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Assessing the survival of discarded sole (*Solea solea*) in an English inshore trawl fishery



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Executive summary

This work was carried out as part of both the Fisheries Science Partnership (FSP) programme and the ASSIST project (Applied Science to Support the Industry in delivering an end to discards), two Defra-funded collaborative programmes of scientific research between the UK fishing industry and scientists.

Article 15 of the reformed Common Fisheries Policy (CFP) Basic Regulation, which came into force on January 1st 2014, introduced a phased discard ban or landing obligation. The policy includes several exemptions and flexibility tools. One exemption from the landing obligation is described for *“species for which scientific evidence demonstrates high survival rates, considering the characteristics of the gear, of the fishing practices and of the ecosystem”*. To support any proposed exemption, scientific evidence for discard survival rates are required.

The objective of this project was to assess and **estimate the survivability of sole caught in the Solent (ICES Subarea VIId) inshore otter trawl fishery**. This project follows a previous study of the east coast (ICES Subarea IVc) inshore otter trawl fishery and was designed to improve the confidence in a fishery wide estimate of sole survival in inshore trawling. There is a strong perception from the fishing industry that sole has a high survival rate in this fishery and, where sole quotas are restricted, landing undersized sole could potentially risk a premature end to the fishing season. Under the landing obligation, all sole (*Solea solea*) catches must be landed unless an exemption, based on scientific evidence demonstrating high survival, is awarded.

Such an exemption was awarded in 2017 (Commission Delegated Regulations (EU) 2016/2375 and 2016/6272), which applies to catches of sole below minimum conservation reference size (24cm) made within six nautical miles of the coast in ICES area IVc and VIId, and outside identified nursery areas, with otter trawls with cod end mesh size of 80-99mm. The exemption applies only to vessels with a maximum length of 10 meters, a maximum engine power of 180 kW, when fishing in waters with a depth of 15 meters or less and with limited tow durations of no more than 1:30 hours. Sole caught in these cases shall be released immediately. The exemption was conditional on additional scientific information to support the exemption being provided to the EU Commission by 1 May 2017.

The selected approach to estimate survival rates was to use vitality (health) assessments of sole caught under normal fishing conditions and combine this information with captive

observation of selected individual sole with different vitality scores to generate a weighted overall survival rate for sole.

This study demonstrated that after an observation period of 336 hours, the estimated overall survival was 89% for sole (n=50) under the Minimum Conservation Reference Size and 88% for the whole sole catch (n=240). Numerical extension models indicated that there may have been limited mortality beyond this period. **The estimated survival rate for the whole sole catch was 79%, and for the under size sole the overall survival rate was 82-89%. Applying rates of estimated avian predation generated an overall survival rate of 80-87% for <MCRS sole.**

The survival estimates exclude marine predation, though avian predation is considered, and therefore may overestimate survival. However, the stressors associated with the captive observation method, including, handling, confinement, changes in temperature, dissolved oxygen and time taken to assess were likely to induce some experimental mortality, although control fish indicate this was minimal. Therefore, the survival rates estimated in this project should be interpreted as the minimum discard survival estimates that do not account for induced experimental mortality, and exclude marine predation.

The previous Cefas study on discard survival of sole caught inshore by under 10m otter trawl fishing vessels (ICES Subarea IVc) demonstrated an estimated overall survival of 51% for those sole under minimum conservation reference size (MCRS) and 46% for the whole catch. These results of 80-87% for sole under MCRS and 79% for the whole catch, demonstrate that survival rates in the wider fishery are likely to be higher than first estimated, and suggest the criteria of the exemption could be extended to include fishing vessel of up to 221kW power and fishing at depths up to 30m.

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Overview

This project was carried out as part of two research programmes: The Fishery Science Partnership (FSP) and ASSIST project. The FSP is a Defra-funded programme of scientific research conducted in collaboration between the UK fishing industry and scientists. Since it was established in 2003, the programme has undertaken over 100 surveys, including fishing gear selectivity trials, examinations of spatial patterns and catch compositions, investigations into potential new fisheries and time-series of relative abundance of commercial species. The ASSIST project (Applied Science to Support the Industry in delivering an end to discards) is a five year Defra-funded programme, which started in 2013 to assist English fishermen in making the transition to the discard ban, and to support and advise DEFRA in the adoption of the reformed CFP. The ASSIST project uses a collaborative approach, working with Defra, fishermen and other stakeholders to facilitate the CFP implementation, by helping the fishing industry prepare for changes to policy.

Introduction

The landing obligation has been phased in for different species and fisheries, since January 2015. It started with the pelagic fisheries, but in 2016 the landing obligation was introduced to several demersal fisheries and species in North Sea and North Western Waters. Among other species, common sole (*Solea solea*), captured with beam trawlers, netters and otter trawlers (<100mm cod end mesh size), in ICES area VIId came under the landing obligation in 2016 (EU 2015/2440).

This regulation affected the inshore otter trawl fishery, for which sole is a main target species, but where the quotas are low and could potentially risk a premature end of the fishing season. For this reason, in 2016, Cefas carried out a discard survival survey on sole caught by inshore otter trawler, using 70-99mm codend mesh and operating on the English East coast (ICES Subarea VIId). That study resulted in a provision of the following survivability exemption, in 2017, to catches of common sole (*Solea solea*) below the minimum conservation reference size caught with “*otter trawl gears with cod end mesh size of 80-99mm in ICES division VIId within six nautical miles of the coast and outside identified nursery areas in the fishing operations meeting the following conditions: vessels with the maximum length of 10 meters, maximum engine power of 180 kW, when fishing in waters with the depth of 15 meters or less and with limited tow durations of no more than 1:30 hours. Such catches of common sole shall be released immediately*” (Art. 2, EU 2016/2375). This exemption was provided with the

condition that further sole survival studies would be carried out to estimate survival rates that are representative of the wider fishery.

This work is expected to complement other studies being undertaken in England and other Member States and the outputs are expected to guide English fisheries managers on whether exemptions from the Landing Obligation should be applied for. We aimed to estimate sole survival rates across the entire length range of the catch, under the assumption that fish at any length could be discarded, despite that under the present regulation, only sole under minimum conservation size has exemption from the landing obligation.

The approach used in this study for a discard survival assessment followed the same procedures as in recent Cefas survival studies to have standardised and comparable results (Catchpole *et al.*, 2015; Smith *et al.*, 2015; Randall *et al.*, 2016; Ribeiro Santos *et al.*, 2016). The approach was to combine fish vitality scores with the likelihood of survival for each vitality category to estimate a survival rate for the fishery. Vitality Assessments were conducted on the entire catch of sole from sample trips, whereby the health status of the subject was scored relative to an array of indicators (e.g. activity, reflex responses and injuries) and a vitality category was allocated. In parallel, captive observation studies were conducted on a sample of the catch, where individual sole representing the various vitality levels were selected and monitored to determine survival rates. Then the estimated survival rates from each vitality category were applied to the proportion of the catch with each vitality category to estimate an overall discard survival rate.

Materials & Methods

The Vessel

The vessel used in this trial was the MFV Double Or Nothing; CS2 (6.6 m, 7.3 t catamaran twin trawler powered by a 221 kw engine) normally operating from Cowes on the Isle of Wight, skippered by Peter Long, and crewed by Wayne Long (Figure 1). The MFV Double Or Nothing fished using a standard commercial twin otter trawl. The net had a combined fishing line of 29m (2*8ftm) with an estimated door spread of 32m (105ft), fishing with a cod end mesh of 86mm diamond, constructed from 4.5mm double-braided twine.



Figure 1. MFV Double Or Nothing (CS2) pictured at Langstone harbour.

Fishing Activity of the vessel

All fishing tows took place in the Solent (ICES Division IVD, ICES rectangle 30E8), at depths ranging between 14 and 29m (Figure 2). The fishing vessel operated on muddy sand to target mixed demersal species, but the main target species was sole. Due to fishing conditions, the sea trials were split into two seasons; 4th – 8th August 2016 and 17th – 22nd October 2016 (Figure 3). In the first trial season, the fishing activity was constrained by the amount of seaweed on the fishing ground, which resulted in shorter tows (on average 22 minutes' duration). While in the second trial, the tows were longer and reflected more the most common practices for this fishery (approximately 1-1.5 hours).

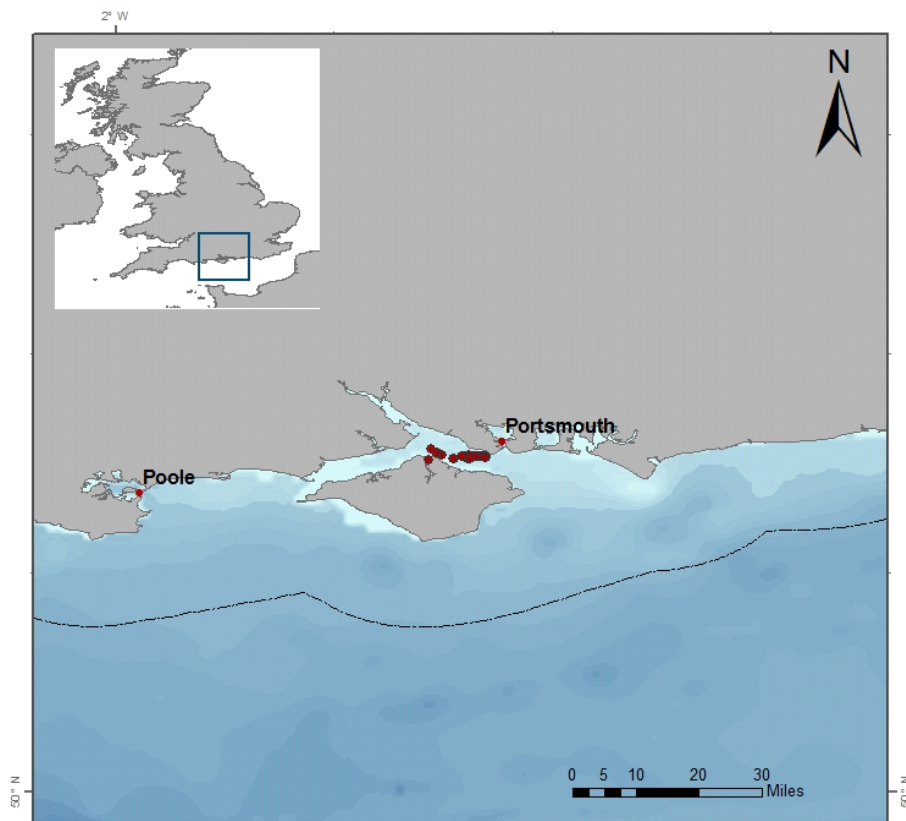


Figure 2. Locations of fishing hauls.

Vitality Assessment

A proportion of the sole caught were assessed for vitality immediately after the period of catch sorting, with some fish being selected for the holding tanks. The usual process on board the vessel is to discard all unwanted fish in bulk at the end of sorting the catch, so vitality assessment commenced at the point that discarding would normally have occurred. When possible all sole were assessed, for large catches a sample was randomly selected. The vitality assessments were conducted in a two-thirds filled, 42 litre Flexitub. The tubs were circular, made of semi-rigid plastic with moulded handles and were frequently but not continuously refilled by the deck hose. Fish were selected for holding tanks based on needing fish to represent the full range of vitalities and of different lengths, so that they could be individually identified. Immediately after the vitality assessment, each sole was transferred to one of six 42 litre Flexitubs. Six fish were put into each of the Flexitubs. At the end of each haul, usually about 30 minutes after the cod end opened, the fish were transferred from Flexitubs to the holding tanks (all fish from each tub were put into one of the six on board holding tanks).



Figure 3. Left – High volumes of weed caught in August from short tows. Right – More usual length tow in October with reduced weed and reasonable catch of sole.

Vitality Assessment Protocols

The health or vitality of fish was assessed using two methods; a semi-quantitative assessment of the vitality of the individual fish and a semi-quantitative reflex and injury scoring method. The vitality assessment was based on four ordinal classes that are defined, at one extreme characterising very lively and responsive fish (E, excellent) and at the other extreme unresponsive (D, dead) individuals (Table 1).

Table 1: 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'	E	Vigorous body movement; no or minor ^a external injuries only
'Good'	G	Weak body movement; responds to touching/prodding; minor ^a external injuries
'Poor'	P	No body movement but fish can move operculum; minor ^a or major ^b external injuries
'Dead'	D	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 ($\leq 10\%$ 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 by Catchpole *et al.* (2015). A series of behavioural reflex tests were applied that consistently produced unimpaired responses in both free swimming and restrained fish, and could be scored rapidly in a replicable manner (Table 2). These reflex and injury assessments (Table 3) have subsequently been applied to sole in two recent studies (Smith *et al.*, 2015; Ribeiro Santos *et al.*, 2016), and further developed for the present study.

Table 2: Vitality reflex assessment protocol developed for sole (*Solea solea*) and applied to all case studies.

Name	Stimulus action	Reflex response
Head complex	Fish held gently out of water	Regular pattern of ventilation with jaw and operculum
Belly Bend	Fish is held outside the water on the palm of a hand	Actively trying to move head and tail towards each other 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
Tail grab	Fish is held gently by its tail and held between two fingers	Actively struggles free and swims away within 5 seconds
Evade	Fish is underwater and hand approaches to touch fish	Actively moves away before or at first touch
Ventilation	The fish is held gently underwater	Regular pattern of ventilation with operculum within 5 seconds

The current study had observations for six reflexes; head complex, belly bend, orientation, tail grab, evade and ventilation. 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 (Figure 4). 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.

Table 3: Injury assessment protocol developed for sole (*Solea solea*) and applied to all case studies.

Name	Injury description
Abrasion	Haemorrhaging red area from abrasion
Bleeding	Obvious bleeding from any location
Bruising Body	A body injury to underlying tissues in which the skin is not broken, often characterized by ruptured blood vessels and discolorations.
Bruising Fin	A fin injury to underlying tissues in which the skin is not broken, often characterized by ruptured blood vessels and discolorations.
Fin fraying	Fins damaged, possibly with slight bleeding
Internal organs exposed	Internal organs exposed with wounds
Net marks	Any type of clearly visible net marks on body from trawl, gill-net, etc
Scale loss	Obvious area of scale loss
Scratches	Thin shallow cut or mark on (a surface)
Wounding	Nicks or shallow cuts on body

To maintain consistency in the vitality scoring all scientists assessing vitality underwent training to become familiarised with the fish, and the levels of activity and reflexes expected of healthy (aquarium kept) fish of the selected species.



Figure 4. Scientist assessing for injury and assessing the vitality of sole.

At Sea Data Collection

The specification of the fishing gear used was recorded along with the times and location the fishing gear was shot and hauled. The times that the sorting process started and finished were also recorded.

Catch Sampling

When the net was brought to the surface, hauling was performed by ropes lifting the net via a block and tackle system to suspend the two cod ends above the deck from an 'A' frame. When all the catch could be seen to have descended to the cod ends, they were opened and the fish dropped onto the deck (Figure 5) where they remained until the trawl was redeployed. Redeployment of the trawl took about 10-15 minutes before sorting of the catch began. The crew sorted the catch by hand, as is normal practice, however, instead of discarding any smaller or unwanted sole back into the sea, and processing any marketable sole, the sole catch were placed into containers (42 litre Flexitubs) filled with sea water prior to assessment by the scientist. The vitality assessment of the sole took place after sorting was complete, to replicate the level of air exposure normally experienced by discarded sole. The catch composition of each haul was also recorded, by species and estimated weight.



Figure 5. Crew opening port codend.

Sole were randomly selected for vitality assessments (Figure 6) and for holding for captive observation at the point the sole would normally be discarded. When possible all sole from a haul were assessed however, when catches were large a sample of the sole were assessed. These sole were assessed, using the vitality assessment score (Table 1), to have excellent, good, poor and dead health states and were scored by the presence or absence of specific reflexes and injuries (Tables 2 and 3).

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

To minimise captivity stress and to remove potential intra-species interactions, the stocking density of the on-board tanks was set at a maximum of six individuals (as supported by the control experiments reported in Catchpole *et al.* (2015)). The tank number was recorded

against the data for each individual sole (haul number; species; length; vitality category) to ensure that each sole stored in the on-board tanks was uniquely identifiable.

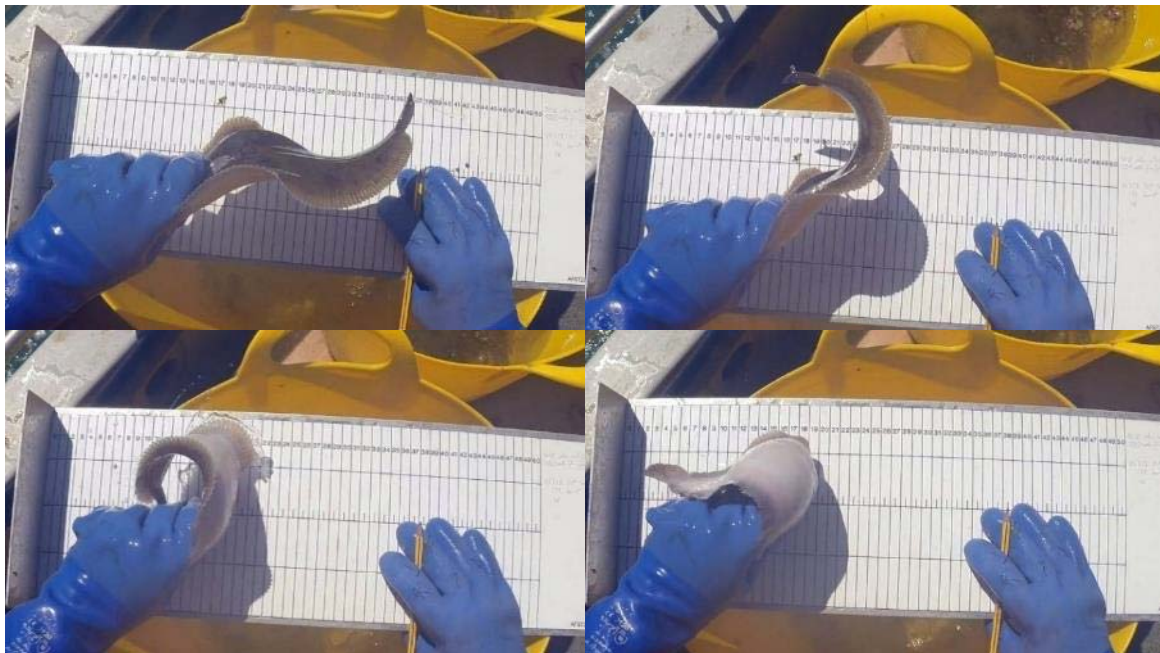


Figure 6. Assessing vitality of sole; sole demonstrating belly bend reflex.

Avian Predation Sampling

Sole below MCRS that were not selected for retention in the on-board tanks were used in simulated discard experiments to determine levels of avian predation. Individual sole were discarded immediately after their vitality was assessed. The scientist then monitored the fate of the discarded sole to record any interaction with avian predators, noting the result. The classification of interactions recorded were “Escaped”, “Bird(s) interested”, “Birds fighting or competing”, “Picked up but lost/rejected”, “Eaten” and “Lost sight of fish”.

On-board tanks

The MFV Double Or Nothing took part in day fishing, landing catches on a daily basis. 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 through an overflow pipe in the bottom tank (Figure 7).

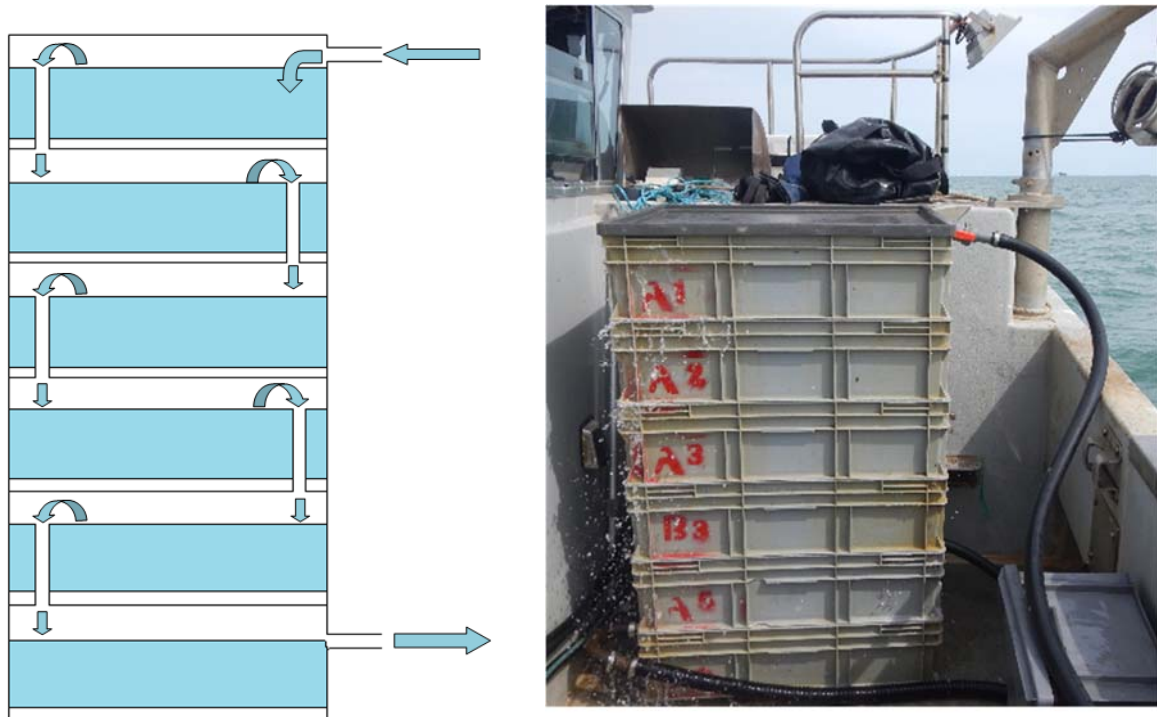


Figure 7. Left - Diagram illustrating the design of the on-board tanks with a gravity fed flow to waste seawater supply fed in series to all tanks. Right - On board tanks with a gravity fed flow in situ on MFV Double Or Nothing.

Transit from Sea to Shore

The vessel returned to port each day with selected fish in the on-board tanks. Shortly before landing, 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 identically 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 300 metres away at the Institute of Marine Sciences (IMS), University of Portsmouth. The fish were transferred in the same batches into each of the holding tanks. 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.

Onshore Holding Tanks

The onshore tanks were located at IMS, in the Eastney area of Portsmouth, adjacent to Langstone Harbour. The tanks were sited within IMS' aquarium (Figure 8). Water from the sea was pumped into the holding tanks via IMS' seawater system. The water supply for the onshore holding tanks was drawn from Langstone Harbour. Flow rate to the individual holding tanks was set at approximately 2.5 litres per minute.



Figure 8. The onshore holding tanks located at the Institute of Marine Sciences.

Monitoring Captive Sole

During the trials, the sole were inspected every 12 hours, for a period of 14 days (336h). This was the time period after which it was considered that the mortalities had substantially slowed or stopped. Any sole that failed to react to being touched were picked up and the operculum inspected while submerged, for signs of respiration (Figure 9). If the specimen met the definition of 'Dead', the sole was removed from the experiment. Any sole assessed as dead

were terminated humanely. Any injuries were logged and photographs were taken of both dorsal and ventral surfaces, before disposal.



Figure 9. Left – Monitoring environmental conditions within captivity tanks. Right – Monitoring captive sole.

Monitoring Control Sole

Prior to the full experimental survey, a control treatment was introduced. These specimens would undergo the same experimental conditions as the experimental treatment but had not gone through the usual 90-minute commercial trawl capture process, instead being caught from tows of 20-40 minutes. It was assumed that the short tow capture method was more benign and less likely to induce any mortality. The control sole went through the same conditions as the experimental fish, and were monitored for 360 hours (15 days). The monitoring of the control sole was exactly as described for the experimental trawl caught sole.

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 using a portable dissolved oxygen meter (Figure 8). In addition, the water supply to IMS was monitored by a data logger which recorded water temperature, salinity, pH and dissolved oxygen (Table 4).

Analytical methods

Survival estimate methods

The captive observation data provide the length of time that each fish was observed following capture and the state of the fish (dead or alive) when the final observation for that fish was made. This longitudinal data is analysed using survival estimation methods. These methods

provide estimates of the survivor function, $S(t)$, the probability of surviving for longer than time t .

Survival estimation methods account for a common property of survival data known as censoring. The data for fish that were still alive at their final observation time are referred to as right censored. Here, we know that a fish survived until at least that observation time but not how long it would have survived if the observation period was extended. In this study the control and experimental fish were analysed separately. Preliminary analysis to the experimental data showed no differences on the survival rates between the two trial seasons (with different tow durations). For this reason, the data were analysed jointly.

Kaplan-Meier plots

The Kaplan-Meier (K-M) estimator generates the survivor function against time. K-M estimates with 95% confidence intervals were calculated for each category of fish vigour, using the R function `survfit`. Confidence intervals were computed on the log-log scale.

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 also be variable towards the end of the experimental period when few fish remain observed. Therefore, a “plus-group” time was defined and times greater than these assigned to the plus-group time when calculating the K-M estimates.

In this study, the controls were under observation during 360 hours, while the experimental fish were monitored during 336 hours. The plus group were 360 and 336 hrs, respectively. The survivor curves from each vitality category (Excellent, Good, Poor, Dead) were then compared using the log-rank test (R function `survdif`). First, an overall comparison of all curves then comparisons between each pair of vitality categories.

Survival estimation models

For discard survivability studies, a plausible description of the results is that the proportion of sole surviving will gradually decrease and then flatten off with a proportion of sole surviving the capture, handling and release process. To model this process and predict 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. The extended models are referred to as 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 (Benoît 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.

Model (1) fits a common baseline survivor curve across all vitality, based on the observed pattern of mortalities, and then scales the risk to reflect the survival within each vitality 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 vitality 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.

Applying survival rates to vitality data

The survival rates estimated for each of the categories of vitality (Excellent, Good, Poor, Dead) were applied to the proportion of sole assessed with that category from the total catch of sole.

Summing across the proportions of catch at each vitality, multiplied by the survival rate for that category gave an overall estimated survival rate of the observed hauls combined. Three survival rates are presented, 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.

The effect of reflex impairment and injury on survival

A Generalized Linear Model (GLM) with the binomial family and a logit link was used to examine which injuries and reflexes had a significant impact on proportion of dead (D) and alive (A) fish. For both species in study 1 we fit a binomial GLM to the reflexes and injuries, separately. The models were estimated using the software R 3.1.0.

Results

Sampling and Catches

Initially, seven hauls during two trips were carried out to collect sole to be used as a control, on the 21st and 22nd July, to assess the potential levels of experimental mortality. The tow duration was 20-40 minutes, at depths ranging between 19 and 29m. A total 173 sole were assessed for vitality and 72 were kept captive. The length range of the control sole was 20 to 45 cm (Figure 10).

The experimental sole were captured between August and October 2017 during 25 hauls. The survey trips carried out in August encountered excessive seaweed on the fishing grounds and so tows were shorter than for most fishing trips, ranging between 13 and 29 minutes. While the trips conducted in October followed more normal fishing practices, with tow duration ranging between 1 and 1.5hrs. Sole was the predominant species in all hauls. A total of 744 sole were assessed for vitality and injury with a subsample of 290 sole retained for captive observation. The length distribution of captive and all catch sole is showed in Figure 9. The mean length of sole was 27.6 cm. There fishing was selective towards the target species of sole with a small proportion of under sized sole caught.

Any sole that were not transferred to the on-board tanks, were either processed for landing, or were discarded. Any sole discarded by the scientist were monitored upon release to see whether avian predators attempted to consume the discarded sole (Table 4). Of the 405 sole discarded by the scientist, 8 sole were seen consumed by birds which equates to 2 percent of the discarded sample.

Table 4. Avian interaction with discarded sole showing number for each vitality category.

Action	Excellent	Good	Poor	Dead
Escaped	259	97	2	0
Bird(s) interested	0	3	0	0
Birds fighting or competing	0	0	0	0
Picked up but lost/rejected	1	1	0	0
Eaten	2	6	0	0
Lost sight of fish	7	23	1	3

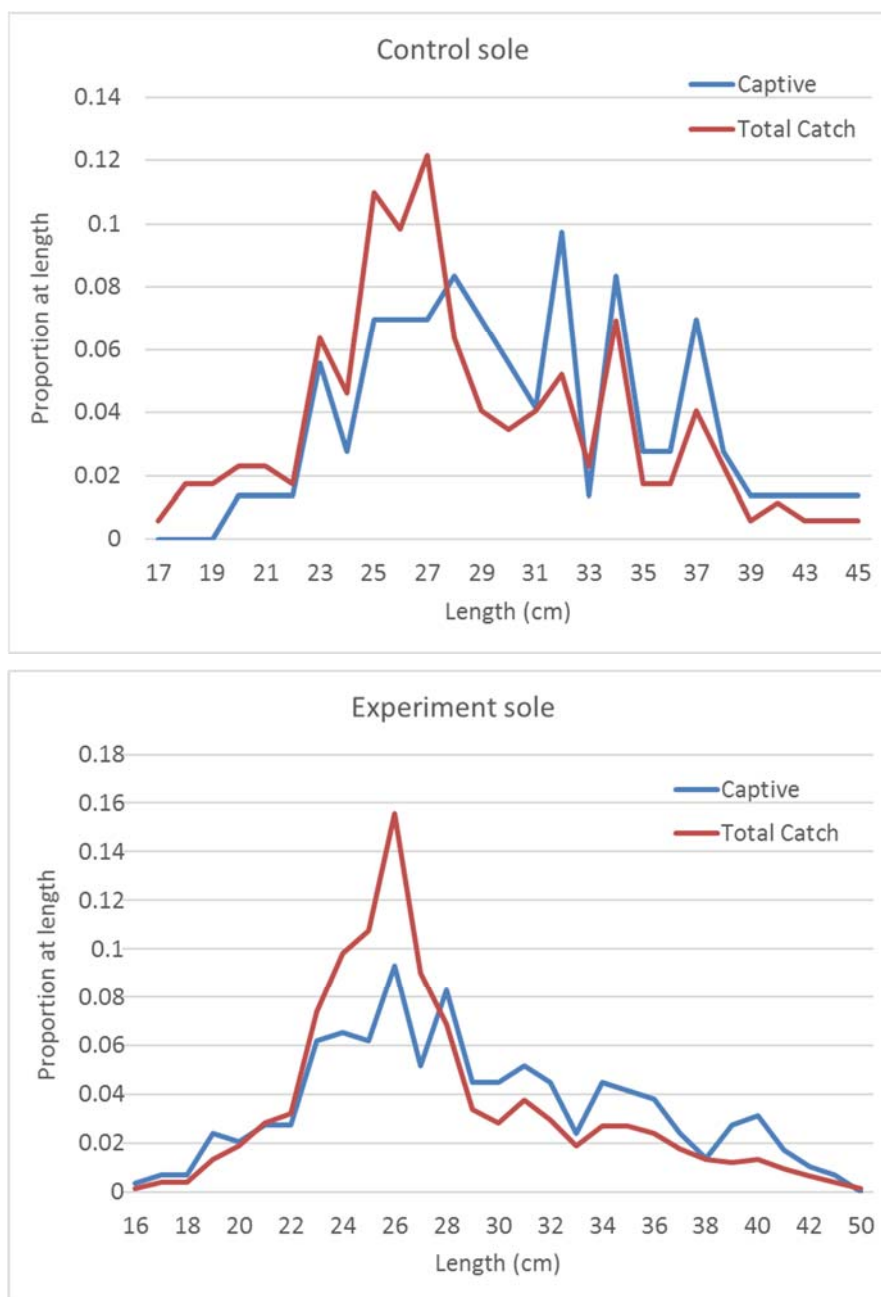


Figure 10. Length frequencies of sole in inshore otter trawl catches and held for observation. Top – For control; Bottom – Experiment sole.

Table 5. Data summary of the environmental conditions and number of fish assessed for vitality during the control and experiment, including IMS data log records(*)

	CONTROL	EXPERIMENT
AREA	Eastern Channel (ICES area VIIId)	
GEAR	Twin Otter Trawl (TR2)	
MESH SIZE (mm)	86	
HAULS	7	25
DEPTH RANGE (M)	19-29	14-27
RANGE AIR TEMPERATURE (°C)	17.2-19.1	8.1-18.4
RANGE SEA SURFACE TEMPERATURE (°C)	19.2-19.5	12.9-19.6
MEAN LENGTH SOLE CATCH CM	28.3	27.6
VITALITY ASSESSED FROM CATCH N	173	744
NO. SOLE CATCH ASSESSED AS EXCELLENT	149	508
NO. SOLE CATCH ASSESSED AS GOOD	19	222
NO. SOLE CATCH ASSESSED AS POOR	3	9
NO. SOLE CATCH ASSESSED AS DEAD	2	5
OBSERVATION PERIOD	360 hrs	336 hrs
VITALITY ASSESSED FROM CAPTIVE N	72	290
NO. SOLE CAPTIVE ASSESSED AS EXCELLENT	65	229
NO. SOLE CAPTIVE ASSESSED AS GOOD	7	59
NO. SOLE CAPTIVE ASSESSED AS POOR	0	2
NO. SOLE CAPTIVE ASSESSED AS DEAD	0	0
RANGE ONSHORE TANK WATER TEMPERATURE (°C)	18.7-24.1	11.4-16.7
RANGE ONSHORE TANK % DISSOLVED OXYGEN	51.5-97.3	60.1-90.6
RANGE SEA TEMPERATURE (°C) *	18.2-21.9	10.7-21.5
RANGE SALINITY (PSU) *	33.1-34.6	33.2-35.3
RANGE PH *	8.3-8.9	8.1-8.7
RANGE DISSOLVED OXYGEN (mg/L) *	6.6-7.8	6.6-8.6

Vitality Assessment

During this study, 173 sole were assessed for vitality for the control experiment and 744 for the survival experiment. In the control fish, 86% (n=149) of sole were assessed as Excellent condition, 11% (n=19) were Good and only 1% (n=3) were Poor and 1% (n=2) Dead. For experimental fish, the same proportion of sole were Poor (n=9) and Dead (1%) (n=5), of the remaining sole 68% (n= 508) were Excellent and 30% (n=222) in Good condition. When considering only the undersized sole (<24cm), the vitality profile does not change appreciably, with 74% (n= 97) in Excellent condition, 24% (n=32) were Good and 1% were Poor and 1% Dead (n=1) (Figure 11).

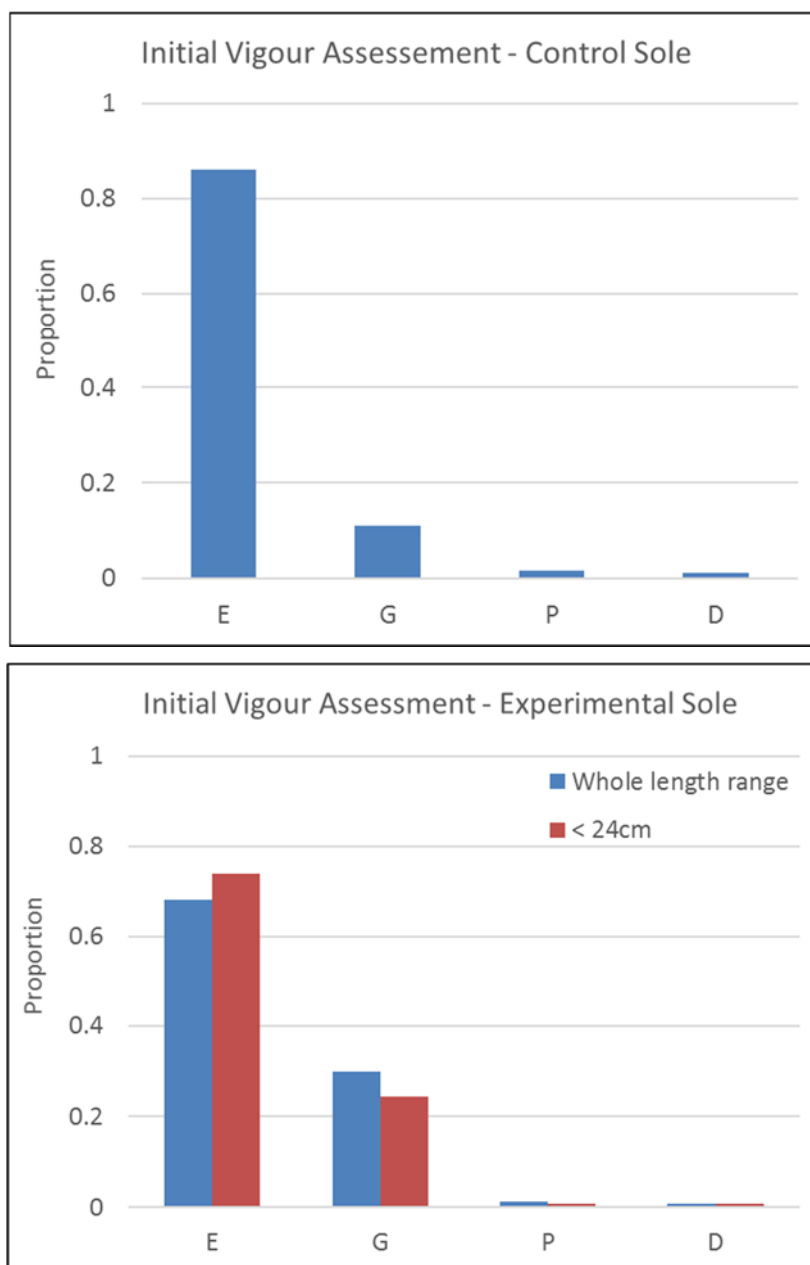


Figure 11 – Semi quantitative vigour vitality score for sole catches for the control (top plot) and experiment (bottom). E – Excellent; G – Good; P – Poor and D – Dead.

Survival of the Captive Fish

A proportion of fish at each vitality score was selected (by length) for the on-board observation tanks. In total, 290 fish were kept for the survival experiment. Fish were held in captivity for 336hrs; survival for sole was 95% for Excellent fish, 78% for Good and 0% for Poor fish (Figure 12). However, only 2 sole were assessed as having poor vitality and held in captivity.

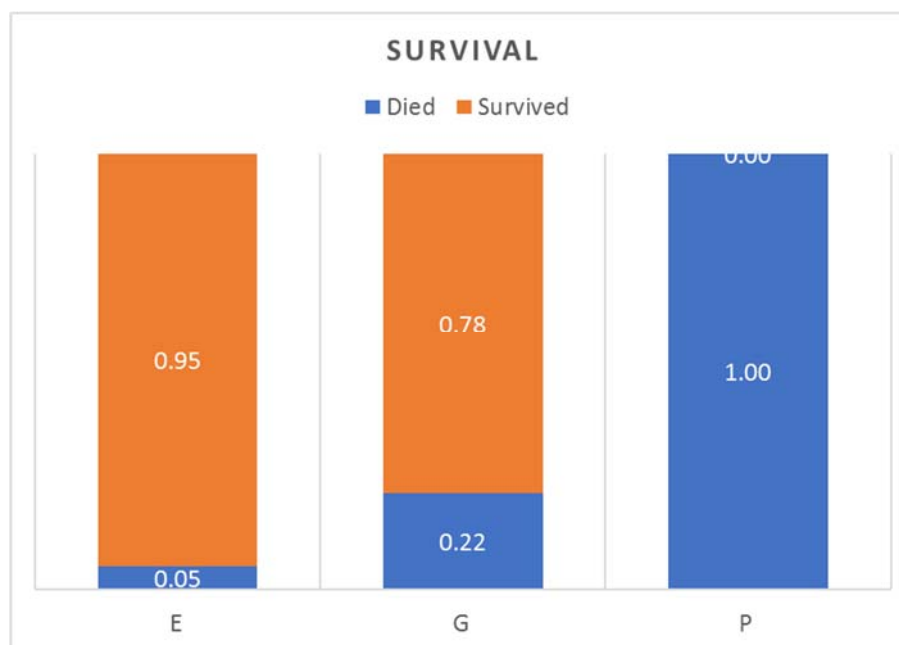


Figure 12 – proportion of captive fish that died and survived during the experiment, at each vitality category. E – Excellent; G – Good and P – Poor.

The Kaplan-Meier (KM) plots for the control and uMLS fish did not show significant differences between the Excellent and Good fish (Figure 13). For both vitality categories, the survival rates were high and the curves reached the asymptote a few hours after the monitoring started. On the other hand, the KM plots for the experimental fish showed a clear separation between the vitality categories, with the amount of survival in the expected order, i.e. the highest survival for Excellent fish and survival decreasing with vigour (Figure 13).

The outputs from the two models used to forecast the survivability probabilities did not vary or showed a small decrease from the KM estimates. With the predictable model 1 (ph), the forecast survival estimate was equal to the KM estimates, 95% for Excellent fish and 78% for Good sole. The second prediction model (wei) outputs provided slightly lower survival estimates for all vitality categories, varying between 77% for Good sole and 95% for sole in Excellent condition (Table 7).

When weighted to the proportion of each vitality category of the whole length range sole and under MLS sole, the estimated overall survival probability during the observed period was 89% for the under sized sole and 88% for the whole catch. The estimated survival rate from the two extension models was similar, for the whole catch and 79.3% and 79.1%, and 82% and 89% for the under sized sole, for the ph and wei models, respectively.

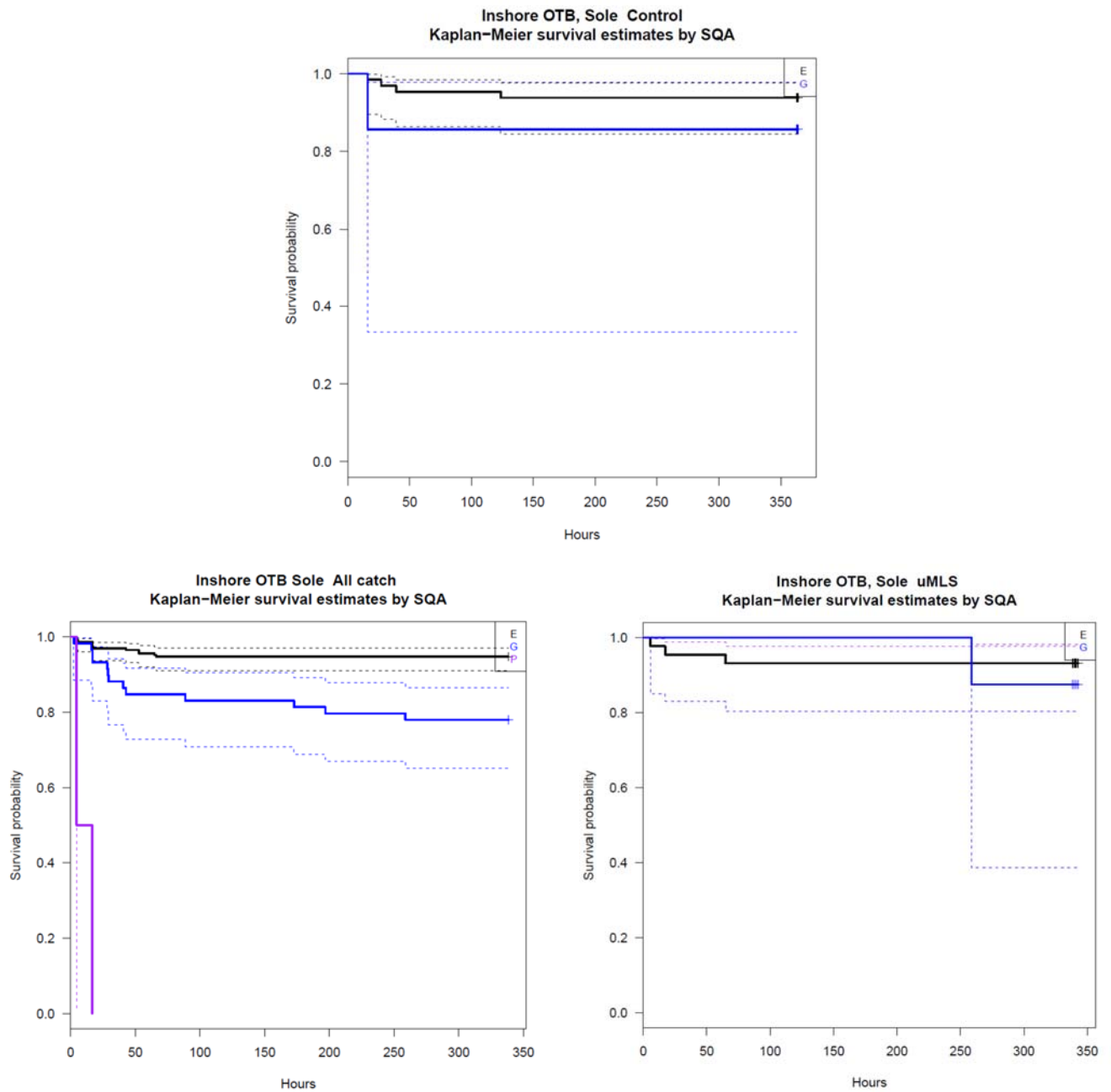


Figure 13. Kaplan-Meier estimates of survival are shown as solid lines and 95% pointwise confidence intervals as dashed lines, for control sole (top plot) and experimental sole (bottom plot). The small crosses at the end and along the lines mark times when one or more surviving sole stopped being observed; the x-axis is the time from the beginning of the sort period until death or the end of the observation period. E – Excellent; G – Good; P – Poor Top – Control fish; Bottom left – All sole catches and bottom right – uMLS sole (<24cm).

Table 6. Log-rank test to compare surviving curves, in the control and experimental (all catches and uMLS) fish.

	Comparison	Chisq	p-value
Control	E - G	0.70	0.396
Experimental	E - G	17.0	<0.001
	E - P	98.4	<0.001
	G - P	37.0	<0.001
uMLS (<24cm)	E-G	0.30	0.616

Table 7. Survival of captive Sole during observation period and modelled for extended period. The table gives the overall percentage survival of the captive sole, in the control and experiment; the survival probability within the observation period with upper and lower 95% Cis (in brackets) from the K-M analysis and 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 (Benoît, Hurlbut et al. 2012).

Species	SQA	Percentage survival of captive fish	Survival probability (KM) as percentage	Lower 95%	Upper 95%	Extension model 1 (ph, %)	Extension model 2 (Wei, %)
Control	E	9.8%	93.8%	84.4	97.6	93.8	93.8
	G	85.7%	85.7%	33.4	97.8	85.7	90.6
All catch Sole	E	94.7%	94.7%	90.9	96.9	94.7	94.5
	G	77.9%	77.9%	65.1	77.9	77.9	77.4
	P	0.0%	0.0%	na	na	0.0	0.0
<24 cm	E	93.8%	93.8%	80.3	97.7	93.1	93.1
	G	85.7%	85.7%	38.7	98.1	87.5	86.6

Table 8. Estimated overall survival rates for Sole caught with the inshore otter trawl. Table presents the weighted overall survival rate for each model, based on the catch vitality profiles, for the under minimum landing size sole (<24 cm) and all sole catches.

Species	SQA	Proportion at each vitality of catch	For the obs. period	Survival probability	Extension model 1 (ph)	Extension model 2 (Wei)
All catch Sole	E	0.68	88%	88 (81-89)%	79%	79%
	G	0.30				
	P	0.01				
	D	0.01				
<24 cm	E	0.74	89%	89 (69-96)%	82%	89%
	G	0.24				
	P	0.01				
	D	0.01				

Factors influencing discard survival

The effect of impaired reflexes

The binomial GLM model in this study showed that sole with impaired orientation and tail grab had significant higher mortality than the unimpaired sole. The impairment of these two reflexes showed significant association with the proportion of dead: alive fish (Table 9).

Table 9. – Summary data, with the number of fish dead and alive in the experiment, when impaired and unimpaired for each vitality reflex, percentage (%) of dead fish impaired, percentage (%) of alive fish impaired, p value from binomial GLM. Number of impaired/ unimpaired and proportion of impaired sole in the total catch. * significant difference for $p < 0.05$

Reflex name	Response	Alive	Dead	Experiment				Population
				% dead fish impaired	% alive fish impaired	p-value	Number	Proportion impaired
Tail grab	Unimpaired	261	21	22%	1%	0.021*	719	3%
	Impaired	2	6				25	
Orientation right	Unimpaired	259	21	22%	2%	0.030*	693	7%
	Impaired	4	6				51	
Belly bend	Unimpaired	257	24	11%	2%	0.384	688	8%
	Impaired	6	3				56	
Head complex	Unimpaired	263	26	4%	0%	0.992	737	1%
	Impaired	0	1				7	
Ventilation	Unimpaired	263	27	0%	0%	na	741	0%
	Impaired	0	0				3	
Evade	Impaired	247	20	26%	6%	0.617	669	10%
	Unimpaired	16	7				75	

The effect of injuries

The main injuries found on sole during this study were abrasion, fin bruising and fin fraying, with 64%, 47% and 22% of sole caught with these injuries, respectively. The binomial GLM results showed that none of the injuries were significantly associated with mortality of sole (Table 10).

Table 10 - 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 sole in the total catch. *significant differences for $p < 0.05$.

Injury	Response	Alive	Dead	Experiment			Population	
				% dead fish injured	% alive fish injured	p-value	Number	Proportion injured
Abrasion	Not injured	83	10	63%	68%	0.180	271	64%
	Injured	180	17				473	
Bleeding	Not injured	263	27	0%	0%	na	742	0%
	Injured	0	0				2	
Bruising body	Not injured	259	27	0%	2%	0.994	739	1%
	Injured	4	0				5	
Bruising Fin	Not injured	143	11	59%	46%	0.090	396	47%
	Injured	120	16				348	
Fin Fraying	Not injured	205	20	26%	22%	0.804	582	22%
	Injured	58	7				162	
Internal organs exposed	Not injured	263	27	0%	0%	na	744	0%
	Injured	0	0				0	
Net marks	Not injured	263	27	0%	0%	na	739	1%
	Injured	0	0				5	
Scale loss	Not injured	253	25	7%	4%	0.316	716	4%
	Injured	10	2				28	
Scratches	Not injured	259	27	0%	2%	0.994	731	2%
	Injured	4	0				13	
Wounding	Not injured	262	27	0%	0%	0.997	740	1%
	Injured	1	0				4	

Reflex action mortality predictor – RAMP

The quantified reflex actions were used to correlate the percentage of reflex impairment at the time of discarding with the level of delayed mortality. This approach is known as RAMP – Reflex Action Mortality Predictor and has been used to assess vitality and predict mortality in various studies. We plotted the percentage of dead sole, from captive observation against the percentage of reflex impairment at time of discarding. Figure 14 shows that the percentage mortality increases with the sum of the number of reflex impairments. In this study, it was observed that all fish with 80% reflex impairment died and 7% of fish without any apparent reflex impairment observed would die.

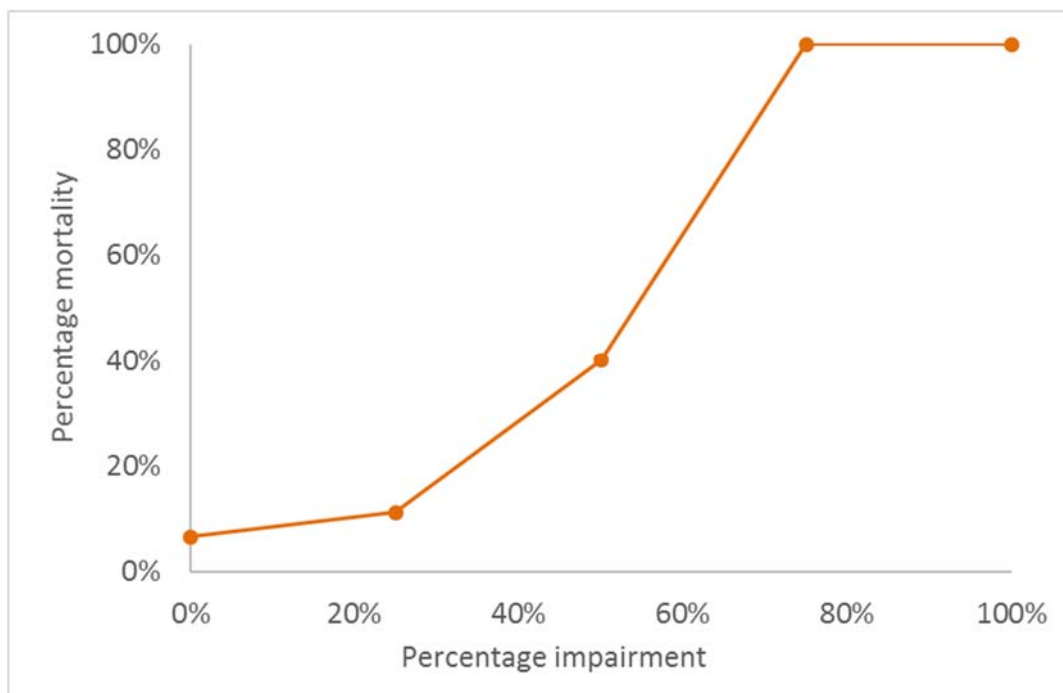


Figure 14. Variation of percentage of dead with percentage impairment in each case study.

Discussion

The project achieved its aim to generate a discard survival rate for sole captured in the Solent inshore trawl fishery in ICES Subarea VIId. The structure of this project followed the methods and concepts adapted from the previous survival studies (Catchpole et al, 2015; Smith et al., 2015, Randall et al., 2016, Ribeiro Santos, et al., 2016), to allow comparisons between studies and fisheries. As with the previous studies, the selected approach was to use vitality assessments conducted during normal fishing activity and combine these with captive observation of selected individuals of various lengths with different vitality scores to generate a weighted overall survival rate for sole. During a period of captivity, the estimated overall survival was 88% for the whole catch. The extension models indicated that there may have been limited mortality beyond this point in time, predicting a final survival rate of 79%. For sole under MCRS, the extended survival estimate was 82-89%. Avian predation assessments indicated there could be an 2% mortality by seabirds on live discarded sole (<MCRS). Applying this figure generates an adjusted discard survival rate of 80-87% for <MCRS sole.

Previous published studies to investigate sole survivability rates are scarce and focused on beam trawl fisheries (van Beek et al., 1990; Berghahn et al., 1998; Revill et al, 2013; Uhlmann, *et al.*, 2016) and gill net fisheries (Smith et al., 2015). A recent study investigating the discard survivability of sole focussed on the English east coast inshore otter trawl fishery (Ribeiro Santos, et al., 2016). The present study had the objective to complement and build on the results of the previous study on estimating sole discard survival. To capture survival estimates at an earlier point in the fishery than previously, to cover more of the conditions representative of the fishery and to provide further evidence to inform on the suitability of an exemption to the discard ban. The sampling and experimental approach was the same as used in the previous study. The previous sole survival study had a similar observation period (360 hrs) but the estimated overall survival was lower, 51% for sole under the legal landing size (or Minimum Conservation Reference Size) and 46% for the whole catch. The extension models estimated survival varied between 42% for the whole catch and 48% for the under sized sole. In the present study the overall survival rates were higher, with an estimated overall survival of 88% and 89% for the whole catch and under sized sole, respectively.

The differences in the survival rates between the studies could be related to technical influences (capture stresses; fishing method, catch composition and size), environmental conditions (temperature, depth, light, swell, etc) and biological traits (species, size or age, physical condition) (Davis, 2002). The fishing gear used in both studies was very similar,

inshore twin rigged otter trawl, with a codend mesh of 86mm. The sorting and handling practices were also similar between the two studies. However, the tow duration was shorter in the current project (1 – 1.5hrs during normal practice and less when weed was prevalent), while in the previous study they were around 1.5h and 2hours long. The catch composition may also influence the condition and mortality of sole since the presence of hard shelled species or fauna with rough skin make negatively affect survival due to injury. In the previous study, most of the hauls had high volumes of benthic species (e.g. whelks, star-fish and crabs), and other flatfish species, while in this study the catches were less diverse, dominated by sole, with few shellfish caught and less benthic species in the catch.

The environmental conditions that may have had impact on the survival probability are water and air temperature and depth at which the fish is caught. It is perceived that warmer temperatures and deeper fishing grounds can negatively affect fish survival. However, this study was carried during Summer and Autumn (July – October), when the air temperatures ranged 10 and 19 °C, and sole were caught at greater depth (14 - 26m), than in the previous survival study.

The condition of sole caught and kept captive may have been different between the two studies. In the first study, sole were caught at the end of the reproductive season, while the present study was carried during the peak of reproductive season, when sole may be in a better condition with a better chance to survive capture and discarding. The size of sole also may impact the ability of sole to survive – bigger sole may be more resistant to injuries caused by fishing gear or stress caused by handling and air exposure.

During the captivity period in the first study, it was observed that some of the sole developed injuries, such as extreme fin fraying, severe ventral abrasion and infections. In this study, such severe injuries were observed less frequently in the captive sole, which may have improved the estimated survival rates. The on-shore tanks were the same in both studies, however in the present study, sand was added to the bottom of each tank, which may have prevented the development of severe abrasion and fin fraying. Also, the better initial condition of sole in this study may have made them more resilient to the stress associated with the extra handling, transport from the on-board to on-shore tanks, changes in temperature and oxygen. In the previous study, sole were transported 1.6 miles in about 10 minutes, in the current study the sole were transported 0.2 mile in about 1 minute.

A common observation among discard survival studies is the large number of variables that could have a potential effect on the survival of captive species and the low sample number from which survival or death is directly observed (ICES, 2014). This makes it difficult to identify the factors that have a direct impact on mortality, and to understand their interaction and accumulative effect on the survival probability. It is difficult to tease apart their relative importance and different models and analytical approaches would be needed, together with collecting more data under different conditions, to identify key influencing variables.

Unlike the previous survival studies where the extended models showed an accentuated decrease on the long-term survival probability (Catchpole et al, 2015; Smith et al., 2015, Randall et al., 2016, Ribeiro Santos, et al., 2016), the extended model results did not show any decrease for Excellent fish and a slight decrease for Good fish. This may be because the KM curve reached the asymptote after 50hrs for the Excellent fish and very few mortalities were observed for the Good fish. This indicates that the period of two weeks in captivity was sufficient to estimate the discard survival for sole, excluding the effects of predation.

To assess the extent of experimental mortalities, it is favourable to use control subjects. To have genuine controls, one would require sole that were comparable to the treatment sole in every way, except having not gone through the catch and discard process, but this was not practically possible in the current study. However, in this study we used sole that had been caught in shorter tows than usual for commercial practice, the hope being that this shorter fishing time would be less stressful and less likely to injure the fish. The survival rates from these two days of fishing, 89% and 97% respectively, suggest minimal levels of experimental induced mortality. It is recognised that some of the commercial tows were of similar duration to the tows used to catch control fish.

The type of fishing method is an important factor affecting survival. All fishing methods induce stress and cause a degree of injury to the captured fish (e.g. abrasion, scale loss, wounding, etc.). These injuries were caused by scrapping and pressing of various objects and other marine organisms in the cod end. The sole captured with the otter trawl were contained in the cod end and some of them were stuck or “meshed” in the cod end meshes. This would cause compression at the abdominal area, abrasion, net marks and scale loss. According to the GLM results, no injury was significantly associated with the increased mortality of sole in this study.



Figure 15. Injuries appeared in some on the captive sole; Left – dorsal view, extreme caudal fin fraying; Right – ventral view, abrasion, with evidence of being meshed. 24cm sole, died 24 hours after capture.

In some studies, it has been noted that the haul duration was negatively correlated with the sole discards survival (van Beek *et al.*, 1990; van Marlen *et al.*, 2016). In the present study, due to the fishing conditions, sea trials were split in two seasons: one where the hauls were shorter due high volumes of seaweed and a second where the hauls were done under the more usual commercial conditions. Although the tow time varied, preliminary analysis did not show significant differences to the survival rates between the two trial seasons. Haul durations were relatively short and we are confident, based on previous observed trips in this fishery, that our presence on-board did not change the catch handling process and the stressors exerted on the fish were consistent with normal commercial practice.

The normal commercial process on the vessel after hauling is to re-deploy the trawl before sorting the catch, this takes 10-15 minutes. The sorting process takes 10-15 minutes at most. Once sorting is complete all unwanted catch is then discarded. Potentially any unwanted sole would be on deck for 20-30 minutes. With such a short sorting process, it is necessary for the scientist to keep sole on board beyond the time they would normally be discarded, or processed for landing. The sole vitality assessments and selection of fish for the tanks, started when the fish would have been discarded. At which point the sole were maintained in containers of seawater vitality assessments took place. These fish would have otherwise been released straight back to the sea (or landed) and so there was additional handling than would be the case under normal fishing practice. It is also conceivable that being kept in a Flexitub of seawater with a high stocking density may cause a degree of trauma. These additional stresses have not been quantified in the current study.

The initial vitality and reflex impairment assessments of fish showed a good agreement with the mortality estimates, with those in better condition having higher percentage of survival, than those in poorer condition. Reflex impairment appears to be a useful immediate sign of

stress that can be correlated with mortality (Davis, 2002, Benoît *et al.*, 2012). As in the previous study, impaired tail grab and orientation were the only reflexes that showed significant association with mortality.

The previous Cefas study on discard survival of sole caught inshore by under 10m otter trawl fishing vessels (Ribeiro Santos, *et al.*, 2016) led to a conditional exemption from the landing obligation based on the estimated overall survival of 51% for those sole under minimum conservation reference size (MCRS) and 46% for the whole catch (Art. 2, EU 2016/2375). The current study results of 80-87% for sole under MCRS and 79% for the whole catch, provides further evidence on sole discard survival from this fishery, and suggest the criteria of the exemption could be extended to include fishing vessel of up to 221kW power and fishing at depths up to 30m.

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References

- Benoît, H. P., T. Hurlbut and J. Chasse (2010). "Assessing the factors influencing discard mortality of demersal fishes using a semi-quantitative indicator of survival potential." *Fisheries Research* 106(3): 436-447.
- Benoît, H. P., T. Hurlbut, J. Chasse and I. D. Jonsen (2012). "Estimating fishery-scale rates of discard mortality using conditional reasoning." *Fisheries Research* 125: 318-330.
- Berghahn, R., Purps, M. (1998). Impact of discard mortality in Crangon fisheries on year-class strength of North Sea flatfish species. *Journal of Sea Research*, 40: 83-91.
- Cai, C., Y. Zou, Y. Peng and Z. J. (2012). "Smcure: An R-package for estimating semiparametric mixture cure models. ." *Computer methods and programs in biomedicine*, 108: 1255-1260.
- Catchpole, T., Randall, P., Forster, R., Smith, S., Ribeiro Santos, A., Armstrong, F., Hetherington, S., Bendall, V., Maxwell, D. (2015). Estimating the discard survival rates of

- selected commercial fish species (plaice - *Pleuronectes platessa*) in four English fisheries (MF1234), Cefas report, pp108.
- Davis, M. W. (2002). "Key principles for understanding fish bycatch discard mortality." Canadian Journal of Fisheries and Aquatic Sciences 59(11): 1834-1843.
- Davis, M.W and Ottmar, M.L (2006). Wounding and reflex impairment may be predictors for mortality in discarded or escaped fish. Fisheries Research, 82:1-6.
- Davis, M. W. (2010). "Fish stress and mortality can be predicted using reflex impairment." Fish and Fisheries 11(1): 1-11.
- ICES (2014). Report of the Workshop on Methods for Estimating Discard Survival (WKMEDS), 17–21 February 2014, ICES HQ, Copenhagen, Denmark. ICES CM 2014/ACOM:51. 114 pp. M. Breen and T. Catchpole.
- Randall, P., Armstrong, F., Ribeiro Santos, A., Catchpole, T. (2016). Assessing the survival of discarded Plaice in the English NE *Nephrops* trawl fishery, February 2016, Cefas report pp37.
- Revill, A. S., M. K. Broadhurst and R. B. Millar (2013). "Mortality of adult plaice, *Pleuronectes platessa* and sole, *Solea solea* discarded from English Channel beam trawlers." Fisheries Research 147: 320-326.
- Ribeiro Santos, A., Duggan, K., Catchpole, T. (2016). Estimating the discard survival rates of Common sole (*Solea solea*) in the English east coast inshore otter trawl fishery, Part of the Cefas ASSIST Project, February 2016, Cefas report pp29.
- Smith, S., Elliot, S. and Catchpole, T. (2015). Estimating the discard survival rates of Common sole (*Solea solea*) and plaice (*Pleuronectes platessa*) in the Bristol Channel trammel net fishery and of plaice in the Bristol Channel otter trawl fishery. Cefas report, pp64.
- Uhlmann, S. S., Theunynck, R., Ampe, B., Desender, M., Soetaert, M., and Depestele, J. (2016). Injury, reflex impairment, and survival of beam-trawled flatfish. – ICES Journal of Marine Science, doi: 10.1093/icesjms/fsv252.
- Van Marlen, B., Molenaar, P., van der Reijden, K.J., Goudswaard, P.C., Bol., R.A., Glorius, S.T., Theunynck, R. and Uhlmann, S. (2016). Overleving van discard platvis; Vaststellen en verhogen. Wageningen, IMARES Wageningen UR (University & Research center), IMARES rapport C180/15. 116 blz.; 21 tab.; 17 ref.
- Van Beek, F.A., van Leeuwen, P.I. and Rijnsdorp, A.D. (1990). On the survival of plaice and sole discards in the otter trawl and beam-trawl fisheries in the North Sea. Netherlands Journal of Sea Research, 26(1):151-160.

Annex 1:

Details of the hauls, including, sorting and sampling time, and environmental conditions

Haul Date	Haul No.	Tow Duration	Haul Time Ends	Haul Depth (m)	Time Sorting Starts	Time Sorting Ends	Total sorting time (min)	ICES Area	ICES rectangle	Wind Force	Wind Direction	Sea State	Air Temp. °C	Water Temp. °C
21/07/2016	1	00:12	09:16	25.5	NA	NA	NA	VIIId	30E8	2	WNW	Calm	16.1	19.5
21/07/2016	2	01:17	10:45	18.8	10:55	11:05	00:10	VIIId	30E8	1	NW	Calm	17.2	19.5
21/07/2016	3	01:28	12:35	28.4	12:40	12:48	00:08	VIIId	30E8	2	W	Calm	18.8	19.2
21/07/2016	4	00:37	13:37	25.0	13:43	13:45	00:02	VIIId	30E8	3	W	Calm	18.7	19.2
21/07/2016	5	00:35	14:43	26.9	14:55	14:58	00:03	VIIId	30E8	3-4	WSW	Calm	19.1	19.2
22/07/2016	1	00:24	09:40	24.0	09:45	09:49	00:04	VIIId	30E8	1	WSW	Calm	18.4	19.4
22/07/2016	2	00:20	10:35	29.0	10:45	10:50	00:05	VIIId	30E8	2	WSW	Calm	18.9	19.5
04/08/2016	1	00:18	10:06	23.0	10:11	10:15	00:04	VIIId	30E8	5	WSW	Slight	17.1	18.8
04/08/2016	2	00:21	10:41	25.6	10:46	10:52	00:06	VIIId	30E8	5	WSW	Slight	17.2	18.8
04/08/2016	3	00:14	11:22	23.5	11:26	11:30	00:04	VIIId	30E8	5	WSW	Slight	17.0	18.7
04/08/2016	4	00:29	12:23	24.0	12:30	12:37	00:07	VIIId	30E8	5	WSW	Slight	17.4	18.6
04/08/2016	5	00:24	13:18	26.0	13:24	13:30	00:06	VIIId	30E8	5	WSW	Slight	17.4	18.6
05/08/2016	1	00:13	10:26	24.0	10:40	10:45	00:05	VIIId	30E8	3	WSW	Slight	16.9	18.8
05/08/2016	2	00:19	11:26	27.0	11:40	11:45	00:05	VIIId	30E8	4	WSW	Slight	17.4	18.8
05/08/2016	3	00:16	12:49	25.0	12:55	13:00	00:05	VIIId	30E8	4	WSW	Slight	17.6	18.7
06/08/2016	1	00:18	10:37	27.0	10:48	10:52	00:04	VIIId	30E8	3	SW	Slight	17.3	19
06/08/2016	2	00:16	11:46	27.3	12:00	12:04	00:04	VIIId	30E8	3	WSW	Slight	18.2	18.9
06/08/2016	3	00:25	13:18	25.7	13:21	13:26	00:05	VIIId	30E8	4	WSW	Slight	18.4	18.8
08/08/2016	1	00:19	09:28	22.9	09:36	09:40	00:04	VIIId	30E8	4	NW	Slight	16.1	19.6
08/08/2016	2	00:39	10:41	24.0	10:50	10:55	00:05	VIIId	30E8	4-5	NW	Slight	16.7	19.4
08/08/2016	3	00:42	12:12	23.3	12:24	12:28	00:04	VIIId	30E8	4	WNW	Slight	17.5	19.3
17/10/2016	1	01:21	10:45	20.0	10:45	10:50	00:05	VIIId	30E8	4	SW	Slight	14.4	14.2

17/10/2016	2	01:20	12:45	22.0	12:50	12:55	00:05	VIIId	30E8	4	WSW	Slight	14.3	14.3
17/10/2016	3	01:40	15:05	21.0	15:10	15:17	00:07	VIIId	30E8	4	WSW	Slight	14.7	14.3
19/10/2016	1	01:29	10:50	17.9	10:56	11:07	00:11	VIIId	30E8	4	NW	Slight	13.3	15.5
19/10/2016	2	01:12	12:20	20.0	12:55	13:10	00:15	VIIId	30E8	4	NW	Slight	13.0	13.8
19/10/2016	3	01:57	15:05	23.0	15:10	15:24	00:14	VIIId	30E8	4	NNW	Slight	13.5	13.8
20/10/2016	1	01:35	10:50	17.0	10:55	11:05	00:10	VIIId	30E8	4	NNW	Slight	11.4	13.5
20/10/2016	2	01:20	12:30	23.0	12:40	13:00	00:20	VIIId	30E8	4	NNW	Slight	13.5	13.6
20/10/2016	3	01:15	14:55	24.0	15:00	15:10	00:10	VIIId	30E8	4	NNW	Slight	13.4	13.6
22/10/2016	1	01:00	10:27	22.9	10:30	10:35	00:05	VIIId	30E8	2	NNE	Calm	8.1	12.9
22/10/2016	2	00:55	11:55	23.0	12:00	12:10	00:10	VIIId	30E8	2	NNE	Calm	10.3	13.1
22/10/2016	3	01:33	14:10	21.0	14:15	14:27	00:12	VIIId	30E8	2	NNE	Calm	11.0	13.3



Centre for Environment Fisheries & Aquaculture Science



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About us

The Centre for Environment, Fisheries and Aquaculture Science is the UK's leading and most diverse centre for applied marine and freshwater science.

We advise UK government and private sector customers on the environmental impact of their policies, programmes and activities through our scientific evidence and impartial expert advice.

Our environmental monitoring and assessment programmes are fundamental to the sustainable development of marine and freshwater industries.

Through the application of our science and technology, we play a major role in growing the marine and freshwater economy, creating jobs, and safeguarding public health and the health of our seas and aquatic resources

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Customer focus

We offer a range of multidisciplinary bespoke scientific programmes covering a range of sectors, both public and private. Our broad capability covers shelf sea dynamics, climate effects on the aquatic environment, ecosystems and food security. We are growing our business in overseas markets, with a particular emphasis on Kuwait and the Middle East.

Our customer base and partnerships are broad, spanning Government, public and private sectors, academia, non-governmental organisations (NGOs), at home and internationally.

We work with:

- a wide range of UK Government departments and agencies, including Department for the Environment Food and Rural Affairs (Defra) and Department for Energy and Climate Change (DECC), Natural Resources Wales, Scotland, Northern Ireland and governments overseas.
- industries across a range of sectors including offshore renewable energy, oil and gas emergency response, marine surveying, fishing and aquaculture.
- other scientists from research councils, universities and EU research programmes.
- NGOs interested in marine and freshwater.
- local communities and voluntary groups, active in protecting the coastal, marine and freshwater environments.

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