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This report presents the results of marine and freshwater scientific work carried out by Marine Scotland Science.

ScotMap Inshore Fisheries Mapping in Scotland: Recording Fishermen's use of the Sea

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Executive Summary

Marine Scotland requires a detailed understanding of fishing activity in Scottish Territorial Waters to inform marine spatial planning at both the national and regional level, and in relation to marine renewable energy development, marine nature conservation designations and fisheries management. For larger fishing vessels (those over 15 m overall length) which fish mainly in offshore waters, spatially resolved information on the activity and the value of fishing can be derived from Vessel Monitoring Systems (VMS) and landings data. The competition for space is, however, often greatest in inshore waters where most fishing is undertaken by small vessels which are not currently fitted with VMS. To improve knowledge of the distribution of fishing activity and the value of fisheries in inshore waters, Marine Scotland carried out a fisheries mapping study known as ScotMap.

ScotMap provides spatial information on the fishing activity of Scottish registered commercial fishing vessels under 15 m in overall length. The data were collected during face-to-face interviews with individual vessel owners and operators and relate to fishing activity for the period 2007 to 2011. Interviewees were asked to identify the areas in which they fish, and to provide associated information on their fishing vessel, species targeted, fishing gear used and income from fishing.

The dataset, as of July 2013, is based on interviews of 1,090 fishermen who collectively identified 2,634 fishing areas or 'polygons', the majority of which relate to creel (pot) fishing. The data collected were aggregated and analysed to provide raster data and mapped outputs of the monetary value, relative importance (relative value) and the usage (number of fishing vessels and number of crew) of seas around Scotland. Examples of the mapped outputs for subsets of the data representing the main types of fishery prosecuted by the under 15 m fleet, and for the combined data set, are presented and discussed.

Not all fishermen initially targeted for the ScotMap project were interviewed (72% vessel coverage overall) and not all those interviewed provided earnings information

(10% earnings disclosure decline rate overall). Individuals defined their fishing areas with variable levels of precision. Users of the data should be aware of this, particularly of the coverage provided by the ScotMap data which varies regionally.

Aggregated data outputs from ScotMap are available on [Marine Scotland Interactive](#) (MSi) and [National Marine Plan Interactive](#) (NMPI) websites, as pdf maps and downloadable raster data sets.

1. Background and Policy Context

The Marine (Scotland) Act 2010 brought into force a new statutory marine planning system to manage the usage of Scotland's seas. The Act requires the Scottish Government to develop a National Marine Plan (NMP) and introduces general duties to protect and enhance the marine environment whilst allowing for sustainable economic development¹. Scotland's National Marine Plan provides direction regarding a wide range of marine usage decisions, including the management of human impacts, offshore renewable energy development, fisheries, aquaculture, ports and harbours and nature conservation designations.

Marine planning in Scotland will be implemented at a local level and will require the development of regional plans. Scottish Government consulted on the draft Scottish Marine Regions (SMRs) in 2013² but the definitive geographic boundaries of the statutory marine regions have yet to be formally adopted. Regional Marine Plans will be developed by Marine Planning Partnerships to take account of local circumstances and smaller ecosystem units.

Regional marine planning is being piloted in the Pentland Firth and Orkney Waters (PF&OW). The purpose of the pilot spatial plan is to inform use of the sea in a manner which minimises spatial conflict between marine users and takes account of cumulative effects of multiple activities. An initial Marine Spatial Plan Framework and draft Regional Locational Guidance for PF&OW was published by Scottish Government in 2013³. The Framework document sets out a three stage process for the development of regional marine plans. It contains a summary of existing information on different uses of the sea and shows how these may impact on each other. It also includes recommendations for future data collection, assessment and research, to ensure that the Plan is properly underpinned by relevant and good quality information, and sets out how the Plan should be developed. One of the data gaps identified in the Framework document is the spatial distribution of inshore fishing. In order to address this, Marine Scotland carried out a study in the PF&OW piloting an interview based approach, known as ScotMap. Following the successful

¹ Scottish Government 2013. Planning Scotland's Seas – Scotland's National Marine Plan Consultation Draft. <http://www.scotland.gov.uk/Publications/2013/07/9185/downloads>

² Scottish Government 2013, Consultation Report on the Draft Scottish Marine Regions Order 2013. <http://www.scotland.gov.uk/Publications/2014/01/2507>

³ Scottish Government 2013. Pilot Pentland Firth and Orkney Waters Marine Spatial Plan. <http://www.scotland.gov.uk/Publications/2013/06/9672/downloads>

completion of the pilot study, ScotMap was rolled out in other areas around the coast of Scotland.

2. Introduction

Marine planning relies on robust data on marine resources and usage. Capture fisheries are major users of Scotland's seas. Fishing is carried out by a diverse fleet, in terms of vessel types and sizes and the species targeted. Marine Scotland requires a detailed understanding of the nature and value of fishing in Scottish Territorial Waters to inform policy in relation to the sustainable development of offshore renewable energy, nature conservation and fisheries management and in the wider context of marine spatial planning.

Information on the activity and value of landings for larger vessels, those greater than 15 m in length, is available from satellite-based Vessel Monitoring Systems (VMS) offering bi-hourly location data which can be linked to landings information. The Scottish fishing fleet, however, includes a substantial number (ca. 82%⁴) of smaller fishing vessels, those less than 15 m in length, that are not currently fitted with VMS. Information about where these vessels fish is based on landings data which, because they are reported at the ICES statistical rectangle level, are of relatively poor spatial resolution and of limited utility for marine planning. In addition, these small vessels fish mainly in inshore waters where the competition for space is often greatest.

Recognising the need for better information on the under 15 m fleet, Marine Scotland carried out a fishery mapping project known as ScotMap. The aim of ScotMap was to provide detailed, spatially resolved information on commercial inshore fishing activity around Scotland, including:

- definition of the areas fished;
- seasonal usage (the months of the year in which areas are fished);
- the species fished for;
- the fishing method/gear used;
- the number of people employed, and;
- the contribution different sea areas make to income from fishing.

⁴ Scottish Sea Fisheries Statistics 2011: Vessel and Employment Tables – Table 2.3 Number of active Scottish based vessels by district and length group as at 31st December 2011 - <http://www.scotland.gov.uk/Topics/Statistics/Browse/Agriculture-Fisheries/PubFisheries/2011-Ves>

ScotMap uses a participatory mapping and questionnaire approach originally developed for the FisherMap project by des Clers *et al.*, (2008)⁵ and subsequently modified for use in the Finding Sanctuary project and other Marine Conservation Zones (MCZ) projects in England and Wales. The method has been used to collect spatial and economic data on fisheries and also on charter boats, sea angling and water sports. In the case of commercial fisheries, individual skippers or owners of vessels were interviewed. The revised protocol allowed for mapping of fishing grounds, the main target species, the gear used and linked individual grounds to a measure of their relative economic value (percentage gross earnings). As part of Balanced Seas MCZ project, the University of Kent developed ArcFish, a graphical user interface (GUI) linked to ESRI ArcGIS, to facilitate the collection of interview and spatial data. The University of Kent produced a modified version of the ArcFish GUI for use by Marine Scotland in the ScotMap project.

Marine Scotland piloted ScotMap to map commercial fisheries in the Pentland Firth and Orkney waters (PW&OW) in 2011⁶ and extended the approach to other sea areas around Scotland in 2012 and 2013. The project was jointly managed by members of the Scottish Government's Marine Planning and Policy (MPP) and Marine Scotland Science (MSS) divisions. A steering group, comprising fishermen's representatives and Marine Scotland staff was set up to oversee and advise on the pilot project and data collection and treatment. Following data collection and initial analyses, fisheries stakeholders were invited to a series of consultation meetings to view and provide comment on the mapped outputs. It was considered that working with stakeholders, those involved directly involved in fishing, would both improve the detail and resolution of the information and that using the ScotMap methodology would offer a rapid response to policy needs.

⁵ des Clers, S., Lewin, S., Edwards, D., Searle, S., Lieberknecht, L. and Murphy, D. (2008). FisherMap. Mapping the Grounds: recording fishermen's use of the seas. Final Report. A report published for the Finding Sanctuary project.

⁶ Marine Scotland (2012) Draft report on ScotMap: the Inshore Fishing Study Pilot in Pentland Firth and Orkney Waters. <http://www.scotland.gov.uk/Resource/0039/00396598.pdf>

3. Methodology

Target List

Initially, a list of 1,505 vessels to be interviewed for ScotMap was compiled. This list was based on Marine Scotland's records of Scottish registered commercial fishing vessels under 15 m overall length with an active fishing licence entitlement as of April 2011. Vessels administered in ports in Shetland were not included. During the study it became apparent that there were a few (five) other 'relevant vessels' that were not on the initial list, these having acquired a licence entitlement and reported landings from Scottish waters after the list was drawn up. The initial target list was revised to a total of 1,510 vessels.

Data Collection

Data were collected during face-to-face interviews with individual vessel owners and operators (referred to hereafter as 'fishermen'), conducted variously by Marine Scotland Compliance staff, contractors and fishing industry representatives, between June 2011 and March 2013. This period includes the Pentland Firth and Orkney waters pilot study and the subsequent roll out to other sea areas. The majority of those conducting the interviews had first-hand knowledge of Scottish fisheries and had received training in the interview methodology and recording data using the ScotMap GUI.

Prior to the interview, interviewers discussed with fishermen the aims of the study, the type of information they would be asked for and plans for subsequent data handling and treatment. This was to ensure that participants understood the purpose of the study and knew how the information they contributed would be used. A data protocol and a consent form, which were developed by the pilot project steering group, described how the data would be aggregated and set out the obligations of the data collectors and the organisations which would have access to the data to ensure that anonymity and commercial confidentiality are maintained and that fishermen's personal data are not disclosed. Fishermen were asked to sign a consent form. They were also asked for their views of the ScotMap project and these and any other comments were recorded.

During the interviews, fishermen were asked questions about their fishing vessel, crew, home and landing ports, fishing history, fishing patterns and to identify the area or areas in which they fish. They were also asked about their earnings from fishing,

specifically to provide an estimate of their average annual gross earnings over the last five years and/or estimates of their maximum and minimum annual gross earnings over this period (Table 1). Fishing areas or 'polygons', as identified by fishermen, were mapped electronically and associated information on primary and secondary (if applicable) target species, the fishing method and gear used in each area was recorded. Fishermen were asked to estimate the percentage contribution that each fishing area identified made to their gross vessel earnings, again on average over the past five years. The reference year for the study was 2011: the data collected thus relate to the period 2007-2011.

All interview data and fishing polygons were recorded using the ScotMap GUI, which was linked to ArcMap 9.3.1 and written down to geodatabases.

Table 1

Summary of data collected during interviews.

Category	Data	Description
Fishing pattern - data relating to each fishing polygon (area) identified	Species	Primary and secondary target species
	Gear	Gear class, type and gear parameters e.g. mesh size
	Percentage earnings	Fishermen's estimate of the percentage contribution each fishing area made to the gross vessel earnings, on average over the past five years
	Seasonality	Months in which fishing takes place
	Intensity	Days per year an area is fished or number of creels deployed in an area
	Map scale	Zoom level when drawing fishing polygon
Fishermen's information	Role	Skipper, owner, or manager
	Years local	The number of years fishing locally
	Age	Interviewee's age
	Fishing Association	Affiliation - member of a fishing association or not affiliated
	Producer Organisation	Member of a Producer Organisation or non-member
	Multiple vessel	Owner of more than one vessel
	Land activity	Other income sources from land-based activities
Vessel information	Vessel details	Vessel name, PLN and RSS numbers
	Length	Overall vessel length
	Power	Engine kW or horse power
	Home port	Main port of departure
	Landing port(s)	Landing or destination port or ports
	Earnings	Annual vessel gross earnings - average for the past 5 years
	Crew	Average number of crew including skipper
	Vessel years fishing	Years of fishing with this vessel
	Year built	Vessel year of build
Personal data	Personal data	Fishermen's personal data

Each fisherman interviewed was sent an individual report which included a map of the fishing area or areas identified, a summary of the information on fishing and contribution to vessel earnings they had provided and a copy of their consent form.

This was part of the data process stipulated in the data agreement form. It also served as a check on the data collection and recording. Interviewees were invited to submit any amendments and revisions received were incorporated in the data set.

Response Rate

The dataset, as of July 2013, is based on interviews with 1,090 fishermen. Data from 24 additional interviews which were missing essential information or had failed for technical reasons were not included. Collectively, the fishermen interviewed identified 2,634 fishing areas or polygons. The majority of these relate to creel (pot) fishing (Figure 1). Not all fishermen initially targeted for the ScotMap project were interviewed (72% vessel coverage overall). Some declined to take part, often on the basis that they were not actively fishing, others had sold their vessels and some could not be contacted. Not all those interviewed provided earnings information (see Table 2). Eighty six of the skippers interviewed declined to give vessel earnings information (10% earnings disclosure decline rate overall). The monetary value maps are therefore based on information from 1,004 interviews.

Data Treatment and Analysis

The interview data were subject to a series of checks, including target species nomenclature, data range, checks of vessel name, PLN and RSS numbers, duplicated polygons, inconsistencies in gear/target species combinations and polygons with no associated percentage value. In some cases fishermen were contacted to help reconcile anomalies and interview records were corrected as appropriate.

The cleansed data were then aggregated and analysed using a code developed in R to provide information on the monetary value, relative importance (relative value) and the usage (number of fishing vessels and crew) of seas around Scotland. The R code was applied to a series of gear/species combinations (Figure 1), subsets of the data which equate to the main fisheries prosecuted by the Scottish under 15 m fleet, and to the combined data set (all gear/species combinations).

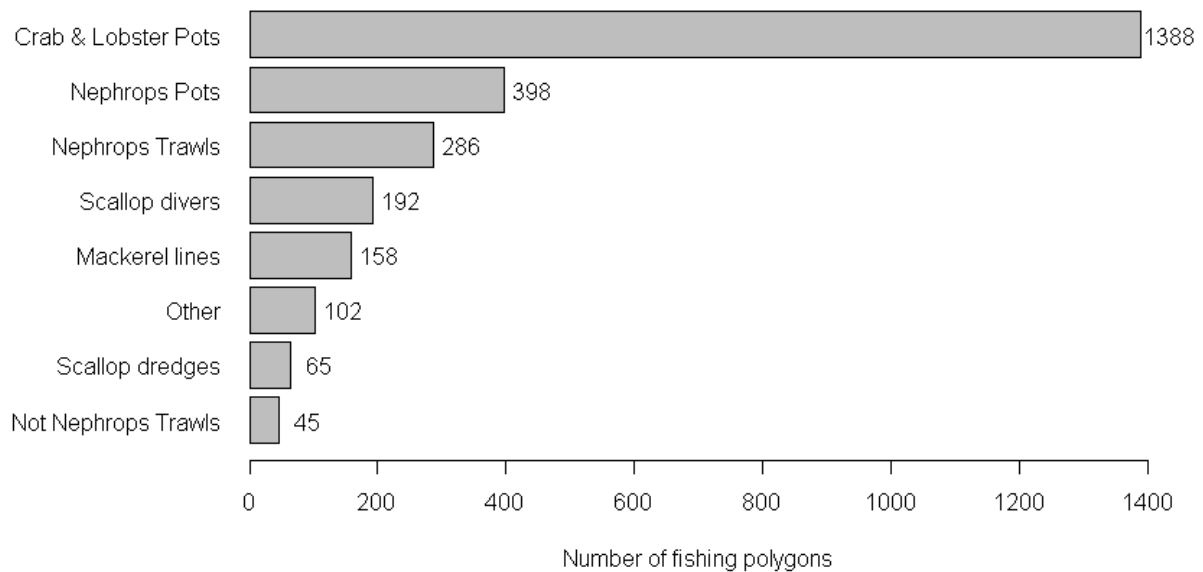


Figure 1: Gear/species polygon combinations representing the main fisheries prosecuted by the Scottish under 15 m fleet as recorded in ScotMap.

These gear species combinations comprise:

- **Crab and Lobster Pots:** Polygons identifying crab and/or lobster (i.e. brown crab and/or velvet crab, green crab, spider/spiny crab, common lobster, crawfish, squat lobster) as the primary target species where fishing gear is creels (pots).
- **Nephrops Pots:** Polygons identifying Norway Lobster (*Nephrops norvegicus*) as the primary target species where fishing gear is creels (pots).
- **Nephrops Trawls:** Polygons identifying Norway Lobster (*Nephrops norvegicus*) as the primary target species where fishing gear is trawls.
- **Scallop Divers:** Polygons identifying king scallop as the primary target species where fishing method is diving.
- **Mackerel Lines:** Polygons identifying mackerel as the primary target species where fishing gear is lines.
- **Scallop Dredges:** Polygons identifying king scallop as the primary target species where fishing gear is towed dredges.
- **Not Nephrops Trawls:** Polygons where fishing gear is trawls and the target species is NOT *Nephrops*. Includes common squid (predominant target species), haddock, plaice and other flatfish.
- **Other:** Polygons relating to fishing for other species (includes: whelks, razorfish, surf clams, brown shrimps, pollack, cod, haddock, plaice, salmon, herring, mackerel, skates and rays, wrasse, bass, cockles, and spotted dogs) and or unusual gear/species combinations, which did not fit into any of the

categories above. Because of the small number of polygons involved and the potential for identifying individuals' fishing activity, polygons in this 'other' category were not separately mapped. They have, however, been included in the combined (all interview) data set.

For **monetary value**, the value associated with each fishing polygon was calculated from the percentage contribution and gross vessel earnings data. Each polygon is overlaid with a grid (800 cells per ICES statistical rectangle) and the polygon monetary value is divided by the number of overlapping grid cells to equally distribute the value to all overlapping grid cells, irrespective of the extent of the overlap. This process is repeated for all polygons and the values associated with each grid cell are finally summed to produce a gridded dataset.

The analysis for **relative value** is similar to monetary value (above) but in this case the percentage associated with each polygon, rather than the absolute monetary value, is divided equally among the overlapping grid cells before being summed to produce a gridded data set. Treatment of the data in this way reduces the influence of larger vessels, which generally have higher gross earnings, and of those vessels fishing for relatively high value species, such as lobster and scallops, which is often evident in the monetary value analysis. Relative value provides an alternative representation of 'the value of fishing' in different sea areas. It can indicate areas of high proportional importance to large numbers of relatively low earning boats, and other small, often remote areas which are particularly important to local boats, which are often less evident from the monetary value analysis.

The **number of vessels** in each grid cell is the sum of the number of polygons which overlap the cell (partially or completely). Thus, if two fishing polygons associated with a single vessel overlap one grid cell the vessel will be counted twice in that cell and, contingent of the size of the polygon, a vessel will be counted in more than one cell. The numbers of vessels analyses provide information on the spatial extent of fishing as reported during interviews and are a representation of fishing intensity i.e. where most boats fish. They are not necessarily a good indicator of fishing effort, particular in the case of the combined (all interview) data set, or for fisheries where activity varies seasonally.

For the analysis of **number crew**, the average number of crew working on a vessel is attributed to each polygon for that vessel. The same value is then allocated to each overlapping grid cell and numbers summed to derive the number of crew associated with each grid cell.

Data were gridded using a fine 0.025 x 0.05 degree grid resulting in a resolution of 800 cells per ICES rectangle. The mean cell size was 4.20 km² (min. 3.89 – max. 4.51 km²). Resolution was selected as a trade-off of potential maximum resolution against appropriate level of aggregation not revealing individuals' fishing areas and reasonable data processing time. Rasters for vessel numbers and number crew were aggregated to a minimum of three vessels per cell.

In relation to the gridding technique, it should be noted that; i) the allocation of polygon values to grid squares is equal irrespective of the actual proportion of the polygon which falls within the grid; ii) the area of the grid squares based on regular latitudinal and longitudinal intervals varies with latitude; and, iii) any rounding up of values or potential inaccuracies associated with particular polygons will be propagated across different grid squares.

Evaluation of interview coverage

As indicated above, not all vessels on the initial target list were successfully interviewed for ScotMap and some anomalies in the interview data could not be reconciled. Reports from data collectors indicated variations in response rate around the coast.

To evaluate the coverage provided by the ScotMap dataset, both nationally and regionally, we used reported landings data for interviewed and non-interviewed vessels and information on port of registration and the ICES rectangles to which landings were reported. For this it was necessary to define the study area. This was done by overlapping the ScotMap interview polygons with ICES statistical rectangles. The area extends from 54°30'N to 60°0'N and from 7°0'W to 0°0', and covers about 332,619 km² (note the area of an ICES rectangle areas varies from 3,132 km² to 3,584 km² over the study area). The study area with relevant ICES statistical rectangles and the draft Scottish Marine Regions (SMRs) areas is shown in Figure 2.

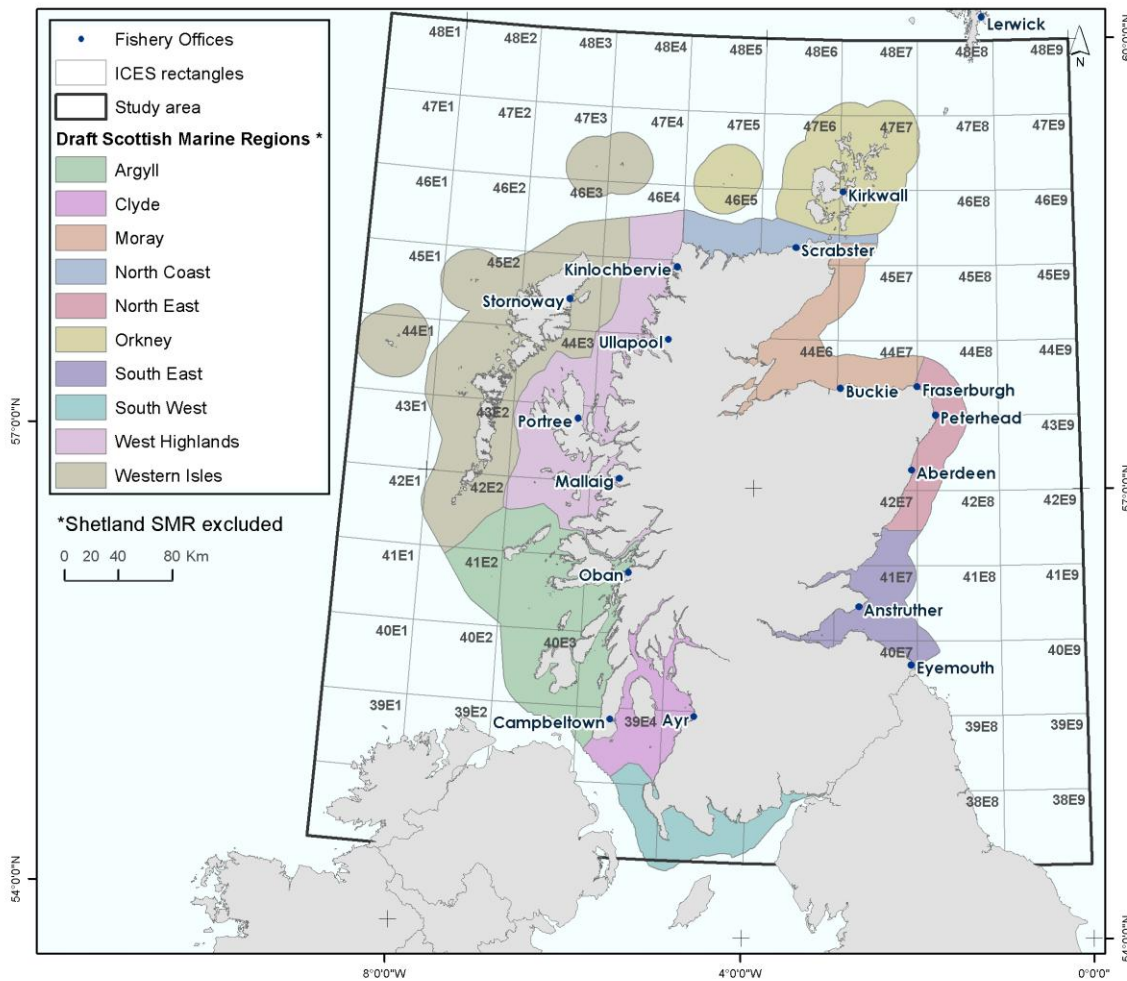


Figure 2: ScotMap study area, fishery offices (or Districts), provisional Scottish Marine Region Boundaries and overlapping ICES Statistical Rectangles.

We carried out two types of comparison:

1. Vessel and landings by registration district

Firstly, the number of vessels successfully interviewed was compared with the number of vessels on the initial target list. We also compared the total value of the reported annual landings of interviewed vessels, as recorded on the Scottish Fisheries Information Network (FIN) averaged for 2010 and 2011, with the total value of FIN-reported annual landings of all vessels less than 15 m in length, averaged for the same period, broken down according to vessels' administration District. Results of these comparisons and the interview decline rate in each District are shown in Table 2 and Figure 3.

2. Spatial comparison by ICES rectangles

For the second spatial comparison, the total annual value of the FIN-reported landings of vessels successfully interviewed, averaged for 2010-2011, was compared with the total value of the FIN-reported annual landings of all vessels under 15 m for the same period, broken down according to individual ICES statistical rectangles in the study area (ICES rectangles being the level at which landings are reported on FIN). Results are shown in Figure 4.

Table 2

Numbers of vessels interviewed and targeted, values of landings on FIN and interview decline rate (%) by Scottish district.

Interview Coverage			
District Name	Vessel Coverage (i)	Average Landings 2010-11 Coverage (ii)	% Decline
Aberdeen	63/81 (78%)	£ 4.02M /£ 4.39M (92%)	12%
Anstruther	92/115 (80%)	£ 7.06M /£ 8.04M (88%)	0%
Ayr	41/98 (42%)	£ 4.53M /£ 6.54M (69%)	37%
Buckie	34/52 (65%)	£ 2M /£ 3.31M (60%)	0%
Campbeltown	80/125 (64%)	£ 7.22M /£ 11.88M (61%)	18%
Eyemouth	78/96 (81%)	£ 7.37M /£ 8.69M (85%)	1%
Fraserburgh	77/96 (80%)	£ 2.33M /£ 4.35M (54%)	0%
Kinlochbervie	11/20 (55%)	£ 0.56M /£ 1.05M (54%)	20%
Lochinver	8/13 (62%)	£ 0.69M /£ 1.22M (57%)	15%
Mallaig	19/39 (49%)	£ 1.11M /£ 2.38M (47%)	26%
Oban	61/107 (57%)	£ 5.9M /£ 8.53M (69%)	7%
Orkney	130/130 (100%)	£ 9.66M /£ 10.34M (93%)	0%
Peterhead	41/45 (91%)	£ 1.42M /£ 1.51M (95%)	9%
Portree	86/133 (65%)	£ 7.96M /£ 11.36M (70%)	23%
Scrabster	50/75 (67%)	£ 2.53M /£ 3.28M (77%)	1%
Stornoway	172/200 (86%)	£ 10.67M /£ 12.22M (87%)	8%
Ullapool	47/85 (55%)	£ 3.67M /£ 5.48M (67%)	13%
Total:	1090/1510 (72%)	£ 78.71M /£ 104.56M (75%)	10%

Vessel coverage (i) is the number of vessels interviewed/targeted and the % interviewed. Average landings coverage (ii) is the value of the landings of vessels interviewed/the total value of landings of all vessels under 15 m in £s millions p.a. as reported and recorded on FIN (average for years 2010 and 2011) and value for interviewed vessels expressed as a % of the total, for each administration port (District).

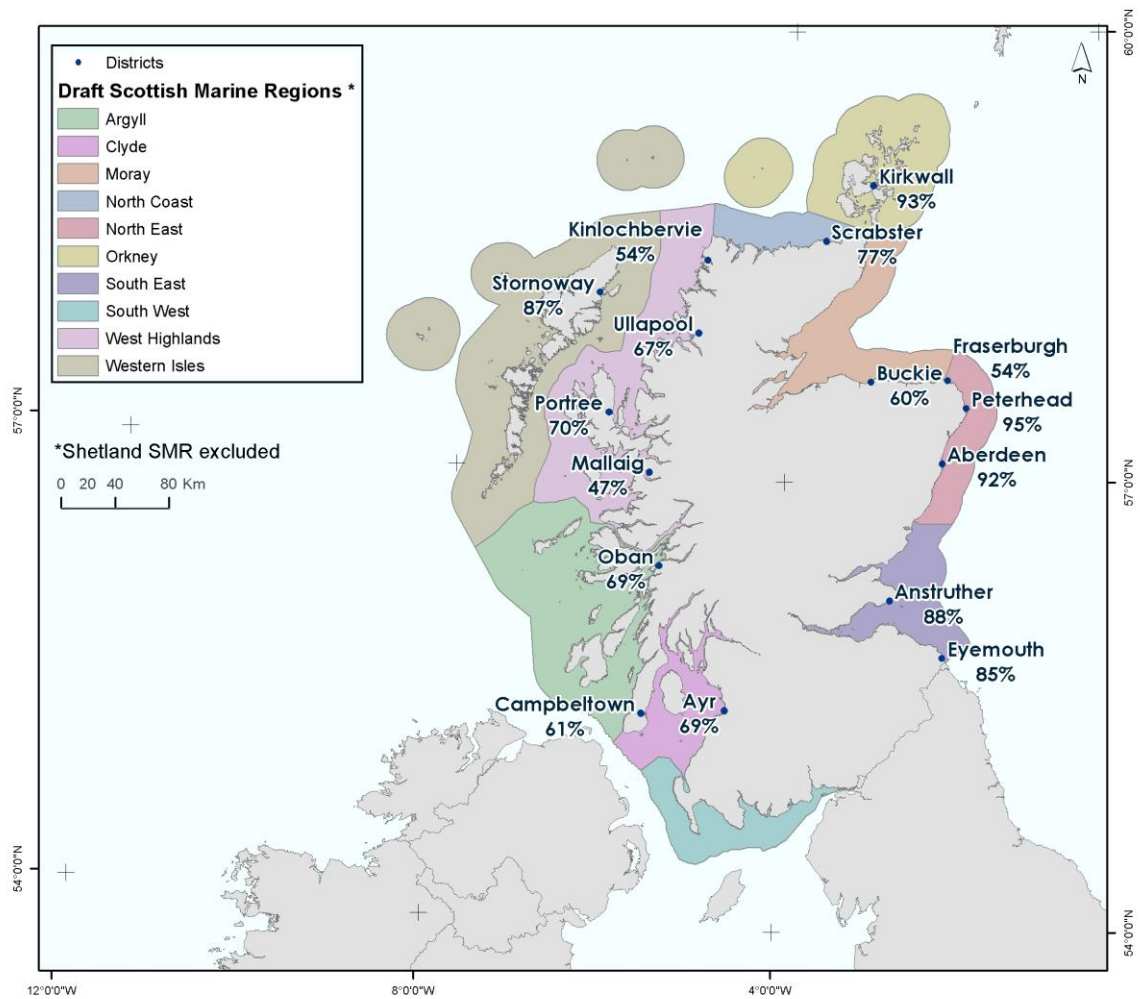


Figure 3: Percentage coverage of the total value of the FIN-reported annual landings of interviewed vessels averaged for 2010 and 2011, by the total value of FIN-reported annual landings of all vessels less than 15 m averaged for the same period, according to District.

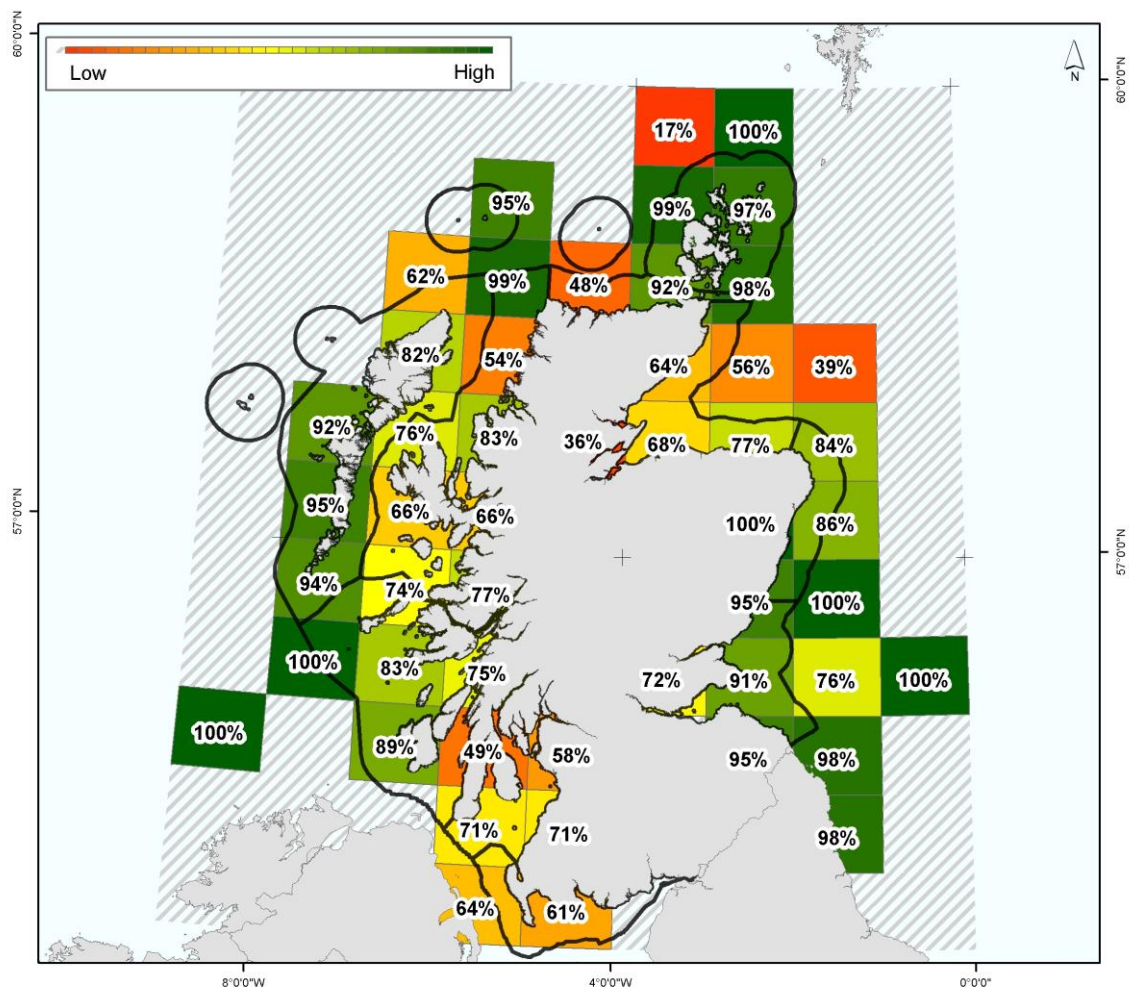


Figure 4: Percentage coverage of the total value of the FIN-reported annual landings of vessels successfully interviewed averaged for 2010-2011, by the total value of the FIN-reported annual landings of all vessels under 15 m for the same period, in each ICES statistical rectangle in the study area. Provisional SMR boundaries are also shown (in black).

The spatial comparison (ii above) provides an assessment of interview coverage for different sea areas. This is more relevant to marine planning than that based on registration district and likely to be more indicative of spatial coverage because not all under 15 m vessels fish in the vicinity of their port of administration. A description of the spatial coverage within draft Scottish Marine Regions (SMR) based on approximation of ICES rectangles is included in the discussion below. Estimates of coverage by ICES rectangle can also be used to assess interview coverage in the the Scottish Inshore Fisheries Group (IFG)⁷ areas.

⁷ IFGs are non-statutory bodies that aim to improve the management of Scotland's inshore fisheries (out to six nautical miles) and to give commercial inshore fishermen a strong voice in wider marine management developments. Six (IFGs) cover all of the Scottish coast (except Shetland where there are separate management arrangements).

The analysis by district indicated that, overall, 72% of the vessels on the target list, which collectively account for 75% of the reported landings (average 2010 and 2011), were interviewed (Table 2 and Figure 3). Coverage as assessed on the basis of reported landings for individual statistical rectangles varied from 48% to 100% (Figure 4).

Regional variation in interview coverage is evident from both the district based and the spatial approach. The high decline rates and relatively poor vessel coverage for vessels administered in Ayr and Campbeltown are reflected in the low spatial coverage achieved for ICES rectangles associated with the South West and Clyde SMRs. Patchy spatial coverage in the West Highlands SMR appears to be associated with high decline rates and or low vessel coverage for Portree, Ullapool and Kinlochbervie. In contrast, very good vessel and spatial coverage was achieved for some areas eg in the Western Isles, Orkney, South East and North East SMRs.

4. Consultation/Validation Meetings

Draft mapped outputs from ScotMap and analyses of interview coverage were presented at a series of meetings with fishermen and fishing industry representatives at 15 locations around Scotland in April and May 2013 (Table 3).

Table 3 ScotMap Validation Events

ScotMap Data Validation Events (April – May 2013)	
1.	Edinburgh
2.	Campbeltown
3.	Oban
4.	Ullapool
5.	Pittenweem
6.	Aberdeen (Skipper Expo)
7.	Peterhead
8.	Inverness
9.	Dumfries
10.	Kyle of Lochalsh
11.	Scrabster
12.	Kirkwall, Orkney
13.	Ardrossan
14.	Newton Stewart
15.	Troon

Presentations were designed to give a regional perspective and focused on the fishing activity in each of the areas. Maps of various aggregations of the rasterised data for vessel number and value for different target species and/or species gear combinations and maps of the data for the combined (all interview) data set at the national level were presented and discussed. The meetings also offered an opportunity for fishermen who had not been previously interviewed for ScotMap to contribute data, and for those who had been already been interviewed to provide additional or amended their existing information.

The maps were generally well received and thought by fishermen to be a good representation of the under 15 m vessels fishing at the national level. Overall impressions of consultees at the regional level varied. For the South East SMR, it was thought that ScotMap had captured the activity and the value of the fishery in a detailed and accurate manner and that spatial extents of the fisheries were on the whole consistent with stakeholder knowledge and experience. Similarly positive feedback was received in relation to mapping of the fisheries around the Western Isles, the Moray and Orkney SMRs. Consultees at the Clyde SMR regional meeting (Ayr) thought that activity mapped for their area was not particularly accurate and there was considerable potential for improvement.

At some meetings concerns were expressed about the 'gaps' in the dataset, relevant vessels which had not been interviewed and those for which earnings information was not available. Comments were also made about the way some fishermen had defined their fishing polygons and the effect this has on the maps, dispersing value and giving a false impression of where some types of fishing are taking place.

Notable gaps identified by stakeholders included dredge fishing activity in the Argyll and Clyde SMRs; it was thought activity east of Campbeltown, west of Islay and south of Jura, was under-represented and that mapped activity was not particularly accurate. Mapping of scallop dredging within the Clyde Sea was also thought to be imprecise and incomplete. Mapping of *Nephrops* trawling in the Clyde was thought to be generally good, with the caveat that activity in the southern (outer part) between Campbeltown and Girvan was under-represented. It was also noted that relatively little creel activity was mapped in the Clyde Sea area or the Solway Firth, most likely a reflection of the relative poor interview coverage in the area. Incomplete coverage for vessels fishing in some west coast sea lochs was also commented on, although additional interview data collected at some of the consultation meetings improved this.

In the North East and Moray SMRs it was thought that the monetary value indicated for creel fisheries along the north coast of the Moray Firth was likely to be misleading, given the numbers of fishermen who declined to give earnings information. The mapping of activity (number of vessels) for these and the mackerel line fisheries was, however, thought to be very good. In this and other regions detailed comments were made about maps of crab and lobster creel fisheries according to primary and secondary target species. Although this worked in the case of *Nephrops* creel fisheries, it could give an erroneous impression of distribution of different crab and lobster species, particularly velvet crab which was only targeted close inshore. It was pointed out that in many areas crab and lobster fisheries were genuinely mixed and that fishermen may target different species at different times of year.

Stakeholders' concerns that mapping might reveal individuals' fishing locations, or encourage some fishermen to change their fishing grounds based on value of catches elsewhere, were, for the most part, assuaged when participants saw the aggregated data. It was agreed that any maps which revealed single vessel activity should not be used. The maps prompted debate about the locations proposed for marine renewable energy development and marine protected areas around Scotland, possible implications for fishing, and discussion of a wide range of local inshore fishery management issues.

As a result of the consultation meetings, it was agreed that creel fisheries for the various species or crab and lobster caught around Scotland (either as primary and or secondary target species) should be mapped as a single 'all species' category, and that the minimum number of vessels that would be depicted on maps should be three.

5. Mapped Outputs

Examples of the maps produced from data collected during the study, aggregated according to the gear species combinations in Figure 1 and maps for the combined ScotMap data set are provided below.

Pots: All crab and lobster species.

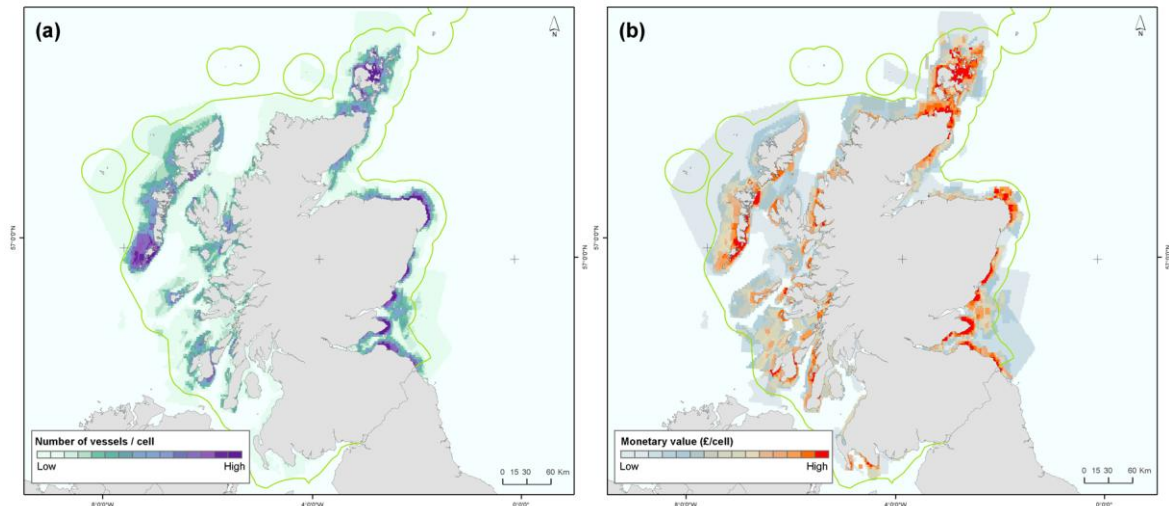


Figure 5: Vessel number (a) and monetary value distribution (b) for creel (pot) fishing for crab and lobster all species. From polygons identifying crab and/or lobster (brown crab and/or velvet crab, green crab, spider /spiny crab, common lobster, crawfish, squat lobster) as the primary or secondary target species where the fishing gear is pots.

The map of aggregated raster data of vessel number for creel (pot) fishing for crab and lobster all species (Figure 5a) indicates that these fisheries are prosecuted around almost all of Scotland. Vessel activity is concentrated inshore with distinct foci around the Orkney Isles and the Pentland Firth, along the Moray Firth coastline, the east coast and around the Outer Hebrides, on both western and eastern seaboard. Fisheries associated with smaller islands, e.g. Tiree, are also evident. Relatively little activity was mapped in the Clyde Sea area or the Solway Firth. A similar distribution is indicated by the monetary value map (Figure 5b). The areas of highest value are often inshore, in areas where the lobster is an important target species. Brown crab is the main target species in the more extensive offshore areas evident on both the value and activity maps.

Pots: *Nephrops*.

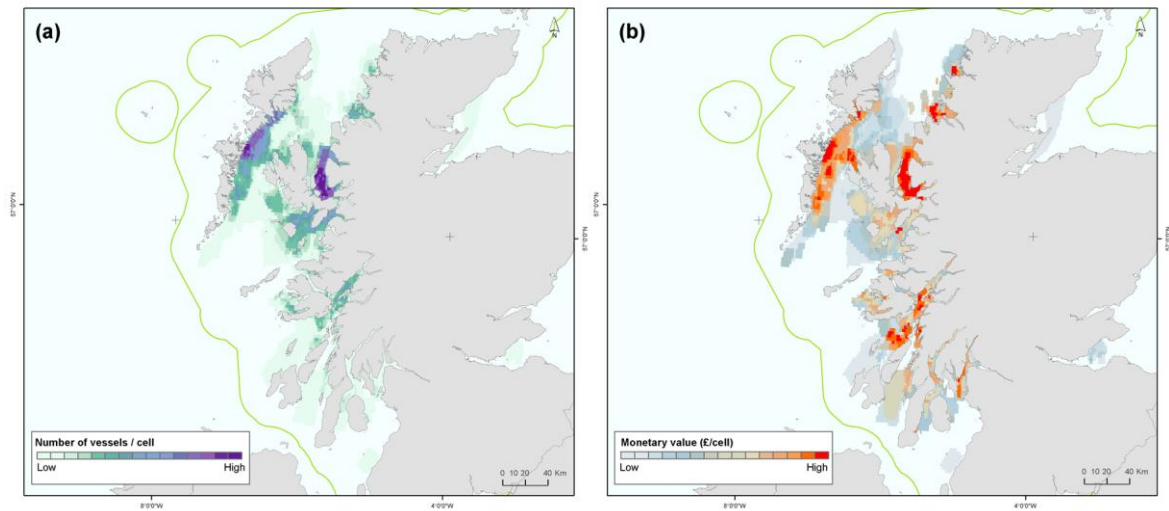


Figure 6: Vessel number (a) and monetary value distribution (b) for *Nephrops* creel (pots) fishing.

Maps of the *Nephrops* creel fishing vessel activity and value (Figure 6a and b) show an almost exclusively west coast distribution. Activity and value are concentrated to the east of the Outer Hebrides extending into both the North and South Minch, around Skye, in the sea lochs along the north west coast and the Inner Sound of Raasay. The mapping also indicates important *Nephrops* creel fishing areas further south, around Mull and Jura and smaller high value areas to the north of Islay and in the sea lochs of the Clyde.

Trawl: *Nephrops*.

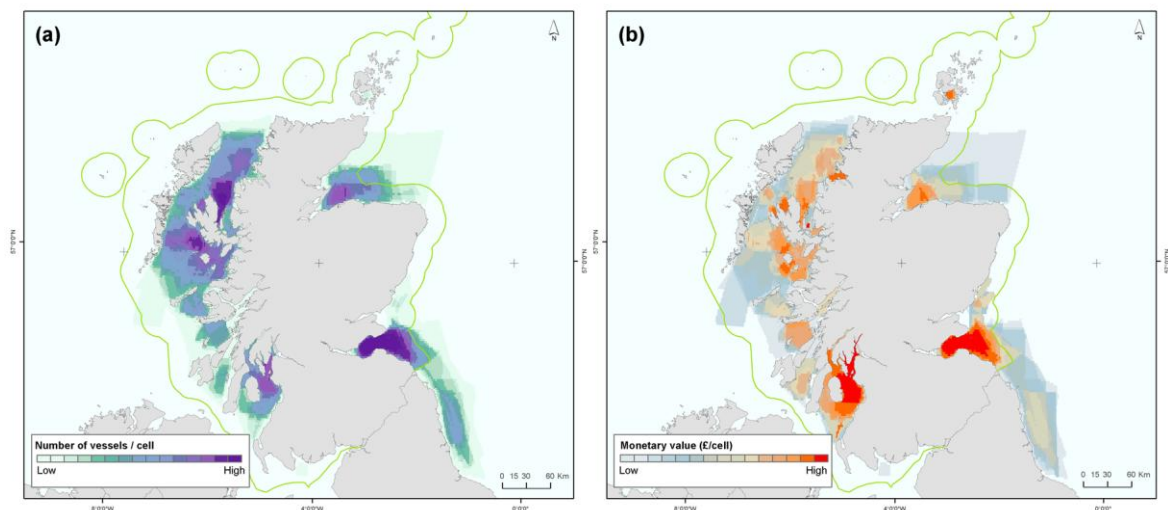


Figure 7: Vessel number (a) and monetary value distribution (b) for *Nephrops* trawling.

The vessel number and value maps of trawl fishing for *Nephrops* (Figure 7a and b) show fisheries off both the east and west coasts of Scotland, with a generally more offshore distribution than those of creels. There are significant concentrations of activity in the Moray Firth, the Firth of Forth and extensive areas in the North and South Minch, with areas of particularly high activity and/or value around Skye, Rum and Eigg and North of Raasay.

Trawl: Species excluding *Nephrops*.

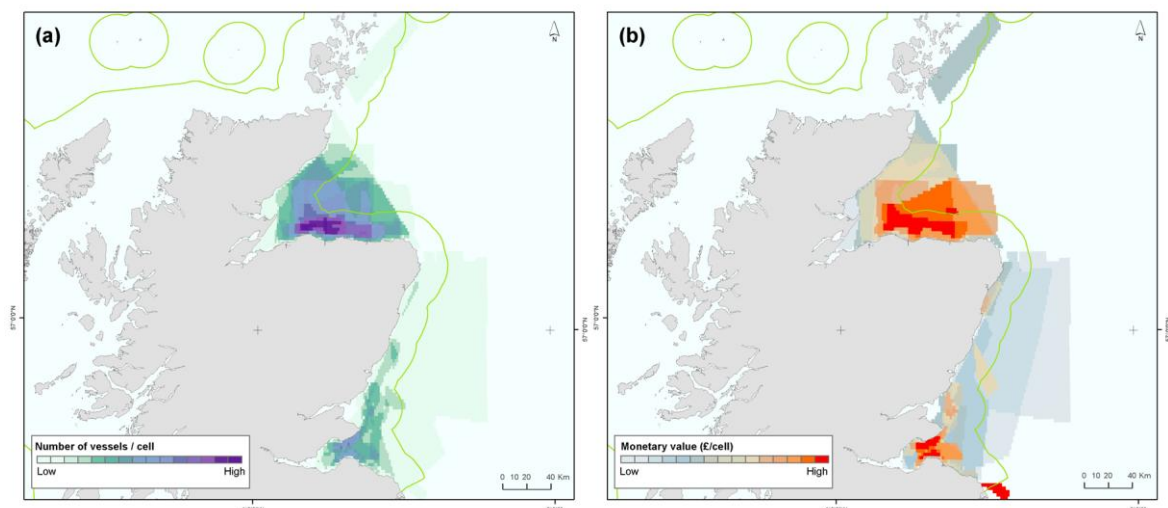


Figure 8: Vessel number (a) and monetary value distribution (b) of vessels deploying trawl as fishing gear with various target species. Includes common squid predominant target species, as well as haddock, plaice and other flatfish.

The majority of fishing mapped in Figure 8 represents fisheries targeting squid. These are located in the Moray Firth and the Firth of Forth and prosecuted on a seasonal basis often by vessels which fish for *Nephrops* at other times of year. Some fishing areas for demersal fin fish species, including haddock and flatfish were identified, but these were few and are included in this category rather than being mapped separately. They are represented by some of the larger offshore extents, but some squid fishing is similarly mapped relatively far offshore.

Towed Dredges: King scallop.

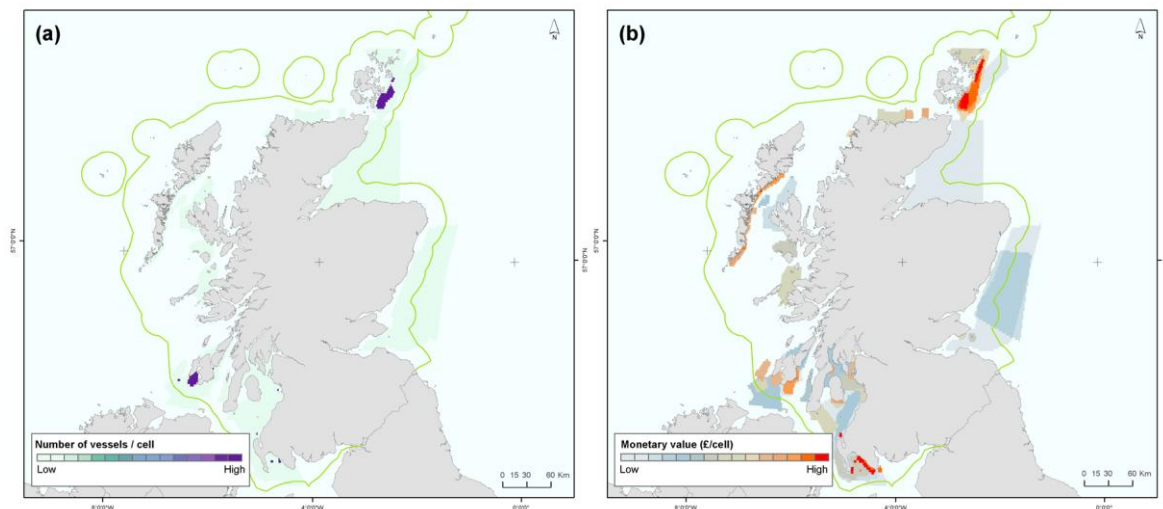


Figure 9: Vessel number (a) and monetary value distribution (b) for king scallop fishing using towed dredges.

Maps of vessel number for towed dredge fishing targeting king scallop (Figure 9a) indicated relatively few vessels fishing over extensive areas in the Moray Firth, off the east coast of Scotland and the inter-island areas of the Minches, with foci of activity to the east of the Orkney Isles and south west of Islay. The monetary value map (Figure 9b) showed relatively high value areas to the east of Orkney and in south west Scotland (Luce Bay) and also an area close inshore on the eastern seaboard of the Outer Hebrides. The value map gives a better impression of extent of the fishery and the importance of different areas than that for vessel number, particularly in the south west, around Islay, Jura and in the Clyde Sea.

Dive (hand): King scallop

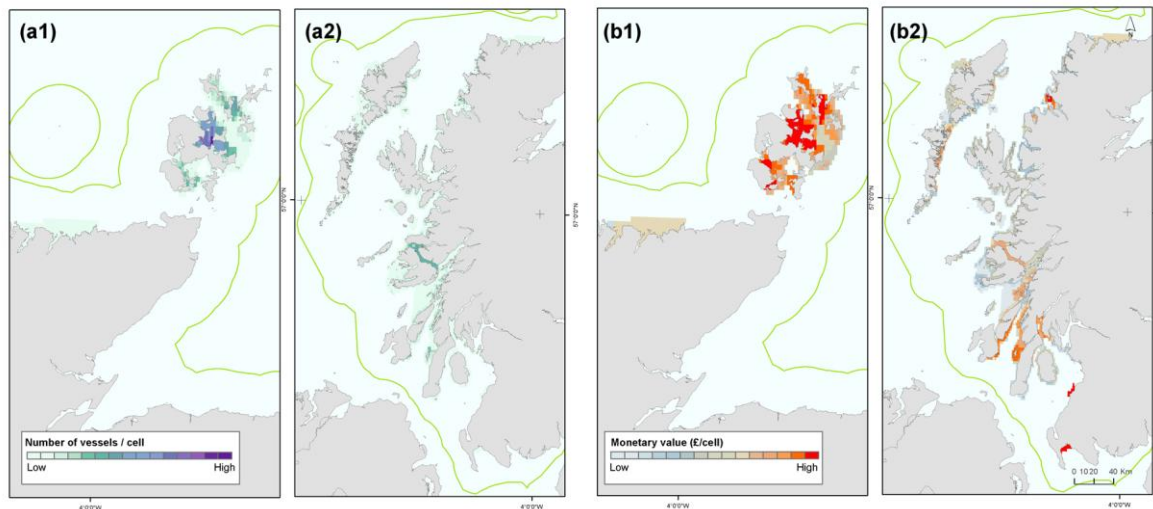


Figure 10: Vessel number (a1 & a2) and monetary value distribution (b1 & b2) king scallop diving.

The landings value for scallop dive vessels (Figure 10b1 and b2) shows an inshore distribution which presumably reflects constraints on divers' working depth. The fishery is evidently very important in the Orkney Islands (Figure 10 a1 and b1) and along the coast from the Sound of Islay to the Mull of Kintyre (Figure 10 a2 and b2). There are also small foci of value in the Clyde Sea and Luce Bay.

Lines: Mackerel

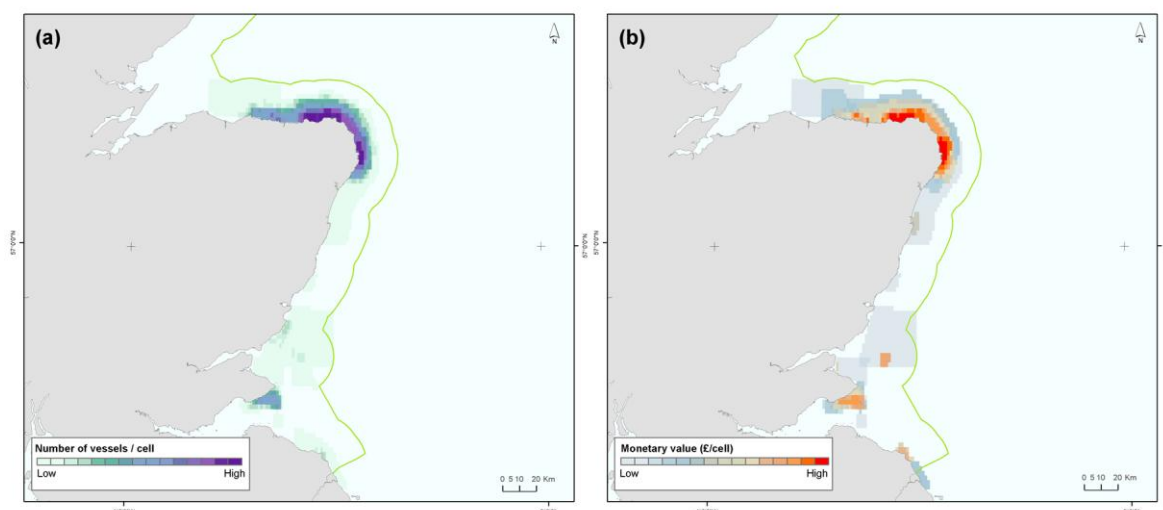


Figure 11: Vessel number (a) and monetary value distribution (b) for mackerel line fisheries.

Vessel number and value for the mackerel line fisheries (Figure 11) map very closely. The most important areas are located on the east coast, particularly around Fraserburgh and Peterhead and off the Nook of Fife.

Aggregated Data (All Interviews Combined)

Aggregated raster data for all the vessels interviewed for ScotMap for vessel number, crew number, monetary value and relative value are mapped in Figure 12 to Figure 15.

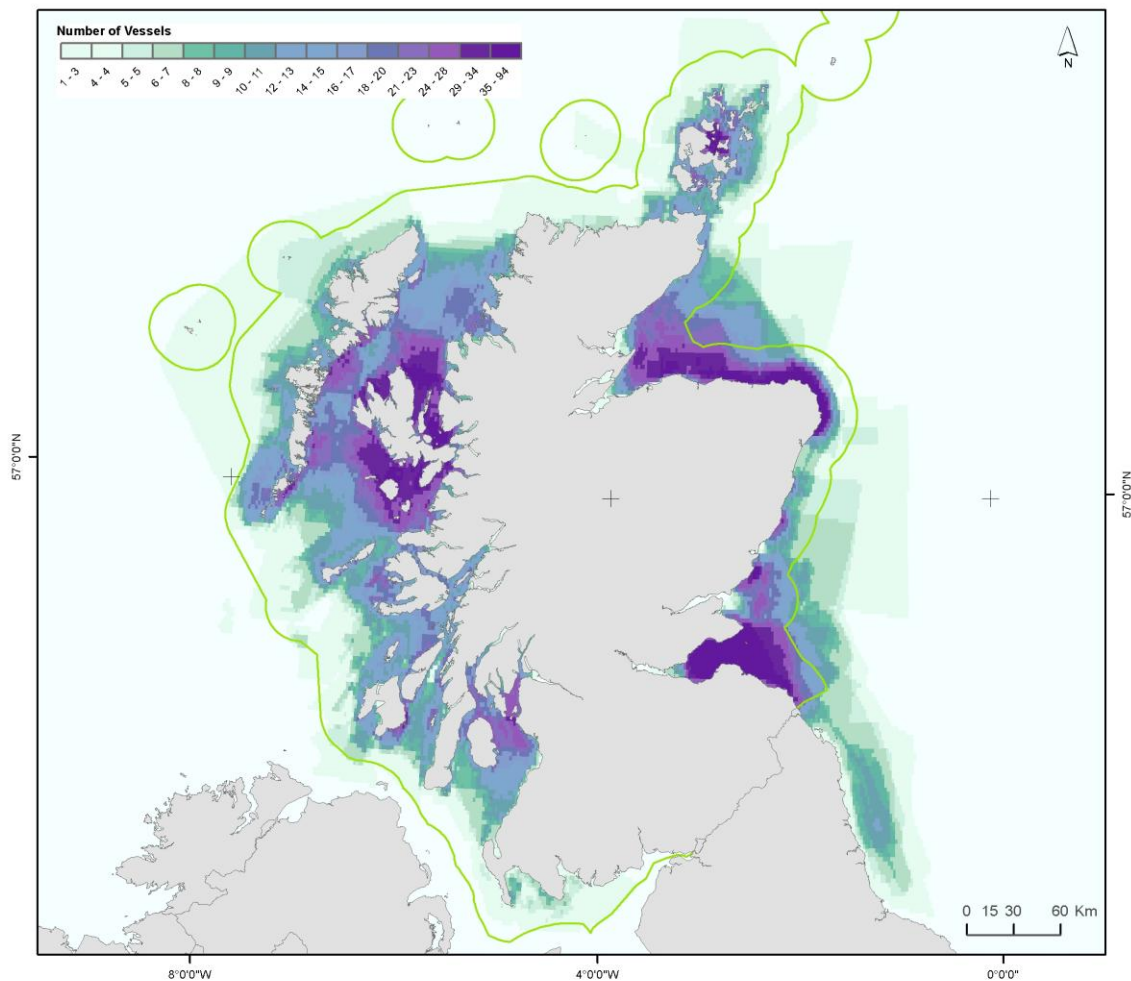


Figure 12: Distribution of the number of vessels from all interviewed vessels.

Vessel number (Figure 12) indicates that under 15 m vessels fish all around the coasts of Scotland, and in some cases more than 12 nautical miles (NM) from the coast. The main foci of activity (i.e. extensive areas with relatively high numbers of vessels per cell) are along the north coast of the Moray Firth, the Firth of Forth and in the North and South Minch particularly around Skye. In most areas activity tends to

be concentrated within 6 NM of the coast but there are areas where intermediate levels of vessel activity extend further offshore e.g. in the North Minch and the Moray Firth.

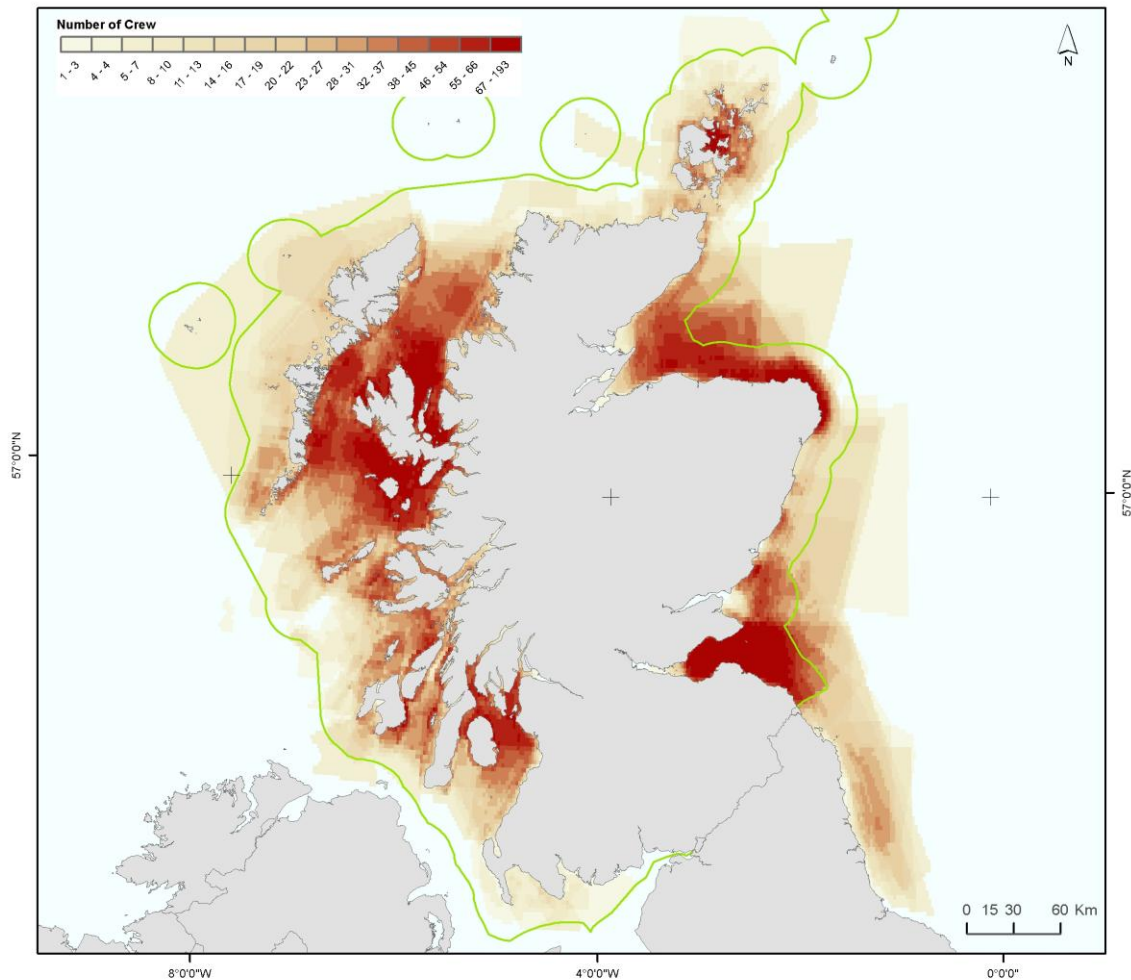


Figure 13: Distribution of the number of crew from all interviewed vessels.

There is a close spatial correlation between the number of vessels and the number of employees (Figure 13). This is to be expected as the number of employees per cell is essentially a function of number of vessels. The average number of crew recorded for smaller vessels (<10 m), is typically one or two as compared with anything between three and five on larger (> 10 m) trawlers and dredges and scallop dive vessels.

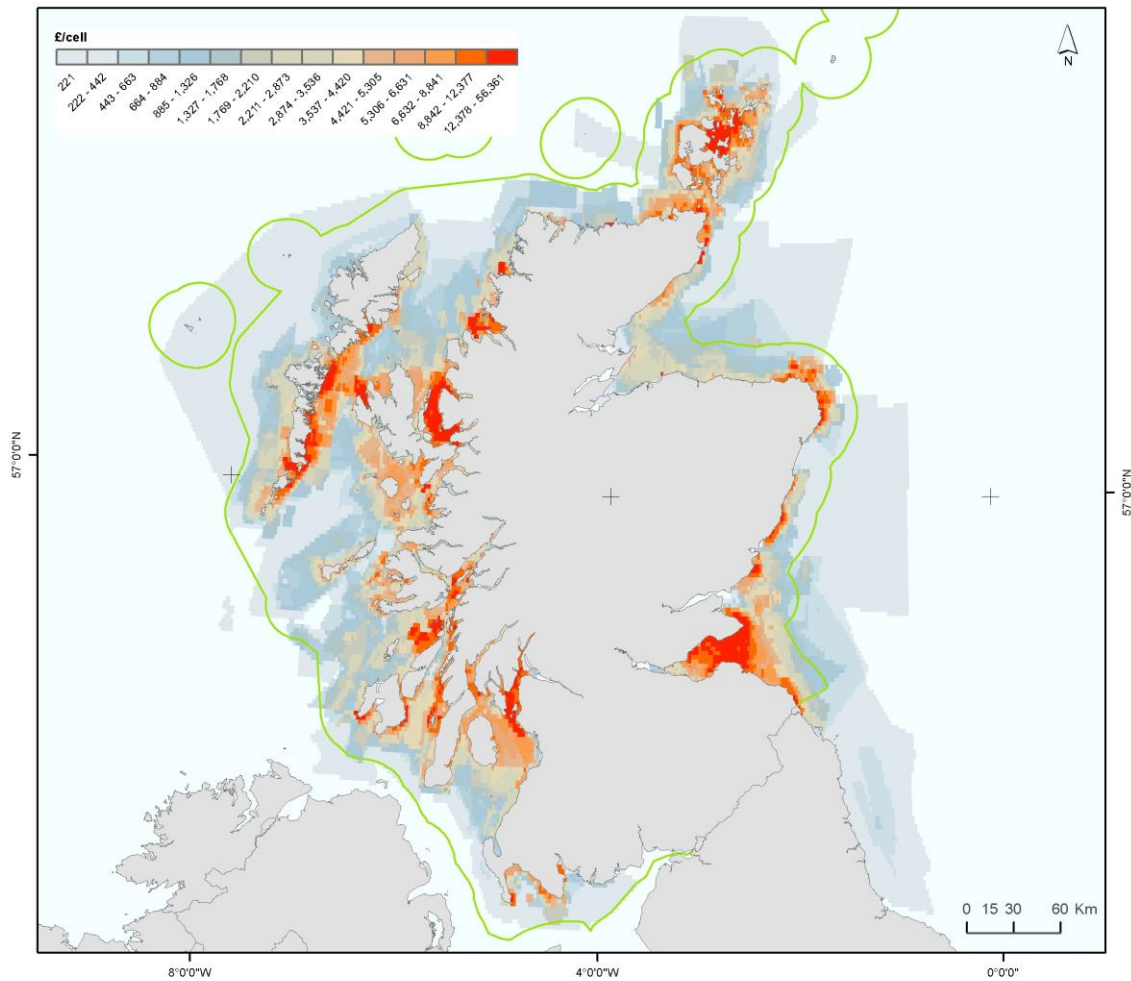


Figure 14: Distribution of monetary value from all interviewed vessels.

On the aggregated value map, data from all interviews combined (Figure 14), the highest value areas are generally within 3 NM of the coast. The distribution of value, classified on a national scale, reflects the distribution of fisheries for high value species e.g. lobster and creel caught *Nephrops*, areas of high vessel activity and, in some cases, relatively small areas where the larger, higher earning vessels fish. The aggregated value map provides useful synoptic information but is probably best interpreted in conjunction with the fisheries breakdowns (above) particularly if working in a regional context. It should be emphasised that the data are likely to under-represent value in regions where a high proportion of interviewees declined to give earnings information or where interview coverage was poor.

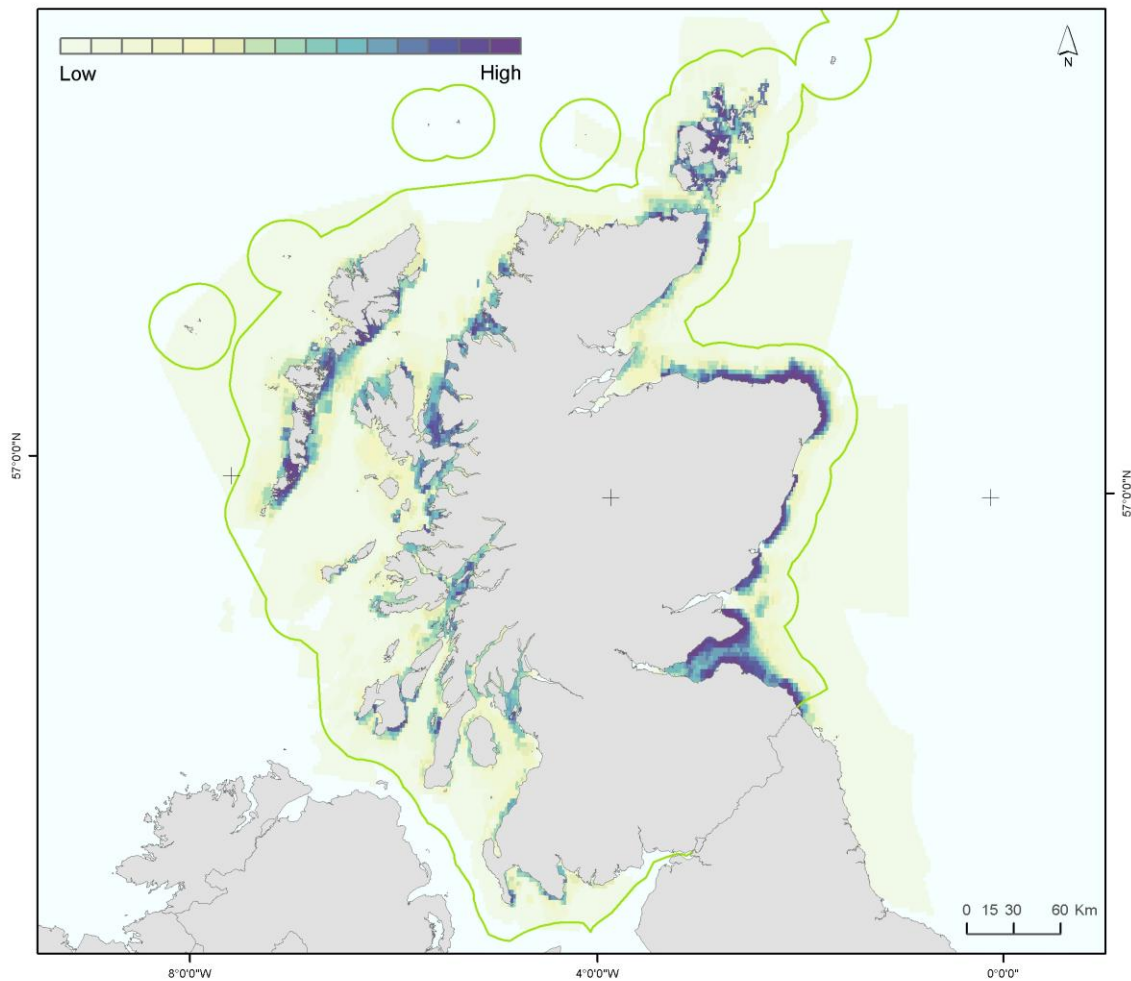


Figure 15: Distribution of relative value from all interviewed vessels.

The map of relative value (Figure 15) provides an alternative representation of the importance of fishing. Because it is based on the percentage contribution sea areas make to vessel earnings, rather than the absolute value, it is less influenced by species value or high earning vessels. Areas of highest relative value are, in general, those where there are numerous overlapping polygon extents or areas where there are intermediate numbers of small polygons (e.g. with extents comparable to the size of a cell). All of the highest relative value cells map close inshore, within 3 NM. This reflects the distribution of creel fishing, its representation in the interview sample and its predominantly inshore distribution. Relative value can be a useful indicator of sea areas of particular importance to remote communities, e.g. north of Kirkwall and around Westray and North Ronaldsay, which are less evident on a value map. Relative value is also robust to missing earnings data. In this study it is a better indicator of the important creel fishing areas on the north coast of the Moray Firth than the value map.

Aggregated data outputs from ScotMap are available on [Marine Scotland Interactive](#) (MSi) and [National Marine Plan Interactive](#) (NMPi) websites as pdf maps and downloadable raster data sets.

6. Discussion

The data collected during the ScotMap project show that Scottish registered vessels under 15 m in length fish all around Scotland and in some cases more than 12 NM from the shore. From the aggregated data it is possible to distinguish areas of relatively high fishing activity and/or fisheries value. Mapped outputs from ScotMap provide information on the distribution of fishing, both in terms of where different types of fishing take place and the economic importance of different sea areas, at a much higher spatial resolution than was previously possible i.e. at the level of ICES statistical rectangles. Any use or interpretation of the outputs should, however, take account of the information on which they are based, particularly the extent to which they represent all the relevant fishing activity within an area and also the accuracy of the information provided.

Although the majority of fishermen contacted for agreed to be interviewed and many were enthusiastic about the project, a proportion of skippers declined to take part or to provide earnings information. In some areas it was not possible for interviewers to make contact with all the vessels on the initial target list. On the basis of analyses of interviewed versus non-interviewed vessels, there is appears to be some regional variation in the refusal or contact failure rate. This will affect the outputs and variation in interview coverage should be recognised by users of the data.

The representations of the vessel number and value of fishing in different sea areas are based on the spatial (the fishing polygons) and value information (the estimates of average annual gross earnings and percentage associated with each polygon) that fishermen provided. Whilst it is possible to check fishermen's estimates of earnings against those of landings as recorded on FIN, it is much more difficult to validate the accuracy of the spatial data, there being no alternative source of information at such fine spatial scales.

For validation of the spatial aspects the project relied on feedback provided at the consultation meetings, particularly that regarding the location, extent and areas of highest intensity of the different fisheries as indicated by the maps. Attendees generally had good local knowledge and, in some cases, knowledge of fisheries elsewhere and were able to offer informed comment. ScotMap also benefitted from

the involvement of Marine Scotland Compliance in the data collection and validation process, Compliance staff having detailed knowledge of the fisheries and fishing practices in their locales. At most meetings there was good agreement about the main fisheries identified, their location and the foci of activity, and the feedback received provided reassurance that the aggregated data were a good, and in some cases an excellent, representation of fisheries on a regional basis. Several comments were made about the extent of certain fisheries implied by the aggregated data; the maps indicating that fishing, albeit at low intensity, takes place on grounds which are known to be unsuitable for particular species or fishing method. It is thought likely that these reflect the size of polygons and variable precision with which fishermen delineated their fishing areas. There was a lot of variation in these parameters, often related to fishing gear. Creel fishermen typically identified more small and more closely defined fishing areas than trawl or dredge fishermen, whose fishing areas were generally mapped as one or two large polygons. On finer spatial scales unrealistic extents may be an artefact, a result of the gridding process which does not take account of the extent of polygon/grid cell overlap.

Maps of the monetary value of fisheries were presented at consultation meetings, for individual fisheries and for all gear/species combined. It was recognised that spatial distribution of landings value for specific fisheries generally reflects activity (number of boats) and that value for mobile gear fisheries e.g. trawl and dredge fishing value tends to be dispersed over large areas compared to that for creel fishing. However, when data for all fisheries are combined, high value species, such as lobster and creel caught *Nephrops*, have a strong influence on the distribution of value. Perceptions of value, which are high and which are low value areas, can also be affected by the classification of the raster data, the breakpoints and the colours used in the maps.

Concerns most commonly expressed at consultation meetings were those regarding interview coverage, and the effects of missing earnings data and non-interviewed vessels on the value maps. Some queried whether fishermen had reliably estimated gross earnings. We have since compared the value of landings as reported on FIN with fishermen's estimates. There is no evidence of any systematic bias and if anything a slight tendency of fishermen to underestimate gross vessel earnings. The analyses of landings data for interviewed and non-interviewed vessels indicate that coverage was poorest in the Clyde and South West SMR and in some parts of the West Highland SMR, and this was borne out by comments made at some of the consultation meetings. Overall, the data are likely to under-represent the value of fishing by under 15 m vessels, particularly in regions where coverage is poor. The

spatial representation of the extent of fishing will also to be less robust in regions where interview coverage is poor.

Notwithstanding the above, data outputs from the ScotMap project have already made an important contribution to marine spatial planning in Scottish waters, particularly in regional evaluations of the potential impacts of renewable energy development and marine protected areas. To date, most emphasis has been placed on absolute monetary value and because of this various ways of raising the interview data to account for non-interviewed vessels and to combine data from ScotMap with that of the VMS monitored fleet have been developed⁸. The relatively coarse (five year) time scale of ScotMap assumes that fishing patterns are reasonably stable both in space and time. Whilst the assumption of stable spatial extent is probably reasonable for static gear fisheries, it is less so for mobile gears e.g. trawling and dredging. In both cases the value of landings and the distribution of value is likely change over time in relation to changes in the markets, stock abundance and alternative fishing opportunities. The period for which ScotMap data will remain relevant will therefore need to be assessed. VMS systems are being fitted to vessels between 12 and 15 m in length but it will be some time before data are available. In response to the need for better data upon which to better manage Scotland's inshore fisheries, various options including repeating ScotMap, data loggers systems (e.g. Succorfish) and improving spatial resolution of landings information through fishermen's logbooks scheme are being considered. Some of these will be addressed in a series of pilot studies funded under the European Fisheries Fund (EFF) in 2014-15⁹.

It is important to recognise that ScotMap's main strength is in the provision of synoptic information and that there will be limits to its accuracy, particularly at fine spatial scales. The potential of the data collected to inform marine spatial planning and fisheries management has yet to be fully explored. Future analyses to map fishing effort and alternative ways of representing the relative importance of fishing grounds at the regional level are being considered. The latter is particularly relevant

⁸ Kafas, A., Davies, I, McLay, A, Gubbins, M., and Beth Scott (2014) New perspectives on fisheries: Combining the distributions of inshore and offshore commercial fisheries in Scotland. Proceedings of the 2nd International Conference on Environmental Interactions of Marine Renewable Energy Technologies, Stornoway, Scotland.
http://tethys.pnnl.gov/sites/default/files/attachments/EIMR2014_209_Kafas.pdf

⁹ Seafish Inshore fisheries project - Evidence Gathering In Support of Sustainable Scottish Inshore Fisheries.
<http://www.seafish.org/research-economics/evidence-gathering-in-support-of-sustainable-scottish-inshore-fisheries>

in remote areas where income from fishing has a relatively low absolute monetary value, but where fishing nevertheless plays a crucial role supporting small communities. The data collected as part of ScotMap interviews, could be useful in wider socio-economic analyses, when eg used in conjunction with other information on population and employment.

The ScotMap project is considered to have been successful at various levels. In many areas there was very good uptake by fishermen who welcomed the opportunity to get inshore fishing better recognised in the context of marine spatial planning. The interview approach, although labour intensive, enabled an extremely useful data set on recent fishing activity for the under 15 m fleet to be compiled over a relatively short period of time. The project brought together staff from different parts of Marine Scotland and promoted wide ranging discussion with fisheries stakeholders on the development of marine spatial planning in Scotland, the policy drivers, plans and proposals and the evidence base.

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