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Remote Electronic Monitoring (REM) to validate fishermen's self-sampling records of skates and rays in the Bristol Channel

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Executive Summary

In the Bristol Channel (ICES Divisions VIIf-g), commercial trawl and net fisheries have historically had important target and non-target fisheries for various skate and ray species, such as thornback (*Raja clavata*), blonde (*Raja brachyura*) and small-eyed ray (*Raja microocellata)*. These fisheries operate under an increasingly restrictive skate and ray Total Allowable Catch (TAC) or quota, as stock assessments for these species are hampered by the limited population and fisheries data available. Consequently, their management is precautionary and viewed by some sectors of the fishing industry as overly punitive and/or ineffective, having closed the fishery in 2014 and displaced fishing vessels from the Bristol Channel skate and ray fishery in 2017.

Working directly with the fishing industry, utilising fishermen's knowledge and using fishing vessels as scientific platforms provides an alternative and complementary way to fill these data gaps. Training fishermen to self-sample their catch and record the necessary catch and biological data, offers a practical and effective approach to collect these data. However, without quality assurance and independent validation of fishermen's self-sampling records, stock assessment scientists are unlikely to accept them, therefore the potential value of this information to inform fisheries management and policy is lost.

Remote Electronic Monitoring (REM) systems on fishing vessels usually consist of cameras, global positioning system (GPS), and sensors for detecting fishing gear use. In the UK, REM has been used primarily by enforcement agencies (e.g. Marine Management Organisation) in trials for monitoring catches, primarily discards in the advent of the landing obligation. However, other recent Cefas research has indicated, but not unequivocally, that REM could be used to validate fishermen's self-sampling catch and biological data.

The aim of this project was to determine whether REM can be used to accurately verify and evaluate self-sampling records of the skate and ray catch (retained and discarded) made by the skipper and crew during typical commercial fishing operations. For 7 commercial fishing trips between December 2016 to February 2017, our analyses show that the REM video footage allowed for successful verification of the crews self-sampling records of 50% (39) of the hauls analysed, with high agreement in the number (100%), weight (99%) species (99.5%) and sex (83%) of the retained skate and ray catch in the Bristol Channel trawl fishery. The REM video analyst recorded that the vessel retained 11.25 tonnes, and discarded 1.6 tonnes of skates and rays, with a catch composition of 52% thornback ray, 31% blonde ray, 10% spotted ray and 7% small-eyed ray. For the hauls analysed, the crews estimated skate and ray discard was 1706 kg, compared to the video analysts' estimate of 1569 kg.

The combined approach of collecting fishery-dependent data through self-sampling with validation using REM could provide data as part of national catch sampling programmes, to help improve the assessment of, therefore management of skates and rays (e.g. blonde ray) in the Bristol Channel. The International Council for the Exploration of the Sea (ICES) advice for blonde ray in ICES Divisions VIIa, VIIf-g for 2017 states the assessment is lacking data on local abundance and for larger blonde ray. The spatial and temporal logging of fishing activity by the REM system, together with the crews self-sampling records allowed us to map the

spatial distribution and abundance of blonde ray in the fishing area, including that of large individuals. This demonstrates that this fishery-dependant approach could help fill these data gaps and the use of REM to validate and enhance fishermen’s self-sampling records is likely to be transferable to other fisheries, and suitable for other data-deficient species.

Introduction

Fisheries Science Partnership

A Fisheries Science Partnership involving the fishing industry, Defra and Cefas scientists was established in 2003 to further relationships between UK fishermen and scientists and to involve fishermen in the co-commissioning of science, with the aims to:

a) Provide information from commercial fishing catches on key stocks to supplement data sources traditionally used in ICES assessments;
b) Investigate concerns raised by fishermen on scientific assessments or on stocks not currently assessed;
c) Investigate innovative scientific methods and or more selective / environmentally friendly fishing methods; and,
d) Support the work of Regional Advisory Councils.

To date, FSP projects have successfully undertaken work on a variety of fish stocks and fisheries, including studies specifically addressing elasmobranch issues, in particular Ellis *et* al., 2008; Bendall *et al*., 2012; Hetherington *et al*., 2015, including ray discard survival in the Bristol Channel (Catchpole *et al*., 2007). A full description of the FSP programme can be found on the GOV.UK website (https://www.gov.uk/government/organisations/centre-for-environment-fisheries-and-aquaculture-science/about/research).

Background

In the Bristol Channel (ICES Division VIIf-g), commercial trawl and net fisheries have historically had important target and non-target fisheries for various skate and ray species, such as thornback (*Raja clavata*), blonde (*Raja brachyura*) and small-eyed ray (*Raja microocellata)*. Although these fisheries continue to operate, they are much reduced as the current skate and ray TAC has become increasingly restrictive.

In contrast to many other commonly exploited fish species like cod (*Gadus morhua)*, haddock (*Melanogrammus aeglefinus*) and plaice (*Pleuronectes platessa*), relatively little is known about the status of elasmobranch populations within UK waters. Current stock assessments are hampered because only limited population and fisheries data are available (Ellis *et al.*, 2015). Consequently, some management measures are necessarily precautionary but viewed by some sectors of the fishing industry as overly punitive and/or ineffective. There is a strong need to gain a better understanding of skate and ray populations in the Bristol Channel, and the wider area to inform management given (i) the early closure of the skates and rays fishery in the Bristol Channel (and other areas) in 2014; (ii) the introduction in 2016 of a limited species-specific TAC for small-eyed ray in the Bristol Channel region; and (iii) the participating fishing vessel in this project (and her sister vessel) has been displaced to another fishery (cuttlefish), in another area (Western English Channel) in the summer of 2017, due to a rapid and exhaustive uptake of the available skate and ray TAC in the Bristol Channel for that year.

Stock assessments use fishery-independent data (collected without any commercial fishing activity) and fishery-dependent data (collected from the fishery). The current ICES advice for blonde ray, for example, published in October 2016 for ICES Divisions VIIa and VIIf-g states landings data "…*for Raja brachyura and spotted ray (Raja montagui) are often confounded…*" and that for the fishery-independent scientific research vessel survey in this area "…*the species is caught most regularly in the Bristol Channel and off the east coast of Ireland. However, surveys have limited coverage in areas of local abundance and larger individuals are not sampled effectively…*". Similarly, the current ICES advice for thornback ray from October 2016 in ICES Divisions VIIa and VIIf-g, describes that the scientific survey "…*used in the assessment covers a large proportion of the stock area, but the gear has a low selectivity for adult fish…*". As part of the national fishery-dependant offshore and onshore catch sampling programmes, Cefas observers collect catch composition, size, age and maturity data for commercial fish stocks. Fishermen's self-sampling data on commercial catches of skates and rays in the Bristol Channel could supplement these existing programmes to help address these knowledge gaps of mis-identification and not sampling representative areas of abundance, as well as using gear types more appropriate to catching skates and rays in the Bristol Channel.

Self-sampling – a fishery-dependant approach

Working directly with the fishing industry in the Bristol Channel, utilising fishermen's knowledge, their commercial fishing gear and their fishing vessels as scientific platforms can offer an alternative and complementary data source to be used in various skate and ray stock assessments for ICES Division VIIf-g. Scientific observers go aboard fishing vessels to collect these data as part of national catch sampling programmes, but on their own might be insufficient to capture all important spatial and temporal nuances in a relatively small but important fishery. Focused sampling effort in this fishery would be costly and or could divert sampling effort away from the coverage of other fisheries. Dedicated sampling effort or charters cost money, and with increasing Government resource constraints, training fishermen to self-sample their catch, and record the necessary catch and biological data, offers a practical and effective approach to supplement existing programmes.

As reported by Hetherington *et al.,* 2017, and described in Ellis *et al.*, 2015, a previous Defra funded fishery-dependant data collection programme, the NEPTUNE Shark, Skate & Ray Scientific By-catch Fishery (October 2013 – December 2014), identified limitations of fishing industry self-sampling data, mainly associated with the quality and timeliness of data provided. Also, without independent validation of fishermen's self-sampling data, stock assessment scientists are unlikely to accept these data (Ellis *et al*., 2015), negating the very point for which these data are collated, to inform fisheries management and policy.

Novel use of Remote Electronic Monitoring (REM)

REM systems on fishing vessels usually consist of cameras, global positioning system (GPS), and sensors for detecting the use of the fishing gear (movement of net drums or hydraulic winches). As reported by Hetherington *et al*., 2016a, REM is not routinely applied to fisheries in Europe, unlike in some other countries, for example in the Canadian West coast hook and line fishery (Stanley *et al*., 2011). Instead it has been used on an adhoc basis, primarily by enforcement agencies in trials for monitoring of the landing obligation (e.g. Kindt-Larsen *et al.*, 2011, Roberts *et al.*, 2015, the Scottish Government, 2011). However, the pace at which REM is being tested for gathering biological data is increasing, whereby Needle *et al.,* 2014, van Helmond *et al*., 2014 and Ulrich *et al*., 2015, have all reported that REM has the potential to deliver a rich source of biological information of the catch in commercial fisheries, in addition to fisheries monitoring activities. Cefas has also recently investigated the compatibility of observer and REM generated data (Elson *et al.*, 2016), and using REM to validate fishermen's self-sampling catch-data of common skate (*Dipturus batis* complex) in the Western English Channel (ICES Division VIIe) (Hetherington *et al.,* 2017).

Aim

Building on the research of the 2 previous Cefas REM projects (Elson *et al*., 2016 and Hetherington *et al.,* 2017.), applying the lessons learnt, and developing expertise, the aim of this FSP project was to investigate whether:

1. A skipper & crew could be trained by scientists to use their commercial fishing vessel as a scientific research platform, rapidly and efficiently collecting biological information such as species, length and sex of skates and rays in the Bristol Channel skate and ray fishery;

2. REM can be used to accurately verify and evaluate these self-sampling records of the skate and ray catch (retained and discarded) made by the skipper and crew during typical commercial fishing operations.

Informing policy

The data collected, and experiences from this project will inform Defra on whether REM can be used to validate fishermen's self-sampling records. This is particularly relevant to data-deficient species such as elasmobranchs, as more and better data are required to improve their sustainable management. Recognising Defra's ambition of 'collect once, use many times' to ensure the efficient and effective use of its investment in data collection, this collaborative project between Cefas and the Marine Management Organisation (MMO) demonstrates how REM on a commercial fishing vessel can be used to supplement traditional fisheries monitoring, where it would be too costly and inappropriate to use other fishery-independent approaches.

Building capacity

This project was a collaboration between Cefas, MMO and Seascope Fisheries Research Limited, building capacity between the Defra agencies of Cefas and the MMO on alternative uses of REM beyond fisheries enforcement, making monitoring more 'smart', collecting data more cost effectively. Seascope Fisheries Research Limited have shared their expertise of using REM in the field, training the fishing vessels crew at sea, refining scientific sampling protocols, to build data collection capability whilst still operating as a commercial fishing vessel.

Method

Fishing vessel and gear

The FV Our Dylan Ben (Figure 1) is a 11.98m otter trawler, using a single trawl with a 120mm square mesh panel and 85mm cod-end, targeting demersal species in the Bristol Channel, ICES Divisions VIIf-g. In terms of landings value, the main target species are blonde ray (*Raja brachyura*), thornback ray (*Raja clavata*) and bass (*Dicentrarchus labrax*).

Figure 1: FV Our Dylan Ben

REM installation

Installed onto the vessel by the MMO, the project used an Electronic Monitoring System (Figure 2) created by Archipelago Marine Research Ltd, which supplies video from cameras, sensors to interpret fishing activity and location via GPS. The camera setup was comprised of 3 cameras, 2 analogue and 1 digital. Camera 1 (analogue) viewed the deck area where the cod-end was emptied and unwanted fish can be discarded. Camera 2 (analogue) viewed the entire deck area, providing an over view of the catch sorting, processing and discarding process. Camera 3 (digital) viewed an area of the deck, including the fish room hatch, where all skates and rays were self-sampled. The camera views are shown in figure 3.

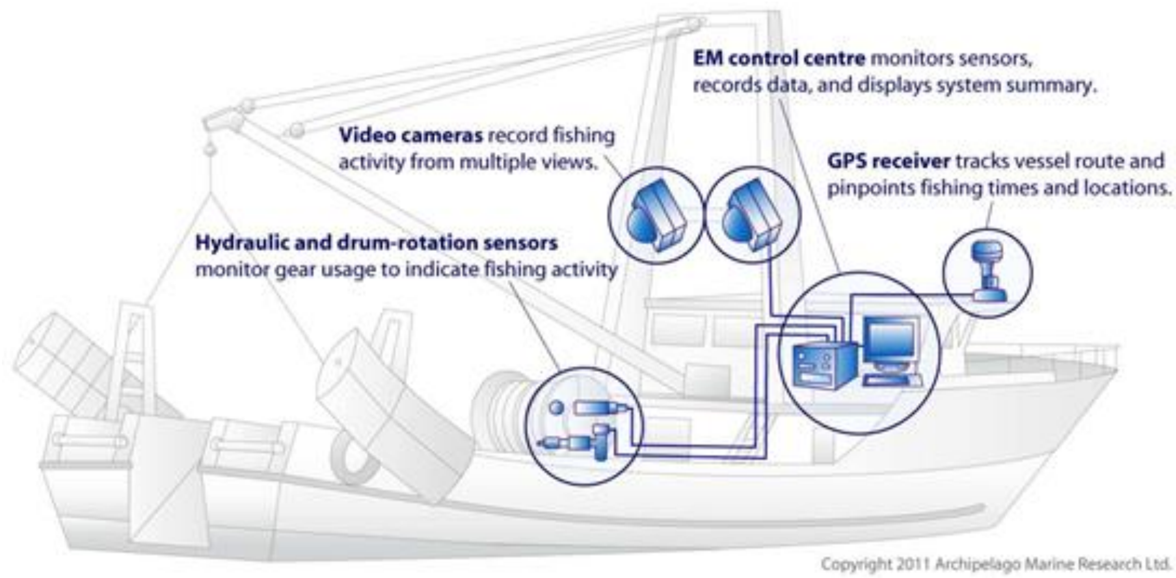

Figure 2: Electronic Monitoring System (Courtesy of Archipelago Marine Research Ltd)

Training & verification by an at sea observer

To optimise best practice of using the REM equipment aboard the vessel to maximise successful validation of the fishermen's self-reported data, an at-sea observer went aboard on 2 occasions. The first trip was on 18th – 22nd December 2016 to check the performance of the REM system and familiarise the crew with both the REM system and to provide training in self-sampling and documenting the catch. After reviewing the REM footage from this and subsequent trips, a follow-up trip (4th – 6th February 2017) was undertaken, with a focus on self-sampling training of the discarded skate and ray catch, and adjusting some catch handling and equipment on board to better allow sex determination and length approximation of the retained and sub-sampled catches of skate and ray by the video analyst.

Self-sampling process aboard

The lessons were learnt from a previous self-sampling programme using similar vessels in the Bristol Channel for the Shark By-Watch UK 2 project (Hunter *et al*., 2016), where what was expected of the crew was too burdensome in terms of time and resource, and not sustainable in the long-term without a significant financial incentive. Instead, a self-sampling process was developed which was easily incorporated into the skippers and crews daily fishing routine, making it viable and sustainable in the long-term. This was achieved by recording only the 'must have' data to meet the projects aims (e.g. species by number, by length and sex), stripping out the 'nice to have' data (e.g. maturity, vitality etc.), thereby reducing the burden of the crew aboard the FV Our Dylan Ben.

Figure 3: Camera views, numbered by camera.

Retained catch

For all hauls, all retained skate and ray were selected out from the total catch and collected in 5-stone baskets (nominal weight when full = 35 kg) on deck within camera(s) view. A sub-sample of the skate and ray catch was then selected at random for species, length and sex sampling. Guidelines on the sample size were provided to the skipper and crew, as in table 1.

The level of sub-sampling ensured that a minimum of 20% of the catch was sampled on a haul by haul basis. The crew were generally sampling more than these minimum sub-sample sizes. An area on the fish room hatch was designated as the sampling area (an area normally used for catch processing), which was covered by the highest resolution (Figure 3, camera 3) camera. Each skate and ray in the sample was measured (total length) to the nearest centimetre, dorsal side uppermost (to facilitate positive ID), then flipped over (still on measuring board) and held still for a second or so to allow both crew and video analyst to view the presence or absence of claspers to determine the sex of the individual. To avoid time delays on deck, one crewman conducted the sampling and called out the species ID, length and sex, which were recorded by the skipper.

Total retained catch (baskets)	Minimum sub-sample size
1-5	1
6-10	2
11-15	3
16-20	4

Table 1: Sub-sampling guidelines provided to the crew of the FV Our Dylan Ben.

Upon completion of catch processing and stowage, the skipper documented total catch weights (wing weight) for all skate and ray species and other elasmobranchs caught (excluding lesser spotted dogfish), along with estimates of skate and ray discards (live weight) by species. These were recorded directly in the REM computer log. A typical example of a REM computer log entry is shown below, with field descriptors shown in blue and the species code used.

201220161. (haul identifier)

SDR (3 letter species code) R (R for retained, D for discarded)15 (kilograms of wing retained), BLR R 25, THR R 40, PTR R 25.

BLR D 5, THR D 12, SDR D 1.

Other retained elasmobranch catch was recorded in the REM log on occasions where more than 50 kg was encountered on a single haul, or cumulatively for a day's fishing, at the end of that fishing day.

Discarded catch

As the catch was sorted from the pounds at the aft of the vessel (views from cameras 1 & 2), all skate and ray discards were stored in 5-stone baskets within view of the REM cameras. This allowed the skipper and video analyst to make an informed estimation of the total weight of skate and ray discards on a haul by haul basis. As soon as this estimation was made, the discards were returned to the sea immediately. Whilst sorting the catch, the crew provided the skipper with a catch composition of the skate and ray discards by species on each haul to allow the weight of the discarded skates and rays to be estimated by species, and subsequently recorded on the REM computer log.

REM verification and validation process

Cefas carried out all the video processing and analysis. The video analyst viewed 50% (every other) of the hauls from 100% of the trips, noting the total number of baskets of retained skate and ray, the number of baskets sampled by the crew and total number of baskets of discarded skate and ray. The analyst recorded the species ID and sex of each skate and ray sampled from the video footage (Figure 4), and the maturity of males where possible, when the maturity was obvious e.g. immature with very small claspers, not extended beyond the edge of the posterior margin of the pelvic fins, or mature, with large rigid claspers. Where the video analyst was unable to identify to species, they were recorded as 'unidentified ray'. From the self-sampling data, the number at length of each of the main species caught (thornback, blonde, spotted and small-eyed ray) were raised to haul level using a raising factor determined from the total number of baskets caught and the number of baskets sampled by the crew. A note was made of the time taken by the crew to self-sample each haul, and for the video analyst to review and validate each haul. The video analyst estimated the weight of discarded skates and rays by multiplying the total number of baskets of discarded skates and rays by a nominal full basket weight of 35kg. Additionally, when individuals were presented to the camera before being discarded, the weight was estimated. The total weight was raised to haul level using the sub-sampled raising factors. After all the video analysis was complete, a comparison was then made with the fisher self-sampling records to determine the concurrence of the species identification, number, sex and weight and an estimate of the skate and ray discard.

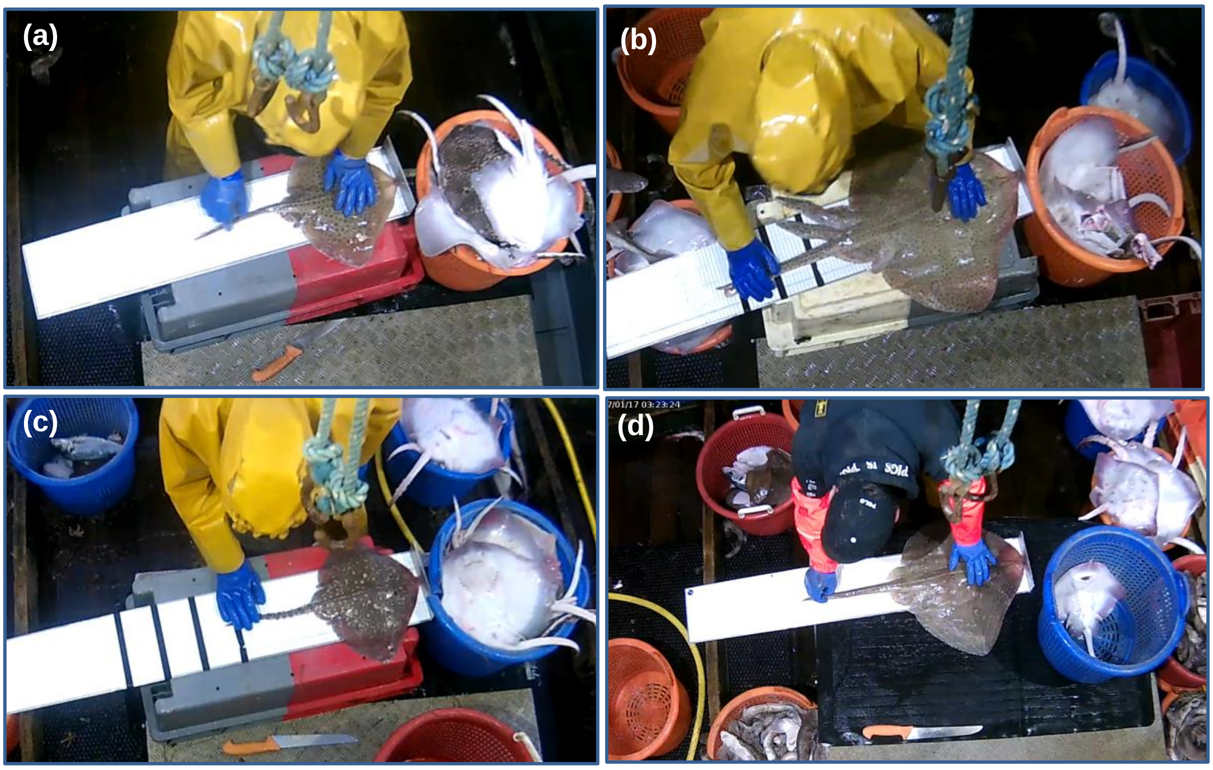

Figure 4: Example image of (a) spotted ray, (b) blonde ray, (c) thornback ray, and (d) small-eyed ray.

Results

Vessel track

The vessel track taken from the REM systems inbuilt GPS for the period of the project is shown below in figure 5. The black lines represent the vessel travelling to and from the fishing grounds. The blue lines denote fishing activity as recorded by the gear sensor data. Figure 5 shows the vessel was fishing in 3 main areas: one to the east in the Bristol Channel in ICES Division VIIf, one to the south-west in the Bristol Channel, again in ICES Division VIIf, and finally the third area to the north-west in the Bristol Channel, across ICES Divisions VIIf-g. Although termed here as the Bristol Channel, the latter two fishing grounds are predominately outside of the Bristol Channel IHO boundary line between the Bristol Channel and the Celtic Sea, from Hartland Point to St Govan's Head.

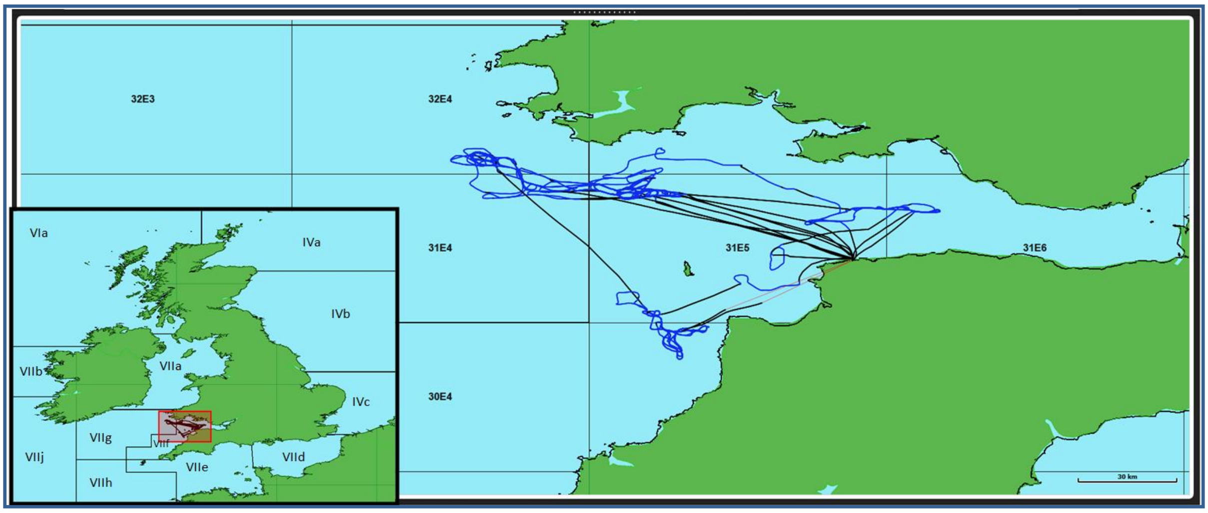

Figure 5: REM location of the fishing operations, December 2016 – February 2017.

Validation of the vessel's self-sampling

The video analyst and crews counts and weights were compared (Table 2, Table 3 and Figure 6) for 50% of the hauls (39 in total) for the 7 commercial fishing trips between 29th December 2016 and 18th February 2017. For the hauls analysed, the video analyst recorded that the vessel caught and retained 321.3 baskets of skates and rays, equating to 11.25 tonnes in weight. Overall, the level of concurrence of the video analyst with the crew's self-sampling records was high. The difference between the video analyst and crew's self-sampling records for the bulk retained catch (Table 2) varied between 0% - 25%, with a mean difference of <1% across all 39 validated hauls.

		Total Number of Baskets Caught		% Difference	Baskets Sampled		% Difference
Trip	**Haul**	Crew	Analyst		Crew	Analyst	
1	**1**	7.25	7.33	**1.1%**	2.25	2.33	**3.6%**
	2	11	10	**-9.1%**	3	3	**0.0%**
	3	6.25	6.25	**0.0%**	2	2	**0.0%**
	5	9	9	**0.0%**	3	3	**0.0%**
	7	12	12	**0.0%**	4	3	**-25.0%**
2	**1**	3.25	3.5	**7.7%**	2	2	**0.0%**
	3	12	11.5	**-4.2%**	3.5	3.5	**0.0%**
	5	10	10	**0.0%**	3	3	**0.0%**
	7	9	8.5	**-5.6%**	3	3	**0.0%**
	9	10	10	**0.0%**	4	4	**0.0%**
	11	10	10.5	**5.0%**	4	4	**0.0%**
	13	10	10.5	**5.0%**	4	4	**0.0%**
3	**2**	7	7.25	**3.6%**	3	3	**0.0%**
	4	5	5	**0.0%**	2	2	**0.0%**
	6	6	6.25	**4.2%**	2	2	**0.0%**
4	**1**	7	7.25	**3.6%**	3	3	**0.0%**
	3	9	9	**0.0%**	3	3	**0.0%**
	5	15	15	**0.0%**	4	4	**0.0%**
	7	15	16	**6.7%**	4	4	**0.0%**
	9	10.5	11	**4.8%**	3.5	4	**14.3%**
	11	7	7	**0.0%**	3	3	**0.0%**
	13	3	3.5	**16.7%**	1.5	1.5	**0.0%**
	15	11	11	**0.0%**	3.5	3.5	**0.0%**
	17	10.25	11	**7.3%**	3	3.5	**16.7%**
5	**1**	2	2.5	**25.0%**	1	1	**0.0%**
	3	4.5	4.5	**0.0%**	2.75	3	**9.1%**
	5	4	4	**0.0%**	2	2	**0.0%**
6	**1**	4	4	**0.0%**	2	2	**0.0%**
	3	3.75	4	**6.7%**	2	2	**0.0%**
	5	3	3	**0.0%**	1	1	**0.0%**
	7	9	9	**0.0%**	3	3	**0.0%**
	9	7	7	**0.0%**	2	2	**0.0%**
7	**1**	9.75	9.5	**-2.6%**	4	4	**0.0%**
	2	13	12.5	**-3.8%**	4	4	**0.0%**
	4	9	9	**0.0%**	3	3	**0.0%**
	6	9	9	**0.0%**	3	3	**0.0%**
	8	7.5	8	**6.7%**	2.5	2.75	**10.0%**
	10	8	7	**-12.5%**	3	3	**0.0%**
	12	9.5	10	**5.3%**	3.5	3.75	**7.1%**
Grand Total		318.5	321.3	**0.9%**	112.0	112.8	**0.7%**

Table 2: Summary of the recorded catch, showing a direct comparison between the crew and video analyst.

	Species	Blonde Ray		Cuckoo Ray		Small-eyed Ray		Spotted Ray		Thornback Ray		Missed Spp		Unidentified Ray	
Trip	**Haul**	Analyst	Crew	Analyst	Crew	Analyst	Crew	Analyst	Crew	Analyst	Crew	Analyst	Crew	Analyst	Crew
	1	10	11	1	1	5	5	1	1	15	15			1	
	2	8	8			3	4			21	21			1	
1	**3**	11	13					2	2	10	10			2	
	5	14	13					1	1	16	17				
	7	17	17			5	5	1	1	29	29				
	1	11	11			2	2			9	9				
	3	9	8	1	1	2	2	4	5	30	30				
	5	21	20			4	4	4	5	5	5				
2	**7**	24	22			3	3	1	3	3	3				
	9	38	39			3	2	1	1	3	3				
	11	34	35			1	1	2	2					1	
	13	47	47												
	2	31	31					7	7						
3	**4**	18	16					3	4	2	3				
	6	18	17					1	2	1	1				
	1	13	13							31	31				
	3	6	6	1	1	1	1	5	5	25	25				
	5	5	5			3	2	1	1	46	47				
	7	7	6					2	2	39	40				
4	**9**	22	22							24	24				
	11	6	6			3	3	3	2	30	31				
	13	4	4			1	1	3	3	13	13				
	15	11	11	2	2	2	2	28	28	13	13				
	17	15	14			12	12	24	25	22	22				
	1	4	4					7	7	5	5				
5	**3**	1	1					1	1	37	37				
	5					1	1			28	28				
	1	5	5			29	30					1			
	3					9	9	7	7	12	12				
6	**5**	3	3			4	4	1	1						
	7	14	14			4	3	12	13	19	19				
	9	4	4			6	6	13	12	12	13				
	1	5	5							54	55			1	
	2	3	3							56	56				
	4	4	4							37	37				
7	**6**	3	3			1	1	2	2	34	34				
	8	2	2					1	1	32	32				
	10	11	11			3	3	6	6	28	28				
	12	3	3					6	6	44	44				
Grand Total		462	457	5	5	107	106	150	156	785	792	1	0	6	0

Table 3: A comparison of the numbers of individuals by species, made by the crew and video analyst.

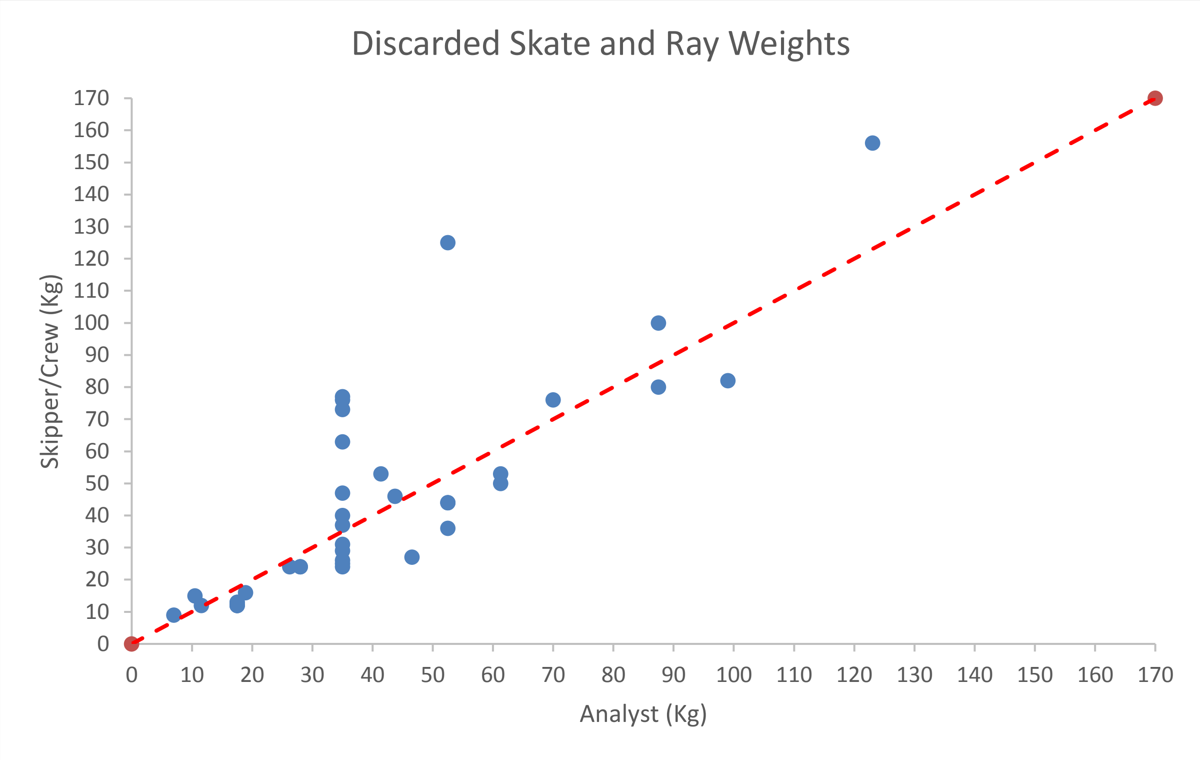

Figure 6: Verification of the crews self-sampling records of estimated total weight of discarded skate and rays.

Across all trips, the crew subsampled and measured 1,516 individuals of thornback, blonde, spotted, small-eyed and cuckoo ray to species and sex, and measured the total length. The video analyst recorded, 1,516 individuals, an agreement of 100%, with 99.5% agreement between video analyst and crew on species ID (Table 3). Additionally, there was 83.4% agreement on gender. Figure 6 shows the correlation between the crews estimate and that of the analyst for the total weight of the discarded skates and rays. The disparity between the crew's estimated discard weights and the analyst's estimated discard weights could be attributed to the crews' deviation from the self-sampling protocol. With the intention of being helpful, large numbers of small-eyed ray above minimum landing size were retained and measured before being discarded, rather than separated from the retained catch and presented to the camera, as for all other species. Weights for small-eyed ray were estimated for the individuals presented to the camera and viewed by the analyst, rather than an estimated basket weight, then raised to haul level.

The time taken for the vessels crew to conduct the self-sampling of the retained skate and ray catch was between 2 and 12 minutes per haul, excluding the time taken for the crew to sort and estimate the weight of the discarded skates and rays. The video analyst took between 10 - 50 minutes (mean: 25.1 minutes) per haul, to review and validate the crews self-sampling records, excluding the time taken to process the hard drive and image's ready for analysis.

The total time taken by the video analyst to validate the catch in 50% (39) of the hauls for the 7 fishing trips was 15 hours and 55 minutes.

Biological and spatial data collected by self-sampling and REM

The crew successfully self-sampled the skate and ray catch, recording the total length of the blonde, spotted and thornback ray retained catch and total length of both the retained and discarded catch for small-eyed ray. Although the system can be set-up to allow length data to be collected by the analyst, in this instance the REM footage was not used to verify the total length. The crews self-sampling data was raised to trip level to provide a length frequency distribution for the total retained catch for blonde, spotted and thornback ray, and total catch for small-eyed ray (Figure 7), where for example, blonde ray have a bimodal distribution, with 2 age cohorts. Not reported here in this proof of concept study, but these data can provide an understanding of the proportion of the entire catch (retained and discard) that is mature, data needed for stock assessment.

Figure 8 shows the spatial distribution, abundance and segregation of the skate and ray catch component for the 7 fishing trips between December 2016 – February 2017 for the area fished, illustrating defined clustering or aggregations for all species except for cuckoo ray (numbers too low).

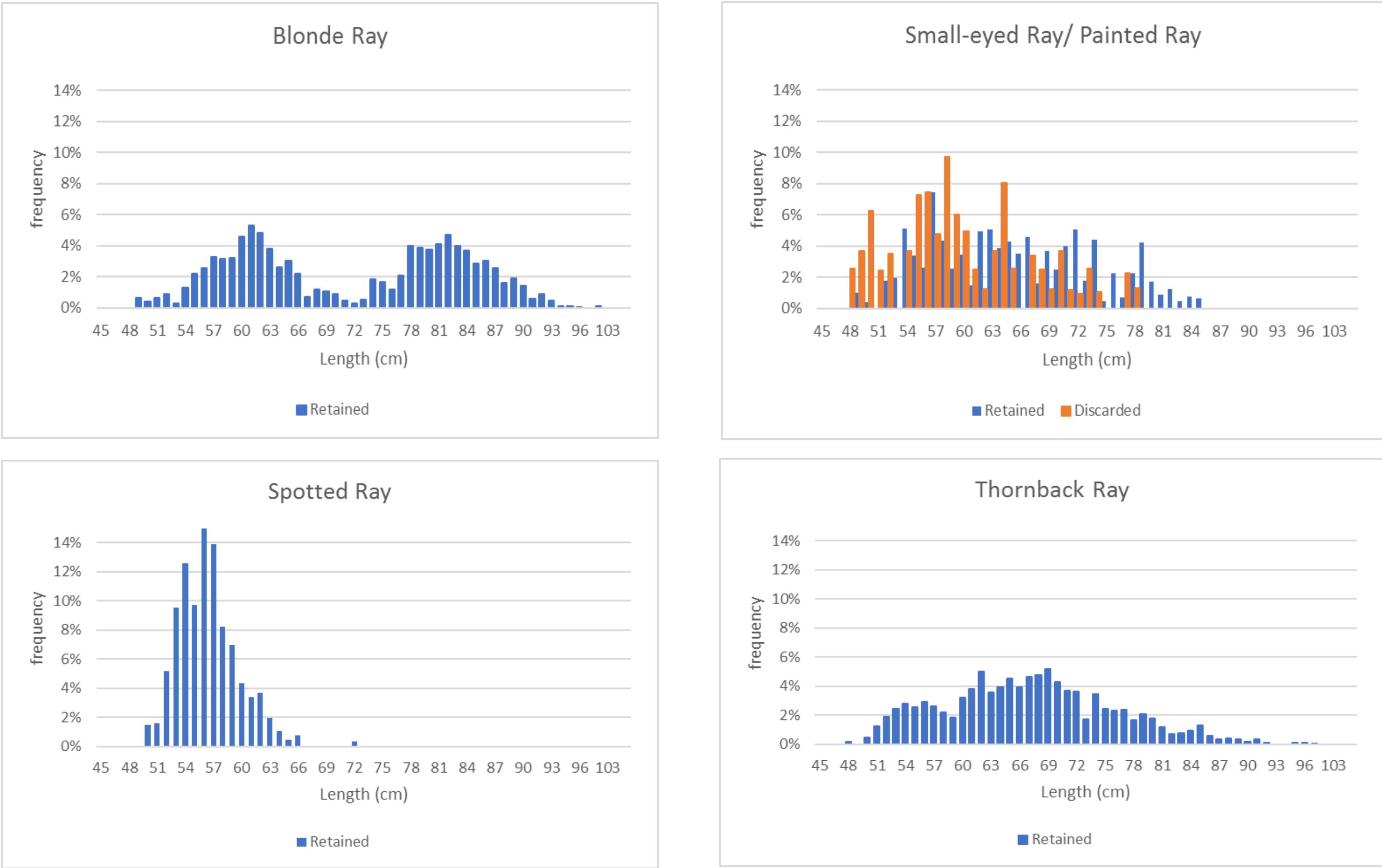

Figure 7: Length frequency distribution of the most common species of skate and ray (Cuckoo ray excluded) above the minimum marketable size, sampled by the crew.

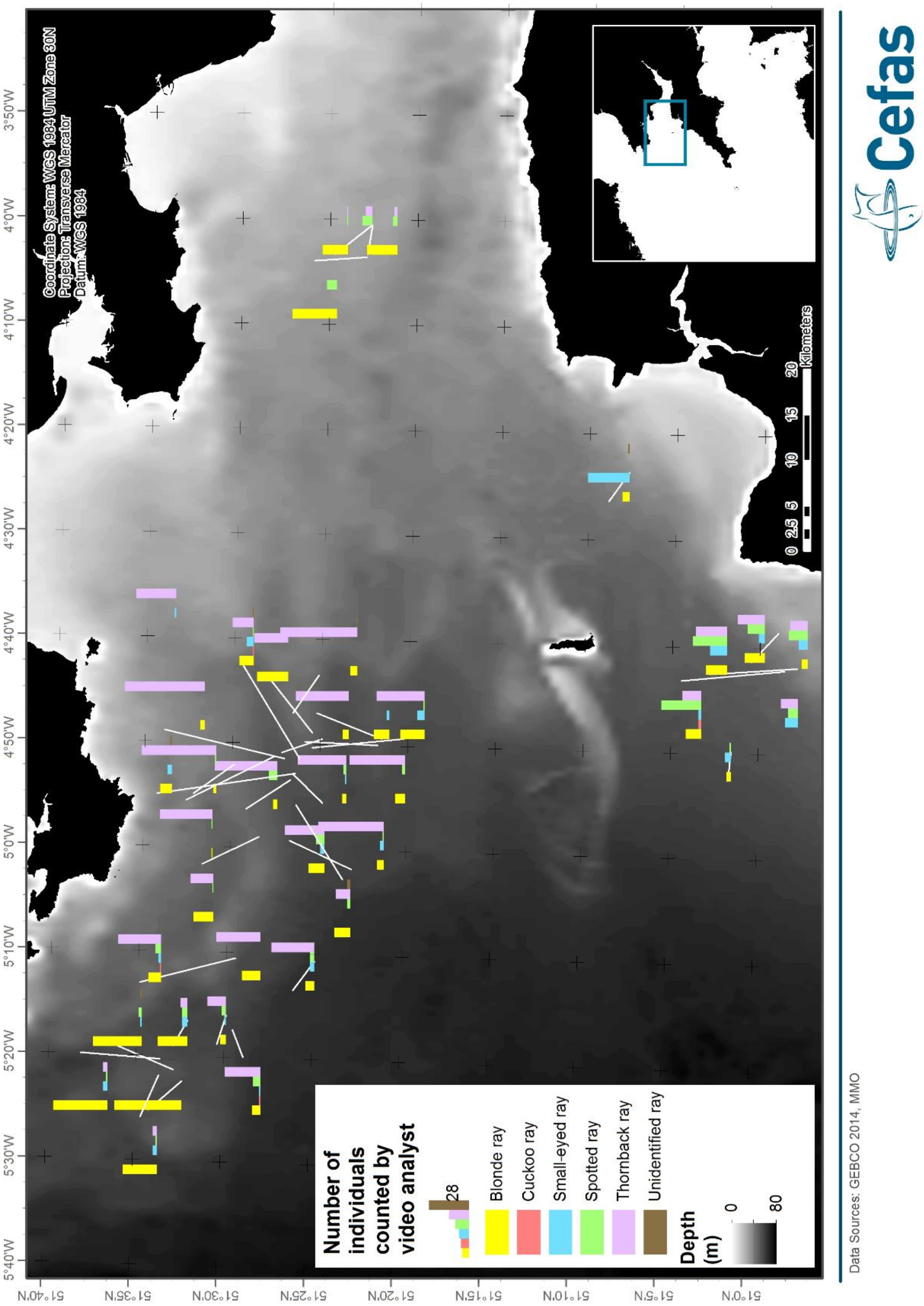

Figure 8: Fishing area showing the catch composition of skates and rays, for all hauls analysed.

Discussion

The installation of the REM system was specifically tailored for this project to validate the crew's self-sampling records. Our analyses showed that the REM generated data successfully verified the crews' self-sampling records, with high agreement in the number (100%), weight (99%), species identification (99.5%) and sex (83%) of the retained skate and ray catch. There was a reasonable agreement between the crew and video analyst of the weight of discarded skates and rays, apart from where the crew deviated from the protocol to self-sample small-eyed ray. The motivation for this was that the vessels crew wanted to provide more data on small-eyed ray discards due to the limited TAC. It's likely that this deviation from the sampling protocol could be resolved by providing feedback to them, improving the estimated weight of the discarded skates and rays.

The success of the fishermen's self-sampling accuracy is in the design and execution of the sampling methodology. As reflected in the skippers' comments on the project (Annex 1), the project benefited from having the right level of data collection activities to be completed alongside normal fishing practice. Too much additional work for the vessels' crew would mean that it was overly burdensome and they may have become disengaged, too little and the utility of the data would be limited. In this case, the crew could effectively adopt the self-sampling into their everyday fishing practices, underpinning the accuracy of what they sampled and recorded.

The crew measured and recorded the total length of those skates and rays they subsampled however, the video analyst was unable to validate the total length due to the REM setup, though an estimate was possible. Black tape was used to distinguish length intervals on the measuring board (Figure 4 b & c) that the crew were using, allowing the analyst to work out the general length range and make a judgement on the reasonable accuracy of the length measures, though not reported here. Although a direct comparison of lengths was not possible, it was considered unnecessary as the technique and process of measuring could be seen and not faulted.

Both the video analyst and crew had difficulty in distinguishing between immature males and females as indicated by the 83% concurrence. Further refresher training on sexing juvenile skate and rays would likely increase the level of agreement between the video analyst and crews' data. The crew were asked to record the condition (lively, poor, dead) of the skate and ray catch. This is not reported in this instance as the condition was not evident on the footage, so could not be verified.

The strength of the approach used in this project was in bringing self-sampling of the skate and ray total catch conducted by fishermen, together with REM technology. Not only did the REM system validate the fishermen's self-sampling records showing them to be accurate, but also captured the sort of data currently deficient from the assessment of these stocks. For example, as detailed earlier for blonde ray, ICES advice states fishery-independent, scientific research vessel surveys *"…have limited coverage in areas of local abundance and larger* *individuals are not sampled effectively…*". In addition, a recent FSP project, 'Fisheries science strategy for industry generated data' (*In press*) recommends an action plan for industry generated data of blonde ray in the Bristol Channel. The REM spatial and temporal logging of the fishing activity, together with crews self-sampling records allowed us to map, at high resolution the spatial distribution, abundance and segregation of blonde ray in the fishing area (Figure 8), including large individuals as illustrated in the length frequency distribution of the retained blonde ray catch (Figure 7).

Skippers estimates of the species composition of the discards could not be validated because of the number of cameras available for the trial. The REM system can accommodate a fourth camera, which would allow an analyst, with additional cooperation from the crew to better capture the species composition of the discards, a crucial component of the catch.

This project demonstrated that good spatial biological information can be collected by fishermen and validated relatively easily using REM. The methods developed in this project should be implemented in a continuous monitoring programme, ultimately expanded across the fleet, for these and further data to have maximum impact on future stock assessments. For this to be possible, investment and resource is required for the purchase and installation of REM systems, analysis of the collected data and finally, to incentivise the fleet to engage in the process.

Conclusion

This project has confidently demonstrated that REM can be used to validate fishermen's self-sampling records in the Bristol Channel skate and ray fishery, providing (i) fishery-dependent information to improve our knowledge and understanding of catches of skate and ray that can supplement traditional fishery-independent data sources for their assessment and management, (ii) information on the current levels of elasmobranch discarding, and (ii) fine scale, high resolution data of skate and ray spatial and temporal distribution and abundance.

Next steps

As REM validated, fishery-dependant self-sampling records offer a novel data source that could complement more traditional sources of fishery-independent data for the assessment and management of skates and rays in the Bristol Channel, a mechanism in which the data can be fed into that process, needs to be identified should the programme continue.

The fishing vessel, Our Dylan Ben, is also participating in the Defra funded, Cefas led, Spurdog By-catch Avoidance Programme (Hetherington *et al*., 2016b) where the skipper reports the spurdog by-catch, in real-time, every 24 hours to Cefas. The REM system aboard could be used the validate the crews' real-time reports of spurdog by-catch (location and amounts retained and discarded). The vessel owner and skipper are willing for the cameras to remain aboard, although an incentive is required, as it was for this project (vessel charter and dispensation to land skates and rays off-quota). The provision of additional quota will be discussed with the MMO for the REM system to remain aboard for the Spurdog By-catch Avoidance Programme.

Acknowledgements

Our sincere thanks go to the skipper, Marcus White, and crew of the FV Our Dylan Ben for their accommodation of the REM system on-board, and their diligence and accuracy in their self-sampling of the skate and ray catch.

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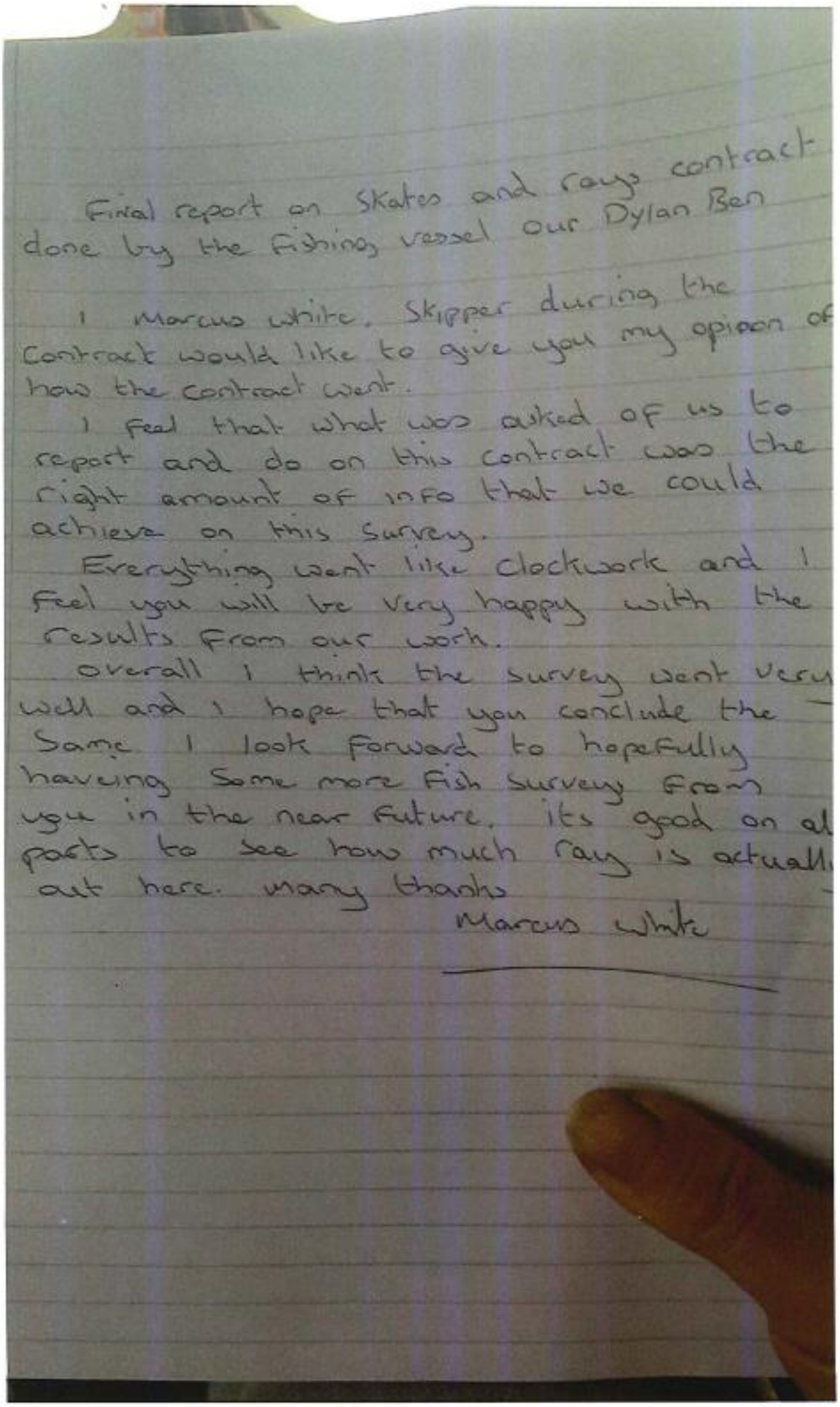
Annex 1: Skipper's feedback on the project



Final report on Skates and rays contract done by the fishing vessel our Dylan Ben

I Marcus white, Skipper during the Contract would like to give you my opinon of how the contract went.

I feel that what was asked of us to report and do on this contract was the right amount of info that we could achieve on this survey.

Everything went like clockwork and I feel you will be very happy with the results from our work.

overall I think the survey went very well and I hope that you conclude the Same I look forward to hopefully having Some more Fish survey from you in the near future. its good on all parts to see how much ray is actually out here. many thanks

Marcus White

Centre for Environment Fisheries & Aquaculture Science

Cefas

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- other scientists from research councils, universities and EU research programmes.
- NGOs interested in marine and freshwater.
- local communities and voluntary groups, active in protecting the coastal, marine and freshwater environments.

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