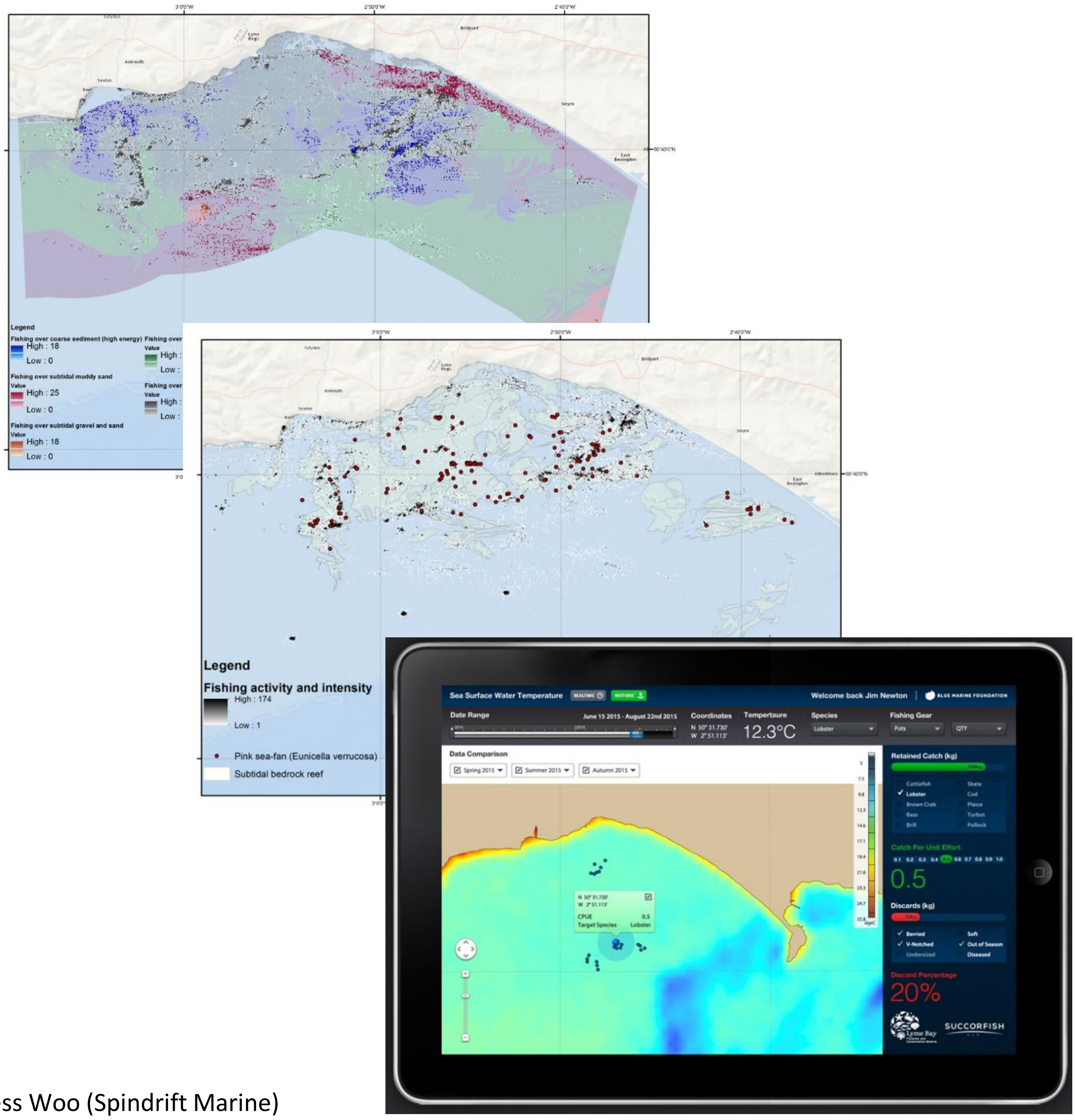
Lyme Bay Fully Documented Fisheries Trial



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BLUE MARINE FOUNDATION

Lyme Bay Fisheries and Conservation Reserve

EUROPEAN FISHERIES FUND

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Table of Contents

Contents

Executive Summary

The Lyme Bay Fisheries and Conservation Reserve project is a collaboration of the local fishermen and seafood businesses, conservation organisations and Inshore Fisheries & Conservation Authorities instigated and facilitated by the Blue Marine Foundation. The Reserve project aims to implement best practice in protecting the biodiversity of Lyme Bay, to implement best practice in managing fish and shellfish stocks and in creating long-term benefits for coastal communities around the bay.

The lack of timely and accurate fisheries and environmental information is a constraint to effective fisheries and conservation management. Information gaps force managers to adopt a precautionary approach and may make poor management decisions leading to ineffective or overly-prohibitive regulations. Clearly neither situation is desirable from a fishing industry perspective. The demand for specific fishery and environmental monitoring data is growing especially in light of the statutory requirements under the Marine Strategy Framework Directive.

In order to address these challenges this collaborative project, under the direction of a multidisciplinary steering group made up of fishermen, fishery regulators, conservation interests, policy specialists and marine scientists, set out to develop and test cost-effective and practical approach to marine fisheries data collection to inform management of the Reserve and that could be subsequently transferred and adopted elsewhere.

The project employed the recently developed Succorfish SC2 inshore Vessel Monitoring System (iVMS) fitted to 45 <10 m vessels to record fishing activity and intensity in the Reserve. The Succorfish SC2 iVMS system is able to provide accurate GPS data accurate to within 2 m. This was married with Radio Frequency Identification (RFID) gear tags and transceiver to test gear-in gear-out recording aimed at mapping the location of static gears such as pots and nets in the Reserve.

Real-time catch and landings data can inform quota management, promote traceability and be used to monitor and assess fish and shellfish stocks. Until now the <10 m fleet has been forced to rely on landings statistics reported by buyers and markets. This project developed and trialled a novel electronic approach using an App running on handheld devices, the Catch App. Fishermen were able to record catch composition and discard data into the Catch App which was then transferred directly to a database thus removing the data entry burden of paper records.

This report presents outputs from the GIS analysis of the iVMS data that have resulted in what are possibly the most detailed visualisation of inshore vessel activity produced to date (Figure 1).

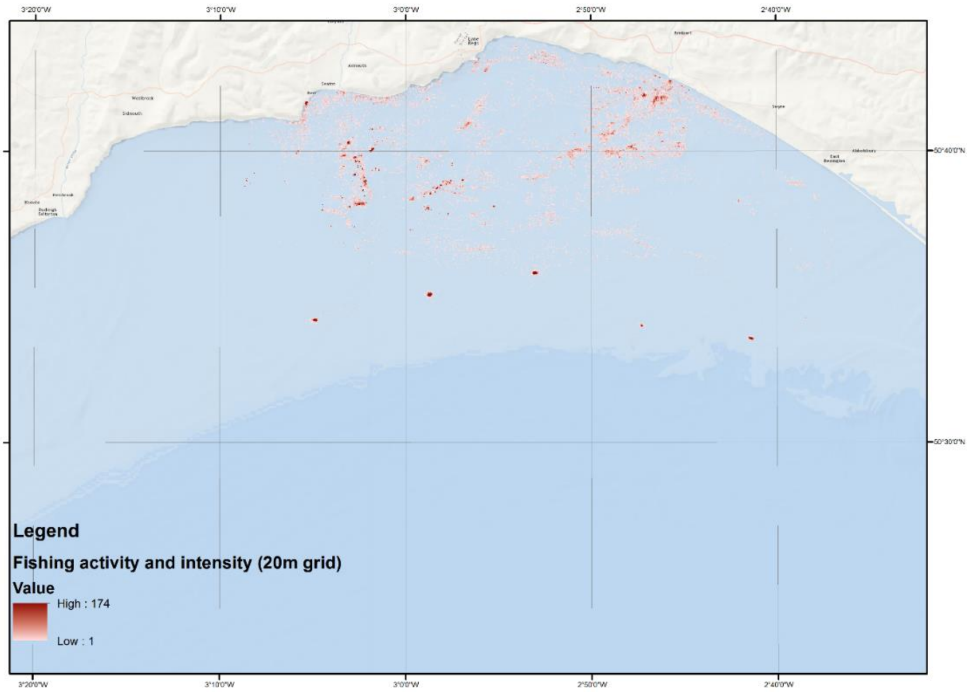

Figure 1. Fishing activity in Lyme Bay from iVMS at a resolution of 20m x 20m.

We have demonstrated how the ability to relate this high resolution spatial fishing activity data to site features and seabed habitats can result in an improved understanding of how fishing activity interacts with them. The habitats risk mapping analysis has produced some important statistics which will change how these interactions are perceived.

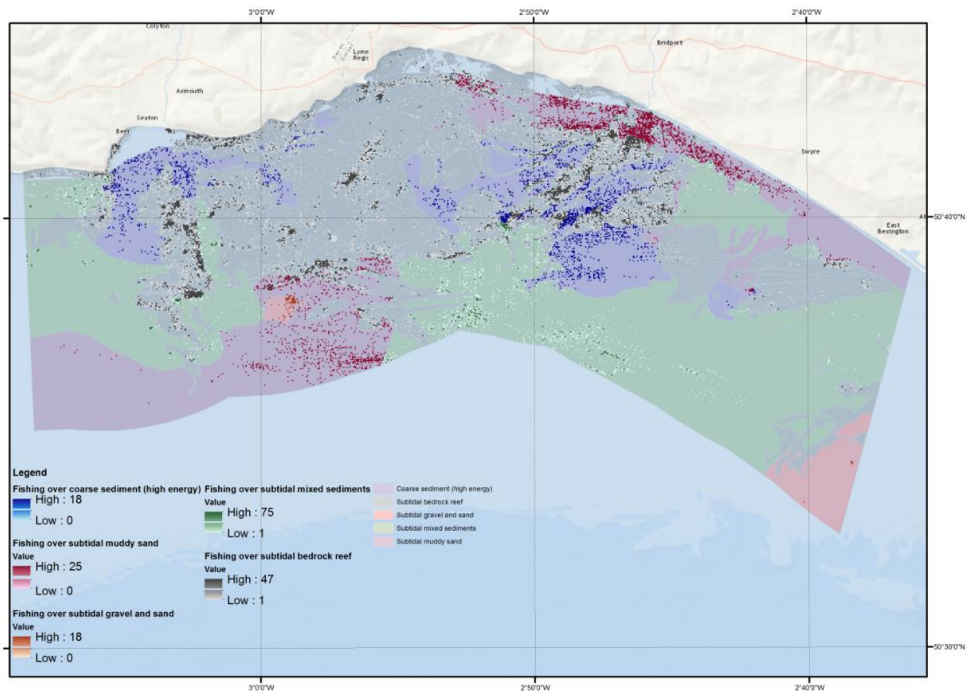

Figure 2. Fishing activity footprint in proportion to site features and seabed habitats

The subtidal bedrock reef, for which the site is protected, has static gear fisheries operating over 16.2% of its 164 km^2 extent and the subtidal mixed sediments which are distributed between the reefs are fished with static pots and nets over only 3.3% of their 144 km^2 extent.

This trial has successfully provided proof-of-concept that that individual fishing gears can be electronically tagged using cheap plastic RFID tags and that a detailed dataset of when and where gears were shot away (deployment) and/or hauled (recovery). This offers a means of gaining a true understanding of interaction is a means to link intensity with actual gear on the ground.

The results of the Catch App trial confirmed viability of using electronic using mobile devices to record detailed catch and discard data. This approach has the potential to act as an enabling technology to inform key aspects of commercial fishery management and businesses. This data collection method offers the ability for near real-time fishery stock monitoring and assessments with quota uptake rates reported as they happen rather than in one or two months' time. It enables full traceability through the supply chain and links with potential buyers may promote better prices and secure markets.

As one buyer said "I could tell my customers tonight exactly what they will have on their menu tomorrow night, before the fish even reaches the shore".

Finally we speculate about the possibility of linking Catch App data to the RFID and iVMS datasets with other diverse datasets and making these available to fishermen, closing the loop, in order to for them to assess and monitor their operations so that they could adapt their practices accordingly.

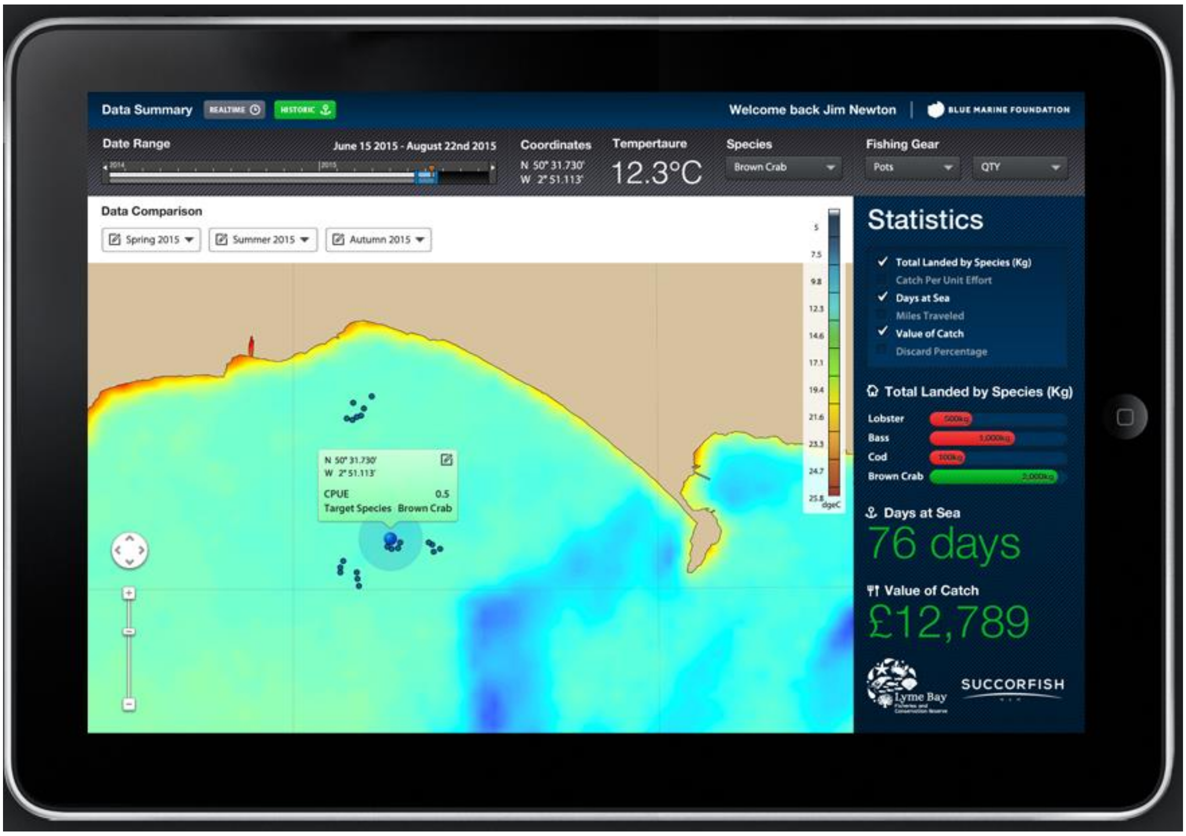

Figure 3. A possible Big Data development direction for the Catch App

Introduction

Context

Lyme Bay became the UK's largest marine protected area in 2008 when scallop dredging was banned under the Lyme Bay Statutory Instrument. Now designated the Lyme Bay Designated Area (Fishing Restrictions) Order 2008, this legislation prohibits use of bottom towed gear such as scallop dredges and trawls in an area of 206 km^2 (60 nm^2). Originally enacted to protect the cobble and bedrock reefs and the fragile invertebrate species that live on them the area has since been designated as the Lyme Bay to Torbay Site of Community Importance (SCI) is a Marine Protected Area (MPA) designated for reefs and submerged or partially submerged sea caves, for which this is considered to be one of the best areas in the United Kingdom. The site is proposed to the EU Commission and once approved it may be designated as a Special Area of Conservation (SAC).

Lyme Bay is the traditional fishing ground for a busy fleet of <10 m vessels operating from the ports of Beer, Axmouth, Lyme Regis and West Bay. These vessels predominately target crustacean, molluscan and finfish using static gears. Anecdotal reports and previous studies suggested that static gear effort had increased after the 2008 mobile gear closure.

In order to address the "unintended consequence" of static gear effort increases and with the intention of developing best practice for managing fisheries within MPAs Blue Marine Foundation formed the Lyme Bay Fisheries and Conservation Reserve project. The Lyme Bay Fisheries and Conservation Reserve project is a collaboration of local fishermen and seafood businesses, conservation organisations and the two local Inshore Fisheries & Conservation Authorities instigated and facilitated by the Blue Marine Foundation. The Reserve project aims to implement best practice in protecting the biodiversity of Lyme Bay, to implement best practice in managing fish and shellfish stocks and in creating long-term benefits for coastal communities around the bay. Working together stakeholders have come together to as the Reserve Working Group to deliver the aims of the project via a Voluntary Agreement that enshrines best practice in a practical Code of Conduct.

Fully Documented Fishery – the Lyme Bay Model

Catch and Discard Data

The term Fully Documented Fishery has entered the fishery management lexicon in the last decade and until now has mainly been used to describe catch reporting or data collection systems that capture both retained catch and discards of pressure stocks. The main statutory driver for this has been the reformed Common Fishery Policy (2013) and specifically the Landings Obligation under which fishermen will have to land all quota fish caught and, importantly, be recorded in logbooks.

European fishing vessels >12 m have to supply logbook information under EU legislation and this is now achieved using e-logs. Further data collection approaches have been trialled using Remote Electronic Monitoring (REM) employing CCTV as part of Catch Quota trials for pressure stocks such as cod (e.g. Defra, 2014). These trials combine selective fishing gears, and FDF recording to help fishermen adjust their fishing strategies in real-time and reduce discards.

At present there is no statutory requirement for <10 m vessels to record catch or landings data for fin-fish, shellfish data is collected under the Monthly Shellfish Returns scheme. The MMO collect landings data through the Regulation of Buyers and Sellers Scheme, which provides information on landings by weight and first sale value (since 2005). However, since 2009 landings of less than 25 kg have not generated a sales note and so have gone unrecorded. There are concerns that these "missing" landings might be considerable (Cefas, 2011a), and the changes in recording have affected the ability of Cefas to undertake stock assessments on some fisheries. There is a general agreement that this historic lack of data limited the ability for the <10 m fleet to prove a track record and secure sufficient quota allocation. Until now there has been no practical means of collecting this information either for management purposes or for the industries own use.

Spatial Activity Data

There is a keen management focus on the fishing related impacts on seabed habitats and sensitive species, both mobile and sessile, and this is of particular relevance in MPAs. Being able to understand the ecological footprint of fisheries is of particular interest to a wide group of stakeholders; the fishing industry have an increasing need for spatial information of their traditional fishing grounds to ensure that they can be considered and incorporated in the development of Marine Plans and to defend their grounds from offshore developments; scientists require this information in order to determine how fishing activity interacts with the natural environment; and IFCA managers need this information in order to enable fishing to take place in and around protected sites whilst affording the sensitive habitats and species high levels of protection.

Early on in the discussions of the Working Group it was recognised that spatial management plans, based upon habitat risk assessments and Habitat Regulation Assessments was a priority for managing fishing activity in MPAs like the Reserve. These plans aim to establish a zoned approach to fishing activity within MPAs that will afford the site features with the legally required protection whilst enabling the fishermen to continue to access their traditional fishing grounds. The capability of inshore VMS to monitor compliance is the key to making these spatial plans work and enable the protection of sensitive habitats from disturbance

The high level of environmental protection afforded to the habitats in Lyme Bay Reserve by the Habitats Directive and the shared objectives of the Reserve Working Group means that a Fully Documented Fishery in the context of the Reserve has to include spatial activity data collection, in essence, a spatially fully documented fishery.

The Fully Documented Fishery Project – Approach and Objectives

This project set out to develop and test cost-effective and practical approach to marine fisheries data collection in the Lyme Bay area that could be transferred and applied elsewhere. It was the intention of the Working Group that the FDF data collection methods would be ultimately used to demonstrate adherence to the voluntary agreement and statutory regulations. Through trialling of innovative technology, the project sought to turn fishing vessels into remote data collection platforms and wherever possible automating the process. Where automation was not feasible the project aimed to define and standardise a process to ensure that the data collected is scientifically robust. (For a table of potential data and uses see over)

The overarching objective of the project was to create a template for a structured and systematic approach to data collection from fishing vessels the outputs of which can be used to inform management of the Reserve and rolled out to other sites.

Table 1. Summary table of potential data than could be collected by the Lyme Bay FDF model

Data	Lobster & Crab / Whelk Potting	Static Nets	Long-Line	Trawling and Dredging	Economic and Business	Environmental
Spatial and Temporal data						
Spatial (from iVMS)	X	X	X	X	X	X
Daily	X	X	X	X	X	X
Per Haul	X	X	X	X		
@ Time of entry						X
Species specific data						
Quantity Retained	X	X	X	X		
Quantity Returned (undersized fish and shellfish, discards)	X	X	X	X		
Gear and Fishing Operation Specific Data						
Gear Used	X	X	X	X		
Gear Multiplier (no. pots or length of net, gear width, no. hooks)	X	X	X	X		
Gear descriptors (mesh size, pot type,)	X	X	X	X		
Soak time (Length of time net or pot was fishing in the water)	X	X	X			
Bait used	X		X			
Business related data						
Crew (no. and cost)	X	X	X	X	X	
Fuel (quantity and cost)	X	X	X	X	X	
Stores (cost)	X	X	X	X	X	
Gear (cost of replacements)	X	X	X	X	X	
Other costs (bait etc.)	X	X	X	X	X	
Environmental data						
Weather conditions						X
Wildlife Species (e.g. cetaceans, climate change or environmental quality indicators)						X
Invasive Species						X
Notes						X

The Steering Group

In order that the project was able to draw upon expertise from a wide specialist group a steering group was formed tasked with guiding the various areas of the project and deliver a successful outcome which can be transferred to other areas of the UK and possibly further afield. The steering group was made up of fishermen participating in the project, fishery regulators, conservation interests, policy specialists and marine scientists. The group participated on an ad hoc basis as and when specialist knowledge or direction was required. The steering group served as an important sounding board for both practical matters of data collection at sea and for the direction of analysis and the production of data products.

The Equipment

Inshore Vessel Monitoring Systems (iVMS) are devices that transmit in real-time GPS derived positions of commercial fishing vessels via Satellite or GSM communications (Figure 4). The systems are able to store and transmit additional data on vessel operations, catches and the environment collected via Radio Frequency Identification (RFID) tags on fishing gear, logging devices and electronic logbooks.

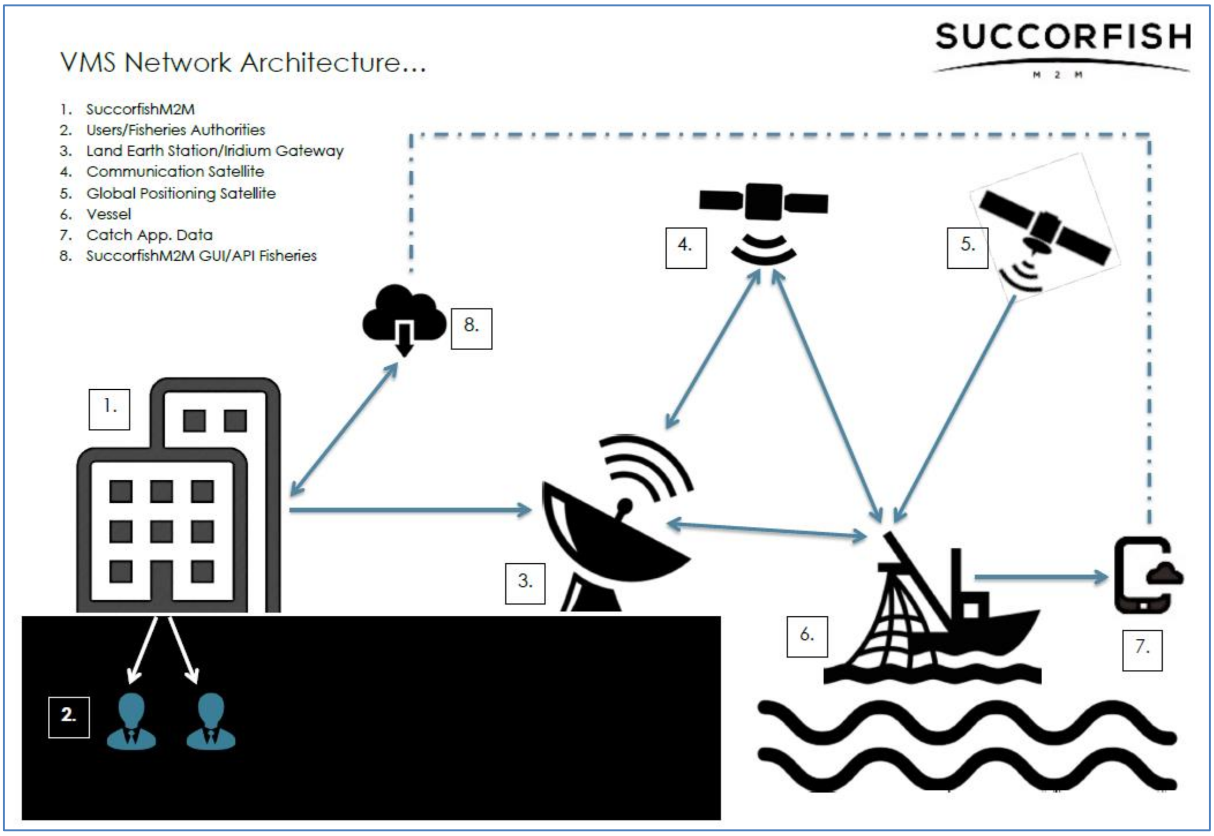

Figure 4. Schematic of Succorfish iVMS system and data flow

iVMS was originally developed and employed as a compliance and enforcement tool. Fisheries enforcement bodies such as the MMO and IFCAs can use iVMS to monitor the activities of commercial fishing vessels and their compliance with closed areas and seasons (for nature and fisheries conservation) in real-time.

The central enabling technology was the Succorfish SC2 inshore Vessel Monitoring System (iVMS) (Figure 2). The SuccorfishM2M SC2-VMS is one of the most advanced, multi-functional, fully integrated vessel monitoring and data communication systems available. It incorporates advanced, dual Iridium satellite and GPS/GPRS/GSM mobile technology to provide accurate global positional data in real-time and to within 2 m.

Figure 5. SC2 iVMS system fitted to a small fishing vessel

Similar systems had previously been installed on mobile gear vessels engaged in the scallop fishery along the South Devon and Dorset coasts where the iVMS is used by the Marine Management Organisation and IFCAs for compliance monitoring and to manage fishing activity in and around the Lyme Bay restricted areas. The project rolled out SC2 systems to all of the remaining static gear vessels operating from the ports in the Reserve giving a complete picture of all fishing activity in the protected area for the first time.

Gear-in Gear-out

Of particular interest at the beginning of the project was a monitoring system for fishing effort amongst the potting fleet. The voluntary agreement and associated Code of Conduct has established an upper pot limit for both crab & lobster and whelk fisheries. At present there is no practical way that this agreement, or and future regulation, could be monitored effectively. Subsequently the need to include static nets was identified and included. The trial aimed to test Radio Frequency Identification (RFID) technology that through the use of cheap gear tags detect when gear is shot away and recovered.

To do this participating Lyme Bay fishing vessels were equipped with a Radio Frequency sensor and tags were fitted to their pot strings or nets. These RFID tags trigger the sensor when passing within approximately 0.5 m and the event is recorded and transmitted by the SC2 back to the database. It was envisaged that each event would represent a hauling or shooting away operation, thus enabling gear specific temporal-spatial data to be collected on when and where the fishermen were fishing. It is envisaged that in addition to providing a compliance monitoring tool for the voluntary agreement this data will give a unique insight into where the majority of the fishing effort is being concentrated in the bay, a very perspective for fishery managers and marine planners alike.

Catch App

Small inshore vessels are often operated single handed resulting in the skipper working on deck in all weathers. Combined with the sheer number of tasks necessary to both work the vessel safely and the business related one once back in port results in a very limited time to undertake record keeping. Paper forms and logbooks may not be practical at sea on a small vessel, many <10 m vessels are open boats without a wheelhouse. Paper records also come with the added data entry burden requiring significant resources for the regulators. To meet these challenges the project developed and tested the Catch App running on a ruggedized iPad.

The Catch App is a novel, free to download app that functions as a digital diary that offers fishermen easy to use means of recording fishing information either on-board the vessel as they are fishing or back in port at the end of the trip. Drawing on the suggestions and experience of commercial fishermen the Catch App was designed to streamline the data entry process to make it as quick as possible.

The App has the facility for fishing businesses to monitor its fishing related costs and to track outgoings across the year. This data can help fishermen to identify the most cost effective activities and fisheries across the year and help with their business planning and development.

Catch records entered into the Catch App are transferred directly to a database via either a Wifi link to the SC2 device on the vessel or any Wifi connection once back ashore. This removes the data entry burden of paper records.

Web-based GUI

All data from the trial, both iVMS tracks and Catch App records, were stored in a secure Succorfish database. Participating fishermen able to access and explore their own data through a private website called the Succorfish GUI. Being able to access and use their data was a primary consideration for the Working Group and adds value to the record keeping process.

Additional Data and Uses

Links to Markets

In recent years much attention has been given over to the issue of underutilised species. It has been recognised that a lack of timely information flowing from the vessels to the buyers acts as barrier to species such as gurnard, dab or red mullet reaching the consumers. Through this project and in conjunction with some of the largest fish businesses in the UK (e.g. Direct Seafoods) the vessels were given an opportunity to report their catch to the buyers whilst still at sea. This ability for fishermen to notify the market in real-time will give the processors more time to plan their operation and ultimately reduce waste and increase profitability, for both themselves and the vessels.

The Lyme Bay Reserve project is currently developing a brand label, Lyme Bay Fish, and associated tagging scheme which in future can be linked to catch reporting capacity will enable the marketing of local provenance and eco-labelled fish.

Environmental Data

Fishermen are at sea on their local fishing grounds throughout the year and are potentially valuable participants in marine monitoring and environmental surveillance. The environmental data collection functions of the App are currently being used to demonstrate the potential for fishing vessels to take the role of environmental data collection.

At the most basic level the App records weather conditions on the fishing grounds. This may differ from the forecast conditions and reflect the local meteorological situation; as any fisherman will tell you the conditions change very markedly around headlands and bays. The iVMS system is also able to link to temperature and depth loggers which when fitted to fishing gear can provide a record of temperatures at depth for use in oceanographic and meteorological models. The fishermen benefit from this involvement through progressive improvements in forecasting. The may also benefit from improved understanding of their fishing grounds and target species behaviour in relation to water temperature.

The App can record a number of wildlife species selected to be easily identifiable but information on which can provide ecologists and conservation managers with important insights to environmental conditions. These include a suite of climate change indicator species such as Trigger Fish, a number of cetacean species such as Harbour Porpoise, and environmental condition indicators such as the presence of algal blooms. This function is supported by the use of photographic guides.

The threat of Invasive Non-Native Species (INNS) or alien species is seen as a key issue for managers and ecologists and can have serious impacts on marine business such as the aquaculture industry. As fishermen are at sea year round and are constantly “sampling” with their nets and pots, they have the potential to be true sentinels providing early warning of these invasive species. The App records a selection of easily identified invasive species (again supported by the use of photographic guides) which as it is linked to the GPS position through the iVMS provides managers and scientists with an accurate and real-time record.

Data Ownership

Data security and ownership are very important considerations for both the fishermen and permitted end-users of the data. The Catch App and SC2 both use AES256 encryption to transmit to the database. The data is then stored in secure databases with triple backup system in place. It is vital that the participants can trust the system and the Succorfish systems are ISO27001 accredited to provide the assurances needed.

Concerns over ownership and access to the data are real and needed to be addressed in this project. The Reserve Working Group discussed this at length and it was agreed that a data agreement would be developed that allowed Blue Marine consultants to use the data in confidence for analysis and research. The data however remained in the ownership of the individual fishermen.

Outputs: Data analysis and outcomes

In order that the data analysis focused on producing data products that will be of use in management of the Lyme Bay Reserve and that the techniques for producing them can be transferred and applied to be used to improved management of other MPAs and the wider marine environment a scoping exercise was undertaken by the authors with members of the steering group.

This exercise resulted in the identification of data products needed by the various sectors engaged in management or as stakeholders in the Lyme Bay Reserve. Data in its raw state is simply a spreadsheet of numbers which requires informed analysis to extract information from. Managers and stakeholders do not require data, they require information upon which to base decisions, carry out assessments and to use to inform their actions. Likewise fishermen require information to monitor their operations and to use as evidence in their discussions with other stakeholder groups.

The scoping exercise resulted in the production of a Scoping Table that outlined the information requirements, suggested potential data products and possible starting points for analyses (Table 2).

Table 2. Data analysis scoping table based upon discussions with Steering Group

End Users	Requirement	Data Product	Possible Analyses
Fishery Managers	Overview of fishing activity and effort for individual gear or fishery types	• Temporospatial fishing effort heat maps • Temporospatial fishing intensity (vessel activity) heat maps • All vessel movements with filters by groups / category (size/ licence/target species / home port etc.)	• Fishing effort e.g. number of pots/length of net per spatial unit by gear/fishery • Fishing intensity i.e. vessel activity per spatial unit by gear/fishery • Heat maps on appropriate grid scale (Annual and monthly)
Fishery Managers	Fishing intensity/effort and habitat interaction metrics to inform HRA for different gear types	• Quantitative maps of intensity/effort over sensitive habitats • Ecologically meaningful metric of pressure	• Fishing effort e.g. number of pots/length of net per spatial unit by gear/fishery over habitats • Pressure or risk maps of effort (no. pots) per spatial unit of habitat
Fishery Managers	Spatial information inform enforcement	• Risk map of geofence breaks • Seasonal patterns (Temporospatial)	• Heat map of geofence breaks • League table of vessels • Seasonal changes in activity spread/heatmap
Conservation Managers/Wildlife Interests	Fishing intensity/effort and habitat interaction metrics to inform HRA for different gear types (as above)	• (as above)	(as above)
Conservation Managers/Wildlife Interests	Risk maps to inform site management	• Fishing intensity/effort maps related to sensitive habitats	• Pressure or risk maps of effort gear type (no. pots) per spatial unit of habitat down to 5m squares resolution. • If effort threshold can be established e.g. pots per unit area
Conservation Managers/Wildlife Interests	Risk maps to mobile species management	• Fishing intensity/effort maps related to mobile species	• Pressure or risk maps of fishing intensity (pings or vessels) per spatial unit over sightings data • Seasonally and annually

Science/conservation	Understand seasonal/spatial fishing effort as it relates to environmental factors (which affect the behaviour, food availability etc.) Understand the real-world frequency of seabed disturbance.	• Fishing activity mapped in relation to environmental data	• Spatial correlation between fishing effort and (e.g.) sea surface temperature??
Fishermen	To see their data turn into meaningful information to monitor their business and fishing strategies To see their individual tracks Analysis of Catch App data	• Spatial and temporal fishing activity overlaid with catch • Tracking data from the GUI • Pivot tables presenting effort, catch, species and time	• Heat maps on appropriate grid scale (Annual and monthly) • None required – exports from the GUI • Tables and charts
Processors	Information to back up their sustainability and traceability requirements Timely catch data with full traceability.	• Spatial and temporal fishing activity overlaid with catch • Catch App reports provided on a real time basis by vessel	• Heat maps on appropriate grid scale (Annual and monthly) • None except data exports from the GUI.

Approach and Methodology

Data and Data Handling

The inshore Vessel Monitoring System (iVMS) comprises satellite tracking boxes, which were fitted on board vessels participating in the Lyme Bay Fully Documented Fishery scheme to collect positional data. The information was relayed to Succorfish's server and stored in a secure database. The data provided for these analyses cover a period from March 2014 to July 2015.

Each fishing trip is represented in the database by a series of records, captured at regular intervals, and including the vessel's name, date of recording, time, latitude, longitude, speed and course.

There were 630,407 records in total, from 36 vessels plus a number of test records of "assets" represented only by a number. The total number of records from named vessels alone was 628,914. Of the 36 vessels, roughly 2/3 submitted records in any given month.

The iVMS data was provided in spreadsheet format, with one file containing data from all vessels for each month. The data was first processed in Excel to split the combined date-time into two separate columns. Next, the Excel spreadsheets were imported into the GIS and combined into one dataset containing all the points collected over the study period (March 2014 to July 2015) to enable everything to be processed at once.

The data was edited to remove erroneous points, such as those on land or far outside the Lyme Bay Area of Interest, resulting from poor GPS reception and the like. This was done by creating a shape to represent the Area of Interest, and using it to select only those points inside it. Additionally, data points recorded in ports were deleted.

Since the vessels within the iVMS trial were predominantly using static gear such pots and nets, a speed filter was chosen to remove records where the vessel was travelling at a speed above which they could reasonably be able to fish. The resulting dataset, containing all records where the vessel registered a speed of 2kt or less. This point data was re-projected from Geodetic Coordinates (latitude / longitude) to a Mercator projection (UTM Zone 30 North), which was the working projection for the project and allowed linear distances to be measured in metres rather than degrees, minutes and seconds.

Finally, the point data was used to create a raster coverage, whereby each raster grid cell held a value equating to the number of iVMS points that had been recorded within the cell boundaries at that location.

Creating Heat maps from Vector and Raster Data

The data collected during the Fully Documented Fishery project that could be given a spatial reference contained latitude and longitude fields for each record. This means that each record could represented in 2-dimensional space along an X (longitude) and Y (latitude) axis as a point object.

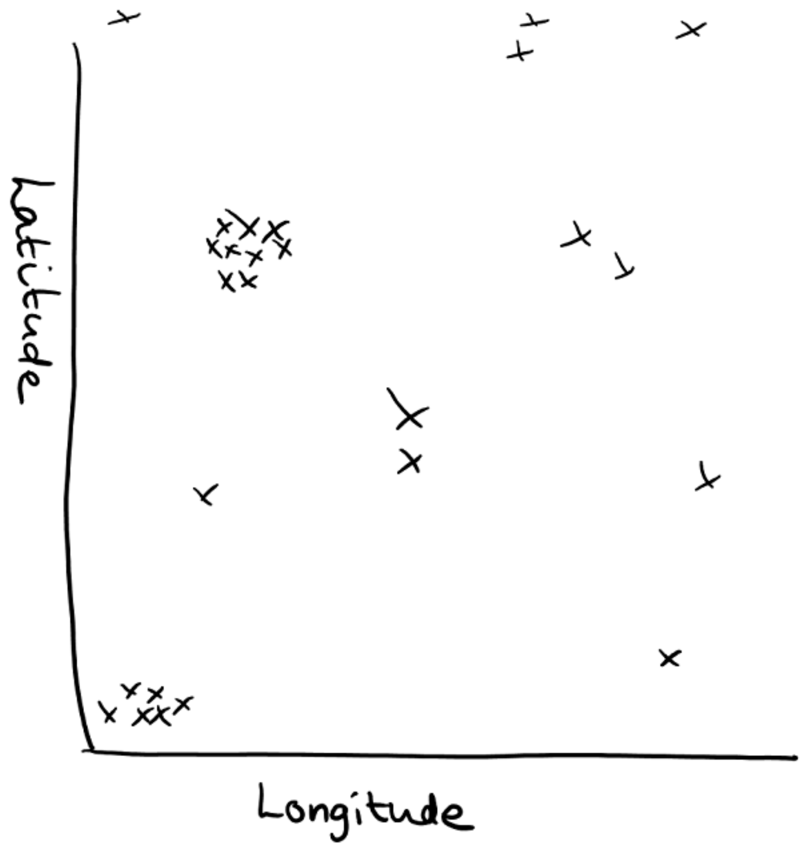

Figure 6. Basic latitude/longitude plotting of data points

In this way, the iVMS data records can be translated into many thousands of points. When these points are viewed in the context of a basemap or chart, they collectively become an illustration of the distribution of fishing activity.

Because of the length of the study period, many points are close enough together that they overlap when viewed on a map, so it is not easy to get a sense of how dense those points are in one area compared to another. Since the point density is analogous to the importance of an area for fishermen or the relative intensity of activity, it is important to be able to represent this information in a way that allows the difference in point density across the fishing grounds and wider area of interest to the Lyme Bay Fully Documented Fishery project to be seen.

To do this, the points, which are a form of vector data, can be translated into a raster. A raster is a continuous grid of cells that provides a coverage of a specified area. Each cell in the grid holds a value; essentially the cells are like pixels in an image. The value of each individual pixel can be expressed as a colour or shade; this builds up across the raster coverage as a whole to show a picture that visualises the data. In this case, the pictures that the rasters show are a snapshot of where fishing activity occurs, and the relative importance of different areas.

The basic concept of translating point (vector) data to a raster is illustrated in Figure 7:

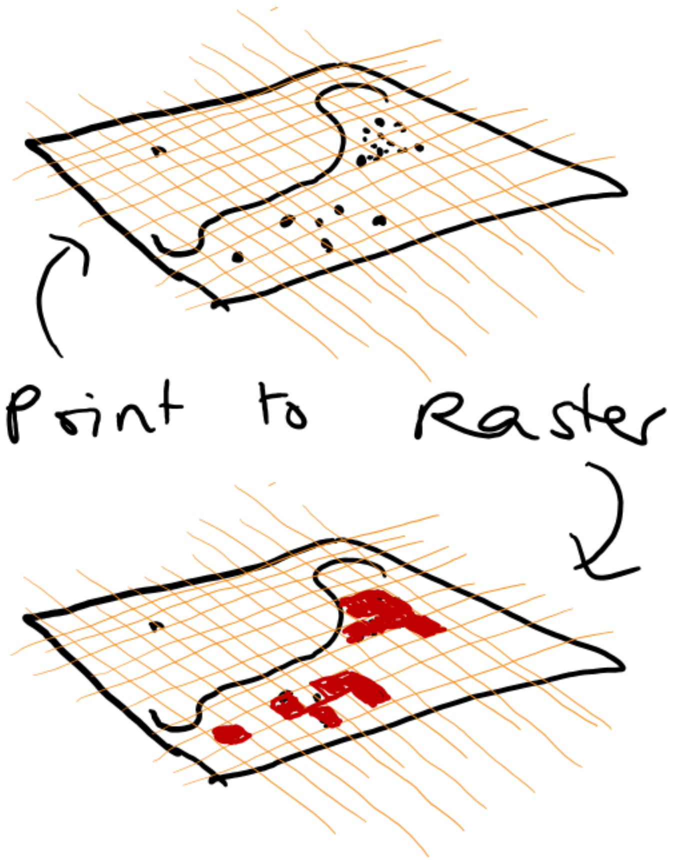

Figure 7. Point (vector) data to Raster translation

The user specifies the extent of the raster grid, and the size of the cells. This grid is then created by the GIS, and each cell populated with information. For this project, a cell size of 50m was eventually selected as being small enough to show spatial variation in activity at a high resolution, and large enough to allow some distinction in intensity by virtue of being likely to contain a number of points. For the habitat analysis, a smaller cell size of 20m was used to better match likely scales of variation in seabed habtiat.

As well as being able to show the intensity of activity, another reason for translating the data into a raster is the ability to overlay it with other data and perform analysis. The diagram below illustrates how two rasters, one representing fishing activity, and another showing the coverage of habitat types, can be combined into a third layer showing where both fishing and a given habitat overlap. This is the analysis carried out in the habitat section of this report.

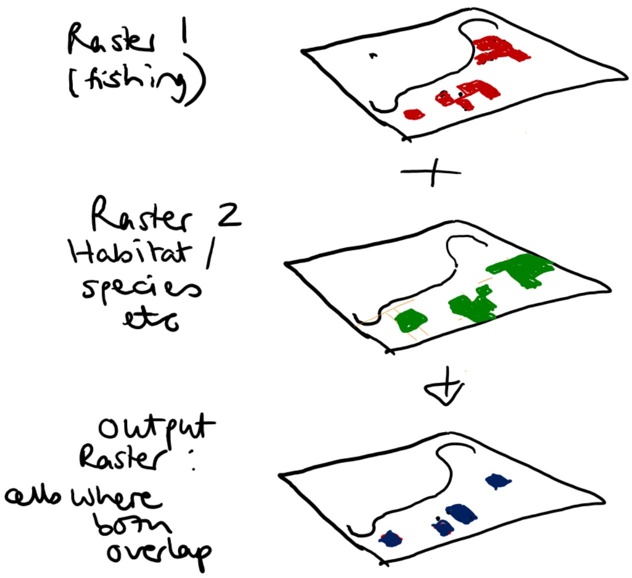

Figure 8. Conceptual analysis model

This principle of an overlay operation is simple: here, the two grids overlap, so a cell in the “fishing” layer has a corresponding cell at the same location in the “habitat” layer. The GIS looks at the values in each layer, and – based on what these values are, and how they compare to the conditions set by the user - calculates a third value which will be put in the corresponding cell in a new layer. The conditions might be “the value of fishing must be greater than 0, and the habitat value must be 1”; the GIS can perform quite complicated maths based on this, or the result might be a logic operation – with cells where the conditions are met having a value of 1, and those where it is not having a value of 0.

Lastly, representing data as a regular grid allows you to compare different grids statistically in a simpler way. For instance, the output raster in the example illustrated above is a coverage showing which cells contain both fishing activity and a certain habitat. The GIS can calculate the number of cells where this condition is true, and also the total number of cells where the habitat exists. By comparing the two values, the percentage of habitat affected by fishing can be calculated. This quantitative information could be very useful in discussions over the extent of the effects of fishing, and it is information that cannot be quantified without having both fishing and habitat data in a format where they can be compared using a common unit.

In short, the process followed here is a way of allowing different types of data to be read in the same “spatial language”

Fishing Intensity Footprint and Patterns

Focus of analysis (from Scoping Table)

End Users:

- Fishery Managers, Conservation Managers/Wildlife Interests (NGOs, SNCBs), Fishing Industry Representatives

Data products:

- Temporospatial fishing effort / intensity heat maps,
- Vessel movements with filters by groups / category (size/ licence/target species / home port etc.)

Analyses:

- Fishing effort e.g. number of pots/length of net per spatial unit by gear/fishery;
- Fishing intensity i.e. vessel activity per spatial unit by gear/fishery;
- Heat maps on appropriate grid scale (Annual and monthly)

Context and Background

A lack of information is one of the biggest barriers to effective fisheries and conservation management. This is changing; ecological data on marine habitats and species is becoming more available due to targeted surveys, there are good time series of environmental data from monitoring programmes, and remote sensing data from satellites is becoming more detailed and more readily available.

Fishing, too, is documented and described in increasing detail. However, data collection has tended to focus on large vessels and the offshore sector; satellite monitoring was originally brought in for vessels over 15m length, and has recently been introduced for vessels over 12m; logbooks and the information collected on catch are also tailored for the fisheries prosecuted by these larger vessels. The inshore sector, meanwhile, is diverse and complex but poorly understood. At the same time, inshore fisheries tend to coincide with areas of interest from a conservation perspective, about which there is, conversely, more information in the inshore area.

From a fisheries management perspective, this means having to make decisions about how, and even whether, to manage fisheries based on information which may be incomplete, or at a broad spatial or temporal resolution which is not best-suited to the task. Where there is a need to manage a perceived risk from fishing activity, data at the appropriate level of detail might be the difference between having to put in precautionary measures restricting fishing across a wide area, just to be sure of addressing the *possible* risk, and not having to take immediate action because the risk is well understood and *known* to be negligible. Both approaches are legitimate, and make use of best available data; the second, though, is far more preferable as it is does not put what it transpires are unnecessary restrictions in place, and allows resources to be used efficiently – targeting instead those areas where management is required. And in these areas, an understanding of the nature of fishing will allow that management to address the risk proportionally and effectively.

Simply put, better data gives you the clarity needed to use management tools with precision rather than as blunt instruments. This improves the chances of success. Current sources of fishing activity data, including MMO catch records, Shellfish Activity Returns, and boardings and sightings observations, are all relatively broadscale, both temporally and spatially, and can take time to collect, compile and analyse.

The fundamental aim of the Fully Documented Fishery project, therefore, is to make available fishing activity data at a more appropriate resolution for local management. While this data can be applied to a number of different purposes, and these are explored within the study, the most important output is simply to describe the spatial distribution and nature of fishing activity. This characterisation is the foundation for everything else.

Here, we describe the process of developing output representing fishing effort and intensity through “heatmaps”, designed to show where fishing occurs and how much of it happens in a given location.

Approach and methods

The vessels participating in the iVMS trial and operating within the Reserve area all used static gear such pots and nets it was necessary to identify where they were actively engaged in fishing operations rather than steaming between sites or port. To do this the iVMS data was filtered using a vessel speed of 0-2knots. This removed all records where the vessel was steaming. Further records in and in close proximity to ports and port entrances where slow speeds or stationary records could also occur.

This point data was used to create a series of raster charts, where each raster grid cell held a value equating to the number of iVMS points that had been recorded within the cell boundaries at that location. Detailed methodology for the processing of the iVMS data into heatmaps is provided in a separate annexe to this report.

Results

Fishing activity heat maps

The first analysis used interpolation between cells to produce a point density map (Figure 9).

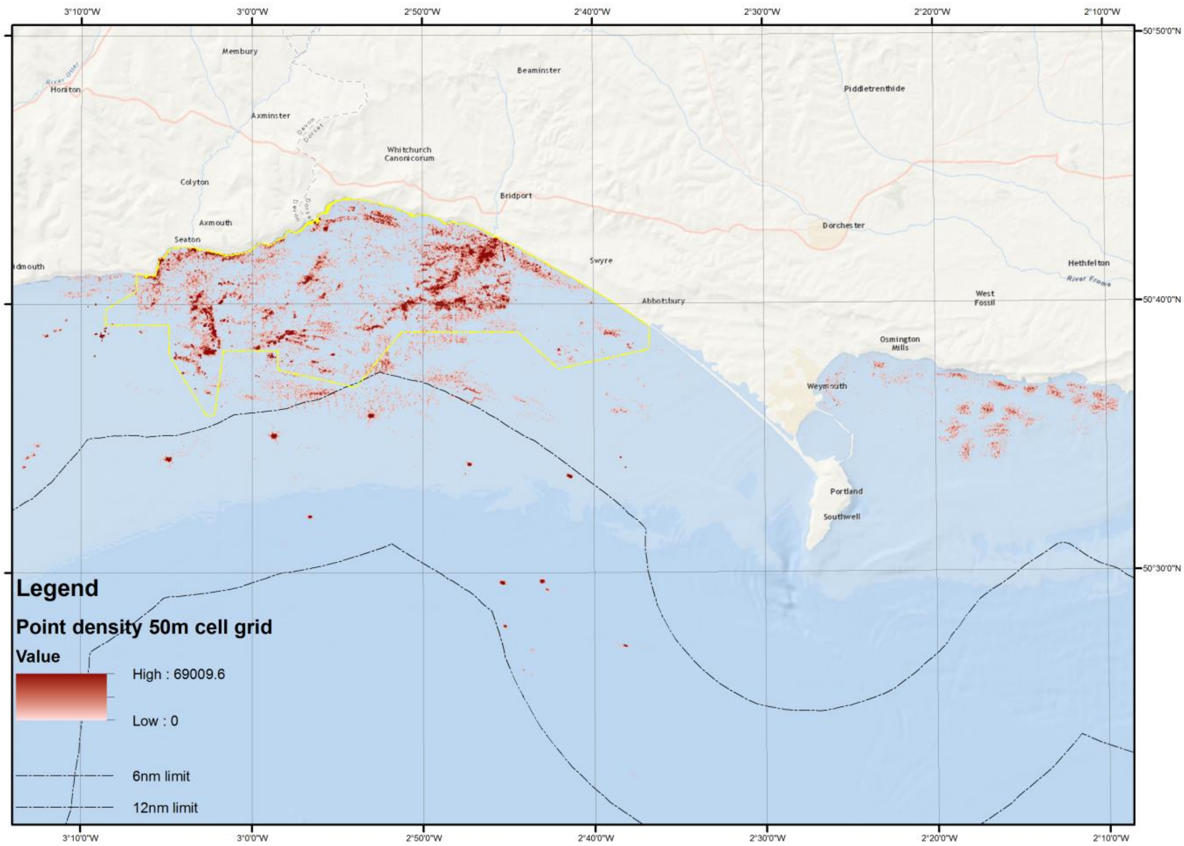

Figure 9. Distribution and relative intensity of fishing effort using a point density method

The darker shading indicates higher relative effort; lower values are shaded more lightly. The units are do not directly quantify activity, but represent 'magnitude per unit area' based on the neighbourhood around each cell. This is a useful means of visually emphasising the areas of high fishing activity, and creates a more smooth coverage, the interpolation can be described as a predictive model for a more complete representation of activity. Blank cells may be populated by a value if there are points close by; this is in essence a probabilistic model of fishing activity. This approach addresses the issue that the 10 minute the iVMS reporting frequency has some effect on point density; there are places in between which may be fished but not represented and smoothing the edges based on the weighting of nearby activity can fill in these gaps.

For this reason, a point density map can be helpful in illustrating fishing patterns. Figure 10, below, shows a close up view of fishing activity and intensity (as a function of point density).

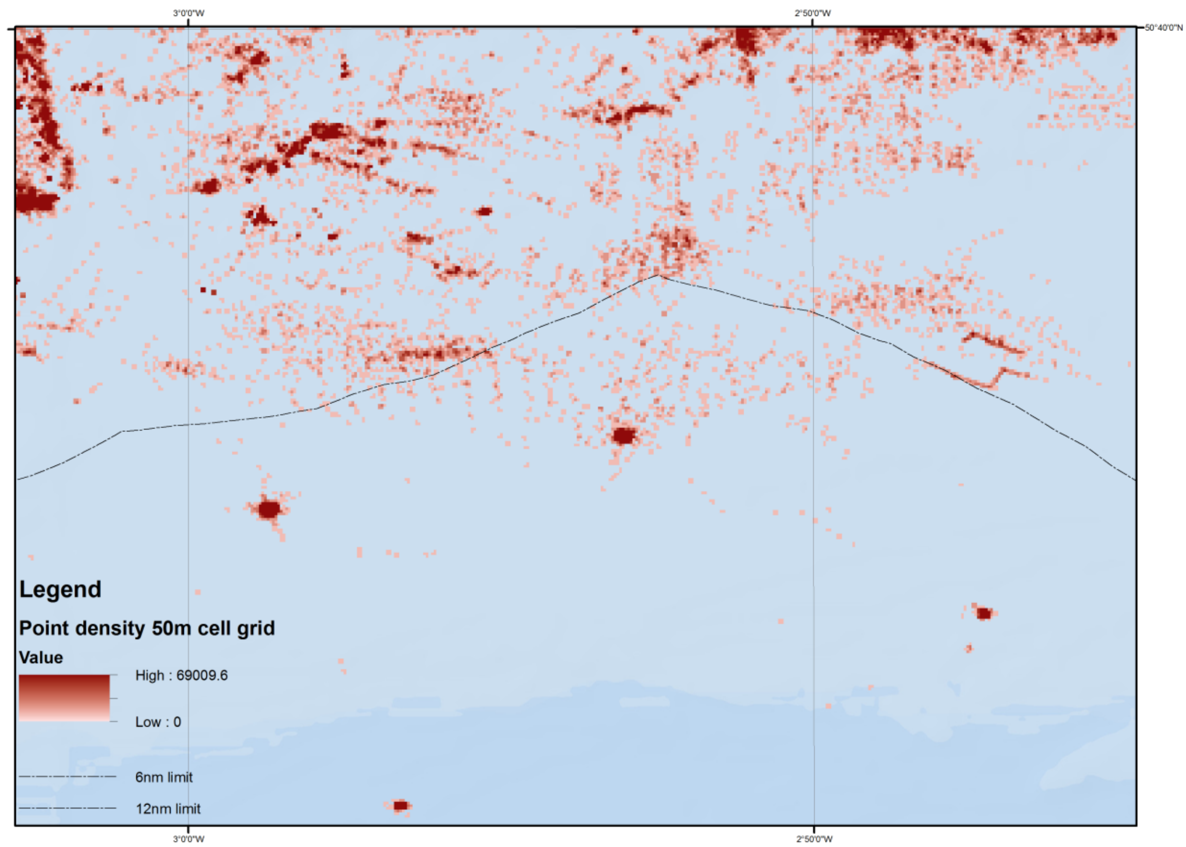

Figure 10. Distribution and relative intensity of fishing effort using a point density method (close-up view).

A number of darker patches, indicating relatively high intensity, can be seen. These are effectively "hotspots" of activity: areas which were consistently popular with the fishermen in the study, over the period of concern – in this case, March 2014 to July 2015. The circular hotspots just below the 6nm limit line actually represent wrecks, as the Admiralty chart in Figure 11, below, demonstrates.

Similarly, the linear patterns seen running parallel to the 6nm line to the right of Figure 10, and within the compass rose in Figure 11, might indicate the regular and consistent use of set nets across contour lines in this area.

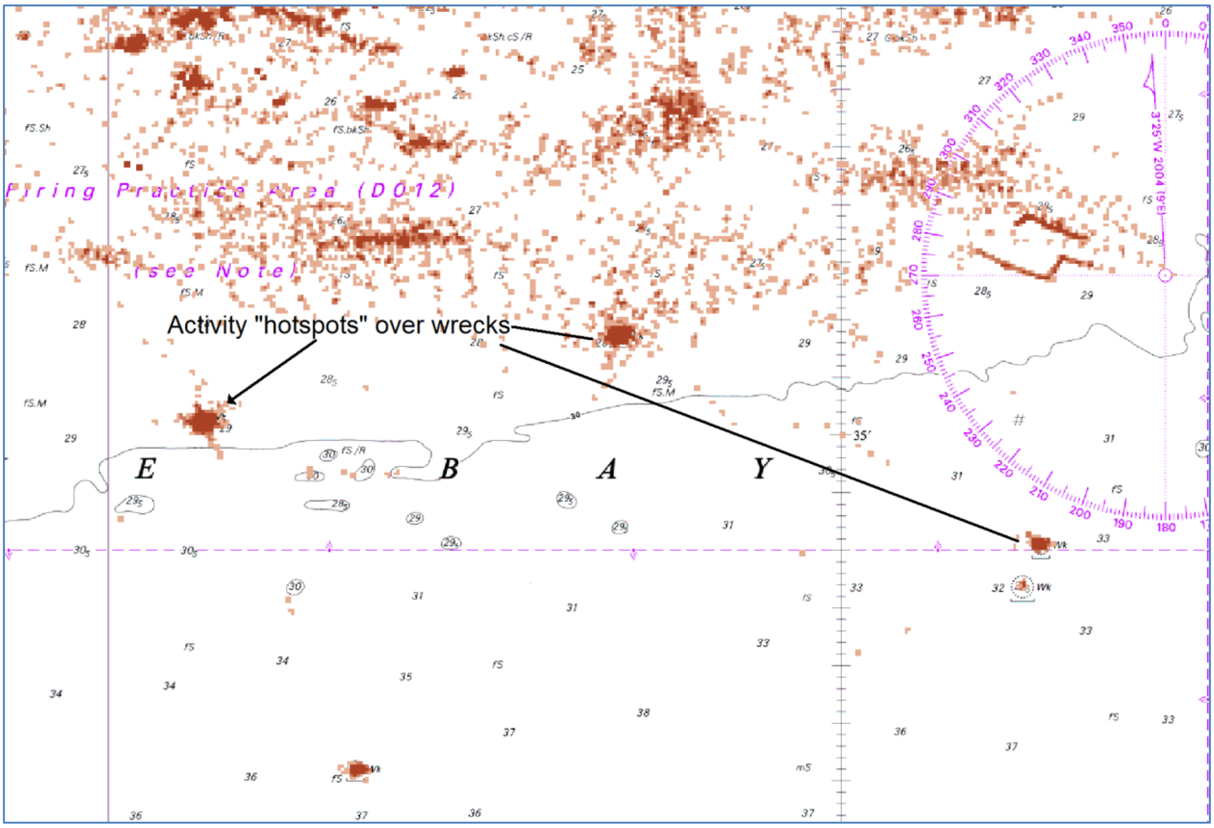

Figure 11. The location of fishing activity hotspots on an Admiralty chart, which also indicates the location of wrecks. Most of the wrecks are important fishing locations

For analysis purposes, it was decided to use the Point Count intensity maps as these better preserve the original data; the cell values are the number of points counted in 50m by 50m cell. In addition, without interpolation, the spatial footprint of fishing activity is based on actual records rather than modelled data and this may be more appropriate for static gear vessels which tend to remain over a fishing site for longer periods and therefore there is a higher probability of a ping being record.

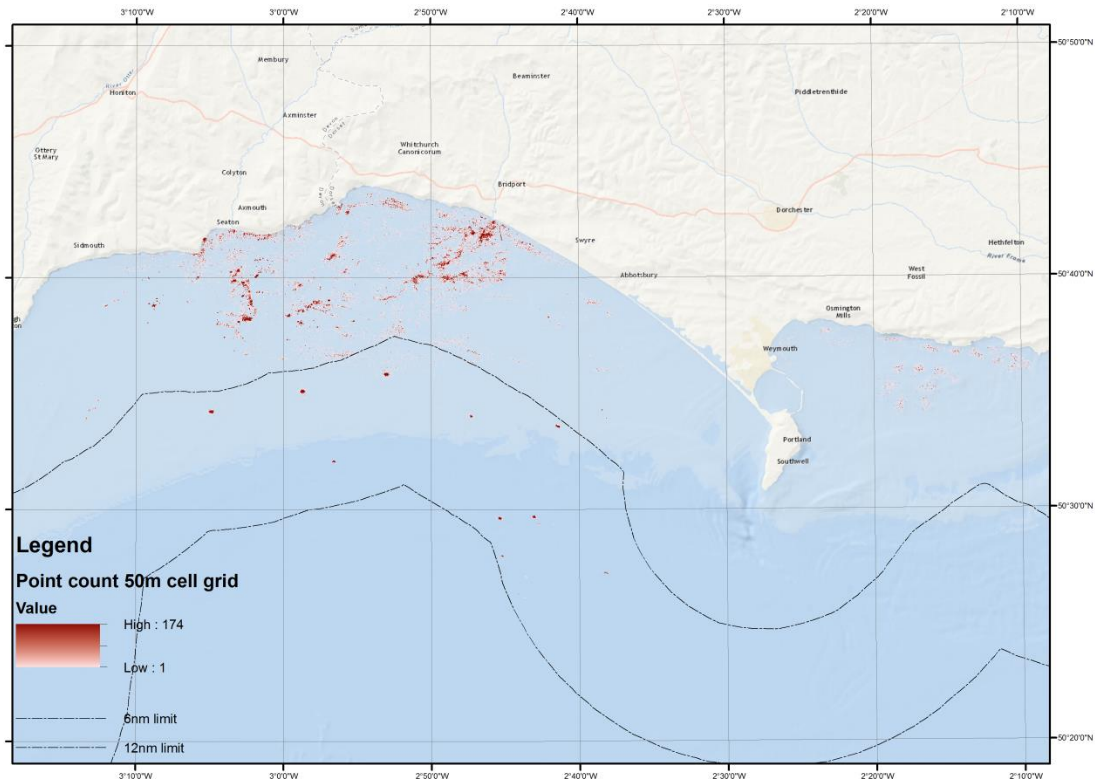

Figure 12. Distribution and relative intensity of fishing effort using a point count method. The darker areas indicate greater intensity of fishing effort, the lighter (pink) cells indicate lower intensity. The data shown here include the full coverage of iVMS data.

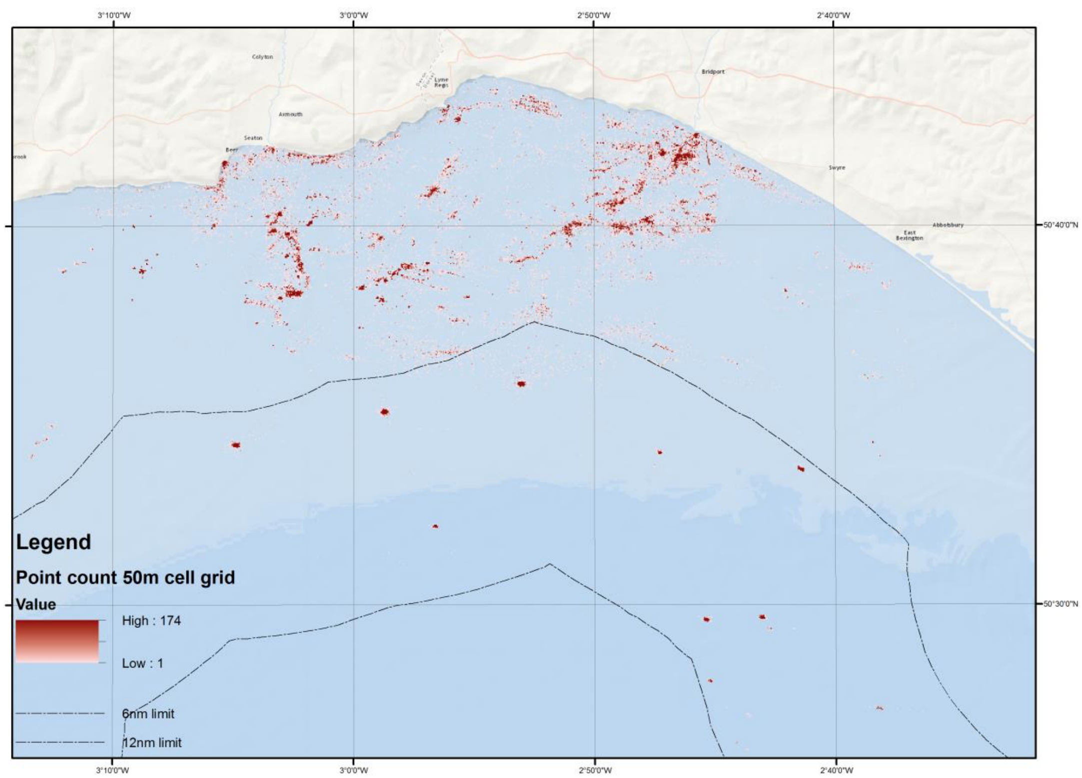

Figure 13. Distribution and relative intensity of fishing effort (point count method). This shows the same data as above, zoomed in to focus on Lyme Bay

The same patterns are evident in the point count maps Figure 12 Figure 13 as for the point density charts, but the distribution is slightly more focussed and there are fewer darker (high activity intensity) areas. This is because the influence of each data point is restricted only to its own cell, rather than being amplified and affecting adjacent cells by the interpolation.

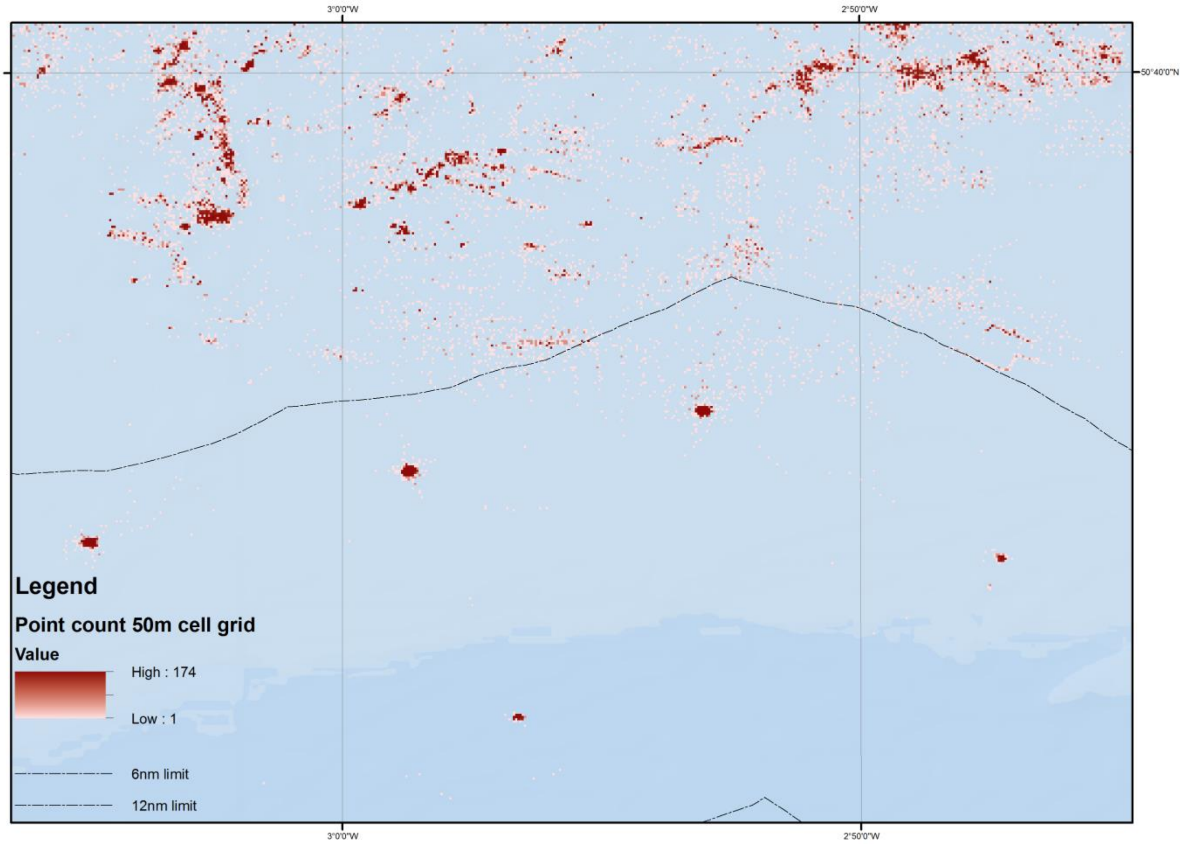

Figure 14. The same "hotspots" illustrated in Figure 10. Note that there are fewer cells (or rather, some of the cells showing in the previous figures have zero values here). Also, the concentration of high-activity hotspots is much more focussed and precise

Seasonal distribution

The previous data all show the full dataset, with data collected between March 2014 and July 2015. This was also split into separate seasons, in order to illustrate any differences in the patterns activity over the course of a year.

For clarity of presentation fishing activity was plotted as presence/absence and red cells indicate simply that fishing took place at that location. By simplifying the way the data is displayed, the distribution is the focus and can be more easily compared between charts. Similarly, the focus is on the Lyme Bay area so that enough detail can be seen to compare patterns of fishing.

There is a clear increase in the range of activity between Spring and Summer 2014, as illustrated in Figures X and X, below. In the Spring, activity seems to be concentrated relatively close to shore, and in particular in areas of Lyme Bay and Bridport. There is some activity further offshore, around a few of the wrecks just beyond the 6nm line. However, by summer, this outer area is far busier, and wrecks further out towards the 12nm are also shown to be attracting some fishing activity.

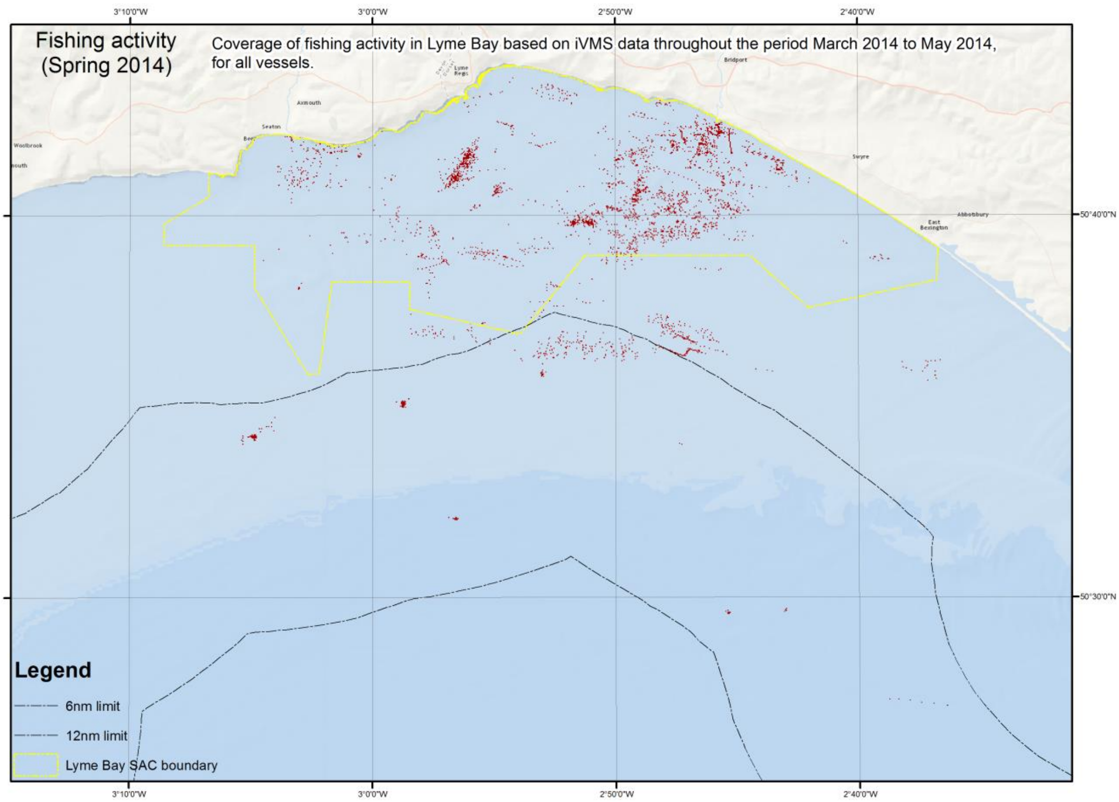

Figure 15. Distribution of fishing activity recorded between March and May 2014. Red areas indicate fishing took place at that location

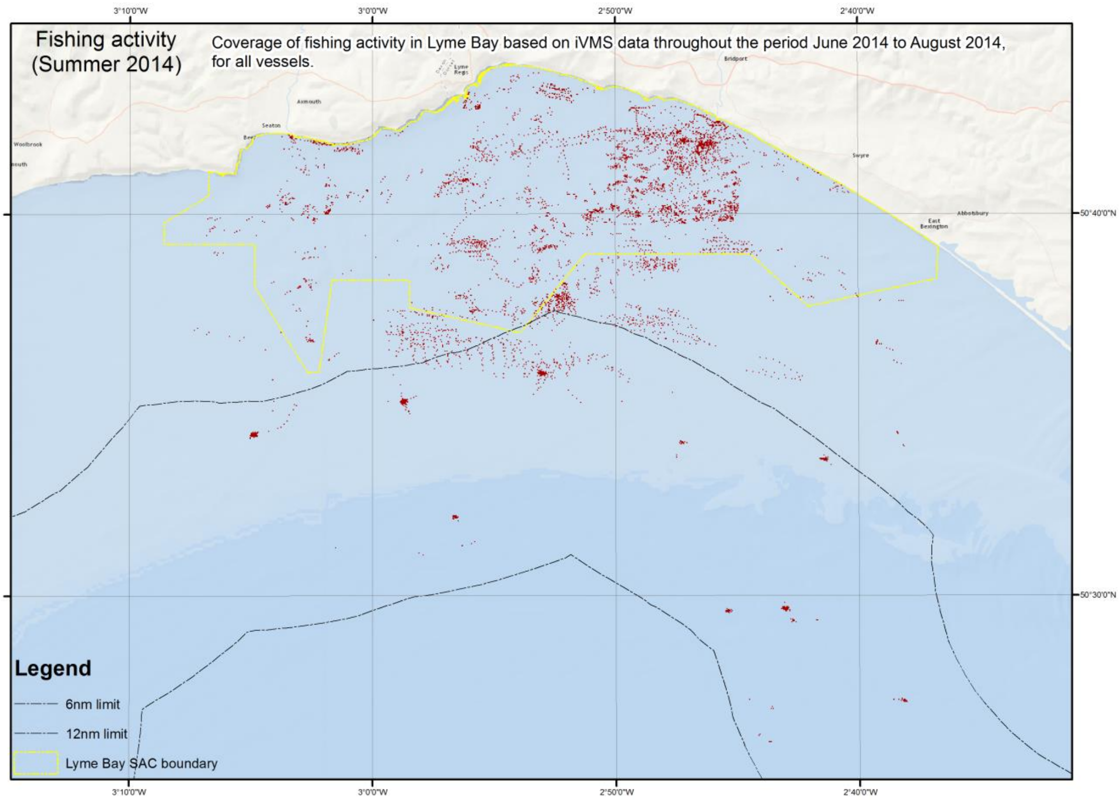

Figure 16. Distribution of fishing activity recorded between June and August 2014. Red areas indicate fishing took place at that location

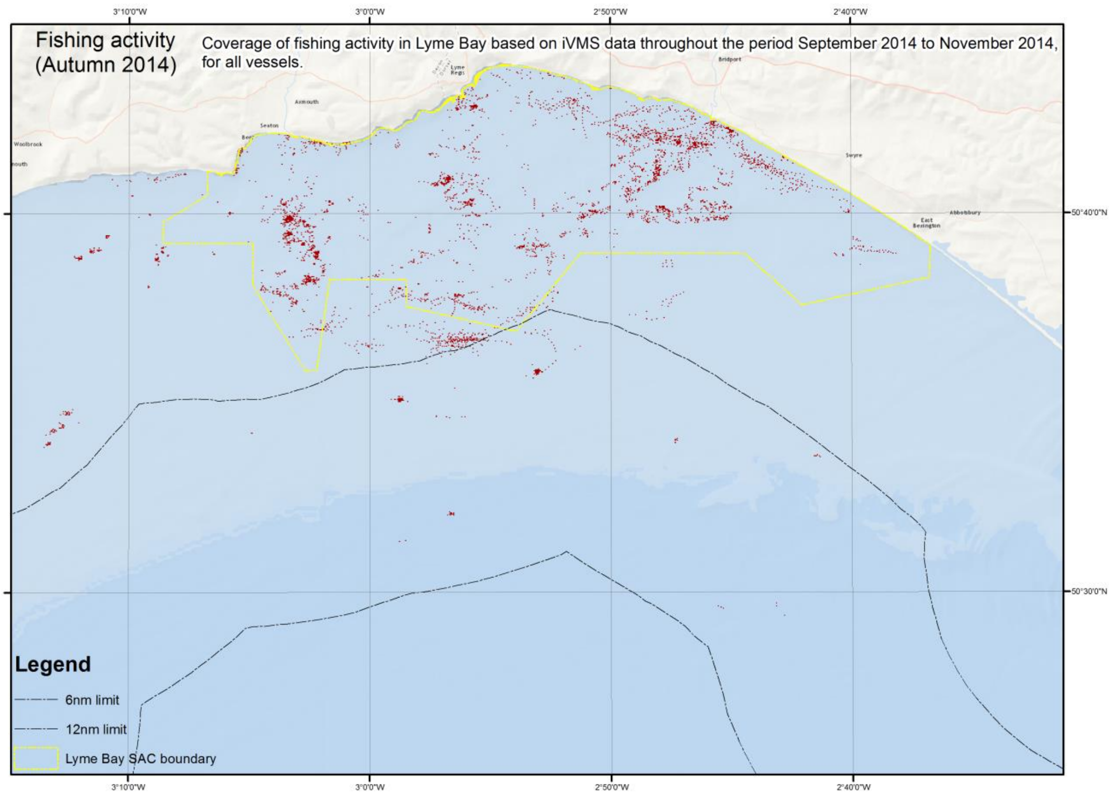

Figure 17. Distribution of fishing activity recorded between September and November 2014. Red areas indicate fishing took place at that location

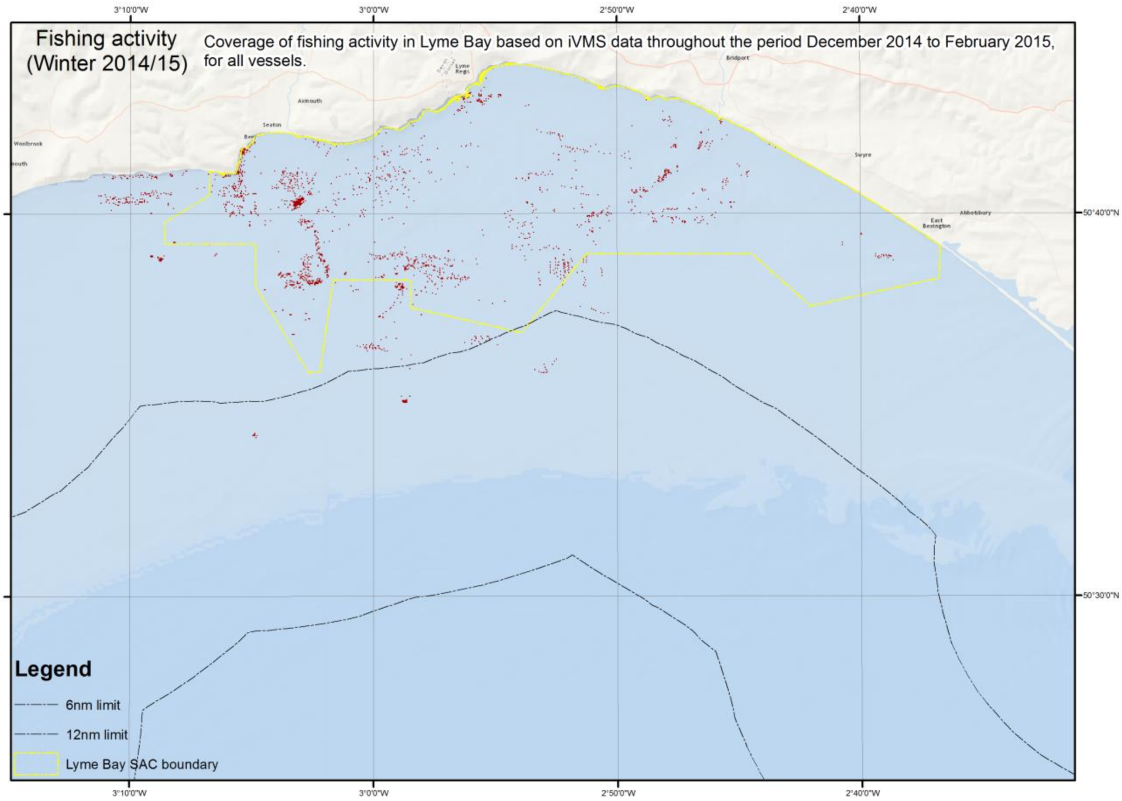

Figure 18. Distribution of fishing activity recorded between December 2014 and February 2015. Red areas indicate fishing took place at that location

Further inshore, the footprint of activity is also larger, encompassing a wider distribution of sites.

Autumn (Figure 17) shows a contraction of activity, which seems to be concentrate within distinct areas within the inshore area (inside the yellow SAC boundary). To the west of this, some new hotspots appear that do not feature at any other time of year. Potting fisheries do follow the seasonal movement of lobster and crab, and it might be that these new areas are favoured habitat in the late summer and autumn, when spawning tends to occur. The contraction within the SAC may also reflect a behaviour in the target species.

By winter (Figure 18), there is much less activity across Lyme Bay. Some fishing is still taking place on the wrecks, but otherwise the offshore grounds are relatively untouched. Inshore, there is more activity to the west of the Bay, out to approximately 4nm off Beer and Seaton in particular.

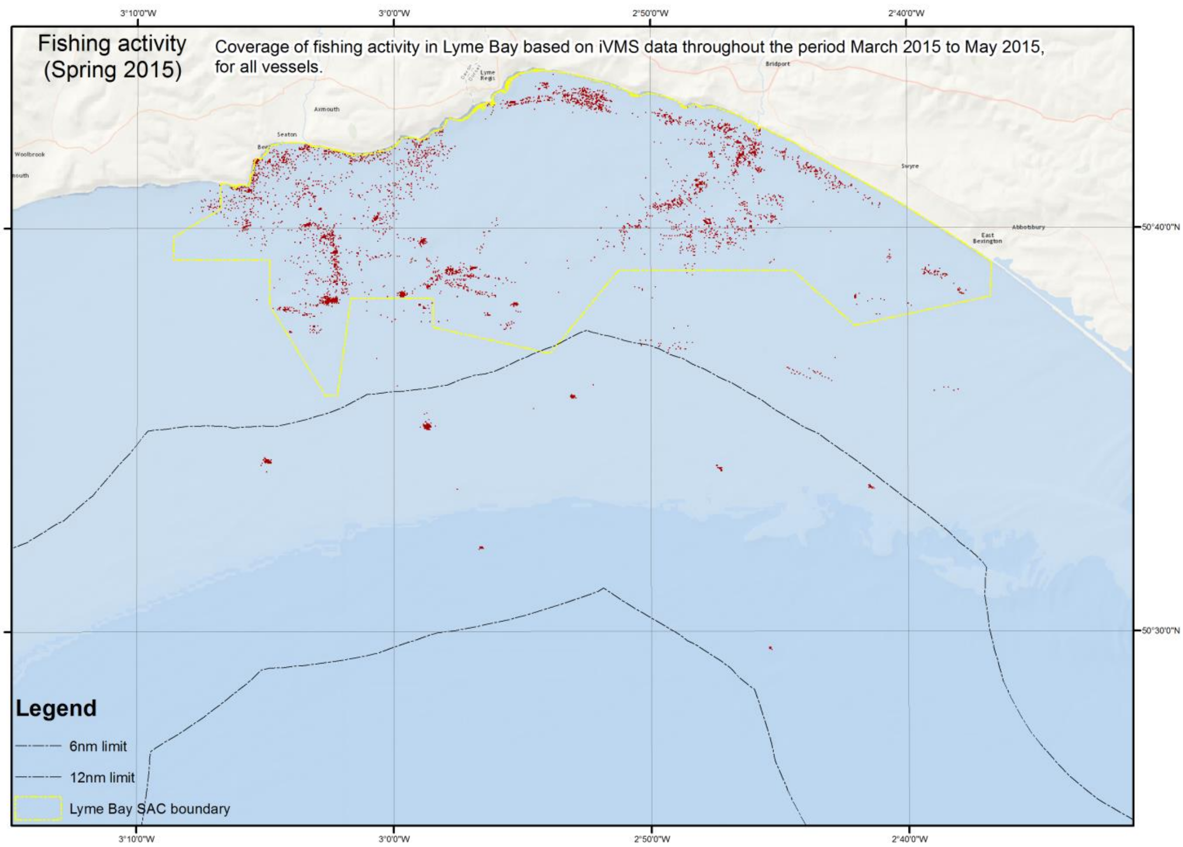

Figure 19. Distribution of fishing activity recorded between March and May 2015. Red areas indicate fishing took place at that location

Figure 19, above shows Spring 2015 fishing activity, which appears to resemble the preceding season (December 2014 – February 2015) more than the previous Spring: there are clusters of activity to the west, off Beer; however, the inshore grounds just off Lyme Regis and further along the coast are also being targeted, as is an area off Bridport.

Finally, data for June and July show a greater spread of activity in the summer months, including more offshore activity around the outer wrecks. Note that this chart shows only two months', rather than three months' data (Figure 20).

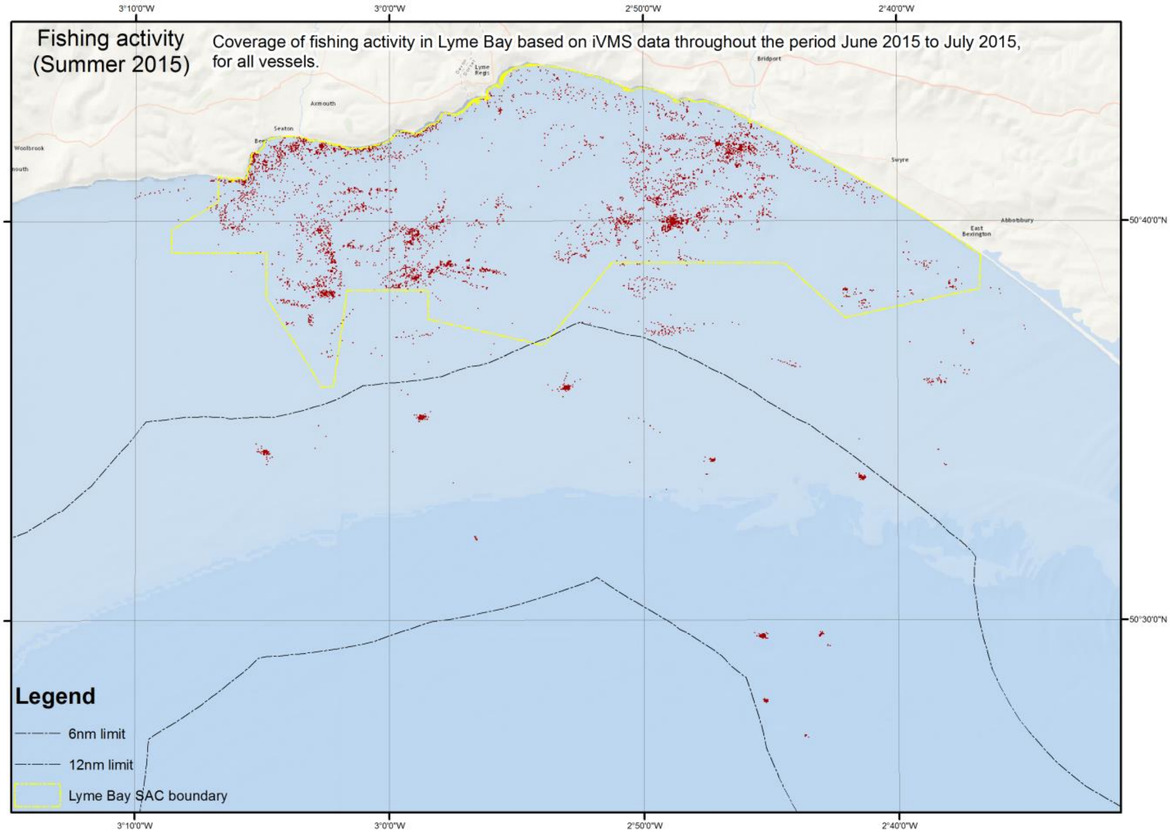

Figure 20. Distribution of fishing activity recorded between June and July 2015. Red areas indicate fishing took place at that location

These figures show that patterns of fishing did change over the study period. Without detail of what gear was being used and what was being caught there no contextual information to underpin an interpretation, but given that potting fisheries form a significant component of the static fishing represented by this data, it is likely that part of what we are seeing is a response to the seasonal movements of the target species (crab and lobster). There is generally much less activity over winter, as the animals do not regularly feed, so it could be that a larger proportion of the winter activity is netting. This will also have an influence on where fishing takes places, as the optimum fishing grounds are not necessarily the same.

Finally, weather has a significant influence on activity distribution. As well as a slowdown in potting in the outer grounds due to lower yields, fishermen are more likely to bring in gear which is in more exposed locations to save it from being damaged or lost. This is likely to be a factor driving activity closer to shore over the winter and spring seasons.

Discussion

The analyses of fishing activity data produced in this study has resulted in possibly the highest resolution and most detailed description of the spatial footprint of an inshore or static gear fleet to date.

Previously fishing activity mapping of inshore vessels has relied on broadscale mapping exercises such as the Fishermap project (des Clers, 2008) or mapping of sightings records from fisheries patrols (Breen et al, 2015). These approaches suffer from issues of low resolution and challenges of data collection and coverage. Even mapping exercises of data from larger >12 m vessels fitted with the EU satellite VMS system are forced to adopt a coarse spatial resolution due to a 2 hour reporting (ping) interval. The 10 minute ping rate of the SC2 iVMS used in Lyme Bay and the 2 m accuracy has enabled the production of very detailed picture of the small boat fleet's activity footprint.

To demonstrate the improvement in the level of information provided by the iVMS data from this project, it might be useful to show how the data relates to what was previously available. Figure 21 toFigure 27, below, show the iVMS data gridded at different spatial resolutions from 5km down to 20m.

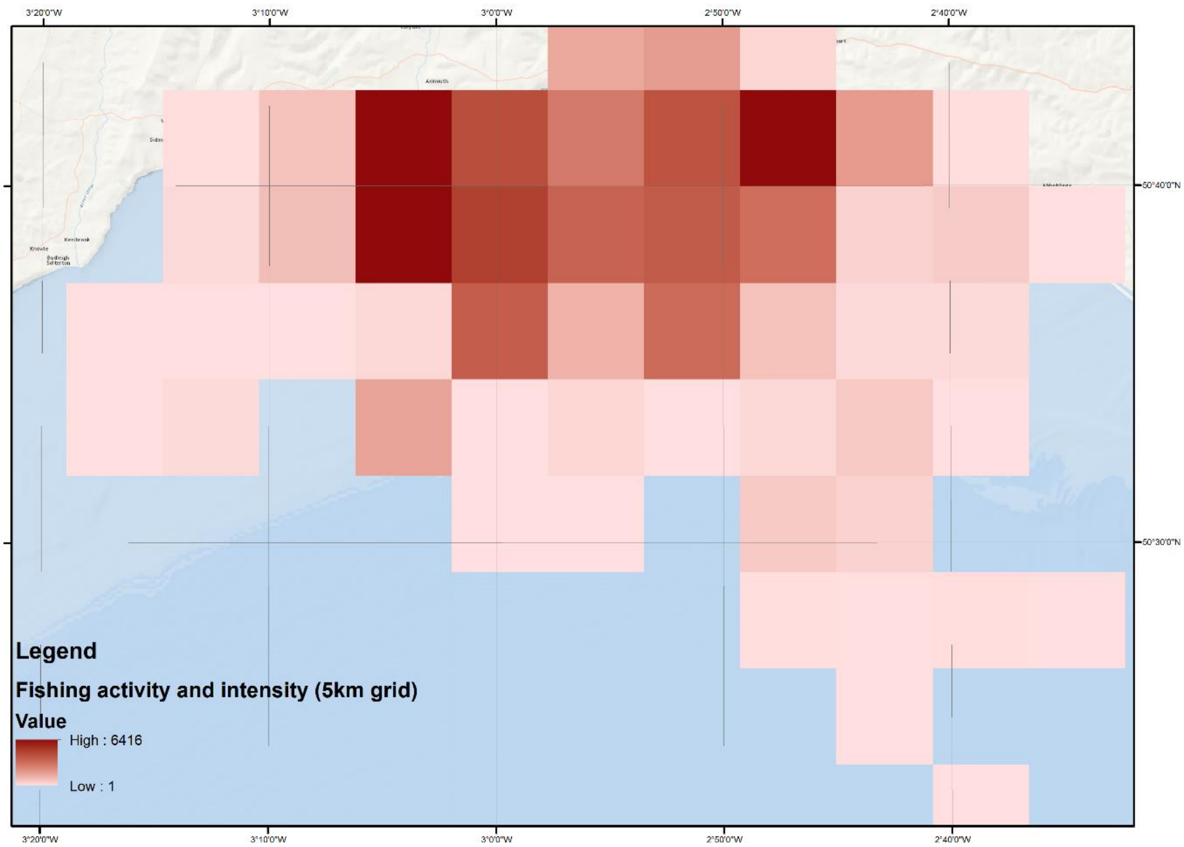

Figure 21. Fishing activity in Lyme Bay from iVMS data gridded at 5km. Darker cells indicate a higher level of activity in that area

The 5km grid shows a very broadscale indication of the distribution and intensity of fishing activity in Lyme Bay. The most-fished areas are seen closer to the shore, with less activity away from the centre of the Bay. However, there is not enough detail of variation at this scale for any analysis of fishing with respect to seabed habitat and other complex information.

The National Inshore Fisheries data layer produced by Cefas from inshore sightings and boardings records was at 0.05 degree resolution, which equates to approximately 5km by 5.5km grid cells (Vanstaen & Silva, 2010). The data used to generate it, collected by the IFCAs (then SFCs) can be gridded at a higher resolution in theory, but the temporal and spatial coverage of observation effort does not support it in practice. This is therefore the most detailed “official” dataset previously available on inshore fishing.

It is clear that this scale of mapping could lead to misinterpreting the scale of potential fishery related disturbance or impact in the Reserve.

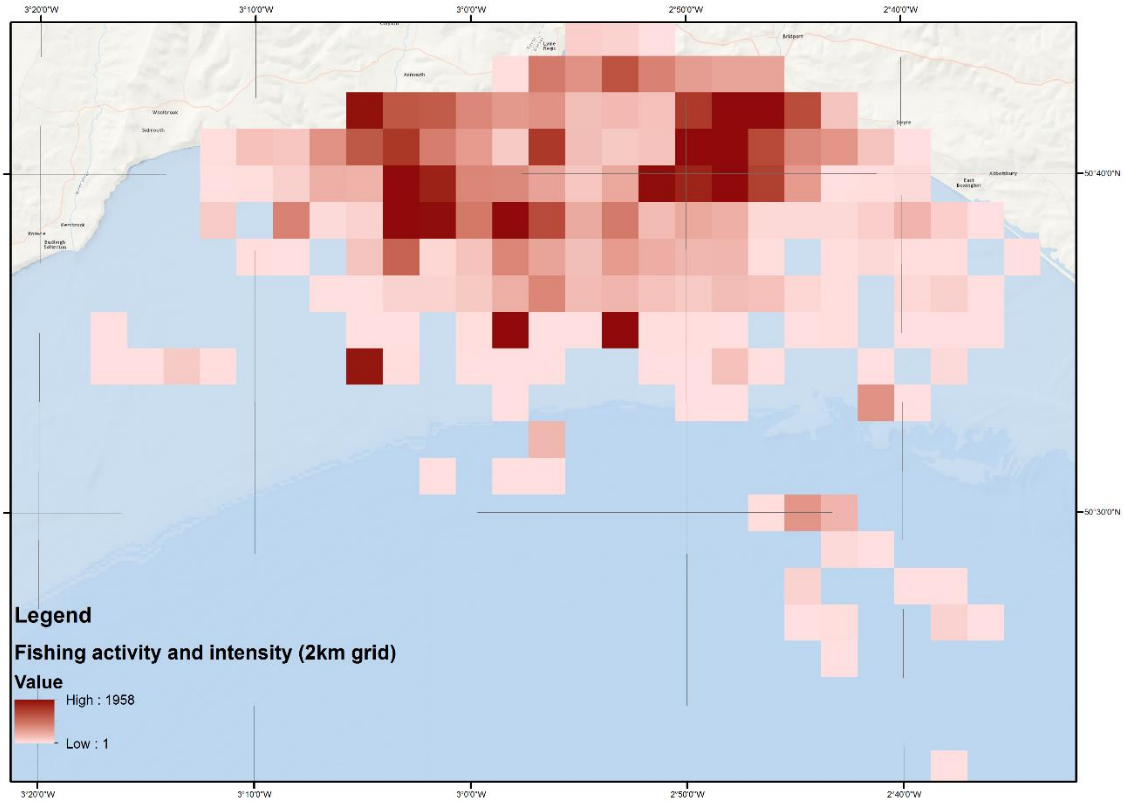

Figure 22. Fishing activity in Lyme Bay from iVMS data gridded at 2km. Darker cells indicate a higher level of activity in that area.

At a 2km resolution, we can see that there is actually some complexity within the central focus of activity, and some hotspots are appearing, including what appears to be the wrecks, which did not appear on the larger grid (Figure 22).

At 1km, the location of the hotspots becomes more precise and some additional patterns become visible within the main grounds (Figure 23).

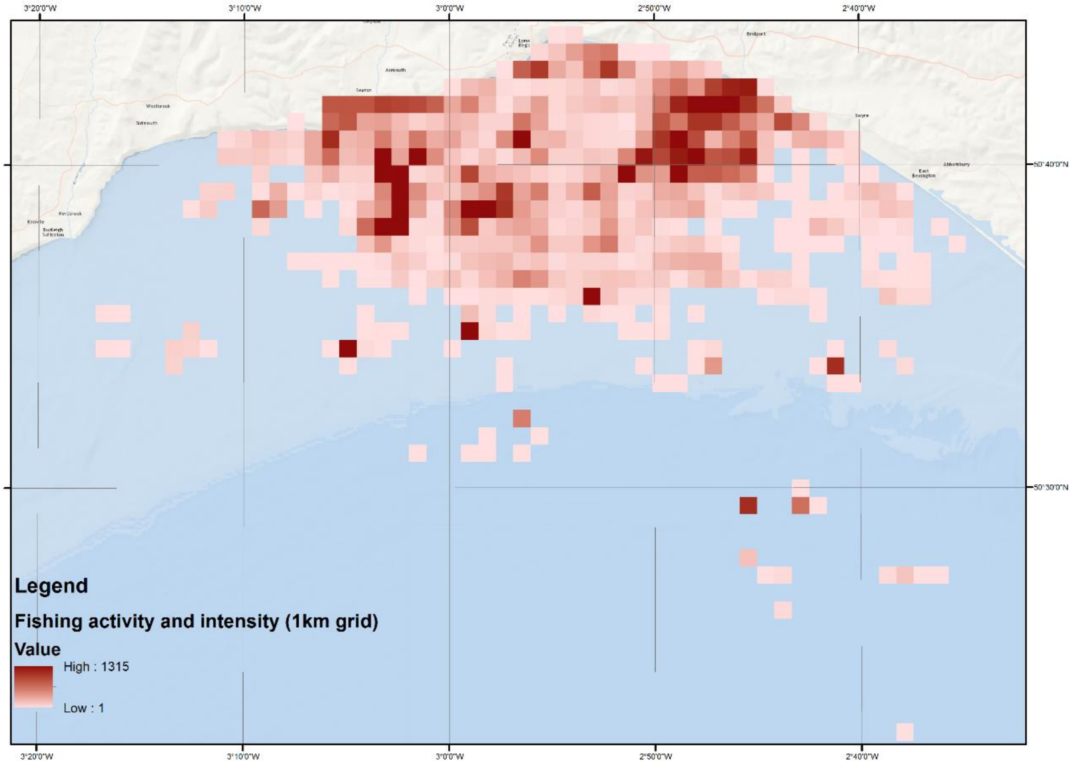

Figure 23. Fishing activity in Lyme Bay from iVMS data gridded at 1km. Darker cells indicate a higher level of activity in that area.

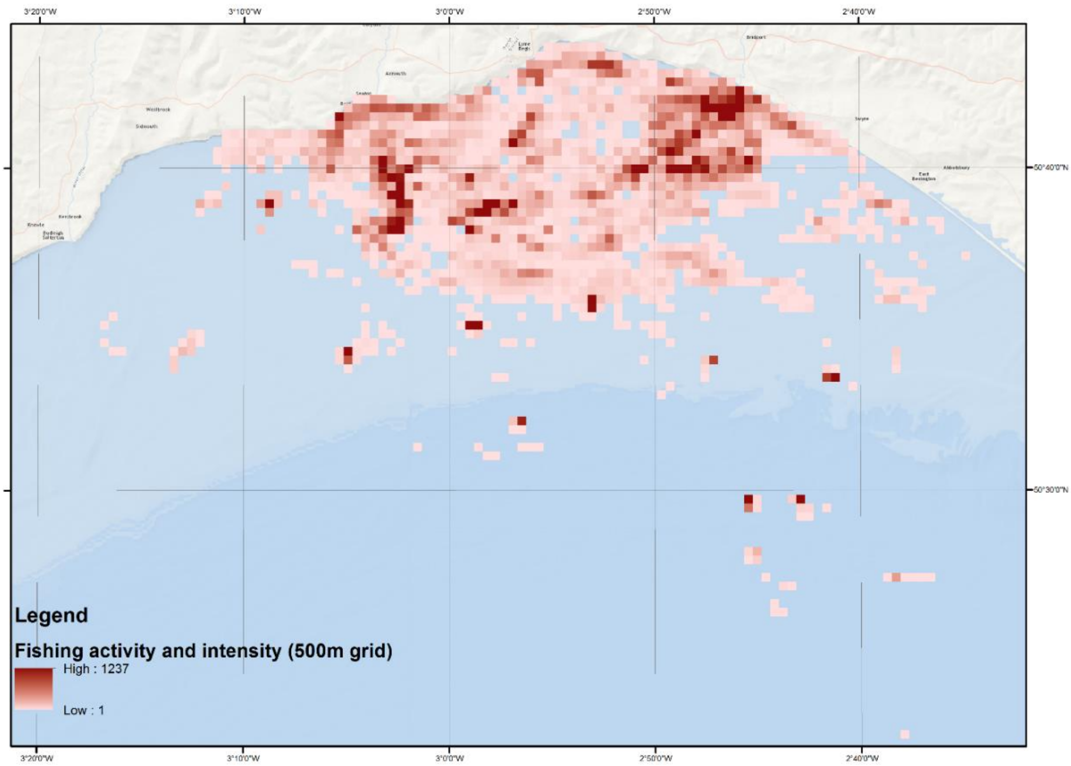

Figure 24. Fishing activity in Lyme Bay from iVMS data gridded at 500m. Darker cells indicate a higher level of activity in that area.

At sub-kilometre resolution, the detail is probably sufficient that the patterns shown could start to be compared to broadscale habitat data.

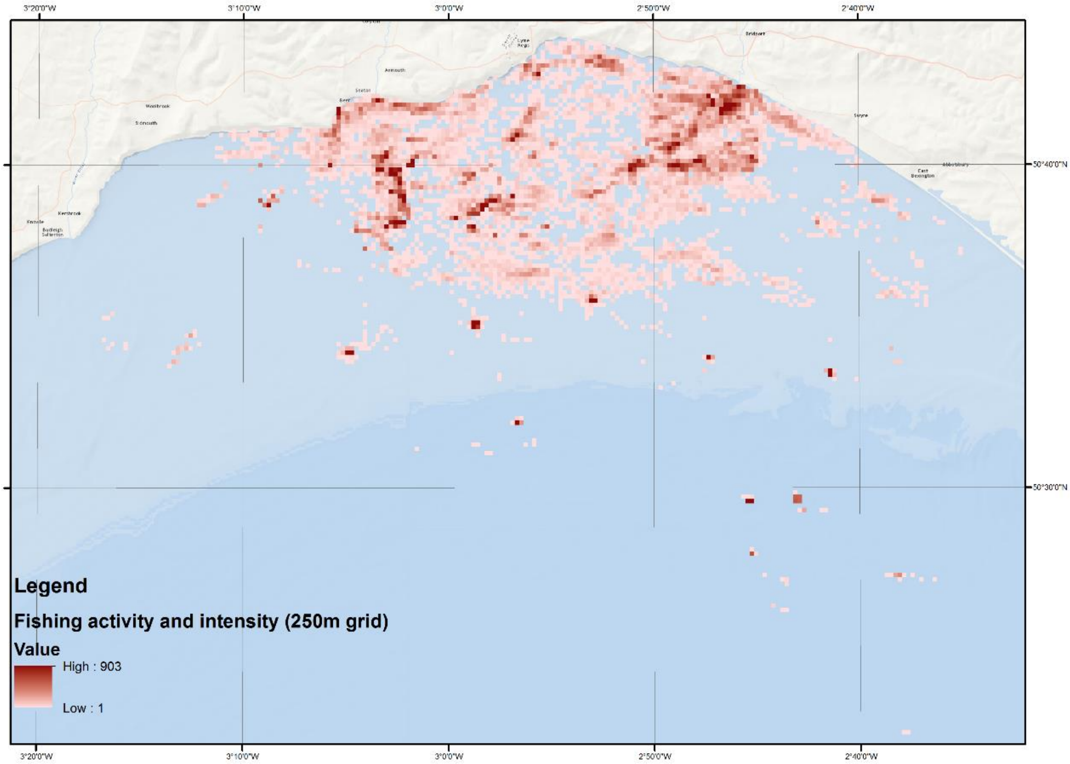

Figure 25. Fishing activity in Lyme Bay from iVMS data gridded at 250m. Darker cells indicate a higher level of activity in that area

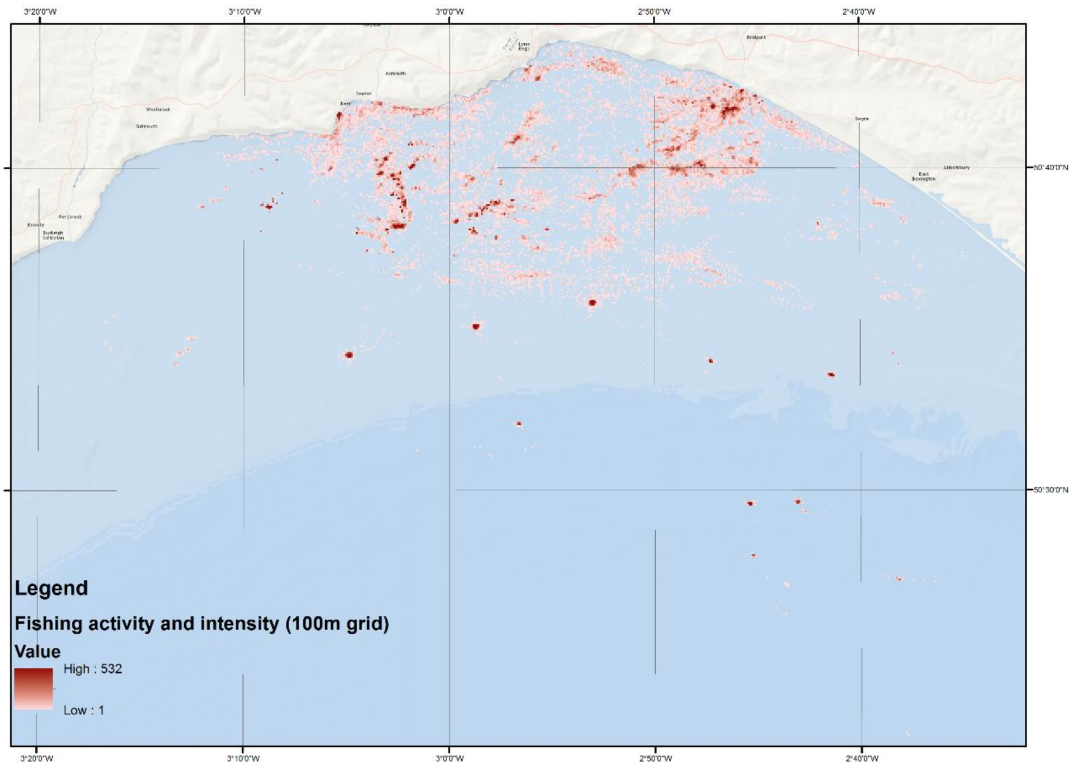

Figure 26. Fishing activity in Lyme Bay from iVMS data gridded at 100m. Darker cells indicate a higher level of activity in that area.

The increase in definition by decreasing the cell size of the gridded fishing activity raster from 250m - 100m (Figure 25 & Figure 26) demonstrates how much detail is gained. Many of the hotspots, which show as the darker areas on the map, are actually quite small areas. Fishing activity is focussed on discrete areas – a fact which was in no way represented by previous fisheries data. This is extremely important, not just in the detail, but conceptually; when discussing the interaction of fisheries with other sectors, or the impact on habitats, failing to recognise how certain fishing grounds are very much more important than others really changes the conversation around spatial management and the choices to be made.

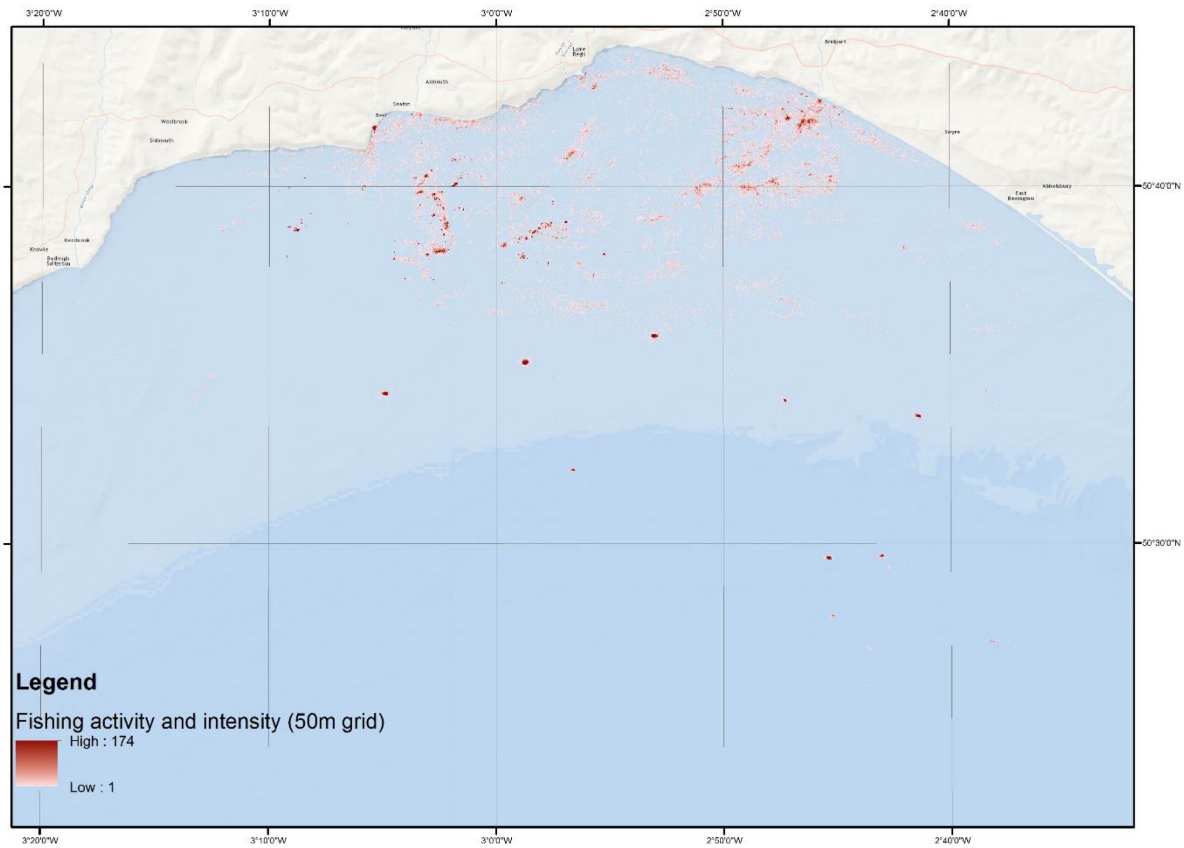

Figure 27. Fishing activity in Lyme Bay from iVMS data gridded at 50m. Darker cells indicate a higher level of activity in that area.

This chart shows the data gridded at 50m, which is the size used most in this report. The reason for this is mostly visual; the detail can be seen, but visibility does not suffer too much. You can see from Figure 27, above, how it is easier to see the cells and pick out patterns in activity with the slightly larger cell size, in the context of viewing the data as a small figure in a report. Clearly, within a GIS, and at a higher zoom level, this is not an issue.

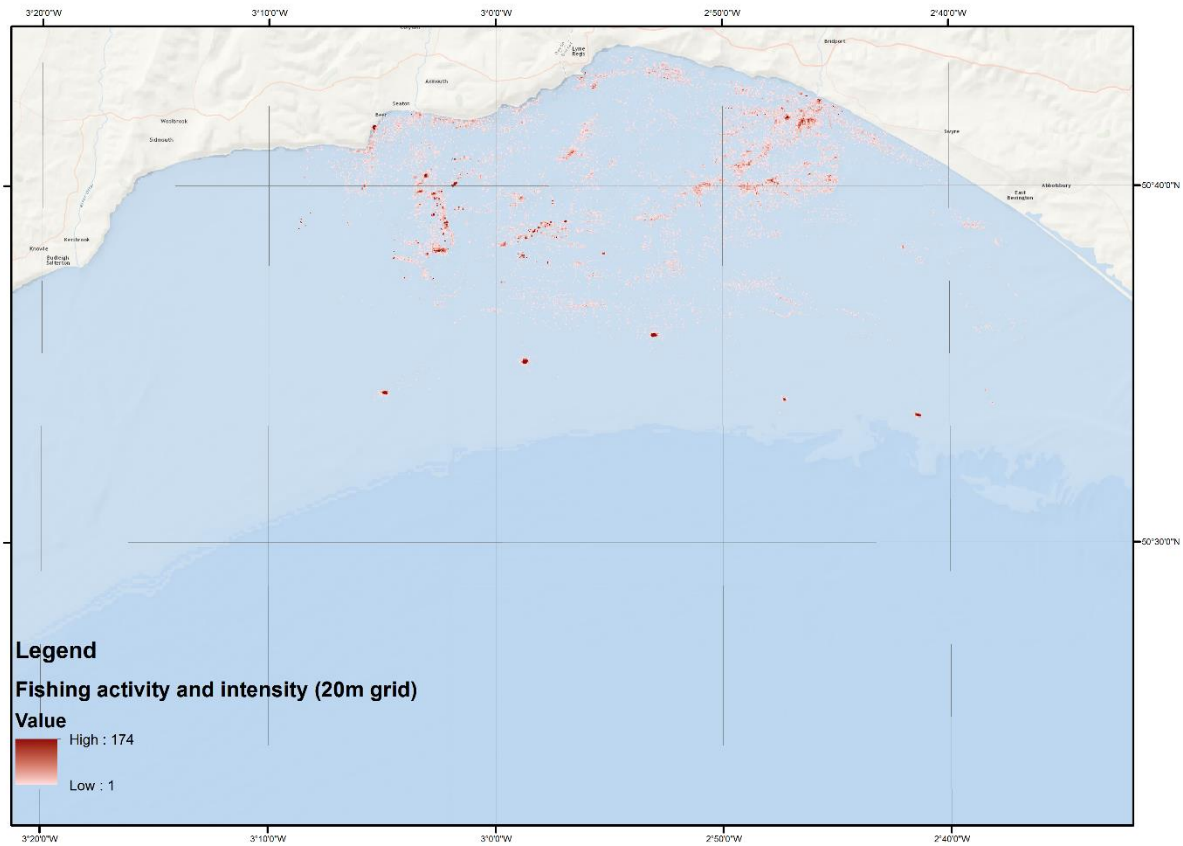

Figure 28. Fishing activity in Lyme Bay from iVMS data gridded at 20m. Darker cells indicate a higher level of activity in that area.

Finally, Figure 28 shows the iVMS data at the 20 m grid size used for the habitats analysis in this report. The level of fine detail, made possible by the high precision and accuracy of the GPS and iVMS units on the vessels, allowed a detailed comparison to be made between fishing and habitat data, as discussed elsewhere in the report.

Activity Metrics

While the metric for level of fishing activity, the number of iVMS data pings per unit area, is not directly applicable as a quantitative measure of effort, it does provide a measure of the relative importance of a given area. It is of course an accurate metric of "intensity". So, while full quantitative analysis of effort is not feasible using positional data alone, the maps provide an excellent qualitative and semi-quantitative illustration of the relative distribution of fishing activity, and which grounds constitute the "hotspots".

This information represents a key pillar in the data necessary for spatial management and assessment enabling further analyses and applications which are explored in detail in subsequent sections. However, at a fundamental level it can provide a much more accurate account of fishing in the Reserve which can help inform day-to-day marine management and planning. The value of good data and its ability to improve the efficiency and outcome of decision-making cannot be over stated, and in the iVMS dataset, the Fully Documented Fishery project has significantly improved the benchmark for "best available information" in inshore fisheries, and demonstrated that it is achievable. Over time, the benefits should be felt not only by those who use the data, but also those on the receiving end of management, including the fishing industry themselves.

Beyond Intensity

The scoping exercise highlighted a variety of potential data products and analyses for potential outputs based on the iVMS and Catch App data. Probably the most ambitious of these was the spatial quantification and visualisation of fishing effort by gear type.

It was not possible to tease out the detail of what fishing activity or gear was being employed by each vessel from iVMS speed/location data alone. In the past it has been sufficient to separate static gears from mobile gears using this data but the increasing more focused management questions on fishery interactions presents a requirement for this ability.

The RFID trial described below offers an approach and a potential solution for generating gear specific spatial activity records. Spatial effort data could be generated using this approach if individual tags are linked to specific gears e.g. tag 1a = string of 10 parlour pots, or Tag 2a = 400 yd tangle net.

The Catch App section below describes a methodology for collecting catch and discard information. It is perfectly feasible to link these records to the spatial effort data to provide the spatial effort visualisations proposed in the scoping table.

Risk maps for habitat management

Focus of analysis (from Scoping Table)

End Users:

- Fishery Managers, Conservation Managers/Wildlife Interests (NGOs, SNCBs), Fishing Industry Representatives

Data products:

- Quantitative maps of intensity/effort over sensitive habitats, Risk maps to inform site management

Analyses:

- Fishing effort per spatial unit by gear/fishery over habitats
- Pressure or risk maps of effort per spatial unit of habitat
- If effort threshold can be established e.g. pots per unit area

Context and Background

Understanding and mitigating the impact of fishing on the environment is a key aspect of the remit of the IFCAs and SNCBs, and there is keen interest from wildlife NGOs and the general public that sensitive seabed habitat is not damaged. A large part of the site management of marine protected areas and particularly sustainable use sites such as the Natura 2000 network (marine SACs and SPAs) consists largely of working towards better risk management. There has been close attention recently on fishing impacts in particular as part of the Defra revised approach of assessing fisheries management in European Marine Sites.

Lyme Bay is a designated area, and there has been a relatively long history of interest in the habitats and seabed ecology well before any statutory designations were awarded. Consequently there is relatively good data available from studies and surveys, including JNCC's MESH (Mapping European Seabed Habitats) project data.

There is also a good broadscale understand of which fishing activities take place in Lyme Bay, and so assessments such as that undertaken by the IFCAs as part of Defra's aforementioned review, and MPC's recent Lyme Bay characterisation for Blue Marine, have been able to identify which types of fishing activity may come in contact with which habitat types. The fishing activity data from IFCA sightings and other holdings has even allowed some spatial analysis to support this (MPC, 2014).

However, these assessments have necessarily been relatively broadscale due the paucity of information of the fine scale fishing effort distribution. Until now there has been no clear measure of relative effort or intensity of different fishing activities, and the spatial resolution and accuracy of the data was also poor. In this project, the new availability of high quality fishing activity information in the form of iVMS data represents an excellent opportunity to better understand, at a finer scale, the extent to which fishing interacts with the seabed environment.

One of the current discussions in marine management is how to quantify risk to habitats (and species) in a meaningful way. This requires an understanding of how vulnerable a given habitat is to the different types of disturbance or pressure it encounters, and at what level of pressure the risk of damage becomes likely. There are efforts to try and determine what these thresholds might be. Another requirement is good understanding of the nature of the “hazard” posed by different activities – the level of exposure of different habitats to different pressures. This latter element of the risk “equation” is something that, it is hoped, the Fully Documented Fishery project data can contribute to.

One of the benefits in a clearer understanding of fishing and habitat interaction is that it will help focus discussions around how to prioritise management of different activities; both in the sense that it can confirm which concerns are valid and which are unfounded, and also that any potential “high risk” areas can be well defined spatially. This has the potential to give fisheries and conservation managers greater confidence in prioritising management objectives, and make the most of their time and resourced. And from an industry perspective it can be beneficial too, by allaying unfounded concerns that might have resulted in precautionary management measures that would have restricted activity.

Approach and Methods

The habitat vector data was part of the GIS Deliverables from the Lyme Bay characterisation study by MPC (MPC, 2014), and is derived from data held by the Devon Biological Records Centre and the JNCC.

This vector data was imported into GIS as a point layer, and transformed into a raster at a 20m cell size. A relatively small size was chosen as it was felt appropriate and better able to capture the boundaries between habitat types.

After creating a raster of the habitat data, it was then necessary to create new rasters based on the fishing and habitat data combined.

First, a 20m by 20m cell raster of the fishing point data was generated, based on the extent of the Habitat raster and snapped to it so that the cells were overlying. With the fishing data now at the same cell resolution and extent as the habitat data, raster calculations were undertaken. These calculations produced two sets of output raster layers created.

The first set showed where recorded fishing coincided with each of five different habitat types. Cells where both these conditions were met were given a value of 1; other cells were given a zero value. The number of cells with a value of 1 was calculated using GIS to give a statistic for interaction that could be compared with the total number of cells of each habitat.

The second set of rasters also compared both fishing and habitat layers, and output a new raster where a specified habitat type AND fishing also had been recorded. However this time, cells where both these conditions were met were given the value contained in the “fishing” raster (the count of iVMS points per cell); other cells were given a zero value. This set of rasters allowed the spatial variation in relative popularity of each habitat to be shown.

A step by step of the final methodology:

1) Import habitat (vector) data as shapefile

2) Ensure projection matches that of fishing data; if necessary, re-project.

3) Create 20m by 20m “habitat” raster from shapefile layer

4) Create 20m raster of fishing activity (count of points per cell) to same extent as habitat raster, and snapped so that cells in both overlaid

5) Perform a raster calculation using Spatial Analyst, comparing the fishing activity raster with the habitat coverage to determine the extent of overlap, and fishing intensity over each habitat type

6) Use cell count data to create statistics describing the interaction between fishing and different habitat types

For detailed methodology, please refer to the technical annex to this report.

Fishing Intensity/Habitat Outputs

Figure 29 shows habitat type overlaid with fishing activity, shaded by intensity. The fishing data here is not clipped to the Area of Interest, and relative fishing effort ranges from 1 to 174 points per 50m by 50m raster cell. The darker points indicate higher relative intensity.

This chart shows what proportion of the different habitats, colour coded as per the legend, were likely fished during the study period using static gear. It is evident that some habitats are more “popular” and coincide with more regularly with fishing activity than others. Coarse sediment and subtidal bedrock reef (represented by the mauve and grey shaded areas) are the focus for much of the activity in the Reserve and are the sites of higher frequency of activity indicated by the darker shading.

In contrast, subtidal mixed sediments (represented by the green shaded areas) are relatively lightly fished.

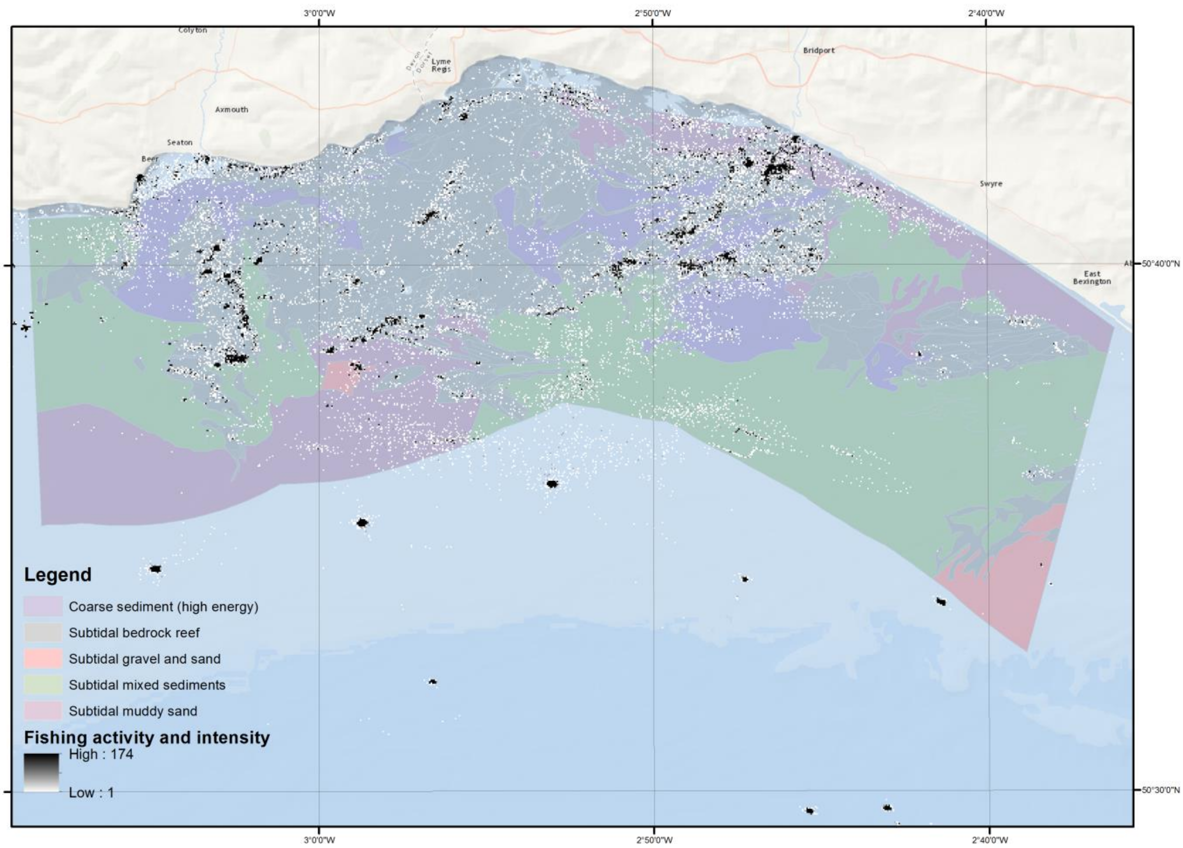

Figure 29. Fishing activity in relation to seabed habitats in Lyme Bay (50 x 50 m grid)

Figure 30 to Figure 34 show fishing activity over the specified habitat types, clipped to the habitat layer and illustrating relative intensity measured in "pings per cell" (here, cell size is 20m by 20m).

The darker areas show cells where there was more activity over the study period. The highest number of records or "pings" in any cell was 47. The shape of the darker areas appears to pick out the edge of features, and perhaps corresponds to the topography of the seabed. It is interesting to speculate if the difference in relative importance of certain areas of a given habitat over others might illustrate the heterogeneity within each seabed type.

Comparing this chart with the amalgamated data in Figure 29, above, shows that the most popular areas of fishing over subtidal bedrock reef correspond to the most popular, darkest areas overall – suggesting that this habitat correlates particularly strongly to favoured fishing ground.

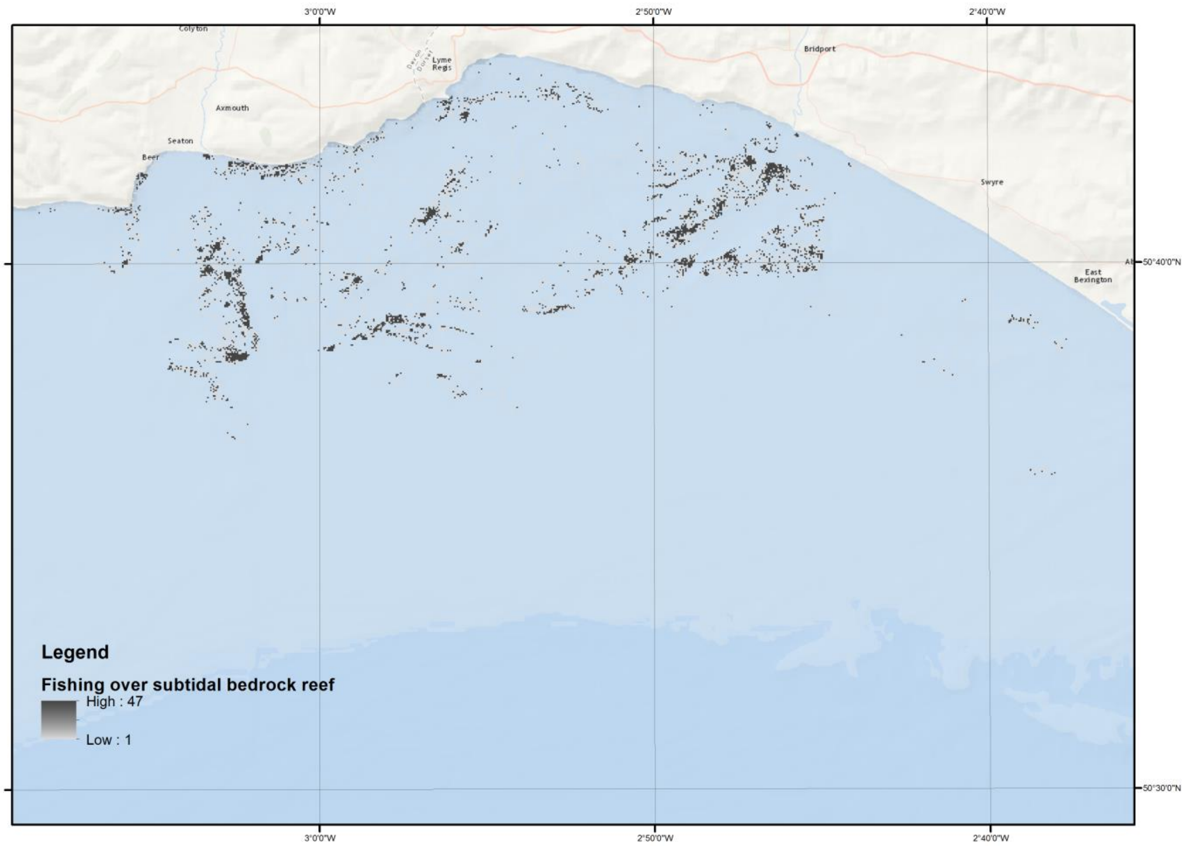

Figure 30. Fishing activity over subtidal bedrock reef (points per 20m by 20m cell)

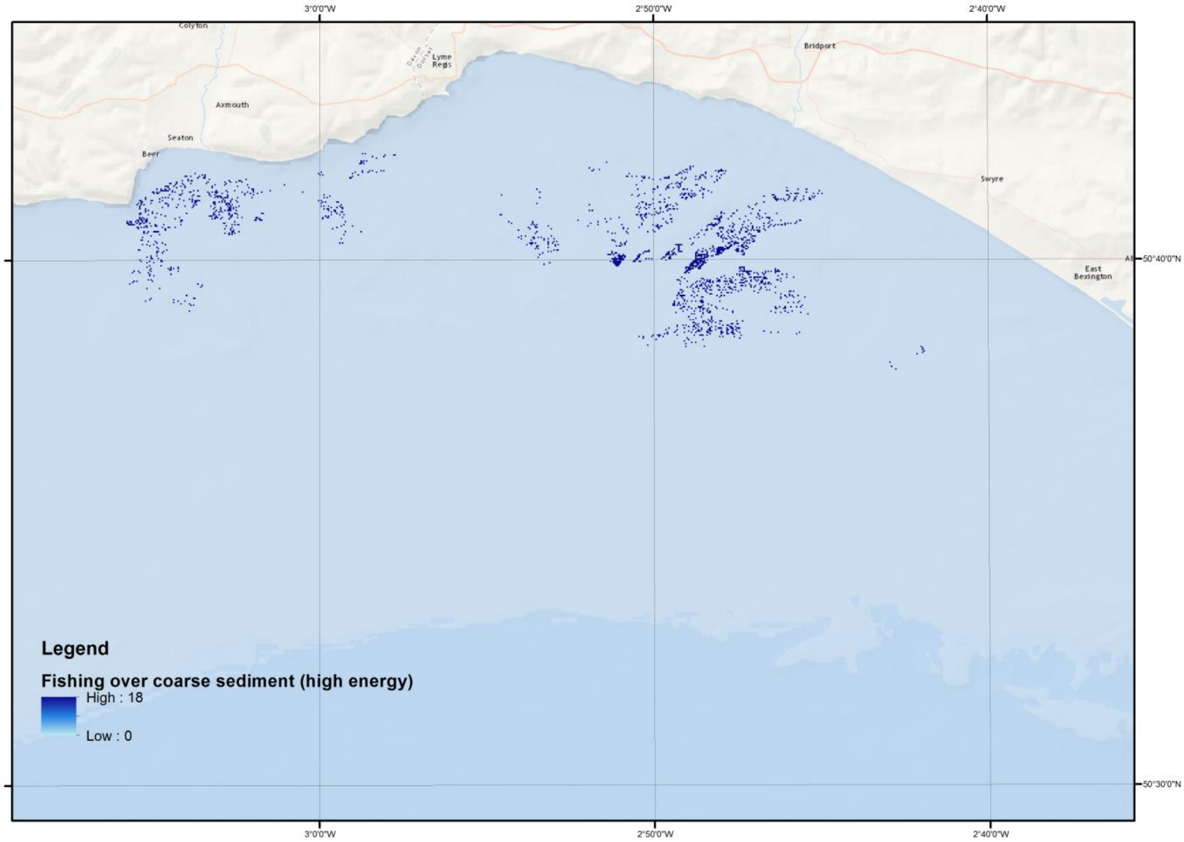

Figure 31. Fishing activity over coarse sediment, (points per 20m by 20m cell)

There does not appear to be as much variation in the relative intensity over the coarse sediment habitats as there is over subtidal bedrock reef; the shading of the cells is reasonably similar. However, there are some darker areas, indicating more popular fishing ground, near the 50°40.0' latitude line, just off West Bay.

The maximum number of times any cell was fished is 18. Coarse sediment habitat is less extensive within the Area of Interest, but the coverage or distribution of fishing over the habitat appears to be relatively uniform. This may be because there is a higher degree of homogeneity of the habitat itself compared to subtidal bedrock reef, which is probably to be expected.

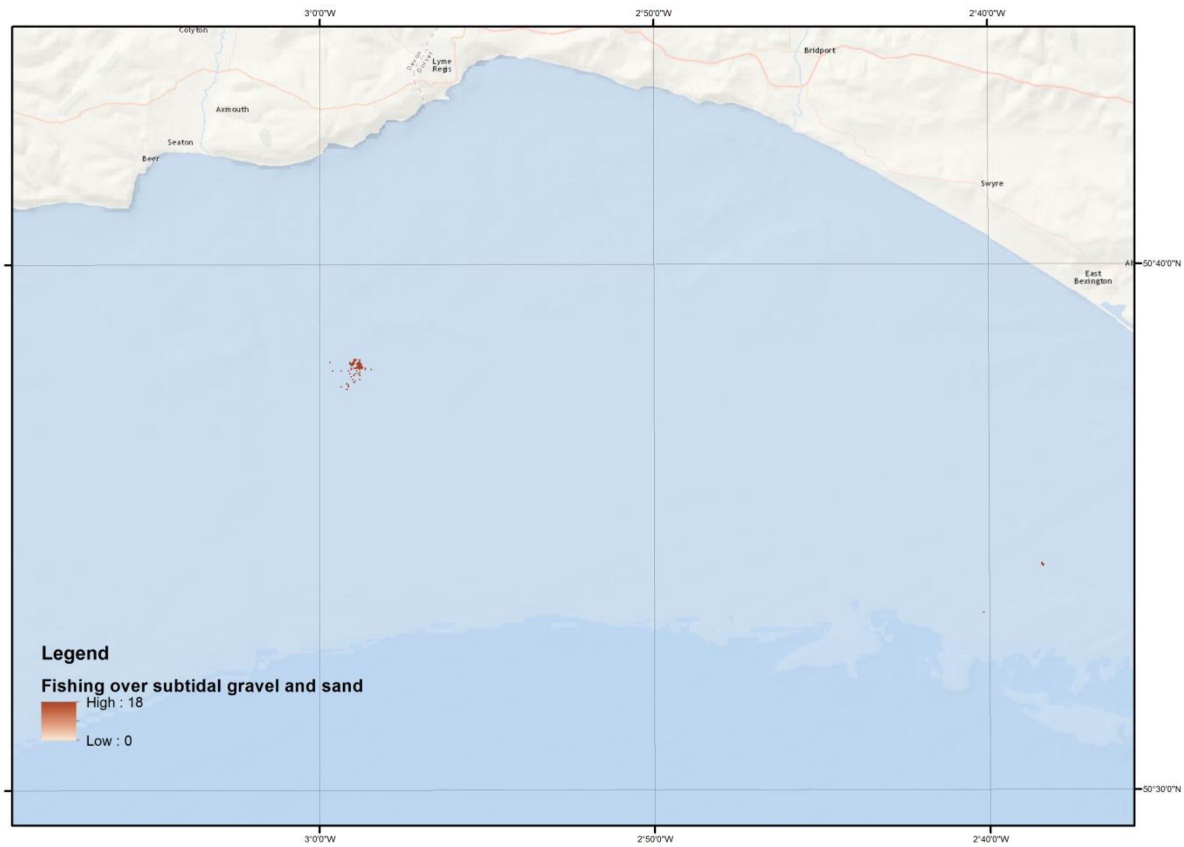

Figure 32. Fishing activity over subtidal gravel and sand (points per 20m by 20m cell)

There is not a large area of this habitat within the Area of Interest. Some cells are visited the same number of times (18) as areas of coarse sediment; the more frequently fished area appears to be the North West corner of the small area shown here. This borders an area of subtidal muddy sand.

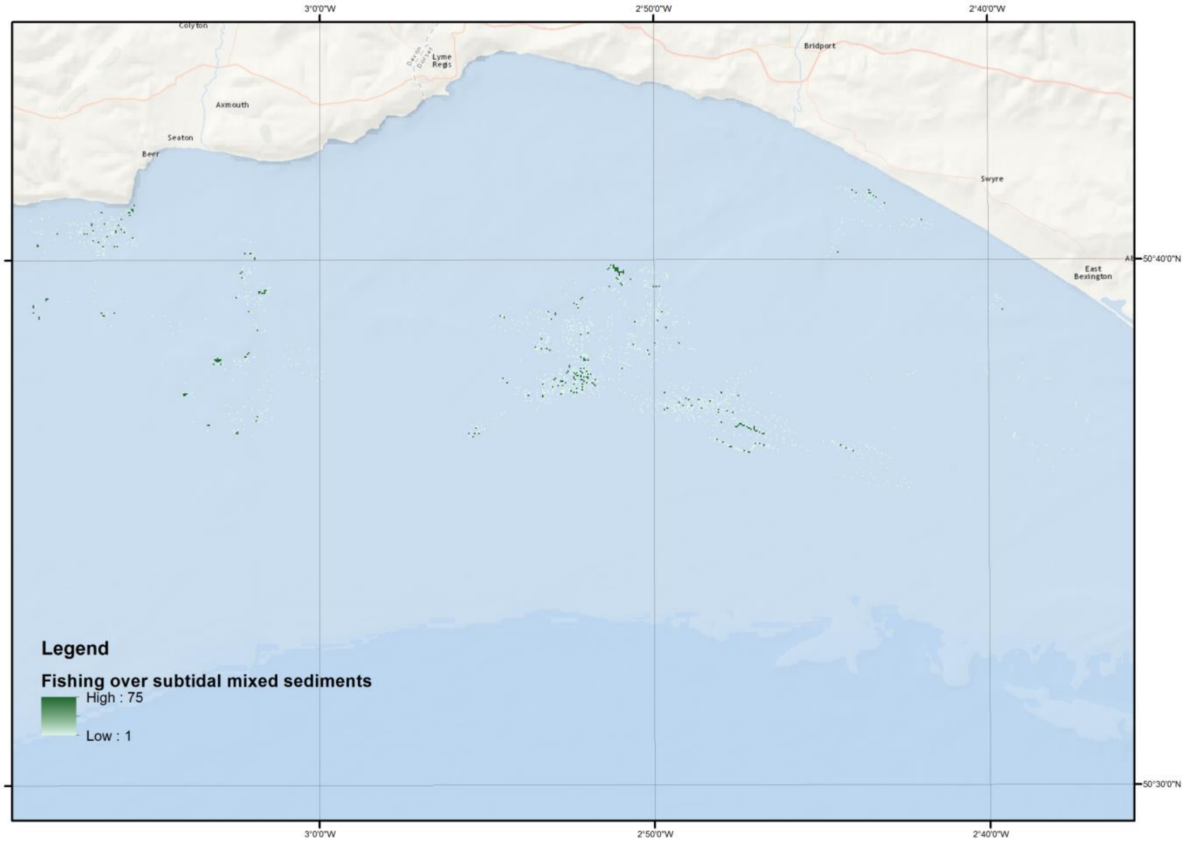

Figure 33. Fishing activity over subtidal mixed sediments (points per 20m by 20m cell)

Subtidal mixed sediment is the most extensive habitat within the Area of Interest, and there are some cells which contained a relatively high number of points, representing up to 75 visits per cell, although in general there does not appear to be a high level of fishing activity over this habitat. There is no clear pattern or clustering of the most popular areas for the most part; although many of the darker more intensely fished cells, appear to be on the edges of the habitat at the boundary with other habitat types.

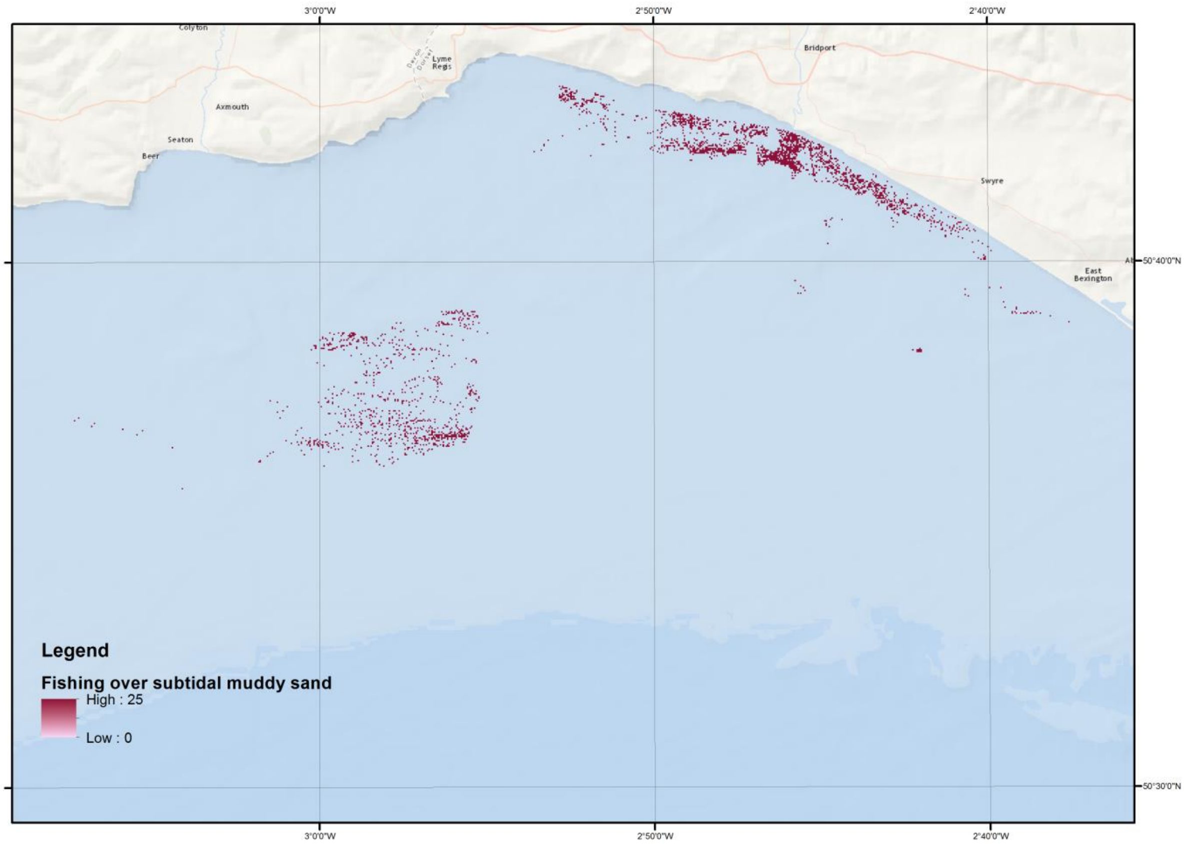

Figure 34. Fishing activity over subtidal muddy sand (points per 20m by 20m cell)

There are two areas of subtidal muddy sand habitat in the Reserve a strip running along the coastline to the east of Lyme Regis, and a larger area further offshore to the south. Of these two patches, the coastal strip is the most important fishing ground; indicated by the dark shaded cells representing a higher number of points (up to 25 visits per cell over the study period), and there is coverage over a large proportion of the habitat.

In contrast, while there is some fishing in the eastern portion of the offshore subtidal muddy sand, there is a large area extending to the west and south west of this that is relatively untouched.

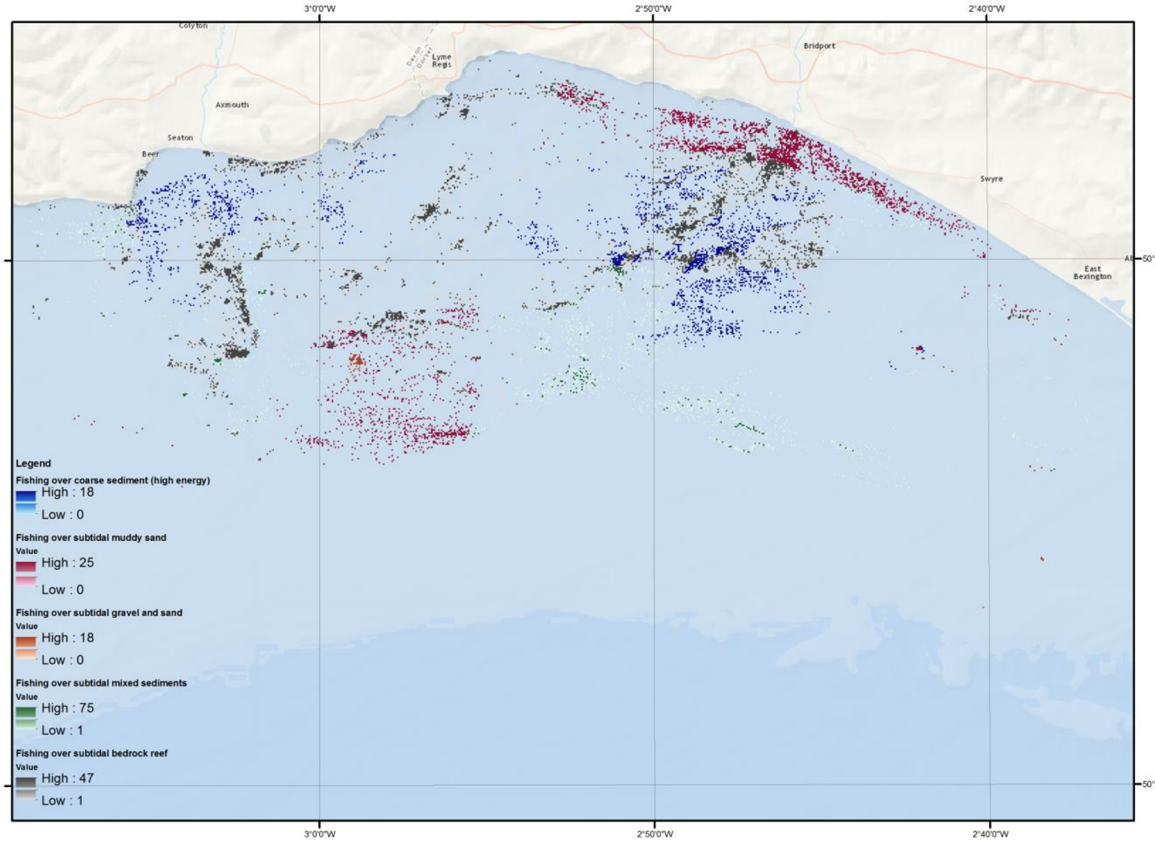

Figure 35. Fishing activity displayed over all five habitat types (intensity as count of iVMS data points per 20m by 20m cell)

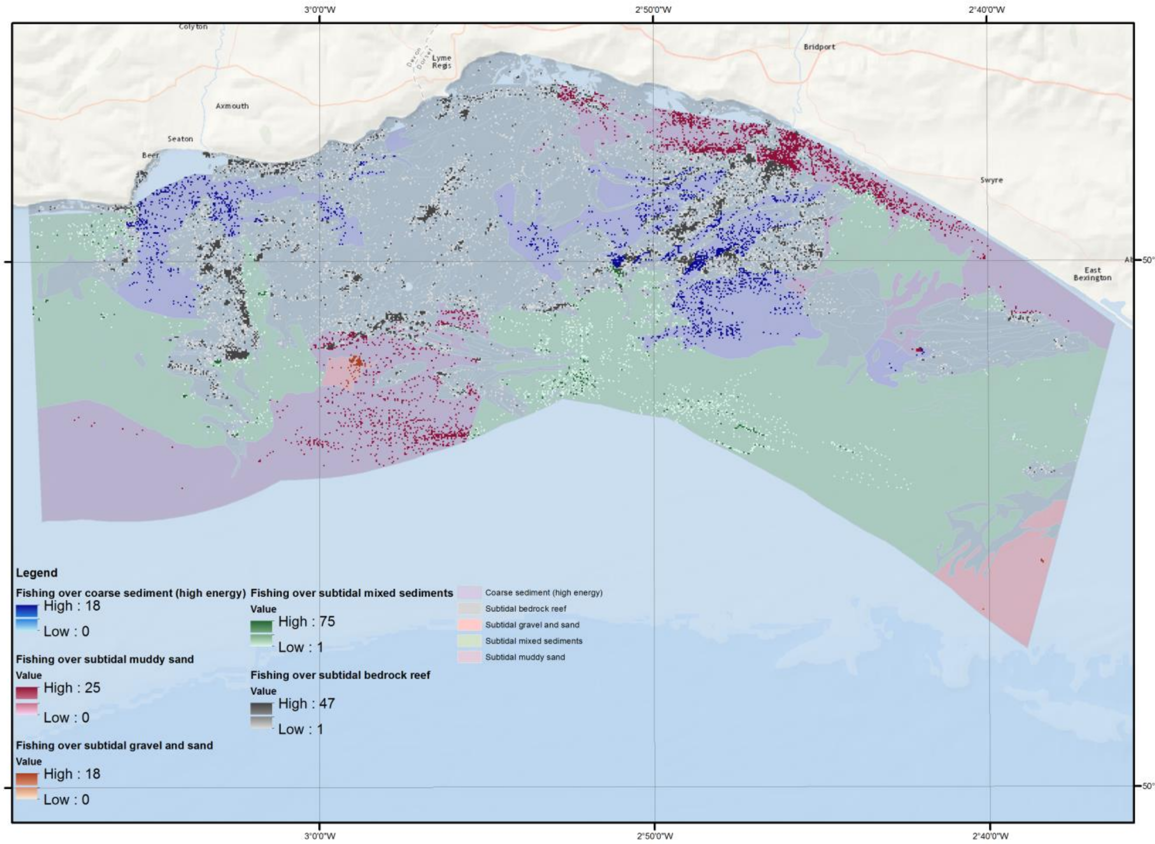

Figure 36. All habitat types, with colour-coded fishing distribution and intensity (data points per 20m by 20m cell)

Table 3. Statistical analysis of the spatial footprint of fishing activity in relation to habitats in the Lyme Bay Reserve

Habitat type	Area (km^2)	% fished habitat	Points/km^2	Max points/cell
Subtidal bedrock reef	164.44	16.2	111.93	47
Coarse sediment (high energy)	43.9	10.6	54.62	18
Subtidal gravel and sand	11.23	1.6	18.61	18
Subtidal mixed sediments	144.11	3.3	16.78	75
Subtidal muddy sand	80.42	7.9	46.16	25

Table 3 shows statistics calculated by the GIS: the "percentage of fished habitat" is the number of fished cells within each habitat type, as a function of the total number of cells of that habitat type. "Points per square kilometre" is the total number of iVMS points found in each habitat type, divided by the total area of that habitat within the Area of Interest. Maximum points per cell indicates the maximum number of times a cell of that habitat type was visited by a vessel that is assumed to have been engaged in fishing activity. The total area of each habitat type within the Area of Interest is also shown.

These statistics successfully describe the spatial footprint, at a high resolution, of the fishing industry in Lyme Bay Reserve.

These statistics underline the patterns observed in the charts, above. Subtidal bedrock reef has a higher percentage of fished habitat and average points per km^2; the total area of habitat is large however, and the activity is relatively spread out across the fished cells, so that the maximum points or visits per cell is moderate. Coarse sediment and subtidal gravel & sand both have a maximum points per cell statistic of 18, but for the former contains more activity covering proportionally more of the total area of habitat.

Subtidal mixed sediments cover a large total area, but a very low percentage of this is actually fished, so the activity is concentrated in a fewer number of cells, leading to a higher maximum than for other habitats. And subtidal muddy sand is relatively moderate for all metrics.

Habitats/Fishing Activity Discussion

This series of analyses represent a step change in how we visualise fishing interactions with seabed habitats. The high resolution spatial data produced by the iVMS units has enabled us to not only present the spatial patterns of static gear fishing in the Reserve but, by using iVMS records or "Pings" as a proxy, to also quantify intensity.

The statistics demonstrate that fishing takes place over relatively small areas of each seabed habitat and that the distribution of this activity is not equal across tem.

Subtidal bedrock reef was the most fished habitat having activity occurring in 16% of the total area. This is unsurprising in the context of Lyme Bay and the importance of the crustacean fisheries to the local fleet. Effort will be concentrated in habitats that support target species and this seabed type is favoured by crustaceans due to the availability of refuges and prey species. Since the target species favours this habitat it is naturally found in higher abundance here and, consequentially, fishermen will target these areas and effort will be correspondingly higher too. Some static net fisheries will also be distributed around the reefs, although not over the very rough ground, as these habitats tend to attract and "hold" some fin-fish species such as bass. Examination of the number of iVMS points per total area of each habitat (i.e. the average intensity across the feature) as "pings per km^2", there is almost twice as much fishing activity per square kilometre over subtidal bedrock reef as there is over the second more popular habitat, coarse sediment (high energy).

Subtidal mixed sediment is the least fished habitat (3% of total habitat), but has the highest "maximum number of points per cell" than any other habitat type of up to 75 pings per 50 m x 50 m grid cell. It appears that those cells "hotspots" are closest to areas of other habitat that are well-fished, so the higher concentration is a function of being near a boundary between seabed types. The use of GPS plotters on vessels can result in the accurate placement of fishing gears at favoured marks therefore high intensity cells can occur from the fishing activity of just one vessel, especially if it is on the site for some time (the iVMS system pinging every 10 mins). It may be the case that hotspots such as this are the favoured marks of rod and line fishermen anchored for long periods over a favoured mark. Without the fleet-wide use of gear tags it is impossible to tease out the fishing methods employed from iVMS position/speed alone.

In contrast, habitats where there is a lower maximum points per cell, such as coarse sediment, can have a higher overall level of interaction with fishing, but spread out more widely across the extent of that habitat; "hotspots" do not occur and intensity is low across the whole feature.

Overall, it appears that activity is highest in the centre of the Area of Interest (AOI), where the likely ranges of vessels from the three nearest ports overlap, fishing intensity is highest for all habitat types within this central area. This area contains the majority of bedrock reef and coarse sediment (the most heavily targeted habitats) and therefore distribution and relative intensity of fishing is likely to be a function of both the distribution of the habitats across the Reserve and the proximity to home ports.

This Zone of Influence (ZoI) of a fishing port is a little reported characteristic of how the spatial footprint of fishing activity can be understood and the drivers of behaviour described. Limited by a variety of constraints including of vessel range, endurance and fishing capacity, available fishing grounds, and by the constraints of weather and safe working, small vessels have a limited distance and spatial footprint in which they can operate. This is particularly true for static gear vessel fleets which are often spatially self-organising through competition and rely on specific habitats for their target species. Clearly, the vessels from the Lyme Bay ports have shared constraints and drivers that makes the central area of the Reserve the key fishing ground.

Probably the most important result of this analysis is that if has allowed us to demonstrate that rather than effort being widespread and affecting all areas of seabed habitat, the reality is that a small proportion of each habitat is actually fished and where fishing gear actually contacts the seabed. A parallel to this picture might be the concentration of the impact on visitors to national parks. Most impact is relatively confined to the footpaths and areas close to the footpaths. There may be a lot of footfall, but away from the hotspots very little effect may be seen. The fishing activity distribution illustrated by the iVMS data suggests that in Lyme Bay, too, the possible impacts are limited to discrete areas and are not diffuse. Conceptually this is helpful from a management point of view: if reduction of effort is needed, managers could prioritise less-fished areas as these are likely to be in better condition and less contentious to close. It also makes it possible for researchers to target areas to study effect, classifying locations based on an understanding of importance, built over a long enough period of iVMS data, that correspond to "low", "medium" and "high" impact areas, and studying each type (or a number of examples of each) in situ to see what the effect is, what habitat looks like as a result of different levels. This could be helpful in developing thresholds and understanding the vulnerability of different habitats to fishing effort (e.g. Lambert et al, 2015).

It should be understood that fishing intensity (pings per grid cell) is simply a proxy for potential impact or disturbance. At present there is no means to determine whether high fishing intensity equates to any impact on the environment at all. In order to do this we would need to be able to link fishing activity with a particular gear type and to have a good level of understanding of the effects of that gear type on seabed habitats.

In future the outputs for this type of analysis would be a series of charts showing effort per unit area for different gear types over different habitat types. We were unable to produce this in the current trial because individual gear type information is not contained in the iVMS. The majority of the iVMS data related to static gear fishing and the only tool that could be applied were speed filters on vessel speed. This results in the aggregation of all static gears into one chart. The gear-in gear-out RFID technology could provide this information if applied in a systematic manner. This would require all fleets of pots and nets to have at least one tag fitted, probably to the ends. If each tag number could be registered to a particular gear type with a description e.g. 10 pot string or 400 yrd net, then very accurate and precise intensity and effort data could be produced.

An alternative approach could employ the Catch App recording system. Catch App data could be recorded in a way that relates the amount of gear hauled to the location where it is being deployed, a more detailed and quantitative picture of effort could be derived, and it would also be possible to easily designated iVMS data to different fishing gear types. In reality this is likely to be impractical for anything other than use in a self-sampling study or targeted data collection.

It is unclear whether the iVMS data collection will continue beyond the end of 2015 but the generation of a long time-series of data would enable some valuable analysis of seasonal fishing patterns. These may identify particular times of year when certain habitats experience most fishing interaction, or is the distribution of activity unaffected by seasonal differences in weather or the behaviour of target species. Currently the data spans a time period of approximately 18 months, but limited uptake until the summer of 2015 resulted in a relatively small number of points over time precluded a seasonal analysis and identification of clear patterns. A larger time series of data from a wider selection of vessels will support future analyses of temporal differences.

After discussion with IFCA officers we attempted to determine whether the data supported an estimation of risk, to be displayed as a map showing the spatial distribution of that risk over each habitat. The intensity maps are simply showing relative level of interaction; in a sense, this might be seen as a proxy for risk, but there is no real understanding of what this means in practice. Risk is a function of the "hazard", in this case, the fishing activity; and "vulnerability", which in this context equates to how sensitive the receiving habitat is to fishing pressure. What the distribution and relative intensity maps provide is a partial measure of the hazard (albeit over a set period of time, and limited to static gear). What is missing is an understanding of the vulnerability. Ultimately, managers want to have an idea of thresholds – what are low, medium and high risk intensities for various habitats?

A central aim of the Lyme Bay Potting Study being carried out by Plymouth University is to establish whether a detectable threshold for potting on bedrock reefs can be established. It may be possible in future with this information and with gear specific activity data to establish real time risk maps for MPAs.

In summary, the outputs of this analysis represent a step-change in how fishing activity can be visualised. That this work has been carried out in a sensitive MPA further highlights the importance and timeliness of the work. The data shows that interaction is not homogenous but is instead isolated to discrete areas, and these areas represent a small proportion of each given habitat. This might help to allay concerns over the cumulative impact of fishing on the seabed environment. Being able to understand the relative intensities of activity in relation to protected site features such as the bedrock reefs in Lyme Bay with such precision enables much better informed assessments and lead to more meaningful and effective management. From and industry perspective these outputs represent valuable evidence for use in dialogue with conservation groups and with the media.

Requirement: Risk maps for sensitive sessile species management

Focus of analysis (from Scoping Table)

End Users:

- Conservation Managers/Wildlife Interests (NGOs, SNCBs)

Data products:

- Fishing activity mapped in relation related to sessile species records

Analyses:

- Pressure or risk maps of fishing intensity data related to sessile species records; Seasonally and annually

Introduction

The environmental impact of activities, including fishing, on the seabed is often discussed in the context of how the distribution of activities relate to habitat.

In Lyme Bay, pink sea fan (*Eunicella verrucosa*) is considered a Species of Conservation Importance and receives a high level of media and public interest. Consequently, there are records spanning quite a long period, consisting of point data showing where it has been found. As a benthic species, pink sea fan is more likely to interact with potting and other static gear. Pink sea fans are ideal model species to use as a test of concept for analysing relationships between the distributions of sensitive sessile species and fishing activity.

It should be noted that although presumed to be a sensitive species pink sea fans are actually quite resilient to disturbance and studies have shown that potting may not actually present a risk (Eno *et al.*, 1996).

Here, an analysis of the interaction between static fishing, as described by the iVMS data, and pink sea fan, as described by the point data, is undertaken. This is not because of any anticipation of high risk, but simply to describe the level of interaction using data which (in the case of the iVMS) is much better and higher resolution than that previously available. The aim is to be able to test the approach and to provide more detailed information and improve understanding so that it can inform any discussions around future management.

Method

The pink sea fan data was combined from multiple sources (JNCC, Bangor University and Seasearch) and includes historic data and more recent records (up to 2012). This means it is possible that a number of points are no longer accurate – but equally, not all the pink sea fan within the study area will be represented as point locations. Using a long time series of data should mean that it is broadly indicative, if not absolutely precise or accurate.

The point data was translated into a raster at 50m grid cell size, the same as the iVMS data, and as described elsewhere in the report. This raster was compared to the fishing activity layer, and a third raster layer was produced: this showed the cells where fishing and pink sea fan had both been recorded.

The methodology for this is described in further detail in the technical annex, and in the methodology for both iVMS data and mobile species data.

Results

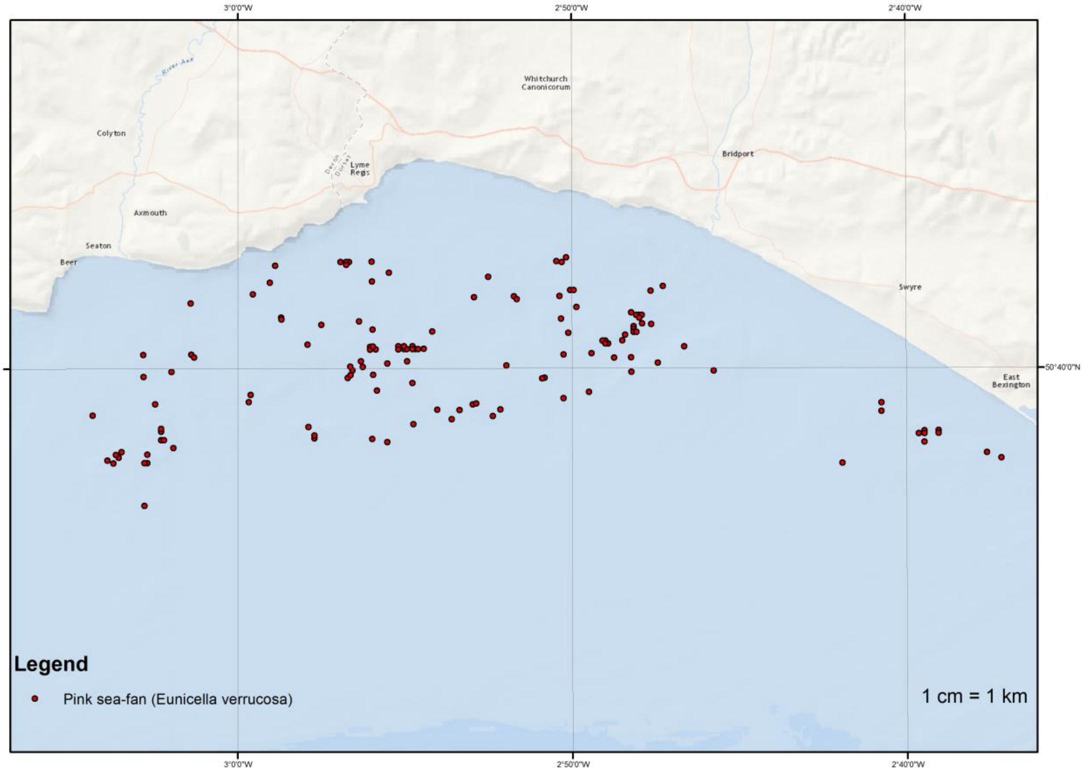

Figure 37. Point locations where pink sea fan has been recorded.

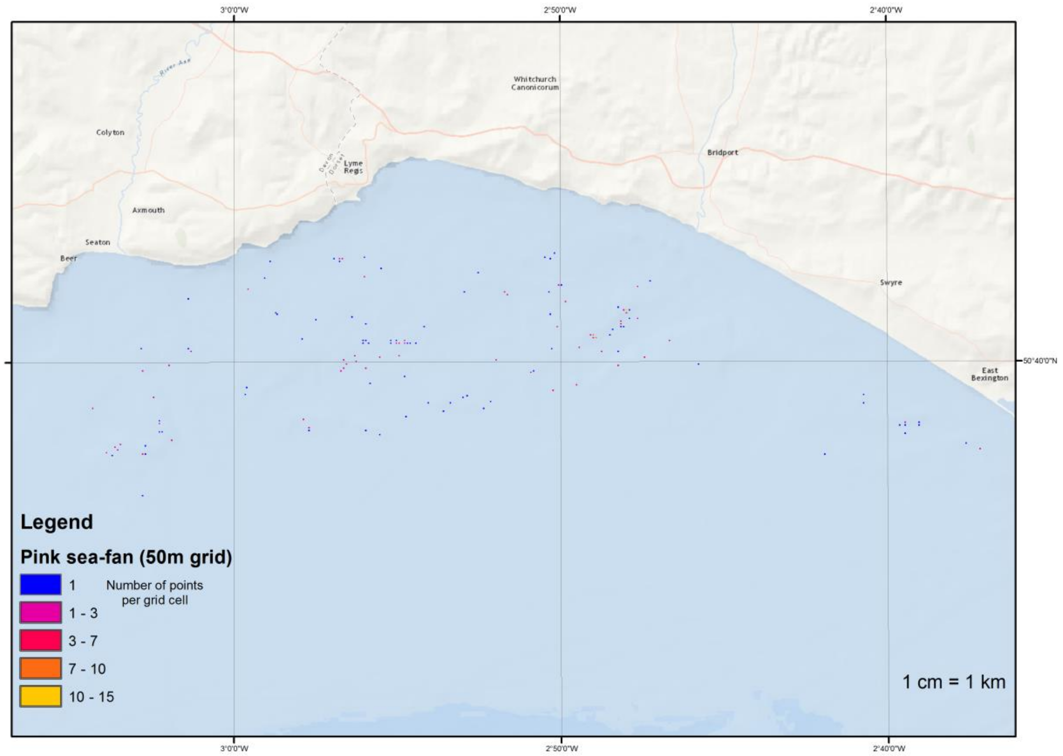

Figure 38. Point data translated to a raster with 50m by 50m cells. This figure shows the entire extent of the data for the Area of Interest.

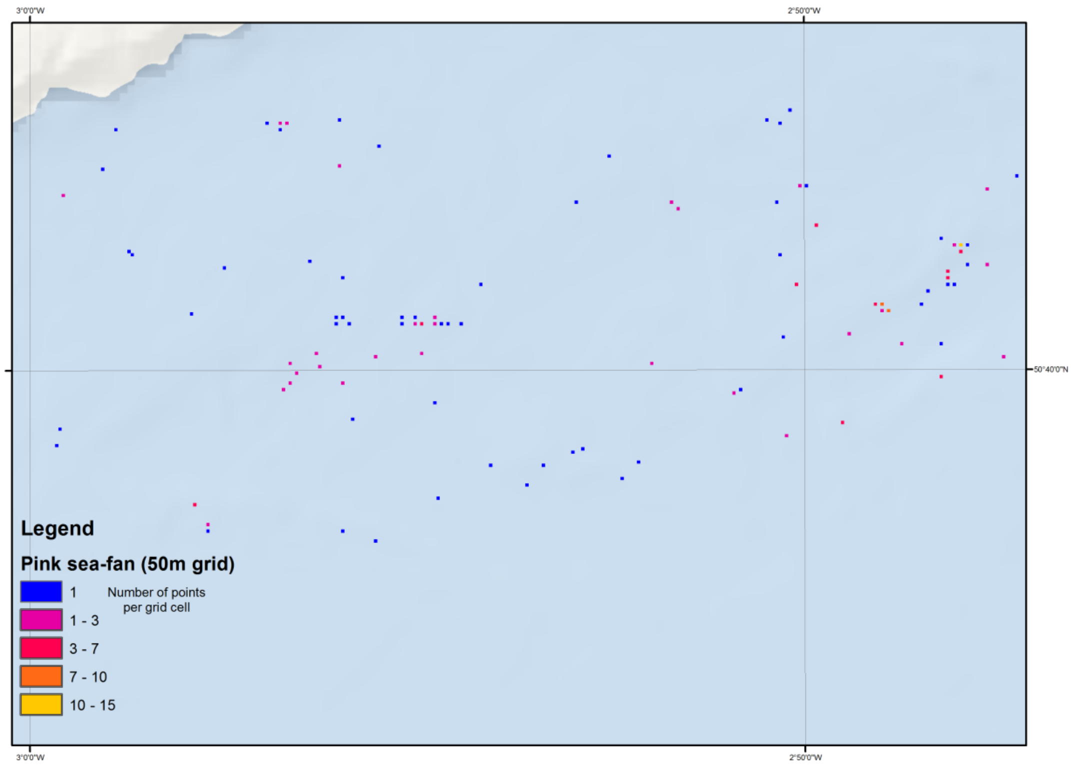

Figure 39. Thematic map of pink sea fan abundances

Figure 39 above, is a closer view of the gridded pink sea fan raster coverage. Here, it is possible to see some differentiation between cells with a lower (blue, pink) and higher (orange to yellow) number of records counted.

Figure 38 and Figure 39 , above illustrate the output raster at two different zoom levels. Pink sea fan is distributed quite widely across the Area of Interest, but most cells did not contain a great number of data points and are coloured blue. However some cells show up to 15 records of pink sea fan in some locations. Since the dataset covers a long period of different surveys, a high number of points per cell does not necessarily correspond to the abundance of sea fan at the location, but does indicate that it has been consistently found there.

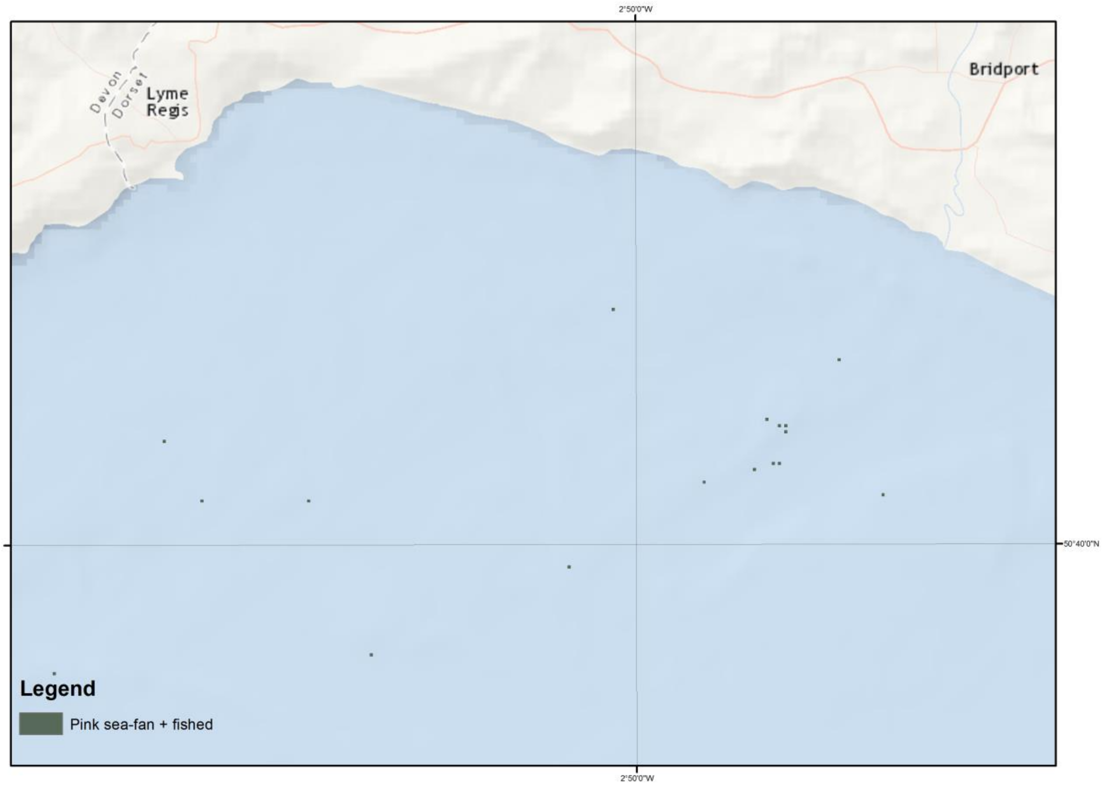

Figure 40. Close up view of part of the resulting coverage showing cells where pink sea fan and fishing activity were both present. There are such 30 cells in total.

The data describes very little interaction between fishing activity and pink sea fan; there is a small cluster of points to the west, on the right of Figure 40.

Discussion

Pink sea fans were recorded throughout the Area of Interest – it is not clear from the charts shown above, but the records correspond mostly to “subtidal bedrock reef” habitat. Figure X, below, illustrates how pink sea fan records correspond strongly to subtidal bedrock reef habitat. Pink sea fan is considered a component of reef within Lyme Bay.

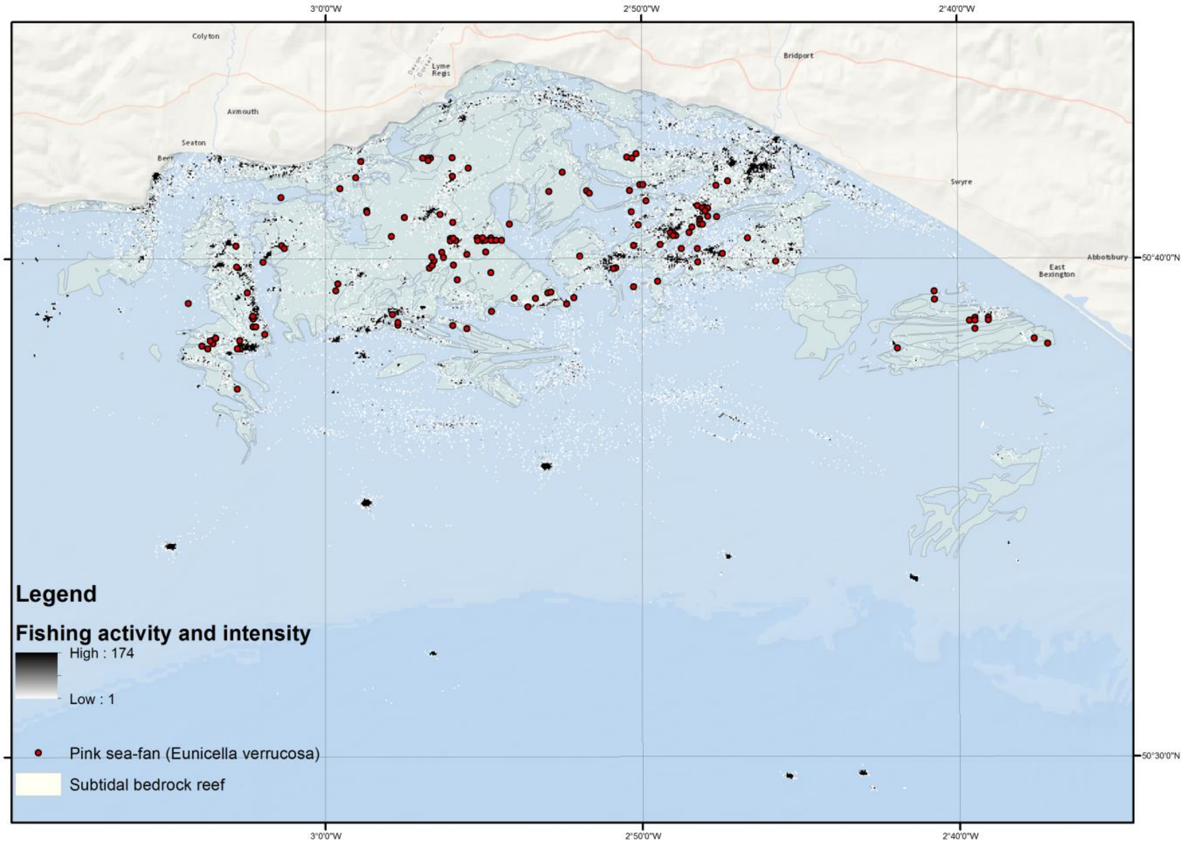

Figure 41. Fishing activity shown alongside records of Pink sea fan and the location of subtidal bedrock reef habitat within the Lyme Bay Area of Interest

Despite what appears to be a high coincidence of pink sea fan with subtidal bedrock reef habitat, and despite the fact that analysis of habitat data shows that static gear activity also shows some affinity to the same habitat type, the level of interaction between pink sea fans and fishing activity described by the data is low.

There were thirty (30) cells where pink sea fan coincided with recorded fishing activity, which represents 0.016% of the AOI. Again, as well as constituting a low return, this is a generous estimate of actual interaction. What this shows is that, as well as posing a low risk of harm to pink sea fan where there is interaction, the opportunity for this interaction to occur is likely to be low, too.

If risk = hazard x vulnerability, in this case risk = (how often fishing interacts with sea fans) x (sensitivity of pink sea fans). Where the research by Eno *et al.* (1999) indicates that the *vulnerability* is low, the iVMS data has provided new, high-resolution evidence that the *hazard* posed by fishing is apparently low, too. This contributes to a bigger picture that the overall risk is low.

What this analysis demonstrates is that increasing the resolution of fishing activity data is critically important in the evaluation of important conservation features, Species of Conservation Importance.

These features, including pink sea fan, are very often understood and described in the context of data points rather than broad coverages. While the supporting habitat of such features is important, often the features themselves need to be considered in isolation, particularly where they may be particularly sensitive to pressures caused by fishing activity.

In the case of pink sea fan, there is thankfully no high risk posed from fishing. However, the method demonstrated here might be applied in the context of *Sabellaria spinulosa* and other sensitive biogenic benthic reef species about which there is particular concern in some areas, and which are often recorded as data points. As well as allowing managers and conservation interests to better understand the risks that might be posed, better information on the precise spatial nature of interaction allows any mitigation to be specific. This is likely to mean less broadscale and more targeted management, which is much more likely to both succeed in its aims, and be at a proportional level less restrictive to fishing.

Requirement: Risk maps for mobile species management

Focus of analysis (from Scoping Table)

End Users:

- Conservation Managers/Wildlife Interests (NGOs, SNCBs)

Data products:

- Fishing activity mapped in relation related to mobile species

Analyses:

- Pressure or risk maps of fishing intensity data related to mobile species sightings data; Seasonally and annually

Introduction

The risks of impacts of fishing activities on mobile species are often discussed in the wider context of the environmental impact of fisheries. The current focus from some conservation NGOs on MPAs for mobile species has resulted in proposals for Special Areas of Conservation for Harbour Porpoise around England and Wales (e.g. Evans & Prior, 2012). Irrespective of their location inside an MPA or not, the majority of cetacean species are highly protected throughout UK waters and negative interactions need to be avoided.

In a Marine Stewardship Council (MSC) Assessment, such as that recently carried out for the Lyme Bay Reserve (MPC, 2014), there is a requirement to assess the likely impact on "Endangered, Threatened and Protected" species, and while some of these are sessile (for example, benthic dwelling organisms associated with certain habitat types, or biogenic reef), others, including cetaceans and protected marine bird species, are mobile.

In practice, this has tended to mean that their interactions with fishing activity are difficult to quantify. Firstly, the availability of data on the location of these species is variable in spatial and temporal coverage. Generally, it consists of sightings information collected sporadically (or at best semi-regularly) by observers, either as part of a regular survey or on an ad-hoc reporting basis. Consequently the resolution of the data and precision of spatial point data can vary, and without careful standardisation there is a risk of observation bias. Sightings frequency does not necessarily correspond to actual frequency of presence, and there is no way to ascertain how well the sightings capture the spatial extent of a particular species' "range," since sightings may correlate with ease of access (proximity) to an observation point, and a chosen site for observations may also be based on where previous sightings have occurred. In short, sampling is very often not random, or systematic. Although these issues are well understood and statistical tools available to attempt to resolve them there still remains a paucity of high resolution distributional data for mobile species.

Secondly, there has been a shortage of data on the spatial extent (and intensity) of fishing activity at a resolution at which meaningful analysis and cross-comparisons to sightings data could be made in the study area. This, clearly, is one of the issues which the study hoped to address, and the inshore VMS data from participating vessels provides information on fishing activity at a very good resolution.

Therefore, this part of the study aims to apply the new spatial data and develop a method by which it can be used to improve the assessment of risk of fishing to mobile species. The intention was to produce maps (and GIS data) to represent this risk spatially, and also look at seasonal trends where possible. Such outputs would be of value to statutory fisheries and conservation managers (including the IFCAs and Natural England) as part of their duties, and to NGOs looking to understand the nature of fishing interaction with protected species. They also have potential value to the fishing industry, in that they may allay concerns about the level of interaction – and provide evidence of a lower level of risk than might be expected in the absence of firm data. This evidence could be used to support a sustainability assessment (MSC or similar), or HRAs should new SACs become designated for Harbour Porpoise or other mobile species.

Approach and Methods

The dataset used was MarineLife's Cetaceans Sightings database, which record individual sightings collected as part of the Charm III Project (MarineLife, 2015) between 2004 and 2012, and consisted of 73 records. The mobile species data was sourced from the Lyme Bay Reserve MPC assessment work (MPC, 2014).

The point data was imported to GIS. As with the iVMS point data, the species records were translated to a raster dataset, with the number of points in each 50m by 50m cell calculated and stored as a value for that cell. The raster was "snapped" to the fishing activity 50m raster so that the two layers could be compared directly. The extent of both layers was, as for the habitat data, the extent of the "Area of Interest".

Once a species layer had been produced, it was possible to use ArcGIS's "raster calculator" to compare the two raster layers and create a third layer – this contained values describing whether or not both fishing AND the species occur, or were found in, each cell.

A step by step of the final methodology:

1) Import point data as shapefile

2) Ensure projection matches that of fishing data; if necessary, re-project.

3) Create raster from points, clipped to and snapped to raster of fishing data (for details on this process, please see section X, where it is described along with screenshots).

4) Perform a raster calculation, comparing the fishing activity raster with the species coverage (for details of how to do this, please see section X).

For detailed methodology, please refer to the technical annex to this report.

Results

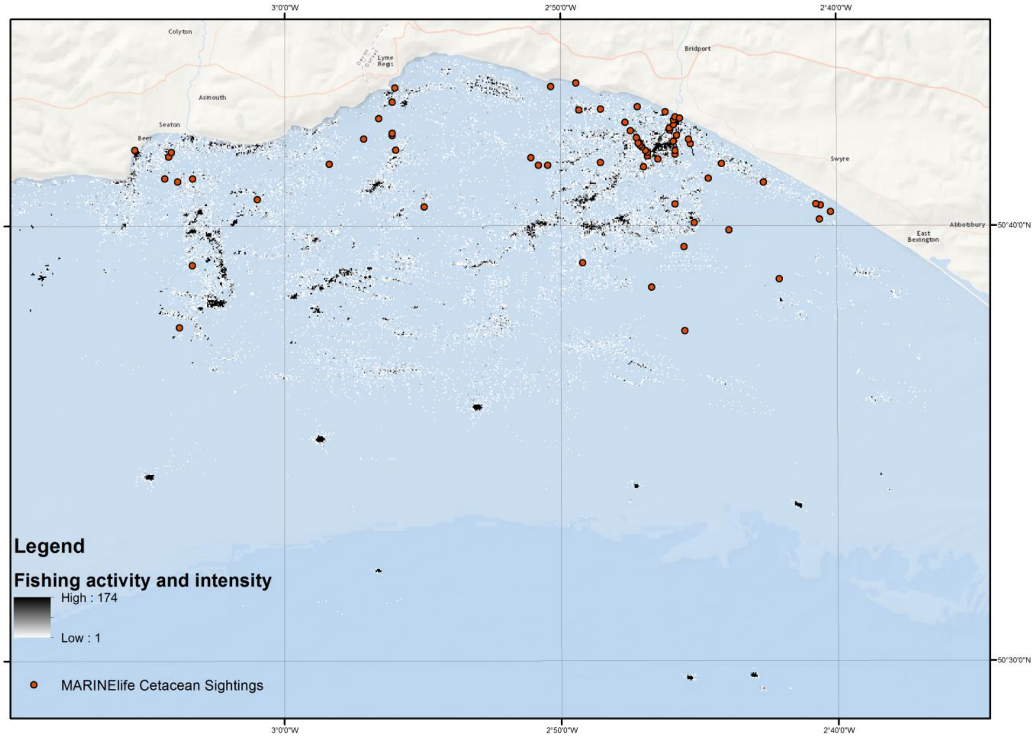

Figure 42. Location of cetacean sightings in Lyme Bay, overlaid on the gridded fishing activity layer. This is shaded to show intensity of fishing, from 1 to 174 data points/ 50m by 50m grid cell.

While the point data are confined to within the Area of Interest, the fishing activity layer does include coverage outside this area. For the analysis, the coverage was clipped to the same extent as were the point data.

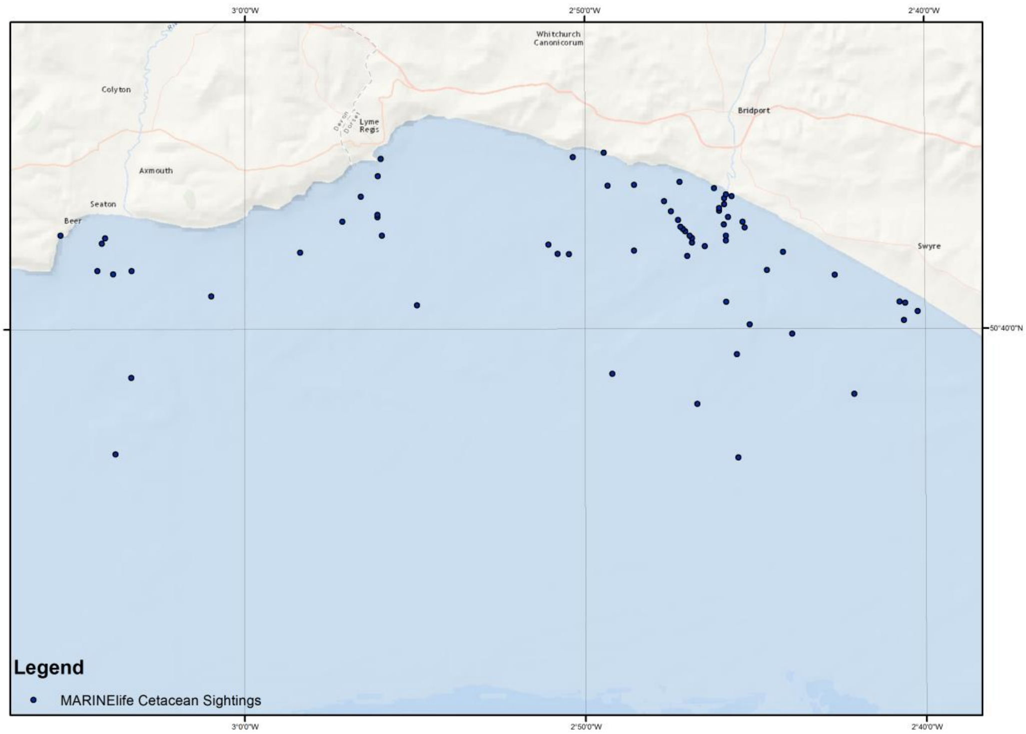

Figure 43. Cetacean sightings points from the MarineLife dataset. They are relatively close inshore, clustered near the coastline and ports – although this may be an artefact of sightings effort coverage.

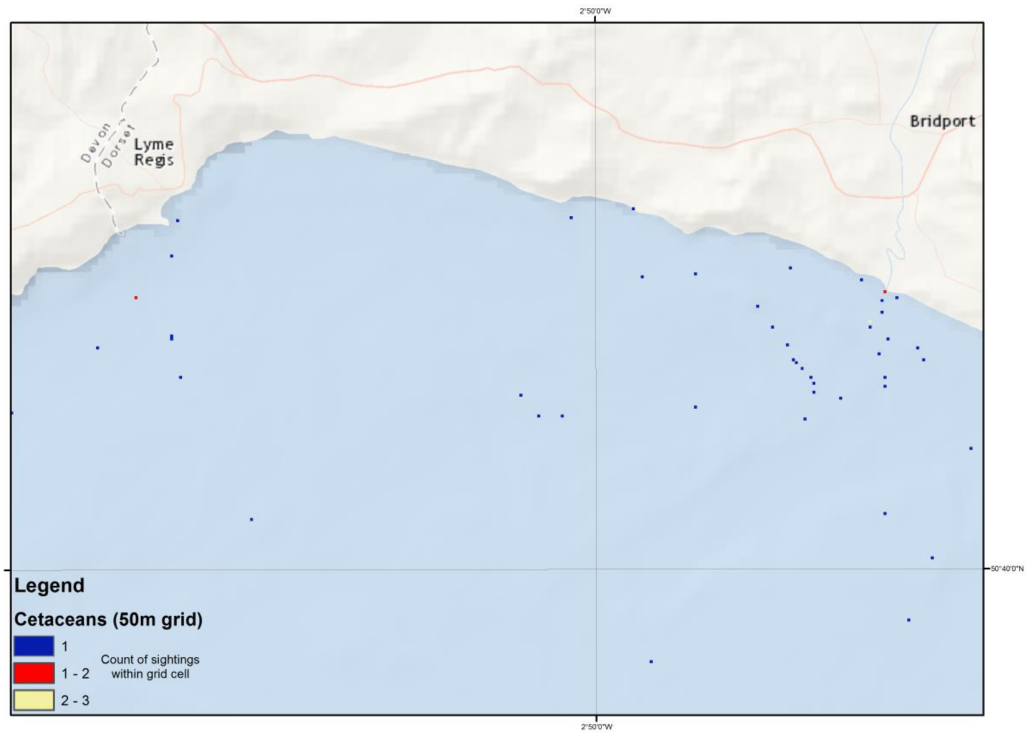

Figure 44. Sightings data transformed to a 50m x 50m gridded raster coverage, with cells coloured according to the number of points within the grid cell.

Figure 44 is a magnified projection for clarity. Notably, of the 66 cells containing sightings, most (63) represent only one (1) sighting; three cells show 2 sightings, and two cells contain 3 sightings

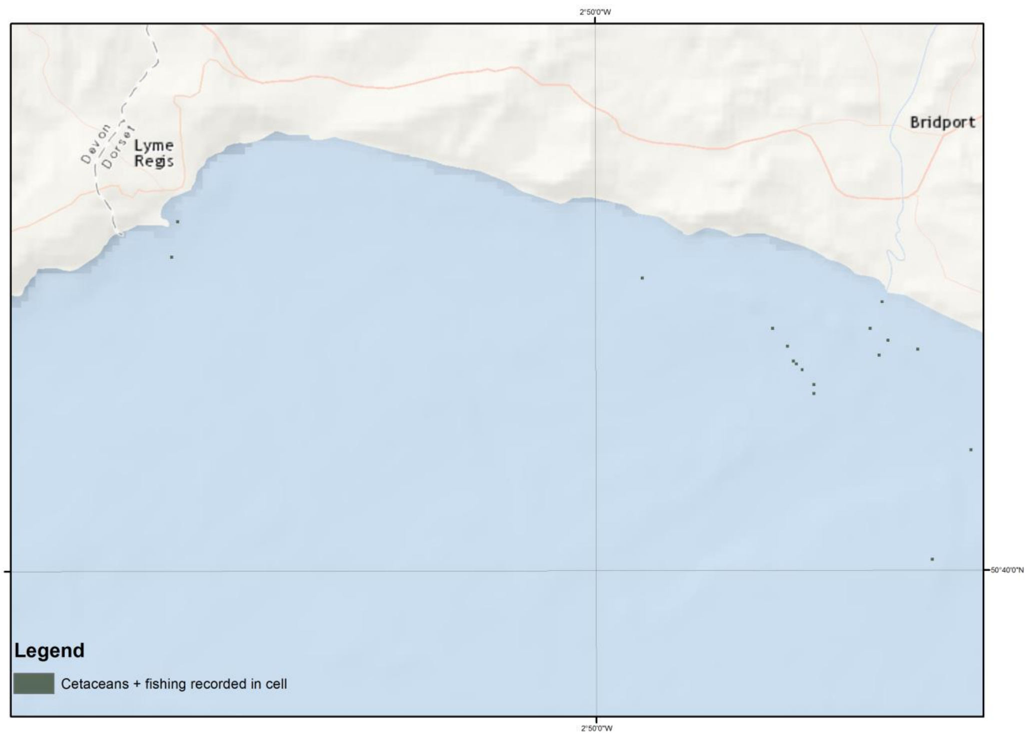

Figure 45. All nineteen (19) cells where cetaceans were sighted and fishing was recorded within the iVMS dataset.

Figure 45 shows that the majority of cells where cetaceans have been sighted and which correspond with fishing areas are in the vicinity of Bridport, with two cells just outside Lyme Regis. Again, this may be an artefact of sightings location and effort.

Discussion

The distribution of the cetacean sightings data is affected by sightings effort bias which may be higher closer to the shore and near to ports. The current analysis used the only available data which was in its unstandardized raw form which may explain why the cetacean observations were certainly clustered relatively close inshore. Despite a broad coverage of fishing activity within the Area of Interest, including within the same inshore area, there were very few grid cells where sightings of cetaceans coincided with recorded fishing activity. In fact, in only nineteen (19) 50m by 50m cells (each of which represents 2500 m^2) did fishing coincide with cetacean observations.

This represents 0.010 % of the total area of the Area of Interest (AOI) (456 km^2), and this is a conservative (or precautionary) figure, assuming the probability of contact between fishing + species is 100% across the whole area of any cell where both were recorded. At a finer resolution (a 20m by 20m cell size, for example) the number of cells with overlap is likely to be fewer, and to represent a smaller overall area.

Being able to hone in on, or at least approximate, potential interactions between fishing activity and a mobile species of interest in this way is useful because it helps us to understand the degree of possible risk and probability of interaction. These risk maps can enable fishery and conservation managers to identify when and where there is a risk of negative interaction and make an assessment if management action is required or where to allocate resources to investigate potential issues.

Next steps, considerations and further analyses

While this analysis is qualitative (the output raster is binary, with cell values showing presence (1) or absence (0) of interaction), it would be possible to assign risk “levels” based on the frequency of sightings and intensity of fishing in a given cell. The resulting map would show not just the coverage of interaction, but also grade the risk.

If risk = hazard x vulnerability, in this case risk = (fishing intensity) x (frequency of sightings).

Since some of the sightings points represent multiple animals being sighted at once, this could be factored in to the “frequency of sightings” by using the sum of all animals (rather than the count of sightings points) recorded within each cell.

However, there are implications that need to be considered – does the actual risk of a fishing vessel or its gear having a negative impact increase with the number of animals present, for example, or is the likelihood of damage actually lower due to increased visibility? There are behavioural considerations (on the part of both fisherman and cetacean) which may make the relationship less straightforward than simply linear or proportional to risk.

A calculation of relative risk levels was not attempted in this study for a number of reasons, the coverage of species point data was not comprehensive, the level of interaction was very low with only a few cells dotted across a wide area, but most importantly there is an incomplete understanding of the interaction between fishing activity and mobile species making risk quantification difficult.

Additionally, for any “risk levels” map, there would be a danger in seeing those cells with relatively high risk values as in need of attention. There would need to be a decision on what different values actually reflect in order the map could be interpreted intelligently. And in fact, as the analysis here shows, a simple illustration of how little interaction actually takes place might be considered enough to scope out or disregard fishing as being any significant risk to a given species.

It is suggested that if a relatively high (absolute) level of interaction were to be found, the next stage of analysis – to determine where the hot spots are – might be a relative risk map. This could use a wider grid (perhaps 1km^2), and a lot of thought should be given as to how to represent and categorise different values of risk in a meaningful way.

As it stands, the current approach to analysis is very useful to managers for assessments and to the industry in their discussions with conservation organisations. The small number of cells identified as areas where fishing and protected species coincided do not make a particularly exciting chart, but the statistics themselves, the number of cells affected, and what they represent as a proportion of the wider area analysed, are a useful indicator of the level of interaction between fishing and protected species.

Analysis data over a longer timescale, and incorporating data from different gear types when that becomes available would be valuable to get a more useful picture with regards to risk to different mobile species cetaceans. To be able to identify netting activity, specifically via changes to the Catch App or the widespread use of gear tags, would allow an assessment of risks associated with different gears such as entanglement.

More comprehensive species distribution data would enable seasonal analysis. On evaluation of both datasets, this was not taken further in the current study because, in the case of the species sightings data, it was not clear how sightings effort might correspond to the timing of records. The data was collected of a number of years, but across different projects, potentially using different methodologies. In addition, there were not many records, and after analysis comparing the full dataset to the full fishing coverage, very few points were found. Splitting the data further into seasons would not yield any outputs that could be compared in any meaningful way. This may always be the case when focussing on data collected at this local scale. Larger datasets such as regional, or wider and longer time series are likely to be more appropriate to look at broadscale seasonal patterns.

Analysis of seasonal/spatial fishing effort as it relates to environmental factors

Focus of analysis (from Scoping Table)

End Users:

- Scientists, Conservation Managers/Wildlife Interests (NGOs, SNCBs), Individual Fishermen

Data products:

- Fishing activity mapped in relation to environmental data, in this case sea surface temperature (SST)

Analyses:

- Spatial correlation between fishing activity and (e.g.) sea surface temperature, seasonal patterns

Introduction

One of the project aims was to see how the fishing data generated might be combined with other available data, including environmental datasets, and create value-added outputs. These might take different forms, and serve multiple purposes for a variety of end-users including the fishermen themselves.

For scientists, the ability to understand patterns of fishing activity in an environmental context is valuable. Fishing behaviour and activity can be influenced by physical environmental factors acting upon the target species.

For the fishing industry, being able to view their data alongside environmental information, particularly when details about catch are attached to spatial data, might be of interest. Fishermen already have a Local Ecological Knowledge (LEK) understanding of how weather, sea temperature and other environmental factors affect fishing; this is an essential part of their job. Being able to visualise this and have it demonstrated in a scientific context can make it easier to communicate their knowledge to others, and also to consider how longer-term patterns in weather and climate might have an impact on their industry. Being able to understand possible future trends, anticipate their effect on your business, and take measures to adapt may be crucial for the long term, continued success of the fishing industry as whole as well as for individual fishermen.

The high level aspiration for this analysis was to use the data from the iVMS and Catch App to describe spatial and temporal patterns in fishing effort and catch composition, and to examine these patterns against an environmental dataset, for example sea surface temperature, and to determine what this analysis could show in terms of links between fishing and the environment at a local level. Unfortunately, it was not possible to integrate the Catch App and iVMS data in a meaningful way as the spatial scale of environmental data, which was on a 1 km x 1 km, was far too coarse to correlate to the small scale variation of individual fishing vessels.

In future, if catch records can be linked to iVMS data using RFID tags or similar the techniques developed here can be used in the same manner to then link highly detailed fishing records to environmental data.

Approach and Methods

For the purposes of this study, the spatial resolution of the iVMS data and interest in local patterns in temperature meant that it was necessary to source SST data where resolution was as fine-scale as possible. The data used is satellite data: GHRSST Level 2P North Atlantic Regional Bulk Sea Surface Temperature from the Advanced Very High Resolution Radiometer (AVHRR) on the NOAA-19 satellite produced by NEODAAS. It is up to 1.1km x 1.1km, and available for free download via an online portal.

The downloaded file was in netCDF format, which can be imported directly into ArcGIS. It consists of an extremely large number of data points, each containing a latitude, longitude and the sea surface temperature (SST) calculated from satellite sensor information, and recorded in Kelvin.

The data was checked to ensure it covered the Area of Interest, and that the values were not null, which can happen if there was cloud coverage obscuring the satellite's line of sight. From the data provided, a sub-selection covering only the Area of Interest was exported to its own layer, and the points displayed as colours – coded according to the temperature value at each point.

Temperature values were converted to Celsius, and the point data was then re-projected into WGS 84, UTM Zone 30 N; the working projection for the project.

Finally, the point data was converted into a raster. The cell size used was 1km by 1km, and inverse distance weighting (IDW) interpolation ensured smooth coverage.

A step by step of the final methodology:

1) Decide on data to be used – depending on which product has the necessary spatial resolution, covers the area of interest, and is of the correct time period (whether a composite of that period, or an individual date and time pass)

2) Locate and download netCDF file from online portal (for GHRSST, see NODC (2007) for details)

2) Import downloaded netCDF file into GIS (e.g. via Spatial Analysis in ArcGIS)

3) Check for full coverage of the area of interest

4) Process point data:

- Remove null values
- Translate temperature values from Kelvin to Celcius
- Reproject to local projection

5) Create raster from points (consider interpolation for smooth coverage) with cell size appropriate to data resolution (e.g. $1km^2$)

6) Decide on appropriate symbology to display the temperature range (some of the options are demonstrate in the results section).

For detailed methodology, please refer to the technical annex to this report.

Fishing Activity/Environmental Factors Outputs

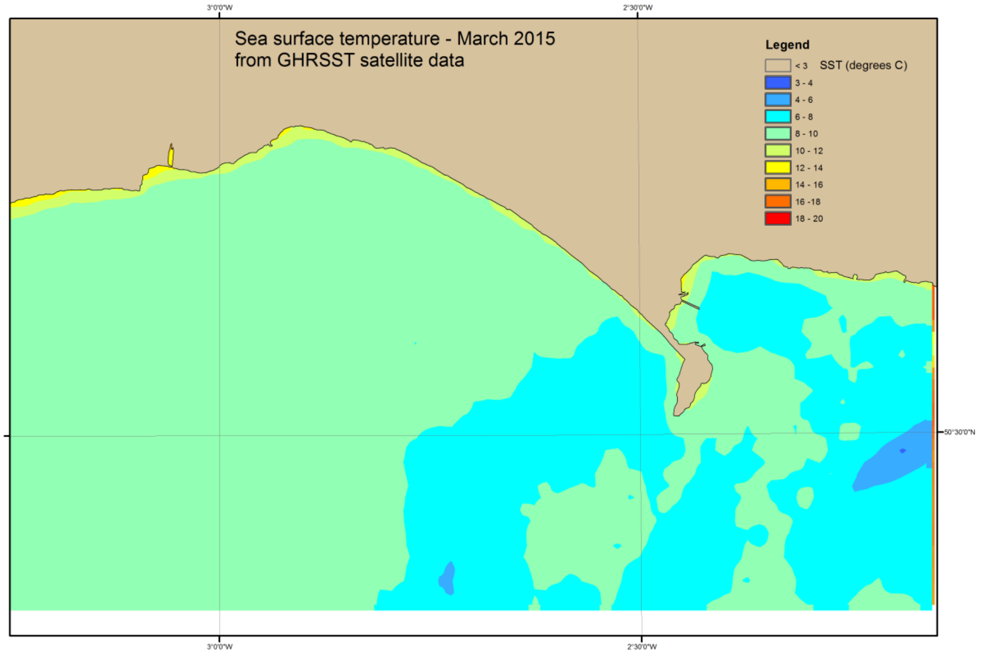

Figure 46. Sea Surface Temperature (SST) on 18th March 2015

Figure 46 shows sea surface temperature (SST) on 18th March 2015. Here, ArcGIS has used Bilinear Interpolation to smooth how the gradient between different temperatures is displayed, so that the resulting chart looks more like vector than raster data.

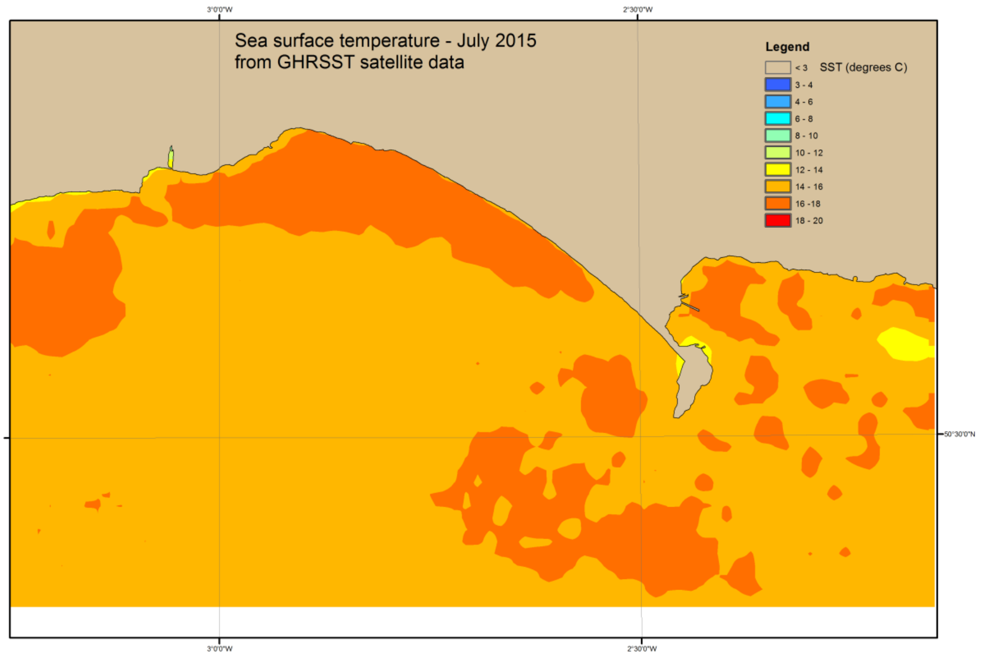

Figure 47. SST variation in using the same colour classification and interpolated as per the previous image

Figure 47, above, shows the SST variation in using the same colour classification and interpolated as per the previous image. This data is from 18th July, and the difference between the temperature measurements now and four months earlier is clear.

The Figure 48 Figure 49 show the same temperature charts with fishing activity (point) data for the corresponding seasons overlaid. There does not appear to be a substantial difference in distribution between the two seasons, although there is more activity in the summer.

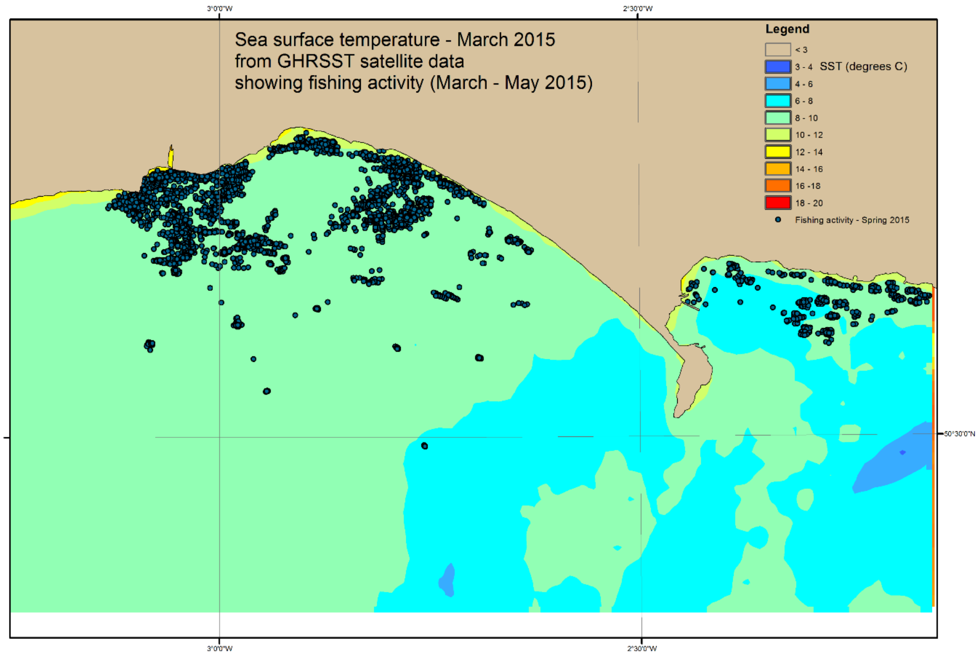

Figure 48. March 2015 temperature chart with fishing activity (point) data overlaid

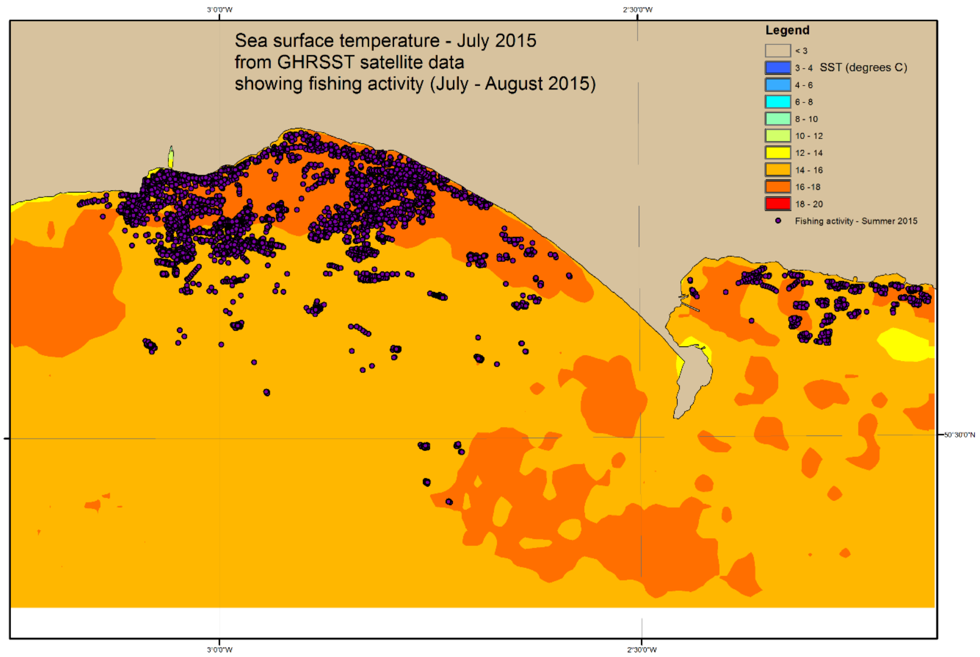

Figure 49. July 2015 temperature chart with fishing activity (point) data overlaid

Fishing Activity/Environmental Factors Discussion

Although constrained by the resolution of the available environmental datasets the results above succeed in showing fishing activity, in the form of seasonal “snapshots”, in the context of sea surface temperature (SST) data.

The high resolution iVMS data if accompanied by catch and discard data produced in the Catch App offers the to explore the temporal and spatial analysis of the relationship between the physical marine environmental and its biological “output” in the form of catch composition and fishing success. Such an analysis may be valuable to both scientists and fishermen alike. Being able to understand which environmental factors drive “catchability” and being able to access that information would help fishermen fish more intelligently and efficiently.

The fishing activity data used in the current analysis focusses on the static gear (which forms the majority of the available iVMS vessel data), and for shellfisheries at least, the target species are benthic dwellers. While water temperatures at depth will have a relationship to SST, this relationship may not be homogenous across the study area, depending on currents and stratification, and seasonal variations in such. New technologies may enable fishermen to collect depth and temperature data using automatic sensors fitted to their fishing gears. The Succorfish SC2 iVMS can be linked to such sensors to enable automated data collection. Conceivably a fleet of vessels fitted with relatively few sensors could generate very high resolution sea bottom temperature maps in real time.

Due to the size of the datasets and time constraints the analysis made use of data from one day’s satellite pass which acted as a proxy for a seasonal SST. Composite images, consisting of data averaged over the season period (or perhaps on a monthly basis) could be used in future. Ideally the temporal resolution of SST data should correspond to that of the iVMS data subset. Such data products are produced (NEODAAS, 2015a) but access to them is restricted to academic and governmental institutions. An alternative is to process enough data to produce a composite “in-house”, but this has cost implications given the processing time required.

One option for anyone hoping to develop this further would be to approach an appropriate research organisation (or NEODAAS) and request a collaboration or joint research into making the most of inshore fishing data and combining it with environmental data products to add value to both. There might be academic and government interest in doing this, although there would need to be discussion around the use of iVMS data outside the Lyme Bay Project. If iVMS, and particularly a system fully linked to Catch App data, were to become more widespread, being able to develop the use of such data at this early stage would certainly be of wider interest.

Perhaps the main outstanding issue with regard to SST data in particular, is the length of time required to get it into a format where it can be viewed by the end user. While the process is not difficult, it is time consuming and does require some GIS knowledge, which does not make it particularly accessible. An ideal scenario would allow SST data to be synchronised to an app or web GIS portal so that the industry could view it alongside their Catch App data. This is outside the remit of this project, but tools are available (GHRSST, 2015) in a range of programming languages that might enable a developer to integrate GHRSST data into a viewing app. If the issues around spatially referencing the Catch App data are also fixed, much more would be possible.

The ultimate aim is to be able to analyse data at an appropriate temporal and spatial resolution for local inshore fisheries. Inshore VMS provides fishing activity data at a better resolution than ever; satellite remote sensing is increasingly yielding environmental data at a usable scale, and this trend will continue with improvements in sensor technology. And the frequency at which the data is being collected allows for excellent temporal resolution; however, joining the dots so that statistical analysis can be made remains a goal for the future.

Catch App

Overview

The Catch App has been developed by Succorfish to provide fishermen with an easy-to-use means of digitally recording fishing activity in real-time. This tool has been developed to provide an easily used solution to the urgent need for much improved data collection and recording tools within the commercial fishing industry. Catch App has been developed in collaboration with commercial fishermen to make it as user-friendly as possible. Envisaged as an electronic diary rather than an elog the Catch App aims to gives users' access to their own fishing data and related information. When combined with the SCS iVMS it has the potential to provide a highly detailed, real time picture of vessel location and activities.

The Catch App allows fishermen to compare gear, bait and season performance as well as calculate catch per unit effort in a bid to encourage efficient practices and fisheries sustainability. Catch App. promotes total traceability through instant catch reporting prior to landing and can manage quotas through efficient, real-time reporting. It can also be configured according to local parameters. Its multi-functionality fully supports the need for documented fisheries and provides critical fisheries and environmental data for effective marine management.

Deployment

The fishermen were each presented with an iPad mini in a robust IP67 waterproof case. The Catch App was preloaded and linked to the skippers account on the web based Succorfish GUI software system where the data entered would be transmitted and stored. The skippers were given one to one training on its operation and asked to provide details to personalise the Catch App including personal fishing grounds, these changes were subsequently made by Succorfish.

Figure 50. Catch App splash screen

Throughout the project regular contact was maintained with the fishermen and support provided for those that wanted it. All the fishermen bar one used the App. All of the fishermen were clear about the objectives of the project and could see to varying degrees why the data would be of benefit to their business as well as managers.

Results

For the period of the trial December 2014 to July 2015, 1011 Catch App reports were generated. Within the Catch App there were 3 focus subjects which data entry fell under; Catch data, Environment data and Weather data. There were 848 catch related entries including reports of non-fishing, 159 weather related and 4 environmental related records (Figure 51).

The fishermen engaged with the App to varying levels. Two of the volunteering fishermen adopted the system and filled it out religiously, a third completed it most of the time and the forth fisherman engaged with it on an ad hoc basis.

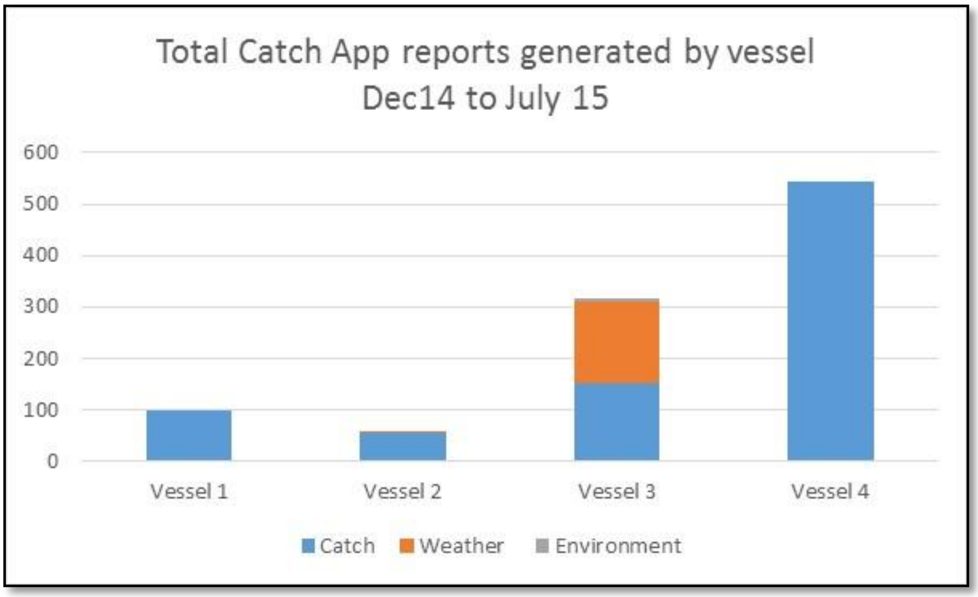

Figure 51. Breakdown of the total number of Catch App records generated by each vessel

The weather related records in all cases bar one originated from vessel 3 who kept a daily record of the general weather conditions. The Catch App enabled the users to record the date, weather conditions, wind speed and direction (Figure 52). This function acts as a simple diary.

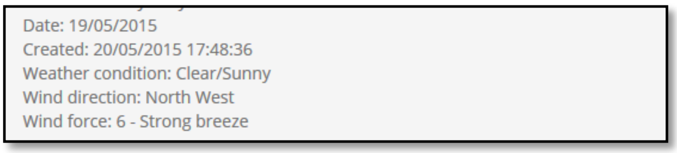

Figure 52. Example of a Weather report generated by the Catch App

Environmental Data

Only 4 records were made of environmental observations. Within the App, users could select either to record information about a list of wildlife Indicator Species or Invasive Species. A total of 7 invasive and 7 indicator species were selected and details were populated into the App. Invasive species were those species to be listed as non-native to the UK and were taken from a JNCC master list (http://jncc.defra.gov.uk/pdf/pub02_nonnativereviewdirectory.pdf) and selected on the likelihood that fishermen could easily identify them thus the list comprised of large charismatic species (Figure 53).

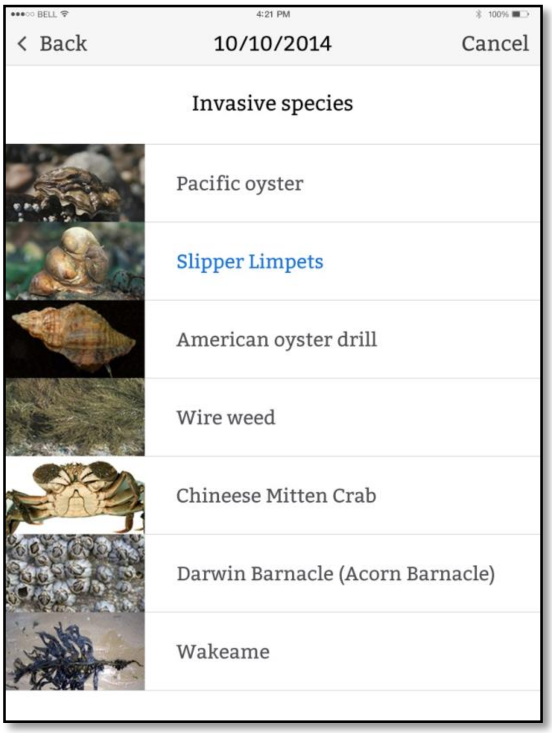

Figure 53. A list of the Invasive species as they appeared in the Catch App

Similarly the list of wildlife Indicator Species were selected on the basis that they would be easy to identity and be more likely to stimulate the fishermen (Figure 54). The purpose of selecting 7 indicator species was to gather information about species that are prevalent in UK waters at certain times of the years, but by recording their sightings fishermen could show where and when they occur and perhaps this might act as an indicator of change within the marine environment.

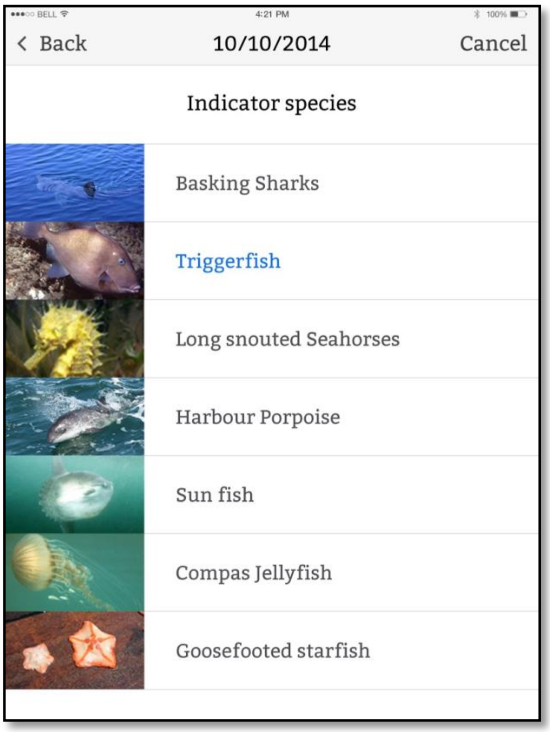

Figure 54. A list of the Indicator Species as they appeared in the Catch App

The 4 records captured for the environmental data were all indicator species. Two species were identified, harbour porpoises and trigger fish. The records show a presence of harbour porpoises in Lyme Bay from May until then end of the project in July. What is notable from the records is that the numbers observed increased as the summer progressed with the last record estimating the pod size to be 50.

Catch Data

The catch App collected up to 16 fields of data for each report with 14 of these being required (Figure 55). Within the database the records were stored in rows with all the values populated. This made it very easy to carry out analysis in Microsoft Excel once the data was exported from the database in a .CSV file format. Pivot tables could be easily created and manipulated to provide insight and analysis of the data.

Catch App data fields	Data captured
Asset	Vessel identifier
Date	Fishing date
Location	Grounds fished
Activity	Trip / haul / no fishing
Gear	General gear clasification e.g. Trawls, pots, nets
Sub gear	Sub clasifications e.g. Trammel, gill, tangle nets
Gear quantity	Number of pots hooks or length of net
Fishing time	Time gear spent in the water
Bait	Bait used if applicable
Gear info	Additional information if desired
Species	Species caught
Retained weight	Weight of fish retained on board in Kg
Retained Number	Estimated number of fish in the retained catch
Returned weight	Weight of fish returned to sea
Returned number	Estimated number of fish returned to the sea
Returned reason	Reason for returning catch

Figure 55. List and description of all the fishing data fields captured by the Catch App

In total, 21 species were recorded by the 4 participating vessels. The data showed that 9 different sub-fishing gears were used and over 20 tonnes of fish were caught. Table 4 below shows the total quantity of catch recorded by all the vessels for all species. This is then broken down into retained and returned components and a returned rate is calculated. For the data submitted by the volunteering fishermen the overall return rate was 20% and varies from 8% to 46% on an individual basis.

Species	(All)		
Row Labels	**Sum of Retained weight (Kg)**	**Sum of Returned Weight (Kg)**	**Returned rate (%)**
Vessel 1	3020	279	8%
Vessel 2	4791	1436	23%
Vessel 3	1613	1370	46%
Vessel 4	7213	1166	14%
Grand Total	**16637**	**4251**	**20%**

Table 4. Total quantity of catch recorded by all vessels over the period of the trial (December to July)

Breaking the returned weight down by species we find only 4 species account for all the fish returned to the sea. Brown crab accounts for the majority by weight with skate and rays also making up a significant part of the overall weight. On a proportional basis vessel 3 returned the most catch with brown crab by a significant margin making up the highest proportion of this.

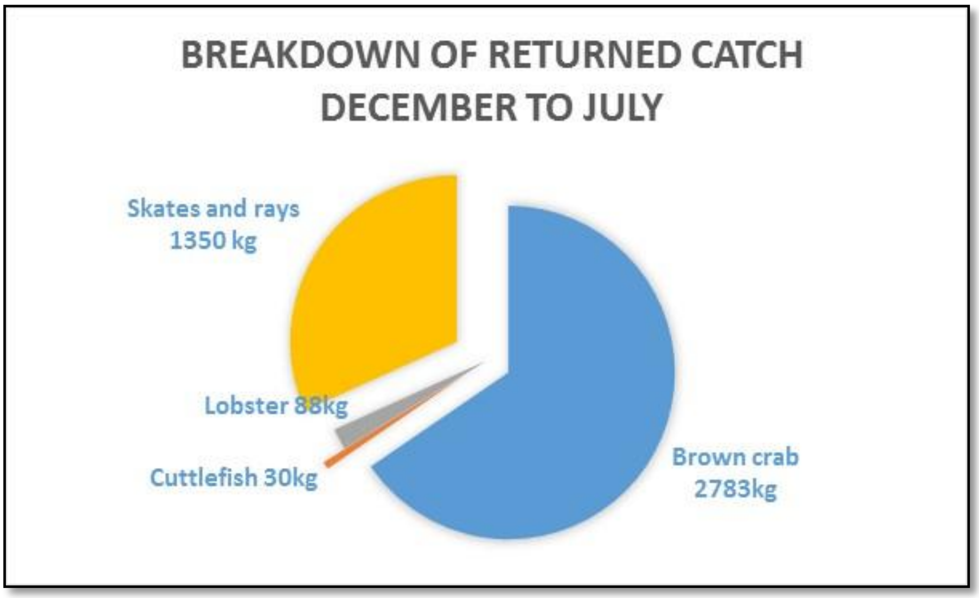

Figure 56. Breakdown by species of the total returned catch weight between December and July

Analysis of the returned catch by gear type illustrates in which gears the returned catch were caught. Table 5 below clearly shows that trammel nets, inkwell and parlour pots account for vast majority of recorded returned catch by weight.

Sum of Returned Weight	**Column Labels**				
Row Labels	**Inkwell**	**Parlour**	**Tangle**	**Trammel**	**Grand Total**
Brown crab	1026	1742	15		2783
Cuttlefish	30				30
Lobster	55	33			88
Skates and rays				1350	1350
Grand Total	**1111**	**1775**	**15**	**1350**	**4251**

Table 5. Weight (kg) of the species returned by gear type

When the fishermen entered the details regarding their returned catch they were required to also record a reason. A set number of reasons were provided within the App. Table 6 below shows the breakdown of reasons by month for brown crab. The same analysis of the skate and ray data showed all the returns occurred in January and the reasons were lack of quota (66%) and out of season (33%). The Brown crab by contrast was recorded as being returned every month barring December and April and undersize accounting for the vast majority of the returns.

Species	Brown crab
Row Labels	**Sum of Returned Weight**

Jan	**35**
Oversized	15
Undersized	20
Feb	**80**
Soft / out of season	80
Mar	**46**
Undersized	46
May	**1482**
Soft / out of season	255
Undersized	1227
Jun	**463**
Soft / out of season	153
Undersized	310
Grand Total	**2106**

Table 6. Returned weight by month and stated reason

Of interest too will be the location of where the returns were made. Is there an even distribution across the bay (which for the purpose of the trial was split into 4 areas) or is it concentrated in one area? Figure 56 below presents the distribution of returned catch by month and by location. This plot suggests that the returned catch is unevenly spread across all the areas and months and that there may be other factors affecting this.

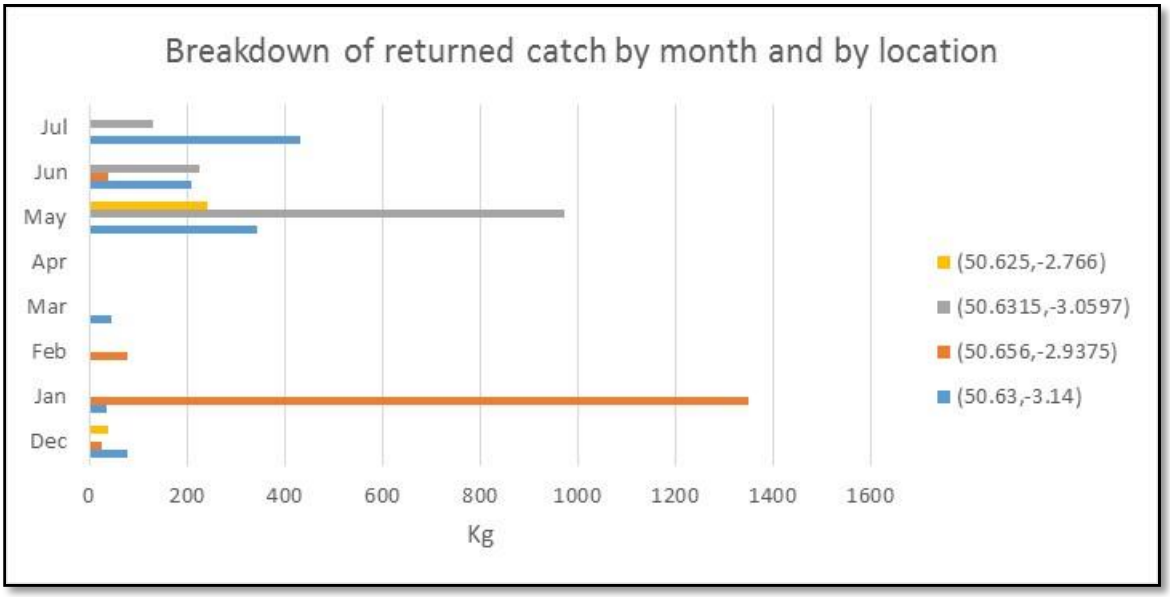

Table 7. Breakdown of returned catch by month and by location

The Catch App required the fishermen to record the number of fish caught as well as the weight. By combining the two values it is possible to get a size value for the fish caught on that day. Below is a line graph showing the average weight of a fish by month (Figure 57).

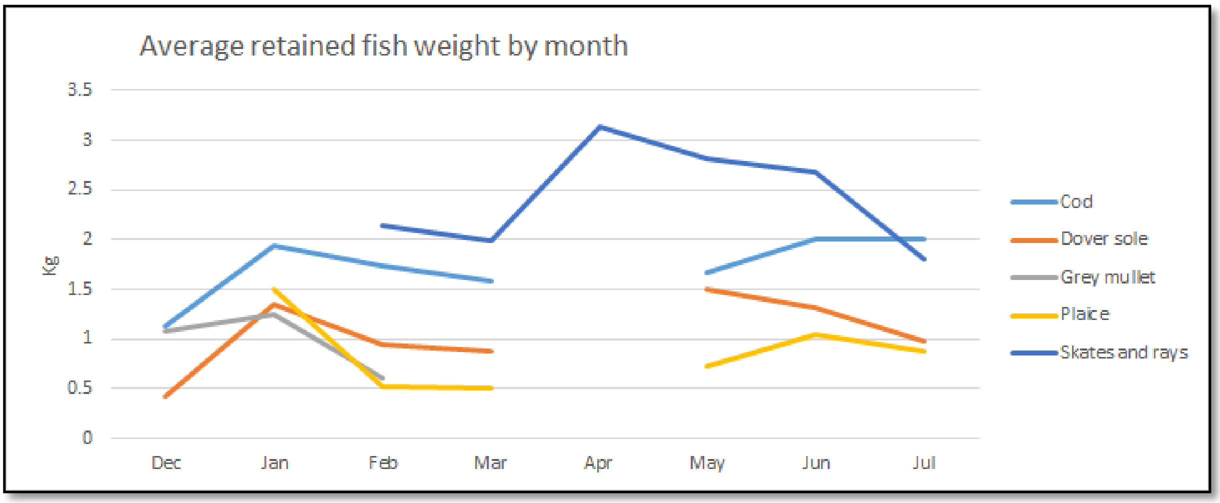

Figure 57. Plot of the average retained fish weight over the duration of the trial

This data can be further broken down by fisherman, location, gear type in order to tease out details such as the areas where and when the largest or smallest fish occur. The plot below shows the size of cod caught by the different gears by month. This plot gives an insight into when each of the gears were used to catch cod and their relative performance. Trammel nets appear to be consistent in terms of the fish sizes while gill and tangle nets show greater levels of fluctuations.

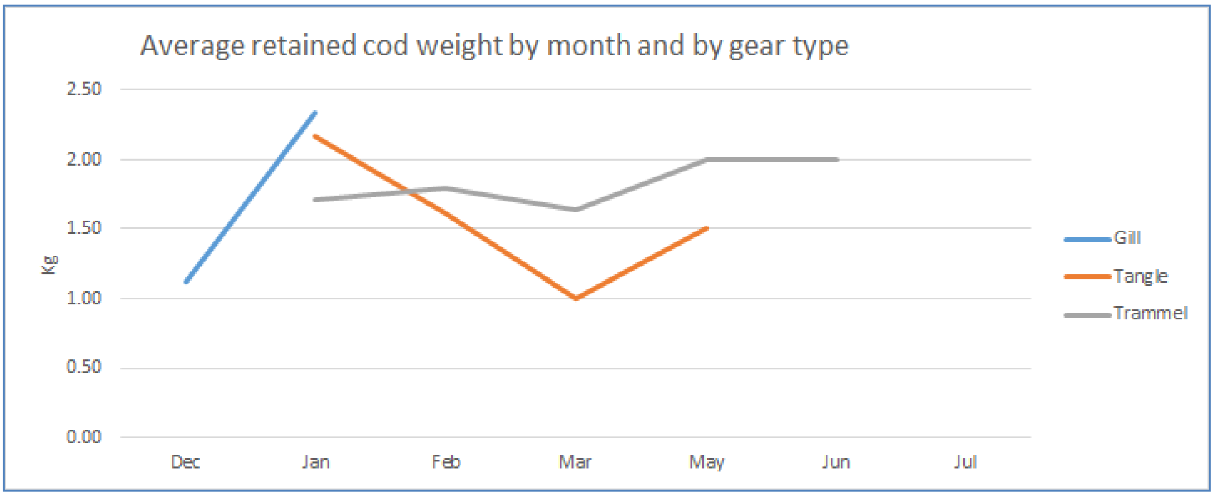

Figure 58. Plot of the average retained cod weight over the duration of the trial

The efficacy of the vessels, their gear and their grounds can also be investigated. A catch per unit effort (CPUE) value based on the KG of fish retained divided by (the time the gear spends in the water times the quantity of gear) was calculated for each data entry (Figure 59). In a similar manner to the other analysis, the CPUE values can be plotted and compared over time and by vessel, gear, location and species. It is not possible to perform a cumulative measure for all gears and species as the CPUE measure is a relative measure to gear type and therefore impossible to compare a trawl to a pot or net.

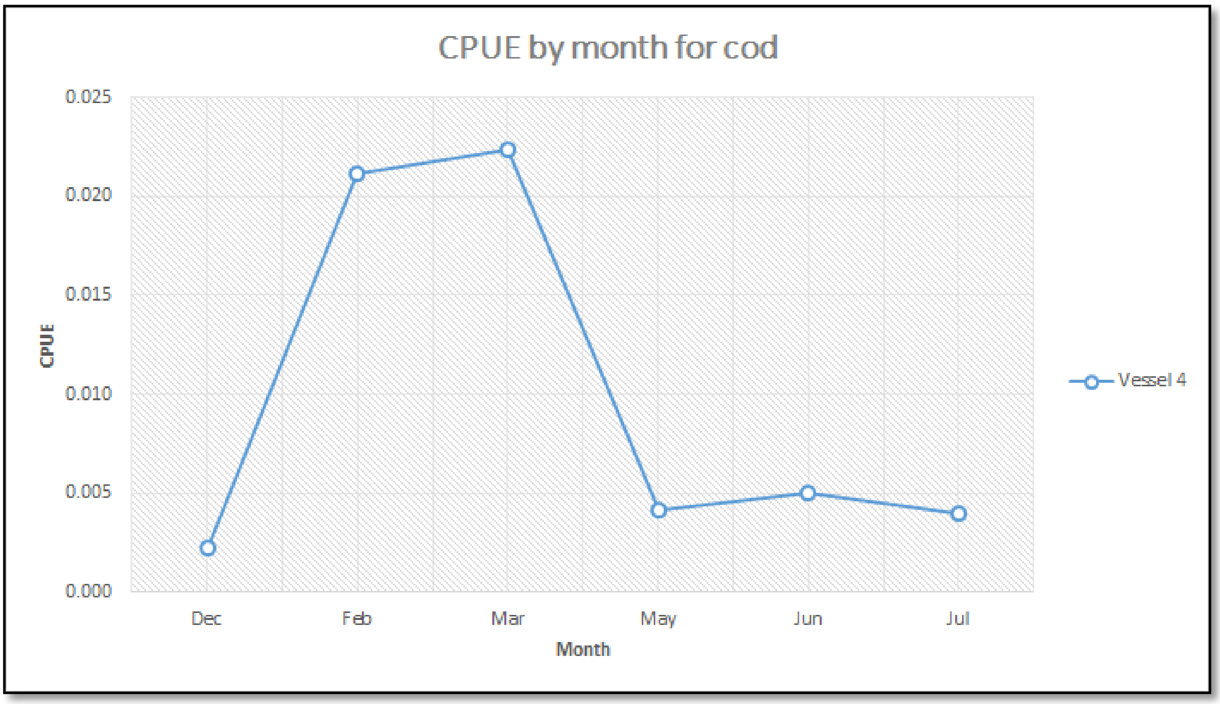

Figure 59. Vessel 4 month on month plot of CPUE for cod

In total there were 9 different gear types used by the 4 participating vessels, all static fishing methods. Different gears will be suitable for different fisheries and at different times in the season. Analysis of the CPUE can show which gears return a better catch rate and when. Figure 60 and Figure 61 below show that Inkwell pots in the month of April gave the highest CPUR for crabs and Parlour pots for lobsters in June.

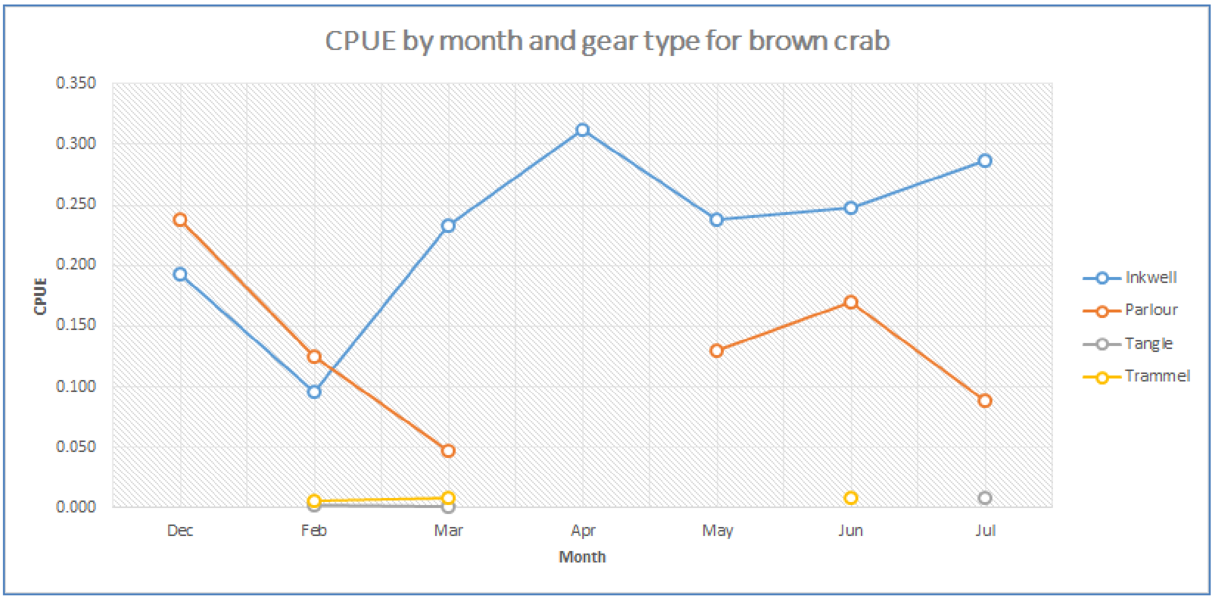

Figure 60. Comparison of the CPUE for the different gears types used to catch brown crab, by month

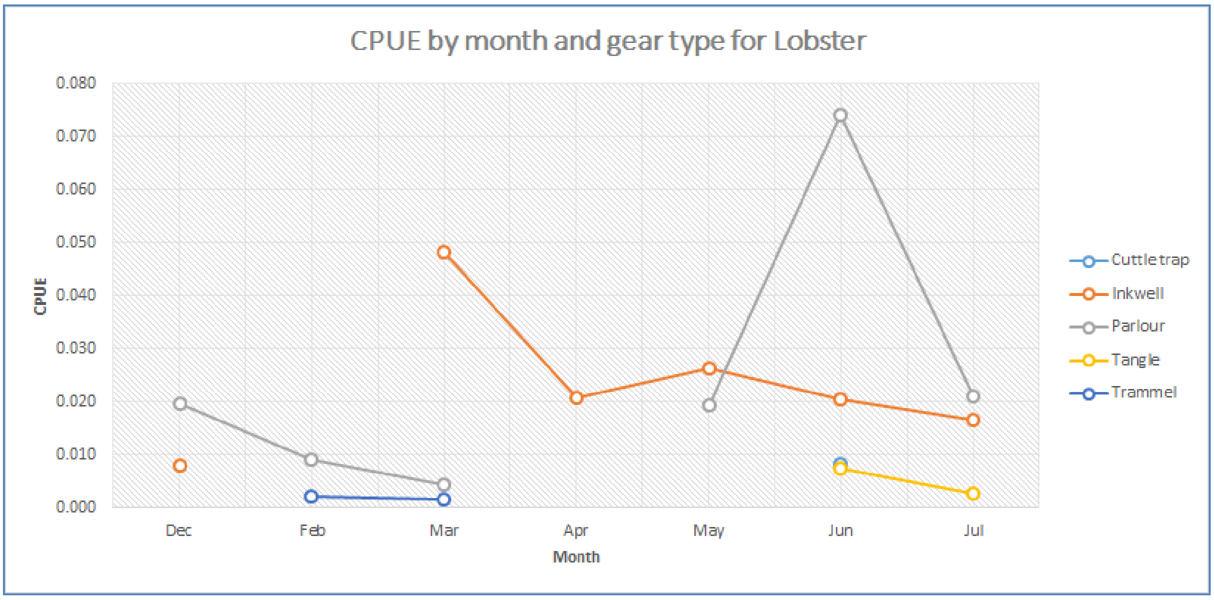

Figure 61. Comparison of the CPUE for the different gears types used to catch lobster, by month

Given the large quantity of data and categories it is not possible to present all the results in a report such as this. A version of the raw data and a number of pivot tables and charts have been saved within a Excel spreadsheet and a protected version of this file will be made available online for interested parties to examine and “play” with the dataset further.

Catch App Discussion

There is a growing need for timely and accurate data on the activities of the fishing fleet and stock exploitation to meet the demands of European legislation (Water Framework Directive 2000/60/EC, Marine Strategy Framework Directive 2008/56/EC, Data collection Framework Commission Regulation (EC) No. 665/2008, Common Fisheries Policy 2013, Marine Spatial Planning Directive 2014/49/EU) and the challenges of sustainable marine management.

Upon first examination the rational for a fully documented fishery seems to be common sense; having good quality appropriate data improves our knowledge of fisheries, the ecosystem and importantly the activities and behaviours of the fishermen that prosecute them. In all sectors, accurate information provided in a timely manner aids better management and nowhere is this more true that in fisheries and conservation management

A Fully Documented Fishery (FDF) can be described as a fishery where all of the key natural resource interactions are documented. From a fishery or quota management perspective the minimum information may include species landing and discard information. The inshore fleet and managers face additional challenges with a growing number of MPAs and related evidence needs including spatial footprint of activity and interactions with sensitive species and habitats.

Until recently there have been a number of very real barriers to collecting the detailed data and information required to achieve a fully documented fishery, not least the logistical and resource constraints of administering and handling of records. This project sought to develop the technologies to address these challenges and to minimise the costs with a maximisation the benefits across sectors.

In order to make the Catch App user friendly and fit-for-purpose it was important to involve both end users of the App and of the data collected. To this end the project team established a steering group to guide the design of the finished Catch App. Discussions with the fishermen involved in the trial and with potential end users of the data including fishery and conservation managers, fishery scientists and seafood businesses enabled a broad range of requirements to be identified.

Importantly, involvement of the fishermen from the beginning ensured a level of buy in from the fishing community and stakeholders and provided valuable guidance on the practical limitations and established realistic expectations of the outcomes. This inclusive approach prevented the natural suspicions of the various stakeholders from being established as each had an open forum to air their views and ambitions prior to the Catch App coming into use.

The development of the Catch App has been undertaken in part to explore the potential and to prove the concept that data and information required for management can be collected in an efficient manner either at sea or upon return to port by fishermen using App technology. The Catch App included a wide variety of options for data collection in order that these could be explored and to inform the development of the next iterations of Catch App. In addition to quantitative species-specific catch data the App includes the facility to record environmental data and data relevant to conservation management such as Invasive Non-Native Species (INNS) occurrence and indicator species.

Deployment of such an innovative tool and approach was always going to be a challenge but informative process yielding quick lessons and enthusiastic responses. It was important that this feedback was collected and where possible acted upon. The trial with the four participating fishermen has indeed highlighted some key considerations both for the future direction that Catch App development should take but also in how the expectation and requirements of regulators need to be reviewed.

Data Collection Assessment

Despite the significant resource provided by the Blue Marine Foundation to implement the Catch App trial, the study relied on the voluntary participation of the four individual fishermen. Fishermen, particularly those operating < 10m vessels typical have a variety of pressing demands on their time both at sea and once they return to shore. These demands often take precedence over non-essential activities such as the regular use of the App. However the application of 3 of the 4 fishermen to the task was excellent. They developed the habit of completing the daily records and submitted them on a regular basis. One of the fishermen whilst making a very good contribution at first failed to use it again after two months as he faced other pressures within his business.

The provision of technical support and regular feedback was important and made available to all the fishermen in order that technical skills or questions over data entry was not a barrier to participation.

Post-trial discussions with the participants highlighted the time resource challenges that singlehanded operators have and the importance of strong motivational factors if regular data entry is going to be a reality across the fleet in future.

Fishery Data Collection

The Catch App has been designed to collect a variety of different catch and operational data such as fishing areas and, gear type and metrics. During the design stage these were considered to be the essential data required for fisheries managers. Feedback from participants suggest that for fisheries targeting few species such as pot fisheries for lobster, crab and for whelks recording catch data for retained numbers or weights are relatively straightforward. In most respects the process reflects their statutory duty to record their shellfish landings on the Monthly Shellfish Return (MSR) forms.

The discard or returned numbers and weights were considered to be less straightforward due to the variations in sizes and relative weights making estimation difficult especially for whelks.

The latter issue will require further development with fishermen. It may be possible to establish a standard metric based upon volume for some of these species i.e. a standard count/weight per fish box or bongo; recording numbers of boxes or part thereof returned may prove more practical for the fishermen. Others suggested that the simple selection of small, medium or large would suffice. Applying either off these approaches would affect the resolution of the data and perhaps a combination of counts and measures based on appropriateness may be best.

The data collection for mixed finfish fisheries was considered to be more of a burden due to the multiple species brought aboard. Retained species was thought to be relatively straightforward but estimating and recording those returned to the sea proved more of a challenge. This was reflected in the drop off of participation beyond the initial reporting attempts by some fishermen. Discussion with the participants suggested that recording of multiple species and the necessity for weight and counts was simply too time consuming. They also voiced doubts over how accurately they could quantify discarded species. Retained catch was less of a problem as fewer species were recorded and quantities were easier to estimate.

There is a fundamental question that needs to be addressed when considering what data should fishermen be expected or required to collect; what is the minimum information that managers require to inform their management?

This question is beyond the scope of the project but it is hoped that the project will stimulate debate and discussion by providing a glimpse at what may be possible.

The challenge for both regulators and the industry is to develop approaches to data collection that can provision management systems with meaningful information on exploitation rates and species stock status in ways that do not impose unrealistic burdens on fishermen resulting in non-participation or possibly in inaccurate estimates being provided. The latter is of concern as this data has a real bearing on fishery management decision making. Bad data, accepted at face value may very well find its way into records that will be drawn upon to inform a variety of management areas such as marine planning and conservation management. It may be the case that the management systems will have to be adapted to reflect the realities of data collection practicalities.

The data collected by the Catch App will also have a value to science and management. The Common Fisheries Policy has introduced the concept of fully documented fisheries and other legally binding drivers from Europe such as the Marine Strategy Framework Directive and the Water Framework Directive require data to evidence their effective implementation. There are not the public resources available to gather this data and it is important that the fishermen contribute as the alternative could well be the application of the precautionary approach and the managers being forced to close the fisheries entirely due to a lack of robust evidence.

Data security and ownership are very important considerations for both the generators and users of the data. The Catch App and SC2 both use AES256 encryption to transmit. The data is then stored in secure databases with triple backup system in place. It is critically important that the users can trust the system and Succorfish have invested in ISO27001 systems and accreditation to provide the assurances needed. Concerns over ownership and access to the data are real and need to be considered. It is possible to use the data in a constructive manner without having ownership. Trust is all important in this and if the users can demonstrate that the commercial sensitivity of the data can be respected, constructive use of the data should be easily facilitated. Once trust and confidence have been won it will be possible to effectively manage the data and apply the principle of "collect once use many times", thus making the whole process of data collection and utilisation a great deal more efficient and effective.

Environmental Data Collection

The project also sought to collect what was perceived by the fishermen to be benign environmental data, i.e. information that would not "come back to bite them". During the design stage of the Catch App it was agreed that three types of environmental data could be collected; weather and sea state, Invasive Non-Native Species and Wildlife Indicator species. These were consider to be the non-essential or "nice to have" data but none the less valuable.

The number of environmental reports submitted was small with the vast majority coming from only one of the fishermen. Discussions with the fishermen suggested that although they have a very real interest in their environment and observe a variety of interesting wildlife and environmental phenomenon they seldom have the time to spend routinely recording non-essential information. The scope for potential data collection by fishermen is impressive given their time spent at sea over the year and their intimate knowledge of what is coming in and on their nets and pots. It may be the case that the conservation or wildlife recording potential could be pursued by a more targeted Sentinel fleet of willing fishermen under a “citizen science” type initiative.

An approach that may offer some potential for further develop is a function for fishermen to record and photograph unusual species via the App. The fishermen commented that they encounter unusual or rare fish and shellfish or see unusual changes in their environment and that these are more engaging. There may be more value in these ad hoc observations and that there may be scope to investigate this under the citizen science banner.

Addressing the Barriers to Data Collection by Fishermen

In order to tackle the practical or technological barriers to data collection via the Catch App one-to-one training was provided with regular telephone, email or text support afterwards. This proved valuable to those participants who were active in data collection. It is acknowledged that the first iteration of the Catch App required some adjustment to improve its function and ease of use. Addressing these issues was only made possible by the feedback and dialog with the participants. Some improvements were made at the time whilst others have been incorporated into the next version of the Catch App to be released in October 2015.

A primary aim of the Catch App was to design a tool that is intuitive to use by fishermen. The four fishermen found this to be the case. The flow and approach was logical and for simple data entry tasks such as reporting the catch of between 1 and 5 species from a trip took only 3 or 4 minutes. Technical and “what if” questions were most frequently fielded and this was to be expected. The next iteration of the Catch App will address many of these hurdles and as more fishermen become familiar with Smart Phone and Tablet technology adoption of this technology will become much easier. Nevertheless training and support needs to be a consideration for future roll out of any electronic data collection scheme if it is to be successful. It is likely that beyond the first year or two that the requirement for on-going training and support would be far reduce.

The use of iPads proved to be a successful approach as the majority of participants found them straightforward to use which as much as anything probably reflects the intuitive nature of the Apple GUI and design. The IP67 covers too worked well and made them suitable to be carried on-board. The availability of iPads on-board fishing vessels also opens up other opportunities such as communication with the fleet in real time and for the fishermen other helpful Apps can be accessed such as plotter, weather or tides.

The available time that under-10 m vessel operators have to fill in lengthy records is limited and is a real barrier to data collection. The shellfish fishermen appeared to be better suited to this than those operating in mixed finfish fisheries. Shellfish fishermen are already subject to a requirement to submit monthly returns via the MSR forms and so the Catch App data collection in this project essentially duplicated that process.

The additional workload created by the data entry process was identified by all the fishermen as a barrier to broad uptake of the technology. These barriers need to be addressed and should be influenced and informed by a critical review of the essential data needs of management. Those management frameworks that require precise and accurate data from the whole fleet will be at a risk of failure due to the difficulty of feeding their data needs.

Beyond the technical and procedural challenges it is likely that a purely voluntary approach to fleet wide data collection is an unrealistic expectation. This trial engaged with a selected set of fishermen who had expressed an interest in the project but the time burdens were perceived to be a disincentive for many of the participants resulting in variable data collection. The reality is that, in the absence of other incentives for data collection, a statutory requirement may be required similar to the current MSR system.

Fisheries management has tended to rely on legal requirements for compliance but this approach is often onerous on both parties. Other motivations for completing the data collection process must also be developed and promoted. The project did touch on a number of these and some did resonate with the fishermen.

Beyond Catch Data

At its simplest the Catch App acted as an electronic diary where the fishermen could record their catch and other data on a daily basis. Most fishermen do this and records are normally written down in diaries or kept in plotters or similar. Both these methods are effective and secure but neither are efficient at providing easy access or analysis of that data. The data remains as data and must be recalled and analysed on a record by record basis. In contrast and given the method of collection and storage insightful information which can be readily gleaned from the Catch App approach. In the future this information could be used to underpin an economic assessment of a particular fishing ground and could mean that the fishermen have grounds on which to claim compensation for a loss of earnings.

The results section illustrates a number of interesting outputs that can be produced from a small data set. With more data and a longer time series the value of this analysis will increase for the fishermen. Insights into the most effective gear, bait, season combinations could potentially allow the fishermen to be more selective and efficient and this information could impact positively on the fishery and the business, thus more than compensating for the time and monies invested in collecting the data in the first place. The production and study of performance analytics is good practice across all types of businesses and fishing should be no different.

The routine recording of fishing activity related to the daily catch is an important aspect of any traceability system. EU labelling regulations still only require fish to be traceable to the North East Atlantic, despite the growing demand for locally sourced seafood from consumers and retailers. The data captured in the Catch App bridges this gap and enables the fishermen and their buyers to demonstrate the provenance of the catch. The Catch App will permit the identification of who caught a particular fish, where, when and how. Moreover this information could be used as is the case in other seafood markets to build a loyal customer base owing to the fact that the customer can clearly identify the fish and access the additional data.

A number of fish buyers did engage with the project and were very interested to have access to the catch data. They also saw opportunity to improve the supply chain by taking data captured by the Catch App and use it to better inform their business and make the general trade of the fish more efficient. One example of this would be a fish buyer knowing in advance the species and quantities of fish being landed by the boats prior to them reaching the shore. This information would allow the buyer to plan their buying and logistics better and as one buyer put it “I could tell my customers tonight exactly what they will have on their menu tomorrow night, before the fish even reaches the shore”. It is unlikely that any buyer will commit to guaranteeing an increase in price based on the availability of the Catch App data, but it is likely that more buyers will be interested in buying the fish and this increase in demand will lead to an increase in price and a better return to the fishermen.

Trialling the use of RFID tags

Introduction

While iVMS data can give detailed information about the location and distribution of fishing activity, in order to understand the nature of that activity in more detail additional information is required. To determine what type of fishing activity is occurring at any given location, effort levels and its actual footprint we require information on what gear is being used, how the gear is set up (length of net, numbers of pots per string, type of pot, bait used if any), what is being targeted and how successfully.

As discussed elsewhere in this report, a great deal of this information can be provided by Catch App records, but it is impractical for fine scale haul information to be collected and then plotted spatially. The use of RFID tags offers a solution to provide a gear and haul specific spatial reference.

Radio Frequency Identification (RFID) is a technology which allows for automatic identification. RFID tags contain two main components: an electronic chip, which stores the identifying information about the item or object of interest and a passive antenna which broadcasts this information when energised by radio waves. When the tag is within range of a base station transceiver, an “event” or record is generated. This record notes the identification information transmitted by the tag, and can mark a number of attributes such as the date and time of the event, and any other information as programmed.

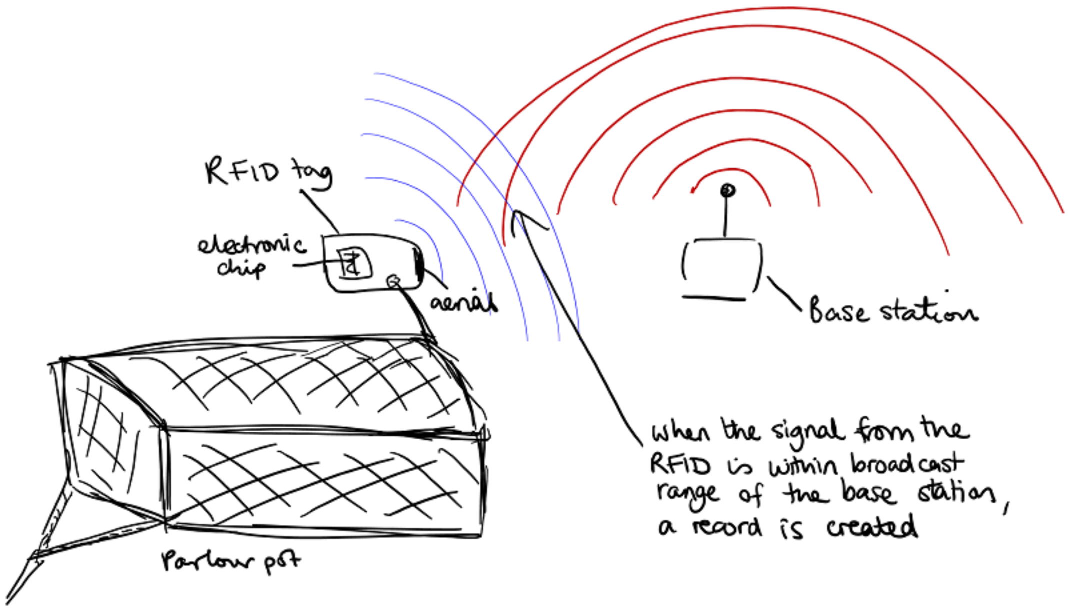

Figure 62. An illustration of how an RFID tag works

Here (Figure 62), a tag attached to a parlour pot has come into the range of the base station on a fishing vessel. The radio frequency transmitted by the tag is detected, and the information contained on the electronic chip is recorded along with position data for the vessel.

The benefit of the technology is that it is active and automatic; it does not require additional effort to scan or process each time the tagged gear is hauled. This makes it convenient in the context of fishing operations.

The aim was to trial the technology and demonstrate proof of concept. Could it be deployed within the inshore fleet, did it work, and what lessons could be learned in order to use it to best effect within the context of the Fully Documented Fishery project in the future?

Methodology

A number of RFID tags were distributed to fishermen participating in the Fully Documented Fishery trial. The RFID tags were attached to gear – mostly pots. RFID readers were also installed on the vessel and connected to the SC2 iVMS. Each time tagged gear was hauled and got close enough to the reader, it triggered an event, which was stored as a record along with tag number, vessel name, date, time, and the latitude and longitude of the vessel. The data was transmitted, along with the iVMS data, the database by the SC2 iVMS device in real time.

Figure 63. RFID reader fitted to a bulkhead close to pot hauler

The data was supplied in a csv format from the database and was imported into Excel, and the date-time field was split into separate date and time columns. Of the original 8979 records, 8860 belonged to named vessels (the others were test records, and were filtered out). The modified data was saved in Excel format, and then imported into GIS. Here, points were generated from the latitude and longitude, and selected only those records within the project Area of Interest.

The remaining 5372 points constitute the final "cleaned" dataset used here.

Results

The Figure below shows part of the data generated over the trial period by the RFID tag system, as it appears in the ArcGIS attribute table.

Gear in/out RFID events

GENERATED	GENERATE0	EVENT	TAG	LONGITUDE	LATITUDE
27/03/2014	0.271528	RFID	214190371	-2.763665	50.706657
27/03/2014	0.271528	RFID	214190371	-2.763665	50.706657
10/04/2014	0.367361	RFID	214818123	-2.783598	50.613509
10/04/2014	0.367361	RFID	214818123	-2.783598	50.613509
10/04/2014	0.367361	RFID	214818123	-2.783598	50.613509
10/04/2014	0.367361	RFID	214818123	-2.783598	50.613509
10/04/2014	0.367361	RFID	214818123	-2.783598	50.613509
10/04/2014	0.368056	RFID	214818123	-2.783598	50.613509
10/04/2014	0.368056	RFID	214818123	-2.783598	50.613509
10/04/2014	0.368056	RFID	214818123	-2.783598	50.613509
10/04/2014	0.368056	RFID	214818123	-2.783598	50.613509
11/04/2014	0.379861	RFID	31488	-2.775013	50.631722
11/04/2014	0.397917	RFID	72704	-2.770348	50.606787
12/04/2014	0.56875	RFID	1755	-2.762385	50.703825
13/04/2014	0.365972	RFID	4227919996	-2.837567	50.670589
15/04/2014	0.651389	RFID	214192333	-3.058259	50.703784
15/04/2014	0.650694	RFID	214192333	-3.057743	50.703825
15/04/2014	0.675	RFID	214192333	-3.057742	50.703817
15/04/2014	0.508333	RFID	203839525	-3.057665	50.703776
15/04/2014	0.515972	RFID	203839525	-3.05764	50.703687
15/04/2014	0.650694	RFID	214192333	-3.057572	50.7038
15/04/2014	0.678472	RFID	214170839	-3.057742	50.703817
15/04/2014	0.509722	RFID	203839525	-3.057665	50.703776
15/04/2014	0.679167	RFID	214170839	-3.057742	50.703817
15/04/2014	0.509722	RFID	203839525	-3.057665	50.703776
15/04/2014	0.509722	RFID	203839525	-3.057665	50.703776
15/04/2014	0.509722	RFID	203839525	-3.057665	50.703776
15/04/2014	0.509722	RFID	203839525	-3.057665	50.703776
15/04/2014	0.509722	RFID	203839525	-3.057665	50.703776
15/04/2014	0.510417	RFID	203839525	-3.057665	50.703776

0 (0 out of 5372 Selected)

Gear in/out RFID events

Figure 64. RFID data attribute table, showing some of the fields recorded

The fields shown in Figure 64 include the date and time (decimal time) that the record was generated, the type of event, the tag number, and geographic position as longitude and latitude. Multiple records can be seen for the same date and time, suggesting that the tag was being registered several times on some occasions. This perhaps happened as the gear was moved around the deck between hauling and shooting away; the tag may have left and then re-entered the range of the base station while it was on board the vessel.

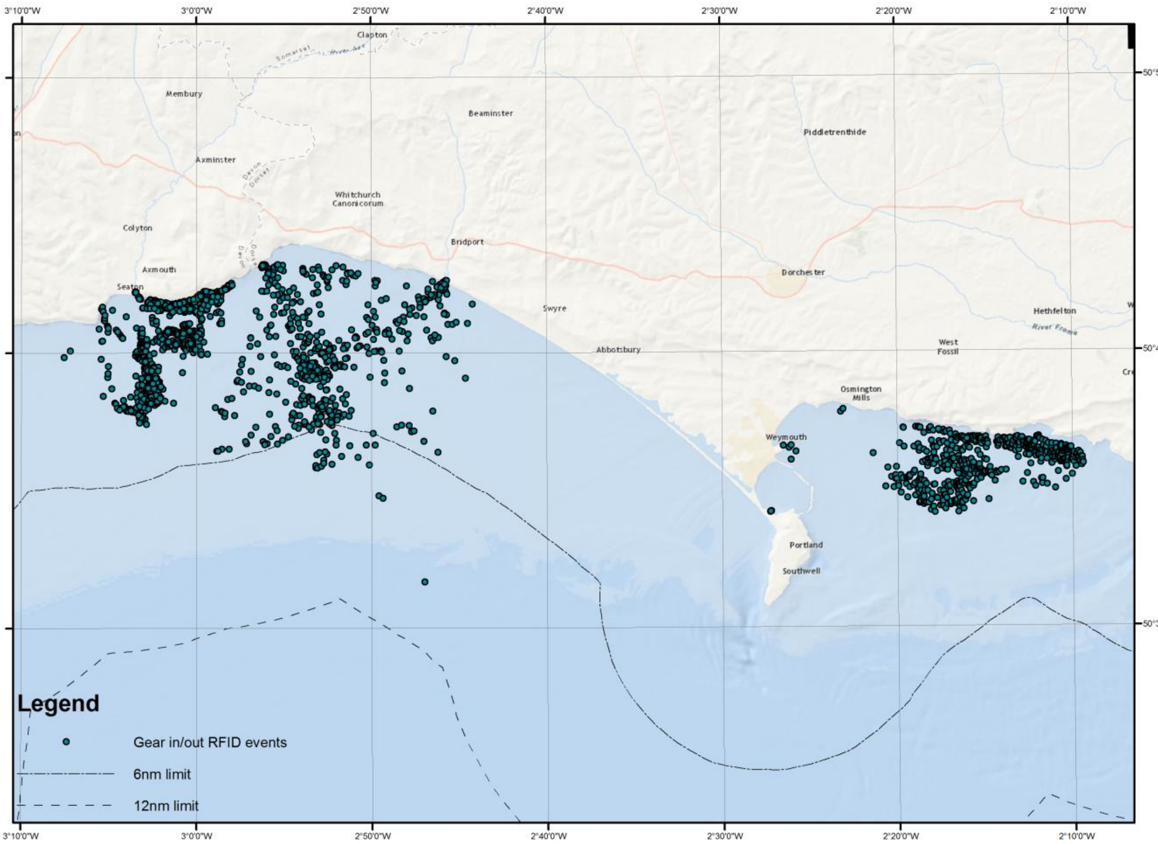

Figure 65. Location of RFID events

Each time the RFID tag entered the range of the base station, an event was recorded, and each point on Figure 65 represents one event. This illustrates the distribution of fishing activity using tagged gear during the course of the project. This is only a subset of all fishing, as only some gear was tagged, so does not represent all activity recorded by the iVMS data.

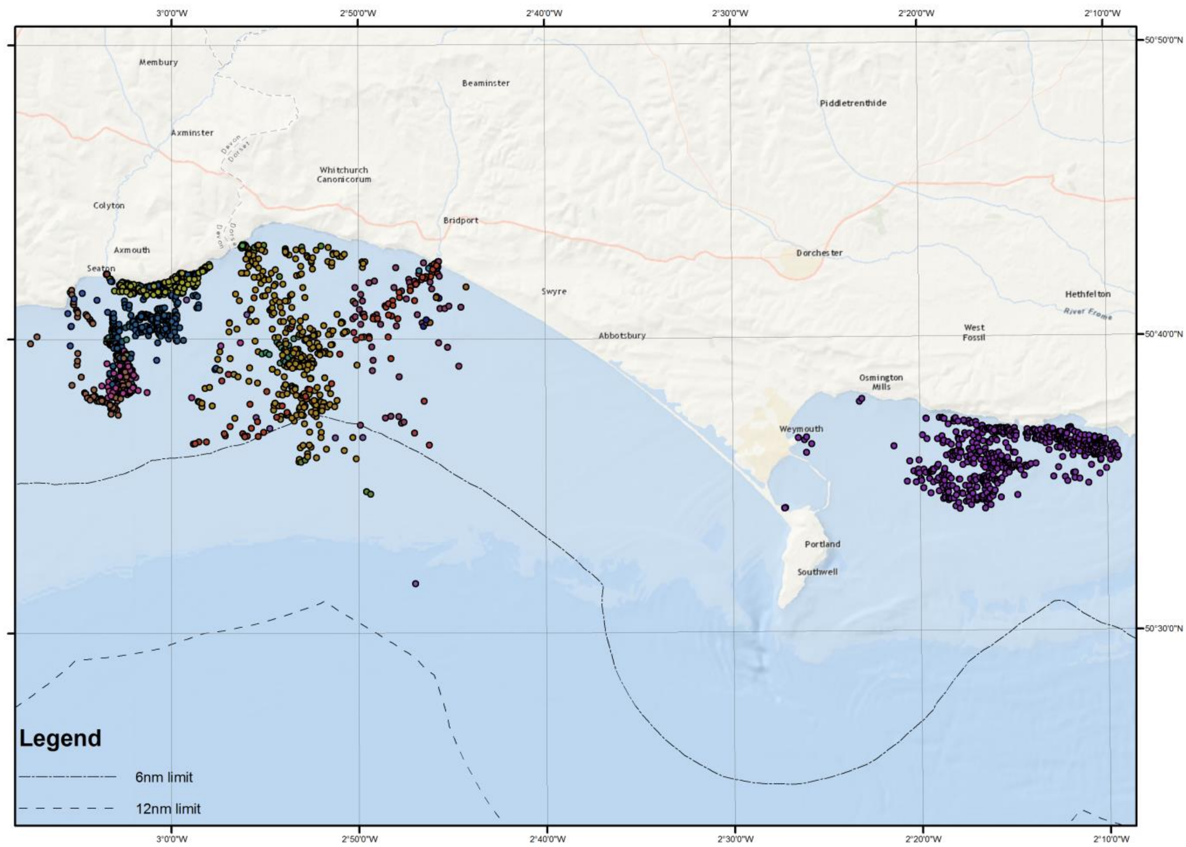

Figure 66. Location of RFID events, colour coded by vessel

This shows the RFID event points with different colours representing different vessel's tags. There is no key to the colour coding to preserve confidentiality of the participating vessels. However, it is clear that there is some clustering of points of each colour, and the separation between different vessels' regular ground is evident.

Discussion

The results illustrate that the system was successful in the use of gear using RFID tags to record fishing events and the location of static gears. This demonstrates that the technique can work in practice, within the context of the inshore fishing fleet.

Only a subset of all fishing gears used by Lyme Bay vessels was tagged, so any difference in spatial patterns activity between iVMS and RFID data simply reflects that the latter is only a subset of activity.

The recording of several consecutive events with the same tag number, within a short period of time, suggests that there is a possibility for duplication. This however is not a serious problem if the RFID events are not equated to amount of activity in the way the iVMS data has been. It may also be avoidable with some adjustments to the setup of the recording device for example, by deleting any repeated events for the same tag within a given period. Alternatively, the output can be filtered to remove duplicates with relatively little difficulty.

For the tag data to be most useful, information on what gear it is attached to or better, a means of directly linking the tags to the Catch App data, should be added. In theory, this could mean that the

RFID events data record could be used independently of the iVMS data, since there is a spatial reference attached to the RFID event. Alternatively, it would be possible to use the timing of the event, but only if the order of gear being hauled is preserved when entering the Catch App data.

The key to improving the use of the RFID tags is being able to add value without creating additional work for the fisherman. Entering details on the gear the tag is attached to (gear type, attributes – e.g. number of pots in a string) is a one-off requirement, and could be added to a database so that the attributes are automatically added to event records.

This gear information could be used to enhance the iVMS-based trip data, by using time stamps to synchronise gear to different parts of the trip, so that it can be split by gear type. This would provide the ability to study temporal and spatial patterns relating to gear and target fishery.

Connecting the RFID event data to Catch App data may be more difficult, in that the Catch App records may not be generated contemporaneously, unless haul information is entered chronologically according to what gear was used and what it caught at different points during the trip. If the time of each haul was noted, this could be linked to the closest RFID event, and thus bring in all the attached information about the gear. Although haul by haul recording is supported by the Catch App it may prove too burdensome a task for routine reporting. However, this approach may have merit for reference fleets or specific studies.

In this context the RFID events could be synchronised to the Catch App , generating new records to be completed by the fishermen at the point when they usually enter trip data. If the RFID tags were linked to a database describing the gear they relate to, this could also reduce the time taken to complete Catch App records as data on the gear would not need to be entered. Selecting the tag from the database could bring up the relevant fields for that gear type, automatically filling it in, with the fields that vary from trip to trip such as bait used, soak time and (importantly) catch remaining for the participant/researcher to fill in.

Before proceeding with rolling out the technique, it is important for developers to talk to fishermen who used it and ask for their thoughts about how easy the tags were to use, any problems encountered, and any recommendations they might have to improve the deployment at sea. Any adaptations that might affect their working could be tested, and feedback sought.

However, the main conclusion must be that the proof of concept was successful. If there is will to fit tags to all gear, and if some of the additional information can be incorporated into the records kept, the RFID tag system has excellent potential to significantly increase the quality of fishery data available.

Summary and Discussion

The Lyme Bay Reserve Fully Documented Fishery Trial began with a series of bold aims and objectives to develop and test cost-effective and practical approaches to marine fisheries data collection that could inform management of the Lyme Bay Reserve and be transferred and applied elsewhere.

The need for methods to collect and visualise spatial fishing activity data for the <10m inshore fleet is particularly urgent both for fishery and conservation managers but, importantly, for the fishermen themselves. The inshore fishing industry are currently presented with multiple challenges of being able to ensure that their fishing grounds are considered in the development of marine plans, of designation of Marine Conservation Zones and in the siting of marine renewable developments. Having access and ownership of robust data on the footprint of their activities and use of the sea provides a strong foundation for fishermen's representatives when engaging with these processes.

From an MPA management perspective spatial information on relative intensity of fishing activity will now enable fisheries and conservation managers such as IFCAs and nature conservation bodies such as Natural England to undertake well informed and well evidenced Habitat Regulation Assessments such as those required under Defra revised approach of assessing fisheries management in European Marine Sites.

From a fishing industry perspective provision of fishing activity intensity information to inform the HRA process should be considered a priority. Without such detailed data on the location, nature and levels of fishing over sensitive habitats there is a risk that a "Precautionary Approach", required by the Habitats Directive, could be adopted. This is not a theoretical risk, a data gap threatened to close important trawling grounds off the Isle of Wight in 2014 until it was address through collaborative surveys between fishermen and Southern IFCA.

Spatial fishing activity data is key in the development of proportionate management beyond the assessment stage. Once such assessments have been completed and if risks of disturbance are identified then spatial management, such as already in place for towed gears in Lyme Bay, can be developed in a proportionate manner without the need for large "buffer" zones. In effect, any spatial restriction necessary scaled according of the extent of the risk therefore affording the sensitive habitat or species with the necessary protection with the minimum impact on local fishermen.

As discussed in the review above mapping the activity footprint of the <10 m has until now been achieved with variable success and at relatively coarse resolution. Even for >12 m vessels fitted with satellite VMS, and due to is use as a compliance monitoring rather than data collection tool, the resolution of mapping is often on a >1km scale. For the purposes of MPA management and to address the multiple challenges of the inshore zone there is a need for high resolution data collection and monitoring data.

The SC2 iVMS technology trialled in this project has been successful in generating accurate position/speed/heading data which at a 10 minute reporting rate resulted in a very large dataset over a year. It was this high reporting rate combined with equipment fit for purpose for fitting to small inshore vessels that enabled the detailed fishing activity maps to be generated. Figures x to y above clearly demonstrate the step change in our ability to collect and visualise <10 fishing intensity data. The authors believe that Figure 67 represents quite possibly the most detailed and accurate visualisation of fishing activity to data. That this activity data is in the Lyme Bay Reserve make it even more relevant to the challenges of future MPA management.

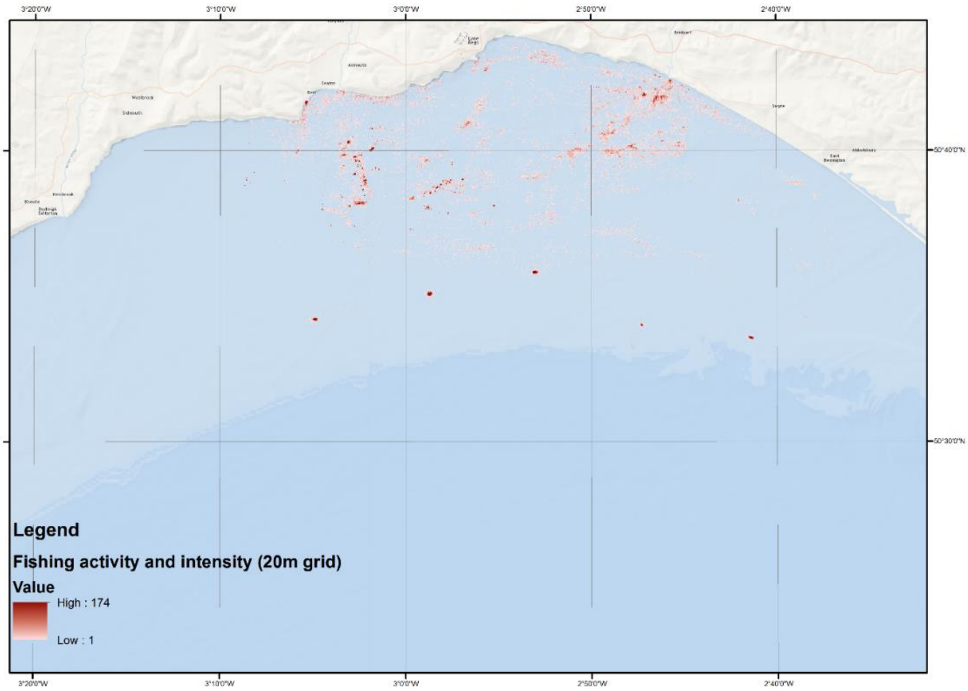

Figure 67. Fishing activity in Lyme Bay from iVMS data gridded at 20m.

We have demonstrated the ability to relate this high resolution spatial fishing activity data to site features and seabed habitats can result in an improved understanding of how fishing activity interacts with them. The habitats risk mapping analysis has produced some important statistics which will change how these interactions are perceived.

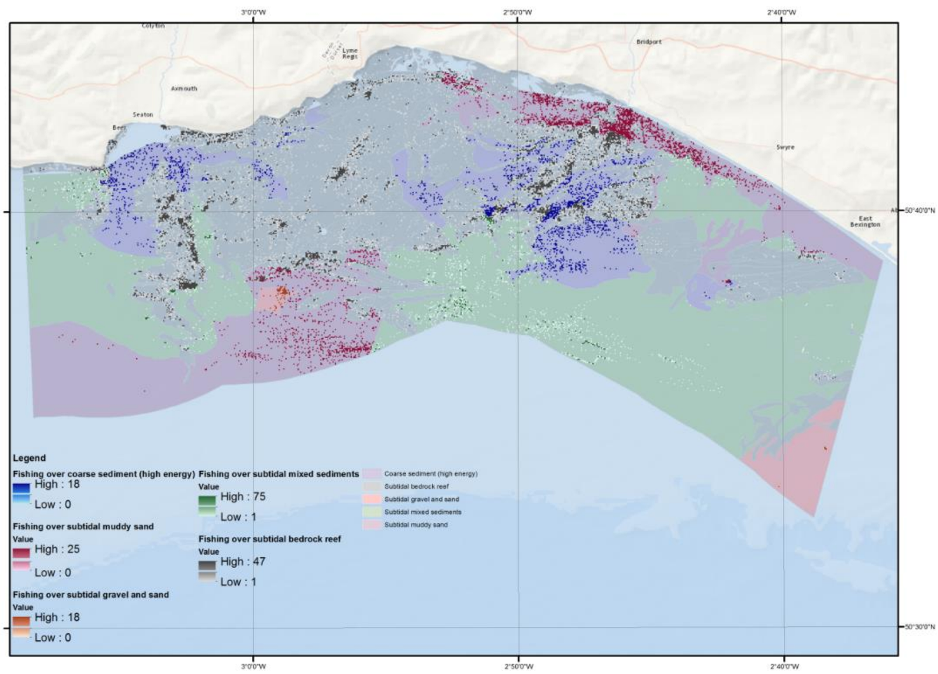

Figure 68. Fishing intensity in relation to seabed habitats in the Lyme Bay Reserve

As

Figure 68 clearly demonstrates the patterns of activity in the Reserve are highly structured and relate to specific areas of habitat. What is important from an MPA management perspective is that we can now quantify the proportions of any given habitat that is subject to fishing effort. The subtidal bedrock reef, for which the site is protected, has static gear fisheries operating over 16.2% of its 164 km^2 extent and the subtidal mixed sediments which are distributed between the reefs are fished with static pots and nets over only 3.3% of their 144 km^2 extent.

Beyond linking fishing patterns with broadscale habitats the high resolution activity data enabled us to analyse at a fine scale potential interactions with individual species both sessile seabed invertebrates and wide ranging mobile cetacean species. This type of analysis and ability to visualise the scale and frequency of these interactions, which as we showed could be carried out seasonally, may open the door to novel approaches in assessment, research and management. Importantly, the latter can be based upon good levels of understanding and be proportionate to any risk. In the context of Lyme Bay Reserve and the sea fans this appears to be low.

Intensity, quantified here as pings (iVMS records) per 20 m x 20 m, may a useful proxy for effort or potential disturbance but what is required for a true understanding of interaction is a means to link intensity with actual gear on the ground. The RFID technology tested in this project demonstrated that this is not only possible but also practical without additional recording burdens to the fishermen. The RFID trial showed that individual fishing gears can be electronically tagged using cheap plastic RFID tags and that a detailed dataset of when and where gears were shot away (deployment) and/or hauled (recovery).

It is conceivable that if such detailed data was required for management or research purposes then a register of fishing gears detailing gear metrics such as length of net, numbers of pots per string, type of pot etc, could be linked to individual gear-specific tags. This approach would take the potential data collection beyond what was thought even remotely possible a short time ago.

Clearly data collection for data collections sake is not an efficient use of resources but developments in our understanding of how fishing gears interact with seabed habitats and new approaches to manage these may result in drivers for adoption of this technology. A recent study carried out in the Cardigan Bay SAC has established thresholds of habitat and community disturbance for a habitat subjected to scallop dredging below which it may be sustainable to continue to fish within the site (Lambert et al, 2015). The Lyme Bay Potting Study currently being carried out for the Lyme Bay Working Group by Plymouth University may establish an upper limit for pot densities in a given area of reef. If such thresholds are established and are thought possible to occur in the fishery then this technology and approach could identify the areas most at risk. Combined with the real-time data transfer capacity of iVMS the RFID tags would also offer a compliance monitoring tool for regulators. Obviously this is highly speculative in the context of static gear fisheries in Lyme Bay but it is the data from this project and the tools developed and tested that will enable effective assessment and management in the future.

The Catch App trialled in this project offers the final piece of the Fully Documented Fishery jigsaw. The important commercial and regulatory drivers for improving catch recording for <10 m vessels have been discussed above but it is important to reiterate that the coming challenges of the landings obligation or discard ban as it is more commonly referred to may require a higher level of record keeping. From the fishermen's perspective the small boat fleet continues to suffer from inadequate quota allocation for some species resulting in part from a lack of historic landings data. This situation could be avoided in future with the adoption of improved record keeping and removing the reliance on Registered Buyers & Sellers data, with its well acknowledge shortcomings, to inform the allocation of fishing opportunities.

The results of the Catch App trial revealed the potential for electronic reporting systems using propriety iPads and a simple App. The strength of this approach from a practical perspective is that the majority of users are used to tablet and mobile phone technology and if not, the intuitive design of the software overcomes any barriers to use.

The data presented above demonstrates the level of potential detail on not only retained catch but also numbers of discards and, importantly, reasons for discarding. This type of data offers the potential for near real-time fishery stock monitoring and adaptive assessments with quota uptake rates being understood as they happen rather than in one or two months' time after which an overshoot has occurred. The latter is a situation that recently affected the <10 m fleet engaged in ray and skate fisheries in 2014 when an overshoot in quota by larger vessels resulted in the closure of the fishery.

Being able to record and monitor the levels of discards in shellfisheries offers the possibility of real-time assessments of stock status and particularly of the pre-recruits. Knowing the numbers of undersized lobster or crab being returned may help scientists calculate a pre-recruit index and monitor the state of the stock.

Perhaps most exciting is the possibility of linking Catch App data to the RFID and iVMS datasets in order to produce spatial Catch per Unit Effort visualisations across the year. This would enable individual fishermen to assess their past fishing patterns and success and monitor them against their current activity so that they could adapt their practices accordingly. Although this is something that most fishermen do instinctively intuitive tools and good data recording may help them further their understanding. Add to this other relevant datasets such as environmental factors that may affect target species numbers and distribution e.g. water temperature, salinity anomalies or chlorophyll levels, and we enter the area of Big Data. Figure 69presents a possible approach in the form of a future App development.

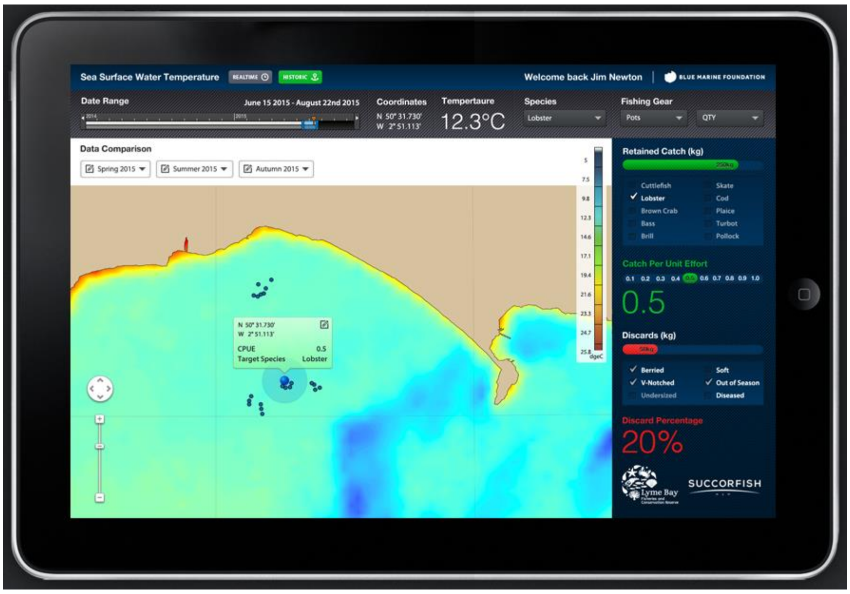

Figure 69. A possible Big Data development direction for the Catch App

The interest from commercial members of the Steering Group in the capability for fishermen to report catches in real-time highlights the future potential for catch recording data. Although EU labelling regulations only require fish to be traceable to the North East Atlantic there is a growing interest in food traceability. The recent horse meat scandal has raised public awareness of the issue of provenance and there is a growing market for locally sourced food. Being able to inform buyers of catches, even before it has been landed, enables buyers to plan their buying and logistics better. As quoted above, one buyer said "I could tell my customers tonight exactly what they will have on their menu tomorrow night, before the fish even reaches the shore".

This traceability capacity of the Catch App demonstrated in this project complements the Lyme Bay Reserve's "Lyme Bay Fish" brand development which aims to promote locally caught sustainable fish to high value markets.

The future ability to spatially link catches and landings with specific fishing grounds would make possible highly detailed ecosystem goods and service analyses. In this case the goods and services are fish and shellfish provision. Such analysis will be able to provide accurate estimates of the value to the individual fishermen and the supply chain of specific areas of habitat. This information could be important for use in marine plan development and for the fishing industry in evidencing the importance of protecting its fishing grounds and supporting habitats.

The Lyme Bay Reserve Fully Documented Fishery Trial was an ambitious marrying of new technologies and data collection approaches with a traditional small boat inshore fishery. Working in the marine environment with new technology is a challenge and on board small vessels particularly so. The fishermen participating in this trial, in the main, work single-handed and have a hard enough job operating the vessel and gears safely without recording information or ensuring that RFID tags have been recorded. It is a testament to the commitment of the Lyme Bay fishermen that this project has been a success and that we have been able to learn so much from it so that this technology and tools can be adapted and rolled out to other areas where there is a requirement for accurate and precise fisheries spatial data.

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