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Inshore longline fisheries in the southern North Sea

Fisheries Science Partnership 2019/20 (Programme 63)

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Executive Summary

- (1) The overall aims of this project were to examine i) the seasonal catch rates of fish taken in the southern North Sea demersal longline fishery; ii) catch composition of all discarded and retained fish; iii) vitality of commercially important skate and ray species, focusing on thornback ray *Raja clavata*; iv) post-release behaviour and discard survival of discarded thornback ray through an electronic tagging programme.
- (2) Three inshore longline surveys were successfully completed, each consisting of three days, and fishing at six locations. These surveys were undertaken seasonally (August 2019, November 2019 and January 2020).
- (3) Catches were dominated by thornback ray and lesser-spotted dogfish *Scyliorhinus canicula*, which accounted for 57.8% and 35.8% of the catch numbers, respectively.
- (4) Other species of local commercial importance were also encountered, including European seabass *Dicentrarchus labrax*, blonde ray *Raja brachyura* and starry smooth-hound *Mustelus asterias*.
- (5) Spurdog *Squalus acanthias* (a prohibited species) and tope *Galeorhinus galeus* (prohibited from landing longline-caught specimens) were encountered in low numbers.
- (6) The proportion of thornback ray being discarded was comparatively low (28.3% by numbers), with the proportion of fish <50 cm L_T discarded ca. 1% of the total catch by numbers. Thornback ray were mostly retained when >60 cm L_T .
- (7) Vitality assessments of 'discarded' thornback ray (which had the hooks removed manually by the crew) showed 68.2%, 26.7% and 5.1% of the fish to be in 'Excellent', 'Good' and 'Poor' condition, respectively.
- (8) Comparable data for 'retained' thornback ray (which had the hooks removed by the bait stripper) indicated 51.2%, 26.4% and 21.5% in 'Excellent', 'Good', 'Poor' condition, respectively. Only 1% of the fish that had gone through the catch and sorting process were assessed as 'dead'.
- (9) A total of 60 thornback rays were tagged with data storage tags, including both females and males, across an overall length range of 64–97 cm total length (L_T). Tags were deployed on thornback rays of a range of vitality states: 41.7% as 'Excellent', 28.3% as 'Good' and 30.0% as 'Poor'.
- (10) Seven electronic tags have been returned to date (as of 4th March 2020) and will be used to inform on discard survival when a enough tags have been returned.
- (11) The inshore longline survey-based approach of the current study could be used as the basis for future monitoring for stocks of interest, although it would benefit from a greater spatial coverage and increased number of stations at an optimal time of the year, depending on the seasonal presence of species of most interest.

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1 Introduction

This work was carried out as part of the Fisheries Science Partnership (FSP), a Defra-funded collaborative programme of scientific research between the UK fishing industry and scientists.

The inshore longline fishery in the southern North Sea (ICES Division 27.4.c) is a mixed fishery that catches locally and seasonally important commercial fish species such as cod *Gadus morhua*, European seabass *Dicentrarchus labrax*, thornback ray *Raja clavata*, blonde ray *Raja brachyura*, spurdog *Squalus acanthias* and starry smooth-hound *Mustelus asterias*. Inshore areas of the southern North Sea around the British Isles are known to be of a lower biodiversity compared to other regions (e.g. Callaway *et al.*, 2002; Ellis *et al.*, 2005), which can limit diversification of the fisheries. Hence, management restrictions on the capture and landing of certain species in this area may impact on the economic viability of local fisheries and have social implications on the historical and cultural importance of the inshore fleets.

The current EU policy (EU, 2013) includes several exemptions from the landing obligation (discard ban), which has been fully implemented since 2019, allowing some catches to be returned to the sea. These exemptions include species with proven high discard survival. Under the current North Sea (and NWW) Discard plans, survivability exemptions for skates and rays (Family Rajidae: henceforth termed 'skates')¹ are conditional on the provision of additional robust scientific evidence. The withdrawal of the exemption and obligation to land all catches of skates would affect most UK demersal mixed fisheries, for which skates are often a bycatch species. Where skate quotas are restrictive, relative to the local abundance of skates, there is the potential of a premature end of the fishing season. Under the landing obligation, when catch quotas are met, then fishing activities must stop. The continuation of existing discard survival exemption for all skates in all fisheries is important so that UK vessel operators do not choke due to the exhaustion of skate quota.

Several UK studies have recently been conducted to assess skate discard survival levels under representative commercial fishing operations (e.g. Catchpole *et al.*, 2017; Randall *et al.*, 2019). These have focussed on gill-net and trawl fisheries; prior to this study skate discard survival had not been assessed in a longline fishery and thus identified as a priority evidence gap. Longline fisheries are considered to have a higher selectivity for larger specimens, with associated lower discards rates, in comparison to trawl fisheries (Silva *et al.*, 2012). The FSP programme has provided an opportunity to undertake a case study on thornback ray (*R. clavata*) in the southern North Sea inshore longline fishery (ICES Division 27.4c).

Previous studies of the English inshore longline fishery in the North Sea have provided some information of the level of survival of unwanted skates returned to the sea. These include mark-recapture studies (Walker *et al.*, 1997; Ellis *et al.*, 2008; Bird *et al.*, 2020) and projects using electronic data storage tags to examine the migratory behaviour of thornback ray (Hunter *et al.*, 2005a, b). These studies demonstrated that a degree of discard survivability occurs for elasmobranchs, but they did not

¹ The family Rajidae comprises a range of species that, around the British Isles, have generally been divided into species with more pointed snouts (termed 'skates') and less pronounced snouts (termed 'rays'). In the present report, the term 'skate' is used to denote all members of the Order Rajiformes, with the term 'ray' used for the common names of those species normally termed 'ray' (e.g. thornback ray)

provide quantitative estimates of discard survival rates. A recent study by Ellis *et al.* (2017) provided an overall review of capture and post-release mortality of elasmobranchs around the world using different fishing methods, including longline fisheries.

The present study also presented an opportunity to assess the feasibility of using longline fisheries surveys as monitoring tools towards those species (and size of fish) that may be better monitored in the inshore coastal areas as opposed to the fishery-independent trawl surveys conducted on research vessels. The experience from previous FSP projects, which have included studies of the longline fisheries and elasmobranch catches on the inshore fishing grounds in the southern North Sea (Ellis *et al.*, 2008, McCully Phillips *et al.*, 2013), were used to develop these surveys which aimed to assess catch rates and their seasonality, and inform on vitality of fish caught. A further review of inshore longline fisheries around British Isles and the potential utility of longline surveys to inform on stock status was previously reported by McCully Phillips *et al.* (2019b).

The overall aims of this project were to examine the:

- (a) seasonal catch rates of fish taken in the southern North Sea demersal longline fishery,
- (b) catch composition of all discarded and retained fish,
- (c) vitality of commercially important skate species, focusing on thornback ray *Raja clavata*,
- (d) post-release behaviour and mortality of discarded thornback ray through an electronic tagging programme.

This work was undertaken by conducting three inshore longline surveys in the southern North Sea (ICES Division 27.4c) using the same vessel, gear and bait.

2 Materials & Methods

2.1 Fishing Vessel and Activity

Following an open tendering process, the commercial inshore fishing vessel was selected for this project was *FV Jolene* (LT1020), a 9.83 m overall length (LOA) vessel based in Orford (East Anglia). The skipper and crew of the vessel are experienced in commercial longline fishing, targeting thornback ray in coastal waters of the southern North Sea. This vessel had also been used during an earlier FSP project (FSP 2007–08 “Programme 19: Thames ray tagging and survival”; Ellis *et al.*, 2008).

The project fieldwork involved three surveys (August, November and January), each comprising three days fishing at the same six sites (two locations per day; Figure 3.1). These were selected based on the local knowledge of the vessel owner and skipper and included current fishing grounds for thornback ray, where differences in seasonal local abundance were to be expected. In each location, a line comprising three sets of lines (“baths”) were deployed, with ca. 600 No 7 J-hooks in total. Whilst the number of “baths” deployed was less than the ‘normal’ commercial fishing activity (ca. 8 baths), it allowed for a higher number of locations to be chosen and covered per survey, and still allowed typical commercial fishing operations to be undertaken. Therefore, the fishing area and fishing method were consistent with normal practice and the data on the health condition and survival of discarded skates was considered representative of the commercial fishery.

FV Jolene would normally use frozen squid and/or herring as bait, though to minimise catch variability, frozen herring was chosen as the most economically viable bait and therefore the single bait used in

the surveys. Fishing activity would preferentially occur during slack tides, when tides would be weaker, with soak times varying depending on locations chosen.

Under ‘normal’ commercial longline fishing practices, fish that were to be discarded would typically be ‘flicked’ or ‘shaken’ off the line before going through the bait stripper. Therefore, to fully quantify the catch for each survey, and to quantify the proportion of the catch discarded, any fish judged by the crew to be discarded were removed from the hook and brought onboard before that part of the line went through the bait stripper. These also included other fish species (e.g. lesser-spotted dogfish *Scyliorhinus canicula*, tope *Galeorhinus galeus*, whiting *Merlangius merlangus* and bib *Trisopterus luscus*) and currently ‘prohibited’ species such as spurdog (EU, 2020). Other fish expected to be retained (including thornback ray) were brought onboard under ‘normal’ fishing practices and would usually be removed from the hook by the bait stripper, with the difference that fish would be assessed in terms of its condition prior to being gutted (which was undertaken by the crew when fishing operations had ceased).

2.2 Catch Composition

All fish species brought onboard were recorded in terms of their total length (L_T - measured to the cm below), sex (female, male or undetermined) and maturity. For male skate and shark species encountered (with the exception of lesser-spotted dogfish), maturity was further discriminated as these species could be externally assessed (Table 2.1). Additional wing width measurements (D_W - measured to the cm below), were also recorded for all skate species. Further data collection included whether the fish would refer to the retained or discarded component part of the catch. A random subsample of the retained and discarded thornback ray were further assessed in terms of health condition and vitality (see Section 2.3).

Table 2.1: Maturity key for male skates and sharks used in this project.

Maturity stage	Male
A (Immature)	Claspers undeveloped, shorter than extreme tips of posterior margin of pelvic fin
B (Developing)	Claspers just longer than posterior margin of pelvic fin, tips more structured, but the claspers soft and flexible and the cartilaginous elements not hardened.
C (Mature)	Claspers longer than posterior margin of pelvic fin, cartilaginous elements hardened and claspers stiff (can be soft at some times of the year).
D (Active)	Clasper reddish and swollen, sperm present in clasper groove, or flowing if pressure exerted on cloaca.
U	Undetermined
X	Abnormal

Data collection, which started when the first fish were brought on board, prioritised the processing of ‘prohibited’ species (e.g. spurdog and tope) and commercial species (e.g. thornback ray and European seabass), especially if individuals were below the legal minimum landing size or marketable size, in order to allow the prompt release of fish where required.

The second priority was to assess the health condition of a proportion of the thornback rays, either if they were to be discarded or retained, with this assessed soon after removal from the hook or bait stripper, so as to ensure that the condition and vitality were as representative as possible of 'normal' fishing activities. A selected number of those thornback rays were tagged with electronic tags and released back to the sea, to infer on post-release survival from commercial longline fisheries (see Section 2.4). Additional conventional tagging for other elasmobranch species was also undertaken if time permitted, and fish were deemed suitable for tagging. Other fish would be recorded when time permitted before moving to the next location.

2.3 Vitality Assessment

The health condition of individual fish condition was assessed using a semi-quantitative method based on overall vitality, reflexes and injuries, similar to previous studies (e.g. Randall *et al.*, 2019) but adapted for the present study to better relate to longline fisheries operations.

The overall fish health condition or vitality was recorded as one of four categories (Excellent, Good, Poor and Dead; Table 2.2), in line with other previous projects, with further detailed reflex and injury assessment recorded as present or absent (

Table 2.3 and

Table 2.4). At the start of this project, a new injury type (hook damage) was introduced, given its pertinence to longline fisheries. This was classed as 'absent' (no visible damage), 'minor' (e.g. only puncture with or without bleeding present), 'moderate' (e.g. skin damage with further bleeding occurring) or 'extensive' (e.g. broken jaw). Other relevant observations were also recorded, with special attention to any abnormal or unusual fish features (e.g. blunt nose, stumpy tail, old healed wounds) or fish behaviour (e.g. fish gasping for air). Some examples of conditions that could be observed are described in

Table 2.5.

A reflex was scored as 0 (if present) and 1 (if absent or doubt on response), with an injury scored as 1 (if present) and 0 (if absent or doubt on presence). The lowest scores therefore related to a fish in a better condition and least compromised by the fishing activity. To minimise variability in the assessments and to facilitate consistency between fieldworkers, a discussion with a consensus was obtained for each fish on the initial trip. Maintaining consistency in sea-going staff between trips (with further discussions on consensus) also ensured that consistent vitality data were collected, and that it was comparable with results from other Cefas projects.

Fish brought onboard were assessed for vitality assessments as soon as possible upon removal from hook, either from the discarded or retained catch component. The last fish to be assessed was the last fish caught on the line. If it was not possible to score the vitality of a fish within an appropriate time of it being brought onboard, then vitality data were not recorded (with only length and sex information collected).

Table 2.2: Overall vitality assessment adapted to skates, based on the scale for teleosts developed by Benoît *et al.* (2010).

Vitality	Description
Excellent (1)	Vigorous body movements; no or minor ² external injuries only
Good (2)	Weak body movements; responds to touching / prodding; minor external injuries
Poor (3)	No body movements; but fish can move spiracles; minor or major ³ external injuries
Dead (4)	No body or spiracle movements (no response to touching or prodding)

Table 2.3: Vitality reflex applied to thornback ray *Raja clavata* (adapted from Randall *et al.*, 2019).

Type	Stimulus action	Reflex response
Ocular Tap	The skate 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 (s) (pectoral fin (s)) with a firm object.	Undulating movement of pectoral fin(s), within 5 seconds.
Wing Flex	<p>The skate is held by the anterior end of the disc, one hand either side of the midline.</p> <p>During this project the wing flex was adapted to further benefit fish welfare for when dealing with larger specimens to:</p> <p>The skate is held with one hand supporting the ventral side (anterior end of the disc/wing), and the other supporting the snout from below. For larger animals one hand and lower arm to support organ cavity and anterior end of the disc/wing.</p>	Undulating movement of pectoral fins, within 5 seconds.

² Minor injuries were defined as ‘minor bleeding, or minor tear of mouthparts or wing $\leq 10\%$ of the diameter), or minor surface abrasion.

³ Major injuries were defined as ‘major bleeding, or major tear of mouthparts or wing, or major surface abrasion.

Table 2.4: Injury assessment applied to thornback ray *Raja clavata* (adapted from Randall *et al.*, 2019).

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 marks⁴	Any type of clearly visible net marks on body from trawl, gillnet, longline, etc.
Scratches	Thin shallow cut or mark on (a surface).
Wounding	Nicks or cuts on body.
Hook Damage⁵	Any type of clearly visible net marks on body from longline, annotated as minor, moderate, extensive or absent.

Table 2.5: Other observations applied to thornback ray *Raja clavata* (adapted from Catchpole *et al.*, 2015).

Other observations (some examples)	
Hypo- or hyperventilating	Excessive mucus secretion
Coughing or gasping	Signs of previous damaged (healed)
Abnormal colouration	Regurgitation of food
Change in shading	Oesophagus /rectal prolapse
Signs of oedema	Egg cases present
Exophthalmia (bulging eyes)	Others (with further description)

2.4 Tagging Procedures

A sub-sample of the thornback ray were tagged electronically with data storage tags (DST) to further infer on the post-release survival after capture by longline. These specimens were assessed (see Section 2.3) both before and after tagging, in order to ensure that the tagging procedure had not compromised the state of the fish. The selection of which fish to be tagged was done randomly, due to the nature of longline fisheries, where contrary to trawl fisheries, the overall catch is only truly known after the last hook is brought onboard. Hence, tagging and the tag type used depended on the size of the fish, with the aim to tag across both sexes and a variety of health conditions, reflexes and injuries.

During this project, all electronic tagging procedures were conducted under UK Home Office Animals (Scientific Procedures) Act 1986 (ASPAs) regulations, and under Project License P2296823D (Protocol No 1 “External Tagging”). All staff conducting the regulated procedure were in possession of a UK

⁴ Net marks name convention may be misleading when used for longline fisheries, should only be applicable if recent damaged from line can be observed. Old net wounds to be reported as additional information only.

⁵ This injury was added from the most recent skate study (Randall *et al.*, 2019) as pertinent to longline fishery activities.

Personal License and full training was provided before staff were deemed fully competent to carry out any procedure on their own, or supervised at all times by a staff member competent to train others.

A total of 60 DSTs of the G5 model (20 bar) were provided by Cefas Technology Ltd (CTL, <https://cefastechnology.co.uk>), consisting on (a) 40 G5 tags without a pop-off unit attached and (b) 20 G5 tags with a pop-off unit (hereafter referred to as G5 and pDST respectively, Figure 2.1). Both tag types rely on the physical recovery of the tag, through fishing activity (where either the tag, or the fish and tag could be returned), or beach recovery once a tag had detached from the fish, usually being found by a member of the public.

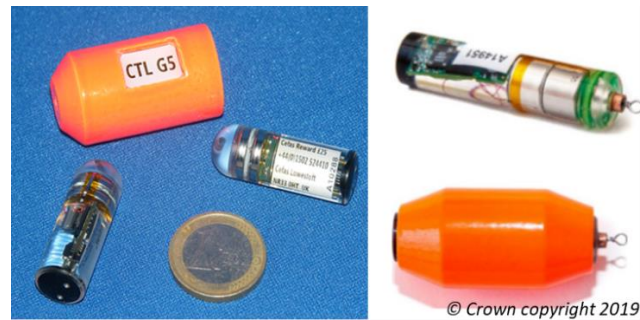


Figure 2.1: Data storage tags (DSTs) used during tagging procedures (left) G5 (20 bar) and (right) pDST G5 (20 bar).

The pop-off unit incorporated within the pDST should increase the chances of tag returns, hence its usage during this project with this larger-type of type being deployed on larger specimens only.

Both tags record temperature and pressure (depth) set to different regimes depending on the tag type. The G5 tags were set to 30 seconds for both pressure and temperature for a duration of 2.5 years (to maximise the battery life). The pDSTs were set to a one second recording regime for both pressure and temperature for a three-month duration, in order to increase the probability of these tags being returned during the duration of the project. The three-month duration is also sufficiently long to monitor post-release mortality following release of the fish.

The tags were attached to individual fish using Petersen discs and stainless-steel wires similar to other Cefas electronic and conventional tagging (e.g. Burt *et al.*, 2006; McCully Phillips *et al.*, 2019a), in order to minimise the potential for biofouling. The electronic tags were attached on the dorsal side of the wing, with the wire passing through the musculature of the pectoral fin, keeping away from both the wing edge and organ cavity. Both types of DST were previously attached to a Petersen wire by way of a small loop of monofilament line and crimp. The crimp was wrapped with self-amalgamating tape to prevent and/or delay corrosion. An example for a G5 is shown on Figure 2.2. The set up for the pDST used a similar monofilament loop, crimp and self-amalgamating tape, but the crimp was placed further away from the pop-off point to prevent any potential interference with the tag-release mechanism.



Figure 2.2: Example of the set up with monofilament and crimp for the G5 (20 bar) used during this project.

Similar to conventional tagging (or mark-recapture), the tagging wire was loaded on the dorsal side with a yellow Petersen disc containing a unique identification number, and the ventral side with a red Petersen disc with tag return information (<https://cefas.co.uk/contact-us/returning-tagged-fish-and-shelfish/>). Both Petersen discs were loaded with a silicone disc to stop direct contact with the skin and to minimise potential abrasion.

Once tagged, fish were reassessed in terms of vitality. If a fish was deemed to have deteriorated in condition post-procedure, this fish would have needed to be euthanised using a Schedule 1 method under HO regulated procedures. None of the tagged fish deteriorated in condition.

2.5 Data Analysis

Data collected were input into an Excel spreadsheet, with adequate quality assurance and control procedures undertaken prior to analysis. Summary tables and figures were generated using Excel and R software (2019).

3 Results

3.1 Fishing Vessel and Activity

A total of three surveys, each comprising of three days, were undertaken, namely Jolene 1/19 (22nd–24th August 2019), Jolene 2/19 (4th–5th and 8th November 2019) and Jolene 1/20 (21st–23rd January 2020). Two locations were visited each day, with a total of six locations sampled per survey (Figure 3.1)⁶.

Each location was fished with a longline consisting of 3 baths, ranging from ca. 200-250 hooks (No 7 – J hooks) per bath and baited with frozen herring (Figure 3.2). The lines were deployed at the beginning of the fishing day on the two locations (Figure 3.3), and after ca. 2–3 hrs soaking time one line would be retrieved, with second line only retrieved post all catch processed (Figure 3.4).

⁶ During Jolene 1/20, gear damage was sustained at one station, with two lines lost from one of the baths, with ca. 50 hooks missing from line.

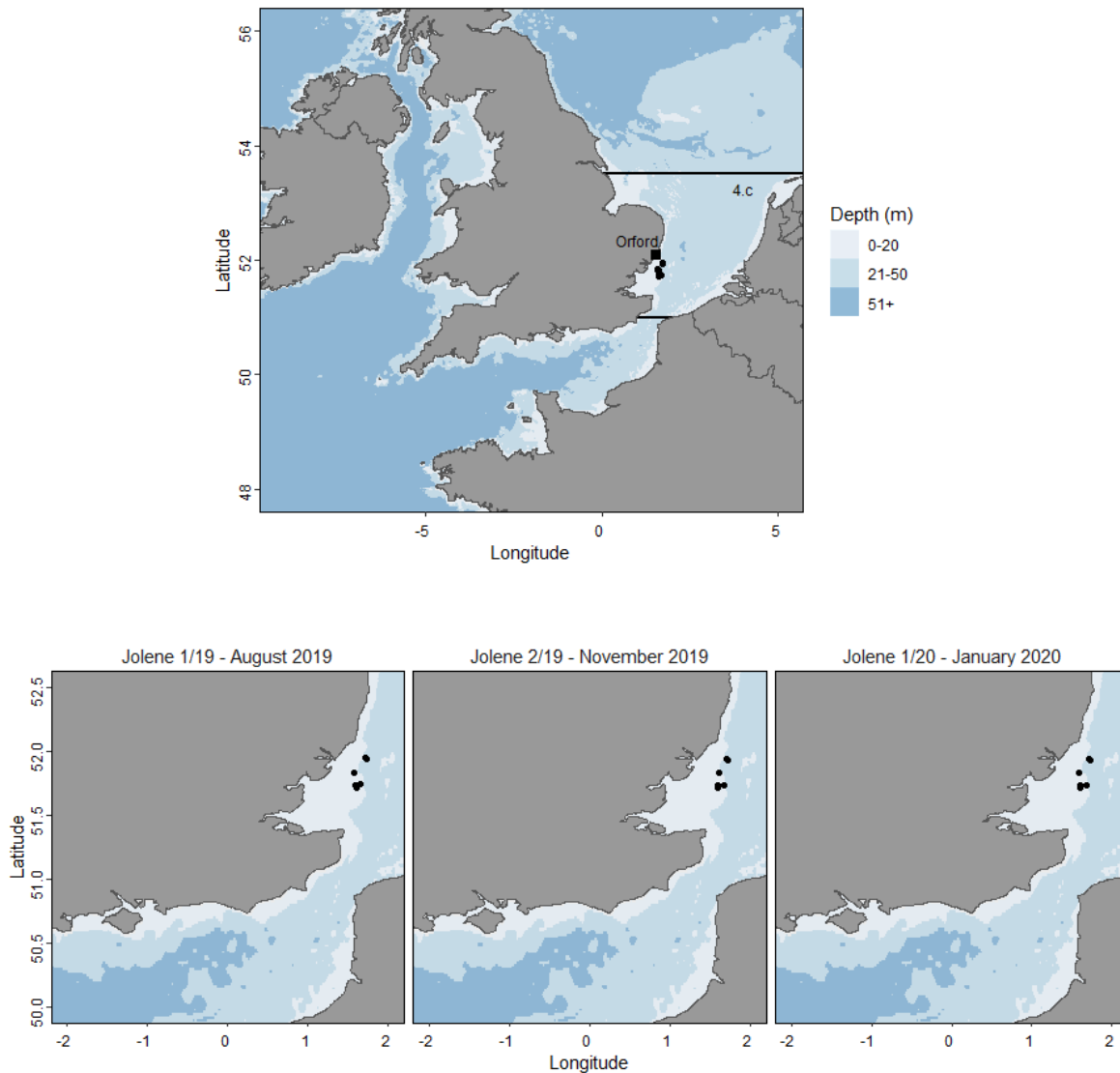


Figure 3.1: Inshore longline fishery surveys spatial distribution of selected fishing locations, (top) showing boundaries for the southern North Sea area (ICES Division 4.c)



Figure 3.2: Fishing gear used during the inshore longline surveys with the six baths deployed each day and a closer image of the frozen herring bait used and set in one bath.

Water depths ranged from 12.8–32.2 meters and soak time duration from 111–326 minutes. Given the need for catch data collection, the hauling speed was sometimes reduced to allow the required data to be recorded from fish brought onboard. Consequently, the haul duration in the present study is expected to be slightly higher than would be observed in normal fishing operations. Only after vitality assessments were completed (last hook brought onboard) would the vessel relocate to the second location for hauling. Stations details are summarised in Appendix 1.



Figure 3.3: Deployment of the longline fishing gear during this project.

Additional environmental conditions were recorded, with wind speed (ca. 1–5 knots), sea state (ca. calm, slight, moderate) and swell height (ca. 0 to <1 m).

Fishing activity and soak times occurred primarily during slack tide, and on weaker neap tides. However, winter surveys and the number of increasing storms during November to January meant that tides were less influential to decision making on a day trip than the overall weather conditions (combination of wind direction and speed, and existence of residual heavy swell).

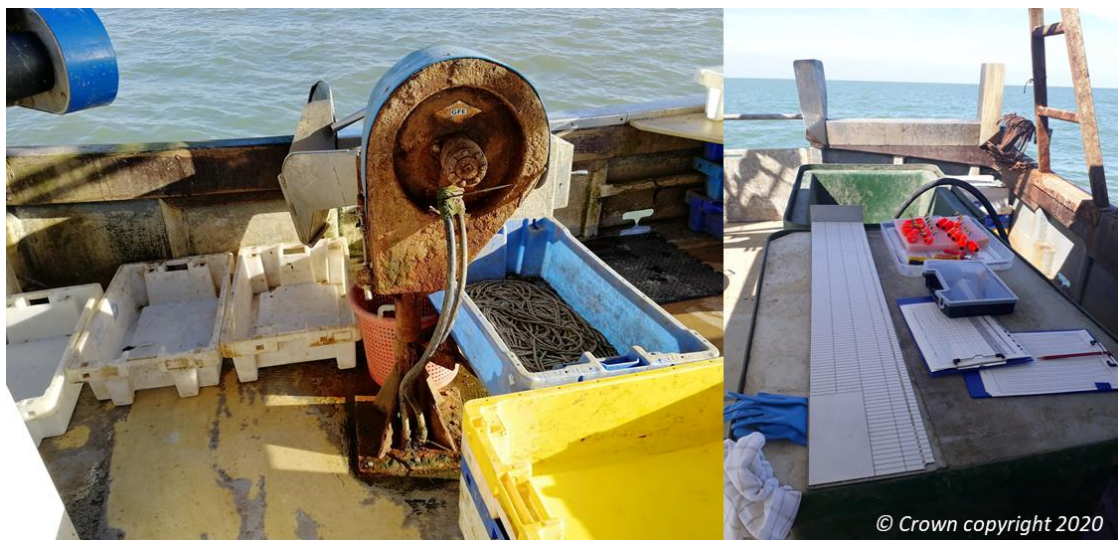


Figure 3.4: Line hauler (with bait stripper) used during hauling operations (left) and work station set up (right) for processing catch.

3.2 Catch Composition

A total number of 1769 fish were encountered across the three inshore longline surveys and, a summary of the catch composition per survey by species and sex is shown in

Table 3.1, including associated total length range (L_T in cm).

The main three species encountered during the field studies were thornback ray ($N_T = 1022$; $L_T = 44$ – 97 cm), lesser-spotted dogfish ($N_T = 634$; $L_T = 40$ – 66 cm) and whiting ($N_T = 81$; $L_T = 21$ – 36 cm).

Thornback ray showed a higher abundance in the Q1 survey (Jolene 1/20), with a ratio between females and males similar between the January and November survey (F: 52% and M: 48%), contrary to the August survey where the proportion of females was higher than males (F: 68% and M: 32%).

Longlines are known to be more selective for larger specimens, and so thornback ray not considered to be part of the exploitable biomass of $L_T < 50$ cm (ICES, 2019) were found in lower numbers, with only 11 fish below 50 cm L_T recorded (and all discarded). Discarded thornback ray ($N_D = 289$) mostly ranged from 44–70 cm L_T (with one individual of 76 cm L_T also being discarded). The retained thornback ray ($N_R = 730$) ranged mostly from 61–97 cm L_T , with two specimens of 52 and 54 cm L_T being retained. Three specimens were not allocated to ‘discarded’ or ‘retained’ parts of the catch and were thus recorded as undetermined fate (female at 81 cm L_T and male at 57 and 70 cm L_T). The length frequency distribution of thornback ray is shown in Figure 3.5 by sex and to the component part of the catch if to be ‘discarded’ or ‘retained’.

Table 3.1: Summary of numbers of fish caught per survey by species and sex (F – female, M – male, C – combined and U – undetermined), with total length range shown in brackets (L_T in cm) and, overall total number of fish (N_T) per survey.

Species	Sex	Jolene 1/19	Jolene 2/19	Jolene 1/20
Thornback ray <i>Raja clavata</i>	F	189 (44–94)	115 (45–91)	274 (45–97)
	M	88 (49–80)	106 (50–82)	250 (44–84)
	C	277 (44–94)	221 (45–91)	524 (44–97)
Lesser-spotted dogfish <i>Scyliorhinus canicula</i>	F	177 (43–64)	114 (46–63)	199 (40–63)
	M	15 (41–57)	122 (45–66)	4 (42–49)
	C	192 (41–64)	239 ⁷ (45–66)	203 (40–63)
Whiting <i>Merlangius merlangus</i>	U	7 (26–33)	59 (24–36)	15 (21–36)
Tope <i>Galeorhinus galeus</i>	F	6 (64–122)	-	-
	M	3 (72–75)	-	-
	C	9 (64–122)	-	-
Spurdog <i>Squalus acanthias</i>	F	1 (60)	2 (97–112)	2 (109–124)
	M	-	-	1 (82)
	C	1 (60)	2 (97–112)	3 (82–124)
Starry smooth-hound <i>Mustelus asterias</i>	F	-	1 (65)	5 (77–97)
	M	-	-	2 (81–83)
	C	-	1 (65)	7 (77–97)
Blonde ray <i>Raja brachyura</i>	F	-	-	1 (90)
	M	-	-	1 (81)
	C	-	-	2 (81–90)
European seabass <i>Dicentrarchus labrax</i>	U	-	1 (62)	4 (62–64)
Bib <i>Trisopterus luscus</i>	U	-	1 (18)	1 (31)
Total number of fish (N_T)	C	486	524	759

⁷ Three fish were lost from the line when hauling, unable to sex and measure so only counted.

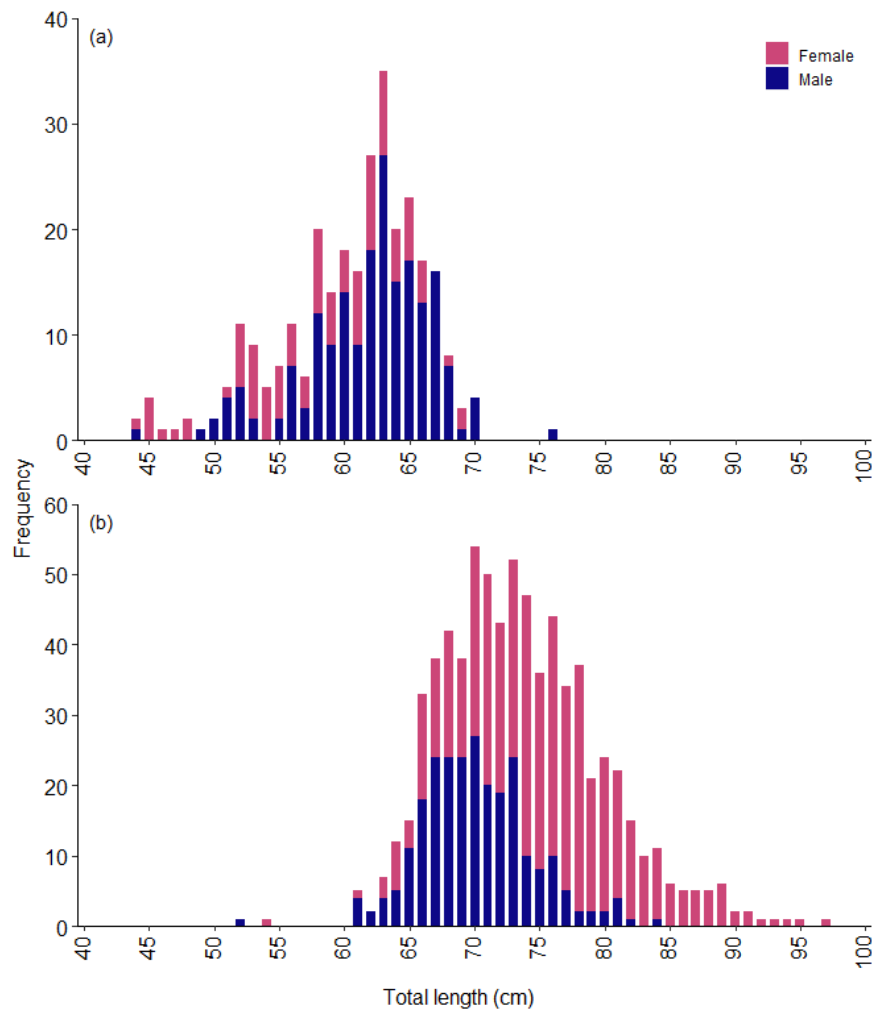


Figure 3.5: Overall length frequency distribution of thornback ray *Raja clavata* by sex and associated component part of the catch (a) discarded and (b) retained (Females: 577, Males: 442, $n = 1019$) across surveys.

Fish tagged and released, as described in Section 3.4, were included in that category (discarded or retained) as identified by the skipper (i.e. the fate if no tagging procedures would have occurred). The overall length-frequency (including tagged thornback ray and those just measured) is shown in Figure 3.5.

Maturity data are also shown for male specimens, as the proportion of immature and mature by total length (Figure 3.6). Immature fish would relate to stages A and B, with mature fish equating to stages C and D. Only one specimen was found to be in stage D at 69 cm L_T . The proportion of mature fish consisted of 83.8% ($n = 372$, 52–84 cm L_T), with 16.2% immature ($n = 72$, 44–71 cm L_T).

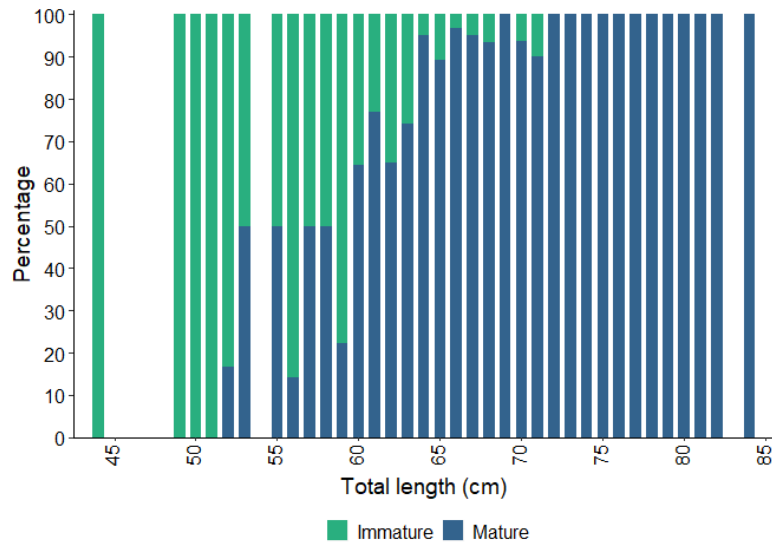


Figure 3.6: Percentage of immature and mature male thornback ray *Raja clavata* across surveys ($n = 444$, $L_T = 44\text{--}84$ cm). Immature fish relates to stage A and B, with mature fish to C and D, as per described in Table 2.1.

Additional measurement of the wing width (D_W) to the nearest cm below was also recorded for thornback ray assessed in terms of their vitality, reflexes and injuries further described in Section 3.3. The relationship between total length (L_T , cm) and wing width (D_W , cm) is shown in Figure 3.7 and equates to $D_W = 0.7063 L_T - 3.3506$ ($n = 520$; $L_T = 44\text{--}97$ cm; $r^2 = 0.9093$), with two outlying data points (open circles in Figure 3.7) excluded. Total length could also be converted using wing width through the equation $L_T = 1.2873 D_W + 10.5368$ ($n = 520$, $L_T = 44\text{--}97$ cm, $r^2 = 0.9093$).

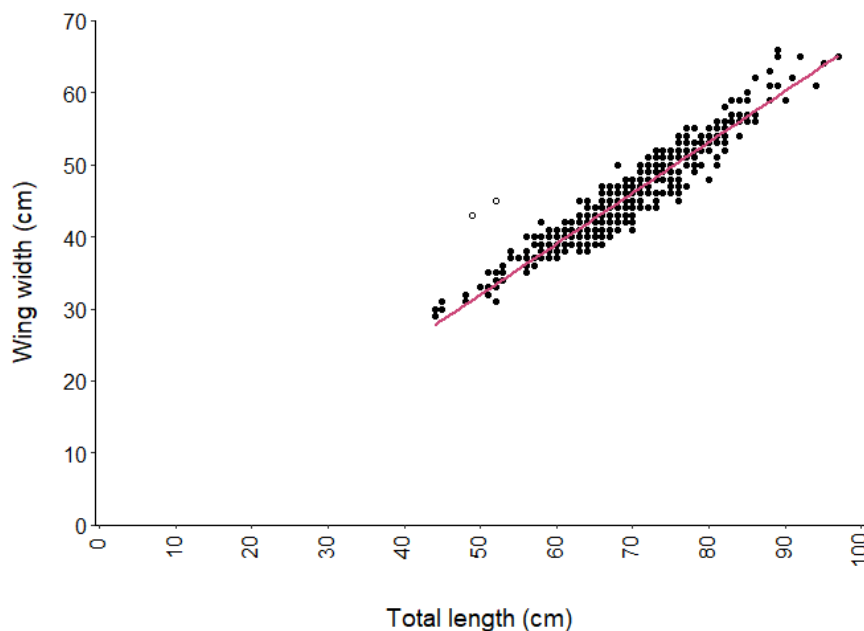


Figure 3.7: Total length (L_T , cm) to wing width (D_W , cm) of thornback ray *Raja clavata* assessed for vitality, reflex and injuries across all surveys ($n = 520$, $L_T = 44\text{--}97$ cm, $D_W = 0.7063 L_T - 3.3506$, $r^2 = 0.9093$). Regression line is shown in pink, with open circles (outliers found within the dataset) excluded.

Lesser-spotted dogfish encountered during the surveys were mainly females (ca. 92% in Jolene 1/19 and 98% in Jolene 1/20), with the second survey in November (Jolene 2/19) showing a more equal sex ratio (F: 48% and M: 52%). The overall length frequency distribution is shown in Figure 3.8.

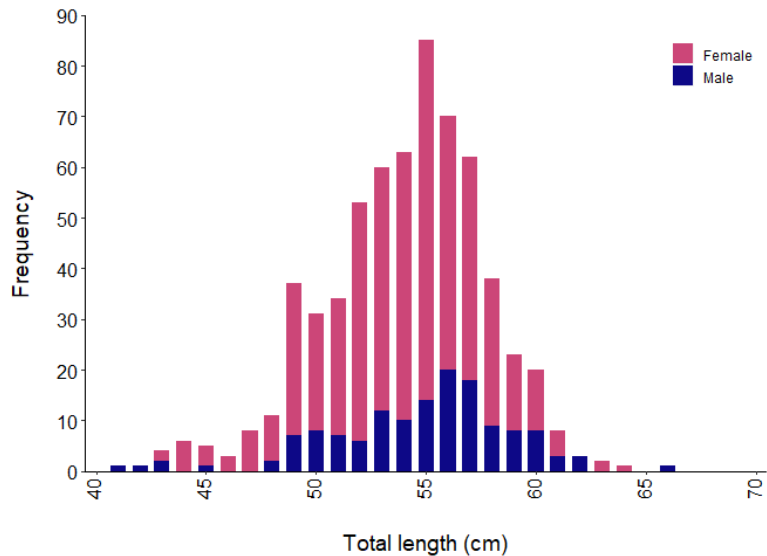


Figure 3.8: Overall length frequency distribution of lesser-spotted dogfish *Scylliorhinus canicula* by sex (Females: n = 490, Males: n = 141) across surveys.

Other recorded species included tope *Galeorhinus galeus* ($N_T = 9$; $L_T = 64\text{--}122$ cm), a species known to occur in the summer in the southern North Sea (McCully Phillips *et al.*, 2019b). Two female specimens (92–122 cm L_T) were tagged with mark-recapture tags. The occurrence of elasmobranch species (other than thornback ray and lesser-spotted dogfish) is shown in Figure 3.9.

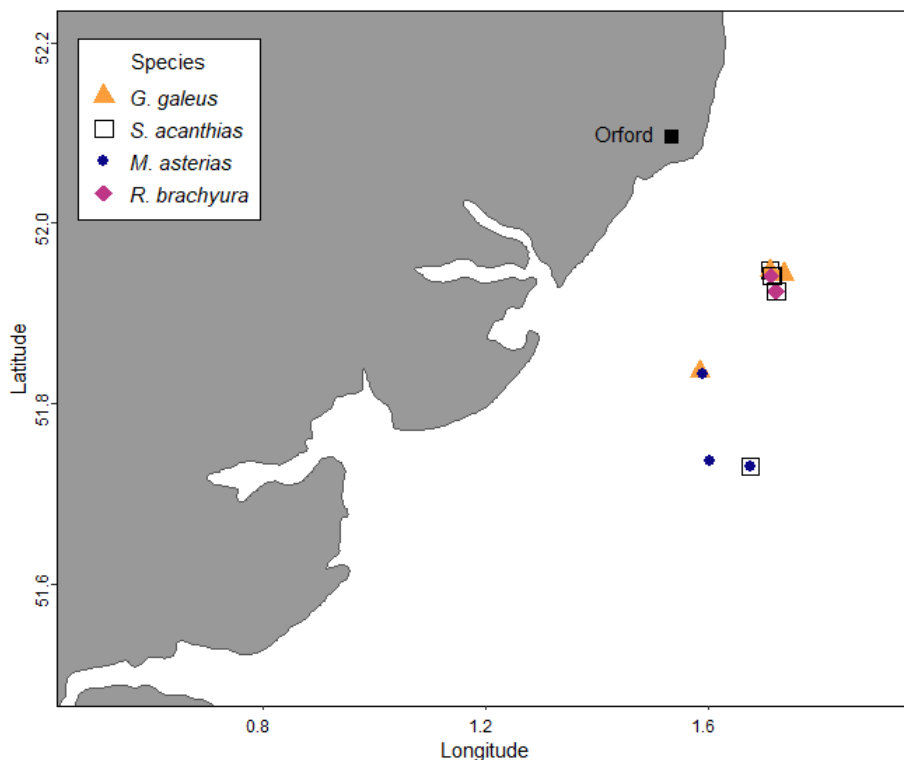


Figure 3.9: Occurrence of tope *Galeorhinus galeus*, spurdog *Squalus acanthias*, starry smooth-hound *Mustelus asterias* and blonde ray *Raja brachyura* caught during the inshore longline surveys (presence only).

Although starry smooth-hounds are known to feed mainly on crustaceans, with no fish observed in their stomachs in a recent study by McCully Phillips *et al.* (2020), a few specimens were caught in the winter surveys using frozen herring as bait ($N_T = 8$; $L_T = 65\text{--}97$ cm). This species has also shown a lower

abundance over the winter months around East Anglia from previous studies (McCully Phillips *et al.*, 2019a).

'Prohibited' species as spurdog (picked dogfish, *Squalus acanthias*) were also observed ($N_T = 6$; $L_T = 60\text{--}124$ cm), with large females encountered during the winter surveys (November and January), with this species known to be locally abundant at that time of the year (Silva, 2009). It should be noted that historical commercial fishing grounds known to the skipper, where this species would aggregate in higher numbers, were not surveyed during this project. Recent management restrictions for spurdog meant that these grounds have been avoided by the skipper and are no longer locations where they would fish when targeting thornback ray.

Despite, blonde ray *Raja brachyura* being an important commercial skate species around the British Isles and, known to occur on similar grounds as thornback ray in the southern North Sea, only two specimens were encountered during this project, a female of 90 cm L_T and a male of 81 cm L_T . Both specimens were conventionally tagged using mark-recapture tags and deemed in 'Excellent' condition.

European seabass *Dicentrarchus labrax* a highly valuable commercial fish species was only observed during the winter surveys ($N_T = 5$; $L_T = 62\text{--}64$ cm).

No specimens of cod *Gadus morhua* were encountered during the surveys, despite being a traditional species of occurrence and commercial interest for the inshore longline fleet in the southern North Sea.

The species retained and landed by skipper during this project were thornback ray and European seabass (all fish were above minimum landing size), with other species discarded.

Overall catch per unit effort, measured as number of fish per bath, is shown in Figure 3.10 for the two main fished species. CPUE was calculated by dividing the total number of fish encountered in each location by the total number of baths ($n = 3$). It was assumed that on all surveys deployed longlines would have each a total of 600 hooks (assuming 200 per bath).

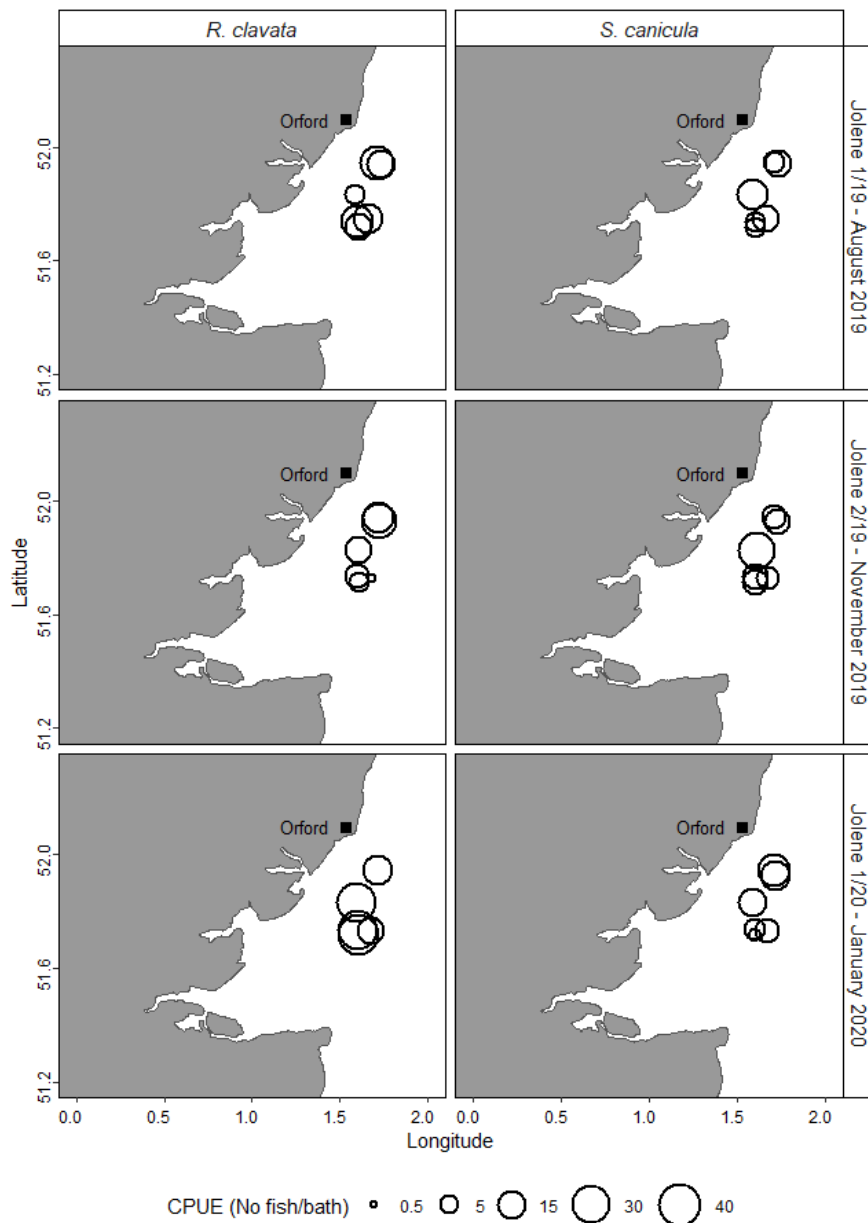


Figure 3.10: Catch per unit effort (number of fish per bath) of the main two species caught during inshore longline surveys, thornback ray *Raja clavata* and lesser-spotted dogfish *Scyliorhinus canicula*.

3.3 Vitality Assessment

3.3.1 Vitality and reflex

From a total number of 1022 thornback rays caught, 523 specimens of 44–97 cm L_T were assessed in terms of their overall vitality, reflex and injury presence or absence, as per methodology described above (Section 2.3).

It should be noted that after the first haul on Jolene 1/19, it was agreed by the scientists onboard that the health condition assessments should be conducted soon after the fish was removed from hook or had gone through bait stripper, with the last specimen assessed as the one from the last hook of the line. However, during this first station, a few specimens may have been assessed after 1–2 minutes from being brought onboard, and a few of the last specimens examined after hauling was finished.

However, data were kept as originally collected as it would be difficult to ascertain which individuals were affected.

Across all surveys, the fish encountered were mostly in 'excellent' condition (58.5%), with 26.4%, and 14.5% considered to be in 'good' or 'poor' condition, respectively. Only 0.6% of fish were considered 'dead' at the point they would have been discarded (Table 3.2). Three length categories were further defined (<50 cm L_T , 50–74 cm L_T and ≥ 75 cm L_T) in order to analyse differences on vitality scoring (Table 3.2). Although, sample size of smaller individuals ($n = 7$, 1.3%) was insufficient to draw reliable conclusions on whether fish were of better condition than fish ≥ 50 cm L_T , no fish were found in 'poor' or 'dead' condition. Intermediate and larger length category fish showed similar proportions of fish scored for all vitalities.

There were a few occasions when individuals that were considered 'lively' (in terms of their body movements) were categorised as 'poor' condition (as opposed to 'excellent' or 'good') due to injuries sustained during capture (e.g. extensive hook damage, broken jaw).

Table 3.2: Summary of thornback ray *Raja clavata* assessed on overall vitality by length category (L_T), includes fish electronically tagged.

Length category	Excellent		Good		Poor		Dead		Total No
	No	%	No	%	No	%	No	%	
<50 cm	6	85.7	1	14.3	0	0.0	0	0.0	7
50–74 cm	224	58.8	103	27.0	52	13.6	2	0.5	381
≥ 75 cm	76	56.3	34	25.2	24	17.8	1	0.7	135
Combined	306	58.5	138	26.4	76	14.5	3	0.6	523

Detailed records suggested similar proportions of vitality scores between females (Excellent: 56.9%, Good: 28.3% and Poor: 14.5%) and males (Excellent: 60.4%, Good: 24.2% and Poor: 14.6%). A summary of data collected in terms of the overall score of vitality is shown on Table 3.3, with further detailed information on Table 3.4.

Table 3.3: Summary of thornback ray *Raja clavata* assessed on overall vitality by sex, with total length range shown in brackets (L_T in cm), includes fish electronically tagged.

Vitality score	Female	Male	Total
Excellent	161 (45–97)	145 (44–84)	306 (44–97)
Good	80 (44–95)	58 (51–82)	138 (44–95)
Poor	41 (52–90)	35 (58–78)	76 (52–90)
Dead	1 (72)	2 (68–76)	3 (68–76)
Combined	283 (44–97)	240 (44–84)	523 (44–97)

Table 3.4: Detailed information on numbers of thornback ray *Raja clavata* assessed on overall vitality by sex (F – female, M – male, C – combined), with total length range shown in brackets (L_T in cm) and, overall total number of fish (N_T) per survey. Numbers discriminated if fish was to be discarded or retained as per skipper decision and, includes fish electronically tagged.

Vitality	Sex	Jolene 1/19 ⁸		Jolene 2/19		Jolene 1/20 ⁹	
		D	R	D	R	D	R
Excellent	F	21 (45–69)	34 (64–89)	7 (52–69)	27(69–91)	19 (45–66)	52 (65–97)
	M	28 (49–70)	12 (66–76)	20 (53–68)	7 (63–81)	53 (44–70)	23 (52–84)
	C	49 (45–70)	46 (64–89)	27 (52–69)	34 (63–91)	72 (44–70)	75 (52–97)
Good	F	10 (44–65)	8 (61–94)	2 (63–66)	16 (64–84)	8 (53–63)	36 (64–95)
	M	16 (51–67)	1 (71)	7 (60–66)	5 (65–82)	15 (52–68)	14 (65–80)
	C	26 (44–67)	9 (61–94)	9 (60–66)	21 (64–84)	23 (52–68)	50 (64–95)
Poor	F	1 (58)	14 (66–83)	2 (61–63)	6 (64–90)	1 (52)	17 (66–81)
	M	2 (62–70)	5 (66–75)	3 (58–67)	4 (65–78)	2 (65–76)	19 (63–77)
	C	3 (58–70)	19 (66–83)	5 (58–67)	10 (64–90)	3 (52–76)	36 (63–81)
Dead	F	-	1 (72)	-	-	-	-
	M	-	2 (68–76)	-	-	-	-
	C	-	3 (68–76)	-	-	-	-
N_T	C	78 (44–70)	77 (61–94)	41 (52–69)	65 (63–91)	98 (44–76)	161 (52–97)

Thornback ray assessed based on reflexes as described on

Table 2.3, showed that ocular tap, spiracle closure, wing stimulus and wing flex were observed for all fish considered to be ‘Excellent’ (n = 306). Four ‘Good’ specimens did not present either ocular tap, wing flex or wing stimulus when assessed, with spiracle closure being present in all fish (n = 138). ‘Poor’ fish showed all reflexes on 60 out of 76 animals, with 16 fish showing absence of one or more reflexes. Two ‘Poor’ fish only exhibited spiracle closure reflex to be present, two with only ocular tap and spiracle closure reflexes present, and one only with ocular tap reflex present. All other ‘Poor’ fish (n = 11) showed only one of the reflexes absent. Three fish were recorded as ‘Dead’ with none of the reflexes observed and present, one ‘dead’ male showed an extensive hook damage due to a broken jaw and, on the other two occasions no other information in terms of injuries were determined and/or recorded.

3.3.2 Hook Damage

For longline fisheries the most important injury to consider is the hook damage, in this project this was classified in most cases as absent, minor, moderate or extensive. From a total of 521 fish where injuries were recorded 77.0% were observed with some type of hook damage (n = 401, Excellent:

⁸ Not considered for this table, one female at 81 cm L_T and one male at 57 cm L_T as not recorded if species deemed discarded or retained. Both specimens were assessed as in excellent condition.

⁹ Not considered for this table one male at 70 cm L_T as not recorded if species deemed discarded or retained, specimen was assessed as in excellent condition.

53.9%, Good: 29.4%, Poor: 16.5% and Dead: 0.2%). The severity of this injury was further classified as 'Minor' (n = 232, 57.9%), 'Moderate' (n = 115, 28.7%), 'Extensive' (n = 53, 13.2%) and 'Present' (n = 1, 0.2%). A total of 109 fish (20.9%) were recorded with 'Absent' hook damage (Excellent: 78.9%, Good: 14.7% and Poor: 6.4%).

For some records (n = 11; 2.1%) there was no available information on hook damage, with these relating to a range of vitalities (Excellent: 36.4%, Good: 36.4% and Poor: 27.3%). In the majority of these cases the hook was still within the fish mouth, and the degree of severity was not fully defined. On other two occasions, an assumption could be made towards 'Extensive' hook damage since there was damage in the jaw and/or oesophagus, however these two records have been left as undetermined.

Further detailed records on injuries are summarised in Appendix 1, where other injuries were associated with severity of hook damage and by overall vitality condition. Examples of 'fresh' injuries observed during surveys are shown in Figure 3.11.



Figure 3.11: Example of 'fresh' injuries of thornback ray *Raja clavata* caught during longline surveys from (top left) spiracle hook damage, (top right) pelvic wound and (bottom) extensive hook damage and/or broken jaw.

The most common injury excluding hook damage was 'bleeding' and this was often related to the hook damage itself, though on occasions it was difficult to ascertain the source of the bleeding. Since other injuries apart from hook damage were only measured by its presence or absence, it can occur that fish presenting a range of minor injuries still be assessed as either in 'Excellent' or 'Good' condition. During the surveys, fish with healed injuries were found, including stumpy tails, blunt nose or even damage of the gills suggesting a species that can be found with healed minor to extensive injuries (Figure 3.12).



Figure 3.12: Example of ‘old’ healed injuries (left) a tagged female 85 cm L_T with an ‘blunt’ snout; (centre) a male 52 cm L_T with a ‘stumpy’ tail. Both animals considered to be in ‘Excellent’ condition. On the (right) observed specimen with damaged gills but no further information if fish was fully assessed.

3.4 Tagging Procedures

A total of 60 thornback ray (64–97 cm L_T) were assessed for vitality, reflexes and injuries and subsequently electronically tagged with one of the two types of tags (G5 or pDST). Tagging effort was primarily aimed for the two first surveys in order to maximise return rates over the course of the project. Tagged fish are summarised by survey, sex, overall vitality and tag type in Table 3.5. The length-frequency distribution (by sex) of thornback ray tagged and released is shown in Figure 3.13.

Although, tagging procedures were meant to occur for both sexes and across overall vitality equally, the use of electronic tags was targeted for larger specimens, which were generally females (Figure 3.5). The proportion of females tagged was 73.3% ($n = 44$, $L_T = 64$ –97 cm), while males only 26.7% ($n = 16$, $L_T = 64$ –78 cm).

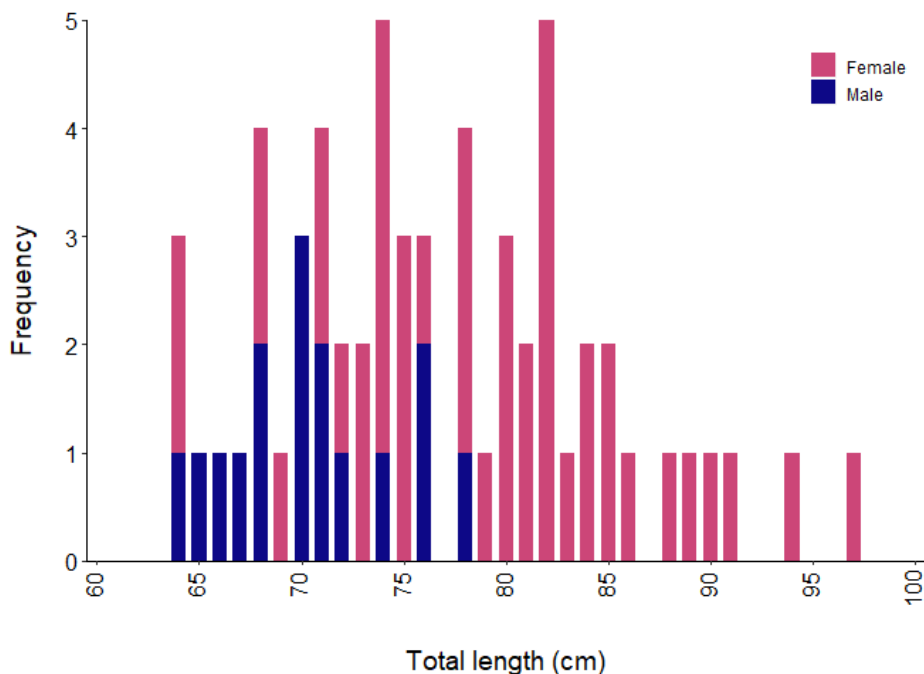


Figure 3.13: Overall length frequency distribution of thornback ray *Raja clavata* electronically tagged by sex (Females: 44, Males: 16, $n = 60$) across surveys. These included specimens that would have been discarded (64–70 cm L_T ; $n = 4$) and specimens that would have been otherwise retained (64–97 cm L_T ; $n = 56$).

Fish tagged scored in terms of overall vitality consisted of 41.7% as 'Excellent', 28.3% as 'Good' and 30.0% as 'Poor'.

Fish welfare considerations meant that pDSTs were better suited for the larger specimens (ca. >75 cm L_T), with only females tagged with this type of tag across different overall vitalities (Excellent: 55.0%, Good: 30.0% and Poor: 15.0%).

Table 3.5: Electronic tagging of thornback ray *Raja clavata*, summary (numbers) by survey, sex, overall vitality classification and tag type. Length range as L_T (in cm) is shown in brackets.

Survey	Month	Vitality	Female		Male	Survey total
			G5	pDST	G5	
Jolene 1/19	Aug	Excellent	3 (68–75)	2 (82–84)	5 (64–76)	21 (64–94)
		Good	-	3 (81–94)	1 (71)	
		Poor	4 (71–82)	1 (81)	2 (71–72)	
Jolene 2/19	Nov	Excellent	4 (73–82)	5 (76–91)	2 (66–70)	30 (64–91)
		Good	7 (64–80)	2 (82–84)	2 (67–70)	
		Poor	3 (64–79)	2 (89–90)	3 (68–78)	
Jolene 1/20	Jan	Excellent	-	4 (82–97)	-	9 (74–97)
		Good	1 (78)	1 (88)	-	
		Poor	2 (74–78)	-	1 (76)	
Total			24 (64–82)	20 (76–97)	16 (64–78)	60 (64–97)

Over the course of the project, seven tags (12%) have been returned (up to 4th March 2020), either through members of the public finding tags on a beach, or through fishing activity. The release and recapture locations of each tag returned are shown in Figure 3.14 and Table 3.6. A tag return does not signify that the thornback ray survived the catch and discard process.

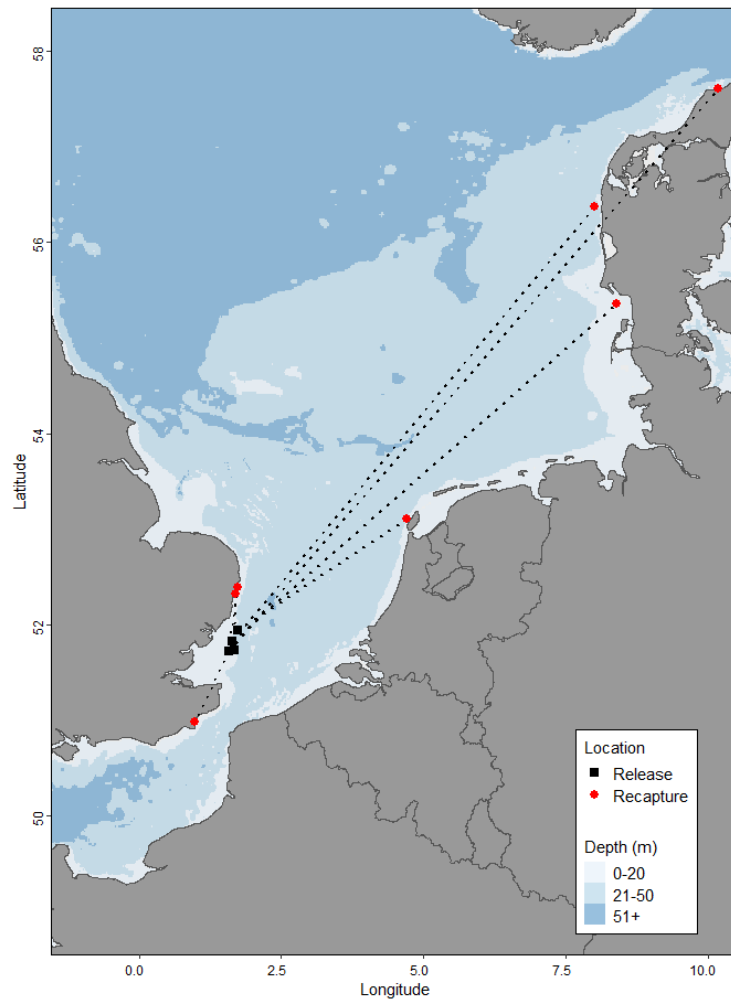


Figure 3.14: Release and recapture locations of electronic tags (including tags found on beaches) deployed during this project (n = 7). Note: the dotted lines represent where the buoyant tags were returned from and so do not generally indicate confirmed movements of the individual fish (see Table 3.6).

Table 3.6: Summary of electronic tagging data for thornback ray *Raja clavata* from this project, with associated release and recapture information.

DST No	Tag type	Sex	Maturity	L _r (cm)	D _w (cm)	Vitality	Release date	Recapture date	Recapture method	Recapture ICES Division	Hook damage*	Other comment on fish condition	Behaviour on release
A16840	G5	M	C	76	48	Excellent	22/08/2019	22/12/2019	Beached	3.a	Minor	Bleed from hook damage	Swam down, upside down
A16881 ¹⁰	G5	F	U	69	48	Poor	08/11/2019	01/02/2020	Beached	4.b	Undefined	Bleed from gills	At surface, weak movement
A16885	G5	F	U	68	46	Excellent	22/08/2019	06/11/2019	Trammel net	7.d	Undefined	Bleed from hook damage, hook still in mouth	Swam down
A16890	G5	M	C	70	44	Good	08/11/2019	22/02/2020	Beached	4.b	Absent	Bleed from gills	Stayed at surface
A16907 ¹¹	pDST	F	U	82	53	Excellent	22/08/2019	01/12/2019	Beached	4.c	Minor	Bleed from hook damage	Swam down
A16908 ¹²	pDST	F	U	94	61	Good	24/08/2019	06/10/2019	Beached	4.c	Present	Bait in mouth, broken teeth from hook damage, internal bleed ¹³	Swam down, righting itself up
A16914 ¹⁴	pDST	F	U	83	56	Good	23/08/2019	23/11/2019	Beached	4.c	Moderate	Bleed from hook damage	Swam down

*Reflex assessment tested showed positive for all fish for: ocular tap, spiracle closure, wing stimulus and wing flex. Other injuries observed (excluding hook damage) showed only presence of bleeding.

¹⁰ Tag return currently being processed with tag yet to be physically recovered and downloaded by Cefas. Recapture information provided by email or phone contact.

¹¹ Pop-off mechanism corroded; tag automatically released from fish.

¹² Pop-off mechanism not corroded; tag returned before pop-off date and 'removed' from fish.

¹³ Assumption that the conditions observed and recorded were not extensive hence vitality as 'Good' as nothing further is suggested from paper records.

¹⁴ See 10.

Data showed that the one tagged fish recaptured was caught in the north-eastern part of Division 7.d, whilst the returned tags (from beaches) were returned from three ICES Divisions: three from 4.c, two from 4.b (central North Sea) and one from 3.a (Skagerrak). Whilst these results all equate with the current ICES stock units used for advice (ICES, 2019), the beached tags will reflect the prevailing water movements as opposed to fish movements.

Further analysis on geolocation modelling and post-release survival following methods described in Randall *et al.* (2019) and Wright *et al.* (in prep) will be conducted once more tags are returned, so as to provide a more robust analysis, with potential for future combination with data from previous studies where other fishing métiers were used.

4 Discussion

4.1 Demersal longline fisheries

Demersal longline fisheries are locally important around the coast of East Anglia for selected fish species of commercial interest, and over the longer-term have taken various skate species (e.g. thornback ray and blonde ray), cod, bass, starry smooth-hound and spurdog. Current restrictions on landing some of these species and restricted quotas for other species have been a challenge to this fleet.

In some respects, longline fisheries are environmentally friendly, with a lower fuel consumption and lower impact on the sea floor (c.f. trawling) and showing a higher catchability of larger specimens and greater selectivity for commercial species, and thus potential for lower discards rates (Silva *et al.*, 2012). Conversely by targeting larger bodied piscivorous species, it could lead to some stocks being locally overexploited.

Although, some longline fisheries around the world may show a degree of a bycatch of other species of conservation interest, such as seabirds (Anderson *et al.*, 2011), no interactions with seabirds were observed during the present study, as also noted for previous FSP projects working with this fleet (Ellis, pers. obs.).

The stocks of many demersal elasmobranchs in European waters are assessed using scientific trawl surveys, though these do not always effectively sample the 'exploitable' or 'marketable' component of the stock. They are also limited to more offshore fishing grounds, as most research vessels do not sample inshore areas (depths <20m). Important nursery and pupping areas within shallower waters are also not effectively sampled through fishery-independent trawl surveys, which if surveyed could provide some further inform on fish stock recruitment.

Elsewhere in the world, there are various fish stocks currently surveyed using scientific longline surveys. Examples of these targeting elasmobranchs species are the Northeast Fisheries Science Centre (NEFSC) Apex Predators Program and Cooperative Atlantic States Shark Pupping and Nursery longline surveys in US coastal waters (see McCully Phillips *et al.*, 2019a for a review of longline surveys).

Given the seasonal inshore nature of species of interest (thornback ray, blonde ray, tope, spurdog, cod and European seabass), and that some of these are faster swimming species that may not be sampled effectively by trawl, there should be consideration of whether inshore longline surveys can

support the monitoring of selected stocks. Such scientific surveys would need to be conducted using the fishing industry, in terms of handling the gear, fisher knowledge and access to coastal waters (c.f. research vessel surveys).

4.2 Catch composition

During this project, a total of 1769 individuals of nine species were recorded, the main species were thornback ray and lesser-spotted dogfish, and to a lesser extent whiting (57.8%, 35.8% and 4.6%, respectively, in terms of the numbers caught).

The overall length range of thornback ray observed was 44–97 cm L_T , and so the catches are more reflective of commercial size fish than would be generally observed in fishery-independent trawl surveys.

Other commercial species were observed in smaller numbers, and included European seabass, tope, starry smooth-hound, spurdog and blonde ray. Interestingly, no cod were caught during the three surveys, despite two of the surveys being in November and January. However, some of these species may be more effectively sampled on other grounds and/or with other baits (e.g. squid).

4.3 Discarding and vitality assessments for thornback ray

Previous studies on discarding and vitality assessments of thornback ray were focused on trawl and gillnet fisheries (e.g. Randall *et al.*, 2019), with the present study providing the first quantitative information on the vitality of longline-caught thornback ray. Although earlier FSP studies also assessed fish health condition for longline-caught elasmobranchs, these used a simpler scale (Ellis *et al.*, 2008 and McCully Phillips *et al.*, 2013).

Across the three surveys, for both ‘retained’ and ‘discarded’ fish, 58.5% were deemed in ‘Excellent’ condition, with only 26.4% and 14.5% deemed in ‘Good’ or ‘Poor’ condition, and 0.6% dead. The most common injury for longline-caught fish was ‘hook damage’ and ‘bleeding’, with the latter mainly originated by the extent of damage from hook (e.g. deep hooking, broken jaw).

The current vitality scoring method used could usefully be expanded to qualify the extent of damage and injury (as opposed to presence and absence information). However, for such data to be collected consistently would require a close collaboration between a smaller number of scientific staff, whilst the presence and absence approach is better suited for those studies using multiple scientific staff and across a longer time period.

It should also be noted that the vitality assessments for retained fish were based on those fish for which the hook had been removed by the bait stripper. Consequently, the degree of hook damage (and therefore the overall score) would be more pessimistic than if fish were shaken off the line or unhooked manually, which often happens for those fish to be discarded due to management regulations (e.g. spurdog and tope). It was also observed that fish could be subject to further injuries from being gaffed (if used when they were being brought on board).

Those thornback ray identified by the crew as part of the ‘discarded’ catch component, which were removed before the bait stripper, as per normal practice, were overall assessed as being in better health condition than fish ‘retained’, with only 5.1% deemed ‘poor’ (cf. 21.5% for the ‘retained’ catch).

4.4 Discard survival of thornback ray

Sixty individuals of thornback ray across sex and lengths, were electronically tagged to further inform on post-release mortality. Although seven tags have been returned (as of 4th March 2020), analyses of these data will be undertaken when a greater sample size of tag returns is available.

4.5 Future work

Analysis of electronic tagging data from DSTs will be further conducted once the rate of tag returns increases, in order to provide a more robust estimate in terms of discard survival of skates caught in longline fisheries. This could also benefit from further combining with data collected on previous studies (e.g. Randall *et al.*, 2019) where different fishing métiers were considered and, also to provide a larger sample size on studies on recent migratory behaviour of thornback ray around the British Isles.

There are potential advantages of using commercial fishing vessels to conduct longline surveys to provide survey indices to assess stocks of interest, and as a platform for additional biological data collection of data-limited species. There should be due consideration of whether a ‘pilot’ survey could be implemented across a wider area to increase coverage of the fishing grounds during a defined season, for which the optimal season would depend on the main species of interest (e.g. winter for cod and spurdog, and summer for tope and seabass).

The use of inshore longline surveys would benefit from further examination on how changes to gear rigging, different baits and different hook type may improve catchability of the various species. The local fishery uses J-hooks, which may result in deep hooking (c.f. circle hooks, Grekov & Pavlenko, 2011), therefore deployment of similar lines using circle hooks could be undertaken to examine the differences in both catch rates and vitality of species caught.

Thornback ray is arguably one of the more ‘robust’ skate species, given the presence of thorns and thickness of its skin, in comparison to other skate species such as spotted ray *Raja montagui*, where the body can be smoother and slimmer, and so potentially more prone to damage. Therefore, further studies on vitality, reflexes and injuries on fish caught by commercial longline fisheries for other locally abundant skate species could usefully be considered.

In terms of the landing obligation, there have now been studies on a range of inshore skates, primarily thornback ray and undulate ray *Raja undulata*, and these add to the evidence to evaluate the suitability of an exemption on the basis of high survival. Further studies are required for those species occurring more offshore e.g. cuckoo ray *Leucoraja naevus* and possibly for species with smaller body size and thin skins (e.g. spotted ray).

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Appendix 1: Summary of stations fished per survey with total number of fish caught per species¹

Survey	Location site	Haul No	Baths N _T (Hooks N _T)	Date	Shot depth (m)	Haul depth (m)	Soak time (hh:mm) ²	THR	LSD	WHG	GAG	DGS	SDS	BLR	ESB	BIB
Jolene 1/19	A	1	3 (600)	22/08/19	13	23.5	02:51	62	16	1	-	-	-	-	-	-
	B	2	3 (600)	22/08/19	19.1	12.8	03:42	40	18	-	-	-	-	-	-	-
	C	3	3 (600)	23/08/19	18	19	05:26	16	57	-	4	-	-	-	-	-
	D	4	3 (600)	23/08/19	24.6	21.8	03:06	48	39	1	-	-	-	-	-	-
	E	5 ³	3 (600)	24/08/19	31.1	30	02:21	66	21	2	3	1	-	-	-	-
	F	6	3 (600)	24/08/19	30.6	28.9	03:06	45	41	3	2	-	-	-	-	-
Jolene 2/19	A	1	3 (600)	04/11/19	20	25	01:51	31	35	20	-	-	1	-	-	-
	B	2	3 (600)	04/11/19	20	21	02:26	16	34	15	-	-	-	-	-	-
	C	5	3 (600)	08/11/19	21	22	04:03	38	84	2	-	-	-	-	-	-
	D	6 ⁴	3 (600)	08/11/19	22	23	01:55	2	24	14	-	-	-	-	1	1
	E	3	3 (600)	05/11/19	31	30.5	01:53	56	28	5	-	2	-	-	-	-
	F	4	3 (600)	05/11/19	30.5	29	02:40	78	34	3	-	-	-	-	-	-
Jolene 1/20	A	1	3 (600)	21/01/20	17.9	25.7	01:52	99	20	5	-	-	-	-	2	-
	B	2	3 (600)	21/01/20	18.9	19.8	02:47	112	5	1	-	-	-	-	-	-
	C	3	3 (⁵)	22/01/20	20	20	04:34	96	42	2	-	-	4	-	-	1
	D	4	3 (600)	22/01/20	22.8	26	02:02	38	27	2	-	1	3	-	2	-
	E	5	3 (600)	23/01/20	31.8	32	02:05	51	59	2	-	1	-	1	-	-
	F	6	3 (600)	23/01/20	32.2	30.7	02:49	128	50	3	-	1	-	1	-	-
Total number of fish (N_T)								1022	634	81	9	6	8	2	5	2

¹ Species three letter codes shown relate to: THR – thornback ray, LSD – lesser-spotted dogfish, WHG – whiting, GAG – tope, DGS – spurdog, SDS – starry smooth-hound, BLR – blonde ray, ESB – European sea bass and BIB – bib.

² Soak time considered from start of shooting to end of hauling of the longline.

³ Line diverted due ship container in the area.

⁴ Tow location moved slightly due to presence of static gear on the original location.

⁵ Gear damage: two lines were lost, with ca. 50 hooks missing from line, suspected damage from sand dredger in the vicinity.

Appendix 2: Injury assessment on thornback ray *Raja clavata* summary (numbers) by degree of hook damage severity and overall vitality classification

Hook Damage	Other injuries	Excellent	Good	Poor	Dead	Total
Absent	None	76	4	3	-	83
	Bleeding	5	10	4	-	19
	Bruising	2	1	-	-	3
	Scratches	-	1	-	-	1
	Wounding	3	-	-	-	3
Minor	None	132	19	1	-	152
	Abrasion	1	-	-	-	1
	Abrasion + Bleeding	-	1	-	-	1
	Bleeding	47	14	2	-	63
	Bleeding + Bruising	-	-	3	-	3
	Bleeding + Wounding	2	1	-	-	3
	Bruising	1	1	2	-	4
	Net marks	1	-	-	-	1
	Scratches	2	-	-	-	2
	Wounding	2	-	-	-	2
Moderate	None	12	59	1	-	72
	Abrasion	-	2	-	-	2
	Bleeding	16	15	2	-	33
	Bleeding + Bruising	-	1	1	-	2
	Bruising	-	2	1	-	3
	Wounding	-	1	2	-	3
Extensive	None	-	1	38	-	39
	Abrasion	-	-	1	-	1
	Bleeding	-	-	9	-	9
	Bleeding + Wounding	-	-	2	-	2
	Wounding	-	-	1	-	1
	Not recorded	-	-	-	1	1
Presence only	Bleeding	-	1	-	-	1
Undetermined	None	2	3	1	-	6
	Bleeding	2	1	2	-	5
Total	Combined	306	138	76	1	521



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