Centre for Environment Fisheries & Aquaculture Science

Cefas

World Class Science for the Marine and Freshwater Environment

Survivability of Discarded Skates and Rays in English Inshore Otter Trawl Fisheries

Part of ASSIST MF1232

Author(s): [redacted]

Issue Date: March 2018

Cefas Document Control

Submitted to:	[redacted]
Date submitted:	28/03/2018
Project Manager:	[redacted]
Principal Investigator	[redacted]
Report compiled by:	[redacted]
Quality control by:	[redacted]
Approved by and date:	[redacted] 28/03/2018
Version:	4

Version Control History

Version	Author	Date	Comment
1	[redacted]	12/01/18	First Draft
2	[redacted]	20/02/18	Second Draft
2	[redacted]	15/03/18	Second Draft
3	[redacted]	21/03/18	Review edit
4	[redacted]	[redacted]/18	Final Draft

Executive Summary

This work was carried out as part of the ASSIST project (Applied Science to Support the Industry in delivering an end to discards), a Defra-funded collaborative programme 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 thornback ray (*Raja clavata*) caught and released in the Thames (ICES Subarea IVc) and undulate ray (*Raja undulata*) in Lyme Bay (ICES Subarea VIIe) inshore otter trawl fisheries. There is a strong perception from the fishing industry that skates and ray species have a high discard survival rate in these fisheries. Where skates and ray quotas are restricted, the mandatory landing of all individuals under the requirements of the landing obligation, could risk a premature end to the fishing season. From January 2019, all skates and ray catches must be landed and counted against quota unless an exemption, based on scientific evidence demonstrating high survival, is awarded.

The selected approach to estimate discard survival rates was to use vitality (health) assessments of rays at the point of release, which were caught under normal commercial fishing conditions, combined with tagging of a sample of rays using Data Storage Tags (DST's). With a sufficient number of tags returns, the relationship between vitality and survival will be determined and applied to the vitality data to enable an estimate of post-release survival of commercially caught rays. Here we present the first phase of the work, describing the tagging methods and the vitality data, a discard survival estimate will be generated when sufficient tags returns have been received.

The study recognises that there are many UK fisheries catching ray species for which discard survival estimates would be desirable, however it is impractical to generate evidence directly for all of these. There is a substantial and increasing body of evidence on the survival probability of discarded rays and on the vitality of rays at the point of release, and this will be further enhanced by new estimates derived directly from selected fisheries. However, there is also a requirement to assess the comparability between fisheries in terms of the stressors exerted on discarded rays, and an assessment of which stressors most influence survival. This will enable risk-based extrapolation of ray survival estimates across fisheries.

Table of Contents

1 Introduction

1.1 Overview

This project was carried out as part of the ASSIST project. 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.

1.2 Summary

The landing obligation has been phased in for different species and fisheries, since January 2015. It started with the pelagic fisheries in 2015, from 2016 the landing obligation has introduced several demersal fisheries and species in North Sea and North-Western Waters. By 2019 all species in EU waters subject to Total Allowable Catch (TAC) limits and those with Minimum Conservation Reference Size (MCRS) in the Mediterranean will be subject to the landing obligation; including species of skates and rays (hereafter collectively referred to as rays), caught by inshore otter trawlers.

This regulation will affect the inshore otter trawl fisheries, for which rays can be either a bycatch or a main target species. Where the quotas are restrictive relative to the local abundance of rays, this regulation could potentially risk a premature end of the fishing season. For this reason, in 2017, Cefas carried out two discard survival assessments:

1. for thornback ray caught by inshore otter trawler, using 80mm cod end mesh and operating on the English East coast (ICES Subarea IVc)
2. for undulate ray caught by inshore otter trawler, using 80 mm cod end mesh, operating on the English South coast (ICES Subarea VIIe).

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 would be appropriate. We aimed to estimate ray discard survival rates across the entire length range of the catch, under the assumption that fish at any length could be discarded.

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

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 ray 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 many cases, injury and reflex impairment have previously been shown to be reliable predictors of discard mortality ([redacted] In parallel, a sample of the ray catch was tagged and released. Data Storage Tags (DSTs) were used to quantify post-release survival of commercially caught rays. In recent Cefas studies, buoyant Cefas G5 DSTs have been shown to record post-discard mortality [redacted]

2 Materials & Methods

2.1 The Fishing Vessels

2.1.1 Study 1 Thames Thornback

The vessel used in the Thames area trial was the MFV Jessica M; CK157 (9.92m, 8.0 t twin trawler powered by an 88-kw engine) normally operating from West Mersea, skippered by Robert Mole (Figure 1). The MFV Jessica M fished using a standard commercial twin otter trawl. The net had a combined fishing line of 22m (2*6ftm) with an estimated door spread of 15m (50ft), fishing with a cod end mesh size of 80mm diamond, constructed from 2.0mm single-braided twine.

2.1.2 Study 2 Lyme Bay Undulate

The vessel used in the Lyme Bay trial was the MFV Sea Seeker; E68 (9.99m, 8.49 t trawler powered by a 95-kw engine) operating from West Bay as normal, skippered by Mark Cornwell, (Figure 1). The MFV Sea seeker fished using a standard commercial otter trawl. The net had a fishing line of 26m (85ft) with an estimated door spread of 91m (300ft), fishing with a cod end mesh size of 80mm diamond, constructed from 6.0mm single-braided twine.

2.2 Fishing Activity

All MFV Jessica M's fishing tows took place in the Thames area of the Southern North Sea (ICES Division IVc, ICES rectangle 32F1), at depths ranging between 6 and 15m (Figure 2). The fishing vessel operated on muddy sand to target mixed demersal species, including thornback ray. Tow times were as per normal for this fishery at approximately 1 hour.

All MFV Sea Seeker's fishing tows took place in the Lyme Bay area of the Western English Channel (ICES Division VIIe, ICES rectangles 29E7 and 30E7), at depths ranging between 19 and 50m (Figure 2). The fishing vessel operated on mixed grounds to target mixed demersal species, including undulate ray. Tow times were as per normal for this fishery at approximately 2-3 hours, depending on seabed substrate in the area.

Figure 1: (Left) MFV Jessica M (CK157) pictured at West Mersea harbour & (Right) MFV Sea Seeker (E68) pictured at West Bay harbour

2.3 Vitality Assessment

All the ray caught were assessed for vitality immediately after the period of catch sorting, with some rays being selected for tagging. The usual process on board the vessel is to discard all unwanted fish in bulk at the end of sorting the catch (Figure 3), so vitality assessment started at the point that discarding would normally have occurred. The vitality assessments were conducted on a makeshift sorting table. Fish were selected for tagging based the requirement for the sample to represent the full range of vitalities and lengths in the catch, although rays below 50cm total length were deemed too small for tagging, and no rays assessed as dead were tagged. Immediately after the vitality assessment, each ray was released, with 51 thornbacks and 49 undulates being selected for tagging prior to release in Study 1 and 2 respectively.

2.3.1 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, characterising fish as very lively and responsive (E, excellent) at one end of the scale to unresponsive (D, dead) individuals at the other end (Table 1).

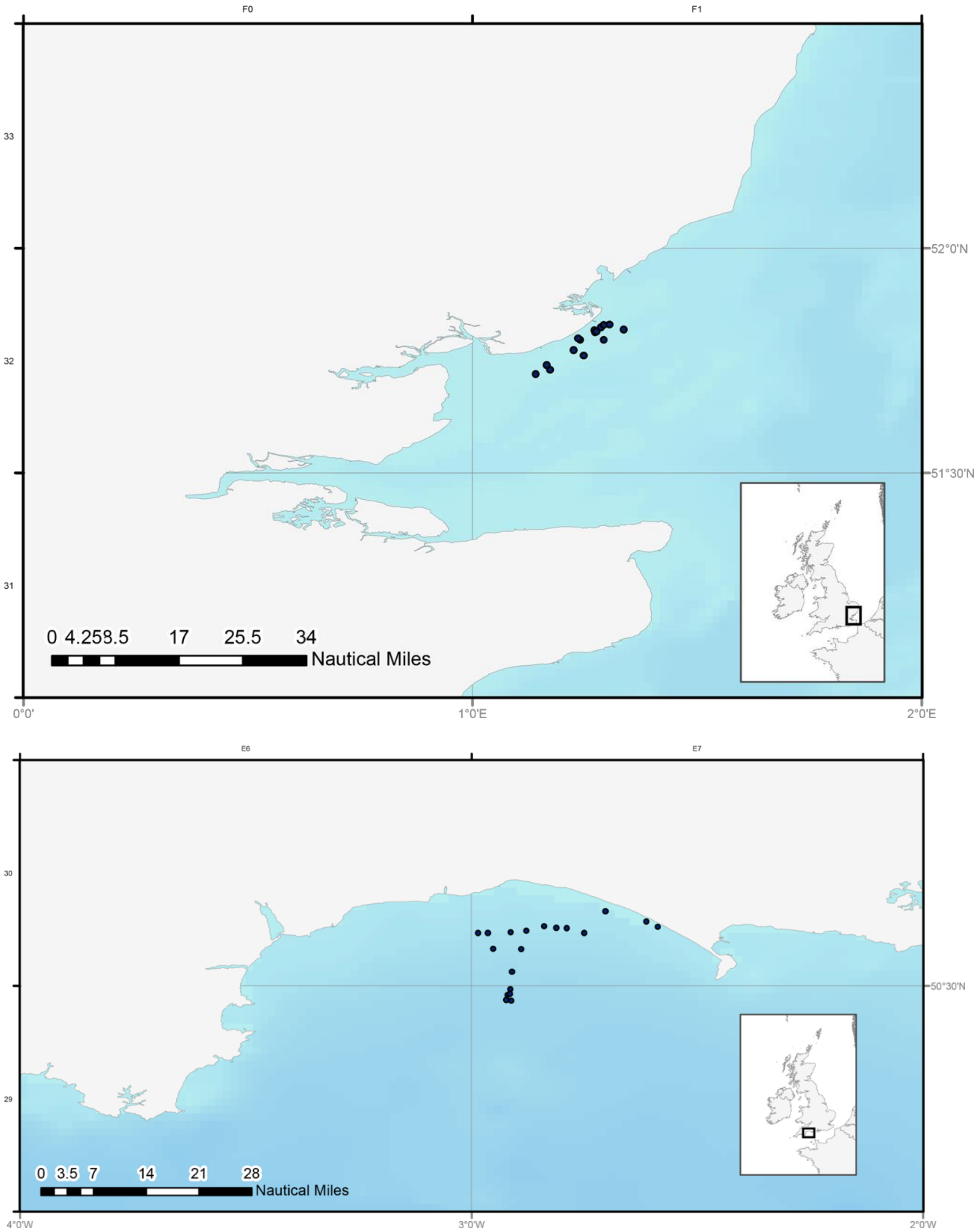


Figure 2: Location of fishing activity for MFV Jessica M (Top) & MFV Sea Seeker (Bottom).

Figure 3: MFV Jessica M: Crew sorting the catch on deck by hand, as per normal commercial practice.

A protocol for the vitality reflex and injury assessment was developed by [redacted] (2015) and further refined as described in [redacted] (2016). A series of behavioural reflex tests were applied that consistently produced unimpaired responses, and could be scored rapidly in a replicable manner (Table 2). The rays were also examined for the presence/absence of defined injuries (Table 3). These reflex and injury assessments have previously been applied to various flatfish species in recent studies [redacted] and further developed to be relevant for rays in the present study.

Table 1: Description of the categories used to score the pre-discarding vitality of individual fish for the semi-quantitative activity method. Developed from [redacted] (2010).

Vitality	Abbreviation	Description
'Excellent'	E	Vigorous body movement; no or minora external injuries only
'Good'	G	Weak body movement; responds to touching; minor$_a$ external injuries
'Poor'	P	No body movement but fish can move spiracle; minor$_a$ or major$_b$ external injuries
'Dead'	D	No body or spiracle movements (no response to touching)

[a] Minor injuries were defined as 'minor bleeding, or minor tear of mouthparts or wing (≤10% of the diameter), or minor surface abrasion.

[b] Major injuries were defined as 'major bleeding, or major tear of mouthparts or wing, or major surface abrasion.

Table 2: Vitality reflex assessment protocol developed for thornback ray (*R. clavata*) and applied to both studies.

Name	Stimulus action	Reflex response
Ocular Tap	The skate/ray is gently tapped on the head, behind the eyes and spiracles, with a firm object.	Actively closes and retracts its eyes, within 5 seconds.
Spiracle Closure	The spiracles are observed.	The spiracles are actively opened and closed, within 5 seconds.
Wing Stimulus	A stroke of the ventral surface of the wing (pectoral fin) with a firm object.	Undulating movement of pectoral fin within 5 seconds.
Wing Flex	The skate/ray is held by the anterior end of the disc, one hand either side of the mid line.	Undulating movement of pectoral fins within 5 seconds.

The current study had observations for four reflexes; ocular tap, spiracle closure, wing stimulus, and wing flex (Table 2). 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 thornback ray (*R.clavata*) and applied to both 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.
Net marks	Any type of clearly visible net marks on body from trawl, gill-net, etc.
Scratches	Thin shallow cut or mark on (a surface).
Wounding	Nicks or 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.

2.4 Tagging (Data Storage Tags)

Every effort was made not to alter typical commercial fishing practice, so that the tagged rays experienced as typical a capture and handling event aboard as possible, and the trial was therefore representative of the fishery. Immediately after the catch was sorted the rays were placed in fish-boxes 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.

Figure 4: Scientist assessing for injury and assessing the vitality of thornback ray.

Each buoyant Cefas G5 DST was attached to a button sure-tag and attached externally to a ray through the wing using a method developed and pplied in previous studies ([redacted] 2015; [redacted] 2017; [redacted] 2016; [redacted] 2016). All regulated tagging procedures were carried out under project licence authorised by the UK Home Office (PPL: 70/7588). For these studies, each Cefas G5 DST (www.cefastechnology.co.uk) was programmed to record depth at one-minute intervals and temperature at 10-minute intervals. 11 of the 51 Cefas G5 tags were attached with a pop-off unit for the Thames study while 46 of 49 tags were attached with a pop-off unit for the Lyme Bay study. The proportion of tags with pop-off mechanisms attached was based on the anticipated returns via recapture versus beach recovery, which was informed by the known prevailing winds and currents in the two study areas, and due to the larger average size of the undulate rays. Physical recovery of the tags is required to retrieve the archived information. Pop-off tags were programmed for 90-day (3-month period) release to maximise the likelihood of having sufficient returns to produce a timely quantified survival estimate.

Physical tag recovery can be achieved through a fishery, by catching a tagged 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.

Whilst each ray was tagged and assessed for vitality the typical commercial fishing practice continued alongside. Immediately after releasing a tagged ray, another was selected at random from the sorted catch. No measures were taken to lessen the stress aboard so that handling practices were typical of normal fishing practices.

Less than 10% of the thornback ray caught (51 individuals) were tagged. All thornbacks caught were assessed for vitality. For the undulate ray, 51% (49 individuals) were tagged. This was because low numbers of ray were caught, due to the low abundance encountered when fishing them in an off-peak season. All undulates caught were assessed for vitality.

2.4.1 Tagging Reward Scheme

To encourage the recovery of the 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. The ray survival studies and the associated reward scheme were advertised via Twitter. Tag-return information can be supplied via the tag-reporting hotline, by post, or on the internet (see www.cefas.co.uk/fishtagreturns).

2.4.2 Tag Returns

To date, 4 of the tags have been returned. All available information on the recapture will be 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. A project summary is sent to the returnee with a letter of thanks.

2.5 At Sea Data Collection

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

2.5.1 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 released onto the deck (Figure 5) where they remained until the trawl was redeployed.

Figure 5: (Left) Crew of MFV Jessica M, and (Right) MFV Sea Seeker, opening cod-ends into the deck pound.

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 rays back into the sea, and processing any marketable rays, the ray catch was placed into fish-boxes prior to assessment by the scientist. The vitality assessment of the rays took place after sorting was complete, to replicate the level of air exposure normally experienced by discarded ray. The catch composition of each haul was also recorded, by species and estimated weight.

After the vitality assessments, some of the target ray species were selected for tagging (Figure 6).

Figure 6: (Left) Assessing vitality; thornback ray demonstrating a wing stimulus reflex. (Right) Undulate ray with DST pop-off tag.

All caught rays were measured for both body length and wing width, and had their sex was recorded.

2.6 Analytical Methods

2.6.1 Survival Estimate Methods

To estimate the survival of discarded tagged rays, mortalities are assumed to relate to capture and handling stress rather than tagging and attachment stress. Disentangling the effect of these two stressors is not possible in the wild, as controls can only be used in laboratory studies ([redacted] 2015). The review by [redacted] (2015) suggests that mortality from external tagging is rare, which is supported by the lack of mortalities for rays released using non-commercial landing practices but the same tagging technique in [redacted] (2005). Further support is provided by a recent study on thornback ray caught using typical commercial practice which demonstrated 95% survival from static trammel nets (Catchpole *et al.,* 2017).

To classify whether discarded rays survived or died after release, two analysis steps will be undertaken using returned DSTs based on (1) the recapture method and (2) the behaviour of the ray. The recapture method provides an accurate indication of ray survival, with all re-caught and landed fish categorised as survived and all fish that washed up on shore with tags still attached categorised as dead (step 1). Predictions about the survival of fish for beached tags (without the fish attached) cannot be immediately assessed, so further analysis of ray behaviour will be used to predict their fate (step 2; Figure 7).

Survival estimates using step 1 assumes that all caught fish are alive when hauled and that all fish that wash ashore with the tags attached died. It may be possible for ray to be hauled dead, though this is unlikely (but can be tested using behavioural analysis of the tag data at the time prior to landing).

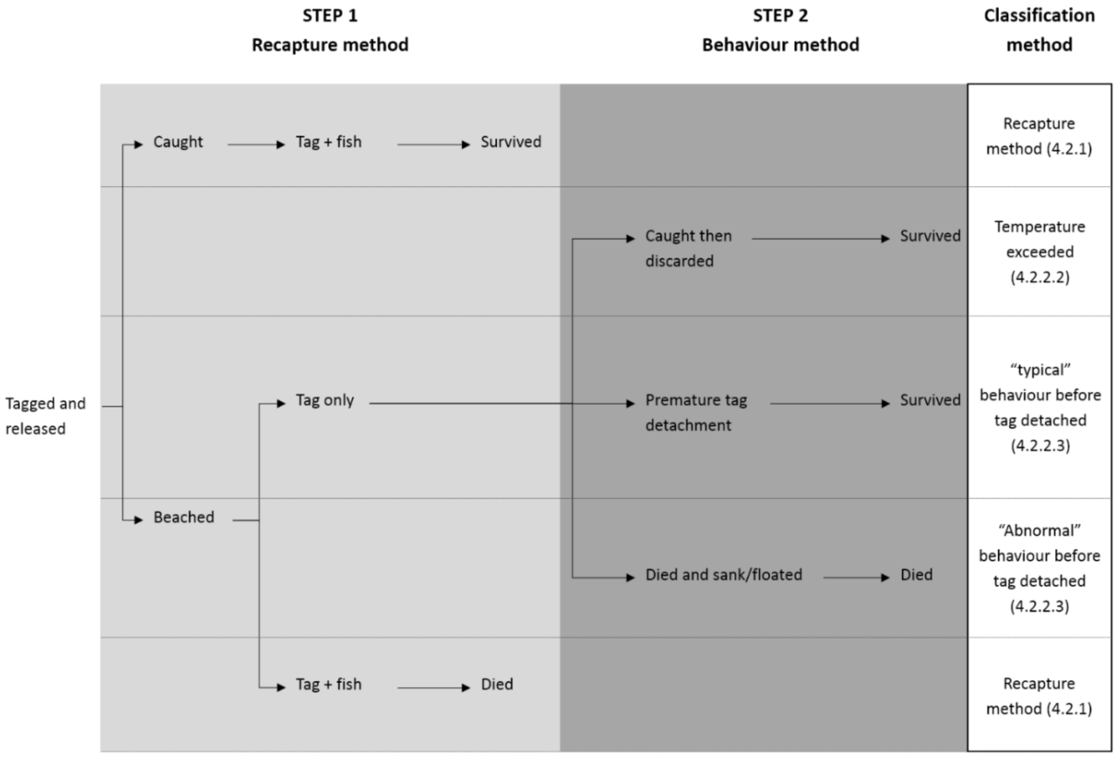


Figure 7: Survival classification tree. Methods used to classify survival for re-caught ray. Step 1 provides an indication of survival based on the method of recapture, and step 2 uses behavioural changes (measured by depth and temperature) to predict survival. The method used to classify survivability is indicated in the final column, with the value in brackets reflecting the corresponding subsection of the report.

Survival estimates using step 2 are carried out for tags which have washed ashore without fish attached. The analysis determines whether tags have detached due to fish death, premature tag detachment, or commercial/recreational capture (with the tag removed and discarded). Individual vertical speed and depth data are analysed at the period prior to a beached tag reaching the sea surface and floating ashore, together with any immediate changes in temperature upon reaching the sea surface. To establish the most probable fate for each ray, these data are compared against tags where the fate of the ray was known (i.e. caught during commercial or recreational fishing).

The point in time that these tags detach or the fish floated to the surface is defined using summarised depth and temperature changes recorded on “typical” rays (using data from thornback rays caught during fishing from the present study and historic records (n=28); ([redacted] 2005)). Secondly, to identify whether any of the beached tags have been caught and then discarded, the temperature range on the day that tags starting floating will be compared to temperature ranges of caught fish, providing an indication of whether tags were exposed to the air (which results in a marked change in temperature indicative of capture). Finally, for tagged fish which were not caught, the behaviour of the ray will be compared to “typical” ray behaviours to identify whether behaviour was abnormal prior to the tags detaching or the fish floated to the surface.

“Typical” behaviours will be identified using the daily proportion of time that individuals spend close to the assumed sea bed (within 20% of the maximum depth), and within 5 m of the sea surface. Additionally, rays will be geolocated to identify spatial movements from the point of release to the point of recapture. A full description of the Hidden Markov Model is provided in [redacted] (2008). Briefly, for each day at liberty, a probability distribution was constructed using a model constrained by the fishes’ maximum depth, tidal geolocation estimates based on tidal range and times of high water and a maximum distance travelled depending on whether ray behaviour was deemed as resident or migratory ([redacted]

3 Results

3.1 Sampling and Catches

For the Thames area study; the thornback rays were captured on the 26th and 27th October 2017 during 15 hauls (Table 4). Thornback ray was the predominant species in all hauls. A total of 537 thornback ray were assessed for vitality and injury with a subsample of 51 thornback ray tagged and released, 11 of the tags were pop-offs. The length distributions of the assessed and the tagged thornback rays are shown in Figure 8. The mean length of thornback ray was 45.4 cm, mean wing width 29.8 cm. The fishing was selective towards thornback ray with small amounts of mixed demersal fish caught, of which most were discarded with the exception of sole (*Solea solea*).

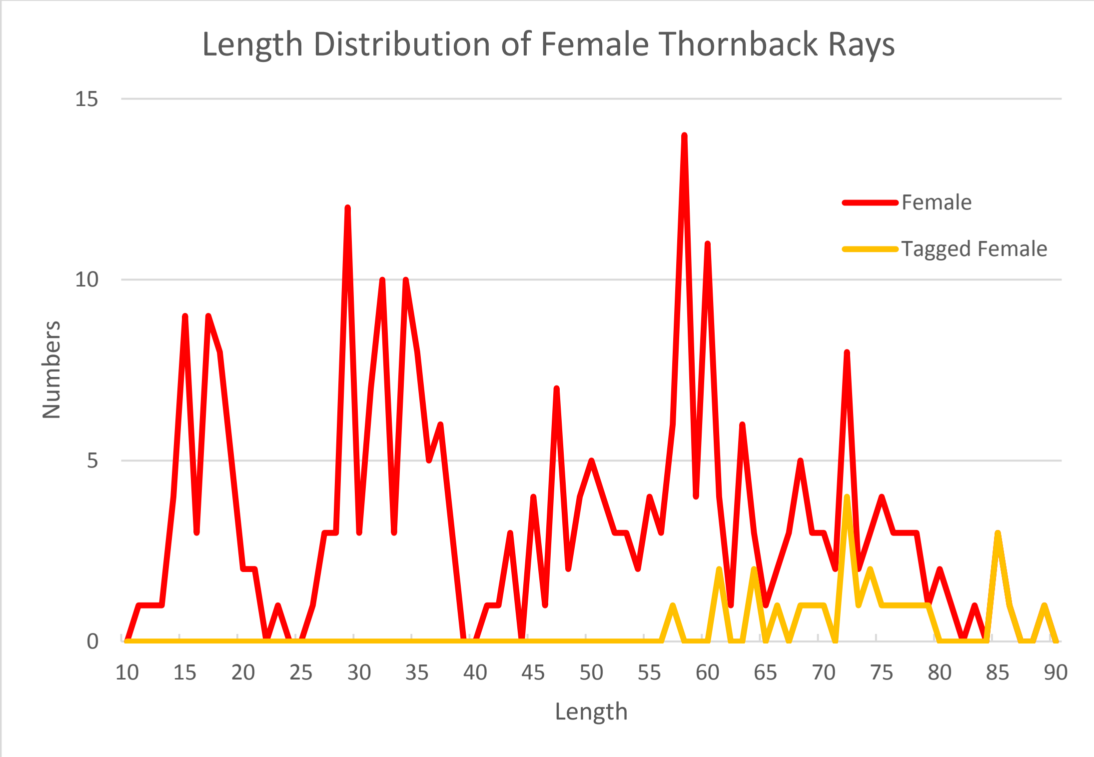
In Lyme bay, the undulate rays were caught over 7 days of fishing, as weather permitted, the first day being 5th February 2018 and the last 20th February 2018. The fishing comprised of 19 hauls and each of which had a catch composed of mixed demersal species. Due to fishing out of season, it took longer than expected to achieve adequate numbers of undulates for the study. 96 individuals in total were caught, 49 of which were tagged. The length distributions of the assessed and tagged undulate rays are shown in Figure 9. The mean length of undulate ray was 83.7 cm and mean wing width 52.2 cm (Table 4). The fishing was selective towards undulate ray, but a variety of commercial demersal species were caught and retained, and small amounts of fish, predominantly lesser-spotted dogfish were discarded.

3.2 Vitality Assessment

3.2.1 Thornback ray

For the thornback ray that were assessed for vitality, 12% (n=67) of thornback ray were assessed as Excellent condition, 50% (n=270) were Good and 34% (n=184) were Poor, and 3% (n=16) were assessed as Dead. For the tagged thornback rays, 31% (n=16) of thornback ray were assessed as Excellent condition, 49% (n=25) were Good and 20% (n=10) were Poor, no Dead rays were tagged. (Figure 10).

The most commonly observed injury throughout was abrasion observed in 448 individuals (90% of 'excellent', 80% of 'good' and 80% of 'poor'), scratches were observed in 108 individuals (20% of 'excellent', 30% of 'good' and 1% of 'poor'), and wounding observed in 83 individuals (10% of 'excellent', 10% of 'good' and 20% of 'poor'). Bleeding, bruising and net marks were found in 49, 50 and 3 individuals respectively. Note that injury scoring does not consider the scale/severity of the injury, i.e. thornbacks in excellent condition but with wounding may have minor injuries compared with ray rated as poor.



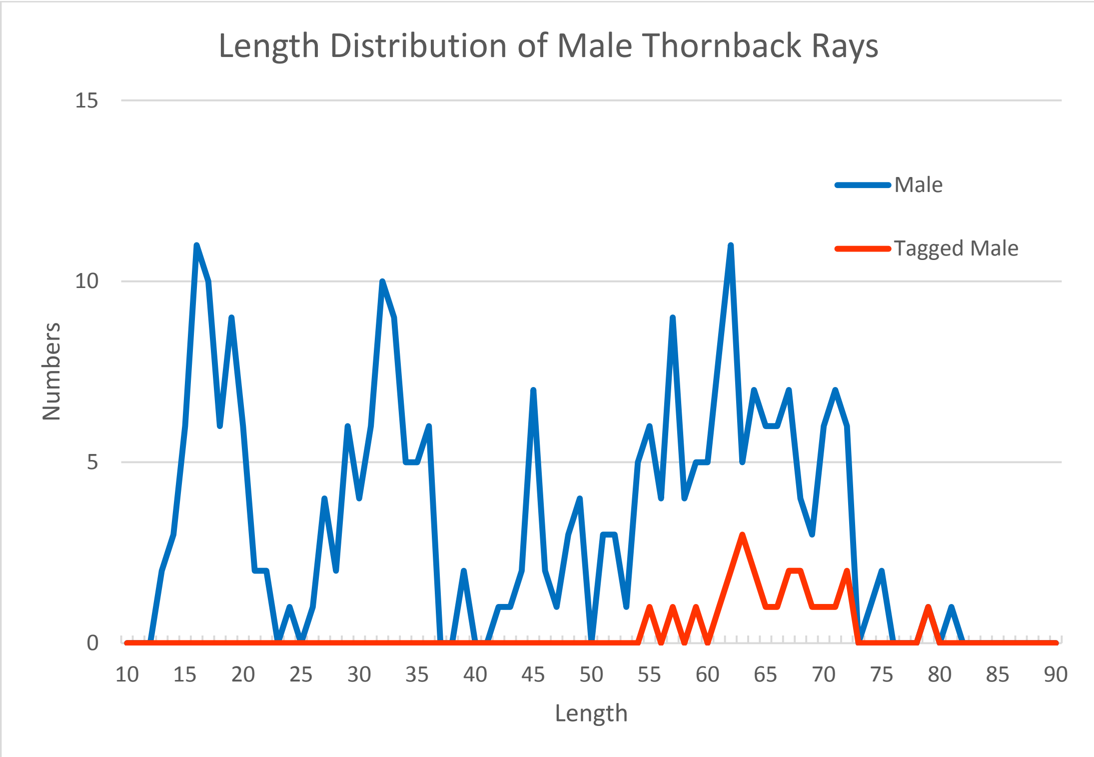
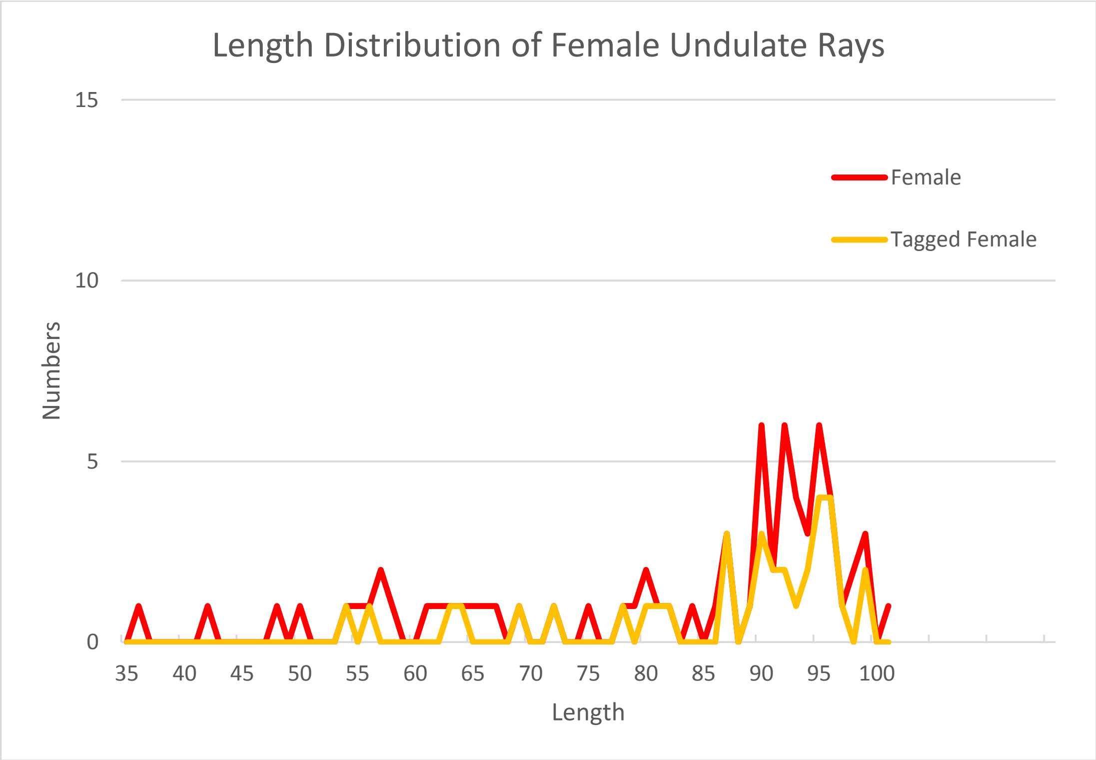


Figure 8: Length distribution of all thornback ray catch and tagged sub sample for female rays (top plot) and the male rays (bottom).



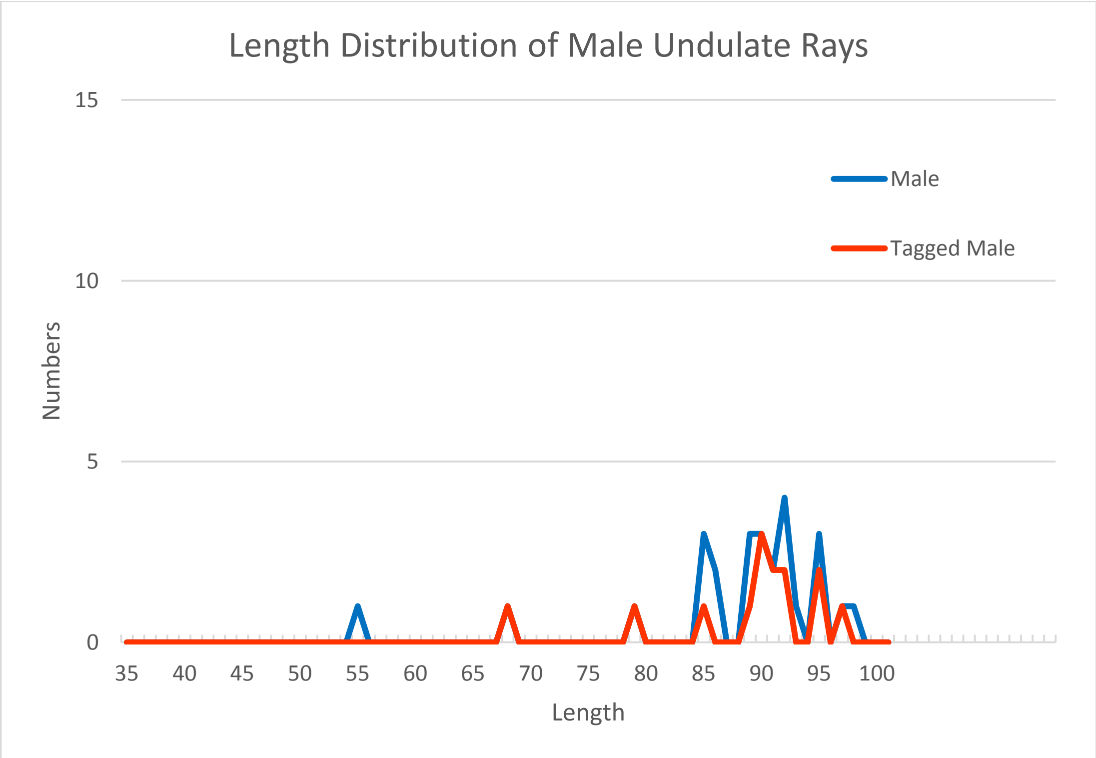


Figure 9: Length distribution of all undulate ray catch and tagged sub sample for female rays (top plot) and the male rays (bottom).

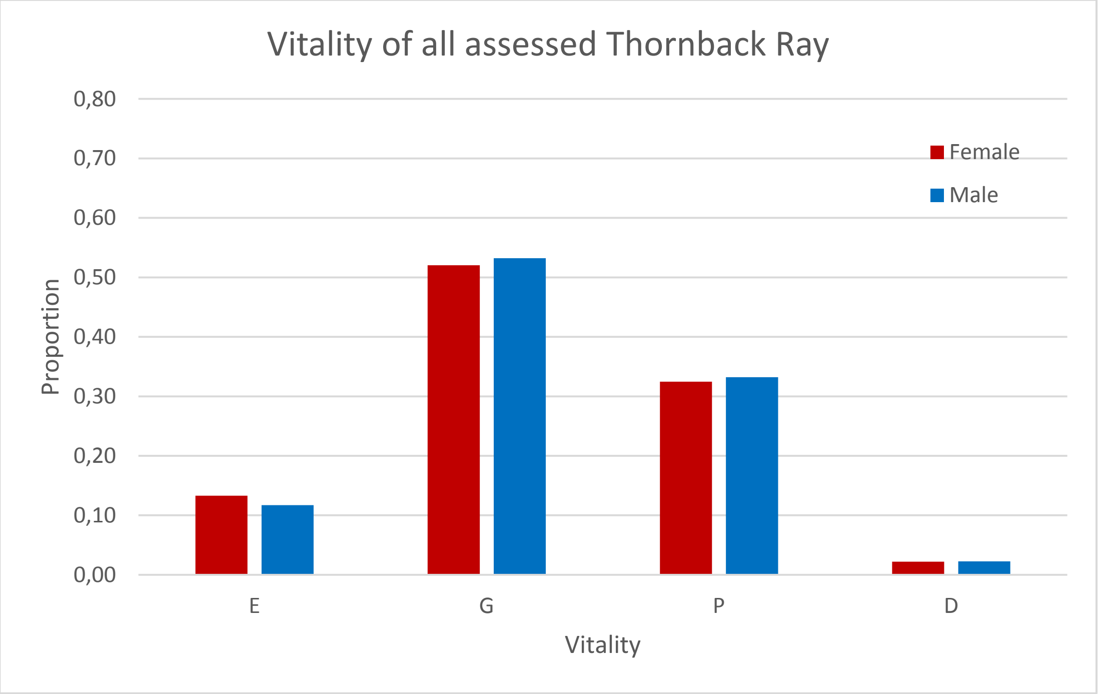
Table 4: Data summary of the environmental conditions and number of fish assessed for vitality.

Area	Thames (ICES area IVc)	Lyme Bay (ICES area VIIe)
Species	Thornback Ray	Undulate Ray
Gear	Twin Otter Trawl (TR2)	Single Otter Trawl (TR2)
Mesh Size (mm)	80	80
Hauls	15	19
Depth Range (M)	6-15	19.4-49.9
Range Air Temperature (°C)	10.8-14.2	6.0-15.7
Range Sea Surface Temperature (°C)	13.3-14.3	7.5-9.4
Mean Length Thornback Ray Catch (cm)	45.4	83.7
Mean Wing Width Thornback Ray Catch (cm)	29.8	52.2
Vitality Assessed from Catch N	537	96
No. Ray Catch Assessed as Excellent	67	65
No. Ray Catch Assessed as Good	270	28
No. Ray Catch Assessed as Poor	184	3
No. Ray Catch Assessed as Dead	16	0

3.2.2 Undulate ray

For the undulate ray that were assessed for vitality, 68% (n=65) were assessed as Excellent condition, 30% (n=28) were Good and 4% (n=3) were Poor, none of the individuals were assessed as Dead. For the tagged undulate rays, 58% (n=28) of thornback ray were assessed as Excellent condition, 39% (n=19) were Good and 4% (n=2) were Poor. (Figure 11).

The most commonly observed injury throughout was abrasion observed in 49 individuals (48% of 'excellent', 54% of 'good' and 100% of 'poor'), bruising was observed in 14 individuals (13% of 'excellent', 18% of 'good' and 34% of 'poor'), and wounding observed in 7 individuals (11% of 'excellent' individuals only). Scratching and bleeding were found in 5 and 4 individuals respectively. Again, please note that injury scoring does not consider the scale/severity of the injury, i.e. undulates in excellent condition but with wounding may have minor injuries compared to ray rated as poor. Many of the animals had parasites (leeches) attached, but we did not score these occurrences as they were deemed not to have a long-term detrimental effect to the health of those individuals.



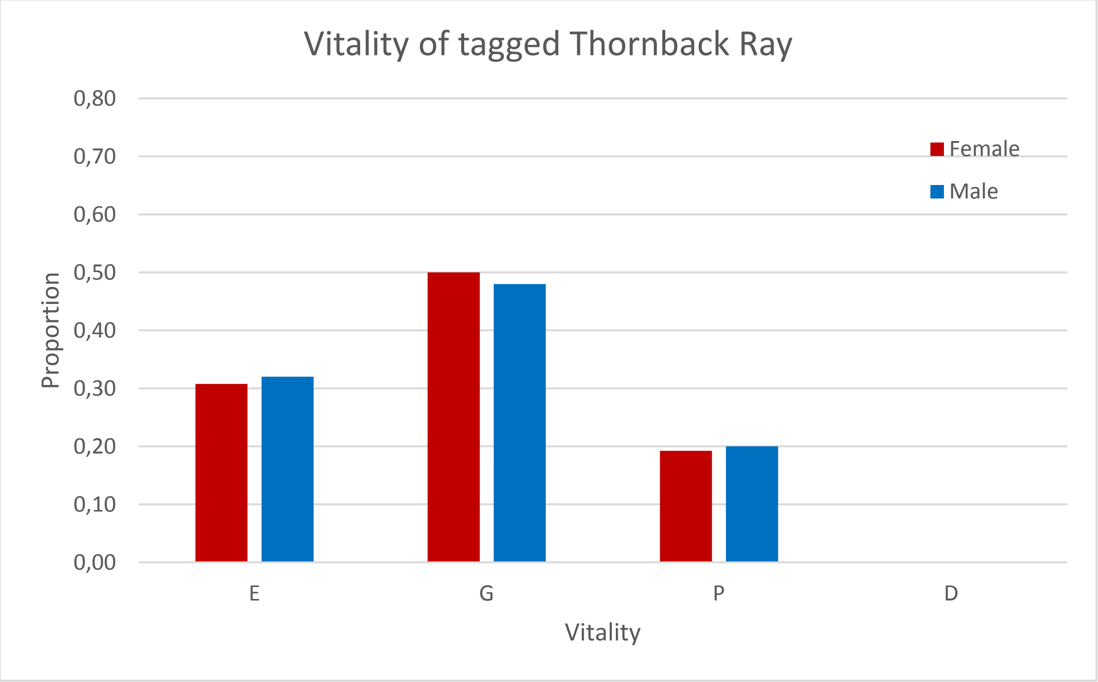
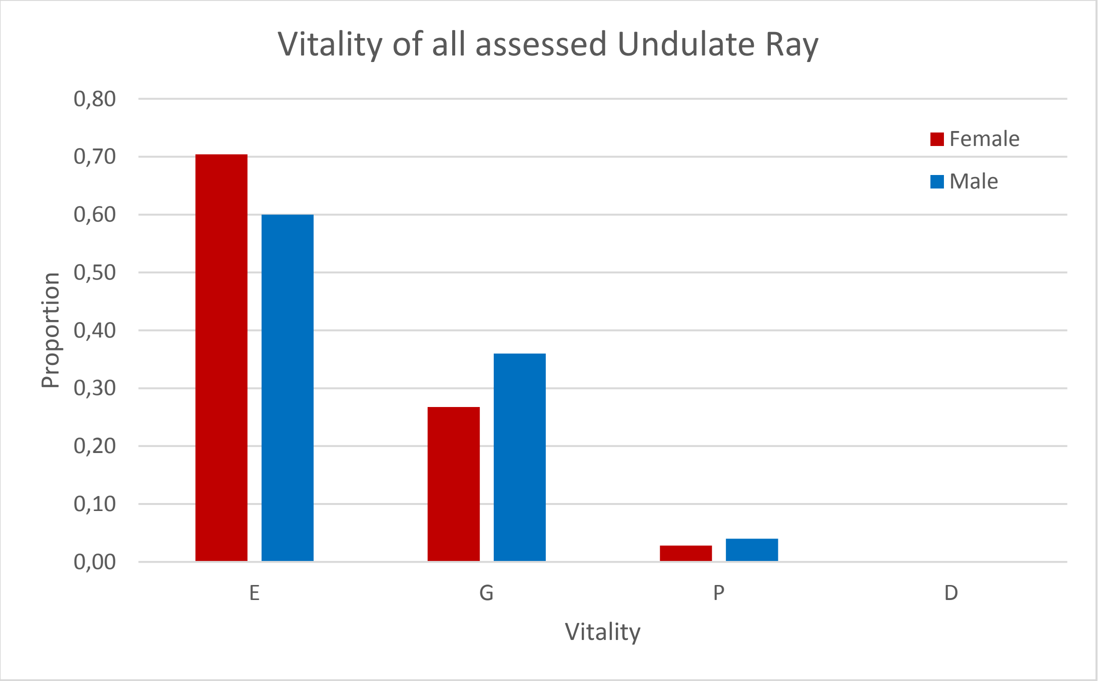


Figure 10: Semi-quantitative vitality score for thornback ray catch for the all assessed rays (top plot) and the tagged rays (bottom). Both plots show proportion for female and male rays. E – Excellent; G – Good; P – Poor and D – Dead.



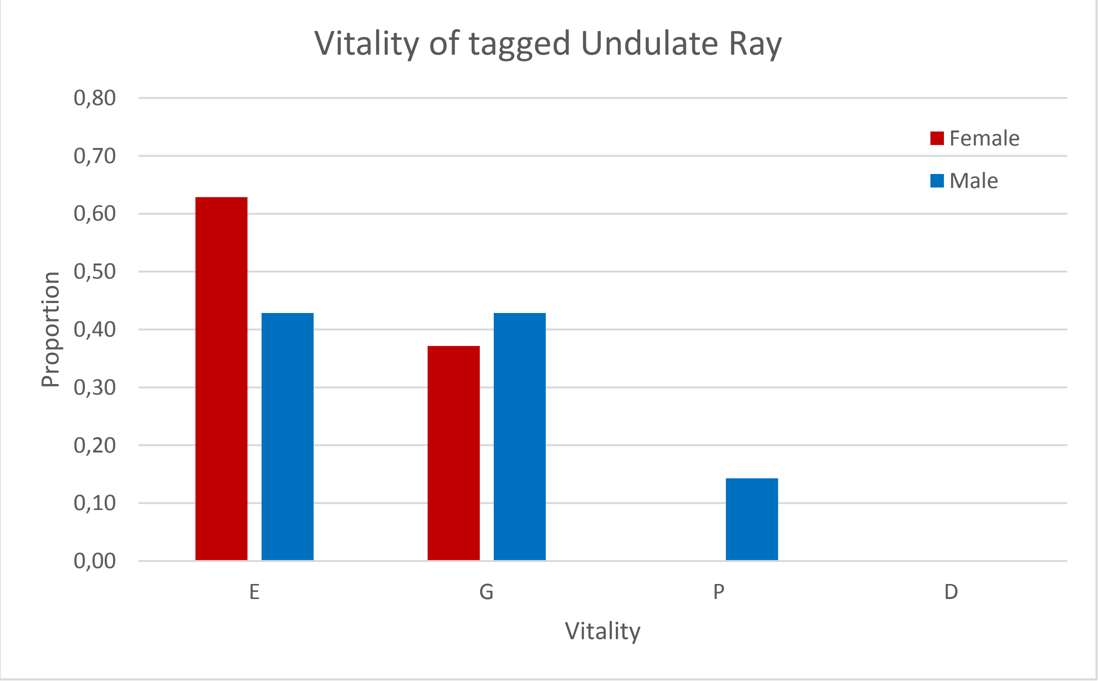


Figure 11: Semi-quantitative vitality score for undulate ray catch for the all assessed rays (top plot) and the tagged rays (bottom). Both plots show proportion for female and male rays. E – Excellent; G – Good; P – Poor and D – Dead.

4 Discussion

The first phase of the project achieved its aim to assess the vitality of thornback ray and undulate ray caught in English inshore otter trawl fisheries and to tag a sample of rays so that estimates of discard survival can be generated once sufficient returns have been received. This project followed the methods and concepts adapted from the previous survival studies ([redacted] 2015; [redacted] 2017), 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, combined with tag returns to generate a weighted overall survival rate for thornback and undulate rays. The project outputs will be updated on completion of the next phase when a sufficient number of tags have been returned and analysed.

To estimate discard survival rates that can be used to support proposed exemptions from the discard ban, there is a requirement that these estimates are representative of normal fishing practice. Both studies attempted to mirror normal fishing practice but some divergence from full commercial fishing practice is inevitable. The rays were handled, had their vitality assessed and were released by scientists, with a sample being tagged before release; it is therefore unavoidable that the rays experience was different from a ‘normal’ fishing trip. The time taken to assesses the vitality of the rays, means in the case of the undersized rays, that some individuals may have spent more time on deck than would normally be the case. As a result, it is possible that some small rays may have been scored at a lower vitality than if they could have been assessed at the normal point of discarding. This possible increase in deck time was less of issue for the undulate study as only three rays (3%) were caught that were too small to tag, however 52% of the caught thornbacks were below tagging size.

For future research into the discard survival of skates and rays, fishing closer to the peak fishing season for the target species would result in larger data sets from higher catch rates, with less effort. It would provide a truer picture of the fisheries and it is possible the stressors exerted on the rays may be different during periods of peak abundance.

Previous published studies to investigate ray survivability rates are scarce; [redacted] (2017) found only eight references which contained original information on survival of the commercial ray species caught in EU fisheries; and only six of these references provided a discard survival estimate ([redacted] 1995; [redacted] 2009; [redacted] 2010; [redacted] [redacted] [redacted] 2014; [redacted] Cefas assessed that there are robust discard survival estimates for the following ray species and fishery combinations ([redacted] 2017):

- Thornback ray discard survival is estimated at 57-69% for the ICES subarea VIIf otter trawl fishery.

- Blonde ray discard survival is estimated at 41-44% for the ICES subarea VIIe beam trawl fishery
- Cuckoo ray discard survival is estimated at 34-35% for the ICES subarea VIIe beam trawl fishery
- Thornback ray discard survival is estimated at 95% for the ICEC subarea IVc trammel net fishery

These are all single point estimates for each fishery and so do not account for within fishery variability. Factors such as temperature can affect survival rates for the same species within fisheries, but the extent of the seasonal variability in ray survival is unknown. Due to the high number of combinations of fishery and ray species in the UK, the evidence requirements to support potential exemptions are substantial. Consequently, the only feasible approach to inform on ray survival across all fisheries, is the development of a systematic and risk-based extrapolation from direct observations.

This extrapolation of discard survival evidence should be evidence driven, and there are two types of information that can assist with this approach:

- Data on the environmental and technical parameters associated with fisheries.
  Where fisheries are comparable then survival levels are more likely to be similar.
- Data on the health condition of fish, including at-vessel mortality levels (immediate survival).
  Where direct survival estimates have been observed, and a relationship between vitality and survival has been determined, discard survival estimates can be inferred from comparable fisheries where only vitality data are available.

In terms of vitality data, the health condition of discarded skates and rays has been collected in many different Cefas projects, and as a part of the ASSIST project, vitality data was collated for 17,259 individual fish from 10 projects ( ). Preliminary analysis found that, of those skates and rays assessed for vitality, 99.75%, 97.90% and 95.38% survived fishing capture in longline, otter trawl and netter fisheries, respectively. In the two studies reported here, 97% and 100% of the catch was assessed as alive at the point of release, providing further evidence of the potential for high levels of survival for ray species.

Therefore, while there are many combinations of fisheries and ray species for which discard survival estimates would be desirable, it is impractical to generate evidence directly for all of these. There is a substantial and increasing body of evidence on the survival probability of discarded rays, and this will be further enhanced by new estimates derived directly from selected fisheries. However, there is also the requirement to assess the comparability between fisheries in terms of the stressors exerted of discarded rays, and use the vitality data from a wider variety of fisheries to investigate which of those variables most influence survival. This will enable risk-based extrapolation of ray survival estimates across fisheries.

5 Acknowledgements

Thanks to [redacted] and [redacted] of the [redacted], for their patience, cooperation and dedication to the project.

Thanks also to [redacted] and [redacted] of the [redacted], for their patience and perseverance with the project and for being so accommodating and supportive with getting the work done.

6 References

[redacted] Common Skate Survey Annual Report (ELECTRA MF6001: Workpackage Task 1.4) Cefas. 30 pp.

[redacted] "Assessing the factors influencing discard mortality of demersal fishes using a semi-quantitative indicator of survival potential." Fisheries Research 106(3): 436-447.

[redacted] Health and vitality of discarded skates and rays

[redacted] Estimating the discard survival rates of selected commercial fish species (plaice - *Pleuronectes platessa*) in four English fisheries (MF1234), Cefas report, pp108.

[redacted] Ray Discard Survival: Enhancing evidence of the discard survival of ray species. CEFAS Report: 1–70.

[redacted] "Key principles for understanding fish bycatch discard mortality." Canadian Journal of Fisheries and Aquatic Sciences 59(11): 1834-1843.

[redacted] Wounding and reflex impairment may be predictors for mortality in discarded or escaped fish. Fisheries Research, 82:1-6.

[redacted] "Fish stress and mortality can be predicted using reflex impairment." Fish and Fisheries 11(1): 1-11.

[redacted] Short-term survival of discarded target fish and non-target invertebrate species in the "eurocutter" beam trawl fishery of the southern North Sea. Fisheries Research 154: 82-92.

[redacted] Assessing discard mortality of commercially caught skates ([redacted]) – validation of experimental results. DEFRA Report MB5202, 142 pp.

[redacted] (2009). The survival of skates ([redacted]) caught by demersal trawlers fishing in UK waters. Fisheries Research 97(1–2): 72–76.

[redacted] (2010). Discard mitigation increases skate survival in the Bristol Channel. Fisheries Research 102(1–2): 9–15.

[redacted] NEPTUNE 2.0: Monitoring of Common Skate in the Celtic Sea in partnership with the fishing industry. Final project report (Cefas). 76 pp.

[redacted] Migratory behaviour of the thornback ray, *Raja clavata*, in the southern North Sea. Journal of the Marine Biological Association of the UK 85, 1095.

[redacted] The use of external electronic tags on fish: an evaluation of tag retention and tagging effects. Animal Biotelemetry 3, 49.

[redacted] Survival of by-catch from a beam trawl. Marine Ecology Progress Series 134: 303-307.

[redacted] Survival of European plaice discarded from coastal otter trawl fisheries in the English Channel. Journal of Environmental Management 204: 404-412.

[redacted] Assessing the survival of discarded Plaice in the English NE *Nephrops* trawl fishery, February 2016, Cefas report pp37.

[redacted] Assessing the survival of discarded sole (Solea solea) in an English inshore trawl fishery, February 2017, Cefas report pp37.

[redacted] 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.

[redacted] The Post-Release Survival of Two Skate Species Discarded by Bottom Trawl Fisheries in Antalya Bay, Eastern Mediterranean. Turkish Journal of Fisheries and Aquatic Sciences 14: 947-953.

[redacted] 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.

7 Annex 1

Details of the hauls, including, sorting and sampling time, and environmental conditions for Thames study of thornback ray.

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
26/10/2017	1	01:01	07:18	10.7	07:22	07:25	00:04	IVc	32F1	0	V	Calm	12.4	13.5
26/10/2017	2	01:00	08:30	7.6	08:32	08:45	00:02	IVc	32F1	0	V	Calm	12.4	13.7
26/10/2017	3	01:00	09:38	7.3	09:40	09:44	00:02	IVc	32F1	0	V	Calm	12.4	13.6
26/10/2017	4	01:00	10:45	6.7	10:47	10:52	00:02	IVc	32F1	2	W	Calm	12.5	13.5
26/10/2017	5	01:01	11:51	6.1	11:55	11:59	00:04	IVc	32F1	2	W	Calm	12.5	13.5
26/10/2017	6	01:02	13:03	7.6	13:08	13:11	00:05	IVc	32F1	1	SW	Slight	14.2	14.3
26/10/2017	7	00:44	14:17	12.5	14:23	14:30	00:06	IVc	32F1	1	SW	Slight	14.1	14.2
26/10/2017	8	00:48	15:24	15.0	15:29	15:33	00:05	IVc	32F1	0	V	Calm	14.2	14.2
27/10/2017	1	01:01	07:38	8.2	07:41	07:45	00:03	IVc	32F1	1	NNW	Slight	11.0	13.3
27/10/2017	2	01:00	08:45	6.7	08:50	09:00	00:05	IVc	32F1	1	NNW	Slight	11.0	13.3
27/10/2017	3	01:01	09:51	9.7	09:59	10:05	00:08	IVc	32F1	1	NNW	Slight	10.8	13.4
27/10/2017	4	01:02	11:06	10.0	11:12	11:20	00:06	IVc	32F1	1	NNW	Slight	13.2	13.9
27/10/2017	5	01:01	12:15	9.4	12:22	12:27	00:07	IVc	32F1	2-3	NW	Slight	14.0	14.1
27/10/2017	6	01:00	13:23	9.1	13:32	13:36	00:09	IVc	32F1	2-3	NW	Slight	13.5	13.9
27/10/2017	7	01:11	14:50	12.1	14:55	14:58	00:05	IVc	32F1	2	NW	Slight	14.2	14.0

8 Annex 2

Details of the hauls, including, sorting and sampling time, and environmental conditions for Lyme Bay study of undulate ray.

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
05/02/2018	3	03:05	17:48	28.70	18:00	18:30	00:30	VIIe	30E7	3.5	NE	slight	7.5	8.2
06/02/2018	1	02:00	10:28	46.10	10:43	10:53	00:10	VIIe	29E7	3.0	N	slight	7.4	8.4
06/02/2018	2	02:20	13:13	32.00	13:23	13:28	00:05	VIIe	30E7	3.0	N	slight	7.1	8.4
06/02/2018	4	02:05	18:15	28.20	18:22	18:40	00:18	VIIe	30E7	3.0	N	slight	7.0	8.0
07/02/2018	1	02:00	10:15	19.90	10:34	10:44	00:10	VIIe	30E7	2.5	N	slight	6.7	8.0
07/02/2018	4	01:35	16:11	19.90	16:32	16:37	00:05	VIIe	30E7	3.5	N	slight	6.3	7.5
07/02/2018	5	01:40	18:40	22.70	18:41	18:47	00:06	VIIe	30E7	3.5	N	slight	6.0	7.5
16/02/2018	1	03:00	10:12	29.40	10:32	11:00	00:28	VIIe	30E7	1.0	W	calm	15.7	8.7
16/02/2018	2	03:00	13:45	28.00	14:05	14:20	00:15	VIIe	30E7	1.5	W	calm	12.6	8.7
16/02/2018	3	02:30	16:58	30.20	17:25	17:40	00:15	VIIe	30E7	2.5	W	slight	9.0	8.4
17/02/2018	1	02:00	09:20	49.30	10:05	10:35	00:30	VIIe	29E7	2.5	WSW	slight	8.7	9.0
17/02/2018	2	02:00	12:15	44.80	12:25	13:15	00:50	VIIe	29E7	2.5	WSW	slight	13.1	9.3
17/02/2018	3	02:10	15:30	31.30	15:40	15:50	00:10	VIIe	30E7	1.5	WSW	calm	10.1	9.2
19/02/2018	1	02:10	10:00	49.70	10:20	10:40	00:20	VIIe	29E7	2.5	NNW	slight	12.3	9.2
19/02/2018	2	02:20	12:52	45.00	13:00	13:40	00:40	VIIe	29E7	3.0	NNW	slight	11.3	9.2
19/02/2018	4	01:30	17:02	39.00	17:17	17:25	00:08	VIIe	30E7	3.5	NNW	slight	9.5	9.1
20/02/2018	1	02:50	10:20	30.50	10:35	10:44	00:09	VIIe	30E7	3.5	NNE	moderate	13.1	9.4
20/02/2018	2	03:05	13:48	28.50	14:00	14:12	00:12	VIIe	30E7	3.5	NNE	moderate	9.8	9.4
20/02/2018	3	03:00	17:18	28.00	17:25	17:38	00:13	VIIe	30E7	2.5	NNE	slight	8.7	9.4

Centre for Environment Fisheries & Aquaculture Science

Cefas

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

Head office
Centre for Environment, Fisheries & Aquaculture Science
Pakefield Road
Lowestoft
Suffolk
NR33 0HT
Tel: +44 (0) 1502 56 2244
Fax: +44 (0) 1502 51 3865

Weymouth office
Barrack Road
The Nothe
Weymouth
DT4 8UB

Tel: +44 (0) 1305 206600
Fax: +44 (0) 1305 206601

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 and 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.

ISO 9001 OHSAS 18001 ISO 14001 Registered Environmental Management POSITIVE ABOUT DISABLED PEOPLE INVESTOR IN PEOPLE

www.cefas.co.uk