Shark By-Watch UK 2 – Understanding by-catch of elasmobranchs in UK waters: A nationwide programme, a regional approach.

Final report of the European Fisheries Fund (EFF)
projects FEF1130 and FEF1169

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Executive Summary:

Commercial landings and sales of sharks, skates and rays (elasmobranchs) contribute to the economic well-being of fishing communities around the UK, but many stocks are thought to be overexploited. Therefore strict TAC and quota regulations regulate fishing, and for some elasmobranchs classed as threatened or endangered, landings are prohibited or highly restricted.

Elasmobranch catch continues however, mainly as incidental by-catch. Often physically robust, many elasmobranchs can be returned to the sea alive following capture ('live discarding'). Live discarding has the potential therefore, to mitigate the impact of the unintentional capture of vulnerable stocks. Consequently, the reformed Common Fisheries Policy's (CFP) ban on discarding poses an unintended but significant challenge to those fisheries in which elasmobranchs form a significant proportion of the catch.

Focused around the accidental capture of elasmobranchs as by-catch, Shark By-Watch UK 2 has pursued a collaborative approach between fishermen, scientists and policy makers. The partnership has (i) investigated levels of catch, by-catch and discards of elasmobranchs in several distinct fisheries around the UK; (ii) investigated and tested innovative solutions to reduce elasmobranch by-catch; and (iii) explored alternative fisheries management techniques in support of a sustainable thornback ray fishery in the Thames Estuary.

In the South West, IFCA participation and fisher knowledge have played an important role in defining the habitat utilisation and distribution of thornback ray, blonde ray and small-eyed ray in the Bristol Channel. IFCA-led surveys have helped define elasmobranch habit on the east coast in The Wash and Thames Estuary, where important new information concerning thornback ray egg-case distribution was obtained.

Basking shark tagging in the Irish Sea – Celtic Sea corridor in collaboration with Scottish Natural Heritage, Manx Basking Shark Watch and the Isle of Man Department of Environment, Food and Agriculture, has provided insights into the potential for entanglement and incidental catch of basking shark in static fishing gear in the north west static creel fishery. Future research requirements around the feasibility and effectiveness of gear modifications and a real-time basking shark hot-spot identification and reporting mechanism were identified.

Innovative methods and existing techniques for applied by-catch and discard avoidance using existing technology were reviewed. Focussing on IUCN red-listed elasmobranchs of Cornwall, UK, a national by-catch avoidance workshop hosted by ZSL identified priorities for future by-catch avoidance research and field trials. A tool allowing fishing vessels to report spurdog by-catch in (near) real time, was successfully trialled under Shark By-Watch in the Celtic Sea.

Building on established working stakeholder relationships established in the original Shark By-Watch project, a case study exploring alternative fisheries management techniques to support a sustainable thornback ray fishery in the Thames Estuary were extended.

Engagement workshops were used to steer fisher-led surveys to better understand the spatial distribution and habitat preference of thornback ray in the Thames Estuary, and to gather supplementary discard survival data. These and existing data were used in a simple model to predict the level of aggregation of thornback ray, which was compared with the fisher-dependent data gathered by the project.

A final workshop attended by Wm. Morrisson Supermarkets plc. concluded that immediate benefits to the Thames Estuary under 10m fleet would be best supported by producing a 'consumer friendly' Thames thornback ray fishery publication. By highlighting fisher engagement with science and commitment to sustainable management, retailers committed to sourcing sustainable seafood could be targeted.

Ideally, a future supporting, Thames fisher-led initiative to collect fishery dependant thornback ray catch data at low cost, and reporting in real-time, would then gage the suitability of real-time reporting and spatial/temporal avoidance. If workable, fishers would generate the evidence-base required for future fishery assessments. Efficiency would be gained by eliminating lost-time through discarding by aggregation avoidance and by more effectively filling quotas.

An important pillar throughout Shark By-Watch was communication. Meetings, workshops and events have been backed with social media and web-presence to disseminate project information and to give project partners wider reach. The positive steps taken by engaged fishers to assess and improve their fisheries has received recognition and media attention.

Overall, the results of Shark By-Watch UK 2 have demonstrated that a collaborative approach between fishermen, scientists and policy makers can help to communicate mutually important issues, break down barriers and lead to changes in behaviour that help to solve fisheries and biodiversity problems.

In addition to the continued support of the inshore fishing industry, MMO, IFCAs, the Shark Trust and the UK Shark Tagging programme, Defra have fully supported this project.

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1. INTRODUCTION

In contrast to many other commercially exploited fish species like cod, haddock and plaice, relatively little is known about the status of elasmobranch populations within UK waters. Consequently, it is difficult to determine the appropriate level of sustainable exploitation for many elasmobranch stocks. This lack of data can trigger the use of precautionary management measures. These precautionary measures can be viewed by some sectors of the fishing industry as overly punitive and ineffective.

Addressing knowledge gaps for these species through appropriate data collection can guide better-informed management decisions, with greater buy-in from industry. A requirement exists, therefore, to gain a better understanding of elasmobranch populations in UK waters to inform both stock assessments and the development of Regional or Local Management Plans to manage and conserve regional stocks, ensuring the sustainability of elasmobranch fisheries for the benefit of local fishing communities.

The reformed CFP contains a range of new measures, including the implementation of a landing obligation (discard ban). In recognition of the significant change that the landing obligation represents, it is being introduced gradually from 2015 to 2019. By 2019, fishers will have to land all their catch of Total Allowance Catch (TAC) species; prohibited species are not subject to the landing obligation and must continue to be discarded.

In accordance with the timeline for the phasing in of the landing obligation, the inclusion of elasmobranch by-catch within targeted fisheries is not likely to be subject to the regulation until 2019. However, it is possible that targeted elasmobranch fisheries - such as skates and rays - may be included earlier.

Although the discarding of unwanted fish is largely seen as a wasteful and destructive process, a large number of elasmobranchs are thought to be returned back to sea alive (although the long-term survival of these fish has yet to be fully researched). This means that retaining by-caught elasmobranchs on board as part of the landing obligation may have additional negative impacts on shark, skate and ray populations in comparison to the current practice of discarding.

In addition, elasmobranchs with a minimal or zero TAC have the potential to become ‘choke’ species in mixed fisheries. The presence of ‘choke’ species in the catch could force fishermen to cease fishing with certain gears, at certain times and in certain areas, and may force them to stop fishing altogether.

As well as being incompatible with the latest reform of the CFP, the current level of elasmobranch discards reported by the fishing industry is incompatible with the UK’s broader objectives of minimising wasteful discards in the marine environment. Given that many bycaught elasmobranchs may still be alive when discarded, it is important that there is an improved understanding of discard survival to inform any exception to a land-all catch policy in a reformed CFP.

Shark By-Watch UK is a fisher-led initiative that aims to improve the long-term management of a range of elasmobranch populations in UK waters. As a participatory initiative, that survey design, implementation and analysis is a collaborative effort between scientists and other stakeholders – in this case, fishers. By training fishers in data collection and using their knowledge, gathered over generations, Shark By-Watch UK 2 aims to improve understanding of elasmobranch distribution, life history, by-catch and discard survival in UK waters.

Shark By-Watch UK 2 is the current, second phase of the project, which builds upon the success of Shark By-Watch UK's original programme, in which fishers gathered biological data on over 8,000 elasmobranchs. The project will improve scientific knowledge and understanding of shark, skate and ray discards to underpin evidence-based policy decisions for their sustainable management.

Alongside fishers, the project involves a range of stakeholders from fisheries associations to scientists, NGO representatives, government bodies and policy makers. By encompassing a broad spectrum of stakeholders, the project ensures that outputs have the maximum impact, generating high levels of 'buy-in' from all involved.

Many elasmobranch species occur in UK waters. Shark By-Watch UK 2 has focussed on a selection of important species in inshore waters and further afield, including (but not limited to) thornback ray, spurdog, common skate and porbeagle.

Shark By-Watch UK 2 was undertaken over a two-year period with the following aims:

(a) To develop and promote strong partnerships between fishermen, scientists, fishery managers, food retailers and NGOs, forming a nationwide consortium to promote greater awareness and knowledge of regional elasmobranch stocks and conservation issues;

(b) To provide information on the current levels of elasmobranch discarding in a number of fisheries around the UK;

(c) To develop best practice on elasmobranch handling and provide evidence of the potential value of live discarding of elasmobranchs in mixed and targeted fisheries;

(d) To map the distribution of commercially important species and identify the characteristics of their essential habitats;

(e) To trial new technologies to reduce unwanted by-catch of threatened and endangered species in mixed fisheries;

(f) To bring stakeholders together to evaluate ICES and EU advice on the management of elasmobranchs in the Thames Estuary, and develop a proposal for a viable regional management plan.

Delivery of the project was achieved through three independent but interlinked Work Packages:

A) Understanding levels of catch, by-catch and discards of elasmobranchs in several distinct fisheries around the UK.

The objective of Work Package A was to develop a better understanding of all aspects of elasmobranch discarding. It was delivered through:

(i) Regional participatory workshops involving all stakeholder groups that have shared and developed knowledge on discarding practices;

(ii) Collation and dissemination of integrated knowledge of regional elasmobranch stocks to promote greater awareness throughout the UK.

(iii) Fishery dependent surveys to collect real-time data on commercial survival rates and levels of elasmobranch by-catch and collection of habitat mapping data of regional coastal areas holding high abundance of shark, skates or rays.

(iv) Reducing the risk of basking shark entanglement

(v) Broad-scale communication and data sharing of the latest data and information on live discarding, tag releases and recaptures through the dedicated Shark By-Watch UK interactive website tools, social forums and media coverage, popular industry and regional press and via relevant ICES Working Groups and fishery managers.

B) Innovative solutions for reducing by-catch and dead discards of threatened sharks, skates and rays.

Work Package B aimed to explore techniques of reducing unintentional by-catch of threatened elasmobranchs in commercial fisheries, in particular for basking shark, porbeagle, spurdog and common skate. Solutions already successfully employed include gear modifications, and novel technologies (e.g. Electro Positive Metals and alarms). Real-time reporting and spatial management can also allow capture evasion by fishers and therefore improve survival. Work package B was delivered through:

(i) Scoping out innovative technology: A scoping review has drawn on international experience and expertise relating to EPMs, alarm systems and other methodologies.

(ii) Technical development workshop: Through presentations, debate, and plenary discussion, the technical workshop unlocked the issue and drivers surrounding by-catch and discards of threatened elasmobranchs from the perspective of fishery, policy, NGO and food retailers' representatives.

(iii) Field trial: Real Time Spurdog By-catch Reporting Tool

C) Scoping alternative fisheries management techniques in support of a sustainable thornback ray fishery in the Thames Estuary, free of regulatory discards, in-line with the aims of CFP reform.

The objective of Work Package C was to work with the Thames Estuary fishermen, the Kent & Essex IFCA, Wm Morrison Supermarkets plc, Defra and the MMO, to develop a regional management plan for a sustainable and discard-minimal fishery for thornback ray in the Thames Estuary. This Work Package built upon the success of the previous Shark By-Watch UK programme. An important aspect of achieving this goal was the development of a sustainable supply chain. The work was supported by Wm Morrison Supermarkets plc (Morrisons) to investigate the use of its supply chain in increasing the sustainability and long-term future of this fishery. Developed in collaboration with Defra to assure governmental buy-in, the intention was that the management plan would ultimately be presented to the ICES WG on elasmobranch fish (WGEF) for evaluation. The work was delivered through:

(i) Stakeholder partnerships: This Work Package built on the successes of the previous EFF funded work in the Thames Estuary, Shark By-Watch UK. We aimed to facilitate the development of practical regional management plans intended to protect thornback ray in the Thames Estuary and to allow them to be fished sustainably, maintaining valuable income within the small-scale coastal fisheries.

(ii) Fishery-dependant surveys: Fishermen lead self-sampling surveys, guided by Cefas scientists, undertaken to establish the current spatial abundance of thornback ray, collecting valuable field data on the health of stock.

(iii) Habitat mapping: Habitat mapping surveys were undertaken by the Kent and Essex IFCA, working alongside fishermen to map the habitat of areas holding high abundances of thornback rays, to inform on key areas of biological and management importance.

(iv) Sustainable supply chain: Through workshops, presentations to fishermen and demonstration of the use of its supply chain, Morrisons have demonstrated their role in the sustainability and long-term future of the Thames Estuary thornback ray fishery.

(v) Scoping the potential for the implementation of ICES advice: Working with our project partners, investigated the potential for implementing regional ICES advice for skates and rays in the North Sea.

(vi) Dissemination of final results to promote local, fishery-specific management measures

Outcomes:
The outcomes of the project will help to support UK and EU policy on sustainable management of elasmobranch fisheries, including reducing discards and unintended fishing mortality for CFP reform. In turn, the increased understanding of elasmobranch biology and distribution will provide evidence to national and international advisors to help design appropriate management objectives.

How to use this report:
We have used the common names of sharks and rays throughout. A glossary of common and scientific names of the sharks, skates and rays named in the Shark By-Watch UK 2 final report is presented below (Table 1).

Common name	Scientific name
Basking Shark	*Cetorhinus maximus*
Blonde Ray	*Raja brachyura*
Blue Shark	*Prionace glauca*
Common skate	*Dipturus batis* -complex
Cuckoo ray	*Leucoraja naevus*
Porbeagle shark	*Lamna nasus*
Small-eyed ray	*Raja microocellata*
Spotted ray	*Raja montagui*
Spurdog	*Squalus acanthias*
Starry smooth hound	*Mustelus asterias*
Thornback ray	*Raja clavata*
Tope	*Galeorhinus galeus*

Table 1. *Glossary of common names and scientific names of all shark, skate and ray species cited in the Shark By-Watch UK 2 final report.*

For brevity, the detailed technical components of the individual work-packages have been included as annexes to the main report. The full list of annexes associated with the final report is presented in table 2 below, for rapid reference.

Where material is already available online, links have been included to accompany the relevant text. A glossary of frequently used terms used in this report is presented below in table 3.

Following the general introduction to the project in Section 1, Section 2 provides an account of the project partners, identifying their roles and interests in the project, and a description of regional fisheries currently experiencing shark and ray by-catch issues. Section 3 describes the work carried out under the three Shark By-Watch 2 work packages:

- Understanding discard survival of commercially important elasmobranchs of conservation interest for input to Common Fisheries Policy (CFP) reform (FEF1130).
- Innovative methods for reducing by-catch and dead discarding of IUCN Red-Listed elasmobranchs off Cornwall, UK (FEF1169)

- Scoping alternative fisheries management techniques in support of a sustainable thornback ray fishery in the Thames Estuary, free of regulatory discards, in line with the aims of the CFP reform (FEF1130)

The results of Shark By-Watch are discussed in section 4, including suggested by-catch mitigation actions associated with the priority species, common skate, basking shark, porbeagle and spurdog. Priority areas for future research, as identified from the project work, are presented in section 5, and our overarching conclusions in section 6. The extent to which the project aims have been met are summarised in Section 7.

Scientific literature cited in the text is listed in section 9. Data collection from fisher-led surveys continued up until the close of project, and is not therefore included as part of the final report. These data will be made available, as described in the text, through the Cefas Data Hub (see section A5)

Annex	Title
Annex 1	Shark By-Watch 2 UK communications strategy
Annex 2	Habitat preferences and fisheries interactions of three commercially important ray species in North Devon, UK based on fishermen's knowledge.
Annex 3	Habitat mapping of ray fishery locations in North Devon.
Annex 4	The Wash Skate and Ray Fishery: Habitat mapping report.
Annex 5	Methods to reduce elasmobranch bycatch and increase discard survival in UK waters.
Annex 6	Research priorities: innovative solutions for reducing by-catch and dead-discards of threatened sharks, skates and rays.
Annex 7	Update on the UK pilot project to develop a real-time surdog by-catch avoidance programme to mitigate a choke species and so minimise fishing induced mortality.
Annex 8	Native Oyster Survey August 2014, Blackwater, Crouch, Roach & Colne Marine Conservation Zone.
Annex 9	Simulating the dynamics of thornback ray catch in the Thames Estuary area.
Annex 10	Using the Thames Estuary Thornback Ray Simulation Model.

Table 2. *Glossary of Annexes in support of the Shark By-Watch UK 2 final report.*

By-catch	The portion of a commercial fishing catch that consists of marine animals caught unintentionally.
Choke species	Species for which there is minimal or zero TAC which have the potential to become 'choke' mixed fisheries, whereby it forces fishermen to stop fishing altogether in those areas or tie-up their vessels.
Common Fisheries Policy (CFP)	The fisheries policy of the European Union. It sets TACs (mostly annually)for key species, for EU member states, as well as encouraging the fishing industry by various market interventions.
Discarding	The process by which fishers throw unwanted catch back into the sea.
Elasmobranch	Sharks, skates and rays are known collectively as elasmobranchs. Elasmobranchs are a group of fish characterised by cartilaginous - not bony - skeletons, 5-7 gill openings on each side and several rows of teeth which are continually replaced, amongst other
Landing obligation (discard ban)	New regulation within the reformed CFP where fishers will have to land all their catch of TAC species.
Participatory research	Collaborative research between a range of stakeholders, where different knowledge types are given equal credence within the design, implementation and analysis of the research - insofar as is possible - by all stakeholders.
Prohibited species	Species prohibited for EU and 3rd country fishing vessels to fish for, retain on board, tranship or land.
Shark By-Watch UK	Research initiative established in 2011 and led by the Centre for Environment, Fisheries & Aquaculture Science (Cefas) where fishermen and scientists work together to improve fishing practices and knowledge for sustainable shark, skate and
Stakeholders	An organisation or individual with a particular interest or concern in a given topic. Here used to refer to any individual with a 'stake' in the Shark By-Watch UK project, or related fisheries, markets and supply chains.
Threatened species	The International Union for Conservation of Nature (IUCN) categories of Vulnerable, Endangered or Critically Endangered species.
Total allowable catch (TAC)	Total allowable catches (TACs) are catch limits (usually expressed by weight) that are set for most commercial fish stocks across the EU. TACs are set annually for most

Table 3. *Glossary of frequently used terms.*

2. PARTNERS & FISHERIES

Partners and roles:

The project built upon the success of the southern North Sea pilot study (FEF0605: EFF funded Shark By-Watch UK – Regional by-catch awareness of elasmobranchs in the southern North Sea 2011 - 2013), by developing strong partnerships between fishermen, scientists, fishery managers, food retailers and NGOs throughout the UK.

The multi-stakeholder consortium established by Shark By-Watch UK 2 comprised:

(i) **Centre for Environment, Fisheries & Aquaculture Science** (Cefas, project leader): Cefas has extensive expertise in implementing fisheries engagement and field research contracts (e.g. M5201: Defra funded "Assessing the survivability of bycaught porbeagle & spurdog & furthering our understanding of their movement patterns in UK marine waters"). As project leader, Cefas' team has worked closely with fishermen, collecting field data and overseeing complex issues, with technical expertise in data collection and analysis underpinning the project overall.

(ii) **Department for Environment, Food and Rural Affairs** (Defra): The government department responsible for fisheries policy and regulation, whilst growing the rural economy and improving the environment. Defra have previously commissioned a range of R&D and advisory programmes to enable the UK Government to meet its commitments to the Shark, Skate and Ray Conservation Plan published by Defra in January 2011, reviewed in 2013. Some of these programmes have been included in Shark By-Watch UK 2 (C5576A, C6122C, MB5201C, MB5201D, MF058A).

(iii) **Individual fishermen**: Sharing knowledge and participating at all levels of this project, fishermen were involved in workshops, field surveys and habitat mapping programmes. Shark By-Watch UK scientists work closely with the fishers, training them in research methods and using their fishing gear and vessels as scientific platforms to collect much-needed data. Through their work with the project, fishermen become the custodians of their own data and are able to input suggestions as to how the sustainability of their fisheries might be practically improved.

(iv) **Inshore Fisheries and Conservation Authority** (IFCA) – Isles of Scilly, Devon & Severn, Eastern and Kent & Essex regions: The discrete regional IFCA's aim to ensure healthy seas, sustainable fisheries and a viable fishing industry by securing the right balance between social, environmental and economic benefits in their region. The IFCAs participated in (i) regional action based workshops to share and develop knowledge, and (ii) habitat mapping studies to inform on areas of significance for development of regional/ local management measures.

(v) **Isle of Man Government Department of Environment, Food and Agriculture (DEFA) Fisheries Directorate** & Manx Basking Shark Watch: DEFA is the Isle of Man Government department responsible for the unstainable management of the Isle of Man's marine resources. Manx Basking Shark Watch is a research organisation that until 2015 operated as part of the Manx Wildlife Trust. The Manx Wildlife Trust is the leading nature conservation charity in the Isle of Man, caring for the marine environment, supporting the local fishing industry's efforts to become more sustainable. The Manx Basking Shark Watch research program included tagging and behavioural studies of basking sharks in Manx waters. Tagging results have provided evidence of the movement of basking sharks from Manx waters into areas where they are at risk for accidental capture. T

(vi) **Scottish Natural Heritage** (SNH): Custodian of Scotland's nature and landscapes, including greater understanding and sustainability of marine fisheries. SNH has collaborated on (i) using innovative methods to reduce by-catch and dead discarding of IUCN Red listed elasmobranchs, including basking shark and (ii) investigating discard survival of commercially important elasmobranchs for input to CFP reform.

(vii) **Wm. Morrison Supermarkets plc** (Morrisons): The fourth largest chain of supermarkets in the United Kingdom, with a 12.2% market share and an estimated 150 metric tons of ray wings sold annually across the country. Sustainable fisheries sits at the centre of Morrisons seafood policy and supply chain for the fish it sells. Through workshops, presentations to fishermen and demonstration of the use of its supply chain, Morrisons have a key role in the delivery of more sustainable elasmobranch fisheries. This in terms of the fishing industry remaining profitable in the long term and competitive in both local and global markets, to the benefit of both producers and consumers.

Expectations of the project partners:

The vision of this nationwide consortium approach was to augment the individual, regional programmes of work currently in place across the UK. Priority partner objectives were to manage elasmobranch stocks sustainably, to aid the recovery of depleted stocks and to ensure that species currently not classed as threatened continue to be fished sustainably. The matched funding approach has made it possible to compile critical data on elasmobranch by-catch in fisheries.

Historically important regional coastal fisheries involved:

i. **Southeast UK (Southern North Sea)**: The under 10 metre fleet in the southern North Sea operates in areas that support historically important target and non-target fisheries, such as those for spurdog, thornback ray, blonde ray, tope and starry smooth hound.

ii. **Southwest UK (Celtic Sea)**: Commercial net fisheries off the South West of the UK have historically included important target and non-target fisheries for various elasmobranchs, including spurdog, porbeagle and common skate. However, due to their vulnerability to fishing and slow recovery from population depletion, spurdog, porbeagle and common skate have all been listed as Critically Endangered in the Northeast Atlantic by the International Union for Conservation of Nature (IUCN).

iii. **Western UK & the Isle of Man (Celtic/ Irish Sea)**: Welsh commercial trawl and net fisheries have historically had important target fisheries for various ray species in the Bristol Channel. A target longline fishery for spurdog operated from the Bristol Channel to the Southwest coast of Scotland, centred on Holyhead. Occasional fisheries for porbeagle and blue shark operated in the Bristol Channel, St. George's Channel and Celtic Sea.

    From mid-May to mid-August, Isle of Man waters are important for basking sharks. They are protected under the Isle of Man Wildlife Act (1990), Convention on International Trade in Endangered Species (CITES), the Convention on Migratory Species (CMS) and TAC and Quota regulations, and cannot therefore, be targeted, retained or disturbed in British waters.

    Seasonal movements of basking sharks into the Celtic Sea make this species highly vulnerable to by-catch in fixed gill net fisheries operating off the South West coast.

iv. **Northwest UK (Firth of Clyde and North Atlantic)**: The Scottish waters of the Firth of Clyde and the Western Isles have historically offered rich and diverse mixed fisheries, of which elasmobranchs are a key component. Commercial fisheries for common skate and spurdog are now closed, but target fisheries for blonde, cuckoo, spotted and thornback ray continue, with the Firth of Clyde fisheries being of particular importance.

3. ACHIEVEMENTS & OUTCOMES

Project work and outcomes delivered through our three Work Packages are described below. For brevity and readability of the final report, the work refers, where appropriate, to more detailed individual reports, which are included separately as Annexes (table 2):

A) Understanding levels of catch, by-catch and discards of elasmobranchs in several distinct fisheries around the UK (50% funded from European Fisheries Fund)

Aim: *To address the current UK fisheries management issue of "live" elasmobranch discards contributing to better sustainable management and conservation of resources.*

Discarding of dead fish back to sea is currently seen as a wasteful and destructive process throughout EU fisheries. The reformed CFP contains a range of new measures, including the implementation of a landing obligation (discard ban). In recognition of the significant change that the landing obligation represents, it is being introduced gradually from 2015 to 2019. By 2019, fishers will have to land all their catch of Total Allowance Catch (TAC) species.

Prohibited species are not subject to the landing obligation however, and must continue to be discarded. Paradoxically, retention on-board rather than discarding could result in further depletion of elasmobranch populations, jeopardising future sustainable fisheries. This is because many elasmobranchs can be returned to the sea alive, a common practice known as live discarding.

Data on live discarding and long-term discard survival are not widely available, however. The challenge therefore, is to identify pragmatic solutions to reduce unwanted elasmobranch by-catch in the first instance, and secondly, to reduce fishing-induced mortality for by-caught elasmobranchs thereafter.

Work-package A focussed on accumulating evidence as to whether live discarding is beneficial to the stock as a whole. Working nationwide in partnership with fishermen, regional IFCAs and fisheries scientists, we collected discard survival data on priority shark, skate & ray species, caught using a variety of fishing gears in areas of historically important elasmobranch fisheries.

A1. Regional action based workshops:

Participatory research is integral to all aspects of the Shark By-watch program. To develop knowledge quickly, scientists and inshore fishermen, together with other engaged stakeholders have worked together to improve knowledge of elasmobranch fishing methods, fishing grounds, and the state of the stocks.

An important aspect of Shark By-Watch was to offer fishermen the opportunity to get their voices heard, providing a platform to better understand discarding practices, and incentives to collect scientific evidence that could be used to co-design fisheries management

measures. Following the model established by the original Shark By-Watch programme, three workshops were held to establish the requirements and protocols for the Shark By-Watch 2 UK surveys:

- North Devon, Barnstaple – 6th May.
- Chelmsford Essex, 21st May (see also section C, below)
- Kings Lynn – 22nd May

The crucial elements of Shark By-Watch UK 2 were to understand why shark and ray fisheries are important to fishermen, to fully understand current discarding processes, and to demonstrate to them ways that the health of the stocks can be assessed, and to identify ways to improve fishing practices and sustainability. As well as fostering new and consolidating established relationships, and shaping the required field work programme to be executed under Shark By-Watch 2, the fishermen in our workshops were extensively consulted on their views to help understand the problems and barriers they experience on a day to day basis.

A2. Collation and dissemination of integrated knowledge

Effective communication has been integral to the overall success of Shark By-Watch UK 2, and to the individual objectives encapsulated in the three work packages (below).

The project developed a communications strategy with Mindfully Wired Communications (MWC) to provide a clear plan describing how Shark By-Watch UK 2 (SBW) was to engage with relevant audiences. Principally intended for use by Cefas and MWC, this document details the projects' communication aims, key messages, target audience groups and methods of approach (Annex 1).

The communications strategy was followed throughout the lifespan of the project to ensure that resources were used to their optimum value in communicating with as many different relevant parties as possible, and in the most effective manner.

Key outputs to date include:

Shark By-Watch UK: Research priorities: innovative solutions for reducing by-catch and dead-discards of threatened sharks, skates & rays. (Section B2, Annex 6)

Shark By-Watch UK, Biological Sampling: Inside One of Nature's Giants. (Section A5, Video)

Shark By-Watch UK Website (Section A5)

A3. Fishery-dependent surveys and habitat mapping

Shark By-watch UK 2 was a participatory initiative, with survey design, implementation and analysis driven by collaborating fishermen and scientists. A better understanding of

elasmobranch distribution, life history, by-catch and discards in UK waters has been achieved in targeted fisheries by training fishers in data collection and capturing fisher knowledge, often gathered over generations.

Through stakeholder consultation meetings (section A1), fishing industry priorities were identified around the elasmobranchs and elasmobranch fisheries of greatest concern. Those fisheries identified and targeted by Shark By-Watch UK 2 were:

- The Bristol Channel skate and ray fishery;
- The Wash skate and ray fishery and;
- The Thames Estuary thornback ray fishery.

Cefas scientists worked directly with fishermen who were trained to use their commercial fishing vessels as scientific research platforms. This allowed rapid and effective data collection alongside regular fishing practices. Data collection through fisher-led surveys and supplementary tagging of by-caught fish allowed more effective targeting of spurdog and common skate by-catch in commercial fisheries than would have been possible using established research vessel surveys.

Placing the fishing industry at the centre of data collection, generates both fisher ownership of the information gathered, and as a consequence, buy-in to any outcomes that may be generated as a result. Uptake by the fishing industry of Shark By-Watch UK 2 commissioned work was favourable, with 8 participating vessels in total (four in the Thames Estuary, three in the Wash and one in the Bristol Channel).

Survey work continued until the close of project in December, consequently not all data collected has been returned within the lifetime of the project.

A3.1 Bristol Channel Skate & Ray Fishery habitat mapping

The Bristol Channel is an important area for a number of elasmobranch species and is one of the few targeted skate fisheries in the UK, with landings of ray from this area contributing about 20% by weight of the total skate landed by all English & Welsh fisheries (Catchpole & Enever 2007). The estimated annual value of this fishery is approximately £1 million (Catchpole & Enever 2007). Three species of ray are particularly important to commercial trawlers working out of North Devon ports; thornback ray, blonde ray, and small-eyed ray.

The area also seems to be important for juvenile rays of all three species, being one of only a few locations where juvenile blonde ray have been recorded, albeit infrequently and showing relatively high abundances of young thornback ray and small-eyed ray at least in the northern Bristol Channel (Ellis et al. 2004).

Basic information on stock structure and ecology of rays in the Bristol Channel which could be used to explore alternative, possibly regional management, is also lacking. Fishermen's knowledge on the location of rays within the Inner Bristol Channel were therefore captured, and mapped using GIS. Maps have been constructed and incorporate a qualitative

description of fishermen's knowledge of ray distribution and habitat utilisation in the study area.

Existing mapping data was then collated to compare areas to those fished. To investigate whether ICES BTS locations provide adequate coverage to describe actual patterns of ray abundance in the Bristol Channel, ICES BTS survey stations were then compared with fishermen's knowledge. These data have been used to plan future survey work and direct other aspects of the project. A detailed account of the work undertaken is presented in Annex 2 (Habitat preferences and fisheries interactions), and Annex 3 (Habitat mapping).

Fishermen reported that different ray species aggregate in different areas. They attributed these differences to changes in habitat or sediment type. All fishermen suggested that thornback ray are found on muddier and/or coarser, more broken ground and are not found in sympatry with either of the other two species (Figure 1).

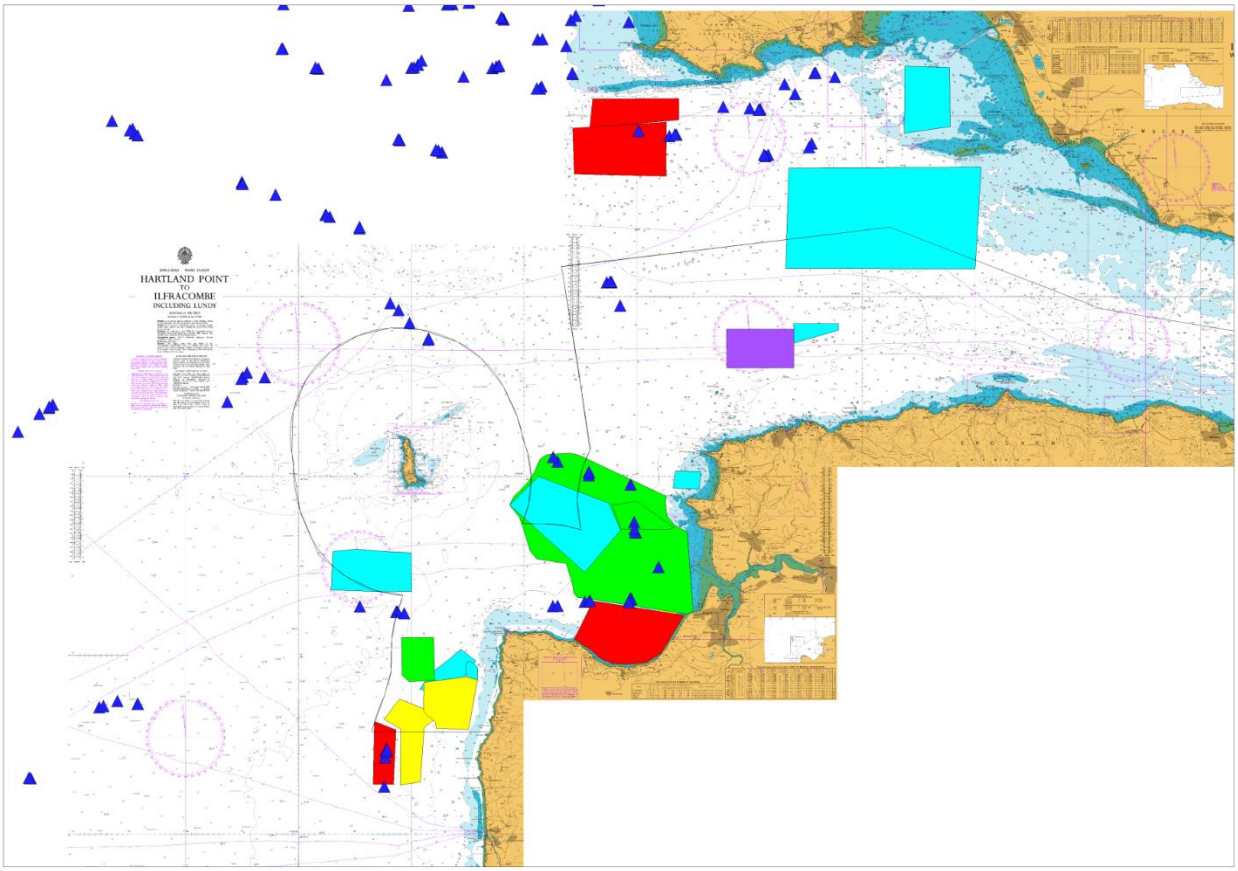

Figure 1. *Ray distribution in the inner Bristol Channel based on all fisher knowledge combined with locations of ICES BTS survey stations (blue triangles) against known ray habitat. Shoot locations only shown in relation to areas important for different species. Red polygons depict areas where thornback ray are found, light blue polygons for blonde ray, yellow areas for small-eyed ray. Green polygons highlight areas where small-eyed ray dominate but blonde ray may also be caught. Purple polygons are areas where blonde and thornback ray may be found.*

This agrees well with findings from the eastern English Channel, where species distribution modelling revealed that adult thornback ray were associated with hard sediments (gravels and pebbles) and coarse grounds with medium to strong tidal currents (Martin et al. 2012).

This study also found a difference between adults and juveniles, with thornback ray juveniles preferring some inshore grounds where seabed sediments were comprised of mud, sand and gravel. The fishermen in this study did not identify any difference between age and sex in the rays that they caught in different areas, but complimentary data collected by fishing vessels during this project may shed some light on this.

The distribution of thornback ray does not appear to correlate to any particular features of the habitat maps available, although the resolution of the mapping data and the degree to which it is modelled and extrapolated means that the existing data is not at an appropriate resolution for further use in this study. However one of the maps does show a patch of mud in the Southern end of Bideford Bay which could indicate a change in ground (Annex 3). Further fine-scale habitat mapping is required to address questions relating to habitat associations of rays in the inner Bristol Channel.

The scale at which habitat changes affect species composition is also of interest. Fishermen reported a change in species within a very small area, e.g. south of Hartland point over a distance of approximately 1km with only blonde ray caught on one side of a 'sand-bank' feature, and thornback ray on the other side. This confirms the need for high resolution habitat mapping to assess whether differences in habitat are causing species to aggregate separately.

Our study underlines the excellent level of knowledge that the fishermen fishing out of North Devon have with regard to the locations where different species can be found. They comprehend the area-specific sediment characteristics and believe the two are related. Initial comparisons of mapped areas of ray distribution from fishermen's knowledge do not currently match closely with existing bottom sediment maps.

As well as helping to assess the extent to which current ICES BTS surveys cover the distribution of adult blonde ray, further work with the fishermen could capture additional data on the distributions of adults and juveniles and incorporate seasonality within the mapping exercises. Collection of CPUE, species composition and morphometric and life-history information from the areas mapped by the fishermen would also greatly expand our knowledge of ray ecology in North Devon. If possible an extension to working with Welsh fishermen would also greatly improve our knowledge of the Bristol Channel as a whole.

A3.2 The Wash Skate and Ray fishery

Habitat mapping within The Wash was undertaken by the Eastern IFCA as part of The Wash Skate and Ray Fishery field study, with the aim of identifying possible areas that may act as suitable habitat. A fuller understanding of habitat distribution, combined with the landings data gathered from fisher-led self-sampling surveys during the original Shark By-Watch UK programme, will provide a more comprehensive evidence base to interpret the spatial abundance and stocks of skate and ray off the Norfolk and Lincolnshire coast and thus better inform management solutions. A detailed account of the habitat mapping work undertaken is presented in Annex 3.

A side scan sonar was used to acquire acoustic imagery (Figure 2), while a camera sled was used with a frame-mounted camera, to acquire underwater videos in order to support the sonar imagery. In addition, a day grab was deployed at each of the sampling stations (Figure 2), and notes were made on the sediment composition and biota.

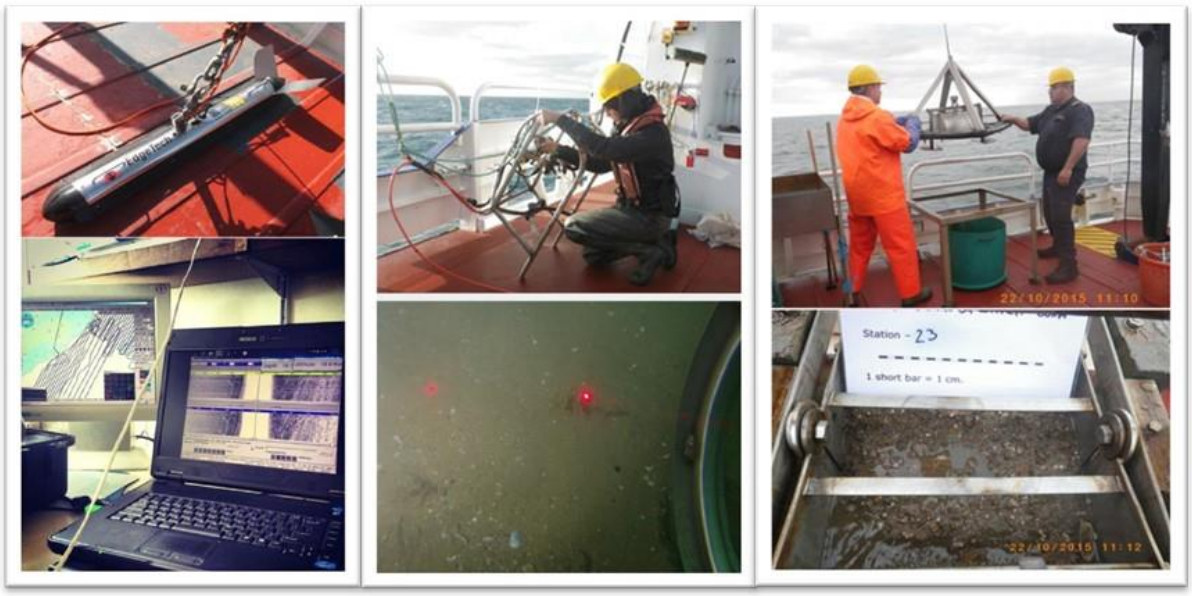

Figure 2. *Methods applied for The Wash skate and ray habitat mapping survey. a) Side scan sonar tow vehicle; b) side scan acquisition software; c) camera sled pre-deployment; d) camera sledge on the sea-bed; e) deployment of the day grab, and; f) day grab containing sediment sample.*

Of seven sea days allocated to the project it was only possible to go to sea on 3 of these due to poor weather. Two of these days however, were successfully spent on side scanning sonar. Seventy linear km of sonar survey lines were covered aboard the R.V. Three Counties covering a total area of 10.2 km^2. The remaining day was used to conduct ground-truthing video surveys and to obtain grab samples. Fifteen grabs were made within Box A and were accompanied by video images taken at the same location. A full account of the methodology and samples obtained can be found in Annex 4.

Side scan sonar data and video footage analysis enabled the identification of sediment distribution differences across the survey area. Acoustically distinct regions are suggested and are shown in the side scan sonar image mosaic in figure 3. We observed a transition from medium/course sediment at the northern end of the survey area to an expanse of sand waves along the western edge and down into the south west corner.

The lower south west portion of the survey box was mobile sand with substantial areas of sand waves and sand ripples (Figure 4). The sand waves extend up the western edge of the box. The central area consists of homogeneous cover of medium to coarse sediment (Figure 4) with patches of mixed and coarse sediment within.

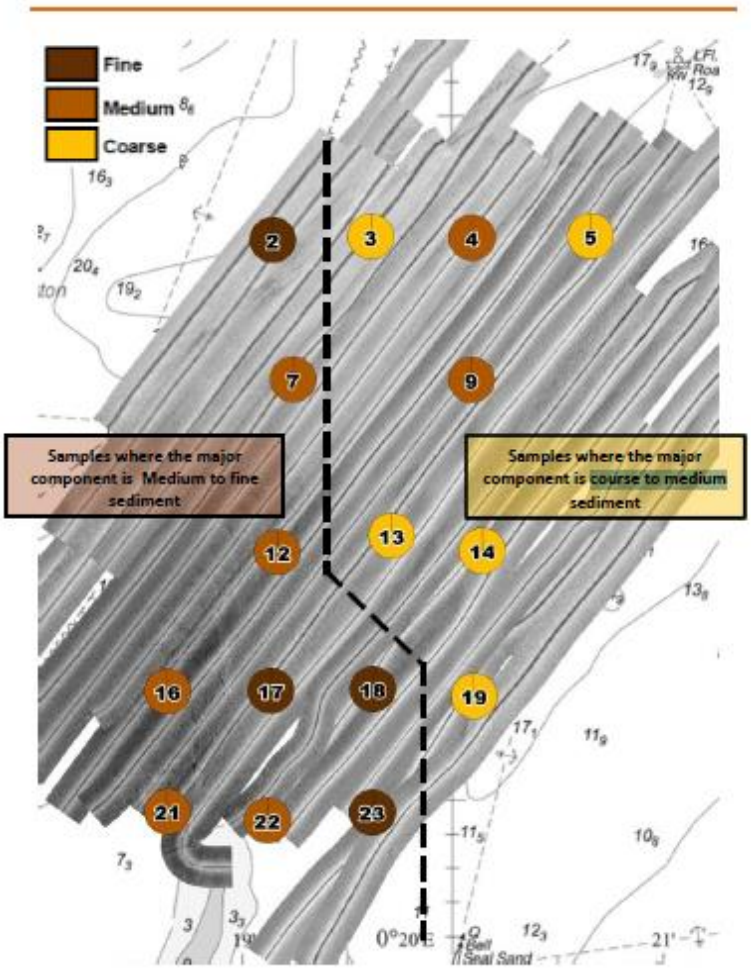

Figure 3. *Side scan sonar mosaic overlaid with pie charts representing the major sediment component of each grab samples. Dotted lines indicate separation of grab sites according major sediment type. To the left of the dotted line are sites containing medium to fine sediment. To the right of the dotted line are sites containing coarse sediment and gravel.*

To provide additional support to the project, EIFCA have agreed to provide the data and results from additional surveys (conducted over 3 days) also carried out during 2015. These data were not available at the time of reporting, but will be made available to Shark By-watch 2 UK following the close of project.

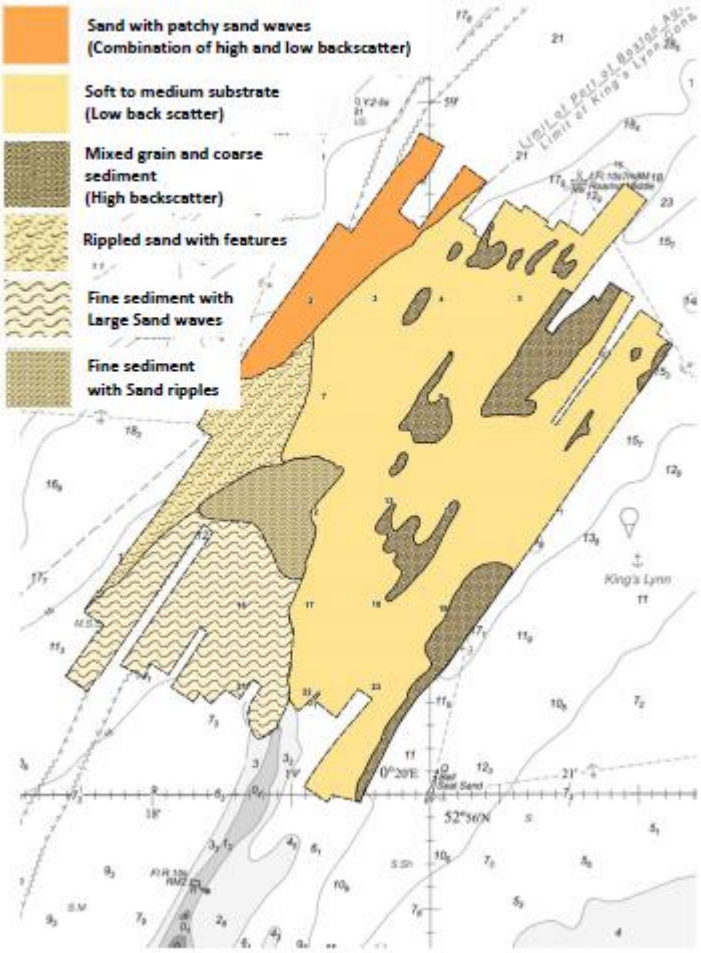

Figure 4. *Side Scan sonar interpretation showing suggested sediment types*

A3.3 Thames Estuary thornback ray fishery

See section C.3 (below)

A4. Reducing the risk of basking shark entanglement

An area of sea stretching from the Isle of Skye to the Isle of Mull, on the west coast of Scotland, has been identified as a Marine Protected Area (MPA) search location as part of the Scottish MPA Project. Large numbers of basking sharks are sighted over the summer months, foraging and engaged in behaviours, such as courtship-like aggregations. This evidence indicates that the area may be important for key life cycle stages of basking sharks.

In order to obtain a more detailed insight into the sharks' distribution, movements and behaviours in these areas, Scottish Natural Heritage (SNH) and the University of Exeter (UoE) initiated a collaborative research project to attach satellite tags to basking sharks in the summer months of 2012 and 2013. The project work relevant to Shark By-Watch UK 2

was the basking shark tagging work that commenced in 2014. An interim report of this second phase of the basking shark satellite tagging project was published in May 2015 and can be found at: http://www.snh.gov.uk/docs/A1609075.pdf (with the final report due to be published in 2016).

To date, results have broadly shown that:

- The tagged basking sharks demonstrate high levels of site fidelity to waters around Coll, Tiree and Hyskeir during summer months (July to September).

- Approximately 85% of basking shark locations occurred within the Skye to Mull MPA search location, with the likelihood of signifying an area of high importance to basking sharks.

- Basking sharks occupy shallow coastal waters during summer months, predominantly using surface waters, but move to deeper waters from autumn onwards.

- Interpretation and conclusions presented in this report are based on initial analyses of collected data, with some aspects of analysis focusing on data collected over short periods of tracking.

- The Irish and Celtic Seas are an important migration corridor for basking sharks moving between the Sea of the Hebrides, the Isle of Man and south-west England.

- Evidence of diel vertical migration (DVM), reverse DVM and yo-yo diving behaviour, suggest basking sharks exhibit a high degree of plasticity when adapting to local conditions.

These results have considerably enhanced the evidence-base needed to inform the possible designation of a possible future MPA but also in relation to the interactions that may exist with human activities, in this case the potential for entanglement and incidental catch in fishing gear. While there is the potential for incidental catch in mobile fisheries, this work has concentrated on mitigating the risk of entanglement in the extensive static creel fishery that is carried out in the area (for crabs, lobsters and Nephrops).

This has involved working collaboratively with stakeholders in the static gear fishery towards the development of best practice and practical measures to help to reduce the risk of basking shark entanglement in static gear. We anticipate the publication of good practice guidance in 2016.

Recommendations from these discussions have also indicated the need for future research into the feasibility and effectiveness of gear modifications and the development of reporting mechanism to identify hot-spots of shark activity in real time. It is worth noting that this work has wider relevance in helping address by-catch risk in other large mobile species including whales, dolphins, porpoise and turtles.

A5. Communication & Data Sharing:

Figure 5. *Flyers for Shark By-Watch UK national events*

An important pillar of Shark By-Watch 2 was communication. While social media were used to broadly disseminate information, face-to-face meetings were also considered to be of huge importance to the ultimate success of the project (Figure 5). These included both the regional technical meetings (see section A.1), but also included specific workshop and showcase events, designed to make the work accessible and to include as wide a range of involved stakeholders as was possible. Our main showcase events are listed below as follows:

Discovering Nature's Giants, Natural History Museum, London, June 11th 2015

This working event run in association with the Natural History Museum, was focussed around the biology of one of the UK's rarest and most striking sharks, the porbeagle. With support from the Natural History Museum and Defra, Shark By-Watch brought together an audience of scientists, policy makers, fishing industry and NGO representatives to observe an expert-led dissection of two legally landed porbeagle sharks.

Porbeagle have been listed as vulnerable by the International Union for the Conservation of Nature (IUCN) since 2006 and are categorized as 'prohibited', meaning fishers must discard any specimens caught by accident. This dissection was made possible thanks to a special scientific dispensation granted by the Marine Management Organisation (MMO) for the landing and study of a number of by-caught porbeagle from Cornish waters.

Due to porbeagle sharks' current 'prohibited' status, the species is rarely sampled and therefore the opportunity to collect new samples created real excitement amongst research scientists present. Samples were taken as follows:

- the eye lens (research exploring the isotopic composition of crystalline proteins within the lens layers aims to create a profile of an individual's location at different stages of its life).
- tissue samples (for genetic interpretation of population diversity).
- gill arches, jaw, and skull.

These samples will help the scientists develop knowledge and understanding of porbeagle sharks in UK waters. The dissection provided new information, even for experienced conservation representatives.

After the biological sampling, a range of science, fishery and NGO participants gave short presentations to the group explaining their progress in porbeagle research, policy development and conservation action. These talks led into a group discussion in which many participants emphasised the need for more scientific research into porbeagle sharks' life-cycles, underlining the issue of mandatory dead-discarding of this species. The Cornish Fish Producers Organisation expressed a deep frustration on behalf of the fishing community, commenting: 'We are on the front line. We witness first-hand the negative impacts the current legislation is causing as we physically have to throw the dead sharks back.'

The participants agreed to collaborate and pool their expertise to produce a supported letter to the EU commission, requesting a scientific dispensation to authorise the landing of dead porbeagle by-catch for scientific study, to further enhance understanding of the species and mitigate the wasteful side effects of the 'prohibited' status.

Innovative solutions to reduce by-catch and dead discards of threatened sharks, skates and rays, Zoological Society of London, September 1st 2015 (see section B2, below)

Thames Estuary Thornback Ray Meeting, Chelmsford, 23rd November 2015 (see section C6, below)

Shark By-Watch 2 UK Showcase Event, Zoological Society of London, December 17th 2015

This meeting provided an opportunity to showcase how a participatory approach has successfully allowed the communication of mutually important issues, the breaking down of historical barriers and behavioural change to help support more sustainable regional shark and ray fisheries. The meeting was structured into four interactive sessions focussing on (i) elasmobranch by-catch in UK fisheries; (ii) reducing elasmobranch by-catch; (iii) alternative management techniques; and (iv) stakeholder views.

This final project showcase was well attended with input from fishermen, IFCAs, Defra, Morrisons, ZSL, Mindfully Wired and the Shark Trust, and provided an opportunity for the

stakeholders to make their voices heard. Two Shark By-Watch engaged fishers gave presentations, flagging both the value of the work, and enthusiasm for future participation. The discussions also included practical suggestions for cost-effectiveness and minimising the burden of data collection for participating fishers in future projects.

With a highly positive outlook, the discussion sessions addressed stakeholders' perceptions as to whether they felt their needs had been met and what were the requirements for future work. The predominant feeling was that trust between fishers, scientists and government was growing, that the industries' voice was being heard, and that basic understanding of fisheries management processes had greatly improved.

Consequently, although industry felt that the need to address quota allocation had only partially been met, they were better able to appreciate the lead-in time required to obtain the evidence base necessary to be used in management decisions. Discussions around follow-on work included e.g. more focussed data collection, integration of new with existing data sources (e.g VMS and Scottish tagging studies) and area based management.

Website and mapping tool

Information about the project is currently available through a dedicated Shark By-Watch UK website **www.sharkbywatch.org** (Figure 6).

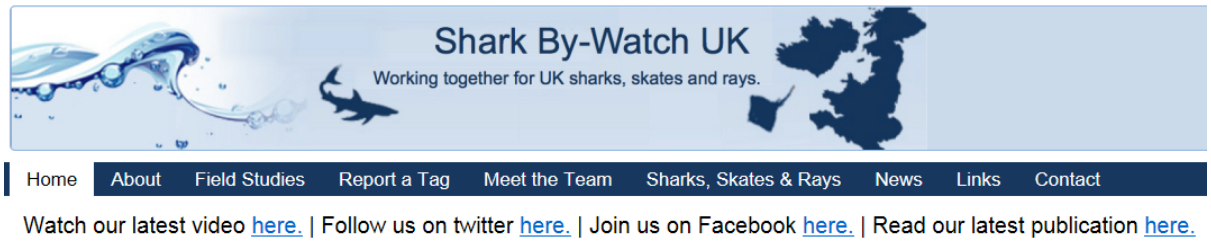

Figure 6. *Shark By-Watch UK website front page*

New field data collected by Shark By-Watch 2 were stored in Microsoft excel 2007 prior to being uploaded. The original intention was to upload these live onto the Shark By-Watch UK interactive web-based mapping tool (www.sharkbywatch.org). The mapping tool originally developed by the original Shark By-Watch programme was until recently directly accessible through the Shark By-Watch UK website, which incorporated the latest data collected by fishermen.

The tool was designed to allow fishermen involved with the fishery-dependent surveys to directly:

- access historic Cefas shark and ray tagging data.
- upload new by-catch & discard data.
- access their own Shark By-Watch UK fishery-dependent survey data

In addition, restricted access to core elements of the mapping tool and associated datasets are available to fishermen and to members of the public outside of the project to help foster greater awareness and knowledge of occurrence and seasonal spatial distribution patterns of elasmobranch species off the coast of East Anglia.

During the course of the project, some problems with the mapping tool were encountered as a result of changing web support provider. While significant effort was made to resolve these issues, the mapping tool was in any case super-ceded by the launch of the Cefas Data Hub (www.cefas.co.uk/cefas-data-hub/), see below, in October 2015.

Shark By-Watch UK Facebook page

Our dedicated Facebook site www.facebook.com/sharkbywatchuk, has been a valuable tool for keeping UK fishermen, scientists, conservation/governing bodies and members of the public in touch with the latest developments of our fishery-dependent surveys (Figure 7). Survey logs, together with photographs from recent surveys, are uploaded on a regular basis.

Cefas Data Hub

In support of their commitment to open data access and open science, Cefas have launched the Cefas Data Hub – an online portal allowing the public and UK businesses to explore, download and reuse the data for their own research (Figure 8).

Datasets available will include many of our legacy datasets covering subjects such as fish, shellfish and plankton survey data from the 1980's to the present day, crab tagging data, otolith sample data, records relating to MEDIN Marine Fisheries Data Archive Centre, water temperature, salinity, and sediment data from across the UK continental shelf.

Consequently, given that this functionality allows the same options to participating fishers (accessing historic shark and ray tagging data, uploading new by-catch & discard data and accessing their own Shark By-Watch UK fishery-dependent survey data), Shark By-Watch UK 2 data will from now on be made available through the Cefas Data Hub.

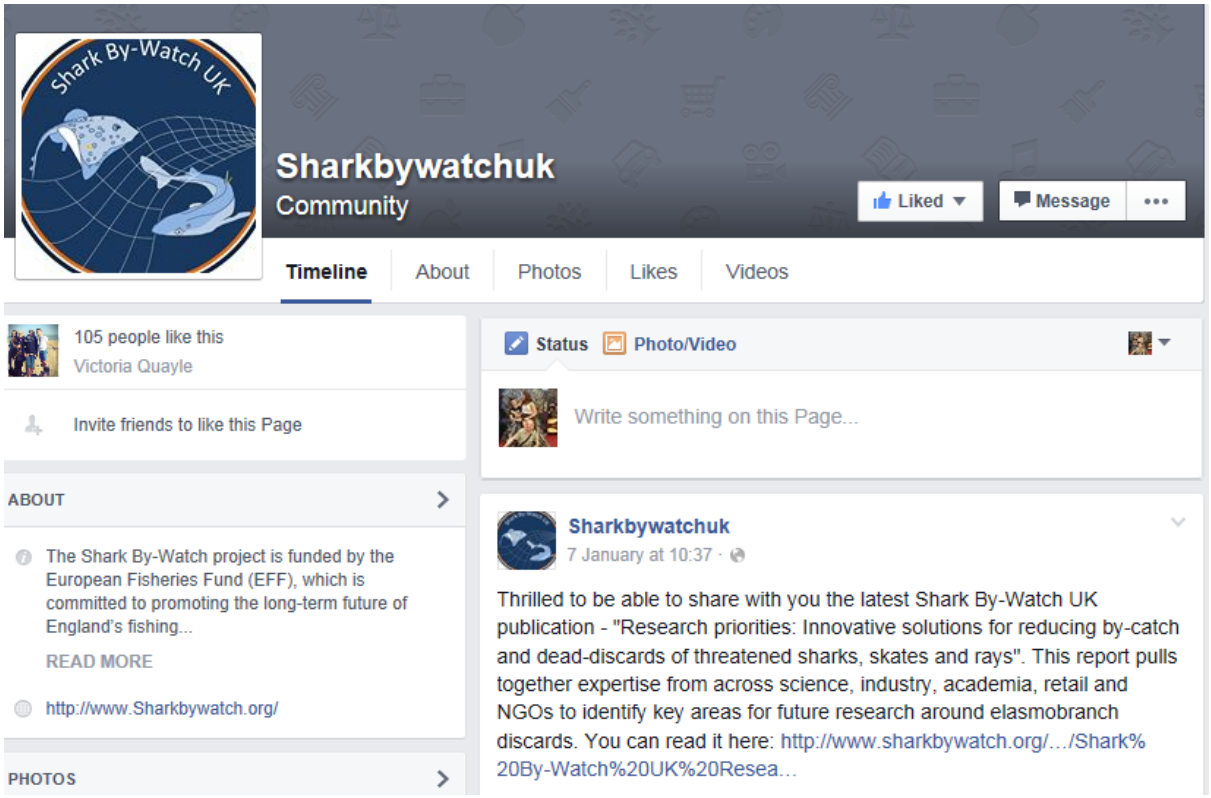

Figure 7. *Shark By-Watch UK Facebook front page*

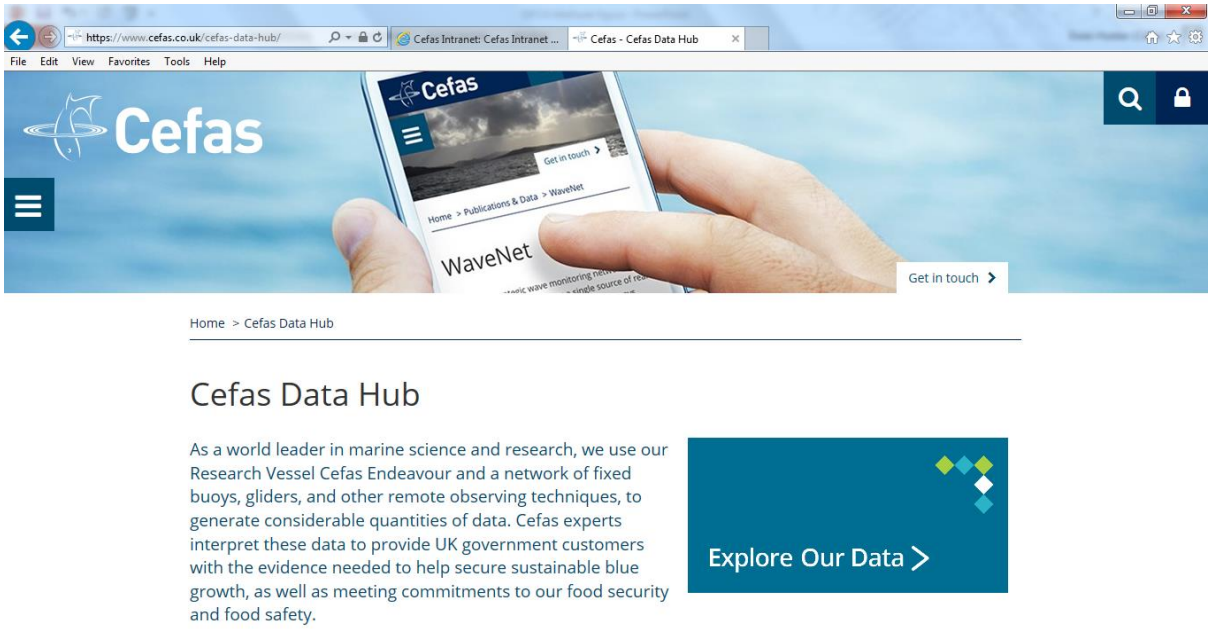

Figure 8. *Cefas Data Hub web page.*

B) Innovative solutions for reducing by-catch and dead discards of threatened* sharks, skates and rays (*IUCN categories of Vulnerable, Endangered or Critically Endangered species) (75% funded from the European Fisheries Fund for Cornwall innovative gear technology pilot).

Aim: *For the fishing industry to lead on pragmatic solutions to reduce the by-catch of vulnerable elasmobranchs in the net fisheries of the Southwest UK, actively demonstrating responsible ownership of environmentally responsible fishing practices, helping to further promote and protect the long-term future for their mixed fishery within the Celtic Sea.*

North-East Atlantic stocks of porbeagle are listed as Critically Endangered and spurdog as Endangered under the IUCN Red List and EC regulations have been put in place to conserve these species, resulting in the closure of their target fisheries, but also preventing the landing of by-catch (with a zero TAC in place since 2010). However, both these sharks appear to be sufficiently locally and/or seasonally abundant off the south west coast of the UK to result in high levels of unavoidable by-catch and dead-discarding in trawl and fixed net (gill, trammel & tangle nets) fisheries.

Some fishermen feel that the current regulations relating to these species are not fully effective, and that scientific knowledge and data are inadequate. There is also growing concern from the fishermen that more stringent, wide-scale, seasonal management closures may be imposed in order to further reduce porbeagle and spurdog stock depletion and conserve these species.

Far less fully understood is the level of basking shark by-catch. Once heavily exploited by the commercial fishing sector but now listed as Endangered on the IUCN Redlist, basking sharks are afforded protection under the Wildlife and Countryside Act (1981), Convention on International Trade in Endangered Species (CITES), the Convention on Migratory Species (CMS) and TAC and Quota regulations. This protection means that this species cannot be targeted, retained or disturbed in British waters. Nonetheless, anecdotal evidence suggests that basking sharks are susceptible to by-catch in fixed gill net fisheries.

To aid recovery of these vulnerable sharks whilst protecting the long-term sustainability of Southwest commercial net fisheries, Work Package B has examined alternative mitigation and avoidance measures that aim to apply innovative methods and technologies to reduce by-catch and dead discarding of porbeagle, spurdog and basking shark.

B1. Scoping out innovative technology:

Preventing the low quotas for elasmobranchs from being reached is best achieved by reducing the total number of elasmobranchs caught. This reduces discard mortalities as well as helping to improve the stocks in the long term. There are a number of different ways in which this can be achieved, including avoiding fishing in areas where the species is known to occur, discouraging fishing in that area and modifying gear or fishing behaviour so that only the target species is caught (table 3).

Gear Type	Long line	Gill net	Trawl	Purse seine
Modification	Surfactants, semiochemicals Bait type and colour Dead sharks Light sticks Leader type and colour Magnets Lanthanide metals Electric devices	Surfactants, semiochemicals Net illumination and colour Models of predators Electric field 'barrier' Magnetic field 'barrier' Pre-net fence	Flashing lights Water jets Electric pulse generators	Remote attraction or bait stations

Table 4. *Summary table of the by-catch reduction technologies. Modified from Jordan et al. (2013).*

Voluntary and temporary closed areas have been shown to reduce unwanted catches, however a good understanding of species' behaviours in each area is necessary to implement such measures. When detailed information is unavailable, or when species' behaviour is less predictable, methods can be put in place to avoid species on a near real-time basis.

The move-on rule is one such method which can give guidance on a distance and/or time that fishers should move away from a certain area to avoid catching certain species, based on threshold weights or volumes of individuals caught previously. The move-on rule has successfully been implemented in a number of parts of the world, but it requires cooperation and communication between vessels.

Cooperation between vessels can also be successful in a type of catch share programme, where quota can be traded between vessels as long as real time reporting of catches and bycatches are provided. Vessels can then also voluntarily avoid an area to prevent the closure of a fishery.

Gear modifications are another effective way of reducing elasmobranch capture. Fisheries- and species-specific approaches should be targeted when designing gear modifications, as multiple options for different fishing gears are available that may highly situation-specific in their effectiveness.

Attractants and deterrents, such as lights, chemicals, baits or magnets can be used with many different gear types to help ensure that only the target species is caught. The use of excluder grids or changes to net sizes and filament materials can alter the composition of a catch, and do not necessarily reduce the target catch.

Reducing fishing mortality may also be improved by enhancing the bycatch survivability of catch subsequently returned to the sea. Survival rates differ greatly between fisheries and elasmobranchs, with a range from 15 to 100 % cited in the literature. Some fishing gears such as long lines have higher survival rates, while altering fishing practices slightly can increase survival through e.g. shorter tow and soak durations. Gear and tow modifications which result in smaller cod-end weight may also increase survivability.

The full review (Annex 5), including examples of field application, demonstrates a number of approaches which can reduce elasmobranch catches and improve their survival once discarded. A combination of approaches can be used to reduce the burden on fishers while continuing to maintain sustainable stocks.

B2. Technical development workshop:

On 1st September 2015, in partnership with the Zoological Society of London (ZSL), Shark By-Watch UK 2 held a workshop at ZSL on 'Innovative solutions to reduce by-catch and dead discards of threatened sharks, skates and rays' to collate stakeholder knowledge on the focus species Common Skate, Basking Shark, Porbeagle and Spurdog. The meeting was attended by representatives from 16 national and international stakeholder organisations including the fishing industry, scientists, Government policy representatives, NGOs and retail.

Group discussion underscored that more research is needed to fully understand the levels and occurrence of interactions between threatened elasmobranchs and fishing gear, which can lead to by-catch and dead discards. With more information on elasmobranch distribution and incidences of elasmobranch by-catch in UK waters, steps can be taken to reduce unwanted interactions with fisheries. This will protect both fishers (from potential gear damage, time taken to disentangle by-caught species, and un-saleable catch) and the species themselves.

As a consequence, Shark By-Watch UK was able to identify a number of key areas for further consideration and research, based around the focus species discussed (see Annex 5). Opportunities for reducing elasmobranch by-catch centre around investment in the testing and use of new, innovative gears, technologies and approaches to management.

The participatory discussions held at the workshop formed the basis for the publication of a high level outreach document (Figure 9, Annex 6) that underlines a broad need for more in-depth research into measures for avoiding by-catch of threatened elasmobranchs. Ultimately, this document identifies five specific areas that workshop participants agreed require prioritisation in future research around shark, skate and ray by-catch and discards. These are as follows:

(i) To ensure science and industry work together to make best use of the full range of knowledge and expertise available.
(ii) To trial innovative technologies (see also B4, below).
(iii) Development of alternative management approaches.

(iv) Full utilization of existing and novel data sources.
(v) Understanding long-term discard survival for the reformed CFP

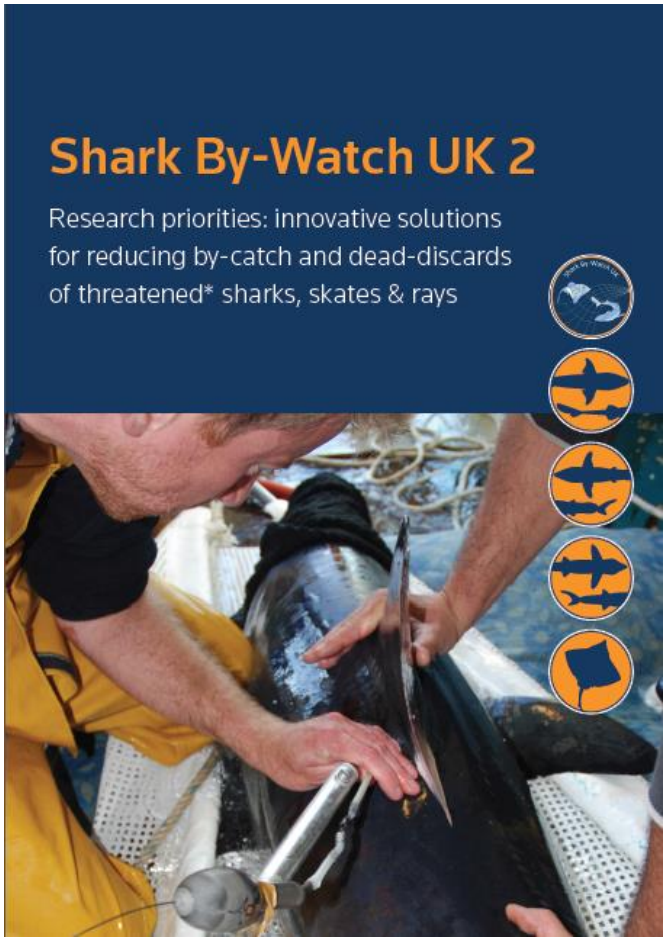

Figure 9. *High level outreach document, "Research priorities: innovative solutions for reducing by-catch and dead-discards of threatened sharks, skates and rays".*

A range of advancements in fishing gear technology may help reduce or prevent elasmobranch interaction with fishing gear. Innovations such as grids, deterrents, decoys and line modifications may be part of the solution to reducing by-catch of threatened sharks, skates and rays in UK waters. However, these technologies need to be proven in UK fisheries before they can be disseminated on a scale that will impact overall rates of by-catch. With this in mind, rigorous trialing of these technologies, with participation from willing fishermen, will provide a greater understanding of how they can best contribute to by-catch reduction in UK fisheries and will secure broader uptake in the long term.

Of particular relevance to UK fisheries (identified following participatory discussion, and the 'Innovative solutions to reduce by-catch and dead discards of threatened sharks, skates and rays' workshop held at ZSL, London, September 15th 2015), are the following recommended trials:

(i) Fine monofilament mesh and individual panels joined by weak links to allow bycaught porbeagle and/or basking shark to break-through and/or break free of entanglement in static gear.
(ii) The use of selectivity grids in otter trawls to allow common skate to escape capture.
(iii) The use of weak links in tensioned, non-buoyant creel ropes, preventing basking shark entanglement at the sea surface for creel fisheries around the Western Isles of Scotland.

B3. Field trial: Real Time Spurdog By-catch Reporting Tool

Spurdog is currently managed by a zero TAC. However, incidental by-catch of spurdog in mixed fisheries in the North-east Atlantic (NEA) can be high. Under a landing obligation in mixed fisheries, spurdog has the potential to become a choke species whereby it forces fishermen to stop fishing in areas where spurdog is caught as by-catch.

One option for preventing spurdog from becoming a choke species would be to add it to the Prohibited Species list, thereby ensuring zero retention and continued discarding. However, this contradicts the spirit of landing obligation implementation, does not recognise the need for regional solutions to fisheries management, and also fails to address the continued issue of wasteful dead discarding.

Consequently, the UK has implemented a pilot project under article 14 of Regulation (EU) No 1380/2013 of the European Parliament and of the Council to allow industry participants to adapt their fishing behaviour to avoid significant spurdog by-catch. The UK pilot project is underway in the Celtic Sea (ICES Divisions VIIe-j) and involves close collaboration between policy makers, scientists, industry, and NGOs.

A full report has been produced which outlines the progress made to implement the pilot project for fishing vessels to report spurdog by-catch and discards in real-time. This will aid spurdog conservation and aid stock recovery in the NEA, contributing to the development of a rebuilding and management plan for spurdog. The full report can be found as Annex 7.

The pilot project has addressed the points raised in previous STECF advice (PLEN-14-03) as follows:

i. Indicators have been identified to allow for fishing behaviour and the uptake of a hypothetical dead spurdog by-catch quota to be closely monitored against controlled baselines, allowing avoidance of spurdog by-catch and therefore a reduction in spurdog by-catch, to be evaluated.

ii. Quota accrual of any spurdog by-catch at an individual-vessel level, or between-vessel quota trading would be forbidden. This would help prevent deliberate targeting of spurdog and the initiation of a limited target fishery which would be counter to the objective of minimising fishing induced mortality.

iii. Scientific observer coverage to provide a comparative assessment of relevant scientific data provision and quality, and a safeguard against misreporting of the health state of “lively” fish as “dead” so as to obtain marketable landings, hence increase fishing mortality.

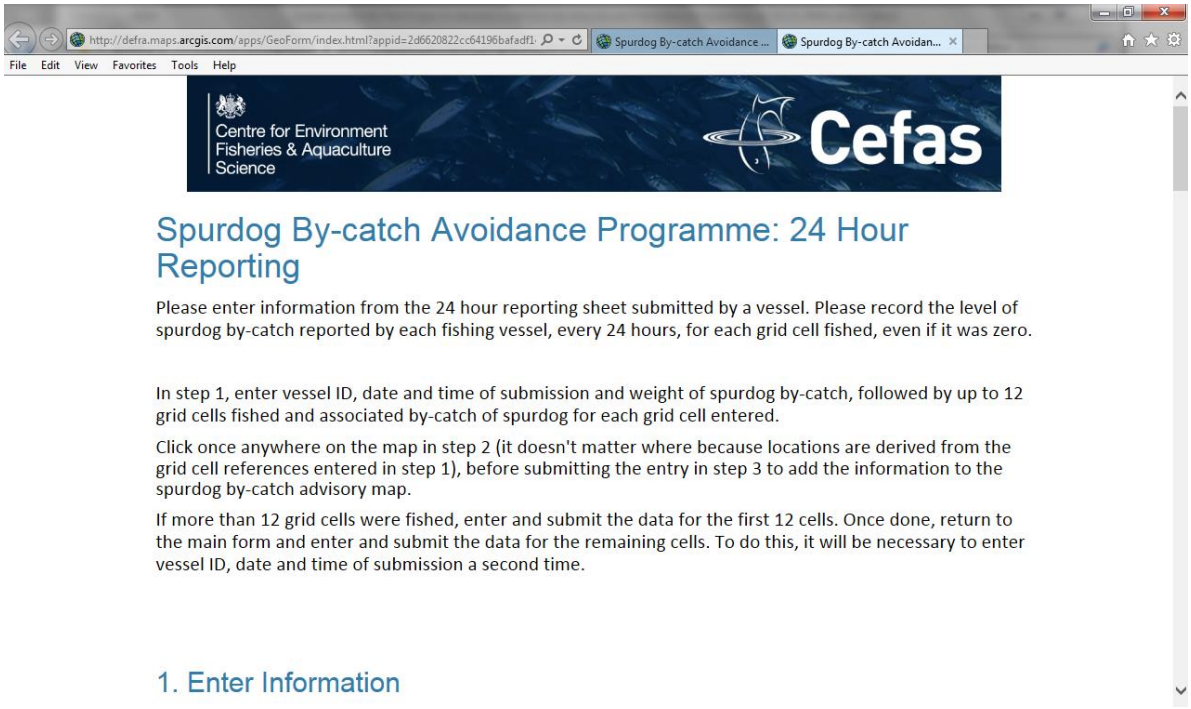

Figure 10. *The spurdog by-catch reporting tool web interface, hosted on the Cefas website.*

The spurdog by-catch reporting tool (Figure 10) successfully collates the real-time spurdog by-catch data in each grid cell classified to predetermined thresholds, using a traffic light system. From 2nd November 2015 an advisory notice is sent back in near real-time to the vessel, alerting the skipper of spurdog aggregations to avoid significant spurdog by-catch events (Figure 11).

The pilot project (Spurdog By-catch Avoidance Programme) is successfully demonstrating the feasibility of a straight-forward, low-cost, functioning, real-time spurdog by-catch reporting tool. The tool provides a pragmatic solution to current dead discarding by allowing for the future retention of spurdog, adhering to a by-catch quota, whilst reducing overall fishing mortality.

At the close of project, we have successfully implemented reporting, semi-automated running of the advisory tool. Limited historic and recent hotspot information have currently been incorporated in the tool. Automation of channels of communication will be completed in the months following the close of Shark By-Watch 2.

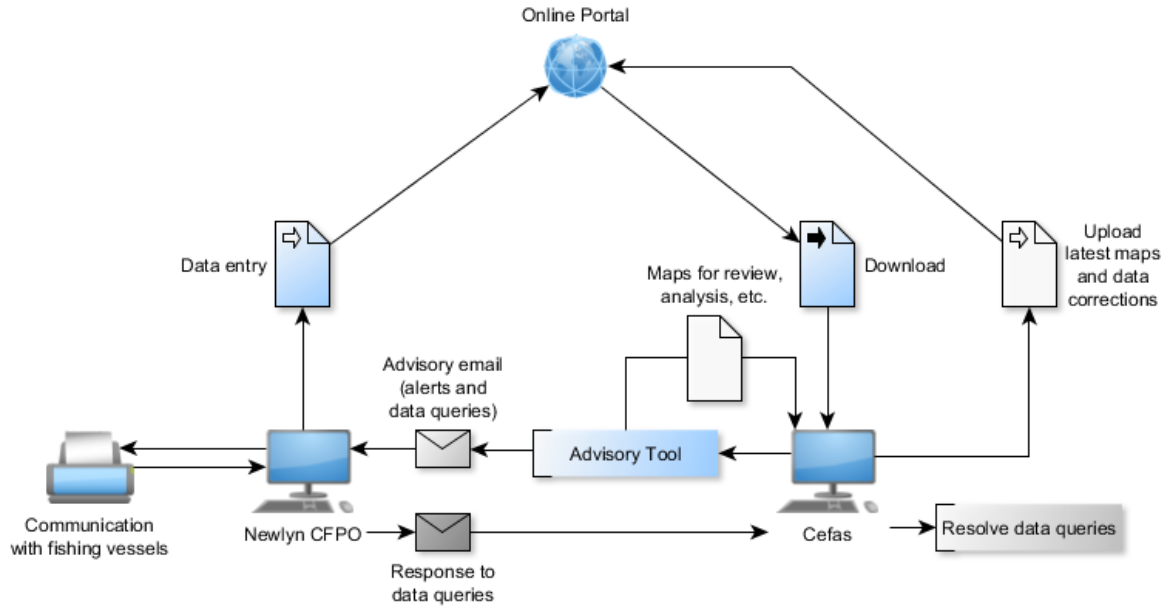

Figure 11. *The spurdog by-catch reporting tool channels of communication.*

C) Scoping alternative fisheries management techniques in support of a sustainable thornback ray fishery in the Thames Estuary, free of regulatory discards, in-line with the aims of CFP reform. (50% funded from European Fisheries Fund)

AIM: *To use the Thames Estuary area as a test-case towards implementing regional ICES advice of fishery-specific management measures for thornback ray in the North Sea.*

Working in partnership with the Kent and Essex Inshore Fisheries and Conservation Authority (KEIFCA), we have focussed on the Thames Estuary as an ideal test-case for implementing fishery-specific, regional management measures.

The KEIFCA district seaward boundary, in which regional management can be enforced, extends to the 6 mile nautical limit, measured from the 1983 baseline. However, due to drying sand banks, the KEIFCA district boundary now extends up to 15 miles offshore in some places, covering an area of over 3,412 km^2, making it an ideal test area for the purpose of regional management.

The previous EFF pilot project successfully investigated the Greater Thames Estuary thornback ray fishery, where thornback landings are locally and seasonally abundant. Significant biological data on thornback rays (e.g. distribution, sex-segregated aggregations, maturity & size composition) throughout the Greater Thames Estuary region were collected, and attempts have been made to determine the extent of spatial abundance and stock residency within the area. The evidence suggests that the Thames Estuary is of significant importance to all life history stages (i.e. sexual aggregation of adults, spawning grounds, juvenile and nursery areas) for thornback ray in the Southern North Sea.

A low allocation of TAC for thornback ray to the local under 10 metre fleet in the area mean that high levels of discarding remain a significant issue. North Sea skate and ray fisheries are currently managed under a common TAC. ICES advises that TACs alone may be inadequate to protect these stocks caught in both target and non-target fisheries, as restrictive TACs may result in significant regulatory discards.

ICES advice (October 2012) for thornback ray in the North Sea for the period 2013 and 2014 stated: “Additional measures should be identified that can regulate exploitation of this species” (valid 2013-2015). Such measures may include seasonal and/or area closures, technical measures, and tailored measures for target fisheries.

Such measures should be developed by managers through stakeholder consultations, considering the overall mixed fisheries context”. The advice concluded that there should be no TAC for thornback ray, and that as an alternative, species-specific measures were needed, and that if successful, catch rates could subsequently increase by a maximum of 20%.

Fisher reports suggest that thornback ray abundance appears to be increasing in the Thames Estuary area, making this an ideal case study candidate for specific spatial, seasonal and technical measures to develop local management procedures, as the vast majority of the Thames Estuary is managed locally by the regional, KEIFCA.

C.1 Stakeholder partnerships:

This Work Package has built on the successes of the previous EFF funded work in the Thames Estuary, Shark By-Watch UK. The project aim here was to facilitate the development of practical regional management plans intended to conserve thornback ray in the Thames Estuary and to allow them to be fished sustainably, maintaining valuable income within the small-scale coastal fisheries.

Partnership work focussed on a) the Thames Estuary fishermen leading fishery-dependent surveys, b) the KEIFCA conducting habitat mapping, identifying key areas for local management; c) Wm Morrison Supermarkets plc, contributing to workshops, presenting to fishermen and; d) Defra and the MMO contributing to workshops, with all partners scoping regional management scenarios for a sustainable fishery of thornback ray in the Thames Estuary, minimising regulatory discards.

C.2 Fishery-dependant surveys:

The previous EFF funded programme collected 12 months of survey data for thornback ray in the Thames Estuary, which has informed the process of scoping local, species-specific, management measures for thornback ray in the Thames Estuary. Because of inter-annual variation (i.e. the difference in abundance between years), additional survey data were required for this purpose.

To this end, Thames fishermen lead self-sampling surveys, guided by Cefas scientists, to establish the current spatial abundance of thornback ray, and collecting field data on the health of stock (species abundance, sex ratios & maturity oogives), feeding and/or spawning and/or nursery grounds. For Shark By-Watch 2, additional fisher-led surveys were commissioned to make better use of existing knowledge. So that the data collected can be used to inform stock management, additional information on the size of stock, the health of stock, discard survival rates and seasonal changes in distribution.

Vessel	Trips	Gear	No hauls	Survey Dates	Total Fish	Total tagged
Jolene	6	Longlines	21	Aug-Oct	853	244
JessicaM	5	Otter trawl	27	Oct-Nov	355	228
Suvera	6	Otter trawl (single)	32	Oct-Dec	1444	393
Total					2652	865

Table 5. *Summary of fishery-dependent survey activity in Shark By-Watch UK 2.*

The bulk of the survey work was undertaken using 3 fishing vessels, the Jolene (longlines), the Jessica M (paired otter trawl) and the Suvera (single otter trawl), which surveyed the catch from a total of 80 hauls made between August and December 2015 (table 5). In addition, the F.V. Julie M II sampled on 2 days using static tangle nets.

Discussion with fishers prior to the surveys were used to determine 'ideal' fishing locations. Although sampling effort was limited, consideration was given to contrasting habitat types ('bank' vs. 'deep', Jolene, Jessica M and Suvera, figure 12) and different tidal conditions (Julie M II, figure 12).

Initial sampling trips were accompanied by a Cefas scientist for fisher training in handling, measuring, recording, tagging and release techniques. Focusing on thornback ray, all elasmobranch catch was counted, and thornback ray in good condition were tagged. Additional tagging was required to provide supplementary information on survival, ray movements, and ultimately, to map the distributions of fish and their habitats.

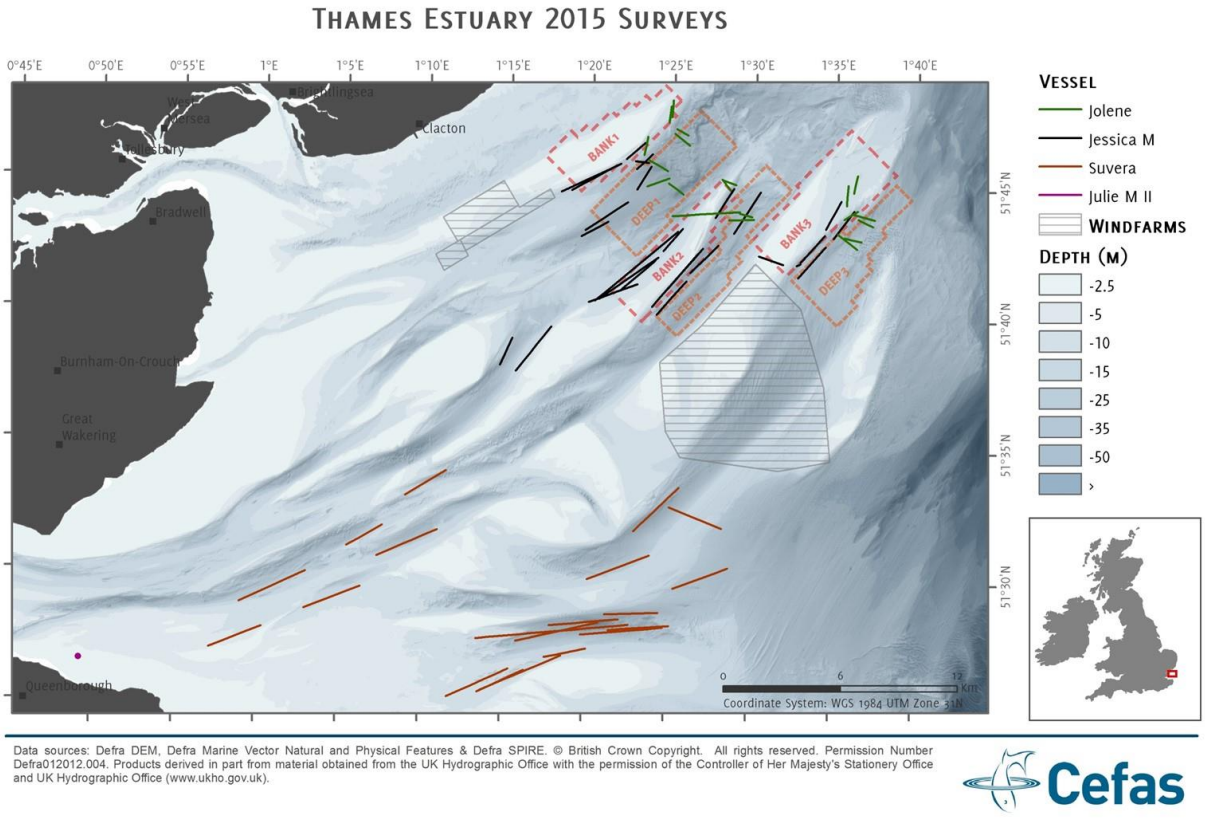

Figure 12. *Map of study areas used in Shark By-Watch UK 2 fishery-dependent surveys.*

Data from our surveys was being gathered right up until the time immediately before close of project. These data will eventually be made available through the Cefas Data Hub (see section A5, above).

C.3 Habitat mapping:

Running alongside their 2014 Oyster survey (full details of locations and methods can be found in Annex 8), t`he KEIFCA also recorded the occurrence of thornback ray egg cases, noting whether these contained live embryos, yolk only, no embryo or when the egg-cases

were empty. A plot showing the locations of the egg-cases sampled is shown in figure 13 below.

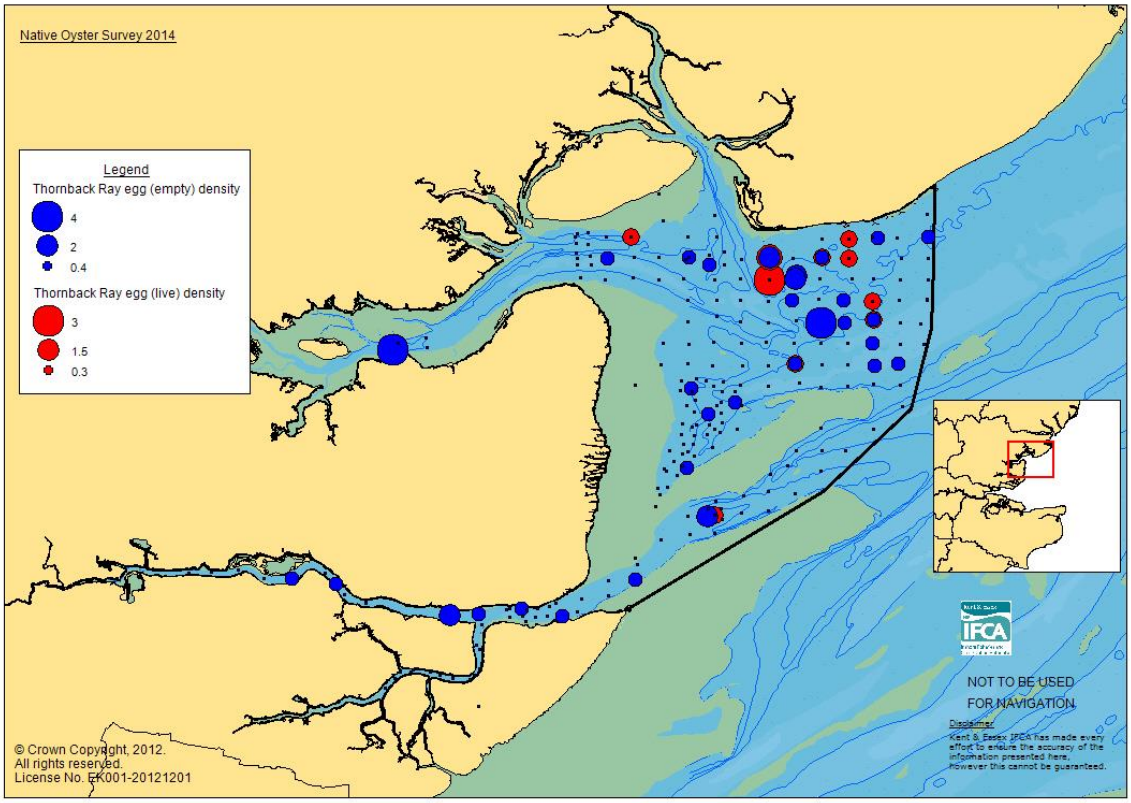

Figure 13. *Location of live and empty thornback ray egg cases sampled from the KEIFCA 2014 oyster survey.*

C.4 Sustainable supply chain:

Key to achieving a local management plan for a sustainable thornback ray fishery in the Thames Estuary, free of regulatory discards, is a sustainable supply chain. Through workshops, presentations to fishermen, and demonstration of their use of a sustainable supply chain, Morrisons have promoted their potential role in the sustainability and long-term future of Thames Estuary thornback ray fishery.

By working with Morrisons and the Kent and Essex IFCA, the project has examined good management practices to conserve and secure the thornback ray population in the Thames estuary for the future. We hope to have demonstrated that, whilst helping to protect the marine environment, good management practices will also safeguard jobs. With sustainable fisheries being recognised and rewarded in the marketplace, providing an assurance to buyers and consumers that their seafood comes from a well-managed and sustainable source, income for the inshore fleet from Morrisons sustainable supply chain would be secured as a consequence.

As well as having a restrictive TAC, sustainable fishing for thornback ray in the Thames by the under 10m fleet is also negatively impacted by the low price the fishermen obtain for their catch (sometimes as low as £1/kg). During the project workshops (see section C6,

below), Wm Morrison Supermarkets Plc put forward the view that even when poorly evidenced, proactive management measures are often viewed positively and can be marketed more favourably.

There is an opportunity therefore, for the Thames fishers to work proactively with NGOs such as the Marine Conservation Society and the Shark Trust to demonstrate their sustainability credentials so as to engage consumers. By lowering the barriers to environmentally-conscious consumers buying skates and rays, the market value can be raised as a consequence, making the economics in support of sustainable supply chain more favourable. The social aspects of the supply chain should simultaneously be considered. Therefore fishing communities, and for example the fish processor, should also form part of the sustainable supply chain engagement.

An outcome from the final Shark By-Watch 2 Thames Estuary Workshop (see section C6, below) was a proposal that the sustainable supply chain approach should form the basis of an independent, buyer-led (e.g. Wm Morrison Supermarkets Plc.) pilot project bid focussing on Thames Estuary sourced thornback ray.

C.5 Scoping the potential for the implementation of ICES advice:

Working with our project partners, we investigated the potential for implementing regional ICES advice for skates and rays in the North Sea. For example, we posed the question as to whether management measures such as closed areas and/or closed seasons, or effort restrictions, might provide better protection for demersal elasmobranchs.

Simulation modelling of Thames Estuary thornback ray

Recent ICES advice has identified the potential for regional management measures for skates and rays in the North Sea, suggesting that “Management measures such as closed areas/seasons or effort restrictions may better protect demersal elasmobranchs. In particular, measures to protect spawning/nursery grounds would be beneficial”. In some cases, single-species TACs may be appropriate, especially for easily identified species, and/or discrete stocks in limited distribution areas.”

As part of Shark By-Watch UK 2, we aimed to scope the potential for such management measures and find evidence to support area or season controls. Dynamic measures that use real-time data collection have been shown to outperform harvest control rules such as TAC (e.g. Kraak et al. 2015), or allow more efficient fleet operation through habitat mapping (Gondra et al. 2008). Development and implementation of such measures or the Thames Estuary <10m fleet will require a greater understanding of small-scale distribution and behaviour of thornback ray.

To examine the potential effects of aggregation and habitat-use (as suggested by fishers' knowledge), an individual-based simulation model (IBM) was developed. The spatially-explicit model used a simple habitat map of the northern part of the inner Thames Estuary.

The model was populated with individual thornback ray 'agents' that moved, sensed the local environment, and aggregated based on the presence of other individuals and different habitat-types (Figure 14a). Simulated fishing events took place on and off sandbank areas, comparable to survey trawls undertaken during Shark By-Watch UK 2 (Figure 14b).

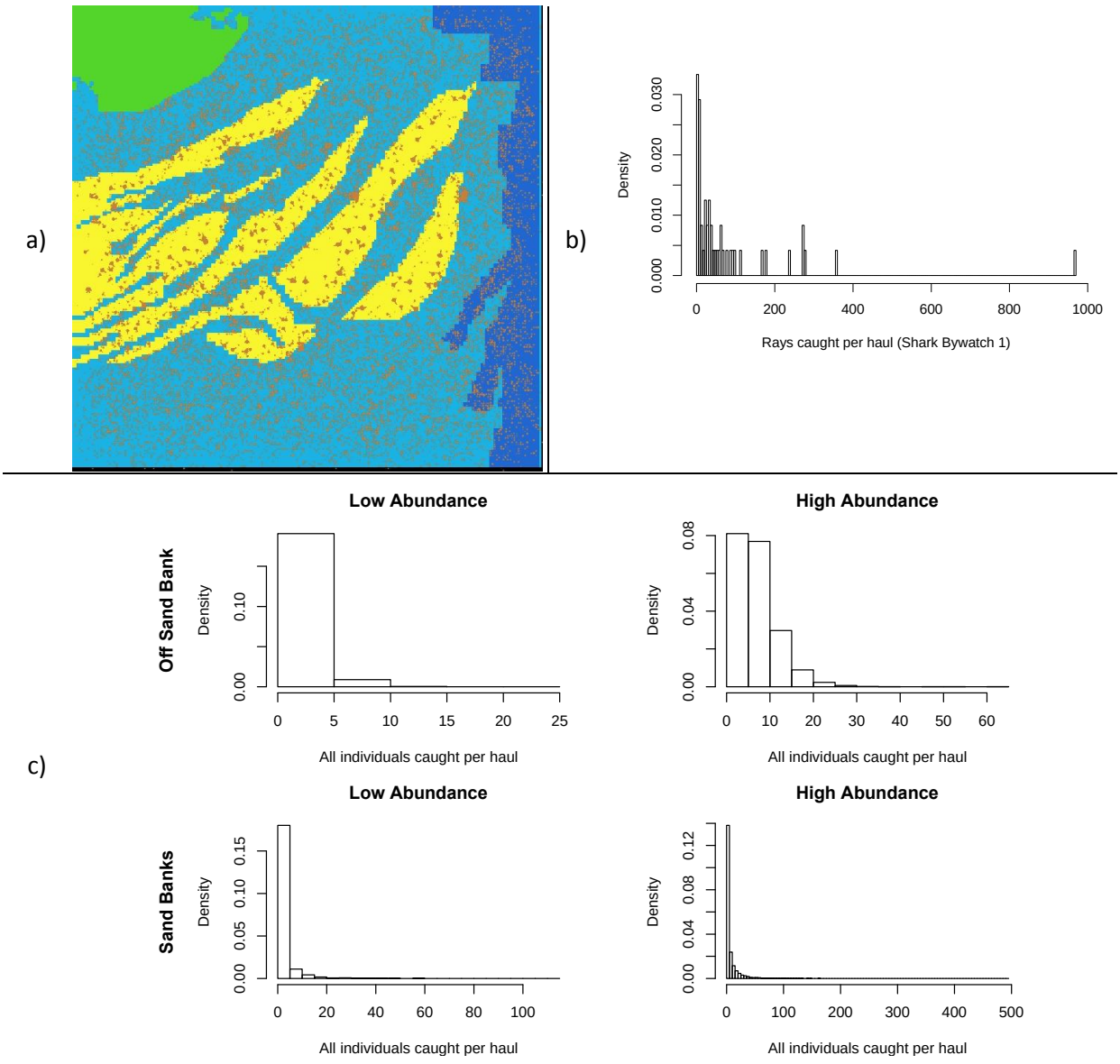

Figure 14. *a) Example of simulated Thames Estuary thornback ray. Sandbank habitat shown in yellow, with rays shown as brown spots. Spot size is relative to aggregation size, with large aggregations present on sandbanks. b) Histogram showing frequency density of rays caught per haul from Shark By-Watch UK 2 summer trawls. c) The same distributions from simulated catches under two abundance scenarios and across two habitats.*

As the local abundance and behaviour of thornback ray is not well known, a number of alternative scenarios and parameterisations of the IBM were assumed for model runs, examining the effect on the emergent numbers-per-haul simulated.

Increasing aggregation caused greater patchiness in the meso-scale distribution of simulated rays, and greatly affected numbers-per-haul. More patchy distributions resulted in a considerable increase in the number of hauls with no or few rays caught, but increased the size of occasional heavy catches. Scenarios that assumed the strongest levels of aggregation and highest total abundance of thornback ray were most similar to the positively skewed catch data observed in the original Shark By-Watch UK surveys.

When sandbank habitats only were assumed to drive dense aggregation, simulated catches from these cells were comparable to runs in which the same level aggregation occurred in the entire world space (figure 14c). Despite the thin and elongated structure of many sandbanks, it appears that they are capable of causing the dense school formation required to drive patchy distribution and catches, assuming the sub-kilometre scale nature of aggregation in this model. Furthermore, formation of schools on sandbanks drove a slight increase in patchiness in non-sandbank habitats, as aggregations moved off sandbanks and were occasionally caught before dispersing.

The results of our simulations highlight the potential importance of small-scale movement and aggregation in driving catch dynamics for thornback ray. However, none of our simulation scenarios or parameterisations resulted in aggregations nearing the maximum numbers-per-haul data observed from Shark By-Watch UK. Note that the ecological interactions between species and heterogeneous environments are known to amplify or exaggerate heterogeneity (Levin 1976), and so the structural nature of sandbank or other habitat may be responsible for local scale patchiness in the wider Thames Estuary.

Given the simple assumptions of the model and the relatively modest sample sizes of trawl data generated by Shark By-Watch UK, we suggest that additional data describing the behaviour and catches of thornback ray in this area, particularly between different habitats, would be beneficial.

An extended version of the model, using a simple age- or length- structure, would allow a more integrated approach of comparing landings, fisheries-dependent survey, and fisheries-independent survey data. Real-time data collection by commercial fisherman, as gathered during Shark By-Watch UK, may form the basis for on-going time-series that could further inform these models and ultimately a full stock assessment for thornback ray.

C.6 Dissemination of final results to promote local, fishery-specific management measures

A final participatory workshop based around our central theme “Scoping alternative fisheries management techniques in support of a sustainable thornback ray fishery in the Thames Estuary, free of regulatory discards, in-line with the aims of CFP reform” was held in Chelmsford, 23rd November 2015. The workshop was used as a platform to use the material

collected under Shark By-Watch to drive forward fishery-specific management measures, local to the Thames Estuary.

Possible regional management scenarios for a sustainable fishery of thornback ray in the Thames Estuary:

During the workshops, fishermen provided much anecdotal information on the spatial abundance and distribution of thornback ray in the Thames Estuary. These included a perception that the entire Thames Estuary system is a thornback ray nursery area.

In addition, fisher perception was that a distribution shift had occurred, with thornback rays now present in areas where they weren't observed in previous generations. This perceived shift was partially attributed to changing predator-prey interaction: for example, local fishers report that thornback ray now feed on non-native razor clams which only appeared relatively recently in the Thames.

Alternate and potential management measures were discussed by the group, and included (i) an increase to the minimum landing size; (ii) a maximum landing size; (iii) seasonal avoidance or closures; (iv) spatial avoidance or closures; (v) licences; and (vi) a Code of Conduct to promote live discarding. The necessity of scientific evidence in the demonstration and evaluation of any alternative management measure was recognised by the group.

Targeted by inshore commercial fishermen, thornback ray in the Thames Estuary is an ideal candidate for specific spatial, seasonal and technical measures to develop local management procedures, as the vast majority of the Thames Estuary area is managed locally by the regional, Kent and Essex IFCA. Fisher led self-sampling surveys, guided by Cefas scientists have been undertaken in the Greater Thames Estuary, and have tested, for example, whether thornback ray aggregate in specific areas (defined by habitat-type & depth) more than others (i.e. Bank versus non-bank).'

Development of a sustainable supply chain:

As well as having a restrictive TAC for thornback ray imposed, a further hurdle to a sustainable under 10m fleet fishery in the southern North Sea, is the low price (sometimes as low as £1/kg) obtained by fishermen. During the workshops, Wm Morrison Supermarkets Plc explained that from a market perspective, proactive management measures, even if poorly evidenced, can be viewed and marketed favourably.

Working with NGOs such as the Marine Conservation Society and the Shark Trust can engage customers, lowering the barriers to consumers buying skates and rays, in turn raising the market value, making the economics more favourable for a sustainable supply

chain. The social aspect of the supply chain must also be considered, engaging with fishing communities to proactively engage with the supply chain, such as the fish processor.

It was suggested that the sustainable supply chain approach described above should form the basis of an independent, buyer-led (e.g. Wm Morrison Supermarkets Plc.) pilot project proposal focussing on Thames Estuary sourced thornback ray (see below).

A test case for an alternative management approach for a sustainable and discard-minimal fishery for thornback ray in the Thames Estuary:

Outcomes from the workshops were identified as follows:

(i) fishermen agreed to explore alternative management approaches to achieve an increase in their TAC for Thames thornback ray;

(ii) Defra felt that any proposed management measures that supported continued data collection and were dynamic in both space and time were likely to be viewed more favourably by the European Commission than voluntary area closures (which provide little evidence for assessment);

(iii) KEIFCA, in the medium term wanted to understand discard survival of thornback ray for possible survival exceptions under the reformed CFP. In the longer term they wanted to explore a discrete, regional thornback ray TAC, distinct from the generic North Sea skate & rays TAC;

(iv) Wm Morrison Supermarkets Plc wanted to support and build the supply chain of Thames Estuary thornback ray.

For the future, Cefas proposed a fisher-led initiative with short-, medium- and long-term components. The aim would be to provide the best immediate benefits to industry, whilst simultaneously building towards the evidence-base required to underpin full scientific assessment.

Short-term: Lead by fishermen, and for the best immediate benefits to the under 10m fleet operating in the Thames Estuary, production of a consumer 'friendly' Thames thornback ray fishery publication. Highlight fisher engagement with science, data collection, and commitment to sustainable management. Material to be used in outreach work with NGOs, promoting underpinning science to retailers committed to sourcing sustainable seafood products.

Medium-term: A fisher-focused pilot project, collecting fishery dependant thornback ray catch data at low cost, reporting in real-time. Gage the suitability of real-time reporting and spatial/temporal avoidance. This would allow fishers to increase

efficiency by either effectively filling quotas or by eliminating lost-time through discarding by avoiding aggregations. In addition, the fisher-led data collection would supply the evidence-base required for future assessments of the fishery.

Long-term: Drawing on the fisheries-dependent catch and landings data collected over the course of the medium-term component of this initiative (above), plan and execute a full assessment of the Thames Estuary thornback ray population.

4. Recommendations

The collective outputs from Shark By-Watch UK clearly underline that further work is required to fully understand the levels and occurrence of interactions between threatened elasmobranchs and fishing gear, leading to by-catch and dead discards. With more information on elasmobranch distribution and incidences of elasmobranch by-catch in UK waters, real, practical steps can be taken to reduce unwanted fishery interactions – protecting both fishers (from potential gear damage, time taken to disentangle by-caught species, and un-saleable catch) and the species themselves.

Opportunities for reducing elasmobranch by-catch centre around better understanding species distributions in space and in time, and investment in the testing and use of new, innovative, gears, technologies and approaches to management.

A) Priority species

Shark By-Watch UK has identified a number of key areas for further consideration and research around the key species which were the focus of the September 2016 Shark By-Watch UK by-catch workshop (see section B2). These suggested measures and areas of focus were identified and debated during the workshop by participatory group discussion between fishers, scientists, NGO staff and other fishery stakeholders.

Common skate

To reduce by-catch of common skate, potential modifications to towed commercial fishing gear (i.e. otter trawl) were more easily identified than for static gear (i.e. gill nets). These included the possible use of selectivity grids and the removal of tickler chains on towed gear.

A fisher-focused code of conduct detailing the best practice for handling and releasing common skate was identified as a suitable method to promote 'live' discarding. The uptake of a code of conduct by the fishing industry could be incentivised by the prospect of positive economic advantage by adopting best practice – for example a dedicated 'ecolabel' indicating where fisheries products are supplied by vessels adhering to such a code of conduct.

The collation of all available datasets for these species (e.g. all tag, observer, sightings and strandings data) to better understand movements, behaviour and distribution was also seen as an essential research priority.

Large sharks - Basking sharks and porbeagles

The large size of basking sharks and porbeagle was seen as an advantage when considering solutions to reduce by-catch of these species in fixed, static commercial fishing gear, such as gill nets.

Fine monofilament mesh and individual panels joined by weak links to allow by-caught sharks to break-through and/or break free of entanglement in static gear was seen as a feasible approach for further consideration.

A further modification for consideration in reducing entanglement of basking sharks in creel ropes at the sea surface was the use of weak links in tensioned, non-buoyant creel ropes.

Another solution identified was to develop a self-reporting spatial avoidance scheme, with fishers reporting their basking shark or porbeagle by-catch. This would identify real-time bycatch 'hotspots' to avoid, which could be shared with the rest of the fleet.

The collation of all available datasets for these species (e.g. all tag, observer, sightings, and strandings data) was identified as an essential research priority, to further understanding of their behaviour, movements and distribution.

Spurdog

A selectivity grid was identified as a potential, viable gear modification to reduce spurdog bycatch in towed commercial fishing gear. For the demersal longline fishery, attraction devices such as electric decoys were considered a potential option.

A current UK trial was supported as an approach to reduce spurdog fishing mortality – a real-time, self-reporting spurdog by-catch avoidance scheme in which industry participants report, and subsequently avoid spurdog by-catch hotspots through avoidance measures for relatively small areas, and for limited periods.

Essential research priorities were identified: to quantify spurdog by-catch throughout the UK and to investigate long-term discard survival, through the deployment of electronic tags using a participatory tagging programme.

B) Areas for future work

Participatory discussions with industry, science, policy representatives, NGOs, retail, and the wider supply chain, have highlighted the need for more, in-depth, research into measures for avoiding by-catch of threatened elasmobranchs. A number of innovative potential solutions to this environmental and economic issue have been identified. The Shark By-Watch UK project now believes the following areas need to be prioritised in future research around shark, skate and ray by-catch.

Ensure science and industry work together to make best use of the full range of knowledge and expertise available.

The Shark By-Watch UK project has been built upon participatory research principles; an inclusive method which has put fishermen and fishing communities at the heart of the project's work on elasmobranch by-catch. For participatory methods to work, equal credence must be given to the full range of 'knowledge types' involved in a research project.

Trial innovative technologies

A range of advancements in fishing technology may help prevent or reduce elasmobranch interaction with fishing gear. Innovations such as grids, deterrents, decoys and line modifications may be part of the solution to reducing by-catch of threatened sharks, skates and rays in UK waters. However, these technologies need to be proven before they can be disseminated on a scale that will impact overall rates of by-catch. With this in mind, rigorous trialling of these technologies, with participation from willing fishermen, will provide a greater understanding of how they can best contribute to by-catch reduction, and will secure broader uptake in the long term. Of particular relevance to UK fisheries in the Celtic Sea are the following recommended trials:

(i) Fine monofilament mesh and individual panels joined by weak links to allow bycaught porbeagle and/or basking shark to break-through and/or break free of entanglement in static gear.
(ii) The use of selectivity grids in otter trawls to allow common skate to escape capture.
(iii) The use of weak links in tensioned, non-buoyant creel ropes, preventing basking shark entanglement at the sea surface for creel fisheries around the Western Isles of Scotland.

Development of alternative management approaches

To be considered alongside innovative gear technologies are alternative approaches to fisheries management to lessen the likelihood of unwanted elasmobranch by-catch. In partnership with Shark By-Watch UK 2, a real-time Spurdog By-catch Avoidance Programme is being trialed in the offshore gill net fishery operating from the southwest of the UK, in the Celtic Sea. The trial is adapting a previously used format of Real-Time Closures (RTCs) for cod in the North Sea, and the highly successful real-time by-catch avoidance system in the US scallop fishery, allowing industry participants to avoid significant spurdog by-catch by adapting their fishing patterns and behaviour. If the trial is successful, two additional UK fisheries have been identified where similar approaches could be developed:

(i) Southern North Sea (ICES Division IVc): The under-10 metre, demersal long-lining fleet in the southern North Sea primarily targets cod (*Gadus morhua*), thornback

ray and bass (*Dicentrarchus labrax*). However spurdog is sufficiently common in the southern North Sea, both locally and seasonally between November and April, that the level of by-catch and discarding is significant.

(ii) Western Isles waters (ICES Division VIa): the nephrops bottom trawl fishery around the Western Isles of Scotland (Sound of Raasay and Inner Sound) experiences regular spurdog by-catch episodes during the period between October and January.

Full utilisation of existing and novel data sources.

Better data leading to a more comprehensive picture of elasmobranch populations in UK waters is vital in both reducing discards of threatened sharks, skates and rays, and in determining sustainable catch levels in targeted elasmobranch fisheries. On-going research in this area is crucial to ensure the health of elasmobranch populations.

Two recommendations to increase available data are:

(i) Collation of all available basking shark datasets (e.g. all tag, observer, sightings, and strandings data) could be used to identify 'hot-spot' areas for basking sharks off the Western Isles, Irish & Celtic Seas.
Using Vessel Monitoring System data and fisher knowledge, areas for potential basking shark - fishermen interactions could be identified, raising awareness and pre-empting voluntary avoidance of these areas by commercial fishing vessels, reducing unwanted by-catch.

(ii) Shark strandings offer a novel opportunity to collect biological data and samples to further our understanding of sharks. Although shark strandings are encountered by the UK Cetacean Strandings Investigation Programme (CSIP), there is no coordinated strategy for collecting stranded shark data and biological samples, other than for basking shark, like that available for cetaceans. The inclusion of all stranded sharks into CSIP offers a unique opportunity to collect data for sharks such as porbeagle, which due to their prohibited status can no longer be collected by traditional means – i.e. they can no longer be caught and landed for scientific study.

Understanding long-term discard survival for the reformed CFP

To quantify whether live-discarding of sharks, skates and rays is more beneficial to the overall population of these species than retaining by-caught individuals on board as part of the landing obligation, clear evidence is required. Defra is working to gather sufficient evidence to support 'high survivability exemptions' for when elasmobranch species are included under the landing obligation. It is important that scientists and fishermen continue to work together in gathering the necessary evidence. Tagging programmes can be used to

determine levels of post-discard mortality to help develop a clearer picture of the potential benefits of live-discarding.

Unlike short-term tank based studies, tagging live discards with electronic tags can quantify the increased levels of predation and long-term stress or injury-induced mortality that may be associated with the 'live' discarding process. These data could be used to help quantify the impact that the commercial fishing sector has on threatened elasmobranchs, and quantify long-term discard survival.

5. CONCLUSIONS

By incorporating stakeholders from a range of backgrounds in the Shark By-Watch UK 2 project, we have achieved a better understanding of the discard survival of a range of commercially important elasmobranchs of conservation interest for consideration in CFP reform.

We have reviewed innovative technology with the potential to reduce by-catch and dead discarding, and identified a number of clear priorities relevant to threatened UK sharks skates and rays, which simultaneously promote local management.

In particular, Shark By-Watch UK has worked with stakeholders in the Thames Estuary thornback ray fishery to scope alternative fisheries management techniques to promote sustainable exploitation, local management planning and a sustainable supply chain, with the aim of minimising regulatory discards and in line with the aims of the reformed CFP.

By involving all relevant stakeholders, especially fishers, Shark By-Watch UK has developed significant buy-in to the recommendations presented here. Consequently, the momentum for future engagement in taking forward the recommendations presented is significant, notably for those that involve the fishing industry in gear trials.

6. EXTENT TO WHICH THE PROJECT AIMS HAVE BEEN MET

(a) *To develop and promote strong partnerships between fishermen, scientists, fishery managers, food retailers and NGOs, forming a nationwide consortium to promote greater awareness and knowledge of regional elasmobranch stocks and conservation issues*;

Building on the success and relationships established under the original Shark By-Watch UK project, Shark By-Watch UK 2 continued to promote and expand an engaged participatory network, through targeted meetings, workshops and events. The outputs from all Shark By-Watch UK 2 have been widely disseminated following the Shark By-Watch UK 2 Communication Plan (Annex 1). Project aims met in full.

(b) *To provide information on the current levels of elasmobranch discarding in a number of fisheries around the UK*;

Fisher-led surveys in the Bristol Channel, The Wash and the Thames Estuary have provided new data on elasmobranch discard levels. Project aims met in full.

(c) *To develop best practice on elasmobranch handling and provide evidence of the potential value of live discarding of elasmobranchs in mixed and targeted fisheries*;

Best practice in elasmobranch handling has been discussed at regional workshops, and reinforced during on-board fisher-training on those vessels commissioned for additional survey work. The tagging of by-caught elasmobranchs will ultimately provide evidence of the effectiveness of live discarding. Project aims met in full.

(d) *To map the distribution of commercially important species and identify the characteristics of their essential habitats*;

Fisher knowledge and survey data used to describe distributions of skates and rays in the Bristol Channel and additional survey data to describe thornback ray distribution in the Thames. Habitat mapping in the Bristol Channel, The wash and the Thames Estuary (Annex 2-4). Shark-sighting data to identify basking shark hotspots on the west coast of Scotland. Project aims met in full.

(e) *To trial new technologies to reduce unwanted by-catch of threatened and endangered species in mixed fisheries*;

Real time spurdog by-catch reporting tool (Annex 7). Project aims met in full.

(f) *To bring stakeholders together to evaluate ICES and EU advice on the management of elasmobranchs in the Thames Estuary, and develop a proposal for a viable regional management plan*;

Thames Estuary Shark By-Watch UK 2 consortium activities culminating in short-term, medium-term and long-term priorities to take forward sustainable, regional,

fisher-led management of the Thames Estuary thornback ray fisheries. Project aims met in full.

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8. REFERENCES

Catchpole T.L and R. Enever (2007) Discard survival rates of commercially caught ray, Final Report, Cefas, Lowestoft, UK.

Ellis J.R., Cruz-Martinez A., Rackham B.D. and S.I. Rogers (2004) The distribution of Chondrichthyan fishes around the British Isles and implications for conservation, J. Northw. Atl. Fish. Sci, 35: 195-213

Gondra, J. R., Artetxe, I., & de Zarate, A. G. (2008). Implantación del plan de de recuperación del atún rojo en el País Vasco. Sustrai: revista agropesquera, (83), 62-64.

Kraak, S. B. M., Buisman, F. C., Dickey-Collas, M., Poos, J. J., Pastoors, M. A., Smit, J. G. P., ... & Daan, N. (2008). The effect of management choices on the sustainability and economic performance of a mixed fishery: a simulation study.ICES Journal of Marine Science: Journal du Conseil, 65(4), 697-712.

Martin C.S., Vaz S., Ellis J.R., Lauria V., Coppin F. and A Carpentier (2012) Modelled distributions of ten demersal elasmobranchs of the eastern English Channel in relation to the environment, Journal of Experimental Biology, 418-419: 91-103