An assessment of cuckoo ray (*Leucoraja naevus*) survivability in an Irish otter trawl fishery

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An assessment of cuckoo ray (*Leucoraja naevus*) survivability in an Irish otter trawl fishery

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Key findings

- **Cuckoo ray survival rates of 11 to 16% were obtained.**
- **Cuckoo rays constitute around 1% of total catches in the Irish Sea fishery targeting blonde ray.**
- **Gear modifications such as the raised-fishing line can substantially reduce ray catches in some otter trawl fisheries.**
- **A risk-based approach which includes likelihood of catching and ability to mitigate catches of cuckoo rays should be considered in EU waters.**

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Introduction

The 2013 Common Fisheries Policy introduced a landing obligation (LO) which aims to minimise discarding at sea. Member states are required to land most species subject to catch limits but can avail of an exemption where relatively high post-capture and release survival is demonstrated.

Survival studies have been conducted on various flatfish species such as plaice and sole, and to a lesser extent skates and rays (e.g., Catchpole et al., 2017; Schram et al., 2018; Morfin et al., 2019) resulting in a number of survivability exemptions.

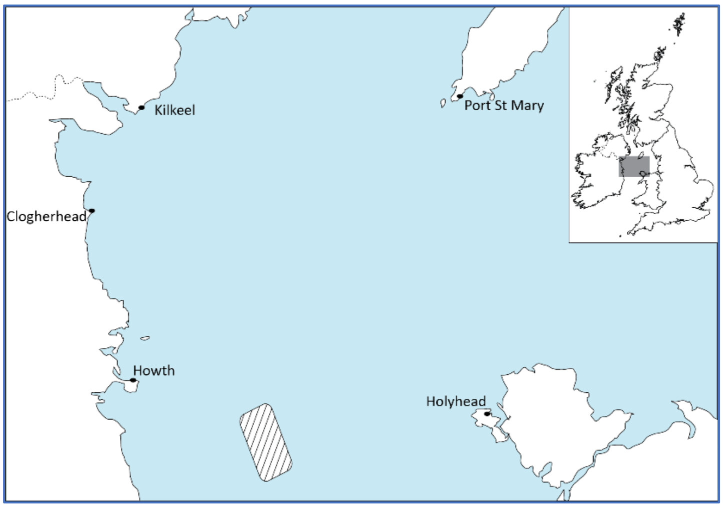
Cuckoo rays were originally granted a one-year exemption due to concerns over survival (EU, 2018). Research in this regard was restricted to a single 35% survival estimate (Catchpole et al., 2017) derived from an English Channel beam trawl study (Ellis et al., 2012). The one-year exemption was granted to facilitate more research in this regard.

A recent French study titled ‘SUrvie des rejets de Raie Fleurie (SURF) obtained cuckoo ray survival results ranging from 12 -22 % in an otter trawl fishery in the Celtic Sea (Baulier et al., 2021).

BIM previously assessed post-capture condition of cuckoo rays on board an Irish otter trawl vessel (Oliver et al., 2019). Fish were generally observed to be in good condition. Such assessments are useful in determining the viability of full-scale survival experiments but are not considered a true indicator of survivability (Kraak et al., 2018; STECF, 2019). Also, as observed by Baulier et al (2021) cuckoo rays are subject to delayed post-capture mortality which detracts from using condition as a proxy for survival of this species.

Here, we conduct a full captive-monitoring survivability experiment on cuckoo rays caught on board an otter trawler in the Irish Sea.

Methods



Ethics statement

Prior to commencement of this study, BIM sought clarification on the status of the project under scientific animal protection legislation from the Health Products Regulatory Authority (HPRA). Following discussion of a detailed application and protocol (Appendix I), HPRA determined that the project fell outside the scope of the legislation and that no official authorisation was required.

At sea operations

Fishing was conducted between September 20th and October 9th, 2021, onboard the MFV Eblana, a 20 m steel vessel using a single-rig otter trawl with 120 mm diamond-mesh codend (Table 1). The vessel targeted blonde ray in an area southeast of Howth Harbour in the Irish Sea (Figure 1). Sampling was conducted on a self-sampling basis following COVID 19 protocols with the skipper and crew shown how to collect and store cuckoo ray on board prior to going to sea.

Test cuckoo rays were sourced from commercial duration tows. Control rays were obtained to help track mortalities potentially associated with on board holding, transit and the onshore holding facility. Except for one control ray caught prior to the trial, control rays were obtained from tows of reduced haul duration.

Catches were landed directly onto the deck as per standard practice and remained there until the trawl was redeployed or stowed away. The crew recorded the maximum time ray spent on deck prior to placement in the onboard holding tanks.

Cuckoo rays were held onboard for up to three days in 3 x 310 litre tanks. The holding tanks were supplied with a flow through of sea water from the deck hose and coral sand to provide refuge. Cuckoo rays could swim freely and bury in the sand and to help reduce stress levels while in captivity. Any mortalities at sea were measured (cm), sexed and recorded for inclusion in the overall survival estimate. Live rays were sampled in the same manner prior to condition assessments ashore. The test rays were marked using non-invasive coloured hook and loop straps wrapped around the tail so they could be individually tracked during monitoring. Species catch weights were recorded by the crew.

Table 1: Gear characteristics

Trawl type	Single-rig whitefish
Headline length (m)	30
Footrope length (m)	18
Ground gear	16 " rubber discs
Fishing-circle (meshes × mm)	540 x 120
Sweep length (m)	30 + 30
Warp diameter (mm)	20
Door manufacturer & model	Morgère Exocet
Door weight (kg)	800
Average headline height (m)	16.1
Average door spread (m)	58.8
Nominal codend mesh size (mm) and orientation	120 diamond
Codend circumference (mesh no.)	100

Vitality, reflex and injury and assessments

Condition assessments ashore were conducted by an experienced scientific observer before being placed into the onshore holding tanks. Condition assessments followed protocols developed by the ICES workshop on methods for estimating discard survival (Breen and Catchpole 2021) and further work by Van Bogaert et al., 2020. Each ray underwent assessments for vitality, reflex, and injury.

A vitality index based on the proportion of each species occurring in four categories, "excellent" (A) to "dead" (D) was used (Table 2). Minor injuries consisted of relatively minor bleeding, or tears of mouthparts or wings (≤10% of the diameter), or surface abrasion. Major injuries consisted of relatively large-scale bleeding, or tears of mouthparts or wings, or surface abrasion (Benoît et al., 2010; Catchpole et al., 2017).

Table 2. Vitality assessments based on Benoît et al. (2010)

Score	State	Description
A	Excellent	Vigorous body movement; no or minor external injuries only
B	Good	Weak body movement; responds to touching / prodding minor external injuries
C	Poor	No body movement but can move spiracles, minor or major external injuries
D	Moribund/ dead	No movement of body or spiracle opening (no response to touching or prodding)

Table 3. Reflex (RAMP) assessment (Davis, 2010; Van Bogaert et al., 2020)

Reflex	Description	Unimpaired response	Score
Tail grab	Gently grab ray by the tip of the tail between thumb and index finger (watch out for any spines)	Actively struggles free and swims away	0 or 1
Spiracle movement	Look at the opening and closing of the valves inside the spiracles	The spiracles actively open and close	0 or 1
Startle touch	Tap gently but firmly behind the eyes and spiracles using a fingertip	Actively closes and retracts its eyes	0 or 1
Body flex	Hold the ray by its anterior end of its disc in a horizontal, plane position, one hand on either side of the mid-line (dorsal side facing up); larger specimens may be supported also by their posterior end	Actively moving its pectoral fins, tail, and body	0 or 1

Table 4. Injury assessment (Van Bogaert et al., 2020)

Injury type	Description	Score
Bleeding head	Point bleeding and / or bruising of the head	0 – 3
Bleeding body	Point bleeding and / or bruising of the body	0 – 3
Bleeding tail	Point bleeding and / or bruising of the tail	0 – 3
Open wounds	Areas where skin was removed, and underlying tissue can be observed	0 – 3
Fin damage	Areas of the fin that were damaged and / or split	0 – 3

Reflex assessments were performed using the Reflex Action Mortality Predictor (RAMP) method. Four reflexes (tail grab, startle touch, spiracle movement, and body flex) were tested and given a score based on the response, 1 = impaired and 0 = not impaired (Table 3). Tail grab, startle touch and spiracle movement were assessed in water. Body flex was assessed in air as it was easier to observe out of water. The maximum possible combined RAMP score was 4 (Davis, 2010; Uhlmann et al.,2016).

A categorical scale was used to assess injury by quantifying the amount of body surface covered by bleeding discoloration of three body regions: head, body and tail (Table 4). No injury or discolouration was scored as 0; < 10% as 1; 10 – 50% as 2; and > 50% as 3. Open wounds and fin damage were scored on the same basis as injury, providing a maximum combined injury score of 15 (Uhlmann et al., 2016; Van Bogaert et al., 2020).

Onshore captive monitoring

The onshore monitoring facility was located on Dun Laoghaire pier, Co. Dublin around 50 meters from where the vessel landed (see cover page). The facility comprised a refrigerated container supplied by Titan containers, housing six 1,100l tanks in a 2 x 3 configuration and two external Tropical Marine Centre biosystems supplied by Galway Mayo Institute of Technology (GMIT) (Figure 2).

To eliminate risk of contamination, saltwater was made using dechlorinated freshwater mixed with aquarium salt. Again, rays could swim freely and bury in coral sand to help reduce stress levels during captivity (Figure 3). Rays were fed squid while in captivity. Temperature control was achieved using water chillers and the refrigerated container. Rays were checked for mortalities four times daily during onshore captivity.

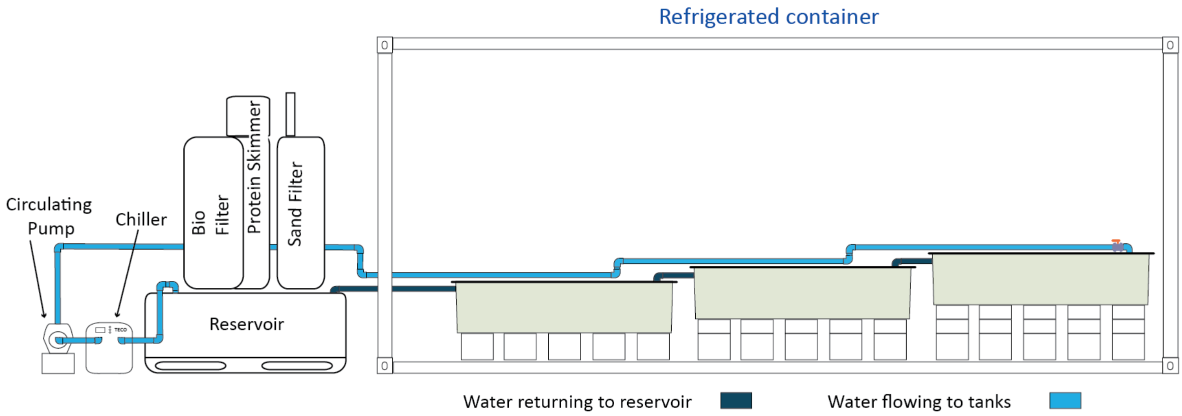


Figure 2. Onshore holding facility

Figure 3: Onshore holding tanks with coral sand

Environmental parameters

Bottom water temperature was recorded every 15 minutes via two Star - Oddi data storage tags, attached to the trawl headline. The skipper recorded bottom depth at the start and end of the haul, sea state, wind direction, air temperature and onboard tank water temperature for each haul. Sea-surface temperature data was obtained from the Irish weather-buoy network (https://data.gov.ie/dataset/weather-buoy-network). Oxygen, salinity, and water temperature was monitored in the onshore monitoring unit four times daily while water quality parameters (ammonium, nitrate, nitrite and pH) were tested periodically throughout the study.

Data analysis

Kaplan-Meier (KM) survival plots of fish in test, control and vitality categories were used to assess survival over 15 days captivity. A monitoring period of 21 days was originally planned but monitoring ceased prior to this due to poor survival. Any mortalities during onboard holding or transport were treated as dead at time zero. Survival over a longer period was estimated using predictive modeling over 25 days. To identify the best fitting model, four distributions were tested under non-cured and cured models with AIC values used to select the optimal distribution.

Reflexes were analysed by summing the scores for each individual fish and the total was standardised to fall between 0 and 1. With four possible reflexes, each reflex impairment was given a score of 0.25 with a potential maximum score of 1. Injury scores were also standardised to fall between 0 and 1. Injury type for each individual fish had a potential score of 0.33, 0.66 or 1 depending on the severity of the injury. Candidate physiological and environmental variables affecting fish condition were explored using dot plots and analysis of variance (ANOVA).

Results

A total of 12 test hauls and two control hauls were carried out over seven days fishing. Mean towing speed was 2.7 kt. Tow duration ranged from 135 – 300 minutes with a mean of 224 minutes for test tows. The two controls tows were 50 and 60 minutes duration. Bottom depth ranged from 64 to 146 m with a mean of 112 m. Bottom depths for the two control tows were 95 and 144 m. Bulk catch ranged from 168 to 553 with a mean of 293 kg. Cuckoo ray numbers were relatively low with a total of 61 test and 12 control fish caught (Table 5).

The main species caught during the study were blonde, spotted ray, mixed flatfish and greater spotted dogfish. Blonde ray made up one third of the entire bulk catch during the study (Table 6).

Table 5. Summary trawl operation and cuckoo ray catch data

Haul ID	Haul type	Date	Haul duration (min)	Bottom Depth (m)	Bulk catch (kg)	Cuckoo ray (n)
1	Test	20-Sep	225	64	205	2
2	Test	20-Sep	265	93	402	1
3	Test	21-Sep	265	87	280	6
4	Control	21-Sep	60	95	80	1
5	Test	22-Sep	230	91	237	2
6	Test	22-Sep	210	93	288	6
7	Test	28-Sep	260	133	553	7
8	Test	28-Sep	135	146	168	9
9	Control	28-Sep	50	144	122	10
10	Test	28-Sep	140	134	212	11
11	Test	29-Sep	210	140	335	5
12	Test	29-Sep	150	139	247	2
13	Test	05-Oct	300			5
14	Test	09-Oct	300			5

A total of 39 test cuckoo rays were retained for captive observation. A further 22 mortalities occurred while at sea and during transit and were treated as mortalities at time zero. Most other test mortalities occurred during the first six days in captivity with a levelling off between days seven and nine followed by further mortalities until the end of observations on day 15. 10 test fish survived for 15 days in captivity providing an observed 16% survival rate over that period. Five out of 12 or 42% of control fish were observed to survive over the same period. No significant difference was observed between test and control fish likely due to the small sample size of control fish (Figure 4).

The KM plot by vitality score showed that all fish in poor (C) and moribund (D) condition died prior to or during the first day of onshore monitoring with no significant difference between these categories (Figure 5). Vitality scores excellent (A) and good (B) had 32 and 40% survival respectively with no significant difference between categories (Figure 5). Grouping vitality scores AB and CD shows a clear difference between groups but the overall survival figure for AB fish was still just 33% (Figure 6).

Table 6. Species catch weights (kg)

Species	Weight (kg)
Blonde ray	1052
Spotted ray	340
Flatfish	329
Greater spotted dogfish	236
Thornback ray	164
Lesser spotted dogfish	134
Whiting	117
Conger eel	112
Gurnard	106
Unwanted haddock	102
Unwanted whiting	92
Tope	77
Unwanted spotted ray	72
Haddock	41
Queenie scallops	34
Cuckoo ray	33
Unwanted blonde ray	28
Poor cod	27
John Dory	21
Unwanted flatfish	19
Monkfish	10
Cod	5
Squid	2
Total	**3153**

Non-cured and cured fraction gamma, generalised gamma, weibull and exponential distributions were assessed for the predictive model. Optimal in terms of AIC were the gamma, weibull, generalised gamma and the gamma mixed cure distributions (Figure 7). The gamma distribution was used to predict an estimated overall survival rate of 11% over 25 days (Figure 8).

Tail grab showed the highest level of impairment across all test fish followed by startle touch and body flex both displaying equal levels of impairment. Spiracle movement was the least impaired reflex, as expected given spiracle movement is required for respiration (Table 7). Fin damage and bleeding head were the predominant injuries for all vitality scores, followed by bleeding body and bleeding tail (Table 8).

Mean reflex scores for each vitality demonstrated a higher level of impairment for fish in poorer condition. Mean injury scores varied little in relation to vitality score due to levels of bruising in all vitality scores. Combined injury & reflex scores showed a positive correlation with vitality (Table 9).

The maximum air exposure time for ray was 20 minutes for any given haul. Total body length for ray ranged from 25 to 60 cm with a mean of 42 cm. 46 individual females and 15 individual males were caught as test fish. No difference in survival was observed between sexes.

Wind speeds ranged from 6 – 55 km/h with a mean of 14 km/h. Swell heights ranged from calm to rough but never exceeded two meters in height during fishing operations or transit (per comms with skipper). Air temperature ranged from 14 – 17 °C. Average sea-surface temperature was 15.1 °C. Bottom water temperature ranged from 14 – 15 °C while temperatures in the onboard holding tanks ranged from 16 – 17 °C during fishing operations (Table 10).

Except for depth, dot plots showed little effect of candidate physiological or environmental variables on fish condition. Most vitality D fish occurred in deeper water with fish in better condition caught in a range of depths (Figure 9).

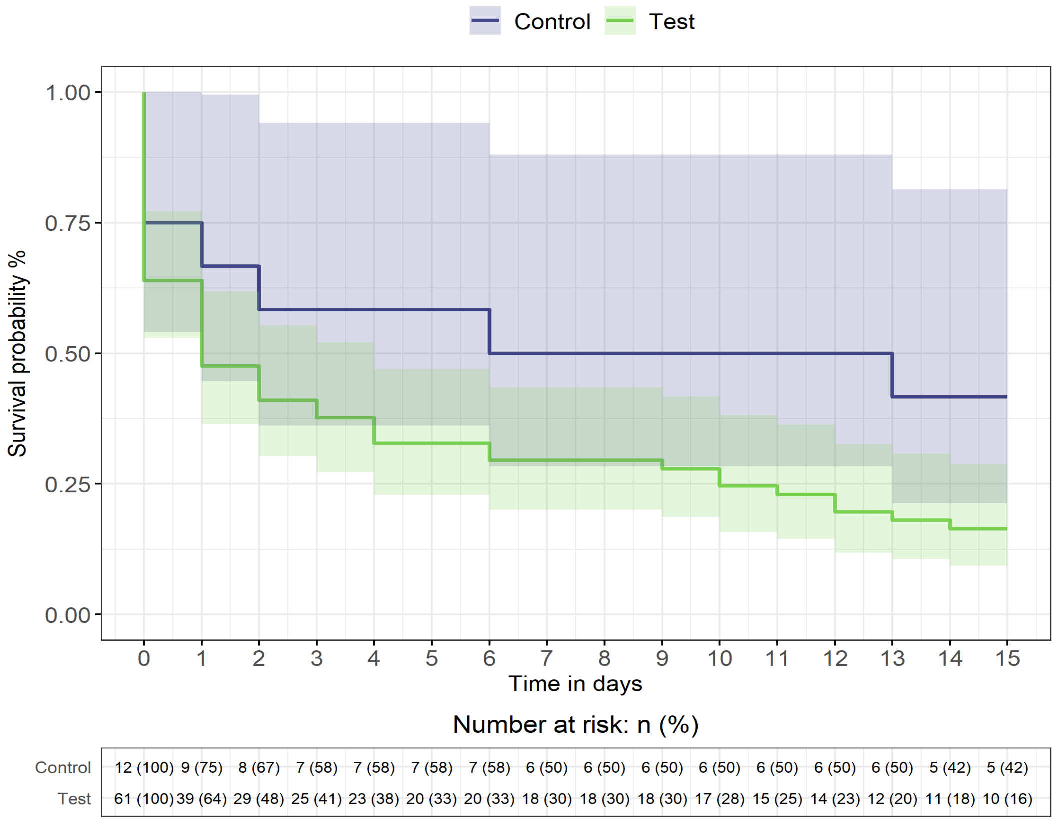


Figure 4: Kaplan – Meier of test and control cuckoo ray

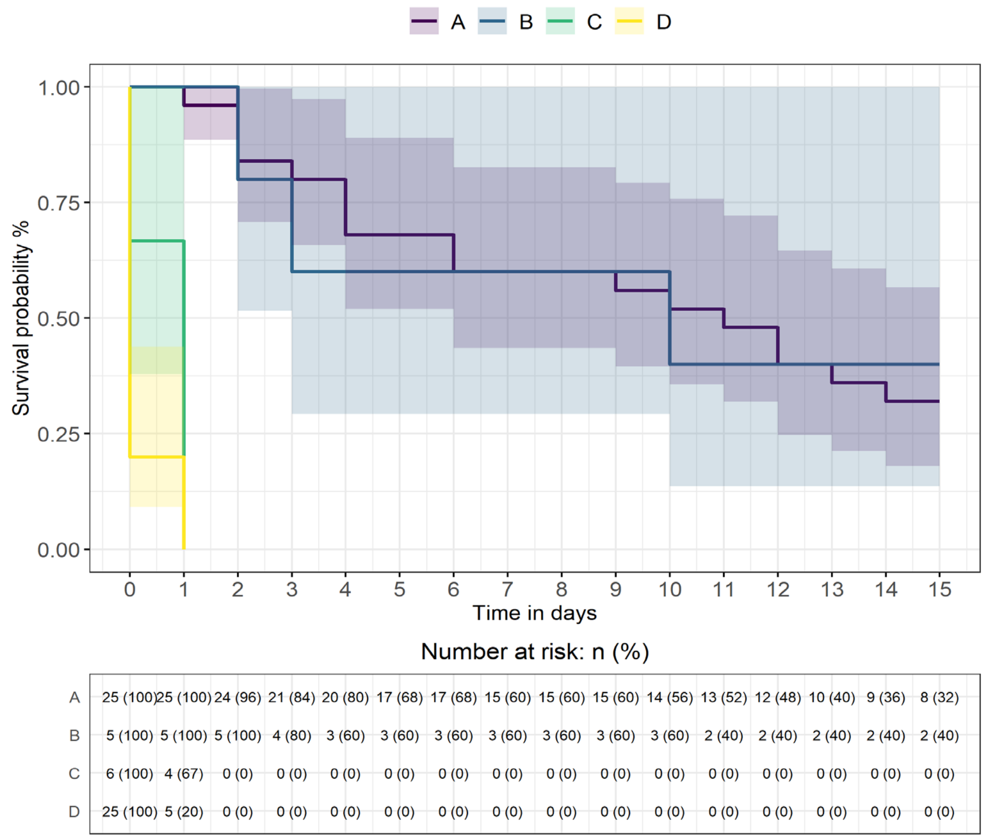


Figure 5: Kaplan – Meier of test cuckoo ray by vitality score

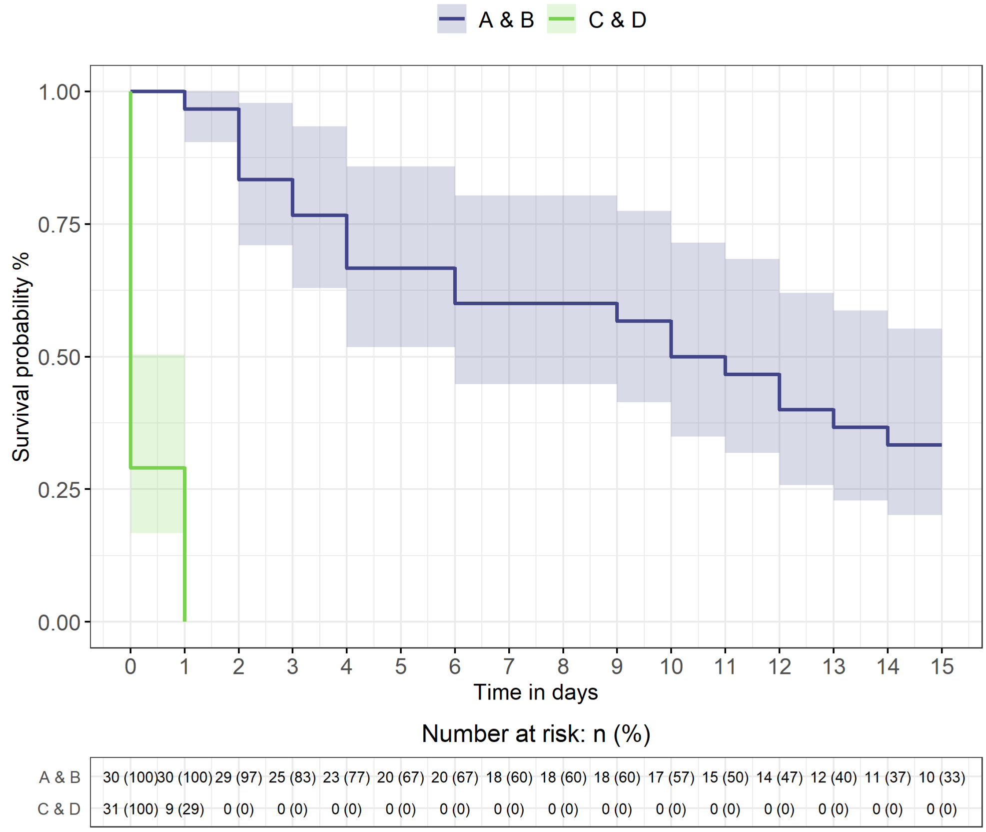


Figure 6: Kaplan – Meier of test cuckoo ray grouped by vitality scores A&B and C&D

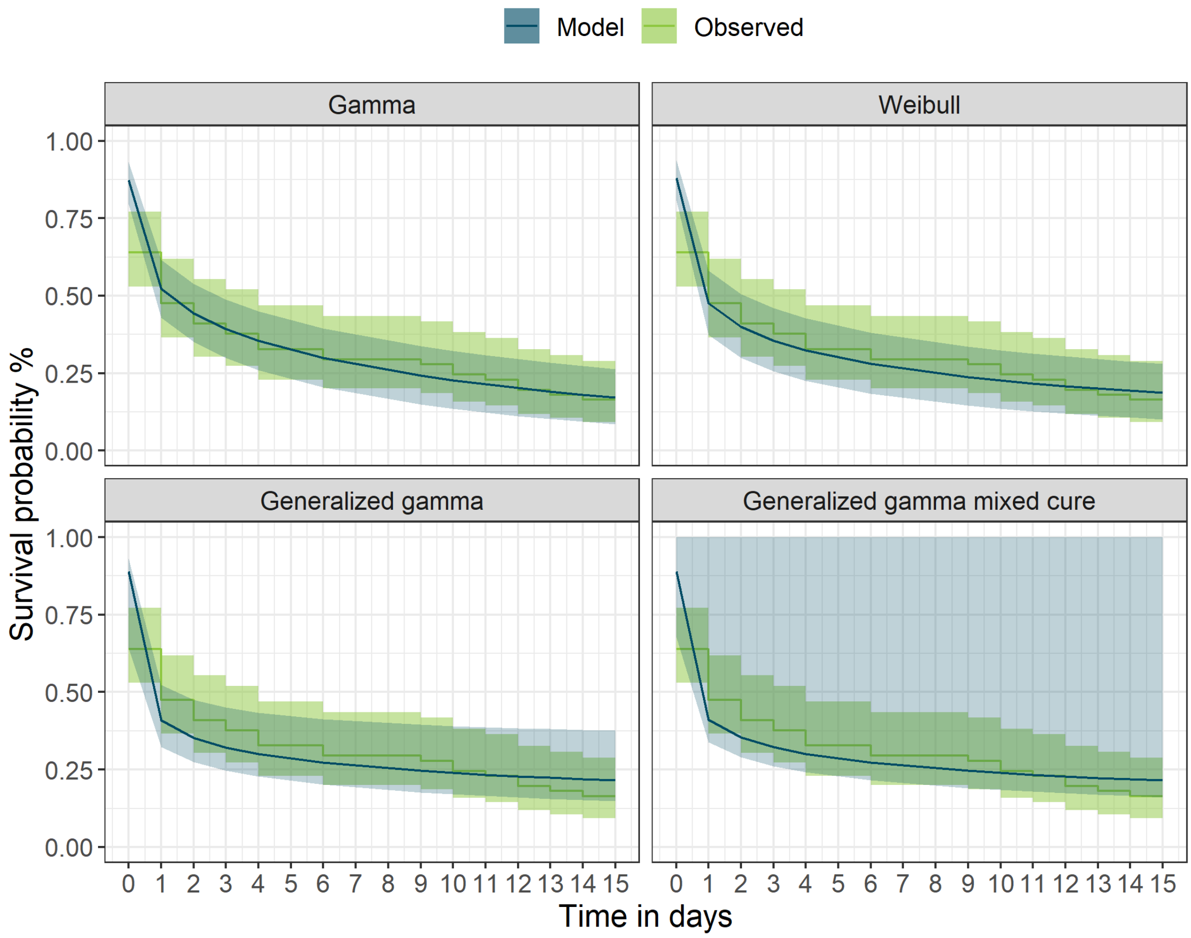


Figure 7: The top 4 performing predictive models in terms of AIC

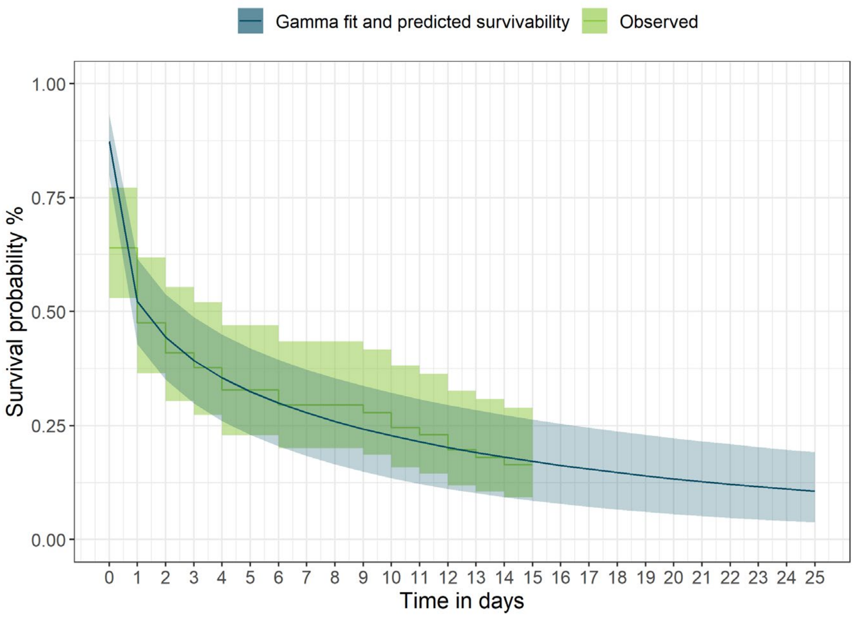


Figure 8: Predicted survival using gamma distribution fit

Table 7: Reflex impairment percentage (%) observed for each reflex and mean RAMP score

Tail grab (%)	Spiracles (%)	Startle touch (%)	Body flex (%)	Mean ramp score
19	11	17	17	0.16

Table 8: Injury percentage (%) observed and mean injury score

Bleeding head (%)	Bleeding body (%)	Bleeding tail (%)	Open wounds (%)	Fin damage (%)	Mean injury score
35	30	26	1	35	0.26

Table 9: Mean reflex, injury and combined scores with standard error (SE) for each vitality

Vitality	Reflex (SE)	Injury (SE)	Reflex & Injury (SE)
A	0.00 ± (0.00)	0.21 ± (0.10)	0.12 ± (0.06)
B	0.03 ± (0.08)	0.30 ± (0.09)	0.18 ± (0.06)
C	0.14 ± (0.20)	0.32 ± (0.12)	0.24 ± (0.07)
D	0.81 ± (0.24)	0.30 ± (0.09)	0.53 ± (0.08)

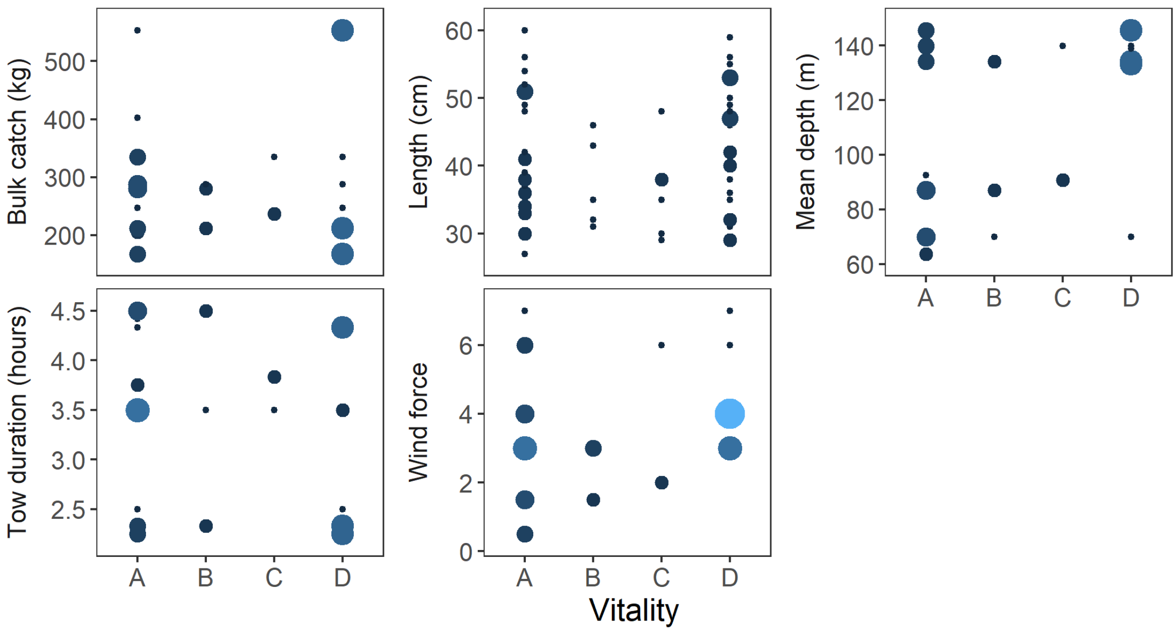


Figure 9: Dot plots of candidate variables in relation to fish vitality

Table 10: Environmental data collected during the study

At sea parameters	Values
Number of Hauls	12
Air temperature range (mean) in °C	14 – 17 (15.4)
Sea surface temperature mean in °C	15.1
Onboard tank water temperature range (mean) in °C	15.5 – 17.5 (16.8)
Bottom water temperature range (mean) in °C	14.2 – 15.8 (15.5)
Depth fished (mean) in m	33 – 147 (96.6)
Swell height in m	0 – 3
Wind force (mean) in km/h	6 – 55 (14)
Onshore parameters	
Tank water °C	10.5 – 11.9 (11.3)
Tank salinity (mean) in ppt (‰)	34.8 – 36.8 (35.8)
Tank dissolved oxygen range (mean) in %	89.7 – 105.4 (93.5)
Tank dissolved oxygen range (mean) in mg/l	8.4 – 10.9 (9.5)
Nitrite (NO_2)	0
Alkalinity (pH)	8.3 – 8.5 (8.36)
Nitrate (NO_3-)	0 – 2 (1.5)
Ammonia (NH3/NH4)	0 – 0.4 (0.17)

Discussion

Survival results of 16% over 15 days down to 11% over 25 days suggest likely poor post-release survival of cuckoo ray due to the capture process in the Irish otter trawl fishery. Caught in hauls of shortened duration, 42% of control cuckoo rays were still alive after 15 days observations. 25% of control mortalities occurred at sea with the remaining 33% occurring in the holding system. Key water quality parameters such as ammonium, nitrate, nitrite, pH were all at acceptable levels during the study. In addition, oxygen, salinity, and temperature were carefully controlled and monitored to ensure optimum conditions (Table 10).

This holding system was previously used in a study on seine caught plaice which resulted in survival rates of 70% of test fish and 100% of control fish. These facts suggest that mortalities were unlikely induced by poor holding conditions. However, we can't be certain whether high cuckoo ray mortality rates are due to the capture process or species-specific susceptibility to captive monitoring. A tag-based survival study where cuckoo ray could be released almost immediately might help elucidate this issue.

Our results are similar to Baulier et al. (2021) who obtained 12 – 22% cuckoo ray survival estimates. Vitality scores were also similar with ~50% of cuckoo rays occurring both in A&B and C&D vitality groups in both studies. This suggests similar post-capture condition and survival rates for cuckoo rays in otter trawl fisheries in the Irish and Celtic Seas.

Results from these studies suggest that alternative measures will be needed to reduce unwanted cuckoo ray catches. Nuanced approaches which account for the characteristics of specific fisheries should be considered. Cuckoo ray catches were sporadic and constituted ~1% of total catch weight in the observed fishery in the current study and a previous BIM study (Oliver et al., 2019).

Reductions in cuckoo ray catches in the observed fishery are unlikely to be achieved using gear-based measures given similarities in morphology and behaviour with targeted blonde ray. However, gear modifications such as the raised-fishing line which reduce catches of ray species by 78% (McHugh et al., 2017) have major potential to reduce cuckoo ray catches in trawl fisheries targeting off-bottom species such as whiting and haddock.

Hence a risk-based approach which includes likelihood of catching and ability to mitigate catches of cuckoo rays should be considered in Eu waters.

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Appendix I

Control: individuals in good condition caught from reduced tow duration

At sea capture using Irish demersal vessel fishing in the Irish Sea

Test: individuals from commercial fishing operations

Reflex (RAMP) assessments – see table 3 (main document)

Injury assessments – see table 4 (main document)

Vitality assessment; control and experimental Length measurement and vitality assessment

Score	State	Description
A	Excellent	Vigorous body movement; no or minor external injuries only
B	Good	Weak body movement; responds to touching / prodding minor external injuries
C	Poor	No body movement but can move spiracles, minor or major external injuries
D	Moribund/ dead	No movement of body or spiracle opening (no response to touching or prodding)

Transfer to holding system and ad libitum feeding

Observe four times every 24 hours

Less than 15-21 days

Greater than 15 -21 days

Individuals with no obvious movement

Individuals with obvious movement

Continue observing

Vitality assessments

Tail grab	Gently grab ray by the tip of the tail
Spiracle	Look at the opening and closing of the valves inside the spiracles
Startle touch	Tap gently but firmly behind the eyes and spiracles using a fingertip
Body flex	Hold the ray by its anterior end of its disc in a horizontal, plane position, one hand on either side of the mid-line

Pass assessment

Fail assessment

Numbers of individuals at the end of the observation period compared to initial sample numbers - survivability estimates

Disposed of appropriately

Control and experimental