SIFIDS

Scottish Inshore Fisheries Integrated Data System

Work Package (5) Final Report

Identifying fishing activities and their associated drivers

Including: Northridge et al., APPENDIX 1 – Review of the Role of Fisher's Knowledge

Project code: WP00(05) SIFIDS

EMFF: SCO1434

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EXECUTIVE SUMMARY

The purpose of this Work Package was to:

1. Define fisher derived data collection parameters.
2. Identify and if possible, develop a quality assured system for the collection of fisher derived anecdotal and experiential information.
3. Develop an appropriate sampling design/method that could be streamed to a relational data resource.
4. Develop risk based management strategies.
5. Investigate applicable techniques/strategies for 'change management' regarding accurate voluntary reporting by the industry.

The following recommendations have been made in relation to the above objectives.

Recommendation 1 – Recognise the limitations of snap shot surveys of fisher's knowledge but, where possible, seek to operationalise the result through statistical modelling as undertaken under WP8b of the SIFIDS project.

Recommendation 2 – To improve the capture of fisher's knowledge, embrace the use of mobile phone App technology to engage a greater number of fishers, over wider geographic range and longer time scales.

Recommendation 3 – Ensure that Apps are available in formats that are compatible across both Android and IOS platforms.

Recommendation 4 – A longer and more geographically dispersed App trial should be conducted to assess the potential to cultivate a community of "responders" whose data is likely to be more consistent and reliable. Novel ways, including feedback and incentives to retain such a community over time should be explored.

Recommendation 5 – Further use of Apps to capture useful data based on fisher's knowledge must go hand in hand with the development of statically robust forms of analyses that can account for the inherent biases that arise from the collection of citizen science data.

Recommendation 6 – Specific citizen science data collection campaigns and events should be initiated once a stable App platform has been established to help kick start the widespread use of the App.

Recommendation 7 – Future App development should seek to embrace some of these suggestions made by stakeholders involved in this work package as they could potentially increase efficiency and traceability.

Recommendation 8 – From a fisheries management, compliance and marine planning perspective, a universally deployed App could provide a medium to engage fishers directly, providing a rapid and cost-effective means of disseminating information and seeking feedback.

Recommendation 9 – Future App development should take place in the context of an open source environment, allowing others to help improve and expand the utility of the App and derivations thereof.

Recommendation 10 – Further refinement of the App would be worthwhile to improve the functionality of FISH1 data collection, building in fail-safe's to prevent inaccurate or spurious data submission. Fishers should be able to access the data they submit in the form of summary statistics and graphs that help them gain a better understanding of their own operational performance.

Recommendation 11 - Increasingly, behavioural insights are being used to help influence decision making and we would recommend that the use of these techniques be further investigated as a means of changing behaviours in all key stakeholders.

Defining fisher derived data collection parameters.

A general review of the role of fisher's knowledge (FK) in fishery management and conservation in Scottish small scale fisheries is provided in Appendix 1. The review looks at examples of the way that fisher's knowledge in the broadest sense is collected and in some cases used and comments on some of the constraints in obtaining and using these data. In conclusion, the review suggests that some rethinking around the issue of fishery access control may be required. Most importantly, all previous work suggests a more positive involvement from fishers when mechanisms are put in place to ensure the development of personal relations between individual scientists, managers and fishers to grow and develop trust and understanding.

From a practical perspective, this Work Package has engaged fishers in face to face interviews (both structured and unstructured) and attempted to collect fisher observations through the use of a mobile telephone application (App) to assess its utility as a means of structuring the collection of fisher's "knowledge" in a day to day basis.

The collection of FK through face-to-face interviews may be of limited value if unstructured. This is also a time consuming and potentially costly means of secure such data. The collection of FK with respect to observations of protected, endangered and threatened species (PETS) or other species together with data related to operational experience requires a means to collect data across the full spectrum of the fishing community in a structured manner.

Identifying and if possible, developing a quality assured system for the collection of fisher derived anecdotal and experiential information.

A prototyopic mobile phone App developed for the SIFIDS project provides a mechanism to achieve structured data collection cost effectively an industry wide scale. Combining statutory data provision alongside non-statutory (voluntary) data acquisition appears to be a way of encouraging both compliance in terms of timely reporting of Fish1 Form data and the volunteering of experiential data. Encouraging fishers to volunteer information equates to "citizen science" and the value of these data are limited even if collected in a structured format. In order to provide a statistically meaningful interpretation, fishers would need to record observation according to an agreed sampling strategy.

Developing an appropriate sampling design/method that could be streamed to a relational data resource.

A statistically meaningful number of fishers need to record both presence and absence of all key species for a specified time period. A stratified random sampling protocol could be developed to achieve this objective. However, the nature of the species, seasonality and rarity will impact on the sample size required. Where possible, a number of trained observers should also record the same data for the same time period with a view to providing some measure of quality control to the process.

Structured data acquisition conducted in the context of a statistical framework (even if a non-probabilistic) could, over time, begin to show patterns that could then be used to develop risk indices for different species and different kinds of interaction.

By encouraging fishers to record observations more generally also has some value in that it may help to guide the development of more targeted sampling to identify specific aggregations of migratory routes for example. Feedback from some fishers suggested that they were more likely to record observations of unusual sightings rather that species that they would typically see. Whilst there is an inherent bias in such data, it should not be dismissed, but viewed in the context of data collected in the more statistically robust scenario outlined above.

Developing risk based management strategies.

The collection of voluntary data through an App cannot, in isolation, be guaranteed to provide an unbiased sample upon which objective and defendable management should be based. Not withstanding this limitation, at present, we have little information on the status of many PETS or their interaction with fisheries either as proximal observations or direct interactions with fishing gear through entanglement or predation on the catch. A reasonable, consistent approach to the collection of fisher observations could generate much needed data to inform further more targeted research using appropriate experimental controls. As the volume of observational data increases, patterns will inevitably emerge which will help to refine the way such data is collected and analysed. Anomalies and outliers will become more obvious, including individual observer bias.

Observer bias could perhaps be reduced by providing fishers with training in making observations and identifying key species. As with the proposed development of a reference fleet for the collection of verifiable fishing activity and biological data on catch, discards and bycatch, there could be merit in having some form of accredited and trained fisher observers.

Investigating applicable techniques/strategies for 'change management' regarding accurate voluntary reporting by the industry.

Critical to the success of all citizen science activities is feedback to the participants. The level and type of feedback may vary depending upon the target group. A regular summary of the collated results of observations may serve to encourage a sense of "community" amongst those submitting observations. With community comes a degree of peer pressure (even if self-imposed) to continue to submit observations. It is also possible to provide more personalised feedback in direct response to the observation(s) that an individual submits. This could range from a simple acknowledgement via email or social media with a summary of the data that an individual has submitted to more complex responses which interrogate other sources to note other similar or local observations perhaps in near real time.

The ability to use artificial intelligence applications to generate "natural language" could provide a powerful feedback stimulus to encourage ongoing reporting of observations. Fishers often work in quite isolated circumstances and are involved in repetitive tasks – often in challenging weather conditions. Experience of observing fishing vessels and crew members would suggest that they spend a considerable proportion of their non-active fishing time interacting with their mobile phones. Providing “observation” alerts, interesting facts and images could further increase engagement in recording observations.

The recording of negative interactions with PETS, such as entanglements is a sensitive issue. Some fishers during the course of our research were prepared to share experiences of entanglement.

Critical to encouraging consistent reporting of observations over time and with minimal or at least quantifiable bias is the need to understand the behaviours and motivations of fishers. The “Individual, Social, Material” (ISM) model is assessed as a tool for contextualising and developing practical solutions to bring about behaviour and systems change needed to encourage fishers to provide observational data.

The use of observational data is of course only part of the potential contribution that FK could deliver in a fisheries management context. The medium of mobile technology and communication could help to engage fishers and encourage further interaction. Critically, fisher’s need to see that the data they provide is feeding into a management system that is responsive and that they feel party to – rather than simply a compliance system linked to top down governance and enforcement. The wider collection, use and visibility of data designed to support sustainable fisheries management will increase transparency and trust between fishers, managers, scientists and other key stakeholders.

CONTENTS

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CAPTURE AND INCORPORATION OF EXPERIENTIAL FISHERIES DATA INTO FISHERIES MANAGEMENT

1. INTRODUCTION

There is a significant potential fisheries data resource existing in the form of fisher derived anecdotal and experiential information: fisher knowledge (FK). These data can potentially be used for: informing management of target species; supplementing physical environmental observations such as distribution of habitats; informing environmental management and protection and; increase engagement of fisheries and environmental science as "citizen scientists". This resource remains largely untapped by the fisheries management and science communities due to the inherent difficulties in capturing, verifying (i.e. Quality Assuring) and parameterising this type of data. There is also the key issue of the perception of the industry (i.e. individual fishermen) to requests, by fisheries management organisations and policymakers, for information. Critical is the widely held opinion that any information volunteered by fishers will ultimately be utilised by the management regime to the detriment of the industry. For accurate information to be supplied willingly there is a requirement to dispel the perception of a 'negative feedback loop' regarding the provision of reports on, for example, the bycatch of cetaceans and other Protected, Endangered and Threatened (PET) species.

This WP seeks to improve our understanding of the impact of inshore fisheries on PET species by evaluating ways in which the level of impact can be quantified and developing strategies for mitigating these impacts. The collection of other data streams relevant to wider environmental considerations are also examined from a practical perspective. From previous literature reviews, it was expected that protected and non-target species interactions with lobster and crab creels mainly include whale entanglement in creel lines, seals removing bait, bycatch of certain types of fish such as wrasse, gobies and other crustaceans species and there is a potential for diving bird bycatch. Sightings on mammals, birds and turtles could potentially be collected. Other FK data such as the high prevalence of shellfish disease indicators (for example, shell necrosis in brown crab), under-sized juveniles, prevalence of infection in Nephrops, or egg bearing females would be of value to fishermen, allowing them to focus fishing effort away from areas with the highest prevalence of such zero/low value stock.

This WP assessed ways to improve the level of data collection, complemented by the addition of fisher's knowledge and reporting. Subject to discussion with fishers and feedback from WP4 of the SIFIDS project that was designed to collect social, cultural and economic data from the fishery, a mobile telephone application (App) was developed to capture fisher's observations and fisheries related biological data. An examination of the potential risks and weaknesses of the proposed approach is provided as well as mechanisms of quality assurance and ways of altering the perception of fishermen to requests for data of this type. The ability to collect and parameterise this information with respect to vessel activity and landings data (within the data resource developed under WP6 and WP8b) would be of great value in developing bycatch 'risk maps' for Scottish inshore waters. Such risk based management would assist Marine Scotland in monitoring, and minimising, the bycatch of cetaceans, seals, seabirds and other PET species as required to achieve Good Environmental Status (GES) under the Marine Strategy Framework Directive or as part of good environmental governance under any proposed changes to legislation which may occur post Brexit. These data may also be of value in informing accreditation assessment and audit for organisations such as the Marine Stewardship Council.

In addition, part of WP5 has been incorporated into WP8b of the SIFIDS project whereby 117 inshore fishing vessel skippers were surveyed, some volunteering to be surveyed twice in winter and summer giving a total of 132 sea trips, to gain an understanding of the experiential drivers influencing fishing behavior i.e. if, when and where fishers decide to fish. These drivers were classified and used to develop a basic statistical model that can predict fishing activity under a given set of circumstances – principally weather related (see WP8b report[1]). Augmented with further data, the predictive capability of such models could improve and help to inform decision making in the future.

Tapping into the knowledge of fishers (FK) as part of a co-management approach to fisheries is gaining traction in artisanal fisheries globally. However, capturing such information in a manner that is useful and consistent with sound decision making is challenging. Fishers are, for logistical reasons, often reluctant to engage with the process of sharing knowledge in a formal context. There is also the perception that by sharing their knowledge and experience, they are giving away valuable information that others may use to profit or use to the detriment of the industry.

Managers and decision makers may also remain sceptical about the value of the information provided in the form of anecdotal experience and in ways that are inconsistent with objective analyses.

However, the collective knowledge and experience of the fishers can play a significant and positive role in providing data that, with obvious caveats, can be used to inform decision making. Perhaps more importantly, the process of acquiring this information engages fishers and helps legitimise the experiences that they wish to be taken into account in fisheries management.

The purpose of this WP was to gain an understanding of what experiential knowledge fishers had and were prepared to share. Following on from this, to consider potential approaches to collecting such information in a reasonably consistent manner and in ways that would facilitate the ongoing collection of such data to reflect changes over time and increase the body of data to analyse. A review of types of FK and the experience elsewhere in capturing FK is reviewed in Appendix 1.

2. OBJECTIVES

1. Definition of fisher derived data collection parameters.
2. Identification/development of a quality assured system for the collection of fisher derived anecdotal and experiential information.
3. Development of an appropriate sampling design/methods that can be streamed to the relational data resource.
4. Development of risk based management strategies.
5. Investigation of applicable techniques/strategies for change management regarding accurate voluntary reporting by the industry.

[1] Course G.P. Pasco G.R., Royston, A. and R. Ayers, 2018. Scottish Inshore Fisheries Integrated Data System (SIFIDS): ON-BOARD OBSERVERS. Published by MASTS. 45pp.

3. APPROACHES

Objective 1: Definition of fisher derived data collection parameters.

With reference to Objective 1, the intention was to conduct a minimum of four workshops and 40 individual interviews with fishers. The primary function of these workshops and interviews was to define fisher derived data collection parameters (what observational data could be collected and collated for analysis).

Discussions with various stakeholders at the start of the project led to the conclusion that it would be unlikely that we would be able to successfully convene the proposed workshops with sufficient industry participation to deliver meaningful results. The focus therefore shifted to securing individual interviews with fishers. WP4 of the SIFIDS project led by SAMS Research Services Limited and Imani Development was committed to undertaking a series of interviews with fishers to collect social, cultural and economic information to populate a sustainable livelihoods analysis of the Scottish Inshore sector. It was agreed that data relevant to fisher's knowledge and experience related to the "impacts" of fishing would be recorded as part of the WP4 survey work.

A total of 45 semi-structured interviews were conducted. The qualitative data from the surveys informed the design of a quantitative online questionnaire that was administered throughout Scotland's fishing communities. Self-selection sampling was chosen as the project team wanted participants, whether individuals or organisations, to choose to take part in research of their own accord, 133 fishers completed the survey. The survey was also used to elicit further information (see WP4 methods[2]). The Sustainable Livelihoods Approach (SLA) was chosen as the most appropriate framework, as it identifies that there are both tangible and intangible components of a livelihood, which are critical to its sustainability and risk resilience.

In addition, a review of available literature related to the collection and use of FK in fisheries management was conducted, with a view to informing or understanding of the need to link FK with management practice.

Although reported under WP8b, a series of 130 interviews with vessel skippers were conducted by on board observers with a view to identifying drivers of fishing behaviours.

Objective 2: Identification/development of a quality assured system for the collection of fisher derived anecdotal and experiential information.

Subject to feedback from initial interviews of fishers conducted a part of WP4, where fishers had been invited to share experiential information it was clear that conventional survey and interview methods were unlikely to yield useful, consistent or contemporary experiential data. The ability to capture information through mobile phone Applications (Apps) is now well established. One of the concerns raised by both fishers and Fishery Officers was the inefficient collection of landings information from fishers through the use of FISH1 Forms often completed by hand and submitted by

[2] Billing, S-L., Anderson, S., Parker, A. Eichhorn, M. Vare, L.L. and Thomson, E. (2018) Scottish Inshore Fisheries Integrated Data System (SIFIDS): Assessment of Socio-economic and Cultural Characteristics of Scottish Inshore Fisheries. Published by MASTS.

vessel owners on a weekly basis. Developing a mobile App which would incorporate an electronic version of the FISH1 Form together with the potential to gather other experiential information was therefore chosen as a method for engaging with fishers and encouraging them to provide observations and insights into interactions with protected, endangered and threatened species (PETS) together with any other observations that fishers may elect to submit using the App.

A prototypic App was developed in Android. The App code was deposited on GitHub (https://github.com/StAResComp/sifids) and initially only made available for testing and feedback to a select group including Marine Scotland Compliance Staff, Fishery Officers, Scottish Natural Heritage representatives and the project Facilitators. The App was iteratively refined based on this feedback to the point where a working prototype was made available to a number of fishers who were invited to participate in controlled trial of the App. In parallel with this the Facilitators engaged with a number of Fishery Offices who would be the recipients of App data from the fishers selected to participate in the trial.

The fishers were provided with a Participant Information sheet, a Coded Data Consent Form and subsequently a Debriefing Information sheet (see Appendices 2, 3 and 4) The collection of this survey material was approved through the University of St Andrews Research Ethics Committee.

Fishers participating in the trial use of the App were selected on the basis that they had taken part in other aspect of data collection within the SIFIDS project or because they had expressed an interest in testing the App.

App design and specification

When designing the SIFIDS FISH1 mobile phone Application (App) key design features the App had to include:

1. be compliant with Marine Scotland legal requirements for FISH1 submissions from the under-10 m vessels (see Appendix 6 example FISH1 form);
2. include a feature that would allow fishers to submit wildlife observations either at sea or afterwards; and
3. use open-source software to code the App.

Additional features included were:

1. systems to provide the fisher with records of their submitted FISH1 forms;
2. systems to save the fisher time when completing FISH1 forms; and
3. a tracking feature for fishers to record where they have been at sea, using the mobile phones internal Global Navigation Satellite System (GNSS) receiver.

Marine Scotland were consulted to ensure the FISH1 form produced was of a format that would be acceptable, understood by Fishery Officers receiving the forms and the data could easily be transferred to the COMPASS database.

Consultation with Scottish Natural Heritage (SNH) provided the key marine wildlife species of interest for fishers to record if seen at sea.

The coding for the App was written by members the University of St Andrews (USTAN) Research Computer Team. After discussions with the Computer Team, it was decided that, in the first instance, creating an App for Android devices, including tablets, would be quicker due to the availability of published open-source coding and the ability to disseminate the App without having to use an Apple iOS platform. All code is stored on the open-source, online community platform GitHub. The App was free to download.

All data generated by the App, including consent forms from participants, were stored on a secure USTAN server and sent electronically to the appropriate recipients (Figure 1). FISH1 forms were sent via email from the App to the nominated local Fishery Office, USTAN and the owner/skipper in CSV format. For the vessel tracking data, these remained on the App and could be reviewed by fishers by selecting dates on the map feature. GNSS data was also automatically forwarded on USTAN. Wildlife observations were sent to USTAN only via the App.

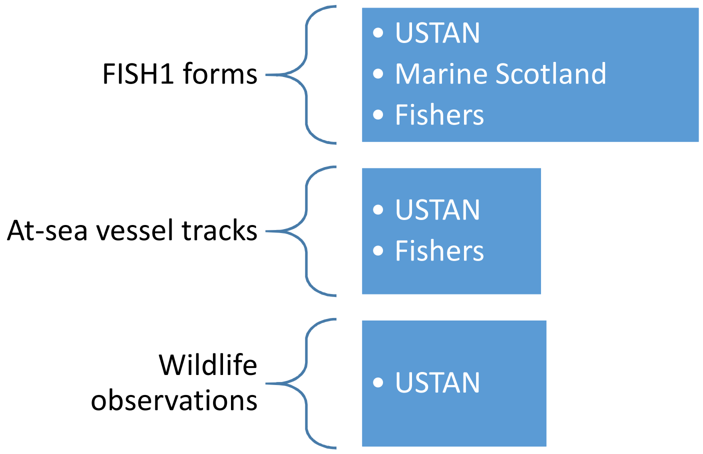


Figure 1. SIFIDS FISH1 App outputs and data recipients

Providing fishers access to their tracks and FISH1 forms submitted via the App was an important feature to include as it offered a novel feedback loop to fishers and a chance to review their historic records. As the vessel-owner is legally responsible for submitting FISH1 forms, their email address was automatically included when the completed form was sent to the selected Fishery Office to provide them with a record or what had been submitted. Details of the appropriate Fishery Office and owner/skipper were saved in the App's Settings feature (discussed below). Submitted forms were also stored within the App and sent to USTAN (Figure 2a).

The design of the App was informed by the desire of fishers to have an electronic means of compiling and submitting their landings data on a FISH 1 form which is a legal requirement and must be completed on a weekly basis. Their completed FISH1 Forms are submitted either manually or via an online form to their local Fishery Office, where the data on the form is transcribes, checked and submitted to the Marine Scotland COMPASS data base to be used for statutory compliance and reporting purposes.

By providing a convenient means of completing and submitting the FISH1 form, it was anticipated that fishers would be prepared to use other non-statutory reporting functionality provided by the App including the reporting of observations and recording their vessel tracks.

Fishers selected to participate in the trial were provided with instructions on how to download the App from the GitHub repository and install it in their mobile telephones. An online video describing the functionality of the App was provided on the MASTS website during the trial and the project

Facilitators were also available to assist. A Frequently Asked Questions (FAQ) document was created and sent to fishers who wished to use the App together with the download link, all of which was available on the SIFIDS website during the trial (https://www.masts.ac.uk/research/emff-sifids-project/).

Once installed, the opening screen of the App provided the terms and conditions for the use of the App. In order to proceed to the data input or acquisition screens, the fisher had to agree to the terms and conditions (Figure 2). Full text of the terms and condition are provided in Appendix 2.

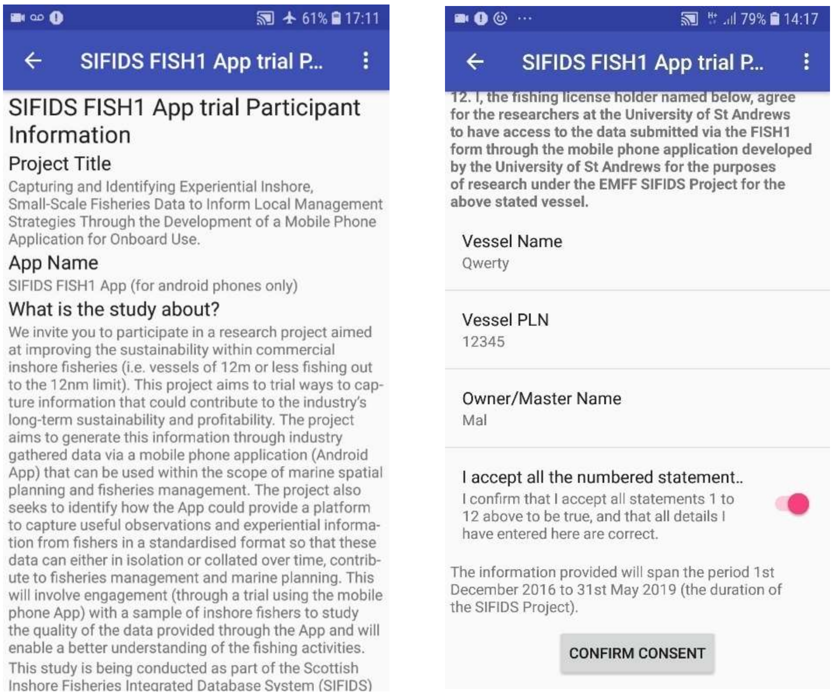


Figure 2. The SIFIDS FISH1 App – Terms and Conditions confirmation page

Subject to the submission of the automated agreement, the user of the App was presented with an input form based on FISH1 form data requirements, together with two buttons inviting the user to start recording their fishing track and the start and end of gear deployment or recovery (Figure 3a). Positional data was recorded every 60 seconds and forwarded to the University of St Andrews SIFIDS database every 3 minutes.

As highlighted above, a key aspect of the App was to save fishers time in their production of FISH1 forms. This was incorporated into the App by creating a Settings page to store all details required to populate the FISH1 form that would be used repeatedly by the fisher (Figure 3b).

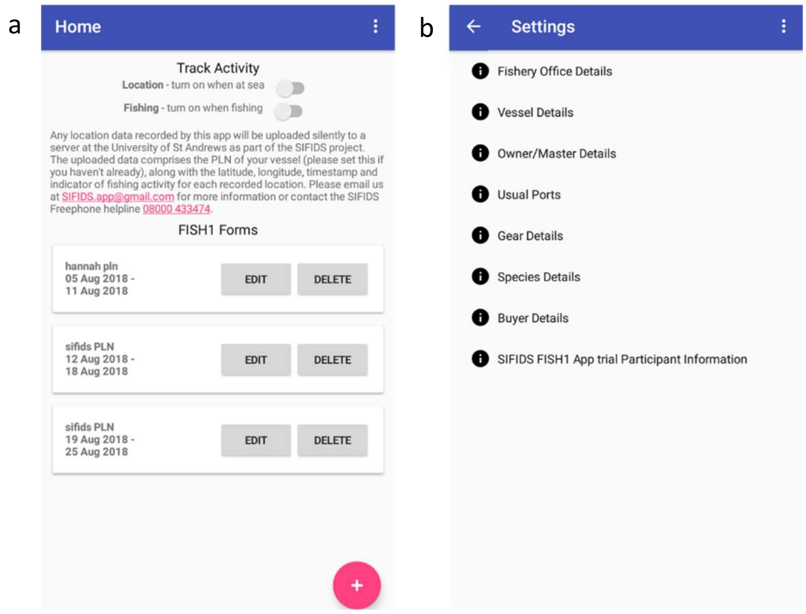


Figure 3. The SIFIDS FISH1 App (a) Home page featuring vessel tracking buttons, disclaimer and previously made FISH1 forms with PLN and representative week (dummy data), a new FISH1 form could be created by selecting the pink + in the bottom right; (b) Settings categories and a copy of the SIFIDS FISH1 App trial Participant Information

Within each Settings category the following details could be saved to pre-populate every new FISH1 form and row appropriately:

- **Fishery Office details –** all administration Fishery Offices (FOs) are listed and the user selects their local FO to automatically fill in the FO's address and email on the FISH1 form. The FO email address also automatically appeared in the "To" address box when being emailed

- **Vessel Details** – The vessels PLN and name

- **Owner/Master details** – Owner/Masters name and their address and email (optional to receive the sent FISH1 form)

- **Fish Buyer details** – Buyer, Registration of Transport Vehicle; or Live shellfish stored for later sale enter "Landed to Keep" details to pre-populate Transporter Reg. etc. field on the FISH1 rows

- **Usual Ports** – The most commonly selected Scottish ports were listed in the normal FISH1 Excel form as a drop-down menu. App users selected all their commonly used ports, these then appeared at the top of the list when completing the form. If a fisher's usual port of departure or landing did not appear in the dropdown list they had to select the nearest port, and make a note of the actual landing port in the section titled "Comment and Buyers Information".

- **Gear Details** – App users selected their most commonly used gear(s) from the approved list, these then appeared in a shortened drop-down menu when completing the FISH1 form. For fishers using pots, a total number could be saved

- **Species Details** – All species are listed when completing the form, however those saved as being mostly commonly landed in the Settings moves them to the top to save the user scrolling every time when recording their usual catch.

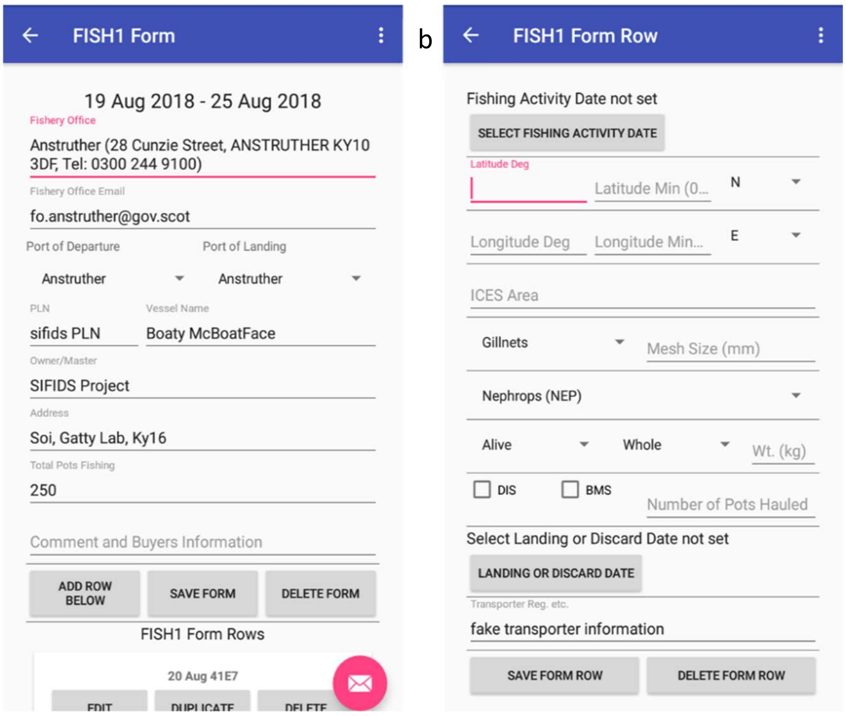
a b


Figure 4. Screenshots of the FISH1 feature of the SIFIDS FISH1 App (a) A FISH1 form pre-populated by dummy details saved in Settings and a FISH1 row at the bottom stating the date and ICES rectangle; (b) a blank FISH form row upon which Latitude and Longitude details can be automatically filled in if a date where the App's tracking feature was used or manually inputted.

When the trial began fishers were legally required to record where fishing began[3] for each species caught and if they moved into a new ICES statistical rectangle. To help save fishers time and potentially improve the accuracy of positional data recorded on the FISH1 form the App's tracker was designed to allow the fisher to indicate when they began fishing (see figure 3a). To distinguish when a fisher was at sea and when they began fishing two tracking buttons were included on the home screen of the App, Location and Fishing. When the fisher indicates they had begun fishing (Fishing switch seen in figure 3a) the App captures the phone's current temporal and spatial information and logs the latitude and longitude values with the associated ICES rectangle. These data then can pre-populate a FISH1 row for the selected day that the tracker was used (Figure 4a and b). Details can be manually inputted if desired. Furthermore, rows can be duplicated saving the fisher time if all they want to do is change one parameter such as the species caught.

The App notifies the fisher when a tracking button was turned on and off to act a reminder (Figure 5a-d). As described above, when Fishing is activated the latitude and longitude generated by the App then feeds into the FISH1 form for that day.

[3] At the time of writing the FISH1 form requires fishers to log the statistical rectangle e.g. 41E3 and Latitude/Longitude for where the majority of catch was taken

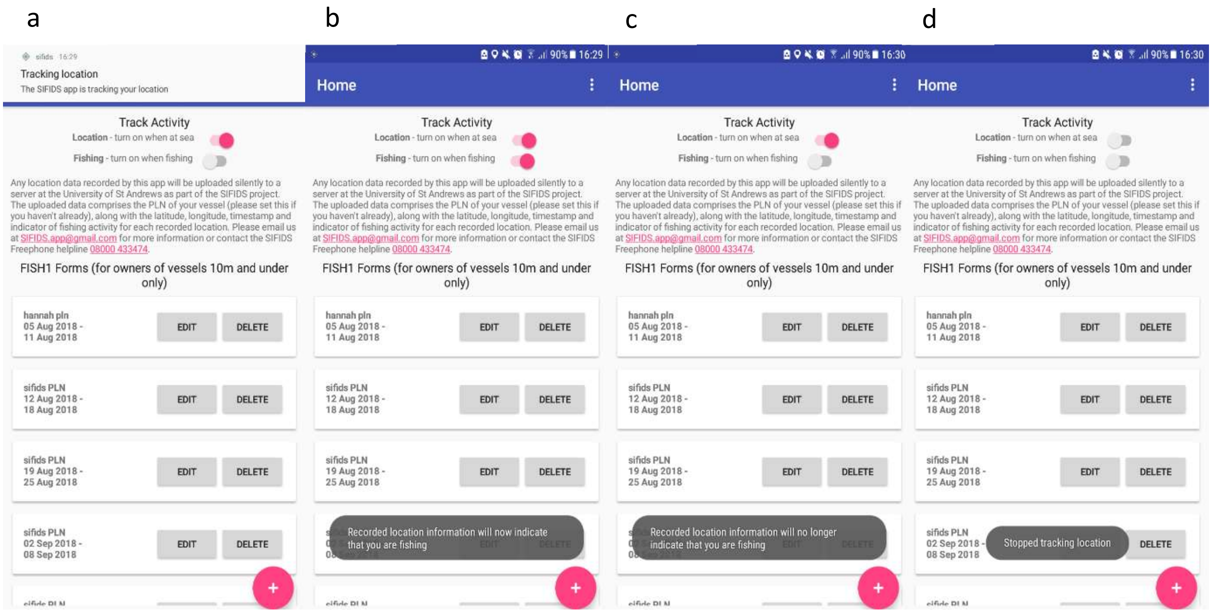


Figure 5. The SIFIDS App notifies when tracking options are activated or deactivated (a) when Location is activated the App puts a reminder in the phone's notification bar; (b) when the fisher has begun fishing the second button can be turned on confirmed by an on-screen notification; (c) When fishing has finished the fisher can either turn of Fishing first then Location or; (d) just turn of just Location for both.

N.B. The small tracking logo can be seen in the top left of figures 5b and c demonstrating tracking is turned off, the logo is not apparent in figure 5d as tracking switched off.

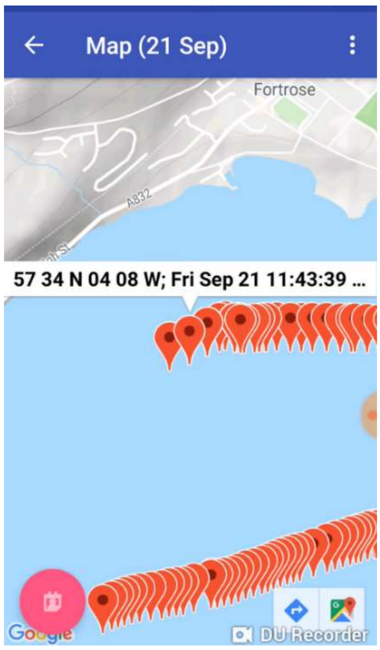


Figure 6. A screenshot of a track from the 21st of September 2018, red pins indicate a logged GPS point which when selected displays spatio-temporal data regarding that specific pin. Previously tracked days can be seen using the calendar feature seen in the bottom left.

Self-tracking was an important feature to offer to fishers as it enabled them to see their vessel tracks, whilst providing additional data to SIFIDS on both the accuracy of mobile phone GNSS systems at sea and tracks that could be linked to FISH1 data (See WP8b Report). When at-sea tracking is activated, GNSS co-ordinates are logged every 30 seconds which are represented by a red pin on the map when a recorded date is selected (Figure 6).

The Observations page of the App provided generic images of the type of animal that SNH would like to see fishers provide information on Figure 6). To help fishers who may not know specific species the first question was “What did you see?” with the following nine options which, when selected, resulted in further questions to confirm if the fisher could identify the species:

- Seal (Harbour/Common or Grey). Protected species – understanding encounter rates is of potential value in understanding seal-fishery interactions;
- Whale (Minke, Orca, Humpback, Long-finned Pilot, Sperm or Sei). Protected species that are readily identified and informing knowledge of encounter rates could inform entanglement mitigation;
- Dolphin (Bottlenose, White-beaked, Risso’s, Common, Short-beaked common, Atlantic white-sided or Striped). Protected species that is readily identified;
- Porpoise (Harbour). Protected species that is readily identified;
- John Dory. A potential indicator of sea temperature change through increase in northern distribution. Seen as a bycatch species in creels and therefore feasible for inclusion in this study;Basking shark. Protected species that is readily identifiable. Improving knowledge of encounter rates could inform entanglement mitigation;
- wrasse (Goldsinny, Rockcook, Corkwing, Ballan or Cuckoo). Seen as a bycatch species in creels and therefore feasible for inclusion in this study. This information is of potential value in relation to management of the wrasse fishery;
- Triggerfish (Balistes capriscus). A potential indicator of sea temperature increase though increase in northern distribution. Seen as a bycatch species in creels and therefore feasible for inclusion in this study;
- Octopus. A species commonly seen as bycatch in creels therefore feasible for inclusion in this study. Abundance fluctuates dramatically, seasonally and annually – a phenomenon which is regularly reported anecdotally. Observations also have relevant in conservation (understanding trends in abundance) eg cephalopods as key prey item of Risso’s dolphin.

The next question asked was where the animal(s) were seen. The App then invites the user to either select a location on a pop-up map to generate latitude and longitude values or use the phone's current GNSS (if recording at sea) location. This is then followed by a confirmation of time for the sighting. The final question logs the number of individual animals seen with the option for the App user to submit any other comments.

Figure 7. Screenshot of the Observations opening screen. The user simply touches the image of the relevant type of group of animals for which they wish to provide information. This then opens subsequent screens with invitations to provide additional information on the observation.

Methods of distribution, guidance and obtaining feedback post-trial

The use of the SIFIDS FISH1 mobile phone Application was entirely dependent on Scottish volunteer fishers (with Android phones) being willing to trial the App from 1st of June 2018 to 28th February 2019 (39 weeks). Communications promoting the App to fishers for recruitment were largely conducted by the SIFIDS Project Facilitators (WP7) with assistance from members of Marine Scotland Compliance and local Fishery Offices further distributing information. Engagement with fishers and other stakeholders began prior to the trial in March 2018 to promote the idea of the App and continued throughout the trial period until March 2019 with the collection of feedback questionnaires from fishers who used the App (Table 1). Assistance through the trial period was offered to all fishers with queries being fed from WP7 team members to both the Project Management Team and USTAN Research Computer Team for further assistance when required.

Table 1. Communication strategies undertaken by SIFIDS Project Facilitators to promote and inform the inshore fishing industry about the SIFIDS FISH1 App between March 2018 to March 2019.

Month/Year	Communication	To Who
March - July 2018	Pre-project awareness only In person Ad-hoc communications: during the recruitment of WP8 vessels RIFG Spring 2018 Newsletter	 2-day Skippers Expo Aberdeen, RIFGs, Marine Scotland Compliance Conference attendees Individual fishers, Fishing Associations (FAs), Fishery Offices (FOs) RIFGS / members, FOs
March 2018 – March 2019	In person: attending RIFG meetings across Scotland promoting the App and reporting on its usage	RIFGs / members
August - November 2018	Email and Telephone: with a flyer to explain purpose and basic functioning of the App, asking interested individuals to contact facilitators for instructions.	FAs, existing fisherman contacts (other WPs) and FOs who helped to promote
August – December 2018	Email: with download instructions, demo video, FAQ sheet, and fixes (on download issues)	Individual fishers
September 2018	Dedicated Email: SIFIDS.App@gmail.com set up for shared viewing and dedicated communications for App	Primarily for fishers but enabling shared access by facilitators / Project Management Team (PMT)
September 2018	SIFIDS Newsletter: discussing the features of the App and requesting for new fishers to become involved in the App trial	Existing SIFIDS project participants, FAs
5 October 2018 and 01/02 November 2018	In person / presentation: at Scottish Inshore Fisheries Conference and MASTS Annual Science Meeting	All delegates (targeting FOs, FAs and fishers)
October/November 2018	Harbour 'Drop-in Info Sessions': six arranged, two cancelled in favour of email circulation/FO dissemination Kyleakin: 22 Oct 2018 Arbroath: 31 Oct 2018 Tarbert: 02 Nov 2018 Campbeltown: 03 Nov 2018 Newton Stewart: email /verbal circulation by FA	Individual fishers, FA reps and FOs Attended by only 10 fishers across 4 workshops, 3 of which were >12m skippers. Remaining workshops not pursued.

	Girvan/Adrossan: no interest generated Eyemouth: Email/verbal circulation by FO	*Despite the App being a popular concept, it was not easy to get fishers to commit, esp. Android only*
October 2018	Telephone and email: Early feedback telephone interviews asking for thoughts on ease of use, problems and forward suggestions. This was used for interim reporting on project	Fishers using the App
October - November 2018	Email and telephone: communications with project leads with other Scottish inshore fishery projects	Mull Crab Inshore Fisheries Pilot and the Scottish Razorfish Electrofishing Scientific Trial coordinators
November 2018	Email: Final push to seek fishers to trial App. New visual guide/manual was created and sent out to new participants, showing elements of the App screen-by-screen and step-by-step, highlighting the essential elements of the FISH 1 form that must be completed for acceptance by FOs.	Individual fishers, sent through to involved FOs
November 2018	One-to-one contact with specific fisher: on App/IT development	Individual fisherman with an IT background that volunteered to work with PMT
December 2018 – February 2019	Email and telephone: responding to queries and downloads issues	Existing App users and fishers who expressed interest
January 2019	In person: attended Community Inshore Fisheries Alliance meeting	Meeting attendees
Mid-February 2019	Email: end of trial notice circulation and end of support notification	Fishers using or who downloaded App
February – Early March 2019	Email (repeated): seeking feedback on App via online feedback form link In person: one interview on App feedback	Users of App and those who downloaded the App

Objective 3: Development of an appropriate sampling design/methods that can be streamed to the relational data resource.

Leading on from Objective 2, the logical ambition for Objective 3, was to be able to develop a sampling design/method that could be streamed to the relational data resource developed as part of WP6 and WP8b. These objectives were partially achieved by linking the outputs from the mobile App to the relational database and integrating this data with other information (data layers) to aid interpretation and explore the potential to develop the risk based management strategies proposed under Objective 4. Whilst the mobile App provides an accessible and almost ubiquitously applicable tool that fishers could use to submit a variety of relevant data to a centralised database, there is little control over the number or frequency of observations that a fisher might choose to make. Dealing with such data in a statistical context is problematic, but some options are proposed based on experience with other forms of “citizen science” data collection.

Objective 4: Development of risk based management strategies.

In the first instance, risk based strategies were considered in the context of the appropriate and proportionate use of electronic data collection systems to satisfy a range of compliance and non-compliance drivers. With respect to Objective 4, the risks to be quantified and mitigated are those related to negative interactions between fishers and protected, endangered and threatened species (PETS). The potential to integrate high resolution vessel track and fishing activity data with fisher derived observations of the presence of PETS or the reporting of entanglements by fishers was explored. In addition, the use of longer term citizen science data derived from pot buoy counts by participants in Whale and Dolphin Trust cruises on the West Coast of Scotland was considered. Data was also provided by the Scottish Marine Animal Stranding Scheme (SMASS) project on strandings of whales and cetaceans recorded over the last 20 years. These data were plotted as data layers and made available through the SIFIDS data base user interface developed as part of WP6 and WP8b. The need to collate and, where possible, verify negative interaction is discussed. Further, the need to develop appropriate and verifiably effective management strategies is discussed.

Objective 5: Investigation of applicable techniques/strategies for change management regarding accurate voluntary reporting by the industry.

The practical challenges and potential techniques/strategies for collecting FK are largely addressed under Objectives 1 to 4. However, these approaches still largely rely upon voluntary reporting by individual fishers. Feedback from the interviews and survey work together with feedback on the use of the App provides a basis for developing a more structured approach to sharing of FK and improving voluntary reporting. Classical change management approaches in the context of the inshore fishing sector is discussed, together with the use of behavioural insights, as a means of improving voluntary reporting.

4. RESULTS

Objective 1: Definition of fisher derived data collection parameters.

A total of 45 semi-structured interviews were conducted in the four case study regions (Billing, S-L. et al, 2018) in May 2017 which identified 21 themes highlighted by fishers. *'Resource management'*, *'relationships'*, *'changes'*, and *'supply-chain'* were the themes that contained the most content from the interviews and across all case studies.

In addition, WP4 conducted a survey attracting responses from 133 fishers across all 11 Marine Regions in Scotland. 90% of respondents were skippers, 7% worked for fisheries associations and 3% were crew. Most respondents were male, had an average age of 51, and identified as being Scottish. Participation rates varied across the Marine Regions with the most responses collected from the Outer Hebrides and the least from the North Coast.

Across all interviews and survey responses there were only 6 instances with PETS interactions recorded – 3 in the Argyll, and 3 in the Forth and Tay Marine Regions. One in the West Highlands

Marine Region was very generic and the location suggested that the respondent was referring to sea birds: Gannets and Fulmars at least, perhaps Golden Eagles as well. Most respondents did not specify a particular species. There observations were communicated in a general sense related to "being in nature" and how this impacts positively in terms of their job satisfaction. On the east coast the issue of increased seal populations (Forth and Tay only) was highlighted. The analysis of this data including other environmental interactions (such as weather and tides) can be found in the SIFIDS WP4 report.

Additional data was obtained from a survey conducted by WP8 observers with 117 vessel skippers covering 132 sea trips which was designed to elicit information on the behavioural drivers which motivated skippers to fish or not to fish an any given day. The results of this survey are presented in the SIFIDS WP8b report.

Whilst these surveys and interviews were not specifically designed to provide quantitative data the aim was to provide, within the context of the free responses given by the subjects, an opportunity to share experiential information, part of which could have referred to interactions with wildlife (negative or positive). The interviews and survey responses from WP4 did not provide experiential data that could be used to inform fisheries management other than to highlight the need to better communication with fishers and to account for their concerns in establishing management regimes that are likely to impact on their fishing activities.

WP8b survey results suggested that a more focused approach to eliciting experiential information from fishers is required and that if categorised and statistically analysed, such data can be used to develop basic decision support tools (see WP8b Figures 22-27).

Objective 2: Identification/development of a quality assured system for the collection of fisher derived anecdotal and experiential information.

Summary of SIFIDS FISH1 App use

Throughout the trial period (Sept 2018 to March 2019) the mobile phone application was downloaded by 11 registered Scottish fishing vessels, identified by their PLN. The intent at the start of the trail period was to try to recruit 50 users, but time constraints linked to the originally agreed end date for the SIFIDS project and the limited use of Android based mobile phones in the target user group limited participation. Eight of the eleven fishers used the App to submit FISH1 forms to the local Fishery Office (Table 2). In total, 99 FISH1 forms were produced using the App and submitted, 35 of which came from one fisher. The tracking feature was used by 6 vessels, three of which submitted FISH1 forms. It was confirmed from one fisher feedback sheet that they did not use the FISH1 form feature because they were over 10m but wanted to track themselves at sea. A total of 28 observations were recorded from vessels. Only one vessel used all three features of the App (FISH1 Forms, tracks and observations).

Table 2 Results from the SIFIDS FISH1 App trial, anonymised to protect App users' confidentiality

	FISH1 forms	Trips	Tracks Positions	Observations
Vessel 1	20	56	14,513	
Vessel 2	1			1
Vessel 3	9			23
Vessel 4	13	6	900	1
Vessel 5	15			
Vessel 6	2			

Vessel 7	4			
Vessel 8	35	4	1473	
Vessel 9		92	33,738	3
Vessel 10		46	21,140	
Vessel 11		4	258	
	99	**208**	**72,022**	**28**

After the trial finished fishers who downloaded the App were asked to complete a feedback questionnaire (Appendix 5).

Summary of feedback from fisher App users

Six App users provided feedback about their experience with the App, five via the online feedback survey link and one was interviewed face to face. Four used their mobile phones and two used tablets. Not all questions were answered or were applicable to each fishers' experience with the App.

Five of the App users stated they found the App easy to use with the sixth saying they needed help at first as they were "not good with change" but they were happy to use the App after instruction. For this fisher, they quoted lack of familiarity with the technology as the reason for their delayed response, but felt the App was the way forward and remarked that if the App became an official form of FISH1 submission it would be useful to offer some form of training in its use. Of the five fishers who answered with reference to the FAQ document provided, three found it useful with two stating it was both helpful and unhelpful. All fishers filled in the settings, a feature designed to save the fisher time and to provide SIFIDS with supplementary information for the data the App was recording. One fisher noted that the App drained their phone's battery when the App was in use. This is caused by the use of GNSS location being turned on to track the vessel. However, many users have the capacity to charge their phones on-board their vessels.

The App's observation feature was the least used and comments from two App users suggested that it took "too long" to complete the screen selections and submit the observations. Furthermore, due to the timing of the trial being late in the year there was a lack of wildlife to record. It is of note that some users indicated that they would be more likely to submit observations of unusual species rather than those that they observed regularly. When one fisher was asked if the Observations part of the App was of no interest, the response was that they found it a useful option and that some fisher's would definitely be interested in recording their observations.

For the tracker, four respondents used both tracking buttons and one stated they had used just the Fishing button, providing them tracks of just where they had been fishing. It was confirmed by one that even though their vessel was more than 10 m they had downloaded the App to track themselves at sea, highlighting fisher's interest in recording their position. With regards to the accuracy of the tracking App it was noted that some tracks might not have represented the true track at sea as some tracks were "on land or outside my area". Nonetheless, it was stated to be a benefit to have tracks of where they had been at sea and if it could show where gear was located.

The mobile FISH1 form App was the most frequently used feature with a total of 99 FISH1 forms submitted to FOs across Scotland. The ease with which forms could be submitted by email from the App was highlighted by one fisher who stated they were no regarded as a "star pupil" for submitting their forms on time and previously to be "chased by Marine Scotland" for their forms. The accuracy of the data submitted was also improved because of the App and provided archives of what fishers caught on each day, making it easier to convey the cumulative weekly catch to buyers. The App saved the fisher time and kept records for future reference, as one user said “no need for writing or guessing and you don’t need to go hand in your sheets” to the local FO. When asked if a website equivalent for submitting FISH1 forms could be useful for the inshore < 10 m community five people said yes. The sixth respondent stated the App was better as you could fill the form whilst at sea or when returning to port instead of when at home as it is “the last thing you want to do when you get home from a day at creels is go to a website and submit data and by the next day you are on to a new day and you have forgotten about yesterday”. Most users appreciated being able to use the App to collate their landings data whilst at sea rather than it being additional task that they would have to undertake at home after a day’s fishing – or to try to remember at the end of the week. Many fishers (other than those surveyed as part of the App) trial have privately stated that they simply quote the same co-ordinates on manually prepared FISH1 forms for their fishing activity, irrespective of whether it is correct.

An unexpected result of using open-source software to construct the App was the offer of assistance from a fisher with an IT background. The individual had experience with coding and now runs a scallop diving business using < 10 m vessels in the south-west of Scotland. He has contributed some code and ideas regarding future iterations of the App. He has also offered his services as an advocate to promote the use of the App to local fishers.

Future considerations and recommendations

Although the number of participants in the initial App trial was limited, the response has been sufficiently positive that further development and testing of and App based system for recording landings, track and other observations is definitely recommended. Feedback from App users indicated possible improvements and additional functionality that would be of use to fishers. Discussions with colleagues in Marine Scotland has also suggest additional functionality should be added to future iterations of the App.

A significant and unanticipated limitation on the scale of the initial trial was that the majority of fishers appear to use iPhones and the first iteration of the App was only designed to be used on Android phones. All future iterations of the App should be developed for use on both iOS and Android platforms.

The following recommendation for improvements to the App are derived from fisher feedback surveys, communications with various stakeholders about the App and the development team’s experience of producing the prototypic version of the App.

It is of note that the majority of suggested improvements relate to additional feedback and communication that could be achieved by using an App. These range from additional feedback to fishers from data either submitted or gathered by them, to the fisher’s ability to share their data in a controlled manner with buyers and other fishers for example. In addition, improving both the uptake, recording and value of App features, it would be useful to link its use to a specific project or event with associated engagement and publicity. This approach is commonly used for other citizen science Apps and projects (e.g. a focus on a given species or data need). This can include time-limited projects where a particular app feature could be added and removed via periodic software updates.

Future development ideas for the tracking and map display features:

- Display Marine Protected Areas
- Different colour pins to visualise where fishing has occurred
- Bigger tracking buttons on the home screen i.e. to make tracking easier for fishers at sea
- Tracking buttons in the phone’s notification bar i.e. the fisher does not have to go back into the App every time

- Set-up geo-fenced areas so the App automatically activates/deactivates tracking eg once a fisher leaves their port the App begins tracking

Future development ideas for the FISH1 form feature:

- Produce FISH1 forms in a suitable format for it to be fed straight into COMPASS once submitted
- Quality checks within the FISH1 form before submission i.e. block submission if mandatory boxes are blank, highlight highly unlikely gear-species combinations and query unusual recorded latitude and longitude co-ordinates
- Automatically pre-populate and refresh each form with the latitude and longitudes from the tracking feature of each fishing activity that was recorded via the tracking feature
- A check FISH1 form page for the fisher to go through before submission
- A summary page to display species totals contained in FISH1 forms and other details i.e. a page showing the total weight for a species caught in a specified time frame or ICES rectangle
- Website equivalent to submit FISH1 forms

Future development ideas for the Observation feature:

- More unusual and/or invasive species
- Display other sightings in the region to notify fishers
- Provide instant (automated) feedback on an observation using “natural language generation”
- Minimise the number of steps required to provide the Observation data

General future development ideas:

- Receive alerts from Fishery Offices and other regulators/agencies i.e. notifications of restrictions, hazards etc.
- Link the App to other necessary documentation needed by fishers i.e. integrate the App with movement and export documents and have them sent to the appropriate recipients
- Export function allowing all data stored on the App to be backed-up i.e. for a fisher to save all App data elsewhere or have the data reappear if the fisher reinstalls the App on a new phone
- More than one supplier details saved in the Settings feature of the App
- Integrate with other safety applications
- Easier download and update system
- “Share with” feature for fishers to share different details with other fishers i.e. submerged gear location to then notify other fishers

The use of open-source software and technology was a fundamental principle upon which the SIFIDS project was based. By allowing others to contribute to the development of technology and computer code in particular has been pivotal in developing globally important products and services – many of which we now take of granted. Critical to the success of open-source development is sufficient users and contributors to make a particular development “sustainable”. Since launching the SIFIDS App even in a very limited and controlled trial, we have received national and international interest in using the App – or at least derivations thereof. The fact that at least one fisher contributed code to the software and others, ideas for its future development, suggests that this is likely to be part of future fisheries data collection and related communication. The term open source relates to system software code that is freely available for possible analysis, modification and redistribution. It does not result in any freely accessible data. In other words, the code used to create a system, program or application is freely available on online platforms, in this case on GitHub, for others who wish to amend the code to suit their requirements, but the data collected or processed by the code cannot be obtained. Open source promotes not only sharing and replication of codes to those who are interested in its capabilities but also enables whole communities of "tech-savvy" individuals to grow and analyse code. Often these communities can provide answers to issues or suggestions for improvements without necessarily modifying the software directly or being able to access the data. The SIFIDS FISH1 App is an example of what open-source coding can achieve and is currently being adapted for trials in Peru.

Objective 3: Development of an appropriate sampling design/methods that can be streamed to the relational data resource.

There are currently about 6.8 billion mobile telephone users globally (~70% of the projected global population). Whilst developed markets are reaching saturation, expansion in developing economies continues and by 2023 the number is expected to reach 7.33 billion. (https://www.statista.com/statistics/218984/number-of-global-mobile-users-since-2010/)
Smartphones can have 19 different sensors (https://www.technologyace.com/technology/types-sensors-modern-smartphones/) and they provide a medium through which humans interact with each other and other technology and increasing the environment. The "smartphone" as a concept is also changing rapidly and as it becomes more of an integrated part of the "internet of things" and embedded in the fabric of our lives, it will be transformed from a device we hold to technology that we wear, or surrounds us. Its ubiquity, accessibility and relatively low cost will transform data collection of all kinds and will fuel "citizen science" capacity as never before.

Collecting experiential data from fishers – even in some of the poorest nations on earth is already possible. However, a key challenge for all areas of citizen science is to be able to utilise data that will by the nature of the way that it is collected, be subject to inconsistency, inequalities and bias.

The SIFIDS App trial has, thus far been limited, but the results are sufficiently encouraging to suggest that further investment in using this medium as a way of collecting structured spatially and temporally referenced observations (experiential) information from fishers is merited. Whilst the current App trial was not of sufficient scale or duration to allow any meaningful data analysis, statistical methods to deal with the challenges these data present are emerging in the form of non-probabilistic surveys. In these surveys, the probability of a particular survey element being selected for a sample cannot be calculated. Non-probability sampling also relies on subjective judgement. Whilst non-probability sampling makes it impossible to know how representative the sample is of the true population, the paradigm of citizen science and relatively largescale data collection from "observers" whose characteristics may potentially be defined to correct for such bias is possible. On the assumption that Apps will provide a spatial and temporal context to an observation, together with associated data related to, for example, weather conditions, sea state, water temperature, corroborative images, observer track record etc., the veracity of a particular observation may be assessed.

Combining non-probabilistic approaches with more discrete (time and resource constrained) traditional data collection methods is likely to be the way forward. Further method development in this area of statistics is required and we would strongly recommend that a more extensive App trial to collect observational data is undertaken. Integrating the observational part of the App with statutory data requirements may have potential advantages in that fishers are obliged to submit catch/landings data and will therefore be interacting with an App for this purpose.

Objective 4: Development of risk based management strategies.

Identification of a wide range of environmental impacts has resulted in increased management of inshore fisheries (eg benthic disturbance, reduction in abundance and diversity of fish populations, entanglement of large mobile species etc[4],[5],[6]) . Over the past 20 years, there has been a shift towards an Ecosystem Approach to Fisheries Management, which includes humans as part of the ecosystem, in a bid to create a more holistic strategy and better social, environmental and economic outcomes.[4]

In order to define risk based management strategies it is important to develop a framework for articulating the objectives of such a strategy and what it should achieve. In this context a broadly based ecosystem approach focusing on the direct impacts of the fishery on target and non-target catch and by-catch together with sensitive species or habitats.

The 'concept' of sensitivity has been developed over many decades and applied in coastal and marine habitats. Numerous approaches have been developed, applied at a range of spatial scales, and to a variety of management questions[7].

The most common approaches define 'sensitivity' as a product of:

- the likelihood of damage (termed intolerance or resistance) due to a pressure;
- the rate of (or time taken for) recovery (termed recoverability, or resilience) once the pressure has abated or been removed.

Or in other words "a species (population) is defined as very sensitive when it is easily adversely affected by human activity (e.g. low resistance) and recovery is only achieved after a prolonged period, if at all (e.g. low resilience or recoverability)"[8],[9].

Sensitivity is an inherent characteristic determined by the biology/ecology of the feature (species or habitat) in question. But it is a 'relative' concept as it depends on the degree (expressed as magnitude, extent, frequency or duration) of the effect on the feature. Therefore, sensitivity assessment uses a variety of standardized thresholds, categories and ranks to ensure that the assessments of ‘relative’ sensitivity compare ‘like with like’. These are:

1. standard categories of human activities and natural events, and their resultant ‘pressures’ on the environment.
2. descriptors of the nature of the **pressure** (i.e. type of pressure, e.g. temperature change, physical disturbance or oxygen depletion).
3. descriptors of the pressure (e.g. magnitude, extent, duration and frequency of the effect) termed the **pressure benchmark**;

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[4]Northridge, S. Cargill, A. Coram, C., Mandleberg, L., Calderan, S., Reid, R. (2010) Entanglement of minke whales in Scottish waters; an investigation into occurrence, causes and mitigation. Final Report to Scottish Government CR/2007/49.
[5] https://www.sciencedirect.com/science/article/pii/S0025326X16304386
[6] https://www.sciencedirect.com/science/article/pii/S0025326X16309729
[7] Roberts, C., Smith, C., H., T. & Tyler-Walters, H., 2010. Review of existing approaches to evaluate marine habitat vulnerability to commercial fishing activities. *Report to the Environment Agency from the Marine Life Information Network and ABP Marine Environmental Research Ltd. Environment Agency Evidence Report: SC080016/R3.* Environment Agency, Peterborough <http://publications.environment-agency.gov.uk/PDF/SCHO1110BTEQ-E-E.pdf>
[8] OSPAR, 2008. OSPAR List of Threatened and/or Declining Species and Habitats (Reference Number: 2008-6). OSPAR Convention For The Protection Of The Marine Environment Of The North-East Atlantic <http://www.jncc.gov.uk/pdf/08-06e_OSPAR%20List%20species%20and%20habitats.pdf>
[9] Laffoley, D.A., Connor, D.W., Tasker, M.L. & Bines, T., 2000. Nationally important seascapes, habitats and species. A recommended approach to their identification, conservation and protection, pp. 17. Peterborough: English Nature.

4. descriptors of resultant change / damage (**intolerance/resistance**) (i.e. proportion of species population lost, area of habitat lost/damaged);
5. categories or ranks of recovery (**recoverability / resilience**) thought to be significant, and
6. resultant ranks of **sensitivity and/or vulnerability**.

For further information see: https://www.marlin.ac.uk/sensitivity/sensitivity rationale

The evidence base for defining risk may be both empirical and heuristic, using best available evidence and expert opinion. Processes such as expert elicitation can be used to integrate this evidence and to achieve a degree of consensus on the risk of any given fishery practice. This in turn can lead to definition of data needed to support an agreed evidential threshold which may be required for the purposes of regulatory compliance and, if necessary, enforcement. However, risks extend beyond simply satisfying regulatory conformity and relates, for example, to financial, reputational, operational risks which may be as damaging from an industry perspective. Interactions with PETS, particularly where there is evidence of entanglement or physical damage resulting in acute or chronic impacts on an animals welfare and survival are likely to be associated with such risks.

The impacts on PETS of fishing and static gear fishing in particular in Scotland is largely unquantified. Data on the distribution of fishing effort coupled to observations of entanglement or related strandings for example do not exist in any coherent form. Whilst isolated examples may be reported, it is not possible to contextualise these data in a meaningful biological or ecosystem context. Whale and Dolphin Trust cruises on the West Coast of Scotland have collected observations on the number of static gear buoys providing some measure of the density of fishing gear deployment. Data was also provided by the SMASS project on strandings of whales and cetaceans recorded over the last 20 years. Cursory analysis suggest that many stranded animals show signs of damage caused by interactions with rope for example, but there is little evidence that such interactions are directly linked to subsequent stranding or mortality. Further detail can be found on the Scottish Entanglement Alliance website at: https://www.scottishentanglement.org/. The attitudes of fishers to this issue is quite nuanced, and the manner in which fishers are engaged in an initiative is important and it is generally better to actively engage fishers in helping to actively develop solutions.

Critical to assessing the potential for interactions between the inshore fishing sector and PETS is to collect data that can be used to model the spatial and temporal distribution of commercial fishing effort. The proposed acquisition of track data for all inshore vessels would provide the basis for this.

Table 3. Hypothetical example of a risk based data collection assessment for the inshore sector

Risk Category	Consequence (A) Mild – 1 Severe – 5	Likelihood (B) Low – 1 High – 5	Details	Risk Consequences	Joint Risk (A*B)	Level of Evidence GNSS – Spatio-temporal data GS – Gear sensor(s) C-IP Video camera E – Effort measure
Gear Type (All Gear types could be subdivided to cover variations in type or operation						
Dredging	5	4	Mobile gear in contact with or in close proximity to the seabed	Damage to the seabed and/or associated fauna/flora/high levels of by-catch	20	GNSS + GS + C
Electric fishing	5	4	Mobile gear in contact with or in close proximity to the seabed. Insufficient information to assess potential environmental impacts.	Possible damage to the seabed and/or associated fauna/flora/high levels of by-catch	20	GNSS + GS + C
Benthic trawling	4	4	Mobile gear in contact with or in close proximity to the seabed	Damage to the seabed and/or associated fauna/flora/ high levels of by-catch	16	GNSS + GS
Pelagic trawling	4	3	Mobile gear not in contact with the seabed	Bycatch of mobile PETS	12	GNSS + GS
Static nets	4	2	Static gear suspended in water column	Possible localised damage to seabed and bycatch of mobile PETS	8	GNSS
Pots/traps in strings	2	3	Static gear strung together and in contact with the sea bed	Possible localised damage to seabed and entanglement with mobile PETS	6	GNSS
Pots/traps singles	2	2	Static gear deployed individually in contact with the seabed	Possible entanglement with mobile PETS	4	GNSS
Long line	3	3	Static gear with multiple hooks on suspended line	Possible by catch and entanglement of mobile PETS	9	GNSS
Commercial Rod and line	2	1	Single or multiple hooks suspended from a fishing rod – static or trawled	Possible by catch of PETS	2	GNSS
Diver hand caught	2	2	Diver collecting shellfish by hand from the seabed	Possible localised overfishing	4	GNSS + E
Location / Time (Where fishing is taking place and time – if relevant to restriction)						
Entering a restricted area	4	3	Accidental or deliberate infringement of an area where fishing is prohibited	Possible damage to habitats, PETS, infrastructure + potential for fishers to be implicated in illegal activity	12	GNSS + GS
Fishing in a restricted area	5	2	Accidental or deliberate fishing in a prohibited area	Possible damage to habitats, PETS, infrastructure + potential for fishers to be implicated in illegal activity	10	GNSS + GS
Other considerations						
Gear conflict	5	2	Mobile and static gear fisheries prosecuting the same area at the same time	Accidental or deliberate loss of static fishing gear. Denial of legitimate mobile fishing opportunities.	10	GNSS + GS
Previous history of non-compliance in sector/fleet	4	5	Any breaches in compliance with respect to Gear Type, Location or Time restriction or Catch/By-catch/Discarding	Lower risk categories for gear type, use, location, time or nature of catch or discarding becomes higher risk because a significant proportion of the fleet is non-compliant	20	GNSS + GS + C

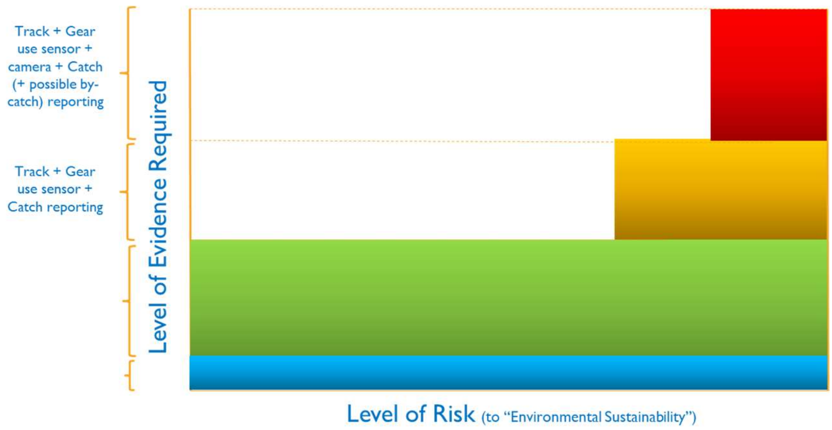


Figure 8. Level of risk assessed and thresholds for level of evidence required, determined through formal risk assessment using expert elicitation process.

A co-occurrence model is then required to assess the likelihood of PETS encountering fishing gear and thus have a greater risk of entanglement. Such a model should identify species-specific areas and times when the risk of entanglement is greatest.

At present, there is insufficient data on the occurrence of PETS to populate a co-occurrence model. However, using the SIFIDS App, fishers could start to provide temporal and spatially linked observations of PETS which, over time could inform a co-occurrence model. In addition, a similarly structured "citizen science" observation programme could be initiated to engage other users of our coastal waters including recreational anglers and pleasure craft users. More formal surveys should be integrated with these data. These surveys may, for example, include direct observations as well as Passive Acoustic Monitoring surveys for cetaceans and whales.

Comparing co-occurrence, with entanglement and strandings data could provide a more reliable assessment of "risk" and inform the need for potential mitigation measures.

One of the most significant threats to many vulnerable mobile marine species comes from unintentional interactions with fisheries, including bycatch of non-target species. These interactions are usually negative to both the marine species and the fishery (through loss or damage to gear, time spent dealing with non-target species, negative publicity etc.). Very little information is currently available on Scottish fisheries to assess the magnitude of these interactions as there is no reliable data-collection and reporting system.

A number of data sources provide incidental information which may help identify areas of significant concern, and direct future data collection efforts. Through the SIFIDS project we have begun to explore the potential for collection of experiential information, and the use of this information for a variety of management requirements.

The current extent of fisheries interactions with PETS in Scotland is not well known. However, we can investigate the incidence of these interactions indirectly when affected animals either become stranded, or die at sea and wash ashore where the carcasses can be recovered and examined.

Strandings data

The Scottish Marine Animal Stranding Scheme (SMASS) has been collecting data on marine vertebrate strandings around the coastline of Scotland since 1990. Wherever possible, a necropsy examination is conducted in order to record species and demographic parameters, as well as identify the cause of death.

While the method by which animals become entangled is not fully understood, it is clear that baleen whales (Minke, humpback and fin whales in Scotland) are particularly susceptible to entanglement in creel gear, used for fishing crabs and lobsters. Apart from baleen whales, there have been occasional records of basking sharks, killer whales, leatherback turtles, Northern bottlenose whales and sperm whales becoming entangled.

A data layer has been included on the SIFIDS database Graphical User Interface showing the distribution of *Minke entanglements* from 1990 to 2018. Data source: Scottish Marine Animal Stranding Scheme (2019).

Creel distribution

Creels (or pots) are known to be one source of negative (deleterious) interactions between marine vertebrates and inshore fisheries. Understanding the distribution and density of creel fishing gear is necessary to inform the temporal and spatial likelihood of entanglement. There is currently very limited information available at a suitable spatial resolution.

Two existing data sources were initially compared, one from the Creel Fishing Effort Study[10] and one from 'ScotMap'[11].

ScotMap collected information from Scottish vessels under 15m in length through face to face interviews from 2007 to 2011. Data were collected on value of catch and number of vessels using a particular area, and we used the number of vessels in a subset area around the Isle of Mull for comparison.

The Creel Fishing Effort Study conducted interviews with creel vessels, collecting information on the number of creels hauled per day from 198 vessels in four Scottish regions in 2015. We combined the data from the nephrops fishery with the crab and lobster fishery from the area around the Isle of Mull (see Figure 9).

We transformed these two datasets into 2km x 2km grid squares for the area centred around the Isle of Mull, a known hotspot for Minke whale sightings. Examining these datasets on a high spatial resolution indicates that they there are significant differences between them which may be due to either uncertainty in the dataset (which were not designed to be viewed at such at spatial resolution) or due to changes in fishing activity in the time period between the two studies. Such temporal variation in fishing activity would be an important factor in understanding the risk of entanglement to baleen whales and so this was examined further using data provided by the Hebridean Whale and Dolphin Trust (HWDT) (See Figure 10).

The HWDT provided GPS tracks and creel sighting locations from their visual cetacean surveys and we used a subset of this data from the area around Mull, from the years 2008 to 2010. Creel sighting rate was calculated for each year in a grid of 1.5nm cells, using a count of GPS fixes (one every 10 seconds) in each cell as a proxy for effort spent in each, and dividing this by the number of creel buoy sightings reported.

Comparing the creel density over the three years shows that although a small number of persistent hotspots exist, there is a high degree of variability from year to year.

Although limited, these data suggest that variability in creel distributions coupled to variability in the movement of species potentially subject to entanglement may preclude predictive risk mapping for species that do not show discrete and repeated movement pathways. This being the case, the use of near real time reporting of creel (and other static gear) positions together with contemporary observations of vulnerable species (using an App for example), could provide a more dynamic way of assessing co-incidence and subsequent risk of entanglement. If SIFIDS systems and processes are operationalised, is should be possible to produce detailed distribution maps for static gear deployment on a daily basis. This would include estimates of creel numbers and from this it should also be possible to estimate the length of rope (possibly a rope length per unit area/volume or more precisely a potential "entanglement" rope length per unit area/volume). Coupled to observations and perhaps a known propensity for a given species to become entangled it would be possible to assign a risk factor and consider possible mitigation measures.

[10] https://www.gov.scot/publications/creel-fishing-effort-study/

[11] https://www.researchgate.net/publication/316606519_ScotMap_Participatory_mapping_of_inshore_fishing_activity_to_inform_marine_spatial_planning_in_Scotland

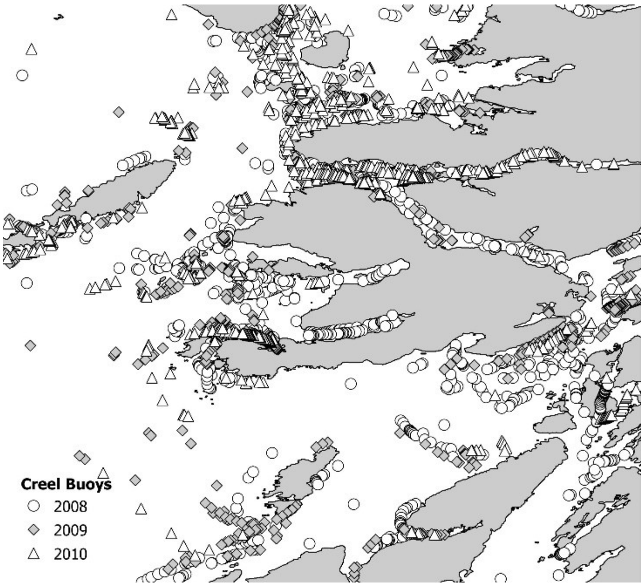
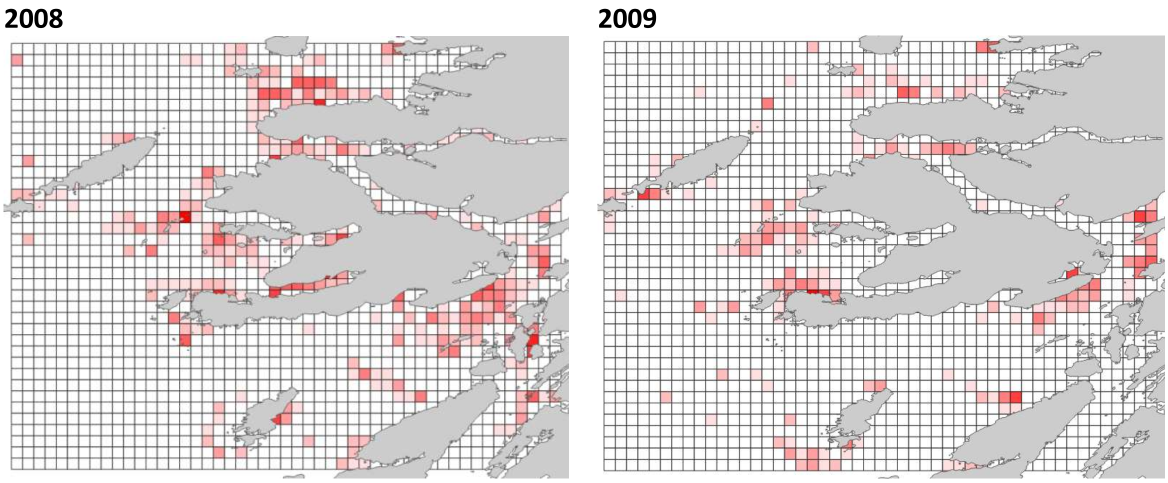


Figure 9. Composite distribution of observations of creel bouys 2008-2010[12].

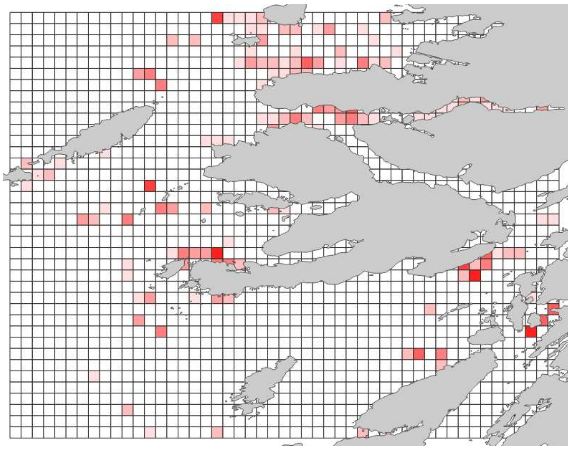


12 *Creel Fishing Effort Data* Source: http://marine.gov.scot/information/creel-fishing-effort-study Reference: Marine Scotland Science, 2017, Creel Fishing Effort Study, Scottish Government

ScotMap Data Source: https://www2.gov.scot/Resource/0046/00466802.pdf Reference: Kafas, A., McLay, A., Chimienti, M. and Gubbins, M., ScotMap Inshore Fisheries Mapping in Scotland: Recording Fishermen's use of the Sea. Scottish Marine and Freshwater Science. Volume 5 Number 17

Hebridean Whale and Dolphin Trust Creel Data Source: *Hebridean Whale and Dolphin Trust* Time period: 2008 – 2010.

2010



Legend

Creel buoy sightings rate, arbitrary units

0.0000 - 0.0050
0.0050 - 0.0150
0.0150 - 0.0260
0.0260 - 0.0390
0.0390 - 0.0580
0.0580 - 0.0830
0.0830 - 0.1410
0.1410 - 0.2500
0.2500 - 0.5000

Figure 10. Creel bouy sightings rate displayed separately for 2008, 2009 and 2010 respectively (1.5nm grid cells).

Because observations will be predicated on an observer actually seeing and reporting sightings of species vulnerable to entanglement, consideration should also be given to using the inshore (reference fleet and other designated vessels) to deploy and retrieve sensors in the coastal marine environment. This could provide a regular, cost effective source of high-quality marine acoustic data. Collection of high-quality acoustic data would assist with developing detection and classification algorithms to differentiate the signals produced by these species. Evidence of the presence of these species can help inform distribution and density maps, which are useful for population assessment and EIAs (e.g. marine renewables). Behavioural information can also be determined, such as feeding rates and communication behaviour (e.g. signature whistles).

Sightings data on PETS could be used to actively mitigate the risk of baleen whale entanglement in creel fishing gear. Real time observations of aggregations of species at high risk (humpback and minke whales) could inform time-limited restrictions to certain gear types within a given area.

Objective 5: Investigation of applicable techniques/strategies for change management regarding accurate voluntary reporting by the industry.

The practical challenges and potential techniques/strategies for collecting FK are largely addressed under Objectives 1 to 4. However, even if we accept that the use of a mobile App has the potential to increase the scope, scale and uniformity of reporting of observation, it still relies upon voluntary reporting by individual fishers. If we are to encourage the use of this approach to data gathering, it will require the co-operation and support of the industry. A more comprehensive trial involving a larger number of participants is now required to understand the full potential of this approach, but it is clear that there are some guiding principles and practices emerging from other sectors that could usefully be applied in the context of the inshore fishing sector. This element of the SIFIDS project was predicated on the generally held view that fishers have useful knowledge of the environment in which they work that could feed into the sustainable management of the fishery. Whilst as a general principle this may be true, the reality is that unless that experience and knowledge can be captured in a consistent and verifiable manner, its value is limited. Pivotal to using an App to acquire observational data will be to encourage its use over extended time periods by individuals who can be relied upon to report observations consistently. This will require some changes in the way that these individuals work and behave.

Classical "change management" approaches in the context of the inshore fishing sector do not necessary align well with its nature and culture. Many of these approaches have been developed with some form of corporate structure and hierarchy in mind. Inshore fishers are disparate in opinions, culture, social background and the only unifying factor would appear (at times) to be the lack of unity and a desire perhaps not to conform to social norms and practices. In the absence of a clear management structure and in the knowledge that most inshore fishers work to some extent in isolation, a more enlightened approach to encouraging fishers to provide observational data and indeed responding positively to compliance requirements would be to recognise their individuality and adopt practices evolving through behavioural insights and more broadly, systems change.

The following information has been distilled from the ISM model (Individual, Social, Material) that has been described as the most comprehensive of the available tools for contextualising and developing practical solutions to bring about behaviour and systems change (see - https://www.ismtool.org/).

There are many different theories which help us understand behaviour and change, drawn from many different disciplines. However, there are fewer practical tools which allow practitioners to mobilise that theory, and apply it in developing and delivering behaviour change interventions on the ground.

ISM is a multi-disciplinary tool for designing effective policy interventions, originally developed in the context of sustainability challenges. It was created by Andrew Darnton with colleagues at the University of Manchester, and launched by the Scottish Government in 2013 (https://www.gov.scot/publications/influencing-behaviours-moving-beyond-individual-user-guide-ism-tool/).

ISM brings together into a single figure the main factors from the three disciplines most concerned with understanding behaviour: behavioural economics, social psychology, and sociology. The factors are arranged into three contexts, symbolised by a head (the Individual) in a circle (the Social) in a square (the Material). Evidence from reviews of international behaviour change interventions suggests that lasting change requires action in all three contexts (Southerton et al, 2011 - https://www2.gov.scot/Resource/Doc/340440/0112767.pdf).

Principles and practice – are there any practical ways that we can improve the reporting of PETS interactions with inshore fisheries?

Using the ISM tool, the following represents an overview of the way that we may begin to engage the inshore fishing community and other relevant stakeholders in providing information (data) that can support the sustainability of the inshore sector more broadly. In addition, and more specifically, provide observations that will allow us to gain a better understanding changes taking place in the marine environment and of the potential impacts of this sector on PETS for example.

Motivate the Change

Leverage positive emotions - In the survey of fishers undertaken through WP4, many highlighted their appreciation of working in the natural environment and the freedom that fishing as a job was able to offer.

Frame messaging to personal values, identities, or interests - There is a strong sense of independence and self-reliance in fishers and that is an important part of their identity. There interests are likely to be varied but using an App suitably imbued with cookies, it would be possible to associate it with images and messages that aligned with fishers' interests.

Personalise and humanise messages – Incorporating personalised feedback in response to submitted observations (or other data) can be an automated process. Humanising these messages is increasingly possible using a variety of **Natural-language generation** (**NLG**) software. It can be used to generate short text messages in interactive conversations (a chatbot) which might even be read out by a text-to-speech system.

Harness cognitive biases - Cognitive biases increase our mental efficiency by enabling us to make quick decisions without any conscious deliberation[13]. However, cognitive biases can also distort our thinking, leading to poor decision-making and false judgments. Three common cognitive biases are fundamental attribution error, hindsight bias, and confirmation bias. In the context of fisher insight, this may chime with the perception that data collection by those in "authority" is often used to the detriment of fishers and that data (experience) that fishers have, is ignored by those in authority. By providing an open and transparent means of fishers submitting data and receiving relevant feedback which could include reference to the experiences and observations of other fishers, may help to encourage more frequent and consistent data recording and submission.

Design-behaviourally informed incentives

The use of mobile telephone technology is almost ubiquitous and the majority of fishers are likely to have and regularly use a smart phone. Anecdotally, we are aware that many fishers are also regular users of social media platforms such as WhatsApp and Facebook. Leveraging this user environment to encourage data provision and to provide feedback is likely to encourage engagement from fishers. In addition, the use of "gamification" i.e. the application of game-design elements and game principles in non-game contexts could also be explored as a means of developing and maintaining a degree of "loyalty" in reporting. With respect to data and observation submission, this could for example relate to some form of performance score or category associated with a given level of achievement. Some form on non-financial reward or incentive based on a given level of reporting performance could also be assessed. The use of analytics to identify the preferences of individuals could be applied to the provision of more bespoke behavioural incentives.

Socialise the Change

Promote the desirable norm - Timely and useful reporting of data and observations needs to be promoted to the industry as the desirable norm. Reciprocity can be a useful tool in achieving this objective.

Reciprocity - Consideration could, for example, be given to reducing the cost of fishing licences to those that achieve a given level of reporting performance. Conversely, the cost of licencing could be increased for those that fail to report to an agreed level of performance.

Increase behavioural observability and accountability – again, using an App provides unprecedented opportunities for increasing behavioural observability and accountability. The time and nature of all data submissions is automatically recorded.

[13] https://science.sciencemag.org/content/362/6417/889.full

Encourage public and peer-to-peer commitments – The ability to share data and experience using Apps is now well established. Developing a sense of "community" among data providers with regular feedback and the opportunity for sharing of data and information may also merit investigation.

Choose the right messenger – Key to the success of any initiative with the fishing sector is to secure the buy-in of respected members of the fishing community. Fishers are more likely to respond positively to other fishers.

Ease the Change

Make it easy by removing frictions and promoting substitutes – The main barrier to the use of the SIFIDS App during the trial period was the fact that it was only available for Andriod phones. Future iterations would need to be available for all popular smartphones and iOS in particular.

Provide support with planning and implementation of intentions – One of the main lessons learned from the trial of the SIFIDS App was the need to provide support to App users and to engage them from the outset in the design and implementation process to ensure that the App fulfilled their needs and expectations.

Simplify messages and decisions – Apps need to be simple and quick to use. The feedback needs to be rapid and easily understood.

Use timely moments, prompts, and reminders – As part of securing the on-going engagement of fishers in using the App, future iterations should include the ability to prompt users for responses. By studying the working patterns of fishers and seeking their views on when they are most likely to use the App, it should be possible to tailor such reminders to individual circumstances.

5. CONCLUSIONS AND RECOMMENDATIONS

Capturing fisher's knowledge through snap shot surveys may be of value in the context of gaining a general understanding of the scope of their knowledge, defining drivers of certain behaviours and fishing practices and, more broadly, their understanding of the environment they work in. However, attempts to quantify this information and to provide any spatial or temporal reference to such information is challenging and often of little scientific value unless it can be operationalised as some form of statistical model, as suggested in work conducted as part of SIFIDS WP8, where fisher's behavioural drivers with respect to "not fishing" have been modelled (Recommendation 1).

The use of mobile phone App's has opened up the potential to engage a greater number of fishers, over wider geographic range and longer time scales. Depending upon the purpose and design of the App, it is possible to collect spatially and temporally referenced semi quantitative data with increased frequency and accuracy. There is also potential to add additional functionality to Apps to encourage greater and more consistent responses (Recommendation 2).

The SIFIDS App was produced as a prototype in Android only. All future iterations of App technology for the inshore sector should be produced in both Android and IOS formats as many, if not the majority of fishers us IOS base mobile phones (Recommendation 3).

The SIFIDS App used the incentive of providing the fishers with the opportunity to complete, compile and submit their FISH 1 landings forms electronically to their local fishery offices, in addition to allowing them to record the tracks of their fishing vessels. The knowledge we attempted to capture was the identification of some key species of interest because they are protected and may interact with the inshore fishery or are species that may be indicative of climate change for example.

Some fishers were clearly encouraged to record their observations using the App, but this was not universal. As a gross observation some fishers were consistent responders whilst others simply ignored this App function. A longer and more geographically dispersed App trial should be conducted to assess the potential to cultivate a community of “responders” whose data is likely to be more consistent and reliable. Novel ways, including feedback and incentives to retain such a community over time should be explored. (Recommendation 4).

Although Apps can usefully engage fishers in observing and recording their interactions with key species, the lack of control in the way that such data is recorded, still presents significant analytical challenges. Further use of Apps to capture useful data must go hand in hand with the development of statically robust forms of analyses that can account for the inherent biases that arise from the collection of citizen science data (Recommendation 5).

Specific citizen science data collection campaigns and events have been used successfully elsewhere. It may be worth trying similar initiatives, once a stable App platform has been established help kick start the widespread use of the App (Recommendation 6).

Although the trial of the SIFIDS App was limited in terms of the numbers of individuals involved, the response was very positive and resulted in a range of suggested improvements and additions to the functionality of the App. These ranged from changes to the format and design of the App to make it physically easier to use, through to the use of the App to streamline transactions with buyers and processors, transport documentation and potentially accreditation schemes. Future App development should seek to embrace some of these suggestions as they could potentially increase efficiency and traceability (Recommendation 7).

From a fisheries management, compliance and marine planning perspective, a universally deployed App could also provide a medium to engage fishers directly, providing a rapid and cost effective means of disseminating information and seeking feedback (Recommendation 8).

The SIFIDS App was designed as an open source project. The App code is freely available on GitHub. We would strongly encourage that future App development also takes place in the context of an open source development, allowing others to help improve and expand the utility of the App and derivations thereof (Recommendation 9).

The App was clearly popular as a means of recording FISH1 Form landings data and submitting it to the local fishery office. Further refinement of the App would be worthwhile to improve the functionality of this process, building in failsafes to prevent inaccurate or spurious data submission. By so doing, it should be possible to automate data submission to the appropriate database, reducing the need for manual checking and data input by fishery officers. In addition, it would be helpful for fishers to be able to access the data they submit in the form of summary statistics and graphs that help them gain a better understanding of their own catch (Per Unit Effort) and other useful measures of their operational performance (Recommendation 10).

Capturing fisher knowledge is inherently useful as a process of engagement, however, the purpose of gathering such data must ultimately be to yield information relevant to the sustainability of the fishery. In this context, fishers and managers need information to underpin and influence their discussion making. Increasingly, behavioural insights are being used to help influence decision making and we would recommend that the use of these techniques be further investigated as a means of changing behaviours in all key stakeholders (Recommendation 11).

APPENDIX 1 – REVIEW OF THE ROLE OF FISHER'S KNOWLEDGE

The role of fisher's knowledge in fishery management and conservation in Scottish small scale fisheries

Northridge, S., Coram, A., Mendo, T., James, M.

1. Introduction

Fishermen's ecological knowledge (FEK) has been very widely discussed and described in the fisheries and natural resource management literature for many years (Berkes, Colding, & Folke, 2000; Hind, 2014; R. Johannes, 1981), and yet the extent to which such knowledge is being used in fisheries management in most European fisheries is limited. Fishermen will often voice the opinion that their views and their knowledge remain poorly represented, especially in the science that underpins management advice (Haedrichet al. 2001; Neis and Kean 2003). Although there are many examples where information has been or is routinely collected directly from fishermen for use in management, most such examples involve scientists employing or persuading fishermen to collect data for a pre-existing management scheme. In this review we explore the idea of using fishermen's ecological knowledge to engage fishers with the management process, and thereby to improve management's effectiveness. This is a broader perspective from that of using industry to collect data on catches and effort, for example.

Referring to 'Traditional Ecological Knowledge' Berkes et al (2007) identified, within this broad concept, three types of knowledge: *(1) observational knowledge of species and of environmental phenomena, (2) practices through which people carry out their resource use, and (3) belief systems regarding how practitioners fit into the ecological and social systems in which they are operating*. All three perspectives are important when considering how 'fishermen's knowledge' might be used by or integrated within the resource management framework.

Within the resource management framework, a further hierarchy of knowledge types is evident in the literature: 'Traditional ecological knowledge' represents just one facet of fishermen's understanding of the fishery and the environment in which they work; it represents *a cumulative body of knowledge and is an attribute of groups of people with historical continuity in the practice of resource use* (Berkes et al., 2000). A more contemporary focus is provided by the term 'local ecological knowledge' representing *knowledge that has been accumulated over an individual's lifetime, equivalent to the prevalent 'expert opinion' within scientific circles*, and a useful complement to the normal scientific approach (Gilchrist, Mallory, & Merkel, 2005). Fishermen's ecological knowledge – perhaps better framed simply as *fishermen's knowledge* (FK hereafter)– *can also include information relating to markets, technology and the social and management framework within which the fishery operates* (R. E. Johannes, Freeman, & Hamilton, 2008; Pantin, Murray, Hinz, Le Vay, & Kaiser, 2015).

In this brief review, we consider some examples of the ways in which FK may be used in promoting sustainable use of marine resources in ways that may be pertinent to Scottish Small Scale (inshore) fisheries. We consider examples, loosely following Berkes et al's (2007) stratification, where (1) *observations of species or ecosystems have been used to inform management*, (2) *where practitioners' ways of pursuing fishing have led to improvements in management overall*, and (3) *ways in which fishers interact with the wider ecological or social systems around them* ***in the context of managing or using the resource.*** We have used these examples to make some suggestions as to how fishermen's ecological knowledge might help develop an integrated resource management approach in Scottish small-scale fisheries.

There is no common definition for Small Scale Fisheries (SSF), but there are some shared features related to vessel, economic and social characteristics (Gibson and Sumaila 2017). For the purposes of this review, we will define SSF as fisheries in which vessel length is usually smaller than 12 metres, and fishing activities occur inside the 12 nm territorial limit (Guyader et al. 2013, Sumaila et al. 2012). Small scale fisheries contribute to food security and the reduction of poverty for millions of people worldwide (FAO 2016). However, several challenges have been identified in this sector including declining fisheries resources, degraded habitats, limitations in securing fishers' access rights to important fishing grounds, and limited participation of fishers in decision making which often lead to unfavourable policies and practices (FAO 2016).

2. Observations of species or ecosystem processes

Fishery observations (of species at least) have been used to inform management routinely for decades through the collection of catch and also effort data. These data, however, have usually mainly been limited to quantifying the landings by species and by length or age class, to inform models that have been developed by fishery scientists. They are collected as input parameters to a predefined and normally biologically framed management schema. Such data can be distinguished from the direct observations of fishermen that might inform alternative views of the system.

Management systems in European countries have therefore traditionally relied on biologically based models of target fish stocks, and relied on measures of fish catches as input parameters. Almost always the fishing community is excluded from the assessments that inform the management process, but is the recipient of advice or management regulations.

Although community-based management is widespread in other parts of the world, in Europe management has been and remains largely top-down. Direct observations by fishermen of target fish species, associated species or natural processes have been very rarely used in the management of inshore fisheries in Scotland or elsewhere in Europe at least until the 21st century. Typically management has been stock assessment led, (Mahon, 1997) and to a lesser extent has involved controls on fishing effort, fishing efficiency or on fish/shellfish landing size, often to limit exploitation to within historical maxima, or to fit a biological preconception about maximising yields.

Since at least the 1990s however, there has been a widespread recognition in Europe that wider participation in management processes is not only desirable but essential if marine natural resources are to be managed sustainably (Mikalsen & Jentoft, 2008), although the process has been difficult to develop and implement (Hind, 2014). The main ways in which FK has been adopted and used within the broader management framework has been through improvements or elaborations in the fishery data collection process. This has proceeded in at least three directions.

First, the fishing industry has been contracted to collect data, either through the use of chartered vessels or through fisheries-science partnerships that have involved collection of catch, length frequency, maturity, age (otolith) samples or discard estimates. Increasingly, industry is also taking the initiative to collect their own data and is employing scientists to assist them in doing so, in order to support the research that informs management, but in a more proactive way.

Second, data have been collected with fishery involvement through the use of observers and electronic monitoring. This is effectively gathering 'fishermen's experience', or knowledge, without the need for them to commit anything to paper themselves, but ensures that they are aware of what is being counted, where and when, and usually allowing them to review such information. Although misunderstandings and disagreements over interpretation can and do still occur under such schemes, at least such an approach involves the industry in data collection and allows it to see what is being collected and for what purpose.

Finally, and more remotely compared with the preceding two approaches, interviews, questionnaires and surveys have become ever more prevalent as a means of gathering FK.

Examples of all three approaches relevant to Scottish inshore fisheries are described below.

Industry-led FEK and fisheries data collection

Within the UK (as elsewhere in Europe), there has been an effort to engage the fishing community within the science framework that underpins management. The Fishery Science Partnership in England had promoted fishery-led research since the early 2000s, with well over a hundred scientific studies proposed and to a large extent carried out by the fishing community with the aid of CEFAS scientists[14]. A similar programme in Scotland, the Scottish Industry/Science Partnerships (SISP) was superseded in 2012 by the Fishing Industry Science Alliance[15].

Most of these studies have been proposed by the fishing industry and designed and carried out by scientists at the main fishery laboratories or other agencies in collaboration with industry. They have been short term projects designed to address specific questions or areas of interest. Reports from both schemes are available online. Typically, the work has been undertaken by commercial fishing vessels chartered to undertake research that industry considers useful as cooperative research.

While the research carried out by these fishery science partnerships has undoubtedly increased knowledge and understanding of numerous aspects of fisheries and the stocks that they target, the approach has been broad scale, seeking to address many specific questions or areas of uncertainty that might be useful for management. It is not clear to what extent these projects have been useful in management assessment process, though clearly some of them will have informed the work of various ICES stock assessment and other working groups.

A similar, but much broader, approach has been used in the USA for many years, under the Sea Grant Program, operated as a nationwide network of local programs based at Universities throughout the USA. The network conducts “scientific research, education, training, and extension projects designed to increase assessment, development, utilization, and conservation of coastal resources by providing assistance to promote responsive research and training activities and to broaden knowledge and techniques” (National Sea Grant College and Program Act, 1966 [P.L. 89–688] In National Research Council (2006)). The Sea Grant Program facilitates a two-way flow of information, with outreach and extension services sharing scientific research results with fishing communities, but also feeding back the problems and research needs of those communities. Through this (and other) initiatives, cooperative fisheries research has taken hold in several parts of the USA.

In the Northeastern USA for example, the Northeast Consortium was established in 1999 to “develop partnerships between commercial fishermen and scientists, educators, and coastal managers; enable commercial fishermen and commercial fishing vessels to participate in collaborative research; help bring fishermen's information, experience, and expertise into the scientific framework needed for fisheries management; and equip and utilize commercial fishing vessels as research and monitoring platform” (Northeast Consortium, 2015). Over 200 cooperative research projects are listed on the Consortium’s website, several of which are directed at lobster fisheries.

[14] http://webarchive.nationalarchives.gov.uk/20150204060540/http://www.cefas.defra.gov.uk/publications-and-data/scientific-series/fisheries-science-partnership-reports.aspx
[15] http://www.gov.scot/Topics/marine/science/FISA

Despite the plethora of cooperative research studies, Hartley & Robertson (2009) note continuing distrust between the fishing community and scientists. They point out the difference between *cooperative research*, where scientists charter boats or collect logbooks to further science, and *collaborative research*, where "fishermen [are] involved in research design, data collection and analysis, and dissemination of research findings". These are two ends of a continuum, but cooperative data collection can involve the fishing community more fully if the community has a direct interest in the results. For example, Manning & Pelletier (2009), describe how New England lobster fishermen have deployed hundreds of temperature logging instruments on lobster pots which have provided high temporal resolution data that has helped to improve oceanographic models of the Gulf of Maine, while also helping lobstermen to better understand how temperature drives lobster biology and catches rates.

In 1994, a non-profit organization consisting of a partnership between fishermen and scientists was established in Canada. The Fishermen and Scientists Research Society (FSRS) established a network between fishermen and scientists whereby fishermen actively participate in research projects with the common goal of ensuring long-term sustainability of the North Atlantic stocks (http://www.fsrs.ns.ca/). The lobster recruitment index project was conceived in 1999 after concerns by both fishers and scientists were raised about the lack of useful information to manage the American lobster (*Homarus americanus*) stock in Nova Scotia. The project aims to develop an index of recruitment of lobsters by evaluating changes in abundance of juveniles that will be recruited into the fishery. Volunteer fishermen count, sex, and measure size of lobsters from special traps and record them in logbooks. Bottom temperature are monitored by placing a computerised temperature recorded on their special traps (http://www.fsrs.ns.ca/recruit.html). This is an example of a successful partnership between fishers and scientists where the information provided by fishers is used to assess the stock status and contribute directly to the development of indicators of stock abundance, fishing pressure, and stock productivity, which can then be compared to past values (Rondeau et al. 2015).

Closer to the UK, the Norwegian Reference Fleet provides another good example of cooperative research. The Norwegian reference fleet is "a small group of Norwegian fishing vessels that provide the Institute of Marine Research (IMR) with detailed information about their fishing activity and catches on a regular basis. The sampling and data management procedures are similar to the system used on board IMR's research vessels. Data is used for management purposes including stock assessment" (Institute of Marine Research, 2013). There are 19 offshore vessels and 20 coastal vessels that supply prescribed data collected in a standardised way to the IMR. The process has been studied in detail by Bjørkan (2011). In regard to the reference fleet (RF), Bjørkan quotes a Norwegian fisheries scientist who says: "The Reference Fleet is the largest project that we have here at the IMR, and it gives us good data on species composition, length, weight, age and by-catch and time series with regards to effort", while a fisherman is quoted as saying "today we can come to the IMR and the scientists are interested in what we have to say: they listen and say that 'we must take a note on this'. This could never have happened before".

Bjørkan notes that a significant feature of the RF is that annual meetings are held at which scientists and fishermen can exchange views in an informal setting. She suggests this is an important vehicle for enabling fishermen's views to be conveyed to scientists. Likewise, when scientists are on board such vessels, further exchanges of views are possible. Nevertheless, with respect to the cooperative data collection itself, she is more critical: "the fishers' role in data collection is similar to that of a technician or a research assistant, with little responsibility with regard to what data to collect and how to collect and interpret it. While the fishers are indeed working with science, the scientists have not given up much decision making power". She also points out that "if the RF has succeeded in achieving the goals for which this project was established, it is because it actually involves fishers in knowledge production for advice. Nevertheless, this involvement is shallow, and does little to change the fundamental distribution of authority with regard to knowledge provision for fisheries management, which remains securely in the hands of the IMR and marine scientists"; she continues: "*it is naïve to believe that fishers' experience based knowledge can be put to work as it is, when there are no institutions to verify that knowledge or arenas to authorize it*". These are important considerations when deliberating on how and why Scottish fishermen might like to contribute to data collection.

Within Scotland, several examples exist where cooperative research has been used to collect scientific data. In some cases, particularly those under the aegis of the Scottish Industry/Science Partnerships, these projects have mainly been initiated by the fishing industry itself, but the extent to which the results have been used in consultation with the industry in any 'co-management' framework remains unclear. The Clyde Fishermen's Association for example have initiated a biennial series of trawl surveys in the Clyde estuary to monitor trends in groundfish numbers, and hopefully the recovery of local stocks. Data are collated at the University of St Andrews and passed on the Marine Scotland Science, but exactly how these data might be used to inform management decisions in future remains unclear as yet.

Another interesting initiative is the Fishers' North Sea Stock Survey (Napier, 2014), which was initiated in 2002 and has provided fishers perceptions of changes in North Sea fish stocks in a detailed annual report to ACOM – the ICES Advisory Committee that provides official advice to the European Commission and recommends fish stock quotas. A lot of work went into producing these detailed survey reports, yet it is not clear how or indeed whether this concentrated fishermen's knowledge is actually used in the assessment process. Bjørkan (2011) states "The survey's purpose is to assess how fishers perceive changes in the state of selected fish stocks. The result of the survey is then made available for ACOM, which considers it when giving advice. Hence, fishers' experience based knowledge is collected in addition to science and assessed by scientists before it is made available for the ACOM. The weight given to their advice in comparison with the authorized experts' advice, however, is unclear." ICES (2005) report that "the survey was found useful and informative by ICES and is being used in a descriptive way in the ACFM report", but there is no mention of it in recent ACOM/ACFM reports.

We must conclude that whereas industry has been invited to suggest research projects and to help with data collection in Europe at least, thus far fishermen's direct observations of species and ecosystems is largely peripheral to the routine management process.

It must be pointed out, however, that engaging with industry and relying upon it for catch and fishing activity data are not a panacea to management problems. In New Zealand, where a much lauded Quota Management System has given ownership of stocks to individual commercial entities with the aim of encouraging long-term, responsible and sustainable fishery plans, "the evidence of […] stewardship seems to be meagre" (Hersoug 2018). Indeed, unreported catches, high-grading and dumping all appear to have been rife in many fishery sectors in New Zealand, despite or perhaps because of a reliance by assessment scientists on industry provided data to undertake stock assessments (Hersoug 2018). Cuts to government research and assessment budgets, coupled with some in-built incentives for misreporting of fishery data, have led some to conclude that fishery dependent data are a part of the problem here and not the solution (Slooten et al 2017), and as a consequence on-board electronic logbooks, position reporting and camera monitoring are being implemented in most commercial fisheries in New Zealand (Fisheries New Zealand, 2018). This represents the next step in collection and use of fishermen's experience.

Fishermen's experience collected electronically and by observers

It is debateable whether the direct monitoring of fishermen's behaviour and the quantification of their fishing activities by observers or cameras should properly be included in a review of fishermen's ecological knowledge. In many respects such information is just like any other 'fishery dependent data', including logbook returns and sales notes for landed fish. However, logbooks and landings declarations are formulated by a management authority, so the information is constrained before it is provided. There is little scope for adding additional observations, comments or remarks about the amounts of fish landed, and generally no scope for such observations to be included in any official data management system.

Two ways in which fishermen's knowledge can be collected during the fishing process are the use of observers to record data items, as well as to record observations, comments and opinions from fishermen, and the use of electronic monitoring systems.

The use of scientific observers on board fishing vessels has a long history. Several countries began to implement observer schemes in the 1970s around the time that 200 nm fishery zones were being established in part to collect data and in part to monitor regulation compliance (van Helvoort, 1986). In Scotland, a discard monitoring scheme was initiated in 1975 on demersal and later pelagic trawlers (Jermyn & Robb, 1981). Although this scheme persists to the present, some of the observer responsibilities have now been devolved to fisheries themselves (self-reporting: Napier et al 2016), or to an Independent On-board Observer Scheme (Scottish Fishermen's Federation, 2016).

One of the potential criticisms of devolving responsibility for data collection to the industry itself is that the process may compromise data validity through conflict of interest, as seen in New Zealand (Hersoug, 2018; Slooten et al., 2017). Partly for this reason, there has been considerable development of electronic means of collecting data from fishing vessels.

Initiated in the late 1990s to provide an alternate means of monitoring catch and effort in Pacific fisheries (McElderry, Schrader, & Illingworth, 2003), electronic monitoring now includes a wide variety of data collections methods. A key factor in their development has been the emergence of small and reliable electronic geo-locators that can fix the location of a vessel almost anywhere on the globe. Video monitoring and geo-location recording have both expanded greatly as a way of collecting information about fishing activities and has been especially useful in regions with data poor fisheries. Satellite based VMS (Vessel Monitoring Systems) have been in widespread use on larger vessels in the EU since the year 2000. Although VMS is primarily for monitoring compliance, the scientific community was quick to recognise their potential utility in gaining a better understanding of fishing vessel behaviour (Brereton et al., 2016; Gerritsen & Lordan, 2011; Lee, South, & Jennings, 2010; Mills, Townsend, Jennings, Eastwood, & Houghton, 2007). Use of Global Navigation Satellite Systems (GNSS) systems on smaller and inshore vessels has subsequently proliferated in recent years, and there are now many examples in small scale fisheries around the globe, primarily to map resource use (Daw, Maina, Cinner, Robinson, & Wamukota, 2011; James et al 2017; Metcalfe et al., 2017).

Within Scotland, video monitoring was introduced to document all catches on board some trawlers in the North Sea, in order to be able to quantify the bycatch of cod and thereby enable real time redistribution of fishing effort to limit cod bycatch (Needle et al., 2015). In this case, the results of the data collection were used in a very short time frame, such that the experience of fishermen was being used and felt by them as part of an agreed management framework. This contrasts with situations where fishing locations have been collated to explore fishing activity months or years later within a science framework alone.

Other ways in which electronic monitoring has been used creatively has been to monitor the bycatch of protected species (Kindt-Larsen, Dalskov, Stage, & Larsen, 2013) and to provide biological information on crabs and lobsters (sex and size) and fishing effort data in Welsh pot fisheries (Hold et al., 2015).

Remote monitoring of vessels, as with observer data, enables information from a fishery to be passed to scientific or management authorities, but without the need for additional persons onboard. It might be argued, however, that this represents the harvesting of data rather than the transfer of fishermen's experience or knowledge, as it can be achieved with little or no involvement if the fishermen themselves. While it is clear that electronic data gathering is likely to become ever more prevalent and ever more capable, the separation of the fishermen themselves from the data that are being collected and analysed remotely does not encourage a wider participation in management processes that is considered essential if marine natural resources are to be managed sustainably (Mikalsen & Jentoft, 2008). Furthermore, whereas observers, as fellow human beings, are able to capture and report the attitudes, thoughts and perceptions of those with whom they are working on board boats, this element of fishermen's experience is disregarded by electronic data collection.

Gathering fishermen's memories, habits and attitudes

Numerous studies have been conducted by anthropologists, economists, social scientists, geographers, biologists and engineers asking fishermen and others involved with the fishing industry to recall things from the past, describe what they routinely do, recall when they last saw something, or give their opinions about things. Such surveys are typically done as one-off surveys, though in some cases they may be repeated at regular intervals. One-off surveys have been useful in gathering historical data to inform for example biological or ecosystem modelling, but opinion surveys and resource use surveys are quickly out of date. Regular surveys are more useful as means of gathering FK, a good example being the annual surveys conducted by SeaFish on the economics of the UK fishing fleet, where around 700 fishermen are interviewed annually and their opinions catalogued (Lawrence, Moran Quintana, & Motova, 2017).

A key consideration in such surveys in recent years has been how fishermen use the marine environment. Many nations are attempting to establish marine protected areas, and in much of the world there is increasing pressure on sea areas, once the sole domain of fishermen, from a range of industrial and other developments. Marine spatial planning has therefore become a key focus on marine managers, and consequently numerous efforts have been made to try to understand how fishermen are using the marine environment. Several examples illustrate how fishermen's knowledge has been used to map out sea use areas.

The octopus (*Octopus vulgaris*) fishery in Galicia is a small scale fleet operating in coastal waters, predominantly using traps. The fishery is currently under a top-down management (decisions are taken at the level of government, without input from fishers). This form of management has generated a breakdown between fishers and policy makers, whereby fishers complain that managers do not incorporate their opinions into regulations and policy makers complain that fishers do not comply with current regulations (Pita et al. 2016). The utility of collecting FK to obtain maps with distribution of fishing grounds and the use of low cost monitoring techniques were evaluated as means to improve management of artisanal fisheries (Pita et al. 2016). Semi-directed interviews were conducted to get a description of the vessels, gears and target and non-target species, and maps of the location of fishing areas. Portable low cost GPS were given to three fishermen to record the vessel position every

1 minute. Skippers were also asked to provide information on the catch (kg) per haul, and the time of the haul. FK was a useful tool to map fishing grounds. Moreover, high resolution spatial fishing data were collected using low cost GPS sensors, which combined with fishing log-books allowed the mapping of the intensity of effort and of CPUE at fine spatial scales (Pita et al. 2016).

Understanding the spatial distribution of fisheries is an important step towards formulating sound management principles. This step is particularly challenging in small scale fisheries, as they are very often "data poor". Moreno- Báez et al., (2010) used fishers' local knowledge to determine the distribution of data-poor, small scale fisheries operating in the northern Gulf of California. Participatory interviews and mapping through rapid appraisal techniques were used to identify fishing grounds and fishing seasons for 52 different species targeted by 17 fishing communities at a regional scale. Post-survey workshops with fishers were used to validate the spatial information using maps to facilitate visualization of the data. This study provides an example of how FK can be incorporated into a data collection process at large, regional scales and highly diverse fishing activities (Moreno-Baez et al. 2010).

Within the UK, several surveys have been conducted to try to establish resource use patterns to pre-empt conflicts over inshore access and to determine areas that can be set aside as Marine Protected Areas under the Marine (Scotland) Act.

Examples include the ScotMap project (Kafas et al., 2017), in which over a thousand Scottish inshore fishermen from the under 15m vessel fleet (predominantly creel boats) were interviewed to identify and prioritise fishing areas based on the vessel earnings. A similar project was undertaken in Wales by Pantin et al. (2015) who interviewed fishermen around the Welsh coast to better understand fishing patterns, gear use and area usage. As with the ScotMap project, usage maps were produced to show where specific fisheries were focused. This approach, based on interviews, has been criticised by Terry, Lewis & Bullimore (2017), on the basis that there was no independent verification of areas that were reported to be fished.

In 2015, James et al., equipped 274 Scottish inshore vessels with Class B Automatic Identification Systems (AIS). The purpose of this project was to: determine the practicality of using AIS as a reliable means of tracking inshore fishing vessels; and assess the willingness of fishers to accept the use of a tracking technology that openly reports the position of their vessel to anyone with an AIS receiver. Using these data, methods were also developed for assessing the intensity of fishing activity and it special footprint. Whilst those fishers that volunteered to participate in the project were obliged to keep the AIS units turned on all the time they were at sea, most subsequently reverted to not using the system or using it in silent mode whilst fishing, after the conclusion of the project. This suggested that most fishers would not provide openly broadcast track data unless legally obliged to do so. In addition, a combination of modelled transmission and reception for AIS and anomalies in the quality of harvested AIS data, suggested that this would not be an appropriate or universally acceptable method of tracking inshore fishing activity in Scotland.

During 2010, the closure of 22 areas was proposed around Shetland to protect and conserve threatened habitats from dredging activities (Shelmerdine et al. 2014). Horse mussels (*Modiolus modiolus*) and beds of maerl (a common term that includes several species of calcified red seaweed) were recognised by Scottish Natural Heritage (SNH) and the Joint Nature Conservation Committee (JNCC) as Priority Marine Features (PMF), and as such, are considered threatened and require conservation efforts.

Initially areas were identified based on historical point records and estimated species distribution extents from various agencies. Through consultation, scallop fishermen disputed some of the proposed areas, claiming that some did not include any such threatened habitats. An agreement was reached whereby fishermen were to stop fishing activities in all areas on a precautionary basis, until survey work could be conducted. Later survey work confirmed the absence of threatened habitats in most areas previously challenged by the fishermen and a change in local legislation was put in place swiftly to allow fishers to use these areas. This participatory approach facilitated both the correct identification of areas with Priority Marine Features and the compliance of fishers to respect initial delineation of areas until survey work was possible. Since then, further surveys have been conducted based on fishers' reporting the presence of these PMFs by either approaching the Shetland Shellfish Management Organization (SSMO) or reporting them via logsheet entries (Shelmerdine, pers. comm.).

The issue of designating marine protected areas is nevertheless one where collation of FK has proven very controversial (Flannery, Healy, & Luna, 2018; Lieberknecht & Jones, 2016). Fishermen and other stakeholders may end up 'gaming' the process to try to maintain advantage over real or perceived competitors for marine space. But this is far from the only use to which such FK has been put.

Information on previous habitat condition has been collected from fishermen with decades of experience of working in a particular area. Ames (2004) used historical scientific surveys together with fishermen's accounts of cod spawning regions, overwintering areas and migration to piece together an overview of the stock structure of the Gulf of Maine cod population. He interviewed retired fishermen to understand the local cod population structure, information which has subsequently been used to analyse current stock structure and to develop a local collaborative ecosystem based recovery plan (Ames, 2010).

Surveys of fishermen's knowledge have also been used to draw on memories of previous catch rates to place current exploitation patterns in context. In order to characterise changes in catches and extinction risk of the tiger-tail seahorse (*Hippocampus comes*), O'Donnel et al., (2010) linked fisher interviews and fisher logbooks to establish a catch per unit effort (CPUE) trend for this data-poor small-scale seahorse fishery from 1970 - 2003. Even under the most conservative scenario that assumed that fishers consistently over-estimated CPUE they show that the fishery experienced a severe decline and revealed that historic data showed a greater extinction risk than currently assigned by the IUCN Red List.

Currently one of the IUCN criteria used to assign a category (i.e. extinct in the wild, critically endangered, endangered, vulnerable) relates to changes in population size over either the last 10 years or three generations, whichever is longer (IUCN 2012). O'Donnel et al., (2010) highlighted a potential limitation in this criterion, as longer term declines can show quite a different picture. They stress that a retrospective classification could become possible by incorporating fishers' knowledge and discuss how assumptions about the accuracy of fisher's recall affect the assessment of conservation status.

American lobster *Homarus americanus* landings have markedly increased since 1981 in the Gulf of Maine (ASMFC 2018). Two main hypotheses haven been proposed to explain this increase in catches, first, that the increase in lobster landings is partially explained by the decrease in lobster predators, such as the Atlantic cod *Gadhus morhua*. A second hypothesis to explain this increased landings, is the increase in effective fishing effort (e.g. an expansion of fishing area, increased vessel size and number of traps) (Boudreau and Worm 2010). Fishing efficiency may also have increased with the use of sonar technologies which have made the fleet more efficient in discovering fishing grounds. Some management areas in Canada lack long-term survey estimates of lobster abundance therefore the objective of extracting FK was to get information on abundance of lobsters and predatory fish to compare against fisheries-independent data from the United States in the Gulf of Maine to determine if it provided a good alternative to these independent surveys. Fishers were asked what they thought were reasons for the increased number in lobsters and to report in which fish stomachs they had found lobsters. Fishers identified different reasons for the increase in lobster abundances, amongst them the most important was a decrease in lobster predators, followed by an increase in effort, and a success of conservation measures applied (Boudreau and Worm 2010). Fishers found lobsters in stomachs of large predators such as cod, wolffish and cusk (Boudreau and Worm 2010). This study provided evidence in support of the predation hypothesis, which was further corroborated by independent trawl surveys, which revealed negative correlations between these large fish abundance and lobster abundance. These results suggest that Local Ecological Knowledge Surveys may be a useful tool to investigate the ecosystem effects of fishing (Boudreau and Worm 2010).

3. Fisher input to management procedures

Fishermen's Knowledge does not always need an interlocutor to connect observations (data) with management practices. Berkes et al (2007) include in their definition of FK the actual "practices through which people carry out their resource use" and suggest that FK includes practitioners' ways of pursuing fisheries that lead directly to management improvements.

The transcription or recording of fishermen's observations, as described in the preceding section, usually relies on some outside body collating the observations and then translating them, with or without the input of the fishing community, either into some better understanding of the ecosystem, or into management rules. The overall aim is to improve management of the ecosystem, while also recognising that wider participation in management processes is not only desirable but essential if marine natural resources are to be managed sustainably (Mikalsen & Jentoft, 2008). It is therefore worth exploring the extent to which FK is or has been directly responsible for management practices.

Below we consider some examples of operational and other practices developed by fishermen that have been incorporated into management procedures and have improved management outcomes.

Operational practices

Fishing operational practices are generally discovered, developed and refined by practitioners. Refinements of such practices can lead to improved 'management procedures', or can help with management objectives, but often practices that have evolved over decades or centuries form the basis of effective management measures. These may involve restrictions on gear type or usage practices for example, or seasonal or spatial fishing restrictions, or modifications to gear design or use. A few examples serve to illustrate some ways in which fishing communities have used local or ecological knowledge to refine, improve management procedures or deliver management goals.

Traditional fishing methods are often maintained both to honour customary practice, while also minimising resource competition, even of this latter aim is not made explicit within the bye-laws and regulations pertaining to the fishery. Examples include the Fal Oyster fishery, whose sail-powered dredges are manifestly inefficient, but may have enabled this fishery to have maintained sustainability (Long, Ffrench-Constant, Metcalfe, & Witt, 2017). Several wild salmon fisheries within the UK are likewise constrained by restrictions on gear or fishing practice efficiency, restricted by convention, but constrained for conservation. While such practices are clearly based on tradition and it remains hard to demonstrate why such traditions have been transformed into legislation, the seamless exchange of traditional operational practices (FK) with current regulatory measures suggests in these cases that FK is indeed deeply embedded in existing management procedures.

An example where fishermen's efforts to conserve stocks demonstrates a more explicit incorporation of FK into management procedures relates to the preservation of 'brood stock' female lobsters in the USA. Acheson & Gardner (2011) describe the v-notching system that was initiated in the Gulf of Maine in the early 20th century, whereby egg bearing female lobsters are marked and returned to the sea, the v-notch in their tails signifying a reproductive female, so that if caught within the same moulting period (e.g year), it will also be returned by any other fishermen to the sea. There is a strong belief amongst the Maine fishing community that this is an important way to ensure the brood stock is not overexploited. The practice is underpinned by State legislation and has been adopted in other parts of the world too. The principle and initial implementation were developed voluntarily by the fishing community itself (J. M. Acheson, 1989), prior to being adopted officially.

The practice of V-notching of berried female lobsters to help protect lobster stocks, effectively removes breeding females from the fishery in order to help ensure future generations of lobsters. In Scotland it is an offence under the Lobsters and Crawfish (Prohibition of Fishing and Landing) (Scotland) Order 1999 to land lobsters bearing a v-notch, or mutilated in such a way as to obscure a v-notch. To help ensure the maximum potential benefits of v-notch clippers, Marine Scotland requests to be kept informed of how many lobsters are being v-notched, in which ICES areas, and on what dates. However, v-notching is largely a voluntary practice and whilst some fishers have diligently adopted this practice, it is not universal. In addition, there is no monitoring of the impact of this practice and thus no clear evidence of whether it is beneficial for the stock. As a result, some fishers are clearly reluctant to continue with a practice that, at certain times of the year, could significantly reduce their catches and incomes.

In Scotland, Regional Inshore Fisheries Groups (RIFGs) aim to improve the management of inshore fisheries in the 0-6 nautical mile zone of Scottish waters, and to give commercial inshore fishermen a strong voice in wider marine management developments.

The RIFG network includes:

- North & East Coast RIFG
- West Coast RIFG
- Outer Hebrides RIFG
- Orkney Management Group
- Shetland Shellfish Management Organisation

The RIFGs are non-statutory bodies and were established in 2016. They succeed the six Inshore Fisheries Groups (IFGs) that were formerly in place from 2013-16. The RFIGs encourage fishers to articulate their views and to bring their knowledge to bear in informing fisheries management.

By way of example, the North and East Coast RFIG surveyed commercial inshore fishers (December 2018 to 5th January 2019) working static gear within 0-6nm from the north and east coasts of Scotland.

The direct feedback from static gear fishers was designed to help to make informed decisions and recommend actions to Scottish Ministers and Marine Scotland.

The issues considered were generated by the fishers themselves and articulated as follows:

PARLOUR CREELS – Some fishermen have lobbied that parlour creels trap undersize animals and escape panels should be mandatory.

SOAK TIMES - Some fishermen have lobbied that soak times should be restricted suggesting animals are being wasted.

UNWORKED CREELS - Some fishermen have lobbied that unworked/unbaited creels must be lifted so they cannot continue to fish unattended, which is wasteful. Others consider this a ploy by full time fishermen to displace part time fishermen.

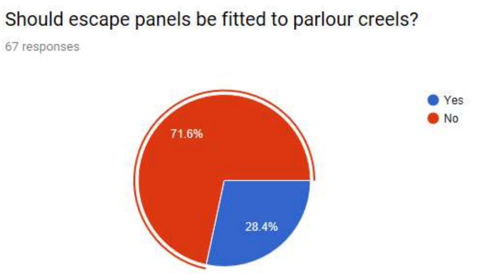
CREEL NUMBERS - Some fishermen have lobbied that their fishery is saturated with creels risking over fishing and creating spatial conflict between static gear fishermen.

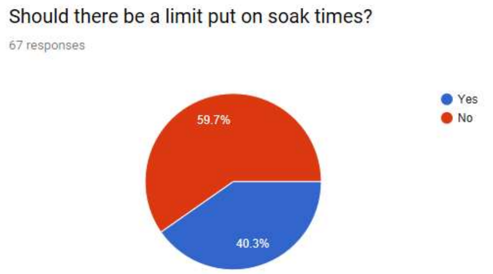
LOCAL FISHERY MANAGEMENT - Some fishermen have lobbied for local controls of their fishery depending upon factors such as boat size, Kw, season and fishing method to help manage stocks and address conflict situations.

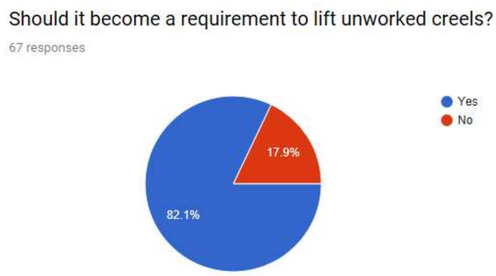
BERRIED HEN LOBSTERS - Some fishermen have lobbied that berried hen lobsters must be v-notched to conserve stocks, whilst some fishermen suggest it is only necessary not to land red berried hen lobsters.

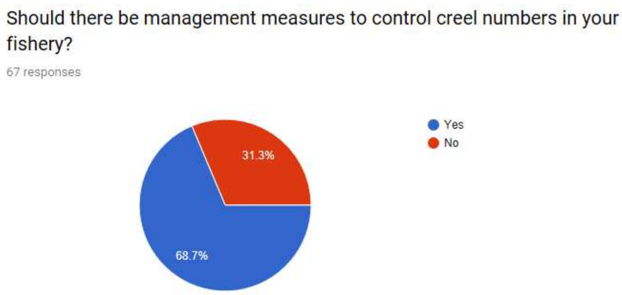
ILLEGAL ACTIVITY - Stories abound of widespread illegal activity such as unlicensed fishermen landing directly to merchants or via licensed fishermen or selling direct to hotels and restaurants. Or, that undersized catch is being sold or berried hens lobsters scrubbed or creels are being worked that are less than the legal mesh size. Or, vessels are longer or higher Kw than their licence. However, this view is not supported by the very few complaints received by Marine Scotland Compliance.

The outcome of the consultation was summarised in Figure 1.









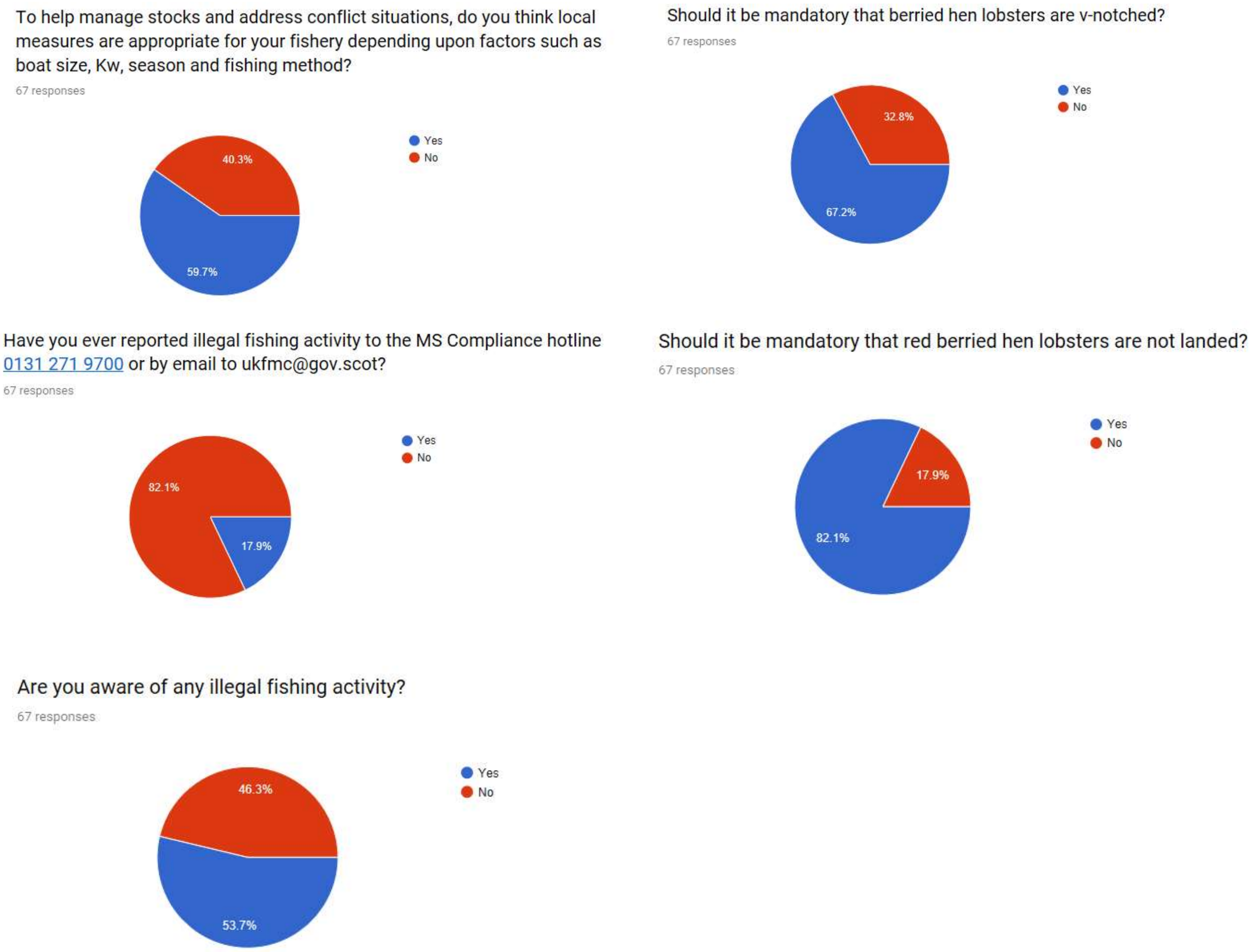


Figure 1. North and East Coast RFIG surveyed commercial inshore fishers (December 2018 to 5th January 2019) working static gear within 0-6nm from the north and east coasts of Scotland.

However, whilst these consultations have clearly engaged the industry and provide an indication of both knowledge and the strength of opinion on issues of concern, in this case to the static gear sector, the mechanism for acting upon this information and translating it into fisheries management practice on a voluntary of statutory basis are still unclear.

The use of escape hatches in creels is a contentious issue. Some view this as a conservation measure, others are sceptical noting that undersized lobsters and crabs caught in creels will be returned to the sea alive and escape hatches significantly reduce the potential to catch velvet crabs.

The promotion of seeding of lobster grounds by hatchery reared juvenile lobsters, promoted by fishermen in some areas and mandated under local bye-laws may be further examples of FK or operational practices being incorporated into local management procedures with the premise that this is helping to conserve stocks. However, this may be an example of a combination of FK, and lack of understanding of the cost benefits of this sort of restocking as there is little evidence that this activity has any stock conservation value (Ellis et al., 2014) and is likely to be economically unsustainable.

Modifications to operational practices can have benefits that go beyond conservation and sustainability. A very important aspect in this regard is safety at sea, which is often affected by management decisions as well as economic factors. Fishing is in fact the most dangerous civilian occupation, with over 100 fatalities per 100,000 fisher-years in the UK between 1976 and 1995 (Roberts, 2004), and 126 fatalities per 100,000 fishermen between 1992 and 2006. Kaplan & Kite-Powell (2000) found that two thirds of fishermen interviewed in the USA thought that fisheries management regulations were an important contributory factor in accidents at sea, and over half thought they were the most important issues in safety at sea. The initial findings of this study suggested that regulations that have been primarily designed to reduce pressure on stocks may also result in increased pressure on fishermen that can result in higher risk-taking and decreased safety at sea. It is not evident that any management measures in Scotland have affected safety at sea among creel vessels in this way, but any measures that encourage single handed operating or an increase in the number of creels used might have this effect. Among creel vessels, accidents are primarily linked to single-handed vessels and the risk of creel lines catching people on deck and dragging them overboard. In this context, several practices have been developed within the industry to modify and improve operational methods to help minimise these risks, including a creel toggle system to decouple creels from the mainline when they are hauled, and shooting techniques that rely on careful management of deck space. (Seafish, 2011).

FK is also used to solve many other practical and operational problems associated with management. For example, seals will frequently raid creels (and other fishing gear) in coastal waters of Scotland (Crossley, 1994; Moore, 2003), and fishermen have found a number of ingenious ways of keeping them from entering creels (where they may sometimes become entangled or trapped and drown), by making the creels more difficult to enter or the bait more difficult to steal (Crossley, 1994), though such measures are not incorporated into any official management system, they are part of an operational framework that helps minimise this particular conflict.

Catches and landings

Catches and landings data are routinely collected by government agencies in most countries, in part to monitor economic activity, and in part to provide data for biologically based management. They are usually recorded in some form of landings declaration such as a statutory form, logbook or onshore at the market. In some cases such data have been successfully augmented by fisher collected data, to the benefit of management.

The abalone fishery (*Haliotis fulgens* and *Haliotis corrugata*) is an important economic activity in western Baja California. This fishery is one of the best in Mexico in terms of recording catch data (Saenz-Arroyo and Revollo-Fernandez 2016), however, during the last three decades, abalone populations have shown a significant decline, due to overfishing and environmental variability (Morales-Bojorquez et al. 2008, Shepherd et al. 1998). Total catches retrieved from official statistics were compared to fishers' perceptions of their best catch ever recorded to assess if FK could be used as good indicators of population trends. Fishers were interviewed and asked about the largest number of abalone ever caught. A high correlation was found between government statistics and FK, suggesting that FK can give an informed trend on the status of marine species (Saenz-Arroyo and Revollo-Fernandez 2016).

Fishermen in La Rosita, a small town in northern Honduras started noticing a decline in catches and that it was taking greater time and effort to catch certain species. However, no data were being collected on the species caught, which hindered sustainable management of the fisheries, and the lack of data meant managers were unable to determine the importance of these fisheries to local livelihoods. Scientists from the Smithsonian Institute and the Center of Marine Studies (Honduras) developed a free Android App which allowed fishers to record the species and quantities caught (https://blog.nationalgeographic.org/2015/09/09/new-app-gives-fishers-a-voice/). This enabled the community to develop a database and more effectively monitor their fishery using bottom up community based monitoring. To further empower the community, and test the effectiveness of this, a solar-powered GPS device is also being trialled. Here small-scale vessels use the device on board their boats to get location and time information on where and when they are catching fish. Now fishers can show precisely how much they catch and in which areas, which will give fishers more weight in terms of the importance of their catch to the local, regional and national economies and the data can be readily incorporated into national statistics (Pauly, pers. comm, https://blog.nationalgeographic.org/2015/09/09/new-app-gives-fishers-a-voice/).

Using readily available, relatively low costs mobile communications technologies there are increasing opportunities for fishers to collect data useful to fisheries management. However, unless these data are collected within a consistent and verifiable framework, their utility in informing management in a statutory context remains challenging. The localised and voluntary collection of data by fishers with a clear vested interest in the sustainability of the resource they are prosecuting, opens up new opportunities for more local and regionally specific management regimes emerging from bottom up processes. Although technology is on the cusp of delivering the data required, structure and regulatory changes in the way fisheries operate and are managed will be needed to utilise industry derived data and FK to full effect.

4. FK in wider ecological and social systems

In this section we discuss the ways in which the fishing community organises itself and manages or interacts with wider social and ecological frameworks. This relates to Berkes et al's (2007) third aspect of FK: *ways in which fishers interact with the wider ecological or social systems around them in the context of managing or using the resource.*

In most UK and other European fisheries, management is typically top down, with fishery regulators consulting with industry but then deciding upon management measures, which are then enforced. Other models do exist, and indeed more 'traditional' forms of fishery management are widespread throughout the world, where the fishing community itself decides on and implements the rules.

In many traditional management systems, traditional resource management is achieved by access control, formally or informally. There are many such examples in the literature with respect to small scale fisheries, in which communities manage their local resources by controlling access. Johannes (1981) describes the situation in Micronesia: "*the most important form of marine conservation used in Palau, and in many other Pacific Islands, was reef and lagoon tenure. The method is so simple that its virtues went almost unnoticed by Westerners, yet it is probably the most valuable fisheries management measure ever devised. Quite simply, the right to fish in an area is controlled and no outsiders are allowed to fish without permission*" (ibid p 64).

On top of this rights-based approach, Johannes describes numerous taboos that relate to individual fish stock conservation that are integrated within traditional social practices, but which lead to robust resource management.

Ruddle (1989) discusses the ways in which village fisheries in Japanese coastal waters are managed by the community. Again, there is a detailed emphasis on the associated tenure rights. Rights to exploit relatively immobile resources, such as demersal fish and shellfish, are held by Fisheries Co-operative Associations (FCAs). Fishing rights and licences are applied separately for these resources. Decisions made by the FCA are arrived at consensually, but primarily management seems to be conducted by access control, which is partly inherited. On a day to day basis and at a fine scale, the right to a fishing site is allocated on a 'first come' basis. Experiential knowledge of fishing sites is critical to success and prestige of individuals (Ruddle, 1989 p. 179-180). Additionally, each FCA also establishes regulations for the control and operation of various types of fishery in its joint rights area in an equitable, efficient and sustained manner, as local conditions dictate. Overall it seems that local access control is the primary management tool, though other measures may be applied consequent to access control.

A similar approach to resource management is described in Maine by Acheson, (1989), who discusses the ways in which the lobster resource in Maine has been successfully managed for decades based on a system of access control. Access control is a form of resource ownership by Maine harbour 'gangs', informal groups within the local community who control specified fishing areas that are closely demarcated around islands off the Maine coast. Acheson refers to these as being "perimeter defended" but nucleated around coastal harbours where gang ownership is graduated from harbour mouth to a distance of perhaps 10 miles. Overlapping areas may be fished by people from more than one harbour. Incomers are denied access in several ways. Initially they may be warned off by tying half hitches into their buoy lines, but their traps (creels) may also be opened or in the extreme may be cut off. Effort is thus limited primarily by access control but in some places also by consensual agreement to limit trap numbers. Some local seasonal fishery closures may also be agreed to. Perimeter defended areas have fewer boats per unit area- and larger lobsters as a result (Acheson, 1989, p205). There are additionally State Laws that prohibit landing lobster less than 81 mm or larger than 127mm, or berried females – which when caught are notched. Tail notched females are those that carry eggs ('berries'). This is now widely held to be a major reason why lobster stocks have been maintained in a state of high productivity for so long. In order to encourage undersized individuals to escape, all traps must also have escape vents. Thus, size limitations and protection of the breeding stock are the main mandated (but accepted) management measures, aside from effort regulation via access control. Acheson (1989) notes that lobbying by fishery representatives has had a significant impact on fishery legislation by the State of Maine and by the Federal authorities.

Clearly access control has played and continues to play a very important role in fishery resource management systems for which fishing communities themselves are legally or practically responsible for management. However, it is also important to recognise that some "community" rights may, in reality only be vested in some individuals within a community for reasons of tradition and, as such, the benefits that accrue to the community may be limited. By way of example, in Palau the lucrative mud crab (*Silus serratia*) fishery is controlled by the tribal Chief's who almost exclusively prosecute the fishery. There is some evidence that this fishery is sufficiently lucrative that it is prone to over exploitation – perhaps because perversely it is within the gift of individuals who are already relatively wealthy and whose livelihoods are not predicated on the fishery alone (James Pers obs. 2018)

Resource ownership is more formally defined in New Zealand, where management is quota based, and companies or legal associations (including Maori communities) have been given quota rights to all fish stocks ((Hersoug, 2018). Nevertheless, the catch limit for each stock is still usually set by government agency. Quota owners can also rent out the right to fish (via annual catching entitlements), making them resource landlords rather than resource stewards. Hersoug writes that "the devolvement of management responsibilities has not succeeded, with a few notable exceptions, and the system is still largely managed 'top down', with a large and increasing number of government regulations".

Within the EU and the UK there is clearly an intention under both the CFP and domestic legislative agendas to devolve management responsibilities down to local fishing communities. This is reflected in the establishment of RACs at the regional level, an Inshore Fishery Strategy at the Scottish level. The establishment of Inshore Fishery Groups and the promulgation of inshore pilot management plans all attest to the political desire to incorporate fishermen's experience and knowledge into management procedures. It is within this context that in the present review we attempt to identify how FK might best be developed and brought to bear in a management framework.

Such a framework need not be focused solely on the exploited resource's management, but could include wider ecological or environmental objectives, if there were ways to make best use of fishermen's experience and knowledge to further wider societal goals. As yet examples of such practices are elusive, but as outlined in Objectives 2 and 3 of the WP 5 Report.

5. Discussion & Conclusions

In this final section we consider the risks and impediments that are seen in trying to promote fishermen's knowledge in the management framework.

Risks associated with the process of collecting Fishers Knowledge

Perhaps one of the main criticisms to integrating fishers' knowledge in science and management is the lack of a rigorous survey design (Hill et al. 2010). This includes describing methods in a detailed manner, secure adequate number of participants, and develop a system for the appropriate identification of participants to avoid bias incorporation (Davis and Wagner 2003). Not incorporating a well-structured, representative and systematic survey can result in different outputs, e.g. increasing the number of participants in a study showed that the recovery of oyster populations may not depend on the recovery of biogenic reefs (Hill et al. 2010).

Another criticism of collecting FK is the falsification of data. Falsification can be expressed in two ways, either as strategic responses that fit a particular agenda, or as self-censorship, which involves fishers only reporting observations that support their accepted theory, deeming other observations less important (Hill et al. 2010). Falsification usually occurs when fishers distrust the aim of the study, for example, a conservation project which used FK to assess the status of marine turtle population numbers, was perceived to have the potential to impact fishermen's livelihoods and cases of falsification of data were revealed (Silver and Campbell 2005).

Other non-intentional biases may be introduced in the data due to cognitive processes. For example, the "shifting baseline syndrome", a term first coined by Pauly (1995) in this context refers to the changing baseline in what is considered "natural" or "status quo". For example, in the Gulf of California, old fishers recalled five times the number of species and four times the number of fishing areas than younger fishers (Saenz-Arroyo et al. 2005). "Memory illusion" can also affect fisher's responses as extremely good catches are most likely to be remembered by fishers, which can have the effect of exaggerating the abundance trends (Daw 2010). Other factors can affect perceptions of catches or population trend estimations from FK. Changes in technologies can increase the efficiency of gear, or expansion of fishing grounds can mask actual trends, while decline in catchability, could result in an exaggeration of a trend (Daw 2010).

Addressing risks associated with the process of collecting Fishers Knowledge

Evidence-based management of fisheries based on FK, requires a critical analysis and scrutiny of FK, similar to any type of scientific data (Davis and Ruddle 2010). Therefore, careful planning of the survey design is of paramount importance when collecting FK. Davis and Ruddle (2010) recommend the identification of participants through systematically gathered peer review recommendations, using a structured sampling technique and the use of a variety of tools such as mapping exercises, timelines, bottom-up and top-down interviews. As well as an appropriate system to identify the participants in a study, depending on the objective of the study, the survey design can address problems related to falsification of FK by including fishers with different theories or points of view, or including of fishers that no longer have a vested interest in the fishery, such as retired fishers (Hill et al. 2010).

Finally, it should be reiterated that the collection of data is not an end in itself, and it is important to ensure any attempt to harness or gather FK by a management authority or scientific body is done so on the basis of a real management or science need. Collecting data 'for the sake of it' only undermines confidence and trust between the fishing community and the science community. Any initiation of data collection must be underpinned by both institutional and practical capabilities to collate, manage, interpret and make use of the data in a transparent manner. There should be a real policy need to collect and use data before its collection is proposed.

Impediments to the transfer and use of fishermen's knowledge.

Even a cursory reading of some of the social science studies that have looked into Scottish fisheries indicate some deep-rooted impediments to the inclusion of FK within the management framework. In large part these studies reflect a sense of distrust between industry on the one hand and scientists and regulators on the other, which will need to be overcome if FK is to be integrated within the management process.

Jamieson 2009 concluded that "The testimonies given by skippers to Williams suggests that dominant discourse [in Scotland] was not railing against large commercial concerns but the regulations and surveillance of government and the European Union, as they struggled with a sense of demoralisation at the impossibility of turning hard effort and skill into a living adequate to pay and keep their crew together as a team while staying within the law. "

Tom Rossiter –Fishermen's Knowledge – Fisheries Research Services undated; main findings:

Fishermen feel their views and interests are not adequately represented in the management process and this is something they want to address.

Fishermen closely observe factors that relate to fishing success; they possess detailed local knowledge of fish distribution and movements, and observe short and long-term changes in fish abundance.

Imani conclude that: Comments on management were strongly linked to the perception that the science that Marine Scotland relies on for decision-making is so separate from the industry that it is at best disjointed and at worst damaging the industry. Interviewees criticised Marine Scotland for the way that it conducts its data collection, advising that it neglects experience in the industry evident through its lack of engagement with fishermen and poor science communication.

Three interviewees expressed frustration at the lack of transparency around inshore fisheries policy, law and the science that is being conducted by Marine Scotland and Scottish Natural Heritage.

Communication was a significant issue, with interviewees criticising Marine Scotland for mismanaging their engagement with the industry on many levels, from individuals through to IFGs, and from fishers through to processing businesses. Most interviewees stated that they are expected to comply with new Marine Scotland instructions without any explanation of why the instructions are being made.

Interviewees advised that they are the best source of information for the management of inshore fisheries but are not being used to their full potential and feel exploited in the process of scientific data collection, rather than feeling like they are part of the process. This was combined with the perception that there is a lack of data on the stocks of inshore fisheries target species and that IFGs and individual fishers are expected to provide comprehensive information to Marine Scotland with little clarity of how it is used or going to be used, in return.

The situation in Scotland seems to be reflected in some other countries, including the USA. **Kaplan and Kite-Powell** (2000) in their interviews with fishermen in the US, reported that fishermen seemed very vague about the roles of the various management bodies, were uncomfortable about contributing information to the government, and felt that their contributions would be used against them in a future regulation that they would have no significant role in shaping. They suggested that the local Fisheries Management Council, created to represent people within the fishing industry, needs to become a better designed organization that will give fishermen a powerful and legitimate voice in the regulatory process. How this might be done is still an open question. In similar vein and despite the plethora of cooperative research studies, Hartley & Robertson (2009) also note continuing distrust between the New England fishing community and scientists.

In Norway too, where there is a long history of accessing FK through the reference fleet (RF), Bjorkan notes that “it is hard to see how fishers could come into a position where they could participate in a meaningful way in the assessment process as this is undertaken today”. She goes on: “the RF has succeeded in achieving the goals for which [it] was established, it is because it actually involves fishers in knowledge production for advice. Nevertheless, this involvement is shallow, and does little to change the fundamental distribution of authority with regard to knowledge provision for fisheries management, which remains securely in the hands of the IMR and marine scientists … it is naïve to believe that fishers’ experience based knowledge can be put to work as it is, when there are no institutions to verify that knowledge or arenas to authorize it.” It seems that in Norway as elsewhere on this issue, “non-scientists still rely on scientists in order to have a voice they have no real authority by themselves”.

These same issues of trust and participation are stressed by Pita, Pierce, & Theodossiou, (2010) in relation to Scottish fisheries, who reported that most consultees felt that industry was not well consulted or involved in management, a sentiment also reflected in several similar studies in other European fisheries

Conclusions

While there are many examples of ‘co-operative research’ between the fishing industry and scientists, and many examples where fishermen provide data to scientists and regulators, there remain some systemic problems associated with the use of FK in fisheries management. First there are there issues about data reliability – underscoring the need for properly designed sampling methods. Conscious and unconscious bias are also key concerns for which some methodological solutions are available.

There are more fundamental issues however, as to how FK may be incorporated into a management framework. It seems widely agreed that the reasons for wanting to incorporate FK into the management process goes beyond simply improving data availability, but is instead part of a wider ambition, common in many jurisdictions nowadays, to facilitate common understandings, establish trust between stakeholders, broaden participation and enhance legitimacy and acceptance of management policies. This requires a more fundamental approach to unpicking existing management procedures and social practices to ensure that industry participants are actively involved. Legitimising the involvement of fishers in the development of management plans will involve some radical changes to the ways in which co-operative research and stakeholder involvement are usually pursued. It may, for example, require some rethinking around the issue of access control, but most importantly it will require development of tools for improving communication between managers, scientists and fishers. Inviting fishermen to meetings seems unlikely to address this concern, but rather the examples shown by the Norwegian reference fleet, the US Sea Grant program and the barefoot fishery liaison officers in Galicia (Macho, Naya, Freire, Villasante, & Molares, 2013) all suggest a more positive involvement when mechanisms are put in place to ensure the development of personal relations between individual scientists, managers and fishers to grow and develop trust and understanding.

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APPENDIX 2 – PARTICIPANT INFORMATION SHEET

University of St Andrews

Participant Information Sheet

Project Title
Capturing and Identifying Experiential Inshore, Small-Scale Fisheries Data to Inform Local Management Strategies Through the Development of a Mobile Phone Application for Onboard Use.

What is the study about?

We invite you to participate in a research project aimed at improving the sustainability within commercial inshore fisheries (i.e. vessels of 12m or less fishing out to the 12nm limit). The project will try to provide information which could contribute to the long-term sustainability and profitability of the industry. Among the potential benefits to industry, the project aims to generate industry gathered data through a mobile phone App that can be used within the scope of marine spatial planning and fisheries management. The project also seeks to identify how the App could provide a platform to capture useful observations and information form fishers in a standardised format in order that these data can either in isolation or collated over time, contribute to fisheries management and marine planning.

This will involve engagement (through a trial using a mobile phone App) with a sample of inshore fishers to study the quality of the data provided through the App and to gain information on the fishing activities of the participants.

With your agreement, we would like you to start recording information about your daily catches through our specially designed mobile phone App which will allow you to review all data saved in the App and send it to us electronically. The application can be readily modified to accommodate any statutory requirements of commercial inshore fisheries. This means you will be able to submit the necessary paperwork regarding your catch, through the App, to your local fishery office. In addition, if you are willing to assist us further, we would like to collect some GPS tracking data from the mobile App which will allow us to understand the area you fish and how often you fish in these locations. An additional feature of the App will be an observation tracker. This part of the App will allow you to record unusual sightings or interactions with species such as whales, dolphins, seals or seabirds. These observations will provide researchers useful, often unrecorded information on the distribution of these species. Other observations might for example include the incidence of unusual by catch, squid eggs on creels or invasive / non-native species.

We will also be interested in your feedback on the functionality of the App and how we might improve it

Please be assured that all the information and data that we collect in this research project will be treated as strictly confidential. The results will be analysed and presented in such a way that no personal details or information which might compromise your fishing activities will be made public.

This study is being conducted as part of a research project, led by Dr Mark James who works in the Coastal Resources Management Group based the University of St Andrews, Scotland.

Do I have to take part?

This information sheet has been written to help you decide if you would like to take part. It is up to you and you alone whether or not you wish to participate. If you do decide to take part, you will be free to withdraw from the study at any time without providing a reason.

What would I be required to do?

This will vary depending on which part(s) of the App you choose to use. Recording an observation could take from a few seconds to a few minutes depending upon the amount of information you wish to provide. This can be done at a time and place that is convenient to you. If you agree to collect information on your daily catch you will be provided with instructions on how to fill in the App form and how to use the mobile phone App including the GPS tracker.

Will my participation be Anonymous and Confidential?

Only project researchers will have access to the raw data which will be kept confidential. The data collected will only be made available in reports or publications in aggregated or anonymised form. Your permission will be sought in the Participant Consent form for the data you provide, which will be coded*, to be used for future research purposes.

*'Coded Data' refers to when data collected by the researcher is identifiable as belonging to a particular participant but is kept with personal identifiers removed.

Storage and Destruction of Data Collected

The data collected will be only be accessed in its raw form by the researchers involved in this study, unless explicit consent for wider access is given by means of the consent form. Your data will be stored for a period of at least 5 years before being destroyed*, i.e. in (1) coded format on the University computer system (2) in the case of hardcopy in a locked storage cupboard.

*Unless secondary data permission has been indicated on the consent form. In the case of electronic data destruction will involve the permanent deletion (overwriting) of files using Eraser© software, while any hard copy records will be cross-cut shredded.

What will happen to the results of the research study?

The results will be made publicly available after the trail of the mobile phone App in aggregated form or be sufficiently anonymised as to prevent identification of the participant. Also, it is the intent of the Coastal Resources Management Group that wherever possible outputs from the trails will be submitted for publication as peer reviewed journal articles.

Are there any potential risks to taking part?

We do not anticipate there being any personal, emotional or financial risks to taking part in these studies. Very limited personal information will be recorded (name and contact details) to be used by the project team for identification purposes. If these data are utilised at any point, it will only be in aggregate form (e.g. participant, age, demographics). In cases where video/images may be taken specific permission (by means of the consent form) will be sort from the participants involved.

Questions

You will have the opportunity to ask any questions in relation to this project before filling in the Consent Form.

Consent and Approval

This research proposal has been scrutinised and been granted Ethical Approval through the University of St Andrews ethical approval process.

What should I do if I have concerns about this study?

A full outline of the procedures governed by the University Teaching and Research Ethical Committee is available at http://www.st-andrews.ac.uk/utrec/guidelinespolicies/complaints/

Contact Details

[To be provided depending upon the region/country in which the App is to be deployed]

For immediate purposes:

If you have any queries regarding the study please contacts the SIFIDS Project Facilitators Kyla Orr and Kathryn Logan using the Freephone number **0800 043 3474**

Or via email at marineconsulting@kylaorr.com and logank2@ukif.com

APPENDIX 3 – FISHER PARTICIPANT CONSENT FORM

University of St Andrews

Participant Consent Form

Coded Data

Project Title
Capturing and Identifying Experiential Inshore, Small-Scale Fisheries Data to Inform Local Management Strategies Through the Development of a Mobile Phone Application for Onboard Use.

The research project aims to improve methods of data collection within commercial inshore, small-scale fisheries.

Researchers
Dr Mark James
Dr Tania Mendo
Dr Simon Northridge
Miss Hannah Ladd-Jones
Mr Patrick McCann
Mr Swithun Crowe

The University of St Andrews attaches high priority to the ethical conduct of research. We therefore ask you to consider the following points before signing this form. Your signature confirms that you are happy to participate in the study.

What is Coded Data?
The term 'Coded Data' refers to when data collected by the researcher is identifiable as belonging to a particular participant but is kept with personal identifiers removed. The researcher(s) retain a 'key' to the coded data which allows individual participants to be re-connected with their data at a later date. The un-coded data is kept confidential to the researchers. If consent it given to archive data (see consent section of form) the participant may be contacted in the future by the original researchers or other researchers.

Consent
The purpose of this form is to ensure that you are willing to take part in this study and to let you understand what it entails. Signing this form does not commit you to anything you do not wish to do and you are free to withdraw at any stage.

Material gathered during this research will be coded and kept confidentially by the researchers with only the research team having access. It will be securely stored; in (1) electronic form (coded format) on the University computer system; (2) in the case of hardcopy in a locked storage cupboard.

Please answer each statement concerning the collection and use of the research data.

I have read and understood the participant information sheet.	☐ Yes	☐ No
I have been given the opportunity to ask questions about the study.	☐ Yes	☐ No
I have had my questions answered satisfactorily.	☐ Yes	☐ No
I understand that I can withdraw from the study at any time without having to give an explanation.	☐ Yes	☐ No
I understand that my data will be confidential and that it will contain identifiable personal data but that will be stored with personal identifiers removed by the researchers and that only the project researchers will be able to decode this information as and when necessary.	☐ Yes	☐ No
Secondary Data Permission/Decline		
I agree to my data (in line with conditions outlined above) being kept by the researchers and being archived for potential use in further research projects / by other bona fide researchers. I understand that this may allow other researchers to de-code the data and identify me.	☐ Yes	☐ No
I have been made fully aware of the potential risks associated with this research and am satisfied with the information provided.	☐ Yes	☐ No
I agree to take part in the study	☐ Yes	☐ No

Photographic Images and Video

Part of our research may involve taking photographic images and video. These images / recordings will be kept secure and stored with no identifying factors i.e. consent forms and questionnaires.

Photographs and recorded data can be valuable resources for future studies therefore we ask for your additional consent to maintain data and images for this purpose.

I agree to have my photo taken / to being videoed	☐ Yes	☐ No
I agree for my photo and video recorded material to be published as part of this research	☐ Yes	☐ No
I agree for my photos and video recorded material to be used in future studies	☐ Yes	☐ No

Participation in this research is completely voluntary and your consent is required before you can participate in this research. If you decide at a later date that data should be destroyed we will honour your request in writing.

Name in Block Capitals ______________________________

Signature ______________________________

Date ______________________________

APPENDIX 4 – PARTICIPANT DEBRIEFING FORM

Participant Debriefing Form

University of St Andrews

Project Title

Capturing and Identifying Experiential Inshore, Small-Scale Fisheries Data to Inform Local Management Strategies Through the Development of a Mobile Phone Application for Onboard Use.

Researcher Name

Dr Mark James

Nature of Project

This research project was conducted to investigate the use of a mobile phone application (App) as a way of improving data collection from fishers within commercial inshore fisheries (i.e. vessels of 12m or less fishing out to the 12nm limit). The project has assessed the potential to collect useful observations from fishers together with catch data and where fishing is taking place. We have also considered feedback from fishers on how the App might be improved. The purpose of the App has been to test the potential to collect information from fishers in a way that is efficient and consistent. The idea being, this information can ultimately be used by fishers themselves to better understand their business and to provide an objective evidence base to inform fisheries managers and marine spatial planners.

The ability of fishers to inform, in a timely manner, managers and legislators of significant events within their own fisheries as well as aiding effective decision making will help encourage industry led, non-legislative mechanisms of fisheries management. The project will provide information that is useful to fishers, fisheries managers and Government. This information will assist in ensuring that the inshore fishery sector is sustainably managed.

The information and data collected in this research project will continue to be treated as strictly confidential. The results have been analysed and presented in such a way that no personal details or information which might compromise fishing activities will be made public. This study was conducted as part of a research project, led by Dr Mark James from the Coastal Resources Management Group based the University of St Andrews, Scotland.

Project outputs

The results of the mobile App trial will be shared with the industry through presentations and written feedback in the form of popular articles in the trade press or bespoke information leaflets for example. We also hope to produce peer reviewed journal publications. If the App is shown by fishers to work as an effective method of collecting useful information to inform fishers' businesses, fisheries managers and marine spatial planners, it may be further developed and deployed more widely. Your contribution to this process is very much appreciated and we hope that it will deliver benefits for you and small scale fisheries generally.

Storage of Data

As outlined in the Participant Information Sheet your data will now be retained for a period of at least 5 years before being destroyed. Your data will remain accessible only to the project researchers, or if you gave permission on the Consent Form your data may be used for future scholarly purposes without further contact or permission. If you no longer wish for your data to be used in this manner you are free to withdraw your consent by contacting any of the project researchers. We would like to thank you for participating in this study.

What should I do if I have concerns about this study?

A full outline of the procedures governed by the University Teaching and Research Ethical Committee are outline on their website - http://www.st-andrews.ac.uk/utrec/guidelinespolicies/complaints/

Contact Details

Researcher: *Dr Mark James*

Contact Details: *maj8@st-andrews.ac.uk*

APPENDIX 5 – FISHER FEEDBACK DOCUMENT

Scottish Inshore Fisheries Integrated Data System (SIFIDS) project – WP5 initial user feedback

Thank you for using the SIFIDS FISH1 App. This document is for you to record how usable you found the App to be and to help us understand what should be improved, removed or added in the next App update. Please answer as many questions as you can. This feedback sheet will remain anonymous if filled in and sent by yourself or by a SIFIDS facilitator over the telephone.

1. **Did you use a mobile phone or tablet for the App?**
2. **Did you submit FISH1 forms via the App?** If no, please say why.
    a. If yes, did you already submit forms electronically (Excel or pdf) beforehand? Was it easier than your previous method?
3. **Did you submit wildlife observations via the App?** If no, please say why
4. **Did you record your vessels tracks at sea?** If no, please say why
    a. If yes, which tracking function buttons did you use?
       - at sea (recording all tracks), fishing (recording when actively fishing) or both (for one trip, differentiating between steaming / fishing)
5. **How did you find the appearance of the App?**
6. **Did you find the App easy to use?** If no, please say why
7. **How useful was the FAQ sheet in helping you set up the app?**
8. **Did you fill in the 'Settings' option with all of your details?** If no, please say why
9. **What were the benefits of using the App for you?**
10. **Were there any issues for you using the App?**
11. **Are there any features you would like changed in the next update?** E.g. bigger buttons, more species on wildlife spotter, separate 'fishing' and 'at sea' tracks, etc
12. **Are there any features you would like added in the next update?** E.g. notes pages, summary FISH1 page, etc
13. **Are there any features you would like to remain optional in the next update?** E.g. vessel tracker, wildlife spotter, etc
14. **Do you think a website version of the App to submit FISH1 forms and wildlife observations would be useful to the inshore fishing community?** E.g. a website you would log into, fill in and then submit your FISH1 form when complete, with all the your details pre-saved as seen with the app
15. **What data would be useful to see on a properly rolled out tool and what display options would be preferred?** i.e. personal historic tracks, alerts from your local FO (closure, weather warnings etc), regional fishery statistics, etc
16. **Do you have any suggestions on how to simplify / clarify the FISH 1 form?**
17. **If you have any further comments, please put them below**

APPENDIX 6 – FISH1 FORM

MARINE SCOTLAND COMPLIANCE

ALL SPECIES 10M AND UNDER WEEKLY LANDING DECLARATION FORM

Fishery Office: **Aberdeen**
Room A30, 375 Victoria Road, ABERDEEN AB11 9DB, Tel: 0300 244 9166

Email: **fo.aberdeen@gov.scot**

PLN ____________ **Vessel Name** ____________

Port of Departure ____________ **Owner/Master** ____________ **Signed** ____________

Port of Landing ____________ **Address** ____________ **Total Pots Fishing (1)** ____________

Fishing Activity Date (2)	Lat (3)		Lon (3)			Stat Rect (3)	Gear (4)	Mesh Size (4)	Species (5)	State (6)	Present-ation (7)	Weight (8)	DIS (9)	BMS (10)	Number of Pots Hauled (11)	Landing or Discard Date (12)	Buyer, Transporter Reg, or Landed to Keeps (13)
	DD	MM	DDD	MM	W E												
					W								☐	☐			
					W								☐	☐			
					W								☐	☐			

Comments (14) ____________

Important Notes

1. Vessel owners must complete a form FISH1 (landing declaration for vessel to which this licence relates, 10 metres and under in overall length) in respect of all landings of all species and submit it to the Fishery Office at which the vessel is administered within 48 hours of the conclusion of the fishing week - a fishing week runs from 0001 hours Sunday to 2359 hours Saturday.
2. All mandatory fields (M) must be completed prior to submission (see Notes on Completion below including examples)
3. It is the responsibility of the Master/Signatory to make themselves aware of the terms of the Landing Obligation (details can be found on the Marine Scotland Website or
4. Landings of all quota species made by the vessel during the calendar year are subject to monthly catch limits set by Fisheries Departments.
5. Landings made by the vessel will not be taken into account in the event of any future decision to introduce quota management arrangements based on landings by that vessel.

Notes on Completion

1. Total number of pots in water (Mandatory when fishing with Pots or Traps)
2. Date of fishing operation (M) A new line must be taken for each day at sea
3. Stat. Rectangle e.g. 41E3. and Latitude/Longitude where majority of catch was taken or first haul if working Pots or Traps (M) A new line must be completed when moving Statistical Rectangle
4. Gear used during declared activity (M)
5. Species declared (M) A new line must be taken for each species on an Activity Date
6. State of preservarion e.g. Fresh, Frozen, etc. (M) For live shellfish chose "Alive" option
7. Presentation of catch e.g. whole, gutted, etc. (M)
8. Landed Weight in kilograms of species (M)
9. Tick if species was discarded at sea (Mandatory if catch is returned see Landing Obligation) For catch discarded Below Minimum Size tick both 9 and 10. A separate line must be taken when recording discarded catch
10. Tick if declared species was retained Below Minimum Conservation Reference Size "BMS" (Mandatory if declared species is BMS) A separate line must be taken when recording catch Below Minimum Conservation Reference size
11. Number of pots hauled during Fishing Activity Date (Mandatory when fishing with Pots or Traps) Enter total only once for each day against first species line
12. Date species line from this Activity was landed (M)
13. Enter Buyer; Registration of Transport Vehicle; or for Live shellfish stored for later sale enter "Landed to Keeps" (M)
14. Please enter any comments relating to the voyage(s)

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