sea was pumped into the holding tanks. There was a seven meter height difference between the water source and the holding tanks which was at the threshold of the pump. This proved problematic at extreme tides with the pump unit losing prime, i.e. the pump reservoir did not have enough water to feed the pump, so the pump pulled air instead of water. When the pump lost prime the water supply to the holding tanks stopped. This issue was resolved by adding a submersible pump to draw the water up the inlet pipe, but at the start of the experiment water flow was lost on several occasions resulting in a depletion of dissolved oxygen levels in all tanks. The water supply for the onshore holding tanks was drawn from the bottom of the Blyth estuary to which the waste water from the tanks was returned. Flow rate to the individual holding tanks was set at 2 litres per minute. The inlet and outlet pipe were separated by several metres.

Monitoring of environmental conditions

During the trials, air and water temperature were measured using an electronic thermometer at the start of each haul. Temperature and dissolved oxygen of each individual onshore holding tank were monitored every 12 hours. During the time when the fish were being transported from the port to the onshore holding tanks in Blyth, approximately 25 minutes, there was no oxygen supplied to the Flexitubs holding the fish.

Figure 5: The MFV Luc (top left), onshore holding tanks (bottom left), monitoring (top right), and fish transfer into on-shore tanks (bottom left).

3.4.2 Case study 2 - Western Channel mixed demersal otter trawl fishery

Vessel & port of operation

The vessel selected for this case study was the Plymouth-based twin-rig trawler 'Guiding Light III' (BD1) that traditionally works from Brixham in January-February to exploit the Lyme Bay lemon sole and squid fishery (Figure 6). She measures 14.98m in length overall and was built of steel in 2005 to undertake 4-5 day trips. She is partly sheltered in and has a stern gantry on which net drums are mounted and cod ends are opened into stern pounds.

Brixham is one of the principal fishing ports in England (Figure 4), and is the base for the largest beam trawl fleet in UK and a fleet of up to 20 inshore trawlers, which are able to land their catches at all states of the tide.

Fishing activity of the vessel

During the winter months, the vessel conducts one-day trips that generally consist of two tows of up to 5 hours duration. The demersal fishery is mixed but the main targets are non-quota species, such as lemon sole, squid and cuttlefish. Horizontal spread and bottom contact of the trawls is more important than headline height. Long bridles (or 'sweeps') maximise the herding of fish (particularly lemon sole) on or near the sea bed into the path of the trawl.

The gear used by the 'Guiding Light III' was a twin-rig otter trawl. Each trawl had a footrope length of 22m, and cod ends were 90mm mesh made of a 4 mm diameter single braid twine. Water depths were generally shallow (26-46 m), but 275 m of trawl wire and 110 m of bridles were deployed to achieve effective herding of lemon sole to the trawl mouth. As a result, hauling usually took about 20 minutes. The trawls were wound onto net drums over the transom, and the cod ends opened into stern pounds.

After the first tow, the gear would generally be shot straight back before sorting the catch. After the second tow, the nets would be cleaned and wound onto the net drums before steaming home, and this, again, would be done before sorting the catch. On occasions, there would be a short steam between tows to shift ground or to avoid other fishing vessels. The fishing operations represented the normal activity of the fleet working this area (Annex 4).

The time interval between the cod end opening and the completion of sorting was typically 30 minutes. Standard practice is to push discarded fish through the scupper back into the sea as the catch is being sorted. Lack of space on-board generally requires this to be a continuous process, so in reality fish would be lying exposed on deck for much less than 30 minutes. The deck area is sheltered as far as the gantry, and much of the fish pound is not in direct sunlight. The 1 m high rail also reduces exposure of the catch to the drying effect of the wind.

Vitality assessment

Fish were selected for vitality assessments and captive observation experiments throughout the sorting period. Due the large quantities of plaice caught, a random subsample of plaice was taken from the estimated full catch.

Selection began as soon as sorting by the crew began. Up to 40 fish were placed in a standard 5-stone (35kg) basket and then transferred to one or two Flexitubs filled with seawater from the deck hose. At this stage, there would be 20-30 fish in a tub. Different coloured buckets were used to ensure that fish of different vitality grades were tracked during the course of handling and transfer ashore. Single fish were taken in turn and placed on a measuring board to obtain length, and the vitality assessments were conducted using another Flexitub to observe reflex responses.

It took 30-45 minutes to work through a sample of 40 or so fish. The seawater in the holding buckets was replaced once or twice during this period to minimise deterioration of condition. Air temperatures (6-10 °C) recorded on deck during the study period were similar to the temperature of seawater supplied by the deck hose (9 °C); dissolved oxygen levels in the holding buckets varied between 45 and 89%.

On-board holding tanks

A selection of fish suitable for short-term survival experiments were placed into the on-board holding tanks in preparation for transportation onshore. Fish were selected across the length range, except for fish larger than 40cm length due to lack of tank space. A full range of vitalities were selected for the tanks. These fish were then transferred to the on board captive observation tanks. Each tank was stocked with up to eight plaice.

The on-board tanks consisted of a vertical stack of five grey rigid plastic tanks with serial water flow. Seawater was supplied to the top tank of the stack, which had a lid, and overflowed into the tank below once full. The stack was located amidships against the port rail, and prevented from toppling over by means of dunnage nailed to the deck and a single lashing. A branch was taken off the port deck hose, and a valve fitted to control the flow of seawater. Water flow was continuous for the period of holding and estimated to be 3-4 l/min.

Some 20 minutes before entering Brixham harbour, the seawater supply was turned off and the deck hose disconnected. Buckets were filled with seawater in preparation for landing and transfer to the onshore tank rig. The stack of on board tanks was dismantled from the top, and fish were picked out manually and placed in the coloured tub corresponding to the particular vitality grade.

Transporting the fish on shore

Fish were landed one tub at a time using the vessels landing gear as soon as the vessel was moored up alongside the landing quay. In most cases the fish for captive observation were transported onshore first. On the occasions the study fish were landed after the main catch. However, this the delay was no more than 5 minutes. After landing the fish were carried in tubs from the landing quay to the onshore holding tanks, a walk of 400m. Carrying the tubs two at a time the transfer into the onshore tanks took approximately 15 minutes. In total, the maximum time from landing to entering the onshore holding tanks was 20 minutes.

Onshore holding tanks

The onshore holding tanks and pump rig were located together in an outside compound belonging to Brixham Yacht Club. Although the rigs were fully exposed to the elements, they were secure and access for monitoring was possible at all times. The tanks were not accessible to the general public.

Seawater was pumped from the seaward side of the fish quay. Site conditions required the intake to be 50m from the tank rig to ensure that the intake point would be fully immersed but well clear of the seabed at all states of the tide. Exposure to wind and wave action meant that the intake pipe had to be securely fastened to avoid connections and seals being damaged. Advantage was taken of a horizontal recess running 1.5 m below the top of the quay, and a vertical recess for a ladder.

A constant flow of seawater was maintained except at spring tides when it not possible for the pumps to maintain prime. An auxiliary submersible pump was fitted at the seaward end of the intake pipe to overcome this problem but, owing to the length of the intake pipe, priming could not occur before electrical safety switches were tripped which meant that on some days there were periods of up to 6 hours when water flow was interrupted. Pumps were sometimes primed by staff making routine examinations of fish being held. At all other states of the tide, a flow of 2-3 l/min was maintained to each tank.

Seawater temperature in the tanks was measured with an alcohol-in-glass thermometer and found to be the same as those measured at sea, i.e. 9 °C. Water in the tanks never rose above this temperature, but did fall as low as 4 °C on at night.

Monitoring of environmental conditions

Seawater and air temperatures at sea were measured before the first haul. Seawater temperature was obtained from the deck hose supply. Onshore, water and air temperatures were noted on each routine examination of fish.

A functioning dO_2 (dissolved oxygen) meter did not become available until the closing stages of the case study. Readings indicated that levels of dissolved oxygen in the on-board tanks did not fall below 88% saturation. Towards the end of transfer in tubs between the landing quay and the on-shore tanks levels fell to 60% but fish would have experienced this for less than 30 minutes. Seawater flow to the onshore tanks was continuous when the meter became available, and levels were the same as those recorded at sea.

Figure 6: MFV Guiding Light III (above) and catch prior to sorting in the fish pound (below).

3.4.3 Case study 3 - Western Channel mixed demersal beam trawl fishery

Vessel & port of operation

The vessel used was FV 'Admiral Grenville' (PH550) (Figure 7), a 24 m 'Euro-cutter' style beam trawler working from Plymouth undertaking week-long trips in the Western Channel. In contrast to the other case studies reported in this project, captive observation experiments for the beam trawl fishery were carried out at sea due to the standard fishing trips lasting 5-6 days.

Fishing activity of the vessel

The study consisted of two trips, 21-27 November 2014 and 8-15 January 2015, when the vessel was primarily targeting cuttlefish. Anglerfish was the next most important component of the catch. Fishing consisted of 2-hr tows and continued round the clock. The respective numbers of tows made in each trip were 57 and 64. The fishing operations represented the normal activity of the fleet working this area (Annex 4).

The gear used was 9 m beam trawls with chain-mat and a ground gear consisting of 10" rubber discs. No flip-ups were fitted to the gear on the first trip, which resulted in boulders entering the mouth of the net and working their way into the cod end on a number of tows. Cod end mesh size was 85mm and constructed of 6mm single braid twine.

Fishing took place some 12-25 miles offshore between Start Pt. and Lizard Pt, in ICES sub Division VIIe, ICES rectangles 28E7, 28E5, 28E6 and 29E7, in water depths of about 57 to 73 m (Figure 4). Hauling, emptying cod ends, and shooting back took about 15 minutes. Sorting the catch began as soon as the gear was back over the side, and generally took a further 15-25 minutes depending on catch volume.

The vessel was fitted with deck pounds (port and starboard) into which the cod ends were emptied. Seawater was pumped into each pound in turn to wash the catch onto a conveyor and to remove fine sediment. The catch was sorted by the crew as it passed along the conveyor under the whale-back, putting fish into baskets. Discard samples were taken from the conveyor before they dropped into a chute and discharged overboard.

Vitality assessment

The first objective on each trip was to catch sufficient numbers of plaice to stock the holding tanks for the captive observation experiments. To complete two 72-hr experiments, the tanks needed to be stocked within the first two hauls. The relatively small numbers of plaice being caught meant that the vitality of all fish was assessed and, on the first trip, over half of those caught on the first and second hauls were selected for the survival experiment.

During the sorting process, fish were picked from the conveyor and placed in a 150 litre tub filled with seawater normally used by the crew for holding crab and lobster. Batches of up to 25 plaice were kept in this tub for a minimum of 10 minutes while the catch was being sorted, before being picked out one at a time to be assessed. The length of each fish was measured, a vigour category given, and injuries and reflex actions recorded. Reflexes were tested by holding the fish in a separate 25 litre Flexitub of seawater. The fish were then transferred into another 25 litre tub containing seawater and carried to the on-board holding tubs located at the stern of the vessel. The process of selection, assessment, and transfer of fish to the stern took up to 45 minutes. Once the on-board tanks were filled, further assessments were made on subsequent hauls.

Onboard holding tanks

The on-board tanks used were unique to this study and consisted of eight insulated tubs arranged in two rows fore and aft of the net drum at the stern, and secured with two ratchet straps (Figure 8). Each tub measured 90 cm (L) x 70 cm (W) x 60 cm (D), holding a volume of 378 litres. Tubs were made of high density polyethylene, and had been in use for fish transport previously.

The vessel’s seawater supply was piped to an 8-branch steel manifold to give each tub a separate feed. Green plastic heliflex pipe (1.5”) from the manifold was plumbed into the drain hole of each tub, and the water inflow was directed upwards inside the tub with rigid plastic pipe. Tubs were supplied with closely fitting lids that were held in place with heavy duty rubber bands, and ensured that tubs remained full so that any free surface effect was kept to a minimum. Outflow was via a drain hole on the opposite side of the tub and a length of the same heliflex pipe. A continuous water flow to each tub was maintained throughout each trip, and estimated to be 3-4 litres/minute.

Each tub was numbered and assigned a vitality grade. Fish placed in a given tub came from the same haul and had the same vitality. In this way, it was possible to hold up to 12 fish of different lengths in each tub. Observations were carried out every 12 hours. The condition of each fish was tested by tail grab, or touching it with the rounded end of a broom handle if it was out of reach. Any dead fish were recovered with a hand net.

Monitoring of environmental conditions

The measurements of dissolved oxygen obtained on both trips were considered unreliable due to faulty equipment. However, the only period when fish may have suffered lower oxygen levels would have been in the recovery tub as the flow rates were maintained in the on-board captive observation tubs.

Figure 7: MFV Admiral Grenville (above); with beam trawl including chain mat typically used in this fishery (below).

Figure 8: Insulated tubs on-board the MFV Admiral Grenville used for the survival assessments showing detail of plumbing.

3.4.4 Case study 4 - Eastern Channel trammel net fishery

Vessel & port of operation

The vessel used in this study was the MFV Halcyon (Figure 9), a Kingfisher 33 built in 2001, with a length of 9.8 m, a width of 3.8 m, a draught of 1.8 m, powered by a 147 hp diesel engine. The vessel operated out of Sovereign Harbour, near Eastbourne, fishing the Eastern Channel (Figure 4).

In this study it was possible to investigate survival rates of both plaice and rays (thornback). Plaice are caught as a bycatch species, mostly during targeted sole fishing, while rays are caught during targeted ray fishing. Therefore, the species were investigated separately on different fishing trips during a period in which the vessel switched from the targeted sole to the ray fishery . The methods used for the two species were necessarily different and are described separately for plaice and then rays.

3.4.5 Case study 4 Plaice

Fishing activity of the vessel

The Halcyon fishes as a day boat with gill, trammel and tangle nets, targeting sole, rays and occasionally plaice but also uses pots to target cuttlefish at other times. For this study fishing took place in the Pevensey Bay area of ICES Division VIId, with a fishing day lasting about 8 hours. Shooting nets to target sole on the first day and then retrieving, emptying those nets, before shooting back on subsequent days. Normal practice is to allow the nets to soak for approximately 24 hours. However, occasionally bad weather may mean soak time extends to 48 hours.

A variety of static nets were used to target sole and plaice. The main gear used for fishing was a 0.45 mm monofilament trammel net with an inner mesh of either 12 cm or 15 cm with either a 61 cm or 64 cm wall. The nets were 25 meshes deep. Each fleet was made of 6 nets, which were 64 metres long each, with a hanging ratio of 0.5. Tangle nets were also used. The tangle net was a 4Z twisted nylon with a mesh size of 92 mm. The nets were 15 meshes deep. Each fleet was made of 6 nets, which were 92 metres long each with a hanging ratio of 0.3.

Vitality assessment

Plaice were removed from the net by the crew during hauling, or just after hauling had finished. No plaice remained in the net as it was flaked back. The crew put the plaice in a basket from which the observer removed them for vitality assessment.

All plaice were measured and vitality was assessed using a partially filled 40 litre grey plastic Flexitub, seawater provided via the rubber deck hose fed by the stainless steel pipework. Immediately after assessment the plaice were transferred temporarily to one of six partially filled 40 litre grey plastic Flexitub. The time the plaice were in these tubs was dependent upon the catch. However, the tubs reached their stocking density of six fish per tub either during the first or second haul, being in the container for a maximum of 50 minutes. The water in the tubs was frequently refreshed between hauls using the deck hose. Once the six Flexitubs were full, fishing was paused while the fish were transferred to the on-board holding tanks.

On-board holding tanks

The on-board tanks were consisted of a vertical stack of six grey rigid plastic tanks (80 cm x 60 cm x 20 cm) with serial water flow (Figure 9). Seawater was supplied to the top tank of the stack, which had a lid, and overflowed into the tank below. The vessels deck hose was attached to the top tank via a ‘T’ flow through valve. This allowed water to be diverted to the tanks while still providing some deck wash. The amount of water entering the tanks was controlled however the actual flow was not metered. Waste water flowed from an exit hole in the bottom tank directly on the deck of the vessel.

Figure 9: Case study 4 MFV Halcyon (below), on-board tanks (above).

Transporting the fish

At Eastbourne it was possible to 'land' the captive plaice directly to the onshore holding tanks. The fishing vessel Halcyon tied up alongside the onshore holding tanks. The fish were transferred from an on-board holding tank to a tub, and were walked to the onshore holding tanks and placed inside a vacant tank. The whole process taking less than 5 minutes per tank.

Onshore holding tanks

The onshore holding tanks were on a small concrete quay adjacent to Eastbourne's Northern Sovereign Harbour. Electricity was supplied via armoured extension lead by the Eastbourne Sovereign Harbour Yacht Club. The harbour water is fully marine, with the harbour separated from the sea via a lock gate system. The harbour lock gate system meant there was minimal variability in water depth (i.e. tidal change was not a factor). The water supply for the onshore holding tanks was drawn from the bottom of the harbour to which the waste water from the tanks was returned. Flow rate to the individual holding tanks was set at 2 litres per minute. The inlet and outlet pipe were separated by several metres.

Monitoring of environmental conditions

The measurements of dissolved oxygen obtained at sea were considered unreliable due to faulty equipment. The only period when fish may have experienced low oxygen levels was while in the flexitubs prior to being transferred to the on-board holding tanks. During the time when the fish were being transported from the vessel to the onshore holding tanks there was no oxygen or water supplied to the baskets transporting the fish, however this process took less than 2 minutes. Temperature and dissolved oxygen of each individual onshore holding tank were monitored every 12 hours. Temperature and dissolved oxygen of each individual onshore holding tank were monitored every 12 hours.

3.4.6 Case study 4 Skates and rays

In this case study, opportunity was taken to conduct a limited assessment of the survival of rays, in particular thornback rays, (*Raja clavata*), which are the most commonly caught ray species in this fishery. A different method compared with that employed for plaice was used to assess the survivability of rays, making use of electronic data tags. Owing to their larger size, keeping rays in holding tanks is less practical but electronic tags are a viable method. Electronic archival tags or Data Storage Tags (DSTs) record fine-scale behaviour movements (swimming movements, depth & temperature measurements at 1 to 10 second intervals). In recent Cefas studies, buoyant Cefas G5 DSTs have shown to record post-discard mortality. For example, a spurdog (*Squalus acanthias*) survived for 10 days after being tagged and released, before coming to a complete rest on the seabed, where it appeared to die (Bendall et al. 2012). Only thornback rays were tagged because these were the most commonly caught species in this fishery and with the limited number of DTSs, had we tagged different species, it was considered the sample sizes would be small, and therefore statistically less robust.

For this study, buoyant Cefas G5 DSTs that are brightly coloured and carry a reward label and return address, were used to tag thornback ray (*Raja clavata*). Unlike captive observation studies, tagging discards with DSTs can quantify the increased levels of predation and long-term stress/injury induced mortality that may be associated with the 'live' discarding process. Physical recovery of the tag is necessary in order to download and retrieve archived data from the tag and survival estimates can only be generated when sufficient numbers of tags have been returned. Reductions in the Skate and Ray quota have reduced the fishing activities which target rays, and therefore the opportunities to retrieve tags from tagged and released rays. For this reason a mixture of 30'fixed' (Figure 10a) and 30'pop-off' (Figure 10b) buoyant Cefas G5 DSTs were used.

(a) (b)

Figure 10: Thornback ray tagged with (a) a 'fixed' buoyant Cefas G5 DST and (b) a 'pop-off' buoyant Cefas G5 DST.

Fixed DSTs are recovered either when the tagged fish is re-caught or the fish dies and the body decomposes releasing the DST to float to the surface to be washed ashore. Pop off DSTs are recovered after a designated period of time, when the tag releases itself from the specimen and drifts ashore where it is recovered by a member of the public. Based upon previous pop-off tagging studies on spurdog within the Celtic Sea (Righton et al. 2012) approximately 30% of the tags are expected to be recovered within 12 months of deployment. Once recovered, they will provide a qualitative assessment of post-discard behaviour and a quantitative assessment of post-release survival.

Fishing operation

The MFV Halcyon shot away trammel nets on the 6th, 7th and 9th March 2015 in Pevensey Bay, ICES Division VIId (Eastern Channel). On the 6th and 7th March 2015, four fleets of trammel nets were shot away on each day, soaked for approximately 72 hours, and hauled on the 9th and 10th March respectively. On the 9th March 2015, three fleets of trammel nets were shot away, soaked for 48 hours, and hauled on the 11th March 2015.

The trammel nets had an inner square mesh size of 30 cm made of 0.6 mm thick monofilament, with outer square mesh walls of 81 cm made of 0.8mm monofilament, with a hanging ratio of 0.5. The nets were 3/ 11 meshes deep (inner/ outer wall), with each net at 90 m long, with a fleet comprising of 5 nets. Each end of the fleet was fixed on the ground with an anchor and marked at the surface by a dan flag and buff.

Each fishing day lasted approximately 6 hours. Each fleet of trammel nets was hauled quickly aboard into a net bin. If the catch was few in number and therefore easily handled, it was immediately cleared from the net, where it was retained for the market or discarded (which in this case meant being kept aboard in water filled tanks – see 'Tagging' in this section. If the catch was large in number, therefore difficult to handle and process, then the catch remained in the net, hung over the net bin until the fleet was aboard, then cleared. The fleet was then flaked (fed) back into a net bin, before the next fleet was hauled.

Vitality assessment

The on-deck vitality of each tagged thornback ray was assessed using a reflex and injury scoring method (Table 6). Reflex action and injury was scored as present or absent against a predefined list for skates and rays that had been developed at the Cefas laboratory. Because different species react differently to stimuli, a protocol that is specific to skate was developed. A reflex impairment and injury were scored as present (1) when clearly observed (0) when it was not present, or there was doubt of its presence.

In addition, a vigour assessment was made of each thornback ray, at the point of discard. The vigour assessment was based on four defined vitality classes from 'Excellent' through to 'Dead' using the same protocol as for plaice.

Table 6: Vitality reflex and injury assessment developed for skates and rays.

Name	Stimulus action	Reflex response
Body flex	The skate/ ray is held by the anterior end of the disc, one hand either side of the mid line.	Actively moving its ‘wings’.
Spiracle closure	The spiracles are observed	The spiracles are actively opened and closed.
Startle touch	The skate/ ray is gently tapped on the head, behind the eyes and spiracles, with a firm object.	Actively closes and retracts its eyes
Name	Injury description	
Bleeding	Obvious bleeding from any location	
Abrasion	Haemorrhaging red area from abrasion	
Wounding	Nicks or shallow cuts on body	
Net marks	Any type of clear visible net marks on the body	

Tagging

Every effort was made not to alter typical commercial fishing practice so that the tagged thornback rays experienced as typical capture and handling event aboard as possible and the trial was therefore representative of the fishery. The thornback rays were immediately removed from the net by the crew during hauling (Figure 11a) and passed to the Cefas scientists aboard. Before tagging each individual was measured (total length and wing width), sexed and a vitality assessment (reflex impairment and injury) made (see above and Figure 11b).

(a) (b)

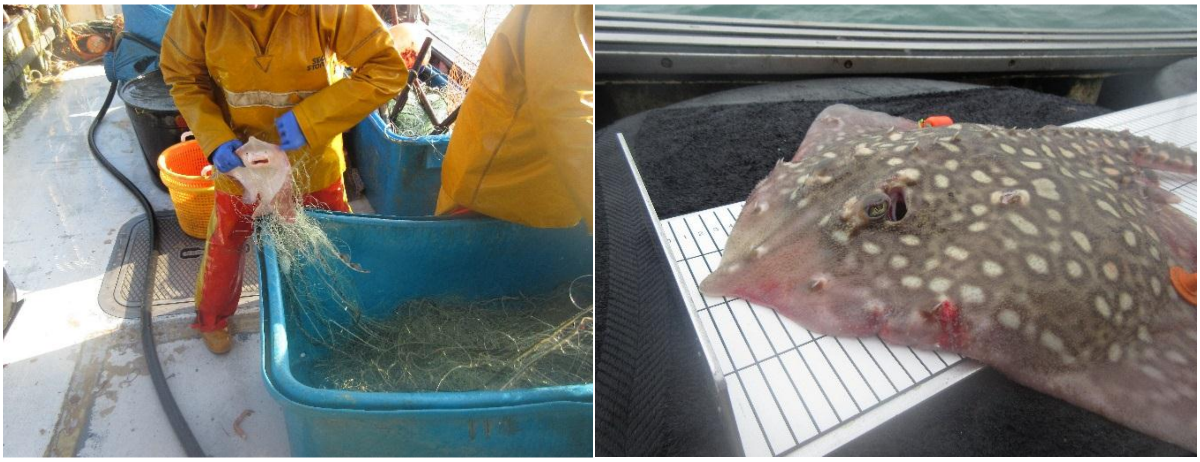


Figure 11: A thornback ray (a) being removed from a trammel net once hauled aboard and (b) showing abrasions and net marks that would have scored as present in the vitality reflex and injury assessment.

Each buoyant Cefas G5 DST was attached to either a Petersen disc wire or a button sure-tag and attached externally to a thornback ray through the wing. An ID marker tag was attached through the opposite wing. For the purpose of the study each Cefas G5 DST (www.cefastechnology.co.uk) was programmed to record depth at one minute intervals and temperature at 10 minute intervals. Thirty of the 60 Cefas G5 tags were attached with a pop-off unit; of which 15 were programmed to detach from their host after 90 days (three month period), and 15 after 365 days (one annual seasonal cycle). Physical recovery is required in order to retrieve the archived information. Tags were programmed for 90 day (3 month period) pop-off to ensure a faster return rate to begin to quantify survival, while tags programmed for 365 day (one year) pop-off provide longer term discard survival as well as one full annual cycle of spatial movements after discard. Physical tag recovery can be achieved through the fishery on capture of a tagged thornback ray or, if the tag is shed from the host either naturally or through activation of a timed pop-off mechanism, tags have the chance of drifting to shore to be recovered from a beach.

A vitality assessment using reflex and injury impairments were observed immediately prior to discarding, with an overall assessment of vigour made at the point of discard at the sea surface. The vigour assessment was based on four defined vitality classes from 'Excellent' through to 'Dead' using the same protocol as for plaice.

Whilst each thornback ray was tagged and assessed for vitality the typical commercial fishing practice continued alongside. Immediately after releasing a tagged thornback ray, another was selected at random from the ongoing hauling operation. No measures were taken to lessen the stress, nor improve the individual's welfare aboard above typical fishing practices.

Less than 20% of the thornback ray caught (60 individuals) were tagged. This was due to the time taken to tag against the speed at which the catch was brought aboard. In order to maximise the biological and catch data collected, rays that were not tagged, which would typically have been discarded were retained aboard, in water filled tanks so not to increase fishing mortality. This allowed for these additional rays to be counted, measured, sexed and a vigour assessment made at the end of the fishing operation, once the process of tagging had been completed. The rays could remain in the tanks for some 30 minutes, potentially recovering from the capture event. For this reason the vigour assessment for these rays should not be compared directly with that made immediately for the tagged thornback ray.

Reward scheme

In order to encourage the recovery of the pop off DSTs, a reward scheme was established for UK and EU commercial fisheries to raise the profile of Cefas' discard survival tagging work which included detailing how to return tags back to the Cefas Laboratory. Reward posters were distributed widely to the local offices of the Marine Management Organization (MMO) and Inshore Fisheries and Conservation Authorities (IFCAs). Tag-return information can be supplied via the tag-reporting hotline, by post, or on the internet (see www.cefas.co.uk/fishtagreturns).

Tag returns

To date, one tag has been returned. For all tags returned as much information on the recapture was recorded e.g. including the receiving port, tag number, vessel name and nationality, gear type, date, capture position (latitude and longitude), and any other relevant information. When all the recapture information has been processed a reward of €100 is paid along with any postage costs with entry into the Cefas Annual Tag Lottery prize draw of £1000. A project summary is sent to the returnee with a letter of thanks.

3.5 Analytical methods

As with the fieldwork methods, at the commencement of the project there were no accepted analytical methods to apply to survival assessments. The statistical methods have been developed from previous studies and within the work of the ICES WKMEDS.

3.5.1 Summary data from each case study

Descriptive and summary data are presented for all case studies, including the period of study, the number of fishing days, the mean length of fish assessed for vitality the mean length of fish under captive observation, the length of observation time and the proportion of fish assessed at each vigour assessed vitality. The summary table also summarises the results from the captive observation trials and the survival estimates derived from the different stages of the analysis.

The proportion of fish in the total catch at each vitality from the vigour assessment and details of the reflex and injury assessment are presented.

3.5.2 Survival methods

The case studies provide the length of time that each fish was observed for following capture and the state of the fish (dead or alive) when the final observation for that fish was made. This type of data is called longitudinal data and is analysed using survival methods. These methods provide estimates of the survivor function, *S(t)*,which is the probability of surviving for longer than time *t*.

Survival methods account for a common property of survival data known as censoring, with data for fish that were still alive at their final observation time referred to as right censored. This means, we know that a fish survived until at least its final observation time but not how long it would have survived if the observation period was extended, i.e. the actual survival time is censored (not available). For example, a fish alive at a final observation time of 120 hours will have its survival time recorded as at least 120 hours.

3.5.3 Kaplan-Meier plots of survival probability against time

The Kaplan-Meier (K-M) estimator generates the survivor function against time. For example, Figure 12a in the Results section 4 shows that for Case Study 1, the fish in the 'Excellent' category (black line) had a probability of survival of 1 at 0 hours, and the probability decreases with time. Giving two example values, the estimated probability of surviving at least 30 hours was 0.96, the estimated probability of surviving at least 65 hours was 0.86 and so on. The K-M estimator is the standard method of summarizing survival data against time and is used because it accounts for any censored observations. K-M estimates with 95% confidence intervals were calculated for each vigour category, using the R function *survfit*. Confidence intervals were computed on the log-log scale as in Venables and Ripley (2002, page 357).

The K-M method has the advantage of making few assumptions about the data, although it cannot be used to predict outside the observed experimental period. K-M estimates can be variable towards the end of the experimental period when few fish remain observed. Therefore, case-study specific "plus-group" times were defined based on when few observations remained near to the end of the experimental period and times greater than these assigned the plus-group time when calculating the K-M estimates. These times were: Case study 1: 104.82 and 114.33 hrs for nominal observation periods of 108 and 120 hrs respectively; Case study 2: 133.5 hrs; Case study 3: 72 hrs; Case study 4:

no plus- group, maximum observation time 342 hrs. (These differ as the length of the observed experimental period was different in each case study).

For each case study, the survivor curves from each vigour category were then compared using the log-rank test (R function *survdiff*). First, an overall comparison of all curves was completed, followed by comparisons between each pair of vigour categories.

3.5.4 Survival models

For discard survivability studies, a plausible description of the results is that the proportion of fish surviving will gradually decrease and then flatten off, with a proportion of fish surviving the capture, handling and release process. Modelling this process and predicting the long-term survival probability requires an extension of standard survival analysis models, as these assume that the discard-related mortality must extend until survival is zero i.e. standard models fit a curve that extends until all the fish are dead rather than having a plateau related to long-term survival. The extended models required are referred to as mixture cure models or mixture-distribution models.

Two such models were fitted to the case study results: (1) a semi-parametric proportional hazards mixture cure model (PHMC) as implemented in R package *smcure* (Cai et al. 2012); (2) a parametric mixture distribution model (Benoit et al. 2012), fitted by maximizing the likelihood function for the model within the R optimization function *optim*. Fitting more than one model using different implementations is valuable to provide evidence on the sensitivity of the estimates to the model properties. Where different models' results are similar it provides increased confidence in the predictions made from the data.

Model (1) fits a common baseline survivor curve across all vigour categories, based on the observed pattern of mortalities, and then scales the risk to reflect the survival within each vigour category. Model (2) assumes that the survival pattern can be modelled by the Weibull statistical distribution, this is a relatively flexible distribution that can represent a range of survival functions commonly encountered in ecological data. Here, we fitted Model (2) to each vigour category separately to remove any assumption of similarities in their survivor curves.

The estimate of survival probability from each model was extracted to apply to the vitality data.

3.5.5 Applying survival rates to vitality data

For each of the case studies, the survival rate for each of the categories in the vigour assessment ('Excellent', 'Good', 'Poor', 'Moribund') were applied to the proportion of fish assessed with that category from all sampled catches. Data were raised where appropriate to give the proportions at each vigour category pooled across all sampled trips.

Summing across the proportions of catch at each vigour category multiplied by the survival rate for that category gave an overall estimated survival rate of the observed trips. Three survival rates are used, one in the context of the captive observation period, the other two using the predicted final survival rates for each of the vitality categories from the extension models.

3.5.6 Identifying factors that influence survival

This was the first dataset using an integrated survival assessment approach that has become available. It was clear that there is a lot of potential to answer many different questions with these data. It was decided that the analyses conducted in this project would focus on developing tools and generating outputs from analysis of the association of impaired reflexes and injuries with survival chances to determine where particular impairments and injury types are more closely linked with fatalities. Secondly, analyses were applied to explore effects of the technical and environmental conditions from each haul on the levels of survival.

3.5.7 The effect of reflex impairment and injury on survival

For each case study a binomial Generalized Linear Model (GLM) was used to examine which injuries and reflexes would significantly affect the survivability of the fish. The hypothesis to be tested was that the number of dead fish was associated with an impaired reflex or injury. For each case study we separately fit a binomial GLM to the reflex impairment, injury score and survival data. Additional resources would enable an analysis across all case studies. The models were estimated using the software R 3.1.0.

3.5.8 Fishing haul effects on survival

As an example, the potential links between the vigour assessment in the sampled catch and variables related to each fishing haul were examined during Case study 1 - plaice from the North Sea mixed demersal Otter trawl fishery. This study was selected as a range of variables covering the sea conditions, environmental variables, catch processing and catch composition were available to analyse within the time constraints of the project. Vigour assessment in the sampled catch was used as the response (rather than survival at the end of on-shore observation), as links between vigour assessment and survival had been observed, using the sampled catch provided a greater sample size and allowed the focus to be on factors related to the hauls.

The number and proportion of fish in each vigour assessment category was calculated for each haul, and then linked to the haul data using a unique combination of haul date and haul number. As a visual analysis, the vigour category proportions were plotted against each potential influencing variable. Where appropriate, smooth curves (loess smoother with span of 0.75) were added to the plots to aid interpretation.

To assess each variable's ability to describe patterns in vigour category proportions, multinomial statistical models were fitted to the counts in each category using function *multinom* in R package MASS (Venables et al. 2002). This approach was used as it allows the proportions in a variable with more than two categories to be related to either continuous or categorical variables. A separate model was fitted for each potential influencing variable, with categorical variables as factors and continuous variables as linear terms within each vigour category. A model's fit was measured using the likelihood ratio statistic from comparing the model to a null model which had the same vigour category probabilities for every haul.

There is considerable scope to develop the analytical methods required for survivability studies. Further useful developments would include generating confidence intervals for the modelled survival estimates and improving the user-friendliness of the modelling functions and associated plotting routines. Similarly, the data collected provides a valuable resource to extend the analysis of factors influencing discard survival. Within the study there was resource to analyse the haul effects only for case study one. There would be substantial value in extending these analyses to the full range of case studies.

4 Results

4.1 Kaplan-Meier estimates of survival probability

The Kaplan-Meier (K-M) plots show clear separation between the vitality categories (‘Excellent’, ‘Good’, ‘Poor’, ‘Moribund’), with the amount of survival in the expected order i.e. the highest survival with ‘Excellent’ vitality and survival decreasing with vigour (Table 7). This finding is supported by the results of the log-rank tests, which compared the survivor curves for the different vitalities within each case study (Figure 12a-d). In each case study, the survivor curves differed significantly between the vitality categories. There were differences between all pairs of categories except for ‘Good’ and ‘Poor’ in Case Study 1, and ‘Excellent’ and ‘Good’ in Case Studies 3 and 4. These results demonstrate that the vitality assessment effectively predicted the chances of survival.

4.1.1 Case study 1 North Sea otter trawl

A total of 1462 plaice were caught and assessed for vitality at the point the fish would be discarded (Table 7).). Observers assessed 50% of the plaice (719) as having ‘Excellent’ vitality, 25% (359) as having ‘Good’ vitality, 14% (197) as being ‘Poor’ and 12% (183) assessed as moribund (Table 7). No plaice were categorised as Dead (Figure 14a). The sample of 292 plaice retained for captive observation, had a length distribution comparable with the total catch (19 cm to 44 cm; mean length 27 cm) (Figure 13a

Fish were held in captivity for 105-120 hrs; survival probability was 63.5% for ‘Excellent’ fish, 25.8% for ‘Good’ fish and 30.0% for ‘Poor’ fish. No fish assessed as ‘Moribund’ survived. When weighted against the proportion of fish in each vigour category in the total catch the estimated survival at the end of the observation period was 42.0% (the 95% confidence intervals (CI) were 33.7%-50.1%) (Table 9). Forecast survival probability beyond the observation period was 18.8-20% based on the two extension models, (Table 9). This was lower because the rate of mortality had not reached an asymptote or slowed substantially within the observation time (Figure 12a).

4.1.2 Case study 2 Western Channel otter trawl

A total of 5379 plaice were caught (raised from a sample of 1040 assessed plaice) (Table 7). The vitality assessment data raised to total catch showed that 38% of the plaice had ‘Excellent’ vitality, 34% were assessed as having ‘Good’ vitality, 18% as ‘Poor’, 8% as ‘Moribund’ and 1% were assessed as Dead (Figure 8b). The 348 plaice retained for captive observation had a length profile comparable to the total catch (19 cm to 60 cm mean length 26.3 cm)(Figure 7b). Some of the largest plaice caught were not retained for captive observation.

Fish were held in captivity for 66-133 h; survival probability was 90.2% for ‘Excellent’ fish, 73.9% for ‘Good’ fish, 36.6% for ‘Poor’ fish and 5% of fish survived that were assessed as ‘Moribund’. When weighted to the proportion of fish in each vigour category in the total catch, the estimated survival in the observation period was 64.4% (CI 55.4-71.8%) (Table 8).As the rate of mortality had reduced within the observation time; the forecast survival estimate was comparable to that at the end of the observation period, 47.1-62.8% (Table 9).

4.1.3 Case study 3 Western Channel beam trawl

A total of 826 plaice were caught and assessed for vitality at the point the fish would have been discarded (Table 7). Observers rated 15% of plaice as having ‘Excellent’ vitality; 38% were categorised as ‘Good’; 42% were rated as ‘Poor’; 4% rated as ‘Moribund’ and 61% were assessed to be Dead (Figure 14c). The sample of 275 plaice retained for captive observation had a length distribution comparable to the total catch (22 cm to 55 cm; mean length of 33.2 cm) Figure 13c. Some of the largest plaice caught were not retained for captive observation.

Fish were held in captivity for 38-72h; survival probability was 66.7% for 'Excellent' fish, 52.0% for 'Good' fish and 32.7% for 'Poor' fish, and no fish survived that were assessed as 'Moribund'. When weighted to the proportion of fish in each vigour category in the total catch, the estimated survival in the observation period was 37.3% (CI 26.9-47.2%) (Table 8). In the extension models, because the rate of mortality had not slowed noticeably within the observation time (Figure 12c) the forecast survival estimate is lower at 4-15.2% (Table 9).

4.1.4 Case study 4 Eastern Channel Trammel net - plaice

A total of 1004 plaice were caught and assessed for vitality at the point the fish would have been discarded (Table 7). Observers rated 68% of plaice as having 'Excellent' vitality, 29% as having 'Good' vitality,1% as 'Poor' and 2% of plaice were assessed as 'Moribund'. No plaice were categorised as Dead (Figure 14d). A sample of 168 plaice retained for captive observation had a length distribution comparable with the total catch (19 cm to 53 cm; mean length of 34 cm) (Figure 13d).

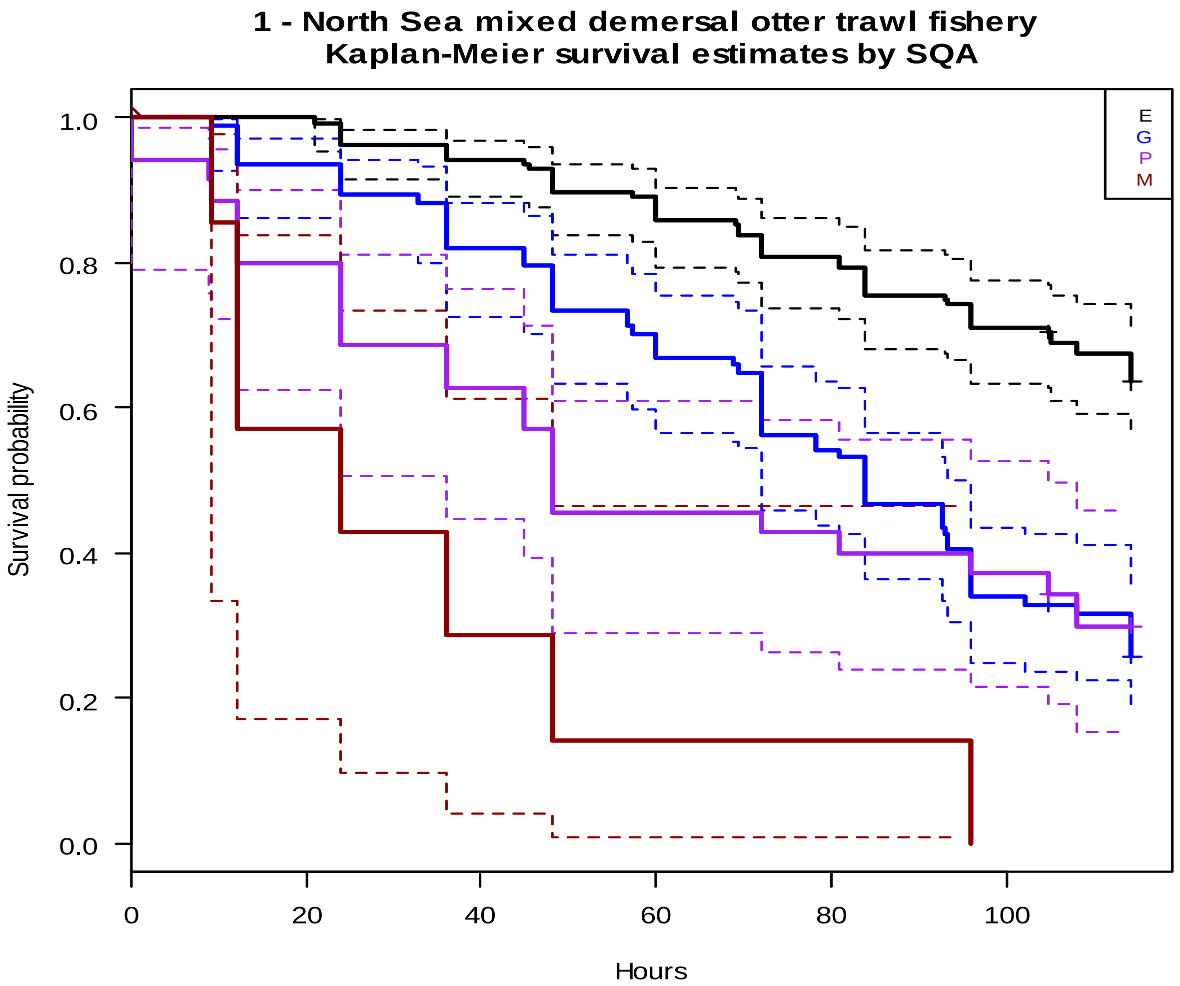
Fish were held in captivity for 168-342h; survival probability was 80.3% for 'Excellent' fish and 71.0% for 'Good' fish, no other categories were caught in sufficient number to investigate. When weighted to the proportion of fish in each vigour category in the total catch, the estimated survival in the observation period was 72.0% (CI 60.5-81.6%) (Table 8). From the extension models, because the rate of mortality had reduced within the observation time (Figure 12d) the forecast survival estimate was comparable at 71.1-71.9% (Table 9).

Table 7: Data summary from all case studies.

Area	North Sea	Western Channel	Western Channel	Eastern Channel
Gear	Otter trawl	Otter trawl	Beam trawl	Trammel net
Mesh size (mm)	80; 99	90	85	92;120;150
Target	mixed demersal	mixed demersal	mixed demersal	sole/plaice
Study period	25 Aug - 16 Oct	19 Jan - 18 Feb	21 Nov - 14 Feb	16 Mar - 10 Apr
Fishing days	12	10	10	7
Hauls	29	19	39	33
Species	Plaice	Plaice	Plaice	Plaice
Mean length plaice catch cm	26.9	26.3	33.2	33.6
Vitality assessed from catch n	1458	1040	826	1004
% plaice catch assessed as excellent	50	36	15	68
% plaice catch assessed as good	25	34	38	29
% plaice catch assessed as poor	14	19	42	1
%plaice catch assessed as moribund	12	9	4	2
% plaice catch assessed as dead	0	1	0	0
Captive observation sample number	292	348	275	168
Captive observation method	Onshore	Onshore	On vessel	Onshore
Mean length observed cm	27.8	27.6	32.3	33.5
Observation period	105-120h	66-133h	38-72h	168-342h
% survival of plaice catch assessed as excellent	63.5	90.2	66.7	80.3
% survival of plaice catch assessed as good	25.8	73.9	52.0	71.0
% survival of plaice catch assessed as poor	30.0	36.6	32.7	-
% survival of plaice catch assessed as moribund	0.0	5.0	0.0	-
% survival in observation period for plaice catch	42.0 (33.7-50.1)	64.4 (55.4-71.8)	37.3 (26.9-47.2)	72.9 (60.5-81.6)
Modelled % survival with no time constraint for total plaice catch	18.8-20	47.1-62.8	4-15.2	71.1-71.9

Figures 12a-d: Outputs from Kaplan-Meier survival analysis.

Figure 12a: Outputs from Kaplan-Meier survival analysis Case study 1 (North Sea otter trawl fishery).

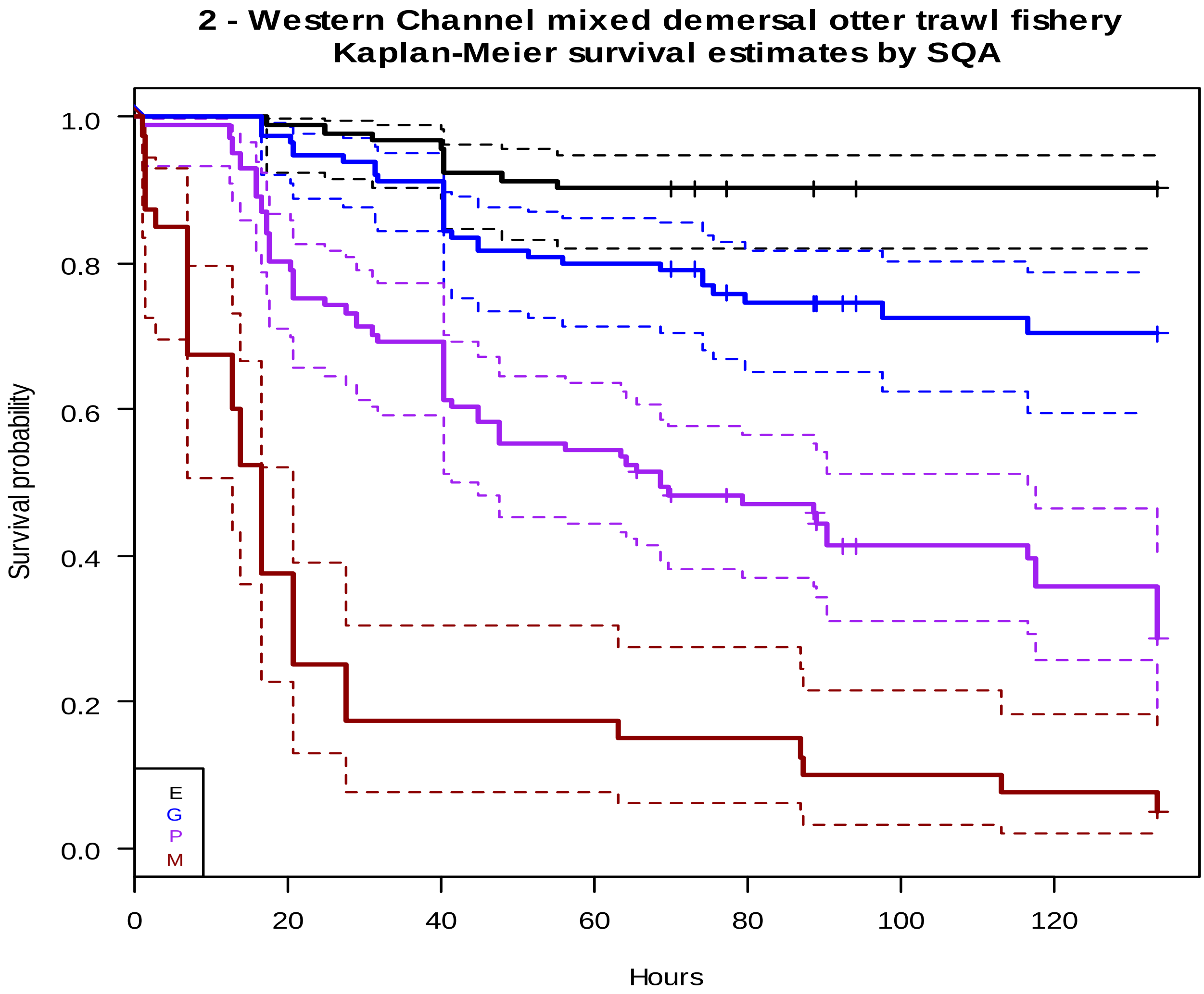


Kaplan-Meier estimates of survival are shown as solid lines and 95% pointwise confidence intervals as dashed lines. The small crosses at the end and along the lines mark times when one or more surviving fish stopped being observed; the x-axis is the time from the beginning of the sort period until death or the end of the observation period.

Comparison	Chi-square	p-value
'Excellent' vs 'Good'	38.7	**<0.001**
'Excellent' vs 'Poor'	26.7	**<0.001**
'Excellent' vs 'Moribund'	57.7	**<0.001**
'Good' vs 'Poor'	0.5	0.501
'Good' vs 'Moribund'	13.4	**<0.001**
'Poor' vs 'Moribund'	4.4	0.036
Overall	71.7	**<0.001**

Paired comparisons of survivor curves for fish with different vigour categories using log-rank test; where p<0.001 indicates the survival probability of fish with these two vitalities differ significantly

Figure 12b: Outputs from Kaplan-Meier survival analysis Case study 2 (Western Channel demersal trawl fishery).

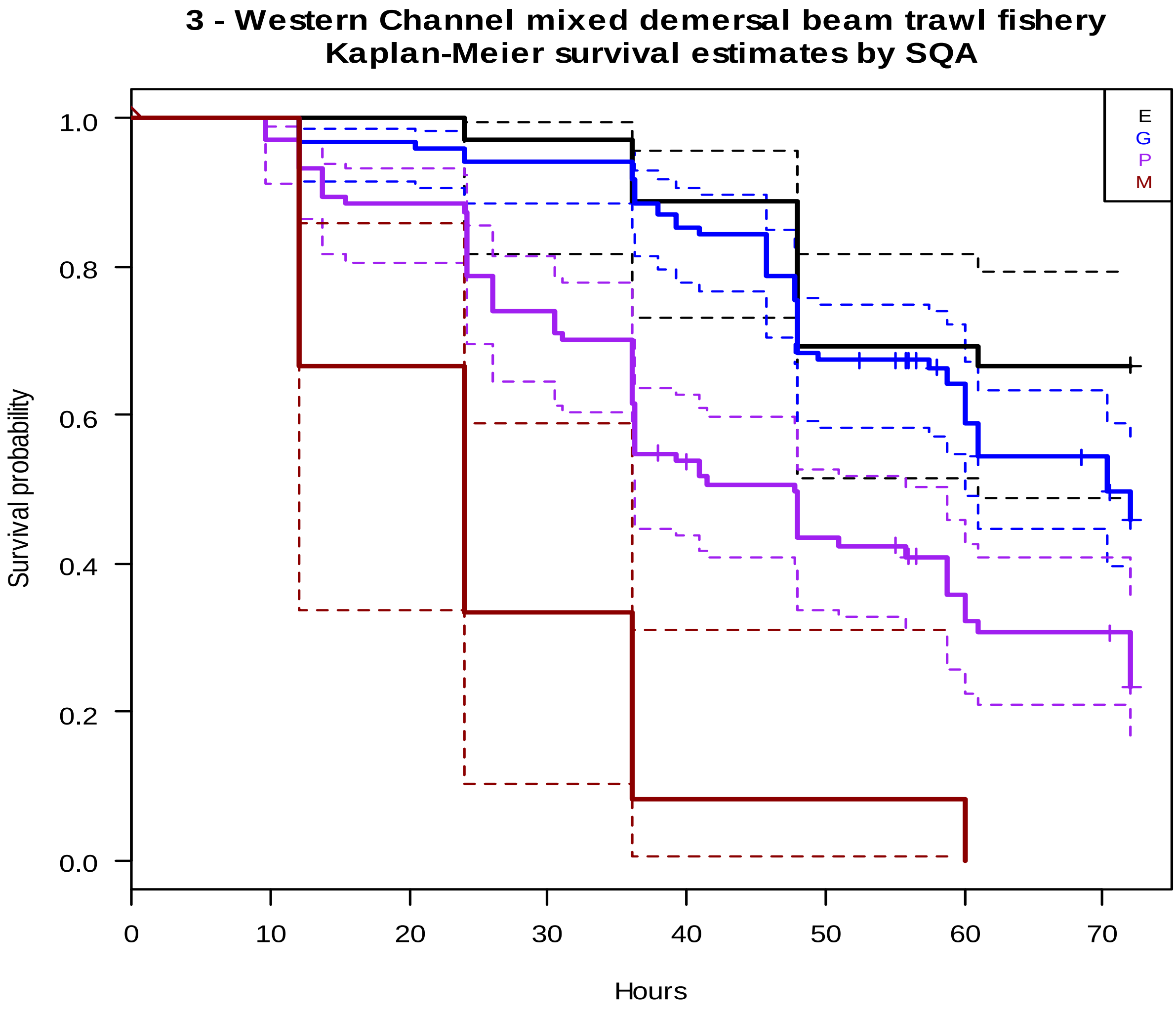


Kaplan-Meier estimates of survival are shown as solid lines and 95% pointwise confidence intervals as dashed lines. The small crosses at the end and along the lines mark times when one or more surviving fish stopped being observed; the x-axis is the time from the beginning of the sort period until death or the end of the observation period.

Comparison	Chi-square	p-value
'Excellent' vs 'Good'	9.0	0.003
'Excellent' vs 'Poor'	59.6	**<0.001**
'Excellent' vs 'Moribund'	141.0	**<0.001**
'Good' vs 'Poor'	30.3	**<0.001**
'Good' vs 'Moribund'	117.6	**<0.001**
'Poor' vs 'Moribund'	37.2	**<0.001**
Overall	213.8	**<0.001**

Paired comparisons of survivor curves for fish with different vigour categories using log-rank test; where p<0.001 indicates the survival probability of fish with these two vitalities differ significantly.

Figure 12c Outputs from Kaplan-Meier survival analysis Case study 3 (Western Channel beam trawl fishery).

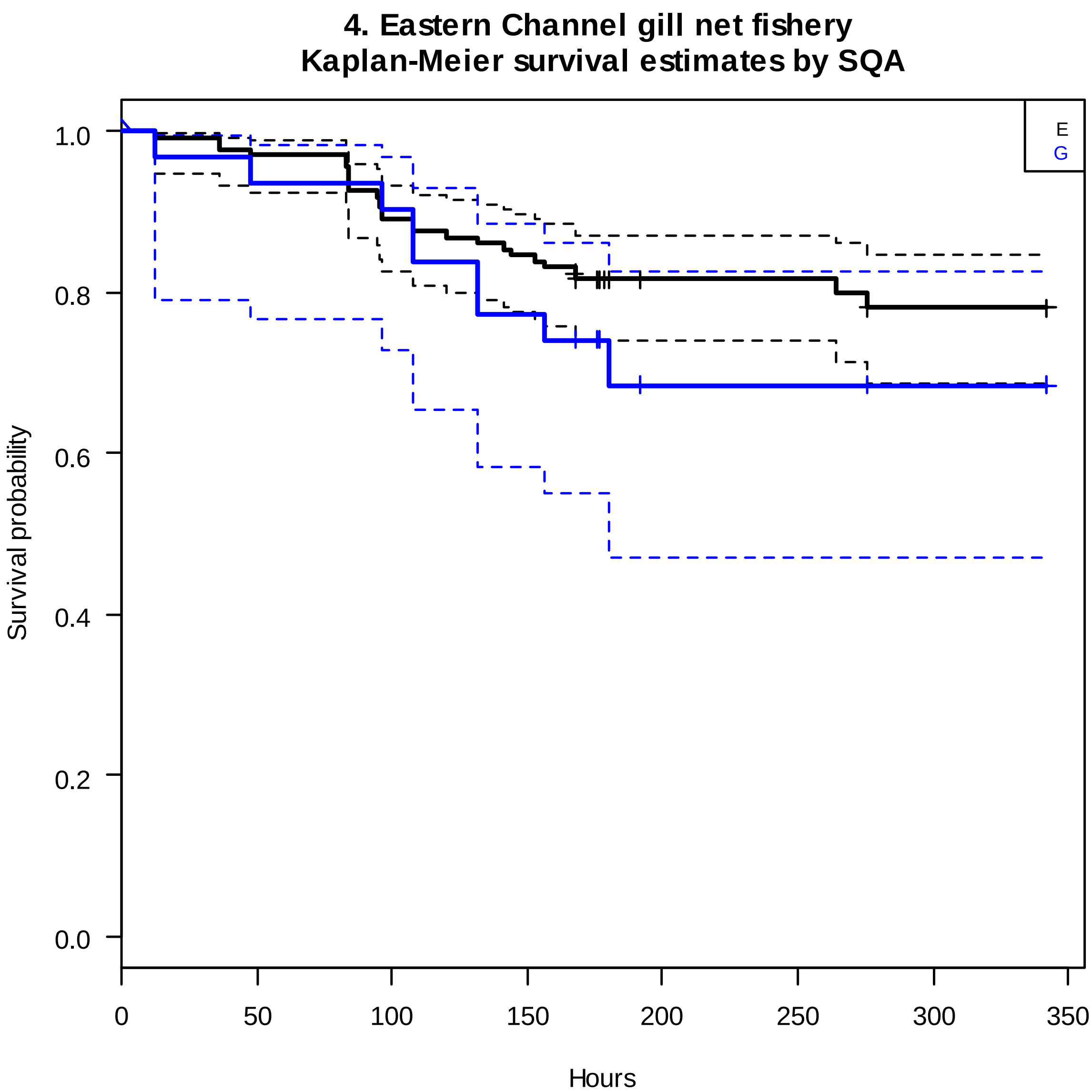


Kaplan-Meier estimates of survival are shown as solid lines and 95% pointwise confidence intervals as dashed lines. The small crosses at the end and along the lines mark times when one or more surviving fish stopped being observed; the x-axis is the time from the beginning of the sort period until death or the end of the observation period.

Comparison	Chi-square	p-value
'Excellent' vs 'Good'	3.5	0.063
'Excellent' vs 'Poor'	17.6	**<0.001**
'Excellent' vs 'Moribund'	41.3	**<0.001**
'Good' vs 'Poor'	20.2	**<0.001**
'Good' vs 'Moribund'	64.4	**<0.001**
'Poor' vs 'Moribund'	18.2	**<0.001**
Overall	77.5	**<0.001**

Paired comparisons of survivor curves for fish with different vigour categories using log-rank test; where p<0.001 indicates the survival probability of fish with these two vitalities differ significantly.

Figure 12d Outputs from Kaplan-Meier survival analysis Case study 4 (Eastern Channel gill net fishery).

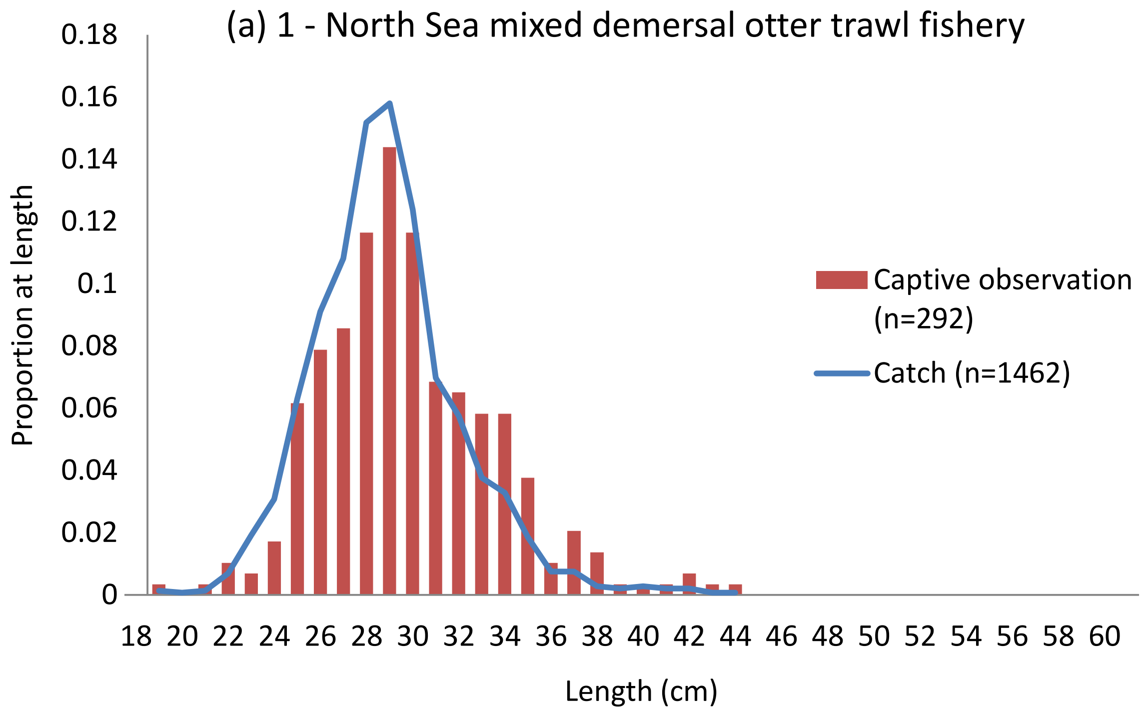


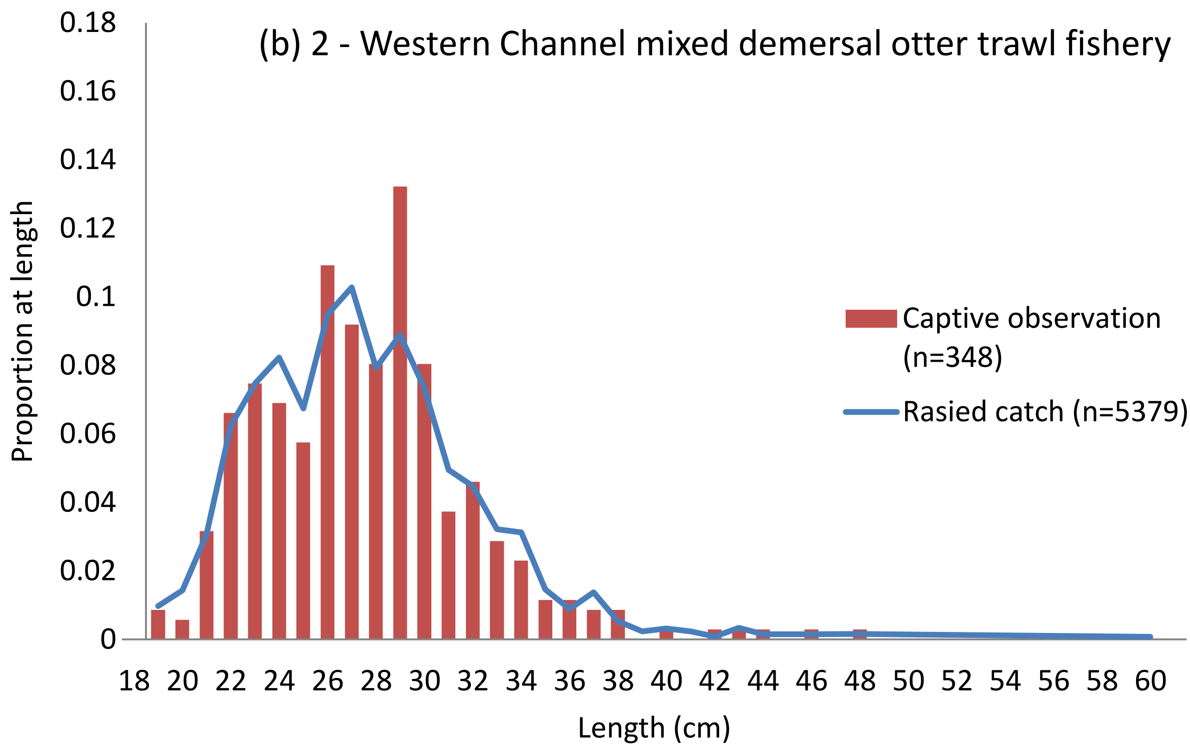
Kaplan-Meier estimates of survival are shown as solid lines and 95% pointwise confidence intervals as dashed lines. The small crosses at the end and along the lines mark times when one or more surviving fish stopped being observed; the x-axis is the time from the beginning of the sort period until death or the end of the observation period

Comparison	Chi-square	p-value
'Excellent' vs 'Good'	1.4	0.243

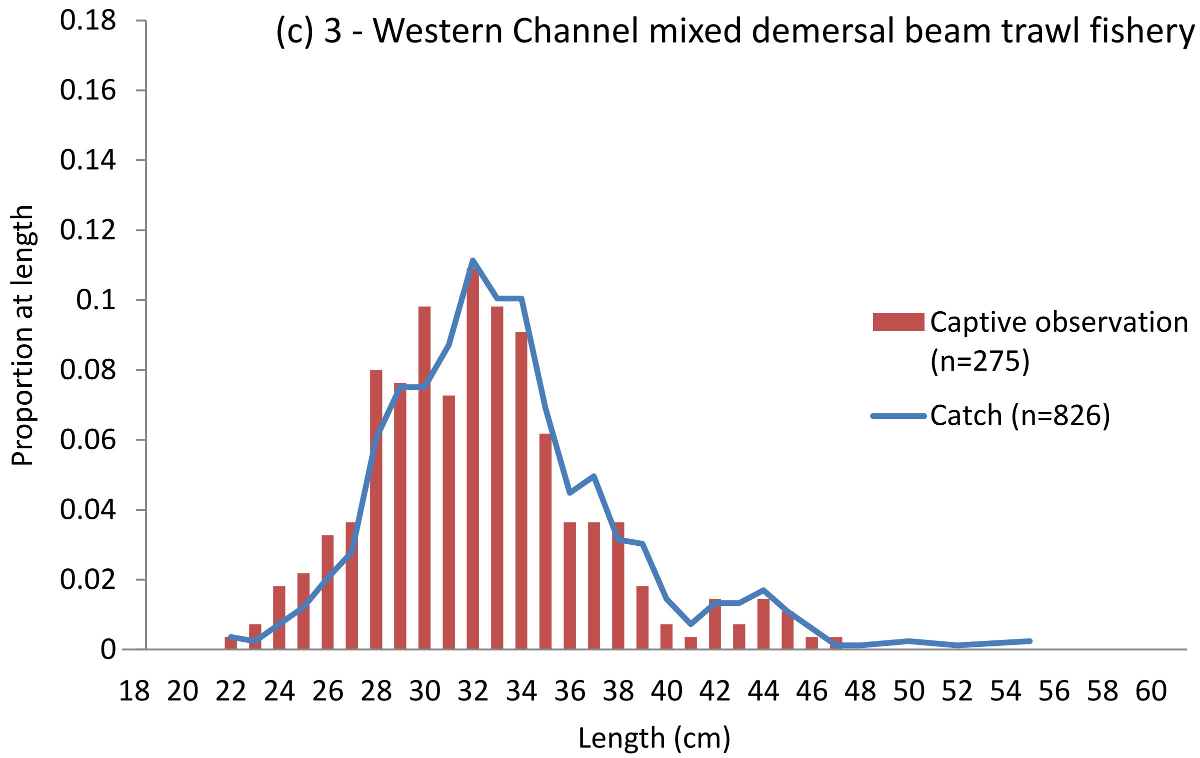
Paired comparisons of survivor curves for fish with different vigour categories using log-rank test; where $p<0.001$ indicates the survival probability of fish with these two vitalities differ significantly.

Figure 13a-d: Length frequencies of plaice in catches and held for observation shown separately for all case studies.

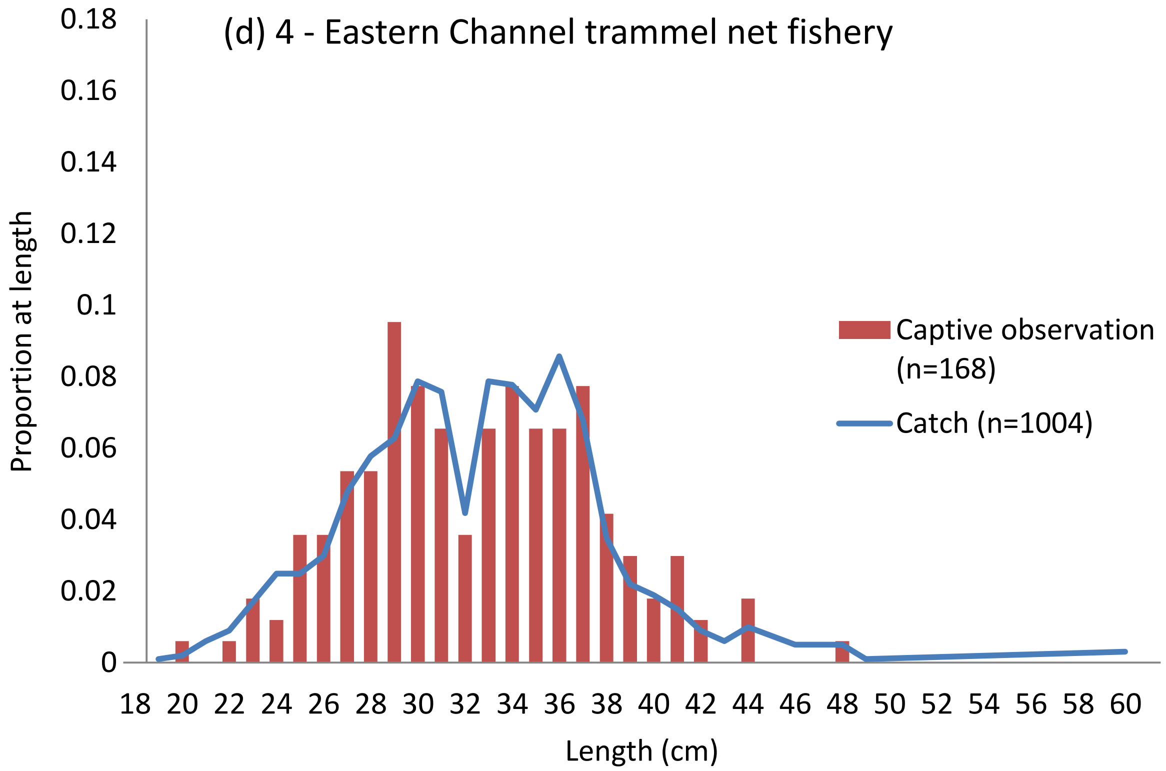




x

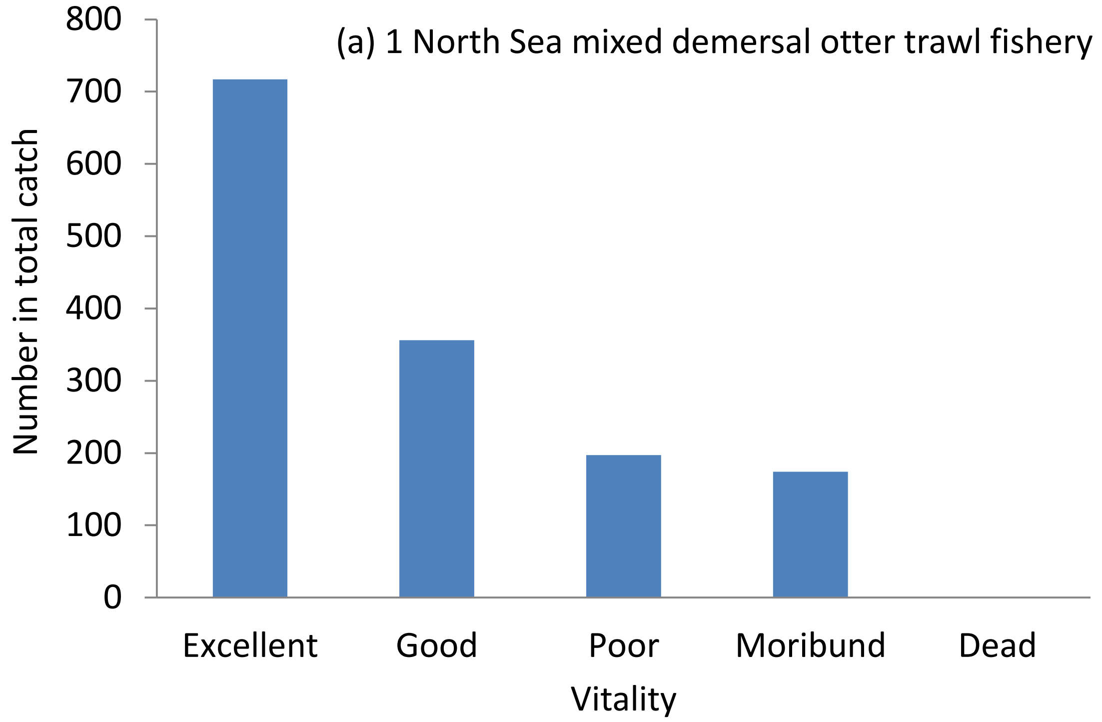


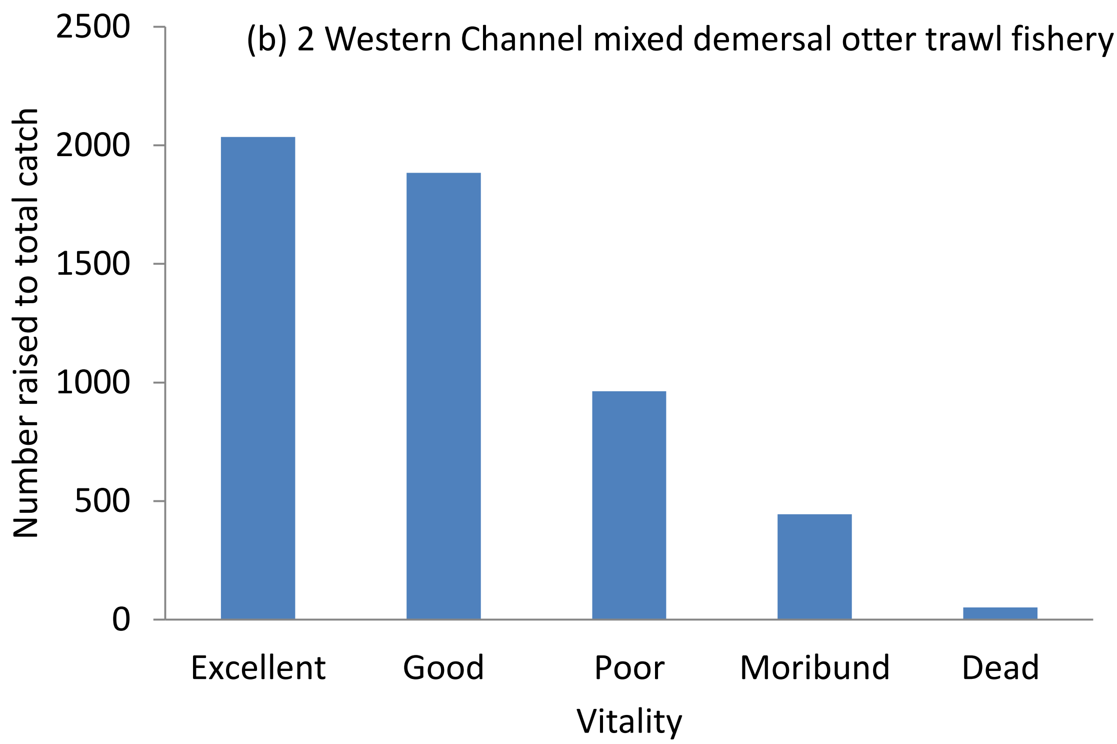
(c) 3 - Western Channel mixed demersal beam trawl fishery
Proportion at length
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60
Length (cm)
Captive observation (n=275)
Catch (n=826)

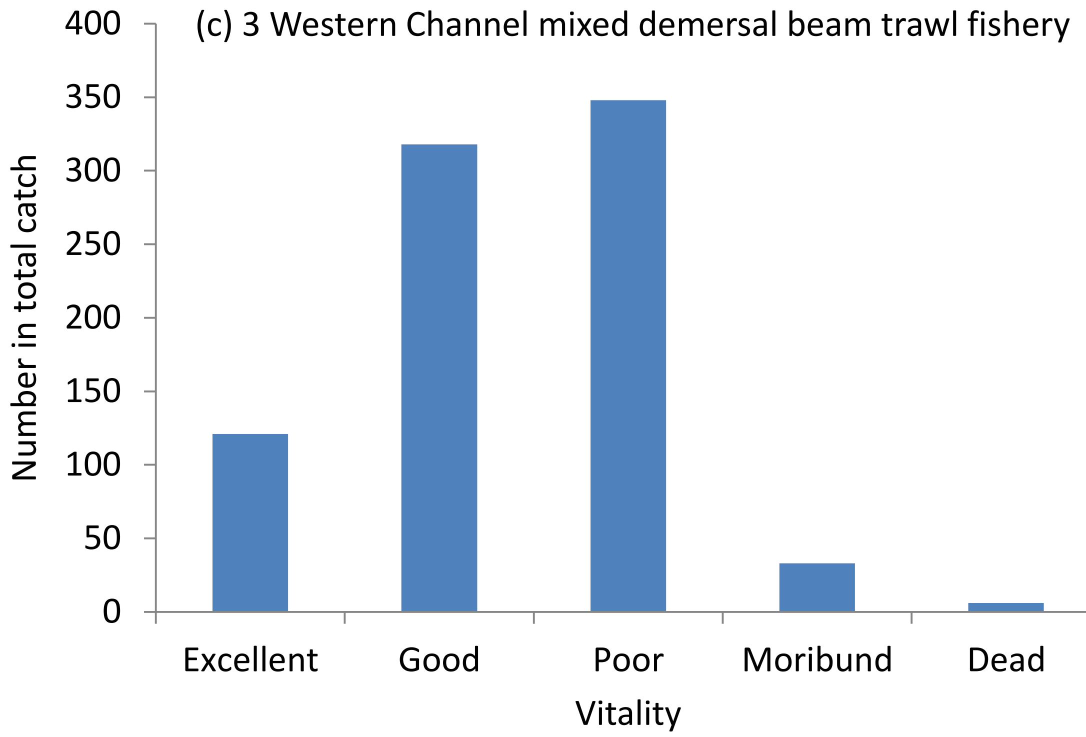


(d) 4 - Eastern Channel trammel net fishery
Proportion at length
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60
Length (cm)
Captive observation (n=168)
Catch (n=1004)

Figure 14a-d: Number of plaice in total catch assessed with each vigour vitality category






(c) 3 Western Channel mixed demersal beam trawl fishery
Number in total catch
400
350
300
250
200
150
100
50
0
Excellent
Good
Poor
Moribund
Dead
Vitality

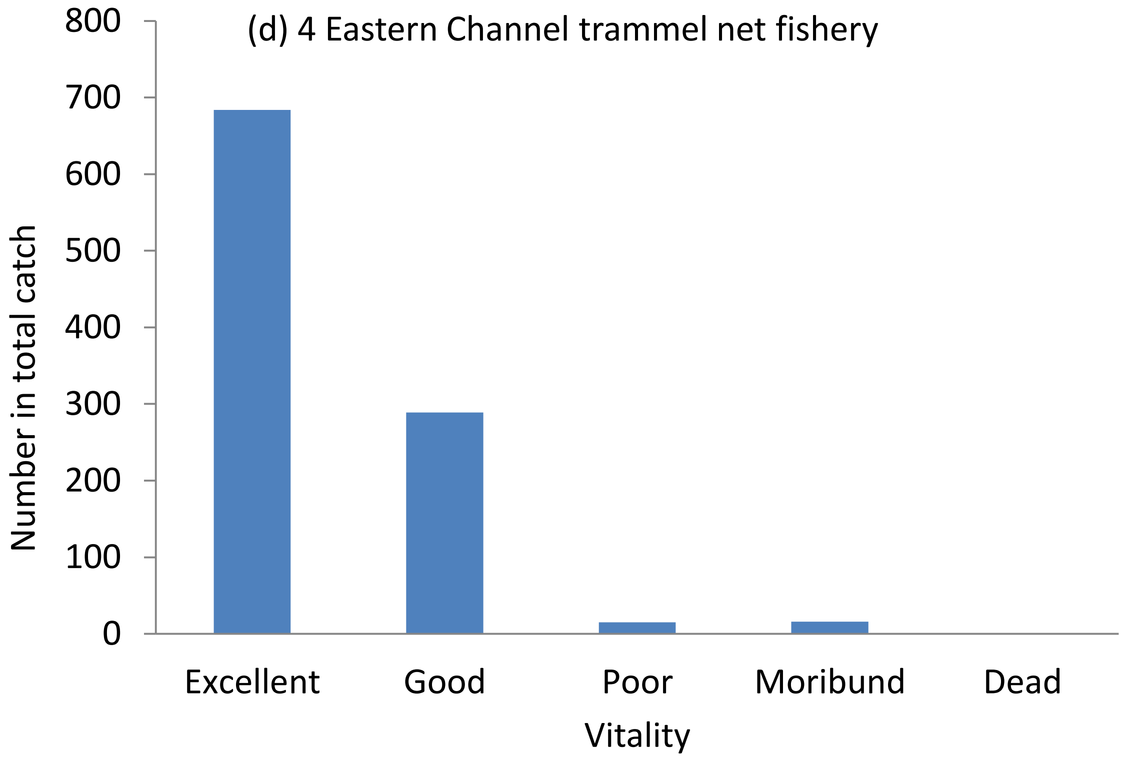

(d) 4 Eastern Channel trammel net fishery
Number in total catch
800
700
600
500
400
300
200
100
0
Excellent
Good
Poor
Moribund
Dead
Vitality

Table 8: Survival of captive fish during observation time period and modelled for extended period.

The table gives the overall percentage survival of the captive fish; the survival probability within the observation period with upper and lower 95% CIs from the K-M analysis and also the predicted percentage survival based on a modelled asymptote in the survival curve from the two extension models. Extension model 1 (ph) gives the output from a semi-parametric proportional hazards mixture cure model (PHMC) (Cai et al. 2012); Extension model 2 (Wei) gives the outputs from a parametric mixture distribution model (Benoit et al. 2012).

Captive observation results							
Case study/fishery	Vitality	Percentage survival of captive fish	Survival probability (KM) as percentage	lower 95%	upper 95%	Extension model 1 (ph)	Extension model 2 (Wei)
1. North Sea mixed demersal otter trawl fishery - Plaice	Excellent	64.7	63.5	55.2	70.7	31.5	37.5
	Good	27.7	25.8	17.1	35.4	1.4	0.6
	Poor	31.4	30.0	15.5	46.0	29.5	0.0
	Moribund	0.0	0.0	0.0	0.0	0.0	0.0
2. Western Channel mixed demersal otter trawl fishery - Plaice	Excellent	90.2	90.2	82.0	94.8	84.6	90.2
	Good	73.9	70.4	59.7	78.8	40.6	71.3
	Poor	36.6	28.7	18.8	39.5	2.3	18.3
	Moribund	5.0	5.0	0.9	14.8	4.7	4.6
3. Western Channel mixed demersal beam trawl fishery - Plaice	Excellent	66.7	66.7	48.8	79.5	24.6	66.7
	Good	52.0	45.8	35.7	55.3	0.6	0.0
	Poor	32.7	23.4	14.3	33.9	0.3	12.9
	Moribund	0.0	0.0	0.0	0.0	0.0	0.0
4. Eastern Channel trammel net fishery - Plaice	Excellent	80.3	78.1	68.9	84.8	77.9	76.6
	Good	71.0	68.5	47.1	82.7	65.6	65.7

Table 9: Estimating discard survival for all plaice caught on observed trips using vitality as a proxy.
The table presents the weighted mean survival proportions of the total catch from the captive observation estimates (Table 8) and the catch vitality profiles

Case study/fishery	Vitality	Proportion at vitality in total catch	Survival probability as percentage in obs. period	Survival probability as % in obs. period Lower 95%	Survival probability as % in obs. period Upper 95%	Survival with no time constraint model 1	Survival with no time constraint model 2
1. North Sea mixed demersal otter trawl fishery - Plaice	Excellent	0.50	31.5	27.4	35.1	15.6	18.6
	Good	0.25	6.4	4.2	8.7	0.4	0.1
	Poor	0.14	4.1	2.1	6.3	4.0	0.0
	Moribund	0.12	0.0	0.0	0.0	0.0	0.0
	Dead	0.00	0.0	0.0	0.0	0.0	0.0
Survival rate %			**42.0**	**33.7**	**50.1**	**20.0**	**18.8**
2. Western Channel mixed demersal otter trawl fishery - Plaice	Excellent	0.38	34.1	31.0	35.9	32.0	34.1
	Good	0.35	24.7	20.9	27.6	14.2	25.0
	Poor	0.18	5.1	3.4	7.1	0.4	3.3
	Moribund	0.08	0.4	0.1	1.2	0.4	0.4
	Dead	0.01	0.0	0.0	0.0	0.0	0.0
Survival rate %			**64.4**	**55.4**	**71.8**	**47.1**	**62.8**
3. Western Channel mixed demersal beam trawl fishery - Plaice	Excellent	0.15	9.8	7.2	11.6	3.6	9.8
	Good	0.38	17.6	13.7	21.3	0.2	0.0
	Poor	0.42	9.9	6.0	14.3	0.1	5.5
	Moribund	0.04	0.0	0.0	0.0	0.0	0.0
	Dead	0.01	0.0	0.0	0.0	0.0	0.0
Survival rate %			**37.3**	**26.9**	**47.2**	**4.0**	**15.2**
4. Eastern Channel trammel net fishery - Plaice	Excellent	0.68	53.2	46.9	57.8	53.1	52.2
	Good	0.29	19.7	13.6	23.8	18.9	18.9
	Poor	0.01	0.0	0.0	0.0	0.0	0.0
	Moribund	0.02	0.0	0.0	0.0	0.0	0.0
	Dead	0.00	0.0	0.0	0.0	0.0	0.0
Survival rate %			**72.9**	**60.5**	**81.6**	**71.9**	**71.1**

4.2 Potential for method induced mortality

It was clear from the experimental method that additional stressors were exerted on the captive fish than would have been the case had the fish been released to the sea as per normal discard practice. Specifically these stressors included:

- Handling fish to conduct the vitality assessments, length measurements and putting fish into the on-board tanks
- Captivity in the on-board tanks (movement caused by vessel movement; proximity with other fish; serial flow of water from top to bottom tank)
- Stopping water flow to on-board tanks on approach to port until docked (reduced dissolved oxygen)
- Transfer of fish into tubs (handling of fish)
- Carrying tubs off the vessel and transporting, by van, to onshore holding tanks (increased temperature, reduced dissolved oxygen, movement)
- Handling the fish to transfer into onshore tanks
- Adjusting to salinity and temperature change in the onshore tanks
- Monitoring captive fish using tail grab

Although the control experiment indicated that the onshore tanks did not induce mortality, this was based on a constant supply of seawater to the tanks. In case studies 1 and 2, there were considerable problems in maintaining water flow to the tanks, due to the location of the tanks being at the limit in height to the water supply for the pumps (Annex 7). This meant that during some low tides and particularly at spring tides, the pump would lose prime and stop feeding the reservoir tanks. The time taken for the reservoir tank to empty and the monitoring schedule of the captive fish meant that there were occasions in which the fish may have had no water flow for up to six hours. These incidents happened at the start of case study 1 and throughout case study 2 (the pump was found to have lost prime at half the monitoring events). Water temperature and dissolved oxygen were monitored throughout case study 1 but only temperature for case study 2, until a faulty dissolved oxygen meter could be replaced at the end of the experiment. The data show that when the pumps failed the dissolved oxygen went as low as 59% for case study 2 and on one occasion 17% in case study 1 (Table 10). This will have induced additional stress on the captive fish, however, there was no obvious associated between the times the pump was not functioning and an increase in mortality, although the effect may not have been instantaneous.

Table 10: Summary of water temperature and dissolved oxygen levels within the onshore holding tanks.

	Water temperature in tank °C				% Dissolved oxygen in tank			
Case study	mean	min	max	readings	mean	min	max	readings
Study 1	13.4	11.7	16.0	438	85.4	17.0	98.0	437
Study 2 (water flow)	7.6	3.0	9.5	26	86.5	85.0	88.0	2
Study 2 (no water flow)	6.5	3.5	8.5	23	65.5	59.0	74.0	4
Study 4	9.5	6.2	12.5	540	88.0	76.0	97.0	499

The seawater temperature data shows that there were substantial differences between studies, with study 2 having the coldest water in the tanks, and study 1 the warmest. The water was pumped from the sea and reflected the ambient sea water temperatures at the different periods the studies were conducted. It can also be seen that there was considerable temperature range in the studies, particularly in study 2 in which cold night dropped the water temperature rapidly by up to 5 degrees and in case study 4, in which the seawater temperature gradually increased over the period of the study. Rapid changes in water temperature in the onshore holding tanks are also considered to have induced additional stress on the captive fish.

The captivity of fish retained in the on-board tanks on the vessel, were subject to movement, changing temperatures and a serial flow of water from the top tanks, with the potential for a gradient of deteriorating water quality and reducing dissolved oxygen down the stack of tanks. The on-board tanks were filled with fish from the bottom up, therefore, any increasing mortality through the stack of tanks would indicate an experimental effect of the time spent in the tanks, the position in the stack of the fish or to different qualities of the seawater. The potential for an on-board tank effect was explored by ranking the proportion of deaths in each tank and conducting a Spearman's rank correlation test. Fish of different vitalities were assessed separately to account for an uneven distribution of vitalities in the tanks. The analysis was possible for 5 groups of fish from 2 of the case studies (Annex 4). In two of the five groups there was a significant increase in mortality from the top to the bottom tank in the stack. This suggests there may have been an experimental effect, with those fish held for the longest period in the on-board tanks more likely to die.

4.3 Factors influencing discard survival

4.3.1 The effect of impaired reflexes

Table 11 shows the proportion of fish in the catch that demonstrated impairment in the different reflex tests. The binomial GLM model estimates showed that different reflex(es) significantly affect the proportion of dead fish, for each case study, at the end of the observation period. In case study 1 (North Sea Otter trawl fishery) the reflex that had a significant effect on the proportion of dead fish was orientation (the ability of the fish to right itself); i.e. in this case study, significantly more of the fish that could not right themselves died than survived (Z = 3.121, p =0.0018).

In the case study 2 (Western Channel otter trawl fishery) the reflexes which had a significant impact on the proportion of dead fish were i) body flex, iii) operculum closure and iii) startle touch. All three reflexes showed statistically significant results i) Z = 5.427, p = 0.005, ii) Z = 3.455, p = 0.005 and iii) Z = 2.315, p = 0.021. So, significantly more of the fish that did not respond to these reflex tests died than survived. In case study 3 (Western Beam trawl fishery) only the body flex impairment had a significant impact) on the proportion of dead fish (Z = 2.435, p = 0.015). Finally, in case study 4 – Eastern Channel trammel net fishery no impaired reflexes significantly affected the proportion of dead and alive fish, suggesting that the reflexes assessed did not provide a useful indicator of mortality.

Table 11: Summary data with the number of fish dead and alive in the experiment, when impaired and unimpaired for each reflex, percentage (%) of dead fish impaired, percentage (%) of alive fish impaired, p value from binomial GLM. Number of impaired/ unimpaired and proportion of impaired plaice in the total catch. * Significant differences p<0.05

Case study	Reflex name	Reflex response	Experiement					Population	
			Alive	Dead	% of dead fish impaired	% of alive fish impaired	p-value	Number	Proportion impaired
1 - North Sea Otter fishery	Tail grab	unimpaired	137	125	14%	7%	0.362	682	20%
		impaired	10	20				166	
	Operculum	unimpaired	119	101	30%	19%	0.679	616	27%
		impaired	28	44				232	
	Startle touch	unimpaired	140	121	17%	5%	0.154	683	19%
		impaired	7	24				165	
	Orientation	unimpaired	123	89	39%	16%	0.0018*	514	39%
		impaired	24	56				334	
2 - Western Channel otter fishery	Body flex	unimpaired	153	33	77%	26%	0.0005*	3465	36%
		impaired	54	108				1913	
	Operculum	unimpaired	203	105	26%	2%	0.0005*	4874	9%
		impaired	4	36				504	
	Startle touch	unimpaired	47	5	96%	77%	0.021*	1568	71%
		impaired	160	136				3810	
	Orientation	unimpaired	129	38	73%	38%	0.921	3147	41%
		impaired	78	103				2232	
3 - Western Beam fishery	Body flex	unimpaired	69	45	71%	43%	0.015*	333	60%
		impaired	53	108				493	
	Operculum	unimpaired	120	140	8%	2%	0.982	786	5%
		impaired	2	13				40	
	Startle touch	unimpaired	2	1	99%	98%	0.981	10	99%
		impaired	120	152				816	
	Orientation	unimpaired	86	72	53%	30%	0.446	431	48%
		impaired	36	81				395	
4 - Eastern Channel gill net fishery	Tail_grab	unimpaired	128	34	6%	3%	0.368	929	7%
		impaired	4	2				75	
	Body_Flex	unimpaired	102	22	39%	23%	0.067	655	35%
		impaired	30	14				349	
	Orientation	unimpaired	107	25	31%	19%	0.254	721	28%
		impaired	25	11				283	

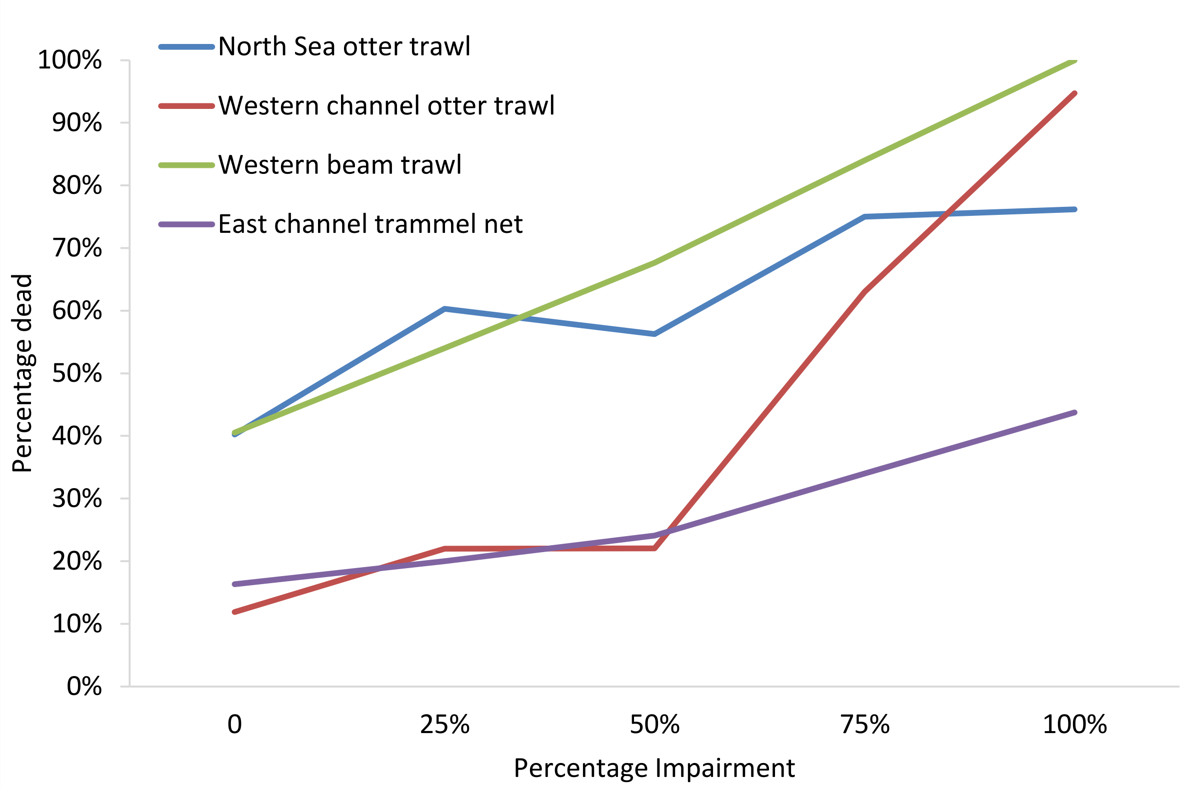
4.3.2 Reflex action mortality predictor - RAMP

The quantified reflex actions were used to correlate impairment at the point of discarding with delayed mortality, this approach is known as RAMP - Reflex Action Mortality Predictor. RAMP has been used to assess vitality and predict mortality in a variety of taxa (ICES 2014).

Here we simply plotted the percentage of dead plaice, from the captive observation, against the percentage impairment of all tested reflexes at the point of discarding. Figure 15 shows that overall, in all case studies, the percentage of dead fish increases with the sum of the number of impaired reflexes; and in all case studies some fish were impaired in all tested reflexes (100% impairment). However, only in the Western Channel beam trawl case study did all fish die that displayed 100% impairment. In the other three case studies even when plaice were assessed as impaired in all reflexes, some of these fish survived. In the Eastern Channel trammel net fishery, only 44% of fully impaired fish died. Similarly, some fish died in the captive observation that responded to all the reflex stimuli, i.e. they had 0% impairment. In case studies 1 and 3, the North Sea otter trawl and Western beam trawl, 41% of fish that were assessed to have no impairment died.

It would be expected that where no impairment is observed, fish would survive, and fully impaired fish would die. Why this was not seen here may be because of experimental induced mortality, whereby fish with no impairment would have survived but instead were killed owing to the experimental conditions they were held in. However, this would not explain why more fish survived that were fully impaired than would be expected. It is also possible, that the reflexes tested here are not good indicators of survival, or that there was observer bias in the reflex assessments. Although this was not analysed, it appeared that this was unlikely because both of the two lead fieldworkers working on the different case studies generated data that displayed higher mortality than would be expected for fish with no impairment. There are also underlying assumptions from applying the RAMP approach as all reflexes are equally weighted and therefore the impairment of any reflexes will equally influence survival chances. Owing the underlying assumptions, which were considered could not be supported, and the uncertainties in the data, the RAMP approach was not applied further in this study.

Figure 15. Variation of percentage of dead with percentage impairment in each case study.



4.3.3 The effect of injuries

Table 12 shows the proportion of fish that presented injuries. Fin fraying, scale loss and abrasion were the most common injuries in the plaice caught by otter trawls in the North Sea and Western Channel. In addition to these injuries, net marks were common in the fish caught by beam trawls. The plaice caught in the trammel net had a different suite of injuries, with lower levels of incidence. The only common injury for trammel net caught plaice was bleeding, which was often associated with the fins.

The same analyses with the binomial GLM used for the reflex responses was applied to the injuries responses in each case study. The GLM results showed that the injury that had the most significant impact on the proportion of dead fish across all 4 studies was the scale loss. In all cases the proportion of dead fish was significantly higher when scale loss was evident. In case study 2 (Western otter trawl fishery) the other injury that resulted in significantly more dead plaice was abrasion. However, this effect was not apparent in the other case studies.

Table 12: Summary data with the number of fish dead and alive in the experiment, when injured and not injured for each injury, percentage (%) of dead fish injured, percentage (%) of alive fish injured, *p* value from binomial GLM. Number of injured/not injured and proportion of impaired plaice in the total catch.

Case study	Injury	Response	Experiement					Population	
			Alive	Dead	% of dead fish injured	% alive fish injured	*p*- value	Number	Proportion injured
1 - North Sea otter trawl fishery	Net marks	not injured	146	144	1%	1%	0.665	835	2%
		injured	1	1				13	
	Internal organs exp	not injured	146	143	1%	1%	0.991	842	1%
		injured	1	2				6	
	Predatory damage	not injured	145	144	1%	1%	0.991	844	0%
		injured	2	1				4	
	Fin fraying	not injured	103	84	42%	30%	0.826	609	28%
		injured	44	61				239	
	Wounding	not injured	146	143	1%	1%	0.991	844	0%
		injured	1	2				4	
	Scale loss	not injured	131	103	29%	11%	0.035*	690	19%
		injured	16	42				158	
	Abrasion	not injured	106	99	32%	28%	na	680	20%
		injured	41	46				168	
2- Western otter trawl fishery	Net marks	not injured	191	132	6%	8%	0.631	4973	8%
		injured	16	9				405	
	Internal organs exp	not injured	206	141	0%	0%	0.991	5372	0%
		injured	1	0				7	
	Predatory damage	not injured	207	140	1%	0%	0.991	5368	0%
		injured	0	1				11	
	Fin fraying	not injured	173	116	18%	16%	0.701	4222	22%
		injured	34	25				1157	
	Wounding	not injured	207	140	1%	0%	0.991	5325	1%
		injured	0	1				54	
	Scale loss	not injured	93	42	70%	55%	0.009*	2104	61%
		injured	114	99				3275	
	Mucus loss	not injured	173	123	13%	16%	0.068	4716	12%
		injured	34	18				663	
	Abrasion	not injured	177	98	30%	14%	0.011*	4480	17%
		injured	30	43				899	
	Exophthalmia	not injured	207	140	1%	0%	0.991	5374	0%
		injured	0	1				4	
3 - Western Channel beam fishery	Net marks	not injured	69	84			0.953	480	
		injured	53	69	45%	43%		346	42%
	Fin_fraying	not injured	108	120			0.054 ·	664	
		injured	14	33	22%	11%		162	20%
	Wounding	not injured	122	149			0.981	791	
		injured	0	4	3%	0%		35	4%
	Scale_loss	not injured	59	54			0.056 ·	365	
		injured	63	99	65%	52%		461	56%
	Mucus loss	not injured	115	145			0.924	782	
		injured	7	8	5%	6%		44	5%
	Abrasion	not injured	83	84			0.092	444	
		injured	39	69	45%	32%		382	46%
4 - Eastern Channel gill net fishery	Net marks	not injured	120	34			0.675	890	
		injured	12	2	6%	9%		114	11%
	Internal organs exp	not injured	129	33			0.298	956	
		injured	3	3	8%	2%		48	5%
	Predatory damage	not injured	130	36			0.992	1002	
		injured	2	0	0%	2%		2	0%
	Fin fraying	not injured	117	26			0.105	863	
		injured	15	10	28%	11%		141	14%
	Wounding	not injured	132	35			0.994	1000	
		injured	0	1	3%	0%		4	0%
	Scale loss	not injured	120	23			0.002*	875	
		injured	12	13	36%	9%		129	13%
	Bleeding	not injured	65	17			0.644	512	
		injured	67	19	53%	51%		492	49%

4.3.4 Factors influencing survival

It was possible to investigate factors which influence survival for Case study 1 only (the North Sea otter trawl mixed demersal fishery). These factors are fully detailed in Annex 6 but include time of haul, depth of haul, sea state and wind force. Annex 6 summarizes the fit of multinomial models to the counts by vigour assessment category (i.e. the number of fish categorised as ‘Excellent’, ‘Good’, ‘Poor’, ‘Moribund’), using each variable on its own. Of the 40 variables considered, 27 were shown to improve the description of the vitality categories by haul compared with using the same proportion of fish in each category for all hauls. However, care in interpretation is required as many of the variables are linked and analysis of large numbers of variables can generate spurious results.

Clear-cut patterns were not seen in the visual analysis of the data, so vitality assessments appeared generally consistent across the range of conditions in Case study 1. Nevertheless, the model results show some potential effects of interest. The maximum time that a fish could have been exposed to the air (“maximum deck time”), defined as the difference between the time that the haul ended and the time that sorting ended, was associated with vigour category as the proportion of ‘Excellent’ fish was slightly larger for hauls that took less time to process (Table 13 and Figure 16). Wind force also showed some association to vigour category. In light winds the proportion of fish classed as ‘Good’ was slightly larger and the proportion ‘Poor’, slightly smaller (Table 14 and Figure 17 for Wind Force). In contrast, no trend in vitality assessment proportions was found in relation to the swell heights of 0 to 2.5 feet recorded.

Figure 16: The proportion of fish in each vitality (E=‘Excellent’, G=‘Good’, P=‘Poor’, M=‘Moribund’) assessment category for each haul vs Maximum deck time (time from the end of hauling to the end of sorting the catch for Case Study 1; smooth curves (loess smoother with span of 0.75) to provide visual analysis.

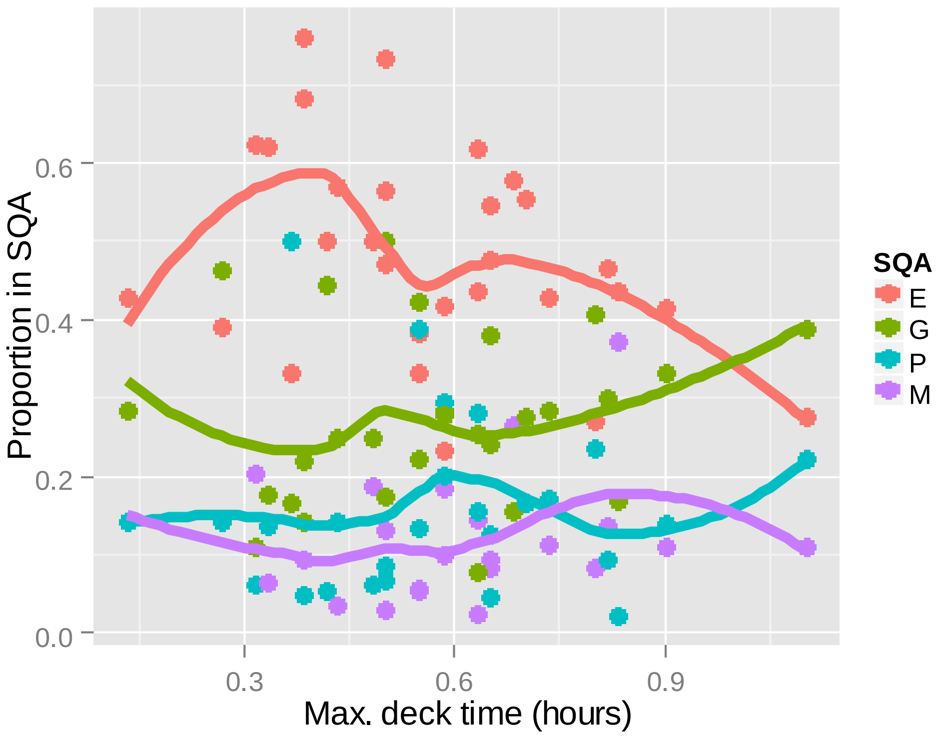


Table 13: Predicted proportion of fish in each vigour category associated with maximum deck time; defined as end of hauling to end of sort time

Max. deck time (hrs)	Predicted proportions in vigour category			
	Excellent	Good	Poor	Moribund
0.33	0.59	0.21	0.12	0.08
0.50	0.53	0.23	0.13	0.10
0.67	0.47	0.26	0.14	0.13

Figure 17: The proportion of fish in each vigour assessment category (E='Excellent', G='Good', P='Poor', M='Moribund') for each haul vs wind force; Case study 1, North Sea otter trawl mixed demersal fishery.

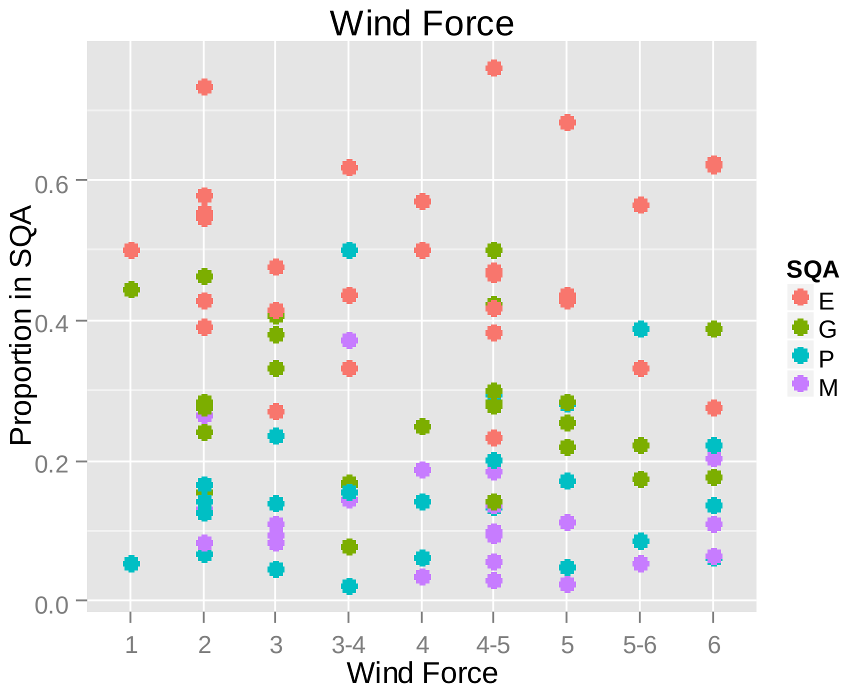


Table 14: Predicted proportion of fish in each vigour category associated with wind force (E='Excellent', G='Good', P='Poor', M='Moribund').

Wind Force	Predicted proportions in vigour category			
	E	G	P	M
1	0.50	0.44	0.06	0.00
2	0.56	0.23	0.11	0.10
3	0.35	0.38	0.17	0.09
3-4	0.52	0.13	0.10	0.25
4	0.55	0.25	0.11	0.09
4-5	0.43	0.31	0.15	0.11
5	0.52	0.25	0.17	0.06
5-6	0.42	0.20	0.27	0.10
6	0.57	0.19	0.13	0.11

4.3.5 Observations on fish sorting and handling

In each of the studies the method of catch sorting and handling was recorded. On the Western Channel otter trawler (Case Study 2), the cod-end was opened directly on the deck until the trawl was shot back and before the catch sorted, the marketable catch picked out and discards pushed out of the scupper. The sorting process lasted from 10 minutes to over an hour. For the Western Channel beam trawler study (Case Study 3) the cod-ends were opened into two deck pounds. Seawater washed the catch onto a conveyor belt that took the fish up and past the crew and marketable fish picked out and discarded fish were left on the conveyor which terminated in a chute over the side of the vessel. Sorting took place after the gear had been shot back and took between 30 minutes to 1 hour. The North Sea otter trawler study (Case Study 1) emptied the cod-end into a hopper. Once the gear was redeployed a small quantity of fish was discharged via a small door to an aluminium sorting table. The crew sorted the catch and at this point and any discards were pushed periodically down a chute to the sea. The sorting process took between 8 to 45 minutes. In the case of the trammel netter, fish were picked out as the net was hauled. Marketable fish would be retained and unwanted fish discarded over the side. Therefore, fish had minimal exposure to the air. Occasionally, fish may be missed during the hauling process and these would be discarded when the net was flaked (loaded) back in to a net bin.

4.4 Case study 4 - Preliminary results on assessing survival of rays in Eastern Channel trammel net fishery

In all, a total of 11 separate trammel net fishing operations were observed over three consecutive days between 9th and 11th March 2015. A total of 328 thornback ray (*raja clavata*), 58 small-eyed ray (*Raja microcellata*) and 4 blonde ray (*Raja brachyura*) were caught. Thornback rays were selected as the study species due to this being as the most commonly caught ray species in this fishery.

4.4.1 DST deployment on thornback rays

Of the 328 thornback ray caught 60 were tagged with DSTs. A total of 53 were female (mean total length 77 cm ±6 cm) and 7 were male (mean total length 77 cm ±6 cm).

Table 15: DSTs deployed on thornback ray with vigour assessment.

Tagged thornback Ray	Females	Males	Total
Total No.	53	7	60
Length Range cm	68 - 95	70 - 86	68 - 95
Mean Length cm (±STD)	77 (±6)	77 (±6)	77 (±6)
No. assessed 'Excellent'	23	1	24
No. assessed 'Good'	22	4	26
No. assessed 'Poor'	8	2	10

4.4.2 Vitality Assessment

The 60 thornback rays tagged with DSTs were assessed using both the reflex/injury as well as vitality scoring methods (Table 16). Of the 60 thornback rays, 24 (40%) were classified as 'Excellent', 26 (43%) were classified as 'Good' and 10 (17%) were classified as 'Poor'. (Table 15)

A consistently positive 'startle response' was shown by all 60 observed thornback rays, with no obvious impairment. The most commonly observed injuries were net marks (observed in 88%), and abrasion (observed in 68%). Impairments in body flex response were observed in 13% of the observed thornback rays.

In addition to the 60 tagged thornback ray, 173 thornbacks (107 females mean total length 74 cm ±7 cm and 66 males mean total length 71 cm ± 6 cm) were assessed for vigour (Table 17). Of the 173 specimens, 98 (56%) were classified as 'Excellent', 60 (35%) as 'Good', 13 (8%) as 'Poor' and 2 (1%) as 'Dead'. As these fish were contained in on-board water filled tanks from the time they would have been discarded, while other individuals were being tagged, these rays had time to recuperate and so the vigour scores were not directly comparable. This may have been the reason why there was a higher proportion of 'Excellent' fish and lower proportion of 'Good' fish for rays held in the tanks for a short period.

Although not tagged for survivability estimates, vitality assessments were also performed on some of the small eyed rays captured during this trial. Of the 58 small-eyed ray, 21 (36%) (5 females mean total length 81 cm ±4 cm; 16 males mean total length 76 cm ±3 cm) were assessed for vigour. Only 1 fish (5%) was assessed as being 'Excellent', 11 (52%) as 'Good', 6 (29%) as 'Poor' and 3 (14%) as 'Dead'. Compared with thornback ray, the small-eyed ray appeared to show less resilience to capture. The 4 blonde ray (*Raja brachyura*) also captured during the study were retained on the deck and assessed as 'Dead'.

Table 16: DST thornback rays showing an 'impaired' reflex or injury assessment against the vigour assessment score.

	'Vigour' Assessment							
Reflex & injury 'impairments' Observed			No. Assessed Excellent		No. Assessed Good		No. Assessed Poor	
	Total No.	%	No.	%	No.	%	No.	%
'Vigour' Total No.	60	100%	24	40%	26	43%	10	17%
Spiracle Closure	2	4%	1	2%			1	2%
Body Flex	8	13%	0		3	5%	5	8%
Startle Touch	0		0		0		0	
Bleeding	11	19%	1	2%	4	7%	6	10%
Abrasion	41	68%	10	17%	22	37%	9	15%
Wounding	36	60%	9	15%	19	32%	8	13%
Net Marks	53	88%	18	30%	26	43%	9	15%

4.4.3 Initial tag return

As of 30 April 2015, one buoyant Cefas G5 DST has been returned. This tag (ID A10246) related to a female thornback ray (82 cm total length) assessed as 'Excellent' condition prior to discarding. Figure 18 shows the depth recorded at one minute intervals post discard, before the tag became detached after three days. The reason for the tag being released early is unknown but it may be a result of the tagged thornback ray being caught in fishing gear and the tag being disposed back to sea or a malfunction of the tag release system. The tag popped to the surface where it was washed ashore onto a beach off Dungeness and was recovered by a member of the public. Following discarding, the depth data recorded by the DST between 07:30 hrs to 18:00 on 10th March 2015 shows the thornback ray displaying vertical movements between five and eight metres. The thornback ray then moves down to rest on the sea bed until 20:45 hrs that evening where it then returns to characteristic nocturnal foraging behaviour patterns, which occur for the remainder of the individual's time at liberty. Though this is only the first short data series to be returned, it shows some 48 hrs of observed recovery from capture and longer-term survival in the wild, prior to the tag's pop off. The results indicate that the ray was alive and functioning normally for the observation period.

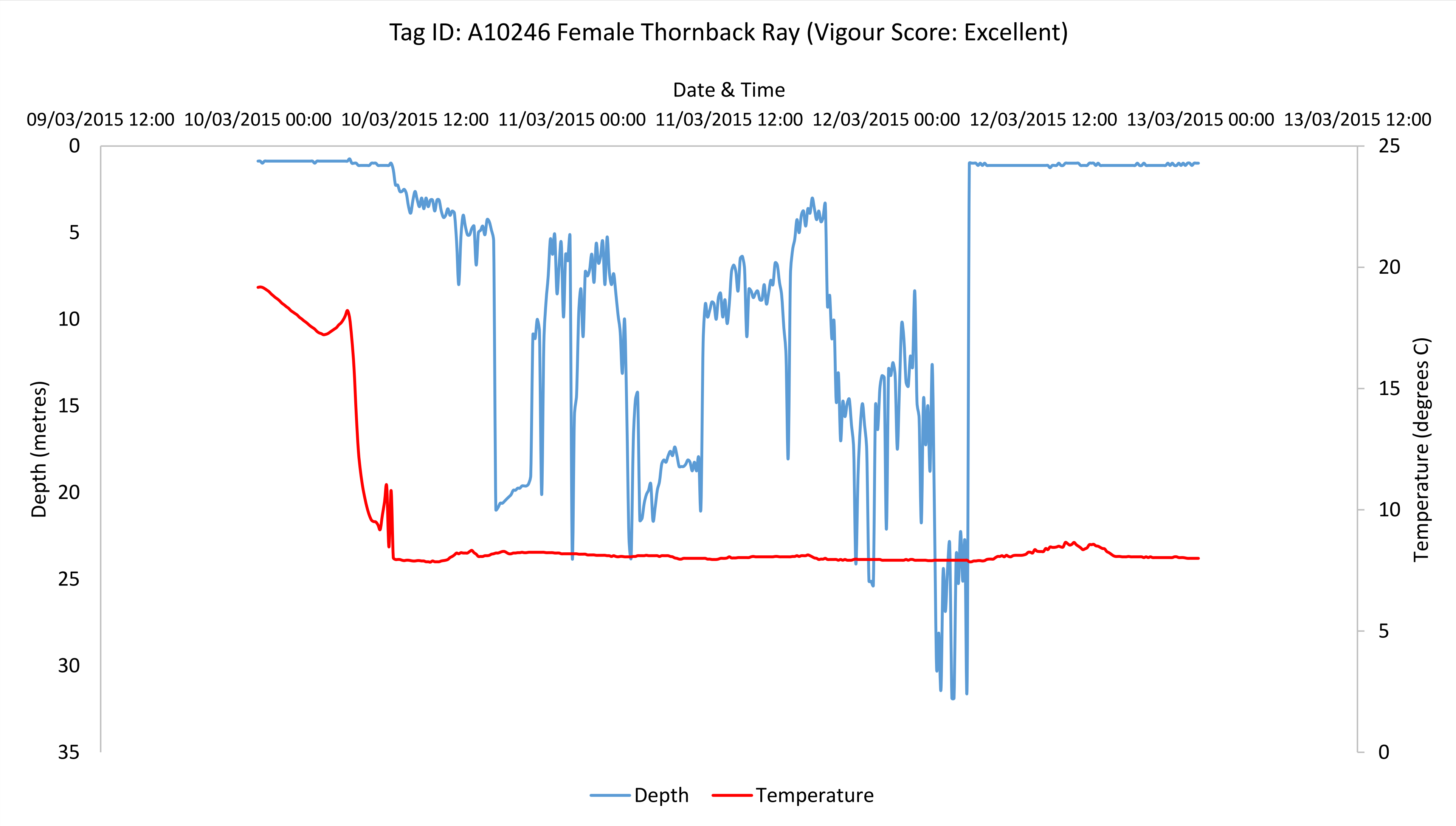
Table 17: Data Summary for ray species observed after capture (excluding tagged thornback ray) from the Eastern Channel trammel net fishery.

Species Observed	Thornback Ray	Small-eyed Ray	Blonde Ray
Area	Eastern Channel	Eastern Channel	Eastern Channel
Gear	Trammel net	Trammel net	Trammel net
Study period	9^{th} – 11^{th} Mar 2015	9^{th} – 11^{th} Mar 2015	9^{th} – 11^{th} Mar 2015
Fishing days	3	3	3
Hauls	11	11	11
Total catch of species observed	328	58	4
Total length range cm	56 - 95	70 – 91	76 - 101
Mean length of species catch cm (±STD)	72 (±7)	78 (±4)	91 (±11)
Vitality assessed from catch No.	173	21	
No. (%) catch assessed as excellent	60 (35%)	1 (5%)	
No. (%) catch assessed as good	98 (56%)	11 (52%)	
No. (%) catch assessed as poor	13 (8%)	6 (29%)	
No. (%) catch assessed as dead	2 (1%)	3 (14%)	

4.4.4 Further analysis

Our expectation is that sufficient tag returns will be made within 12 months of deployment (March 2016) to provide an estimate of long-term discard survival of thornback ray. This will be quantified from the proportion of tags recovered that show normal movement and behaviour for extended periods (weeks and months) after release. This future analysis, and any conclusions drawn, will necessarily fall outside the life time of this project but will be reported in due course as it links with other ongoing research.

Figure 18: Data from 1 returned pop-off DST tag (A10246). Depth record at 1 minute intervals of a female thornback ray (Blue vertical line), depicted against sea surface (Blue horizontal line), assessed as 'excellent' post capture in trammel nets, prior to discard.



5 Discussion

The project delivered its aim to prioritise fisheries and species for investigation and to generate discard survival estimates for selected species for those fisheries. From the prioritisation four case studies were selected, 1) the North Sea mixed demersal otter trawl fishery, 2) the Western Channel mixed demersal otter trawl fishery, 3) the Western Channel mixed demersal beam trawl fishery and 4) the Eastern Channel trammel net fishery. Due to project restrictions (namely time and resources) in each of the four case studies only the highest priority species could be investigated which was plaice in all cases with the exception of case study 4 (English trammel net fishery) where it was also possible to investigate rays. As the survival of rays was assessed using tags rather than captive analysis the results are not yet available (due March 2016). As such this report focuses on the survival estimates derived for plaice.

The structure of the project dictated the method that could be used, and this was developed within the project and in parallel with the ICES Workshop on Methods to Estimate Discard Survival (WKMEDS). Therefore, this project has provided a testing ground for the methods and concepts developed from that ICES group and observations from the project have fed back to improve the guidance on how best to conduct these experiments. The approach selected was to use vitality assessments during a representative range of conditions and combining this with the captive observation of individuals with different vitality levels to generate an overall weighted mean discard survival estimate.

5.1 Interpretation of the results

The selected method limits the conclusions that can be made from the results. These are presented as experimental estimates within a defined observation period and modelled results, which account for all predicted mortalities associated with the treatment irrespective of time. The experimental results gave weighted mean discard survival estimates for plaice of 42.0% for the North Sea otter fishery (105-120h); 64.4% for the Western Channel otter trawl (66-133h); 37.3% for the Western Channel beam trawl (38-72h) and 72.9% in the Eastern Channel trammel net fishery (168-342h). The models predicted discard mortality had virtually ceased during the observation period in the Western Channel otter trawl and Eastern Channel trammel net fisheries were the modelled discard survival estimates were 47.1-62.8% and 71.1-71.9% respectively. In the other two studies the models indicated that further mortality was likely beyond the observation period. Discard survival estimates of 18.8-20% for the North Sea otter trawl and 4-15.2% in the Western Channel beam trawl fishery were predicted.

There are two main factors to consider with these survival estimates. Firstly, all estimates describe discard survival including avian predation but excluding other marine predation. There is some evidence both from this and two other simultaneously conducted studies in Welsh fisheries (Sam Smith et al, unpubl.) that avian predation of plaice discards in UK otters trawl and trammel net fisheries is negligible. These results could therefore be assumed to overestimate total survival.

Secondly, any experimental induced mortality may cause survival rates to be underestimated. The stressors associated with the captive observation method included additional handling, moving the fish to on-board tanks, vehicles and then to on-shore tanks lead to changes in water temperature and reducing dissolved oxygen levels. It was not possible to use control fish to identify experimental induced mortalities. The control test of the on-shore tanks demonstrated that there was no discernible effect on the health of ''Excellent'' fish while the unit was functioning. To have used genuine controls throughout the project would have meant taking a different batch of fish that were comparable to the treatment fish (species, size, condition etc.) that had not undergone the catch and discard process, to sea on each day of fishing. This was practically not possible. However, the survival of 'Excellent' fish stabilised at 90.2% in one case study (Western Channel otter trawl). Therefore, had there been no mortality associated with the catch and discard process for these fish the maximum experimental effect would have been 9.8%. In this study, as well as the treatment effect (being caught by an otter trawler) there was also failure to provide continuous water supply to the onshore observation tanks as well as substantial daily changes in water temperature (more so than in the other studies). These factors may have caused some mortality but, given the final survival estimate, it suggests that there was a very low level of experimental induced mortality from the on-shore tanks.

There is less information on the effect of survival of other aspects of the methods. There was some indication that the location of fish within the stack of the on-board tanks may have effected survival. On some occasions those fish held for the longest period (in the bottom stack of the tanks) showed lower survival rates. Similarly, stressors of handling and reducing dissolved oxygen were most acute during transfer operations. It seems likely that there was some experimental induced mortality. Had controls been used, and had some of those fish not survived, with current accepted analytical methods all that could be concluded is that there was some unknown level of experimental mortality. If we accept that this was true in this project then the results presented here should be interpreted as minimum estimates of discard survival, including avian predation, but excluding other marine predation. Moreover, the stressors exerted on the fish in the method described here, including temperature differences, handing, confinement, proximity with other fish, dissolved oxygen depletion, all indicate that plaice is a resilient and robust species of fish.

In the Western Channel beam trawl study an alternative method was used to access survival due to the fishing practices (i.e. not daily landings). In this case the captive analysis was conducted on board (not onshore) and therefore different on board holding tanks were used. For this study there was no control to evidence experimental mortality and so there is less certainty over the results. It is possible that some method induced mortality resulted in lower survival rates relative to the other studies, however two observations suggest that any method induced mortality was no higher for this study than for the other studies. Firstly, the most frequently assessed condition of fish at the point of discarding in the other three studies was 'Excellent' while in this beam trawl study it was 'Poor'. Therefore, outside of the captive observation experiment there was a strong indication that survival would be lower in this study compared with the other studies. Secondly, the survival rates for fish with different vitalities in beam trawl study were comparable and within the range of the other studies, i.e. a similar proportion of 'Excellent', 'Good', 'Poor' and 'Moribund' fish died in captive observation.

This project has shown that observers can consistently visually assess the health status of fish within a fishery, and that the health status relates significantly to its probability of survival. In all four studies the better the health status the higher the survival; and there was a significant difference in the probability of survival between vitalities in most cases. This provides strong validation for this integrated method. The survival of fish assessed as being in 'Excellent' condition within the observation periods ranged for 63.5% to 90.2% across the four studies. The differences between studies may be due to the different stresses exerted on the fish in the each study or due to differences in how observers categorised the fish. There is the possibility that an observer effect was present, for example, a fish assessed as 'Excellent' by one observer could be categorised as 'Good' by another. Attempts were made to minimise observer bias through consistent training and having two observers each overseeing two studies.

It would be worthwhile to conduct further work to test the level of consistency between observers. Particularly, if vitality data collection became part of ongoing fisheries monitoring programmes, which is conceivable with the introduction of exemptions from the landing obligation. However, in this project any observer effect will not have affected the final survival estimates. For each study the vitality assessments were made by the same individuals, therefore, the vitality of those fish selected for captive observation were assessed by the same observers as the rest of catch. Only when vitality assessments of fish which are selected for captive observation, are used in combination with fish assessed by different observers is there a potential for bias. This suggests that there is a risk of bias if the captive observation results from one study were used to estimate survival from vitality assessments made in another study.

5.2 How representative are the discard survival estimates?

One strength of the method applied in this project is that the survival estimates are based on the total catch in all the conditions encountered during all observed trips. In our opinion, and based upon feedback from the industry involved, the presence of observers on board the vessel did not influence the catch and handling process, so the stressors exerted on the fish were consistent with normal commercial fishing practice.

Therefore, the survival estimates are representative of the observed trips. Beyond that, assumptions must be made to extrapolate the data. To use the results as a basis to estimate discard survival at the vessel level assumes that the conditions encountered during the observed trips included all that are encountered by the vessel. As the fieldwork in these studies was conducted during relatively short periods for each case study extrapolating to the vessel level would assume the absence of any seasonal effect (e.g. catch composition, environmental effects, fish condition). Survival rates have been shown to change as conditions in the fishery change (e.g. seasons, areas fished)(Benoit et al. 2012). Further, to extrapolate from vessel to fleet level would assume that if there are any technical differences between vessels it does not affect survival. These may relate to differences in fishing gear design, fishing operation, sorting and handling practices between the vessels in the fishery.

Having now estimated the survival probabilities for plaice in different vitality states in each fishery it would be possible to assess the variation in vitality profile of the plaice caught by different vessels and at different times to generate a fleet-wide discard survival estimate. This would require the collection of more vitality data from different vessels within the fishery and at different time periods. This vitality data could be converted into a discard survival estimate using the results from the captive observation experiments. This approach assumes that the stressors that are exerted on the fish which effect the vitality of the fish remain the same.

There are few other studies conducted on plaice which provide robust estimates of discard survival. Moreover, in recognition of the varied methods and results reported in these studies a critical review is being undertaken by ICES WKMEDS to enable analyses from different studies to be comparable. To avoid pre-empting this review here we only make reference to the two most relevant and recently conducted studies by Revill et al. (2013) and Depestele et al. (2014) which have both reported survival rates of plaice discarded from beam trawlers. In the Western Channel, Revill et al. used a similar method to the one used here, by combining the results of captive observation (120 fish for 72 h) with estimates of immediate mortality. The equivalent estimated survival rate for plaice was 20.3% in February, 25.6% in March, and 56.8% in May (Revill et al. 2013). This compares closely with the estimate from the same fishery, during November to February, in this study of 37.3% (26.9-47.2%). A study in a southern North Sea beam trawl fishery, also using a captive observation method (88 plaice for 77 h), demonstrated 48% survival in the period from November to December This is at the higher end of the range estimated in this study. The reasons for this difference cannot be determined. In neither of these previous studies were the results modelled to account for mortalities that may have occurred beyond the observation period. Also, in both studies the rate of mortality had not notably stabilised or slowed suggesting that the survival rate was likely to be lower following a longer observation period. There have been no reported studies on the discard survival of plaice from trammel netters and only one from an otter trawler, conducted more than 35 years ago, and so not relevant.

5.3 Factors that affect discard survival

There is considerable scope to develop the analytical methods for survivability studies, for example, by including confidence intervals for the extension model survival estimates. Similarly, the data collected provides a valuable resource to extend the analysis of factors influencing discard survival. The analysis applied to case study 1 could be applied to all case studies in this project to investigate similarities in factors which are shown to influence survival rates. Moreover, combining the data sets from these studies, and with other comparable studies, would increase the statistical power to draw conclusions, improve precision, and could answer questions not addressed by the original studies. This method of meta-analysis is currently being developed within ICES WKMEDS.

There are a number of factors that are known to affect the survival of discarded fish and these can be classified into three broad categories: technical (e.g. fishing method, catch size and composition, handling practices on deck), environmental (e.g. changes in temperature, depth, light conditions) and biological (e.g. species, size age, physical condition) (Davis 2002, Broadhurst et al. 2006).

The results from this project indicate that the type of fishing method is an important factor effecting survival. All fishing methods induce stress and cause a degree of injury to captured fish (e.g. internal and external wounding, crushing and scale loss). The higher levels of plaice survival in the Eastern Channel trammel net study reflected the health condition of the fish at the point of discarding and the relatively low level of injury and reflex impairment. These fish, which are caught by a passive fishing method, appear to have been subjected to less stress compared with those caught by active trawl capture methods and therefore had fewer and different injuries. There was a lower incidence of abrasion, net marks and scale loss in plaice caught with the trammel net. With the towed gears, fish are stimulated to move from the bottom by the bridles/sweeps/footrope in otter trawls or chain mats/tickler chains in beam trawls before being herded in front of the trawl and then dropping back into the trawl when the fish tire and are contained in the cod-end. This process of trawling appears to induce different injuries, including scale loss which was a common injury and associated with increased mortality in the trawl fishery studies.

It has been noted that the longer the fish are exposed to the fishing gear the more severe the stress, leading to exhaustion and increased physical damage (Davis 2002). Because the aim of this project was to generate estimates under normal commercial conditions the tow and soak times did not vary sufficiently to identify any effect. Between studies, the exposure to the gear was least in the beam trawl study (up to 2 hrs) which on average had the lowest level of survival. Exposure to gear was highest for the trammel net fishery (up to 48 hrs) which had the highest levels of survival. Although we cannot draw conclusions on the impact of tow/soak time, we can state that the method of capture is a major determinant of survival.

There was substantial variation in survival between plaice caught by different trawlers. The proximity of the Western Channel studies, occurring during the same four month period and in the same or neighbouring ICES rectangles, would suggest that it was the fishing method that had most influence on the survival, rather than environmental of biological conditions. However, the specific locations for tows were different and the depths of fishing by the otter trawler (31-46 m) were significantly shallower than for the beam trawler (57-73 m). Depth has been shown to influence survival chances of discarded fish (Milliken et al. 2011, Benoit et al. 2013), and may have been a factor here. The depth range for the other studies was 9-18m for the trammel net fishery and 49-90 m for the North Sea otter trawl fishery. Although the depth range in the NS otter trawl study was relatively large it was not identified as having a significant influence on the vitality of fish.

It is difficult to explain the difference in survivability between the two otter trawl studies. The trawl designs used were different, with a much longer footrope used in the North Sea study. There was also a difference in the timing of the studies with the North Sea study occurring in Autumn, at which point the temperature at the sea surface and in the holding tanks was higher (11.7-16 °C) compared with the Western Channel otter trawl study which was conducted in Winter (3-8.5 °C). Temperature has been identified as an important factor effecting survival, with high temperatures of the water associated with lower rates of survival for several species of fish (ICES 2014). The condition of the fish prior to catching and the composition of the catches may also have had an effect. There was also a slight difference in the experimental method between the two studies with fish having to be transported by vehicle to the holding tanks in the North Sea study. However, the mortality rates were comparable at the beginning of the observation period but unlike in the Western Channel, the North Sea results, did not stabilise after the first couple of days.

Another difference between these studies was in the sorting and handling practices on-board. Exposure to air is an integral part of fish capture and is directly related to the sorting and handling times on deck. Previous studies have shown that air exposure is one of the greatest contributors to discard mortality rates (Davis 2002, Broadhurst et al. 2006) and that reducing handling time and exposure to air could be a useful measure to increase discard survival (Benoit et al. 2010). This was also indicated in the analysis for the North Sea otter trawl study, where the proportion of 'Excellent' fish was larger for hauls that took less time to sort. On both otter trawlers sorting of the catch was done after the otter trawls had been shot back and took a comparable amount of time, 10 to 60 minutes in both cases, suggesting that exposure time itself may not have been the cause of the difference between the studies.

The operation method of sorting the catch was different between the two otter trawl studies. On-board the Western Channel otter trawler, the cod-end opened onto the deck and the discards were pushed out of the scupper after the marketable fish were picked up. On the North Sea otter trawler, the cod-end emptied into a hopper and batches of the catch were sorted, with discards discharged periodically down a chute. Sorting differences may have an effect on survival, but further investigation to test the different methods during the same haul would be required to determine this. In the case of the trammel netter, most fish were picked out as the net was hauled from the water and unwanted fish discarded instantly back to the sea. Therefore, fish had minimal exposure to the air, providing another possible reason why survival was highest in this study.

A common observation of survival studies is the large number of variables that have the potential to effect survival and the relatively low sample number of fish from which survival or death is directly observed (ICES 2014). This makes it difficult to identify influencing variables and understand how they interact. For example, the size and composition of the catch will likely be an influencing factor, and this may be influenced by weather conditions, both of which will influence the stresses associated with sorting the catch. With so many interacting variables it is difficult to tease apart their relative importance. This is exacerbated when comparing across studies of different fisheries, conducted in different places, at different times, in which a different suite of stresses are exerted on the fish. Sampling the level of reflex impairment, injury and vitality as part of an ongoing observer programme would likely be necessary to understand the relative importance of these factors. The ICES WKMEDS, have discussed using a fuzzy-logic approach or Bayesian statistics to identify key influencing variables.

In general, the findings from this project support the report from ICES WKMEDS (ICES 2014) in that the key influencing variables are gear type and configuration, handling, water temperature, exposure, injury, depth and air temperature. Other factors identified as influencing variables but not analysed here include deployment duration and body size. To mitigate against environmental variables, would require limiting fishing opportunities to particular conditions, a strategy that is unlikely to be practicable. Therefore, changing the gear type, operational practice and sorting practices offer more potential to increase the survival rates of discarded fish. This could include, using gear designs that reduce injury and stress, having shorter tow or soak times, or complying with a code of good practice for handling and discarding species so that air exposure, handling and time before the fish are released back to the sea are all minimised.

6 Conclusions

The project achieved its aim to prioritise fisheries and species for investigation and to generate discard survival estimates for selected species for those fisheries. Better health condition of plaice was significantly associated with higher survival, validating the integrated method of combining the assessed vitality of fish from the catch with the survival probability associated with those vitalities. The project generated both experimental estimates within a defined observation period, and modelled results to account for predicted mortalities beyond the observation period.

The experimental results gave weighted mean discard survival estimates for plaice of 42% for the North Sea otter trawl fishery (observation period 105-120 h); 64.4% for the Western Channel otter trawl (66-133 h); 37% for the Western Channel beam trawl (38-72 h) and 73% in the Eastern Channel trammel net fishery (168-342 h). The models predicted similar survival estimates for the Western Channel otter trawl (47-63%) and the trammel net fishery (71-72%). In the other two studies the models indicated that further mortality was likely beyond the observation period, predicting discard survival estimates of 19-20% for the North Sea otter trawl and 4-15% in the Western Channel beam trawl fishery.

Based on experimental observation, there was no evidence of avian predation, therefore the estimates can be considered to include avian predation but exclude other predation. Furthermore, the stressors exerted on the fish from the method, including temperature differences, handling, confinement, proximity to other fish, and dissolved oxygen depletion, were likely to have induced some experimental mortality. Therefore, the results presented here should be interpreted as minimum estimates of discard survival, including avian predation but excluding other marine predation.

Some initial analysis of the factors that influence survival showed that lower survival was associated with higher wind strength and longer catch sorting times. There were many factors with the potential to effect survival and the relatively low sample number of fish from which survival or death is directly observed makes it difficult to identify the key influencing variables. In general, the findings from this project were in agreement with other studies indicating that gear type, handling, air/water temperature and exposure are likely to be important variables. Other statistical techniques could be usefully applied to better understand the influencing factors.

The survival estimates generated here are representative of the observed trips. Assumptions must be made to extrapolate the data to vessel and fleet level. However, this evidence is considered to provide scientifically robust estimates of discard survival and will inform fisheries managers of the appropriateness and potential to propose exemptions from the European landing obligation, under the high survivability provision.

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9 Annexes

Annex 1: Criteria used to assign scores to species - fishery combinations in the prioritisation method

Criteria/ attributes	High risk (score = 3)	Medium risk (score = 2)	Low risk (score = 1)
Biological			
Robustness	Characterised by: presence of swim bladder, small maximum length (<50 cm), inhabits deep waters (>200 m)	Characterised by: medium maximum length (50-100 cm), inhabits medium depth (50-200 m)	Characterised by: lack of swim bladder, large maximum length (> 100 cm), inhabiting shallow depths (<50 m)
Population			
Fishing pressure	Low. Indicated by F < Fpa, low or declining trend in F or catch advice for increase in catches.	Medium. Indicated by F > Fpa, < Flim, stable or unknown trend where catch advice is for no change in catch.	High. Indicated by F > F lim or increasing trend where catch advice is for a reduction in catch.
Stock size	High. Indicated by > Bpa or increasing trend, classified as 'least concern' by IUCN classification.	Medium. B > Blim, < Bpa, stable trend or unknown. Classified as 'vulnerable', 'threatened' or 'unknown' by IUCN classification	B < Blim, or decreasing trend. Classified as 'endangered' or 'critically endangered' by IUCN classification.
Fishery			
Gear type	High risk. Characterized by either long soak (>48 hrs) or haul times (>5 hrs), alternatively by the use of heavy towed gears.	Medium risk. Characterized by either moderate soak times (eg 24 hrs) or moderate haul times (eg 2-3 hrs).	Low risk. Characterized by short soak or haul times (<1 hour), alternatively by the use of light towed gears.
Discard levels	Low discards of undersized fish in fishery. In lowest 1/3 of species-fishery considered based on Cefas observer programme (2012)	Medium discards of undersized fish in fishery. In middle 1/3 of species-fishery considered based on Cefas observer programme (2012)	High discards of undersized fish in fishery. In highest 1/3 of species-fishery considered based on Cefas observer programme (2012)
Economic value	Low value. In lowest 1/3 of species-fishery considered based on landings data (MMO, 2013)	Medium value. In middle 1/3 of species-fishery considered based on landings data (MMO, 2013)	High value. In highest 1/3 of species-fishery considered based on landings data (MMO, 2013)

Annex 2. Final results from priorisation matrix. Species-area fishery combinations with rank 1-10 have been annotated with their associated species.

Scientific name	Common name	Species group	Area	Fishery	Biological score	Population score	Fishery score	Discard Score	Economic value score	ASSIST score	Overall score	Rank	Associated species?
Raja undulata	Undulate ray	E	4&7d	Gill_Trammel_nets_u10m	3	3.6	3	3	3	3	18.6	1	Sole, plaice
Raja undulata	Undulate ray	E	4&7d	Otter_trawl_u10m	3	3.6	3	2	3	3	17.6	2	Sole, plaice
Solea solea	Common sole	B	4&7d	Otter_trawl_u10m	3	2.5	3	3	3	3	17.5	3	Skates and rays, plaice
Solea solea	Common sole	B	4&7d	Gill_Trammel_nets_u10m	3	2.5	3	3	3	3	17.5	4	Skates and rays
Pleuronectes platessa	Plaice	B	7bc,e-k	Otter_trawl_o10m	3	2	3	3	3	3	17	5	anglerfish
Pleuronectes platessa	Plaice	B	7bc,e-k	Otter_trawl_u10m	3	2	3	3	3	3	17	6	
Pleuronectes platessa	Plaice	B	4&7d	Otter_trawl_u10m	3	1.6	3	3	3	3	16.6	7	skates and rays, sole
Pleuronectes platessa	Plaice	B	4&7d	Otter_trawl_o10m	3	1.6	3	3	3	3	16.6	8	sole, skates and rays
Pleuronectes platessa	Plaice	B	4&7d	Nephrops_trawl_o10m	3	1.6	3	3	3	3	16.6	9	skates and rays, sole
Pleuronectes platessa	Plaice	B	4&7d	Nephrops_trawl_u10m	3	1.6	3	3	3	3	16.6	10	skates and rays, sole
Raja undulata	Undulate ray	E	4&7d	Beam_trawl_DEF_o10m	3	3.6	2	2	3	3	16.6	11	
Pleuronectes platessa	Plaice	B	4&7d	Gill_Trammel_nets_u10m	3	1.6	3	3	3	3	16.6	12	
Solea solea	Common sole	B	4&7d	Beam_trawl_DEF_o10m	3	2.5	2	3	3	3	16.5	13	
Solea solea	Common sole	B	4&7d	Otter_trawl_o10m	3	2.5	3	2	3	3	16.5	14	
Gadus morhua	Cod	D	7a	Nephrops_trawl_u10m	2	6	3	2	2	1	16	15	
Raja clavata	Thornback ray	E	4&7d	Otter_trawl_u10m	3	1	3	3	3	3	16	16	
Pleuronectes platessa	Plaice	B	7bc,e-k	Beam_trawl_DEF_o10m	3	2	2	3	3	3	16	17	
Raja clavata	Thornback ray	E	4&7d	Gill_Trammel_nets_u10m	3	1	3	3	3	3	16	18	
Raja montagui	Spotted ray	E	4&7d	Otter_trawl_u10m	3	0.8	3	3	3	3	15.8	19	
Pleuronectes platessa	Plaice	B	4&7d	Beam_trawl_DEF_o10m	3	1.6	2	3	3	3	15.6	20	
Pleuronectes platessa	Plaice	B	4&7d	Beam_trawl_CRU_o10m	3	1.6	2	3	3	3	15.6	21	
Raja brachyura	Blonde ray	E	4&7d	Beam_trawl_DEF_o10m	3	1.6	2	3	3	3	15.6	22	
Leucoraja naevus	Cuckoo ray	E	4&7d	Otter_trawl_u10m	3	1.6	3	2	3	3	15.6	23	
Leucoraja naevus	Cuckoo ray	E	4&7d	Nephrops_trawl_o10m	3	1.6	3	2	3	3	15.6	24	
Leucoraja naevus	Cuckoo ray	E	4&7d	Otter_trawl_o10m	3	1.6	3	2	3	3	15.6	25	
Leucoraja naevus	Cuckoo ray	E	4&7d	Nephrops_trawl_u10m	3	1.6	3	2	3	3	15.6	26	
Raja brachyura	Blonde ray	E	4&7d	Otter_trawl_o10m	3	1.6	3	2	3	3	15.6	27	
Leucoraja naevus	Cuckoo ray	E	4&7d	Gill_Trammel_nets_u10m	3	1.6	3	2	3	3	15.6	28	
Solea solea	Common sole	B	4&7d	Beam_trawl_CRU_o10m	3	2.5	2	2	3	3	15.5	29	
Solea solea	Common sole	B	4&7d	Nephrops_trawl_o10m	3	2.5	3	1	3	3	15.5	30	
Solea solea	Common sole	B	4&7d	Nephrops_trawl_u10m	3	2.5	3	1	3	3	15.5	31	
Pleuronectes platessa	Plaice	B	7a	Nephrops_trawl_o10m	3	1.2	3	3	2	3	15.2	32	
Pleuronectes platessa	Plaice	B	7a	Nephrops_trawl_u10m	3	1.2	3	3	2	3	15.2	33	
Pleuronectes platessa	Plaice	B	7a	Otter_trawl_o10m	3	1.2	3	3	2	3	15.2	34	
Pleuronectes platessa	Plaice	B	7a	Otter_trawl_u10m	3	1.2	3	3	2	3	15.2	35	
Gadus morhua	Cod	D	4&7d	Otter_trawl_o10m	2	3	3	3	3	1	15	36	
Gadus morhua	Cod	D	4&7d	Nephrops_trawl_o10m	2	3	3	3	3	1	15	37	
Gadus morhua	Cod	D	4&7d	Otter_trawl_u10m	2	3	3	3	3	1	15	38	
Solea solea	Common sole	B	7a	Nephrops_trawl_o10m	3	5	3	1	2	1	15	39	

Scientific name	Common name	Species group	Area	Fishery	Biological score	Population score	Fishery score	Discard Score	Economic value score	ASSIST score	Overall score	Rank	Associated species?
Solea solea	Common sole	B	7a	Nephrops_trawl_u10m	3	5	3	1	2	1	15	40	
Solea solea	Common sole	B	7a	Otter_trawl_o10m	3	5	3	1	2	1	15	41	
Gadus morhua	Cod	D	7a	Nephrops_trawl_o10m	2	6	3	1	2	1	15	42	
Gadus morhua	Cod	D	7a	Otter_trawl_o10m	2	6	3	1	2	1	15	43	
Gadus morhua	Cod	D	4&7d	Gill_Trammel_nets_u10m	2	3	3	3	3	1	15	44	
Lophiidae	Anglerfish	B	7bc,e-k	Otter_trawl_o10m	3	1	3	3	3	2	15	45	
Microstomus kitt	Lemon sole	B	4&7d	Nephrops_trawl_o10m	3	1	3	3	3	2	15	46	
Microstomus kitt	Lemon sole	B	4&7d	Otter_trawl_u10m	3	1	3	3	3	2	15	47	
Microstomus kitt	Lemon sole	B	4&7d	Otter_trawl_o10m	3	1	3	3	3	2	15	48	
Raja clavata	Thornback ray	E	4&7d	Beam_trawl_DEF_o10m	3	1	2	3	3	3	15	49	
Lophiidae	Anglerfish	B	7bc,e-k	Gill_Trammel_nets_u10m	3	1	3	3	3	2	15	50	
Raja clavata	Thornback ray	E	4&7d	Otter_trawl_o10m	3	1	3	2	3	3	15	51	
Raja clavata	Thornback ray	E	4&7d	Nephrops_trawl_u10m	3	1	3	2	3	3	15	52	
Raja clavata	Thornback ray	E	4&7d	Nephrops_trawl_o10m	3	1	3	2	3	3	15	53	
Solea solea	Common sole	B	7bc,e-k	Gill_Trammel_nets_u10m	3	2	3	1	3	3	15	54	
Pleuronectes platessa	Plaice	B	7bc,e-k	Gill_Trammel_nets_u10m	3	2	3	1	3	3	15	55	
Raja montagui	Spotted ray	E	4&7d	Otter_trawl_o10m	3	0.8	3	2	3	3	14.8	56	
Raja montagui	Spotted ray	E	4&7d	Nephrops_trawl_u10m	3	0.8	3	2	3	3	14.8	57	
Raja montagui	Spotted ray	E	4&7d	Gill_Trammel_nets_u10m	3	0.8	3	2	3	3	14.8	58	
Pleuronectes platessa	Plaice	B	4&7d	Beam_trawl_CRU_u10m	3	1.6	2	2	3	3	14.6	59	
Raja brachyura	Blonde ray	E	4&7d	Otter_trawl_u10m	3	1.6	3	1	3	3	14.6	60	
Raja brachyura	Blonde ray	E	4&7d	Nephrops_trawl_o10m	3	1.6	3	1	3	3	14.6	61	
Solea solea	Common sole	B	4&7d	Beam_trawl_CRU_u10m	3	2.5	2	1	3	3	14.5	62	
Nephrops norvegicus	Norway lobster	C	4&7d	Nephrops_trawl_o10m	3	2.4	3	2	3	1	14.4	63	
Nephrops norvegicus	Norway lobster	C	4&7d	Nephrops_trawl_u10m	3	2.4	3	2	3	1	14.4	64	
Nephrops norvegicus	Norway lobster	C	4&7d	Otter_trawl_o10m	3	2.4	3	2	3	1	14.4	65	
Merlangius merlangus	Whiting	D	4&7d	Nephrops_trawl_o10m	1.5	2.8	3	3	3	1	14.3	66	
Merlangius merlangus	Whiting	D	4&7d	Otter_trawl_o10m	1.5	2.8	3	3	3	1	14.3	67	
Merlangius merlangus	Whiting	D	4&7d	Nephrops_trawl_u10m	1.5	2.8	3	3	3	1	14.3	68	
Merlangius merlangus	Whiting	D	4&7d	Otter_trawl_u10m	1.5	2.8	3	3	3	1	14.3	69	
Merlangius merlangus	Whiting	D	7a	Nephrops_trawl_o10m	1.5	4.8	3	3	1	1	14.3	70	
Merlangius merlangus	Whiting	D	4&7d	Gill_Trammel_nets_u10m	1.5	2.8	3	3	3	1	14.3	71	
Gadus morhua	Cod	D	7bc,e-k	Otter_trawl_u10m	2	2.2	3	3	3	1	14.2	72	
Gadus morhua	Cod	D	7bc,e-k	Otter_trawl_o10m	2	2.2	3	3	3	1	14.2	73	
Gadus morhua	Cod	D	7bc,e-k	Gill_Trammel_nets_u10m	2	2.2	3	3	3	1	14.2	74	
Gadus morhua	Cod	D	4&7d	Beam_trawl_DEF_o10m	2	3	2	3	3	1	14	75	
Gadus morhua	Cod	D	4&7d	Gill_Trammel_nets_o10m	2	3	2	3	3	1	14	76	
Gadus morhua	Cod	D	4&7d	Nephrops_trawl_u10m	2	3	3	2	3	1	14	77	
Solea solea	Common sole	B	7a	Otter_trawl_u10m	3	5	3	0	2	1	14	78	
Lophiidae	Anglerfish	B	7bc,e-k	Beam_trawl_DEF_o10m	3	1	2	3	3	2	14	79	

Scientific name	Common name	Species group	Area	Fishery	Biological score	Population score	Fishery score	Discard Score	Economic value score	ASSIST score	Overall score	Rank	Associated species?
Lophiidae	Anglerfish	B	7bc,e-k	Gill_Trammel_nets_o10m	3	1	2	3	3	2	14	80	
Microstomus kitt	Lemon sole	B	4&7d	Nephrops_trawl_u10m	3	1	3	2	3	2	14	81	
Solea solea	Common sole	B	7bc,e-k	Beam_trawl_DEF_o10m	3	2	2	2	3	2	14	82	
Solea solea	Common sole	B	7bc,e-k	Otter_trawl_o10m	3	2	3	1	3	2	14	83	
Solea solea	Common sole	B	7bc,e-k	Otter_trawl_u10m	3	2	3	1	3	2	14	84	
Solea solea	Common sole	B	7bc,e-k	Gill_Trammel_nets_o10m	3	2	2	1	3	3	14	85	
Pleuronectes platessa	Plaice	B	7bc,e-k	Gill_Trammel_nets_o10m	3	2	2	1	3	3	14	86	
Melanogrammus aeglefinus	Haddock	D	4&7d	Nephrops_trawl_o10m	2	1.9	3	3	3	1	13.9	87	
Limanda limanda	Common dab	B	4&7d	Otter_trawl_u10m	3	0.9	3	3	3	1	13.9	88	
Limanda limanda	Common dab	B	4&7d	Nephrops_trawl_o10m	3	0.9	3	3	3	1	13.9	89	
Melanogrammus aeglefinus	Haddock	D	4&7d	Otter_trawl_o10m	2	1.9	3	3	3	1	13.9	90	
Limanda limanda	Common dab	B	4&7d	Nephrops_trawl_u10m	3	0.9	3	3	3	1	13.9	91	
Limanda limanda	Common dab	B	4&7d	Otter_trawl_o10m	3	0.9	3	3	3	1	13.9	92	
Melanogrammus aeglefinus	Haddock	D	4&7d	Otter_trawl_u10m	2	1.9	3	3	3	1	13.9	93	
Limanda limanda	Common dab	B	4&7d	Gill_Trammel_nets_u10m	3	0.9	3	3	3	1	13.9	94	
Melanogrammus aeglefinus	Haddock	D	7bc,e-k	Otter_trawl_o10m	2	1.8	3	3	3	1	13.8	95	
Melanogrammus aeglefinus	Haddock	D	7bc,e-k	Otter_trawl_u10m	2	1.8	3	3	3	1	13.8	96	
Lepidorhombus spp.	Megrims	B	7bc,e-k	Beam_trawl_DEF_o10m	3	1.8	2	3	3	1	13.8	97	
Raja montagui	Spotted ray	E	4&7d	Beam_trawl_DEF_o10m	3	0.8	2	2	3	3	13.8	98	
Lophiidae	Anglerfish	B	4&7d	Nephrops_trawl_o10m	3	1.6	3	2	3	1	13.6	99	
Lophiidae	Anglerfish	B	4&7d	Otter_trawl_o10m	3	1.6	3	2	3	1	13.6	100	
Lophiidae	Anglerfish	B	4&7d	Otter_trawl_u10m	3	1.6	3	2	3	1	13.6	101	
Lophiidae	Anglerfish	B	4&7d	Gill_Trammel_nets_u10m	3	1.6	3	2	3	1	13.6	102	
Pleuronectes platessa	Plaice	B	4&7d	Gill_Trammel_nets_o10m	3	1.6	2	1	3	3	13.6	103	
Raja brachyura	Blonde ray	E	4&7d	Gill_Trammel_nets_u10m	3	1.6	3	0	3	3	13.6	104	
Molva molva	Ling	D	4&7d	Otter_trawl_o10m	2	2.4	3	3	2	1	13.4	105	
Nephrops norvegicus	Norway lobster	C	4&7d	Otter_trawl_u10m	3	2.4	3	1	3	1	13.4	106	
Molva molva	Ling	D	7bc,e-k	Gill_Trammel_nets_u10m	2	2.4	3	3	2	1	13.4	107	
Pollachius pollachius	Pollack	D	7bc,e-k	Gill_Trammel_nets_u10m	2	2.4	3	2	3	1	13.4	108	
Merlangius merlangus	Whiting	D	4&7d	Beam_trawl_DEF_o10m	1.5	2.8	2	3	3	1	13.3	109	
Merlangius merlangus	Whiting	D	4&7d	Beam_trawl_CRU_o10m	1.5	2.8	2	3	3	1	13.3	110	
Merlangius merlangus	Whiting	D	7a	Otter_trawl_o10m	1.5	4.8	3	2	1	1	13.3	111	
Merlangius merlangus	Whiting	D	7a	Nephrops_trawl_u10m	1.5	4.8	3	2	1	1	13.3	112	
Gadus morhua	Cod	D	7bc,e-k	Gill_Trammel_nets_o10m	2	2.2	2	3	3	1	13.2	113	
Gadus morhua	Cod	D	7bc,e-k	Beam_trawl_DEF_o10m	2	2.2	2	3	3	1	13.2	114	
Trachurus spp.	Horse mackerel	P	7bc,e-k	Otter_trawl_u10m	1	3	3	2	3	1	13	115	
Pollachius pollachius	Pollack	D	4&7d	Otter_trawl_o10m	2	3	3	2	2	1	13	116	
Microstomus kitt	Lemon sole	B	4&7d	Beam_trawl_DEF_o10m	3	1	2	2	3	2	13	117	
Microstomus kitt	Lemon sole	B	4&7d	Beam_trawl_CRU_o10m	3	1	2	2	3	2	13	118	
Lophiidae	Anglerfish	B	7bc,e-k	Otter_trawl_u10m	3	1	3	1	3	2	13	119	

Scientific name	Common name	Species group	Area	Fishery	Biological score	Population score	Fishery score	Discard Score	Economic value score	ASSIST score	Overall score	Rank	Associated species?
Microstomus kitt	Lemon sole	B	4&7d	Gill_Trammel_nets_u10m	3	1	3	1	3	2	13	120	
Limanda limanda	Common dab	B	4&7d	Beam_trawl_DEF_o10m	3	0.9	2	3	3	1	12.9	121	
Melanogrammus aeglefinus	Haddock	D	4&7d	Nephrops_trawl_u10m	2	1.9	3	2	3	1	12.9	122	
Lepidorhombus spp.	Megrims	B	4&7d	Nephrops_trawl_o10m	3	1.9	3	2	2	1	12.9	123	
Melanogrammus aeglefinus	Haddock	D	4&7d	Gill_Trammel_nets_u10m	2	1.9	3	2	3	1	12.9	124	
Pollachius virens	Saithe	D	4&7d	Gill_Trammel_nets_u10m	2	1.9	3	2	3	1	12.9	125	
Melanogrammus aeglefinus	Haddock	D	7bc,e-k	Beam_trawl_DEF_o10m	2	1.8	2	3	3	1	12.8	126	
Lepidorhombus spp.	Megrims	B	7bc,e-k	Otter_trawl_u10m	3	1.8	3	1	3	1	12.8	127	
Lepidorhombus spp.	Megrims	B	7bc,e-k	Otter_trawl_o10m	3	1.8	3	1	3	1	12.8	128	
Lepidorhombus spp.	Megrims	B	7bc,e-k	Gill_Trammel_nets_u10m	3	1.8	3	1	3	1	12.8	129	
Raja montagui	Spotted ray	E	4&7d	Nephrops_trawl_o10m	3	0.8	3	0	3	3	12.8	130	
Lophiidae	Anglerfish	B	4&7d	Beam_trawl_DEF_o10m	3	1.6	2	2	3	1	12.6	131	
Lophiidae	Anglerfish	B	4&7d	Nephrops_trawl_u10m	3	1.6	3	1	3	1	12.6	132	
Molva molva	Ling	D	4&7d	Nephrops_trawl_o10m	2	2.4	3	2	2	1	12.4	133	
Pollachius pollachius	Pollack	D	7bc,e-k	Gill_Trammel_nets_o10m	2	2.4	2	2	3	1	12.4	134	
Molva molva	Ling	D	4&7d	Otter_trawl_u10m	2	2.4	3	2	2	1	12.4	135	
Molva molva	Ling	D	7bc,e-k	Otter_trawl_u10m	2	2.4	3	2	2	1	12.4	136	
Molva molva	Ling	D	7bc,e-k	Otter_trawl_o10m	2	2.4	3	2	2	1	12.4	137	
Pollachius pollachius	Pollack	D	7bc,e-k	Otter_trawl_o10m	2	2.4	3	1	3	1	12.4	138	
Merlangius merlangus	Whiting	D	7bc,e-k	Otter_trawl_o10m	1.5	1.8	3	3	2	1	12.3	139	
Trachurus spp.	Horse mackerel	P	4&7d	Nephrops_trawl_o10m	1	2.3	3	3	2	1	12.3	140	
Merlangius merlangus	Whiting	D	7bc,e-k	Otter_trawl_u10m	1.5	1.8	3	3	2	1	12.3	141	
Merlangius merlangus	Whiting	D	4&7d	Beam_trawl_CRU_u10m	1.5	2.8	2	2	3	1	12.3	142	
Psetta maxima	Turbot	D	4&7d	Beam_trawl_DEF_o10m	3	1.3	2	2	3	1	12.3	143	
Psetta maxima	Turbot	D	4&7d	Otter_trawl_u10m	3	1.3	3	1	3	1	12.3	144	
Merlangius merlangus	Whiting	D	7a	Otter_trawl_u10m	1.5	4.8	3	1	1	1	12.3	145	
Psetta maxima	Turbot	D	4&7d	Nephrops_trawl_u10m	3	1.3	3	1	3	1	12.3	146	
Psetta maxima	Turbot	D	4&7d	Otter_trawl_o10m	3	1.3	3	1	3	1	12.3	147	
Psetta maxima	Turbot	D	4&7d	Gill_Trammel_nets_u10m	3	1.3	3	1	3	1	12.3	148	
Merluccius merluccius	Hake	D	7bc,e-k	Otter_trawl_o10m	1.5	1.6	3	2	3	1	12.1	149	
Merluccius merluccius	Hake	D	7bc,e-k	Otter_trawl_u10m	1.5	1.6	3	2	3	1	12.1	150	
Trachurus spp.	Horse mackerel	P	7bc,e-k	Gill_Trammel_nets_o10m	1	3	2	2	3	1	12	151	
Trachurus spp.	Horse mackerel	P	7bc,e-k	Beam_trawl_DEF_o10m	1	3	2	2	3	1	12	152	
Nephrops norvegicus	Norway lobster	C	7a	Nephrops_trawl_o10m	3	2	3	1	2	1	12	153	
Trachurus spp.	Horse mackerel	P	7bc,e-k	Otter_trawl_o10m	1	3	3	1	3	1	12	154	
Pollachius pollachius	Pollack	D	4&7d	Otter_trawl_u10m	2	3	3	1	2	1	12	155	
Nephrops norvegicus	Norway lobster	C	7a	Nephrops_trawl_u10m	3	2	3	1	2	1	12	156	
Nephrops norvegicus	Norway lobster	C	7a	Otter_trawl_o10m	3	2	3	1	2	1	12	157	
Pollachius pollachius	Pollack	D	4&7d	Gill_Trammel_nets_u10m	2	3	3	1	2	1	12	158	
Trachurus spp.	Horse mackerel	P	7bc,e-k	Gill_Trammel_nets_u10m	1	3	3	1	3	1	12	159	

Scientific name	Common name	Species group	Area	Fishery	Biological score	Population score	Fishery score	Discard Score	Economic value score	ASSIST score	Overall score	Rank	Associated species?
Raja clavata	Thornback ray	E	4&7d	Gill_Trammel_nets_o10m	3	1	2	0	3	3	12	160	
Limanda limanda	Common dab	B	4&7d	Beam_trawl_CRU_o10m	3	0.9	2	2	3	1	11.9	161	
Pollachius virens	Saithe	D	4&7d	Otter_trawl_o10m	2	1.9	3	1	3	1	11.9	162	
Pollachius virens	Saithe	D	4&7d	Nephrops_trawl_o10m	2	1.9	3	1	3	1	11.9	163	
Lepidorhombus spp.	Megrims	B	4&7d	Otter_trawl_o10m	3	1.9	3	1	2	1	11.9	164	
Scomber scombrus	Mackerel	P	4&7d	Nephrops_trawl_o10m	1	1.8	3	3	2	1	11.8	165	
Scomber scombrus	Mackerel	P	7bc,e-k	Otter_trawl_o10m	1	1.8	3	2	3	1	11.8	166	
Lepidorhombus spp.	Megrims	B	7bc,e-k	Gill_Trammel_nets_o10m	3	1.8	2	1	3	1	11.8	167	
Scomber scombrus	Mackerel	P	7bc,e-k	Gill_Trammel_nets_u10m	1	1.8	3	2	3	1	11.8	168	
Melanogrammus aeglefinus	Haddock	D	7bc,e-k	Gill_Trammel_nets_u10m	2	1.8	3	1	3	1	11.8	169	
Molva molva	Ling	D	7bc,e-k	Beam_trawl_DEF_o10m	2	2.4	2	2	2	1	11.4	170	
Molva molva	Ling	D	7bc,e-k	Gill_Trammel_nets_o10m	2	2.4	2	2	2	1	11.4	171	
Pollachius pollachius	Pollack	D	7bc,e-k	Beam_trawl_DEF_o10m	2	2.4	2	1	3	1	11.4	172	
Pollachius pollachius	Pollack	D	7bc,e-k	Otter_trawl_u10m	2	2.4	3	0	3	1	11.4	173	
Nephrops norvegicus	Norway lobster	C	4&7d	Gill_Trammel_nets_o10m	3	2.4	2	0	3	1	11.4	174	
Trachurus spp.	Horse mackerel	P	4&7d	Nephrops_trawl_u10m	1	2.3	3	2	2	1	11.3	175	
Trachurus spp.	Horse mackerel	P	4&7d	Otter_trawl_u10m	1	2.3	3	2	2	1	11.3	176	
Merlangius merlangus	Whiting	D	4&7d	Gill_Trammel_nets_o10m	1.5	2.8	2	1	3	1	11.3	177	
Psetta maxima	Turbot	D	4&7d	Nephrops_trawl_o10m	3	1.3	3	0	3	1	11.3	178	
Merlangius merlangus	Whiting	D	7bc,e-k	Gill_Trammel_nets_u10m	1.5	1.8	3	2	2	1	11.3	179	
Merlangius merlangus	Whiting	D	7a	Gill_Trammel_nets_u10m	1.5	4.8	3	0	1	1	11.3	180	
Merluccius merluccius	Hake	D	7bc,e-k	Beam_trawl_DEF_o10m	1.5	1.6	2	2	3	1	11.1	181	
Pollachius pollachius	Pollack	D	4&7d	Gill_Trammel_nets_o10m	2	3	2	1	2	1	11	182	
Pollachius pollachius	Pollack	D	4&7d	Nephrops_trawl_o10m	2	3	3	0	2	1	11	183	
Pollachius pollachius	Pollack	D	4&7d	Nephrops_trawl_u10m	2	3	3	0	2	1	11	184	
Microstomus kitt	Lemon sole	B	4&7d	Gill_Trammel_nets_o10m	3	1	2	0	3	2	11	185	
Platichthys flesus	European flounder	B	4&7d	Otter_trawl_u10m	3	0.9	3	3	0	1	10.9	186	
Limanda limanda	Common dab	B	4&7d	Gill_Trammel_nets_o10m	3	0.9	2	1	3	1	10.9	187	
Pollachius virens	Saithe	D	4&7d	Gill_Trammel_nets_o10m	2	1.9	2	1	3	1	10.9	188	
Limanda limanda	Common dab	B	4&7d	Beam_trawl_CRU_u10m	3	0.9	2	1	3	1	10.9	189	
Lepidorhombus spp.	Megrims	B	4&7d	Nephrops_trawl_u10m	3	1.9	3	0	2	1	10.9	190	
Pollachius virens	Saithe	D	4&7d	Nephrops_trawl_u10m	2	1.9	3	0	3	1	10.9	191	
Pollachius virens	Saithe	D	4&7d	Otter_trawl_u10m	2	1.9	3	0	3	1	10.9	192	
Scomber scombrus	Mackerel	P	4&7d	Gill_Trammel_nets_o10m	1	1.8	2	3	2	1	10.8	193	
Scomber scombrus	Mackerel	P	4&7d	Otter_trawl_u10m	1	1.8	3	2	2	1	10.8	194	
Scomber scombrus	Mackerel	P	4&7d	Otter_trawl_o10m	1	1.8	3	2	2	1	10.8	195	
Scomber scombrus	Mackerel	P	7bc,e-k	Otter_trawl_u10m	1	1.8	3	1	3	1	10.8	196	
Melanogrammus aeglefinus	Haddock	D	7bc,e-k	Gill_Trammel_nets_o10m	2	1.8	2	1	3	1	10.8	197	
Scomber scombrus	Mackerel	P	4&7d	Gill_Trammel_nets_u10m	1	1.8	3	2	2	1	10.8	198	
Nephrops norvegicus	Norway lobster	C	7bc,e-k	Beam_trawl_DEF_o10m	3	1.6	2	1	2	1	10.6	199	

Scientific name	Common name	Species group	Area	Fishery	Biological score	Population score	Fishery score	Discard Score	Economic value score	ASSIST score	Overall score	Rank	Associated species?
Nephrops norvegicus	Norway lobster	C	7bc,e-k	Otter_trawl_o10m	3	1.6	3	0	2	1	10.6	200	
Molva molva	Ling	D	4&7d	Gill_Trammel_nets_o10m	2	2.4	2	1	2	1	10.4	201	
Molva molva	Ling	D	4&7d	Nephrops_trawl_u10m	2	2.4	3	0	2	1	10.4	202	
Molva molva	Ling	D	4&7d	Gill_Trammel_nets_u10m	2	2.4	3	0	2	1	10.4	203	
Merlangius merlangus	Whiting	D	7bc,e-k	Beam_trawl_DEF_o10m	1.5	1.8	2	2	2	1	10.3	204	
Trachurus spp.	Horse mackerel	P	4&7d	Beam_trawl_DEF_o10m	1	2.3	2	2	2	1	10.3	205	
Trachurus spp.	Horse mackerel	P	4&7d	Otter_trawl_o10m	1	2.3	3	1	2	1	10.3	206	
Psetta maxima	Turbot	D	4&7d	Gill_Trammel_nets_o10m	3	1.3	2	0	3	1	10.3	207	
Trachurus spp.	Horse mackerel	P	4&7d	Gill_Trammel_nets_u10m	1	2.3	3	1	2	1	10.3	208	
Merluccius merluccius	Hake	D	7bc,e-k	Gill_Trammel_nets_o10m	1.5	1.6	2	1	3	1	10.1	209	
Merluccius merluccius	Hake	D	7bc,e-k	Gill_Trammel_nets_u10m	1.5	1.6	3	0	3	1	10.1	210	
Pollachius pollachius	Pollack	D	4&7d	Beam_trawl_DEF_o10m	2	3	2	0	2	1	10	211	
Platichthys flesus	European flounder	B	4&7d	Beam_trawl_DEF_o10m	3	0.9	2	3	0	1	9.9	212	
Platichthys flesus	European flounder	B	4&7d	Otter_trawl_o10m	3	0.9	3	2	0	1	9.9	213	
Platichthys flesus	European flounder	B	4&7d	Nephrops_trawl_o10m	3	0.9	3	2	0	1	9.9	214	
Platichthys flesus	European flounder	B	4&7d	Nephrops_trawl_u10m	3	0.9	3	2	0	1	9.9	215	
Pollachius virens	Saithe	D	4&7d	Beam_trawl_CRU_o10m	2	1.9	2	0	3	1	9.9	216	
Platichthys flesus	European flounder	B	4&7d	Gill_Trammel_nets_u10m	3	0.9	3	2	0	1	9.9	217	
Pollachius virens	Saithe	D	7bc,e-k	Gill_Trammel_nets_o10m	2	0.8	2	2	2	1	9.8	218	
Scomber scombrus	Mackerel	P	7bc,e-k	Gill_Trammel_nets_o10m	1	1.8	2	1	3	1	9.8	219	
Scomber scombrus	Mackerel	P	7bc,e-k	Beam_trawl_DEF_o10m	1	1.8	2	1	3	1	9.8	220	
Melanogrammus aeglefinus	Haddock	D	7a	Nephrops_trawl_o10m	2	1.8	3	1	1	1	9.8	221	
Molva molva	Ling	D	4&7d	Beam_trawl_DEF_o10m	2	2.4	2	0	2	1	9.4	222	
Merlangius merlangus	Whiting	D	7bc,e-k	Gill_Trammel_nets_o10m	1.5	1.8	2	1	2	1	9.3	223	
Trachurus spp.	Horse mackerel	P	4&7d	Gill_Trammel_nets_o10m	1	2.3	2	1	2	1	9.3	224	
Scophthalmus rhombus	Brill	B	4&7d	Nephrops_trawl_o10m	3	1	3	1	0	1	9	225	
Trachurus spp.	Horse mackerel	P	7a	Otter_trawl_o10m	1	3	3	1	0	1	9	226	
Scophthalmus rhombus	Brill	B	4&7d	Otter_trawl_u10m	3	1	3	1	0	1	9	227	
Trachurus spp.	Horse mackerel	P	7a	Nephrops_trawl_o10m	1	3	3	1	0	1	9	228	
Scophthalmus rhombus	Brill	B	4&7d	Otter_trawl_o10m	3	1	3	1	0	1	9	229	
Scophthalmus rhombus	Brill	B	4&7d	Gill_Trammel_nets_u10m	3	1	3	1	0	1	9	230	
Scomber scombrus	Mackerel	P	7a	Otter_trawl_o10m	1	1.8	3	1	1	1	8.8	231	
Scomber scombrus	Mackerel	P	7a	Nephrops_trawl_o10m	1	1.8	3	1	1	1	8.8	232	
Pollachius virens	Saithe	D	7bc,e-k	Gill_Trammel_nets_u10m	2	0.8	3	0	2	1	8.8	233	
Trachurus spp.	Horse mackerel	P	4&7d	Beam_trawl_CRU_u10m	1	2.3	2	0	2	1	8.3	234	
Scophthalmus rhombus	Brill	B	4&7d	Beam_trawl_DEF_o10m	3	1	2	1	0	1	8	235	
Scophthalmus rhombus	Brill	B	4&7d	Gill_Trammel_nets_o10m	3	1	2	1	0	1	8	236	
Scophthalmus rhombus	Brill	B	4&7d	Nephrops_trawl_u10m	3	1	3	0	0	1	8	237	
Platichthys flesus	European flounder	B	4&7d	Beam_trawl_CRU_o10m	3	0.9	2	1	0	1	7.9	238	
Pollachius virens	Saithe	D	7bc,e-k	Beam_trawl_DEF_o10m	2	0.8	2	0	2	1	7.8	239	
Scomber scombrus	Mackerel	P	4&7d	Beam_trawl_DEF_o10m	1	1.8	2	0	2	1	7.8	240	
Scomber scombrus	Mackerel	P	7a	Nephrops_trawl_u10m	1	1.8	3	0	1	1	7.8	241	

Annex 3 Fieldworker step by step guidance to conducting discard survival experiments

This guide assumes that the following has already occurred:

- The vessel selected
- Tank rigs delivered and plumbed in, and run for 24 hours
- On-board tanks installed and secured
- Priority species selected
- Meeting held with skipper and crew to explain project and methods

Step 1

During haul: Record data on fishing event as per haul data sheet (position, gear, environmental conditions (tow duration for trawlers, soak time for netters).

Record the time taken for net retrieval and the hauling position.

Step 2

Once the fish are on-board, begin recording the time taken to the sort the catch.

Step 3

Record the process by which the sorting is done and environmental conditions on-board as per data sheet – description of treatment for discarded fish (fish pound/hopper, left on deck, construction material, conveyor, water usage, use of gloves, shovels, baskets, boxes etc)

Step 4

Crew start sorting fish as per normal. At the point when fish would normally be discarded, take fish of the selected species and conduct BOTH qualitative assessments (reflex/RAMP, as per sheet) and semi-quantitative assessment (score 1 (excellent) - 4 (moribund)).

Select a sample of the assessed discarded fish for keeping in the holding tanks, release others back to the sea. Continue to assess fish throughout sorting process. After a period you will see the range of vitalities of the assessed fish, make sure you have fish with a full range of vitalities in the holding tanks (based on semi-quantitative assessment).

Put up to 6 fish into each tank, identify the fish by unique length (2 cm intervals preferably), measure total length and standard length, and record haul number, fish length and tank number as fish identifier as per data sheet. DO NOT put fish of different species in the same tank.

You should aim to have no less than 18 fish of each species from each haul in the tanks, i.e. three tanks per haul. This is so you can observe a slow down in the mortality rate (see below).

We need to try and get fish across the full length range that has been caught in each haul[1]. Therefore, during the sorting process get some fish that have been selected for landing. Avoid retained fish that have been crushed in baskets and boxes. Assess the vitality of these fish, record as above and put into tanks. If it is possible and does not inconvenience the crew it would be useful to have vitality assessments of the retained fish. For netters it should be possible to assess (some/most) discarded and retained fish as they come on-board.

'What if all the fish are the same length?'

ONLY if the fish have the same vitality based on the qualitative assessment and the semi-qualitative assessment then fish of the same length can be put in the same tank.

Step 5

Record the catch data for the haul, catch composition, estimated discards and retained weights, boulders etc as per data sheet.

Step 6

When the tanks are all full with up to 6 uniquely identifiable fish in each tank, continue to assess quantitative and semi-qualitative vitality assessments of fish for remaining hauls and release them. DO NOT replace any dead fish with fish from a different haul.

Step 7

Monitoring of the tanks. The aim is to replicate, as far as possible the environmental conditions into which the fish would have been released. If the experiment is being run on-board only, ensure constant sea water supply and monitor and record O_2 and temperature levels, and flow rates (~2 litre per min), when conducting 12 hourly checks on fish. Remove dead fish at each observation period and record as per data sheet. When a tank is empty, flush or drain tank and fill with fresh sea water before adding fish.

If the experiment is continued onshore, the on-board tanks should have a constant supply of sea water, monitor and record O_2 and temperature levels[2] and flow rates, during 12 hourly observation periods and when the fish are being moved at the point of landing.

"What temperature should the water be?"

The temperature of the water should be as close as possible to (surface) sea water temperature when the fish were caught. Also, O_2 saturation should be at least 80%.

Step 8

Conduct avian predation simulation (bird feeding). Either as part of the process described above or separately, select fish to discard and track and record any avian predation. The exact method will be dependent on the vessel and sorting process. If fish are discarded individually, then single fish can be tracked. When piles or boxes of material are discarded,

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[1] Any exemption from the discard ban will apply for a species, not just the sizes currently discarded, therefore we need to know what is the survival rate for that species when caught in the fishery.

[2] Using either a probe or data logger eg Oxyguard probe or miniDO$_2$T

you should discard as many fish that you can confidently track (e.g. 5). Before discarding, assess semi-qualitative vitality (1-4) of fish, if discarding more than one fish, then ensure all fish have the same vitality score. The aim is to try and simulate the actual discarding and predation patterns as closely as possible. Record data on fish and predator species etc as per data sheet.

“What typeof bird is that?”

Make sure you have a suitable bird identification guide with you.

Step 9

Moving the fish from on-board tanks to shore-based tanks. If you suspect the water quality or salinity will change as the vessel approaches the quay, stop the water supply to the on-board tanks. The fish should be moved and handled as little as possible. Each experiment will develop a specific protocol, where possible, the on-board tank rigs can be lifted as a unit onto the quay close to the onshore tanks. In some cases fish may require transport to the onshore tanks. This can be done either using the on-board tanks or intermediate containers, you may consider using sealed containers or containers lined with plastic bags to reduce spillage. Try to maintain the sea water ambient temperature, check the O2 and temperature before and after transporting the fish. Place fish held together in each of the on-board tanks into the same onshore tanks.

Step 10

If you have onshore tanks: Monitor every 12 hours, remove and record any dead fish, measure and record O2, temperature and flow rate as per data sheet.

To make sure all dead fish are removed you can complete the data sheet on tank observations, each fish is checked for ventilation, startle response (e.g. tail grab). If there is no response then fish can be categorised as dead and disposed of.

Step 11

End the experiment (for each haul) when fish stop dying, or the numbers dying have slowed down, and kill remaining fish and dispose of appropriately.

“When do I stop the experiment?”

Enter the numbers of fish still alive in each tank onto the spreadsheet provided. Data from each haul for each species should be entered onto one sheet. The mortality rate and estimated survival rate at each observation period is calculated for you on the next sheet. When the mortality rate and survival rate for the haul stops changing (much) you should stop and remove all fish from that haul (see example provided).

If you are keeping fish longer than 72 hours, you will need to offer food (e.g. rag-worms from bait shop). Remove any uneaten food at the following observation period.

“The rate that fish are dying is not slowing”

This indicates that there might be an experimental effect killing the fish, i.e. water quality, low O_2, high temperature, killing the fish. Check the tanks. Once 80% of the fish are dead, stop the experiment.

Step 12

Maximise the use of the tanks to generate as much data as possible. Each project will be different. Once the tanks are full you might elect to postpone sea trips until space becomes available. If staff and vessel availability do not allow this, then collect more vitality and avian predation data. You will need to manage this to get the most from the project and watch your budgets!

This is <u>new for all of us</u> and we may need to revise as we go. Getting feedback from you during the trials will be extremely helpful to improve these methods.

Annex 4 Case Study Haul Data

Details of hauls, including soak time, sea conditions, and sorting times for FV Luc

Shot Date	Haul No.	Mesh (mm)	Shot Time	Shot Depth (m)	Haul Date	Haul Duration (hrs)	Haul Depth (m)	Sort Time (hrs)	Haul Stat Rect	Wind Force	Wind Direction	Sea State	Swell Height (m)	Air Temp. (°C)	Seawater Temp. (°C)	Total Catch Weight (Kg)
25/08/14	1	80	05:30	55	25/08/14	3:08:00	74.07	00:23	38E9	3	SE	Slight	0.5	NA	NA	716.36
25/08/14	2	80	09:15	73	25/08/14	2:43:00	76.81	00:12	38E9	4	SE	Slight	0.5	NA	NA	473.77
25/08/14	3	80	12:10	77	25/08/14	3:15:00	58.52	00:19	38E9	3-4	SE	Slight	0.5	NA	NA	438.94
29/08/14	1	80	06:00	49	29/08/14	2:59:00	53.95	00:26	38E8	5	SSW	Slight	1	15.7	14.1	407.85
29/08/14	2	80	09:25	55	29/08/14	3:02:00	53.22	00:53	38E8	6	SW	Moderate	1	17.2	14.8	679.57
29/08/14	3	80	13:15	51	29/08/14	1:55:00	49.38	00:22	38E8	5-6	SW	Moderate	1.5	17.2	15.4	436.56
30/08/14	1	80	05:35	48	30/08/14	3:02:00	49.38	00:36	38E8	3	W	Slight	0	16.4	14.1	576.96
30/08/14	2	80	09:16	49	30/08/14	2:28:00	53.95	00:25	38E8	5-6	NW	Slight	1	17.1	15.1	452.44
31/08/14	1	80	05:55	49	31/08/14	2:35:00	62.18	00:35	38E8	3-4	W	Moderate	1	14.4	13.6	481.77
31/08/14	2	80	09:00	62	31/08/14	3:22:00	73.15	00:38	38E8	3-4	W	Moderate	1	17.2	14.5	733.23
01/09/14	1	99	06:00	55	01/09/14	2:59:00	76.81	00:26	38E8	2	W	Calm	0	14.8	14.1	595.81
01/09/14	2	99	09:36	77	01/09/14	2:49:00	59.44	00:27	38E8	2	NW	Slight	0	15.7	14.5	512.46
02/09/14	1	99	06:05	69	02/09/14	2:55:00	73.15	00:39	38E8	2	NW	Calm	0	13.2	14.2	579.76
02/09/14	2	99	09:40	73	02/09/14	2:50:00	76.81	00:08	38E9	2	NW	Calm	0	14.8	14.4	55.56
02/09/14	3	99	12:55	77	02/09/14	2:40:00	56.69	00:30	39E8	2	NW	Calm	0	14.9	15.1	451.96
03/09/14	1	99	06:10	73	03/09/14	2:25:00	90.53	00:11	39E8	1	SE	Calm	0	15.4	14.2	412.75
03/09/14	2	99	09:12	91	03/09/14	1:55:00	58.52	00:12	39E8	2	S	Calm	0	16.3	14.1	438.55
02/10/14	1	99	06:20	51	02/10/14	2:23:00	64.01	00:31	38E8	2	WSW	Calm	0	14.3	13.9	753.07
02/10/14	2	99	09:16	64	02/10/14	2:44:00	61.26	00:24	38E8	2	SW	Calm	0	15.9	14	487.16

Shot Date	Haul No.	Mesh (mm)	Shot Time	Shot Depth (m)	Haul Date	Haul Duration (hrs)	Haul Depth (m)	Sort Time (hrs)	Haul Stat Rect	Wind Force	Wind Direction	Sea State	Swell Height (m)	Air Temp. (°C)	Seawater Temp. (°C)	Total Catch Weight (Kg)
02/10/14	3	99	12:36	61	02/10/14	2:24:00	52.12	00:26	38E8	3	S	Calm	0	15.3	13.9	661.79
03/10/14	1	99	06:30	51	03/10/14	2:30:00	63.09	00:15	38E8	6	SSW	Moderate-Rough	1.5	16.8	14.8	662.78
03/10/14	2	99	09:30	64	03/10/14	2:20:00	52.49	00:20	38E8	6	SSW	Moderate-Rough	1.5	14.8	14.8	577.45
03/10/14	3	99	12:20	52	03/10/14	2:08:00	51.76	00:17	38E8	6	SSW	Moderate-Rough	1.5	15	13.8	405.31
07/10/14	1	99	06:45	51	07/10/14	2:35:00	69.49	00:33	38E8	3	W	Moderate	2	11.5	13.1	558.60
07/10/14	2	99	09:58	69	07/10/14	2:18:00	81.38	00:14	39E8	4	SW	Moderate	2	14	13.4	496.65
07/10/14	3	99	12:54	81	07/10/14	2:18:00	61.26	00:22	39E8	4-5	SW	Moderate	2.5	14.1	13.4	583.41
08/10/14	1	99	06:45	51	08/10/14	2:49:00	69.31	00:35	38E8	4-5	S	Calm	0	11.7	13	469.30
08/10/14	2	99	10:00	69	08/10/14	2:30:00	84.49	00:33	39E8	4-5	S	Moderate	0.5	11.9	13.4	505.58
08/10/14	3	99	13:00	84	08/10/14	2:10:00	58.52	00:43	39E8	4-5	S	Moderate	0.5	12.5	14.3	447.48
13/10/14	1	99	06:45	51	13/10/14	2:19:00	82.30	00:15	39E8	4-5	NE	Moderate	1	11.8	12.1	575.47
13/10/14	2	99	09:47	82	13/10/14	2:09:00	65.84	00:18	39E8	4-5	NE	Moderate	1	13.1	12.6	576.02
16/10/14	1	99	08:30	59	16/10/14	2:30:00	77.72	00:30	38E9	5	E	Rough	1.5	13.9	12.7	556.18
16/10/14	2	99	11:30	78	16/10/14	2:30:00	57.06	00:15	38E8	5	E	Rough	1.5	11.7	12.5	405.31

Case Study 2 Details of hauls, including soak time, sea conditions, and sorting times for FV Guiding Light III

Shot Date	Haul No.	Mesh (mm)	Shot Time	Shot Depth (m)	Haul Date	Haul Duration (hrs)	Haul Depth (m)	Sort Time (hrs)	Haul Stat Rect	Wind Force	Wind Direction	Sea State	Swell Height (m)	Air Temp. (°C)	Seawater Temp. (°C)	Total Catch Weight (Kg)
19/01/15	1	90	07:15	44	19/01/15	4.00	35	00:45	30E6	3-4	N	Slight	3	4.5	9	6604.00
19/01/15	2	90	11:50	36	19/01/15	4.25	44	01:20	29E6	1	SE	Calm	2	6	10.5	2730.50
20/01/15	3	90	07:10	44	20/01/15	4.00	38	00:55	30E6	3-4	SE	Moderate	4	6	10	2667.00
20/01/15	4	90	11:50	38	20/01/15	1.83	37	00:45	29E6	6	SE	Moderate-Rough	6	5	9.5	769.94
22/01/15	5	90	07:15	38	22/01/15	4.00	29	00:45	30E6	3	E	Moderate	3	4	9	1730.38
22/01/15	6	90	11:45	29	22/01/15	4.00	40	00:30	29E6	1-2	E	Calm	2	5	10	1524.00
27/01/15	7	90	06:50	40	27/01/15	4.00	36	00:30	30E6	2-3	W	Slight	2	9	9.5	1968.50
27/01/15	8	90	11:35	36	27/01/15	4.00	35	00:20	29E6	3	WNW	Slight	1.5	8	9.5	1746.25
02/02/15	9	90	07:10	42	02/02/15	4.50	35	01:05	30E6	2-3	NNW	Slight	2.5	8	9.5	2667.00
02/02/15	10	90	12:15	35	02/02/15	4.50	40	00:45	29E6	4-5	N	Slight	3			2571.75
03/02/15	11	90	07:00	42	03/02/15	4.25	35	01:00	30E6	5	NE	Moderate	2	5	9	2444.75
03/02/15	12	90	11:45	36	03/02/15	3.75	46	00:45	29E6	4-5	NE	Moderate	2			1301.75
09/02/15	13	90	07:00	35	09/02/15	4.25	31	00:28	30E6	1-2	NNE	Calm	1	9.5	9	1778.00
09/02/15	14	90	12:00	31	09/02/15	4.00	37	00:30	29E6	1	NNE	Calm	0			1333.50
11/02/15	15	90	07:00	38	11/02/15	4.75	31	00:30	30E7	2	SE	Slight	2	7.5	9	2571.75
11/02/15	16	90	12:15	31	11/02/15	4.00	42	00:25	29E6	2	SE	Slight	2			2174.88
17/02/15	17	90	06:35	38	17/02/15	4.50	26	00:50	30E6	2-3	N	Slight	2	13.5	9.2	2159.00
17/02/15	18	90	11:35	26	17/02/15	4.50	44	00:25	29E6	1	NW	Calm	0	10	9	1746.25
18/02/15	19	90	06:45	37	18/02/15	4.50	29	01:10	30E6	2-3	SW	Slight	1	9.5	9	2587.63
18/02/15	20	90	11:50	29	18/02/15	3.67	38	00:25	29E6	3	SW	Moderate	3			1349.38

Case study 3 Details of hauls, including soak time, sea conditions, and sorting times for FV Admiral Grenville

Shot Date	Haul No.	Mesh (mm)	Shot Time	Shot Depth (m)	Haul Date	Haul Duration (hrs)	Haul Depth (m)	Sort Time (hrs)	Haul Stat Rect	Wind Force	Wind Direction	Sea State	Swell Height (m)	Air Temp. (°C)	Seawater Temp. (°C)	Total Catch Weight (Kg)
21/11/14	3	85	23:45	66	22/11/14	01:30	70	NA	28E5	NULL	NULL	NULL	NULL	NA	NA	203.91
22/11/14	6	85	06:00	73	22/11/14	02:00	71	NA	28E5	NULL	NULL	NULL	NULL	NA	NA	260.26
22/11/14	7	85	08:15	71	22/11/14	02:00	70	NA	28E5	NULL	NULL	NULL	NULL	NA	NA	177.25
22/11/14	8	85	10:30	70	22/11/14	02:00	71	NA	28E5	NULL	NULL	NULL	NULL	NA	NA	229.13
22/11/14	9	85	12:45	71	22/11/14	02:00	73	NA	28E5	NULL	NULL	NULL	NULL	NA	NA	223.29
22/11/14	10	85	15:00	73	22/11/14	02:00	73	NA	28E5	NULL	NULL	NULL	NULL	NA	NA	261.58
22/11/14	11	85	17:15	73	22/11/14	02:00	73	NA	28E5	NULL	NULL	NULL	NULL	NA	NA	172.18
23/11/14	14	85	00:30	68	23/11/14	02:00	71	NA	28E5	NULL	NULL	NULL	NULL	NA	NA	236.10
23/11/14	15	85	02:45	71	23/11/14	02:00	73	NA	28E5	NULL	NULL	NULL	NULL	NA	NA	318.33
23/11/14	16	85	05:00	71	23/11/14	02:00	71	NA	28E5	NULL	NULL	NULL	NULL	NA	NA	177.59
23/11/14	19	85	11:45	70	23/11/14	02:00	70	NA	28E5	NULL	NULL	NULL	NULL	NA	NA	124.81
23/11/14	21	85	17:30	73	23/11/14	02:00	71	NA	28E5	NULL	NULL	NULL	NULL	NA	NA	123.20
24/11/14	24	85	00:45	70	24/11/14	02:00	68	NA	29E5	NULL	NULL	Slight	NULL	NA	NA	195.47
24/11/14	25	85	03:00	68	24/11/14	02:00	70	NA	29E5	NULL	NULL	Slight	NULL	NA	NA	146.88
24/11/14	26	85	05:15	70	24/11/14	02:00	71	NA	28E5	NULL	NULL	Slight	NULL	NA	NA	160.43
24/11/14	29	85	12:15	70	24/11/14	02:00	70	NA	28E5	NULL	NULL	NULL	NULL	NA	NA	118.58
25/11/14	38	85	06:15	68	25/11/14	02:00	68	NA	28E6	NULL	NULL	Rough	NULL	NA	NA	299.18
25/11/14	39	85	08:30	68	25/11/14	02:00	66	NA	28E7	NULL	NULL	Rough	NULL	NA	NA	138.67
25/11/14	40	85	10:45	66	25/11/14	02:00	60	NA	28E7	NULL	NULL	Rough	NULL	NA	NA	163.05
25/11/14	43	85	17:45	66	25/11/14	02:00	64	NA	28E6	NULL	NULL	Rough	NULL	NA	NA	190.49
25/11/14	44	85	20:00	64	25/11/14	02:00	64	NA	28E6	NULL	NULL	Rough	NULL	NA	NA	327.17
25/11/14	45	85	22:15	64	26/11/14	02:00	64	NA	29E7	NULL	NULL	Moderate	NULL	NA	NA	191.46

Shot Date	Haul No.	Mesh (mm)	Shot Time	Shot Depth (m)	Haul Date	Haul Duration (hrs)	Haul Depth (m)	Sort Time (hrs)	Haul Stat Rect	Wind Force	Wind Direction	Sea State	Swell Height (m)	Air Temp. (°C)	Seawater Temp. (°C)	Total Catch Weight (Kg)
26/11/14	49	85	07:30	68	26/11/14	01:45	66	NA	28E6	NULL	NULL	Moderate	NULL	NA	NA	240.13
26/11/14	50	85	09:45	66	26/11/14	02:00	60	NA	29E7	NULL	NULL	Moderate	NULL	NA	NA	147.30
26/11/14	51	85	12:00	60	26/11/14	02:00	57	NA	29E7	NULL	NULL	NULL	NULL	NA	NA	211.37
26/11/14	52	85	14:15	57	26/11/14	01:30	62	NA	29E7	NULL	NULL	NULL	NULL	NA	NA	130.12
26/11/14	53	85	16:00	62	26/11/14	02:00	64	NA	29E6	NULL	NULL	NULL	NULL	NA	NA	147.72
26/11/14	54	85	18:15	64	26/11/14	02:00	66	NA	28E6	NULL	NULL	NULL	NULL	NA	NA	198.73
26/11/14	55	85	20:30	66	26/11/14	01:45	66	NA	28E7	NULL	NULL	NULL	NULL	NA	NA	195.00
09/02/15	4	80	18:30	68	09/02/15	02:00	68	NA	28E6	NULL	NULL	Slight	NULL	NA	NA	219.21
09/02/15	5	80	20:45	68	09/02/15	02:00	68	NA	28E6	NULL	NULL	Slight	NULL	NA	NA	509.89
09/02/15	6	80	23:00	68	10/02/15	02:00	66	NA	28E6	NULL	NULL	Slight	NULL	NA	NA	253.96
10/02/15	7	80	06:15	68	10/02/15	02:00	68	NA	28E6	NULL	NULL	Moderate	NULL	NA	NA	437.41
10/02/15	8	80	09:30	68	10/02/15	02:00	68	NA	28E6	NULL	NULL	Moderate	NULL	NA	NA	464.73
10/02/15	9	80	11:45	68	10/02/15	02:00	66	NA	28E6	NULL	NULL	Moderate	NULL	NA	NA	239.39
10/02/15	10	80	18:45	68	10/02/15	02:00	70	NA	28E6	NULL	NULL	Moderate	NULL	NA	NA	1106.77
10/02/15	11	80	21:00	70	10/02/15	02:00	68	NA	28E6	NULL	NULL	Moderate	NULL	NA	NA	333.97
10/02/15	12	80	23:15	68	11/02/15	02:00	66	NA	28E6	NULL	NULL	Moderate	NULL	NA	NA	343.32
11/02/15	13	80	06:00	70	11/02/15	02:00	71	NA	28E6	NULL	NULL	Slight	NULL	NA	NA	760.49
11/02/15	14	80	08:15	71	11/02/15	02:00	71	NA	28E6	NULL	NULL	Slight	NULL	NA	NA	789.60
11/02/15	15	80	10:30	71	11/02/15	02:00	70	NA	28E6	NULL	NULL	Slight	NULL	NA	NA	464.69
11/02/15	16	80	18:00	66	11/02/15	02:00	68	NA	28E6	NULL	NULL	Slight	NULL	NA	NA	352.17
11/02/15	17	80	20:15	68	11/02/15	02:00	68	NA	28E6	NULL	NULL	Slight	NULL	NA	NA	303.57
11/02/15	18	80	22:30	68	12/02/15	02:00	68	NA	28E6	NULL	NULL	Slight	NULL	NA	NA	786.35
12/02/15	21	80	12:00	68	12/02/15	02:00	66	NA	28E6	NULL	NULL	Slight	NULL	NA	NA	265.11

Shot Date	Haul No.	Mesh (mm)	Shot Time	Shot Depth (m)	Haul Date	Haul Duration (hrs)	Haul Depth (m)	Sort Time (hrs)	Haul Stat Rect	Wind Force	Wind Direction	Sea State	Swell Height (m)	Air Temp. (°C)	Seawater Temp. (°C)	Total Catch Weight (Kg)
12/02/15	22	80	14:15	66	12/02/15	02:00	66	NA	28E6	NULL	NULL	Slight	NULL	NA	NA	241.40
12/02/15	23	80	16:30	68	12/02/15	02:00	68	NA	28E6	NULL	NULL	Slight	NULL	NA	NA	278.33
12/02/15	24	80	18:45	68	12/02/15	02:00	71	NA	28E6	NULL	NULL	Moderate	NULL	NA	NA	219.51
12/02/15	25	80	21:00	71	12/02/15	02:00	73	NA	28E6	NULL	NULL	Moderate	NULL	NA	NA	320.24
13/02/15	26	80	19:15	66	13/02/15	02:00	66	NA	28E6	NULL	NULL	Rough	3	NA	NA	323.77
13/02/15	27	80	21:30	66	13/02/15	02:00	71	NA	28E6	NULL	NULL	Rough	NULL	NA	NA	281.31
13/02/15	28	80	23:45	71	14/02/15	02:00	70	NA	28E6	NULL	NULL	Moderate	NULL	NA	NA	483.63
14/02/15	29	80	06:30	66	14/02/15	02:00	68	NA	28E6	NULL	NULL	Moderate-Rough	NULL	NA	NA	923.19
14/02/15	30	80	08:45	68	14/02/15	02:00	70	NA	28E6	NULL	NULL	Moderate-Rough	NULL	NA	NA	509.58
14/02/15	31	80	11:00	70	14/02/15	02:00	68	NA	28E6	NULL	NULL	Moderate-Rough	NULL	NA	NA	263.37
14/02/15	32	80	17:45	66	14/02/15	02:00	64	NA	28E6	NULL	NULL	Slight-Moderate	NULL	NA	NA	381.95
14/02/15	33	80	20:00	64	14/02/15	02:00	66	NA	28E6	NULL	NULL	Slight	NULL	NA	NA	343.45
14/02/15	34	80	22:15	66	15/02/15	02:00	68	NA	28E6	NULL	NULL	Slight	NULL	NA	NA	366.06

Case Study 4 Details of hauls, including soak time, sea conditions, and sorting times for FV Halcyon

Shot Date	Haul No.	Mesh (mm)	Shot Time	Shot Depth (m)	Haul Date	Haul Duration (hrs)	Haul Depth (m)	Sort Time (hrs)	Haul Stat Rect	Wind Force	Wind Direction	Sea State	Swell Height (m)	Air Temp. (°C)	Seawater Temp. (°C)	Total Day Catch Weight (Kg)
15/03/15	1	150	NA	18	16/03/15	24	50	00:13	30F0	3-4	NE	Slight		8	NA	147.91
15/03/15	2	150	NA		16/03/15	24	50	00:15	30F0	3-4	NE	Slight				
15/03/15	3	120	NA		16/03/15	24	50	00:12	30F0	3-4	NE	Slight				
15/03/15	4	120	NA		16/03/15	24	50	NA	30F0	3-4	NE	Slight				
15/03/15	5	150	NA		16/03/15	24	50	00:15	30F0	3-4	NE	Slight				
15/03/15	6	150	NA		16/03/15	24	50	00:15	30F0	3-4	NE	Slight				
16/03/15	1	150	NA	18	17/03/15	24	50	00:13	30F0	3-4	NE	Slight		12	NA	110.36
16/03/15	2	150	NA		17/03/15	24	50	00:16	30F0	3-4	NE	Slight				
16/03/15	3	120	NA		17/03/15	24	50	00:14	30F0	3-4	NE	Slight				
16/03/15	4	120	NA		17/03/15	24	50	00:14	30F0	3-4	NE	Slight				
16/03/15	5	150	NA		17/03/15	24	50	00:15	30F0	3-4	NE	Slight				
16/03/15	6	150	NA		17/03/15	24	50	00:15	30F0	3-4	NE	Slight				
25/03/15	1	92	NA	18	26/03/15	24	50	00:15	30F0	6	WNW	Rough		12	NA	174.12
25/03/15	2	92	NA		26/03/15	24	50	00:20	30F0	6	WNW	Rough				
25/03/15	3	120	NA		26/03/15	24	50	NA	30F0	6	WNW	Rough				
25/03/15	4	120	NA		26/03/15	24	50	00:11	30F0	6	WNW	Rough				
25/03/15	5	150	NA		26/03/15	24	50	NA	30F0	6	WNW	Rough				
25/03/15	6	150	NA		26/03/15	24	50	NA	30F0	6	WNW	Rough				
26/03/15	1	92	NA	18	27/03/15	48	50	NA	30F0	NA	NA	NA		12	NA	254.4
26/03/15	2	92	NA		27/03/15	48	50	NA	30F0	NA	NA	NA				

Shot Date	Haul No.	Mesh (mm)	Shot Time	Shot Depth (m)	Haul Date	Haul Duration (hrs)	Haul Depth (m)	Sort Time (hrs)	Haul Stat Rect	Wind Force	Wind Direction	Sea State	Swell Height (m)	Air Temp. (°C)	Seawater Temp. (°C)	Total Day Catch Weight (Kg)
26/03/15	3	120	NA		27/03/15	24	50	NA	30F0	NA	NA	NA				
26/03/15	4	120	NA		27/03/15	24	50	NA	30F0	NA	NA	NA				
26/03/15	5	150	NA		27/03/15	24	50	NA	30F0	NA	NA	NA				
26/03/15	6	150	NA		27/03/15	24	50	NA	30F0	NA	NA	NA				
02/04/15	1	150	NA	9	03/04/15	24	50	00:16	30F0	4-5	NE	Moderate		11	NA	165.74
02/04/15	2	150	NA		03/04/15	24	50	00:22	30F0	4-5	NE	Moderate				
02/04/15	3	150	NA		03/04/15	24	50	00:14	30F0	4-5	NE	Moderate				
02/04/15	4	120	NA		03/04/15	24	50	00:11	30F0	4-5	NE	Moderate				
02/04/15	5	150	NA		03/04/15	24	50	00:10	30F0	4-5	NE	Moderate				
03/04/15	1	150	NA	9	04/04/15	24	50	00:19	30F0	1	S	Moderate		9	NA	62.4
03/04/15	2	150	NA		04/04/15	24	50	00:14	30F0	1	S	Moderate				
03/04/15	3	150	NA		04/04/15	24	50	00:11	30F0	1	S	Moderate				
03/04/15	4	120	NA		04/04/15	24	50	00:12	30F0	1	S	Moderate				
03/04/15	5	150	NA		04/04/15	24	50	00:18	30F0	1	S	Moderate				
09/04/15	1	120	NA	17	10/04/15	24	50	00:10	30F0	1	V	Slight		19	NA	79.3
09/04/15	2	120	NA		10/04/15	24	50	00:12	30F0	1	V	Slight				
09/04/15	3	150	NA		10/04/15	24	50	00:10	30F0	1	V	Slight				
09/04/15	4	150	NA		10/04/15	24	50	00:06	30F0	1	V	Slight				
09/04/15	5	150	NA		10/04/15	24	50	00:12	30F0	1	V	Slight				
09/04/15	6	150	NA		10/04/15	24	50	00:11	30F0	1	V	Slight				

Annex 5 Table of Spearman's rank test results investigating tank effect on survival

Yellow cells* indicate significant results i.e. where the survival rates are correlated with the position of the fish in the stack of on-board tanks.

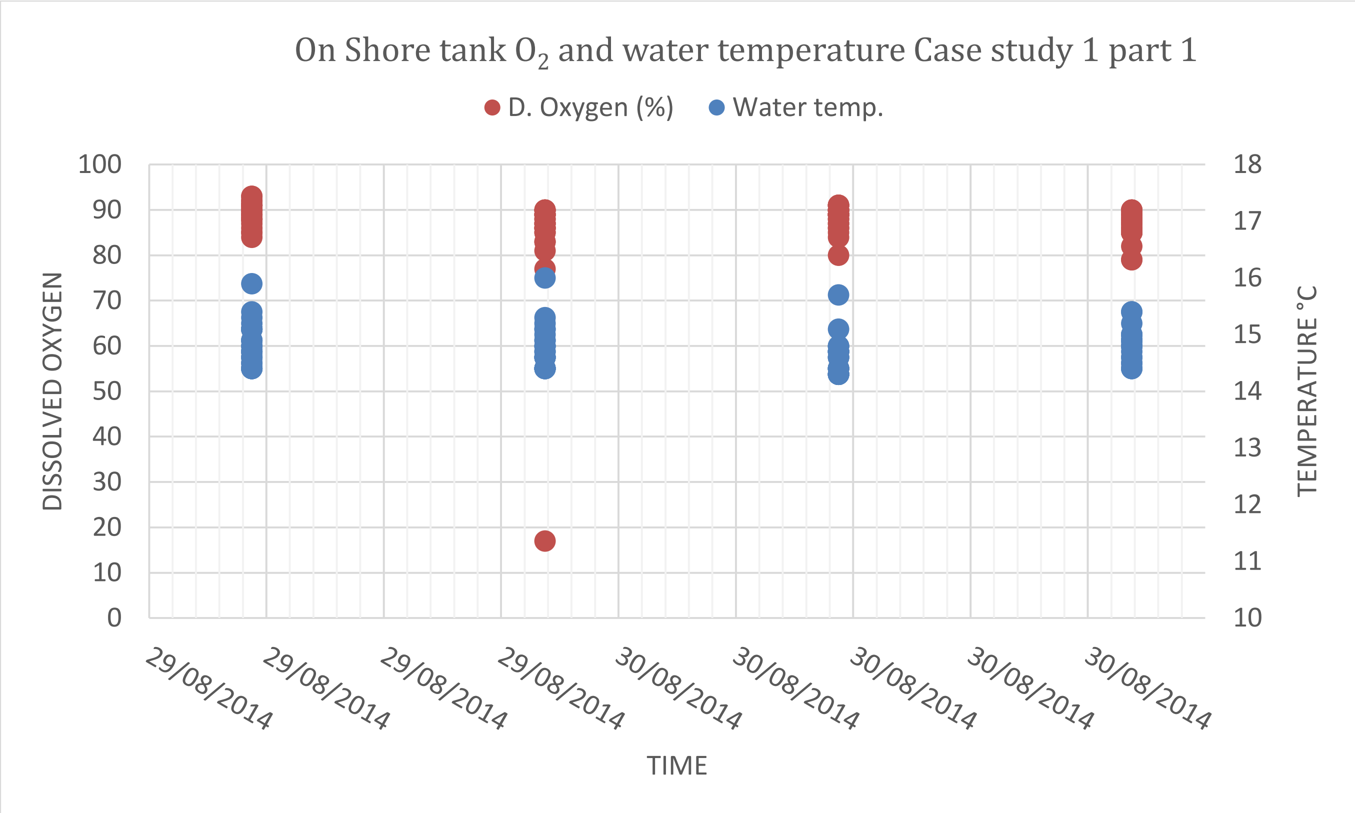
Case study	Vitality	Tank	Total observed	Dead	Proportion dead	RANK	Spearman's rank
1	'Excellent'	1	33	12	0.36	2	-0.0286
		2	24	8	0.33	5	
		3	27	3	0.11	6	
		4	26	11	0.42	1	
		5	20	7	0.35	3	
		6	26	9	0.35	4	
1	'Good'	1	18	7	0.39	6	-0.8286*
		2	19	13	0.68	4	(p<0.025)
		3	9	7	0.78	3	
		4	14	9	0.64	5	
		5	21	17	0.81	2	
		6	13	11	0.85	1	
1	'Poor'	1	3	1	0.33	6	-0.2571
		2	3	2	0.67	4	
		3	10	8	0.80	1	
		4	7	5	0.71	3	
		5	4	3	0.75	2	
		6	8	5	0.63	5	
4	'Excellent'	1	25	5	0.2	4	-0.7714*
		2	26	5	0.19	5	(p=0.05)
		3	24	2	0.08	6	
		4	24	5	0.21	3	
		5	14	3	0.21	2	
		6	24	7	0.29	1	
4	'Good'	1	5	1	0.20	4	-0.1429
		2	4	1	0.25	3	
		3	6	0	0.00	6	
		4	6	3	0.50	2	
		5	4	3	0.75	1	
		6	6	1	0.17	5	

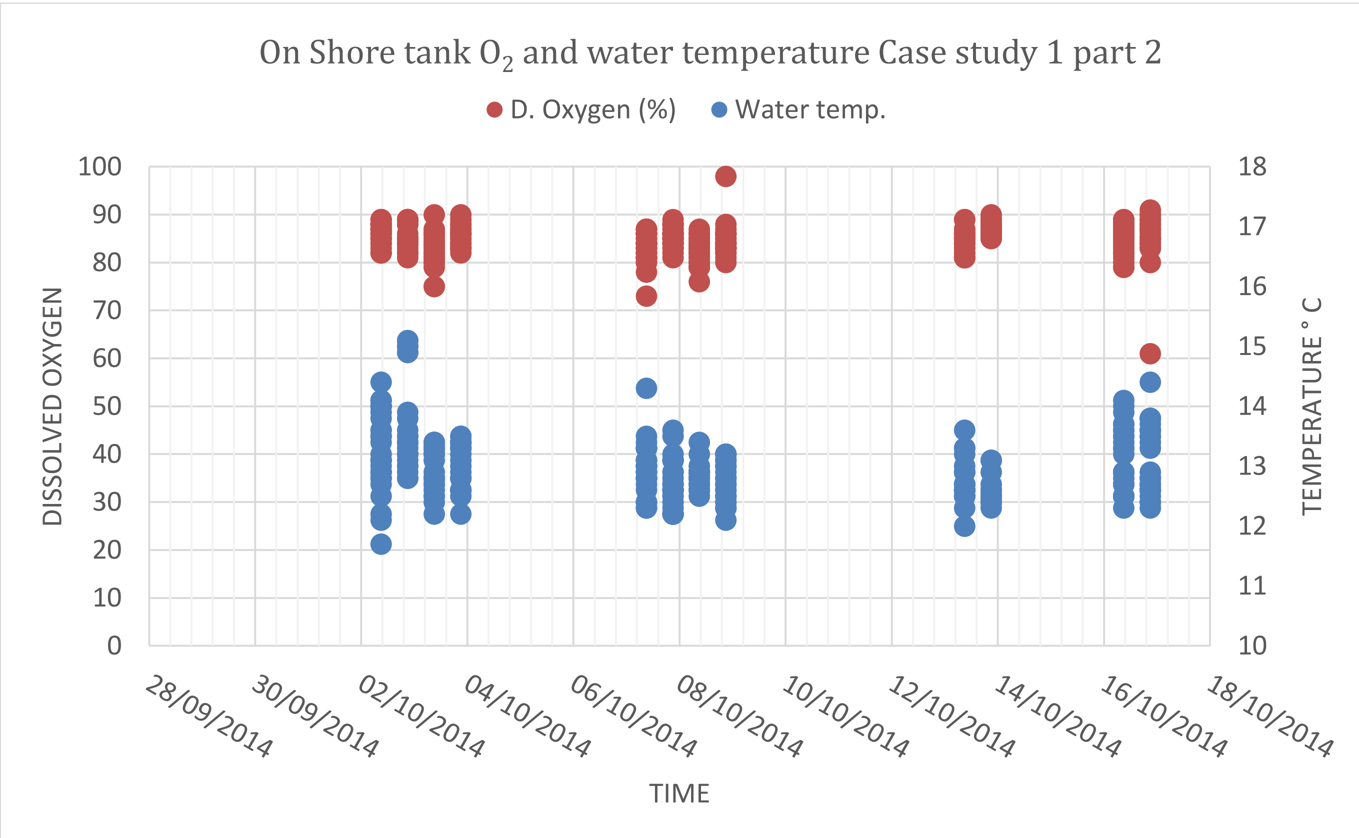
Annex 6 Identifying factors that influence survival

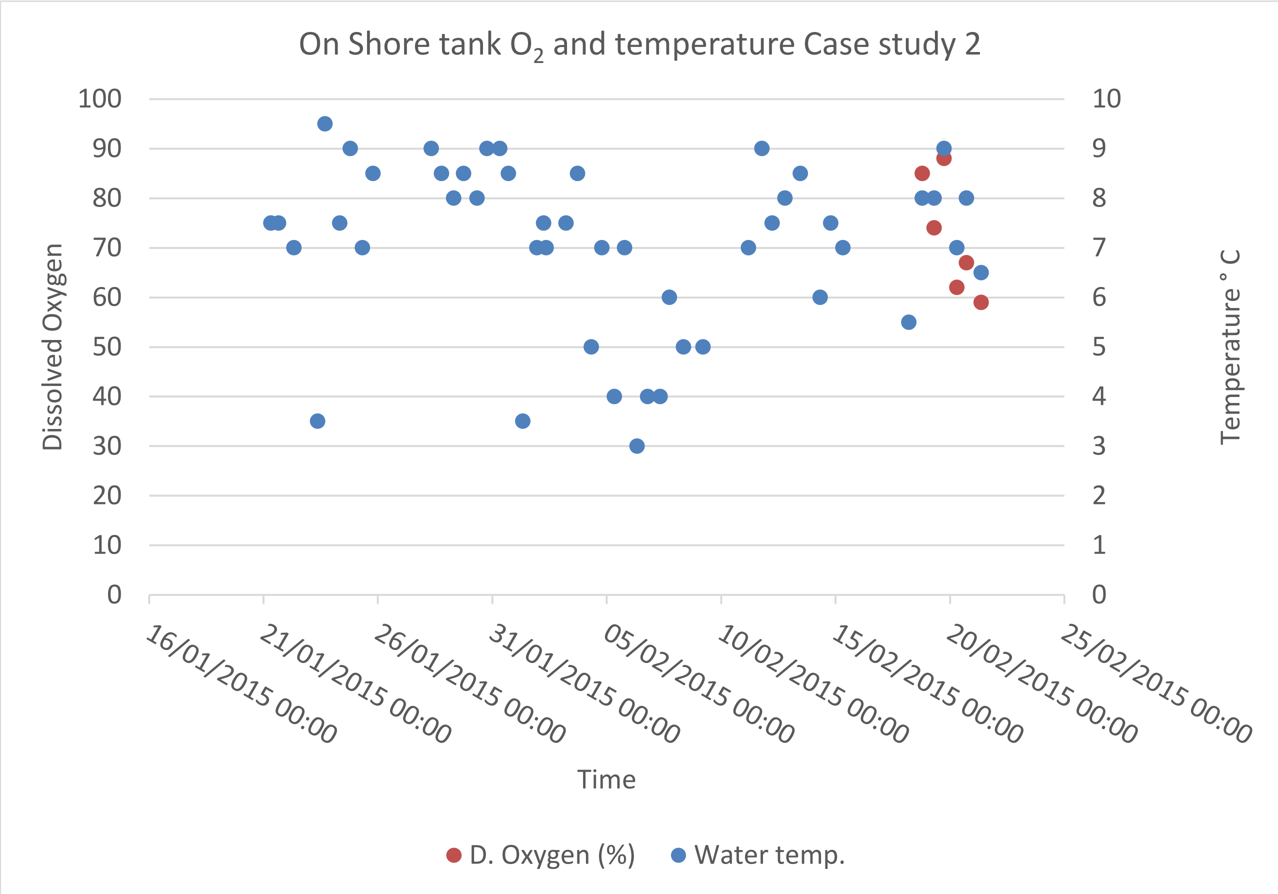
Variable	n	df	LR.stat	p
Day	109	18	94.4	< 0.001
Wind Force	109	24	93.1	< 0.001
Wind Direction	109	24	83.4	< 0.001
Mix discarded	109	3	32.3	< 0.001
Maximum deck time	109	3	29.2	< 0.001
Herring retained	109	3	27.3	< 0.001
Haul Longitude	109	3	25.6	< 0.001
Sea State	109	12	38.7	< 0.001
Haul No.	109	3	19.8	< 0.001
Haul Start Time	109	3	19.7	< 0.001
Haul Latitude	109	3	19.2	< 0.001
Flatfish retained	109	3	19.1	< 0.001
Pot Bait retained	109	3	18.7	< 0.001
Cod retained	109	3	18.6	< 0.001
Mackerel retained	109	3	17.1	0.001
Horse mackerel retained	109	3	15.9	0.001
Plaice retained	109	3	15.3	0.002
Seawater Temp (°C)	98	3	14.6	0.002
Haul Date	109	3	14.3	0.003
Air Temp (°C)	98	3	14.2	0.003
Prime retained	109	3	13.5	0.004
Cod discarded	109	3	12.5	0.006
Dab discarded	109	3	11.3	0.010
Trawl Time hrs	109	3	10.9	0.012
Dab retained	109	3	10.6	0.014
Total retained	109	3	10.2	0.017
Total catch	109	3	7.9	0.047
Grey gurnard retained	109	3	6.2	0.103
Haul Depth (m)	109	3	5.0	0.171
Whiting retained	109	3	5.0	0.174
Edible crab discarded	109	3	4.1	0.256
Total discarded	109	3	3.9	0.276
Plaice discarded	109	3	2.5	0.469
Mix retained	109	3	2.3	0.504
Nephrops retained	109	3	1.9	0.598
Flatfish discarded	109	3	1.7	0.629
Grey gurnard discarded	109	3	0.9	0.832
Lemon sole discarded	109	3	0.9	0.832
Whiting discarded	109	3	0.6	0.898
Swell Height (feet)	109	3	0.5	0.913

Model fit statistics from multinomial model for vigour assessment category, using each explanatory variable singly. Here, n is number of haul-category combinations; df is change in degrees of freedom compared to null model; LR.stat and p are the likelihood ratio statistic and p value from comparison to null model.

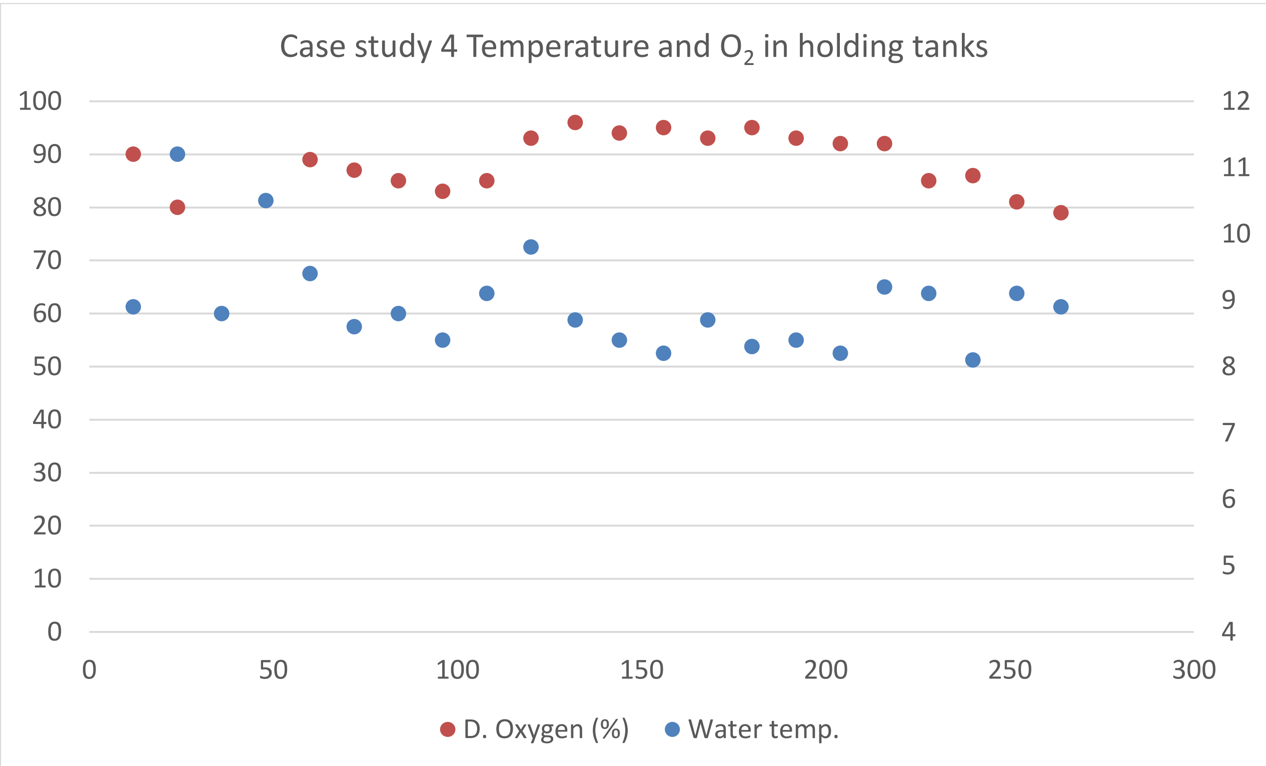
Annex 7 Temperature and dissolved oxygen in the on-shore holding tanks







On Shore tank O2 and temperature Case study 2
Dissolved Oxygen
Temperature ° C
100
90
80
70
60
50
40
30
20
10
0
10
9
8
7
6
5
4
3
2
1
0
16/01/2015 00:00
21/01/2015 00:00
26/01/2015 00:00
31/01/2015 00:00
05/02/2015 00:00
10/02/2015 00:00
15/02/2015 00:00
20/02/2015 00:00
25/02/2015 00:00
Time
D. Oxygen (%)
Water temp.



Case study 4 Temperature and O2 in holding tanks
100
90
80
70
60
50
40
30
20
10
0
12
11
10
9
8
7
6
5
4
0
50
100
150
200
250
300
D. Oxygen (%)
Water temp.