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ScotMap: Participatory mapping of inshore fishing activity to inform marine spatial planning in Scotland

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ABSTRACT

A detailed understanding of fishing activity in Scottish waters is required to inform marine spatial planning. Larger fishing vessels are fitted with Vessel Monitoring Systems (VMS) offering spatial information on fishing activity. VMS does not cover smaller vessels (under 15 m), which fish predominantly in inshore waters where the competition for space is often greatest. To improve knowledge of the distribution of fishing activity and value of fisheries in Scotland's inshore waters, Marine Scotland conducted a participatory fisheries mapping project, known as ScotMap. The data were collected during face-to-face interviews with 1090 fishermen of Scottish registered commercial fishing vessels under 15 m in overall length and relate to fishing activity for the period 2007–2011. Interviewees were asked to identify the areas in which they fish, estimate the contribution these areas make to vessel earnings, and to provide associated information. The majority of interviews relate to creel fishing. The data collected were aggregated to provide mapped outputs of the monetary value, relative importance to fishermen and the usage of the seas around Scotland (number of fishing vessels and number of crew). ScotMap outputs provide information on the locations of inshore fishing activities and the economic importance of different sea areas at a much higher spatial resolution than was previously possible. Outputs have informed marine policy development, provide a valuable resource for marine spatial planning in Scotland and illustrate how participatory mapping can generate useful resources on the location and importance of inshore fishing areas.

1. Introduction

Scotland has one of Europe's largest commercial fishing fleets with 2030 working vessels, around 4800 fishers and landings valued at ca. £514 million in 2014 [1,2]. Seas around Scotland support a variety of fisheries which have an extensive spatial distribution. Spatial information on the activity of larger vessels (over 15 m [40] in length) is available from satellite-based Vessel Monitoring Systems (VMS). VMS offer bi-hourly location data which can be linked to landings information [3,4]. While larger vessels dominate the Scottish commodity market, smaller fishing vessels (ca. 82% of the Scottish fleet) are particularly important for employment, coastal community welfare and cultural contribution [5,6]. From 1 January 2012, all vessels over 12 m in length fishing in EU waters have been required to carry VMS. This, however, is a relatively recent development and for the remainder of the Scottish fleet, information on the distribution of fishing activity is limited and based primarily on landings data which are reported at the International Council for the Exploration of the Seas [ICES, [7]] statistical rectangle level. The area of ICES rectangles around the Scottish coast varies from 3132 km^2 to 3584 km^2. Landings data are therefore of relatively poor spatial resolution and of limited utility for marine planning.

Smaller vessels fish mainly in inshore waters where the competition for space is often greatest. Reliable spatial data help marine users better represent their activity and can protect their interests in situations where they may conflict with other user groups [8–14]. Increasingly, plans for new marine uses in Scotland e.g. offshore renewable energy [15] and marine conservation, particularly through the designation of Marine Protected Areas (MPAs) [16,17] have catalysed progress in Scottish marine planning, leading to the preparation and adoption of a statutory National Marine Plan [18]. As part of this process, the need for better information on the under 15 m commercial fishing fleet was highlighted [18,19]. To fill this data gap, an inshore fisheries mapping project, known as ScotMap, was carried

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out. The topic of mapping fisheries resources and exploitation patterns through participatory mapping has been of interest in the literature due to its ability to generate reliable, quick, and low cost data. The methodology for this study, which is based on face-to-face interviews with fishermen, was originally developed for the FisherMap project by des Clers et al. (2008) and subsequently modified for use in the Finding Sanctuary project and other Marine Conservation Zones (MCZ) projects in England and Wales [21]. Fisheries mapping literature includes similar case studies in other geographical areas, methodological considerations, and extensions to the methodology followed here e.g. evaluating the sustainability and environmental impacts of coastal fisheries [22–29]. In particular, Shepperson et al. [25] considered the methodological accuracy of participatory mapping by studying the effect of sample size and scale on the concurrence between fisher derived (e.g. interviews) and independently derived (e.g. VMS) information. They concluded that participatory mapping can provide data of a similar accuracy to conventional scientific data that are of particular use in data poor situations, but advised that caution should be taken as agreement between the two is significantly affected by the sample size. This study overcomes the issues of sample size by targeting the entire under 15 m fleet around Scotland.

The aim of this study was to collect detailed, spatially resolved information on commercial fishing activity of under 15 m vessels around Scotland, including: definition of the areas fished, seasonal usage, species fished for, fishing method/gear used, number of people employed, and contribution of different sea areas to income from fishing. The ScotMap methodology was first piloted to map commercial fisheries in the Pentland Firth and Orkney waters in 2011 [19] and the approach was extended to other sea areas around Scotland in 2012 and 2013.

2. Materials and methods

2.1. Vessel target list

All under 15 m commercial fishing vessels with an active fishing licence entitlement as of April 2011 and administered in Scottish ports, excluding those administered in Shetland, were targeted for interview. The list comprised 1510 vessels. Shetland registered vessels were covered as part of a separate study [30].

2.2. Interview methodology & data collection

Face-to-face interviews with individual vessel owners and operators to map fishing activity were conducted around Scotland between June 2011 and March 2013. Participants were asked to identify fishing areas (polygons) and associated primary and secondary target species and gears used (Table 1). Participants could identify one or more polygons depending on how they described their individual fishing patterns. For example, if participants used more than one fishing method within the same area, this was represented as separate polygons. Interviewees were also asked about their average annual gross earnings from fishing over the preceding five years (monetary value), and an estimate of the percentage contribution that each fishing area identified made to their gross vessel earnings (relative economic value) over the five year period. Information about the fishing vessel, crew, home and landing ports, and fishing history was also recorded. The reference year for the study was 2011; the data collected thus relate to the period 2007–2011. All 38 interviewers had first-hand knowledge of Scottish fisheries and comprised fisheries compliance staff, government scientists, contractors and fishing industry representatives. A data collection and treatment protocol, and a consent form were provided and discussed with participants prior to the interview. After the interview, all participants were sent a personalised summary report of the information they provided. These reports served as a participant record and provided an opportunity for participants to check their data, reconcile any anomalies and rectify interview records, as appropriate. Revisions received were incorporated in the data set. The documents ensured that the research was conducted to high ethical standards and protected privacy and anonymity of interviewees.

Interview data were recorded electronically using ESRI ArcMap 9.3.1 [31] combined with a dedicated software plugin, the ScotMap Graphical User Interface (GUI). The ScotMap GUI is a modified version of ArcFish, a customisation of the interface of ESRI's ArcGIS software developed as part of Balanced Seas MCZ project by the University of Kent [21,32].

2.3. Data analysis

The interview data were checked for any obviously erroneous data. The cleansing process included rectification of typing errors, validation of target species nomenclature, and interrogation of any incompatible gear/target species combinations. It also included checks of vessel names and respective registration numbers and removal of duplicated records.

A comparison of fisher self-reported estimates of average annual gross earnings with the respective administrative landings data as recorded on the governmental Fisheries Information Network (FIN) [33] was undertaken to identify potentially mistyped earnings estimates and explore systematic interview errors of over-/ under-estimation.

Fishing areas, complemented by attribute information, were gridded to produce mapped outputs providing information on:

i. the economic importance of different sea areas around Scotland (monetary value),
ii. an alternative representation of ‘the value of fishing’ and the most important grounds that the inshore fishing communities depend upon in different sea areas around Scotland (relative economic value), and
iii. fishermen's use of the seas around Scotland (number of fishing vessels and crew).

A fine 0.025×0.05 degree grid with an average cell size of 4.20 km^2 was used for all mapped outputs. 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. Attribute values were distributed uniformly to all overlapping grid cells irrespective of the proportion overlap. All analysis was undertaken in R statistical software [34].

2.4. Monetary value

The average annual gross vessel earnings from fishing (E_n) and fishing area percentage contribution to gross vessel earnings (p_n is the fraction of contribution) were combined to map the distribution of monetary value ($p_n \times E_n$). A regular grid was overlaid with each polygon (n), and the polygon monetary value was divided by the number of grid cells falling within the polygon (M_n). Polygon monetary value on each grid cell was calculated by equally distributing the polygon monetary value to all overlapping grid cells, irrespective of the extent of the overlap (Fig. 1a). This process was repeated for all polygons (N) and the values associated with each grid cell were finally summed to produce a single gridded dataset.

$$\textit{Monetary value} = \sum\nolimits_{n=1}^{N} \frac{p_n \times E_n}{M_n} \quad (1)$$

2.5. Relative economic value

For relative economic value, the fishing area percentage contribution to gross vessel earnings was divided equally among the over-

Table 1
Summary of data collected during interviews.

Category	Data	Description
Fishing pattern	Species	Primary and secondary target species (if applicable)
(Data relating to each fishing area identified)	Gear	Gear class, type and gear parameters e.g. mesh size
	Percentage earnings	Fishermen's estimate of the percentage contribution each fishing area (polygon) made to the gross vessel earnings, on average over the past five years. Reference period 2007–2011.
	Seasonality	Months in which fishing takes place
	Intensity	Days per year an area was 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 and UK vessel registration numbers (Port Letter and Number - PLN and Registry of Shipping and Seamen - RSS)
	Length	Overall vessel length (m)
	Power	Engine kW or horse power
	Home port	Main port of departure
	Landing port(s)	Landing or destination port(s)
	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

lapping grid cells before being summed to produce a gridded data set (Fig. 1b).

$$\textit{Relativeeconomicvalue} = 100 \times \sum_{n=1}^{N} \frac{p_n}{M_n} \qquad (2)$$

2.6. Number of vessels and crew

The number of vessels in each grid cell represented the sum of the number of polygons which overlap the cell (partially or completely). For the analysis of number of crew, the average number of crew working on a vessel was allocated to each overlapping grid cell and the number of crew associated within each grid cell was summed (Fig. 1c). Rasters for both number of vessel and crew were aggregated to a minimum of three vessels per cell to ensure data privacy.

The same analyses were applied to a series of gear/target species combinations, subsets of the data which equate to the main fisheries prosecuted by the Scottish under 15 m fleet. Details and outputs can be found in the Supplementary material. All ScotMap outputs are available on the Scottish National Marine Plan Interactive website (www.gov.scot/nmpi).

2.7. Validation

Following data collection and analysis, 15 local consultation meetings around Scotland were organised to qualitatively validate regional mapped outputs and collect feedback from fisheries stakeholders.

A quantitative evaluation of interview coverage for different sea areas was undertaken at the ICES statistical rectangle level. Percentage landings coverage for each ICES rectangle was calculated by splitting reported landings contribution between interviewed and non-inter-

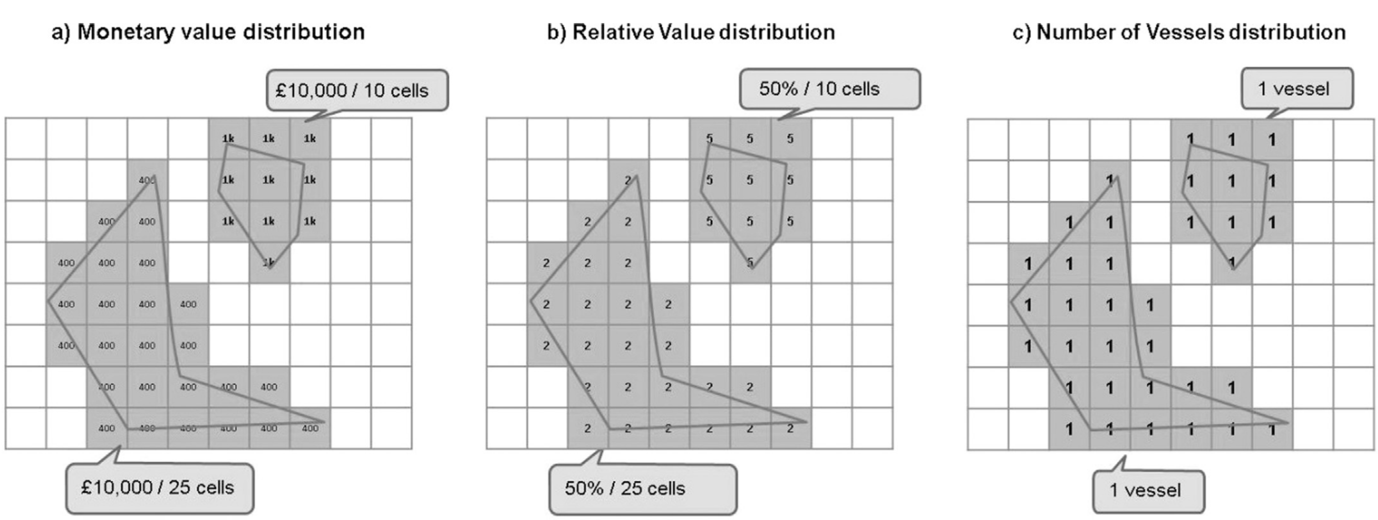

Fig. 1. Illustrative example of a fisherman earning £20,000 per annum from two fishing areas (a). Both areas contribute equally to the fishermen's earnings i.e. 50% each (b). The fisherman uses one vessel in both areas (c). The methodology used for number of vessel distribution was also used for the number of crew distribution.

viewed vessels. FIN-reported landings value averaged for 2010–2011 were used.

2.8. Addressing gaps in the interview coverage

Not all of the vessels on the target list were successfully interviewed and not all skippers disclosed earnings information. In an attempt to compensate for this, a method which combined landings value data from interviewed and non-interviewed vessels was developed. This involved distributing the value of officially reported landings of non-interviewed vessels uniformly across the ICES statistical rectangle(s) to which landings were reported. These values were then added to a monetary value layer derived from areas extents indicated by the interview data but with value from the official landings data. This method was used for all gear/species combination with the exception of *Nephrops* trawlers. In this case, the total value of non-interviewed vessels was uniformly distributed to the combined area outline of all fishing areas identifying by interviewed *Nephrops* trawlers (dissolved spatial extent), rather than the ICES rectangle. The areas defined by interviews in this grouping, and their close association with the mud and muddy sand habitats where *Nephrops* are found, indicated the interview data were a reasonable predictor of the fishery distribution. This alternative representation of value based on official reported landings value, also obviated possible effects of under or over estimation of landings values in the interview data and interviews where skippers declined to give landings information.

3. Results

3.1. Interview coverage

The dataset comprised interviews with 1090 fishermen who collectively identified 2634 fishing areas. Data from 24 additional interviews which were missing essential information or where recording had failed for technical reasons, were excluded. Excluded data accounted for ca. 1% of annual reported landings value averaged for 2010 and 2011. The fishing areas mapped were of variable size (Fig. 2) and the majority of the areas related to creel (pot) fishing (Fig. 3). Variation in size was often related to fishing gear. Creel fishermen and other static gear operators typically identified smaller and more closely defined fishing areas than trawl or dredge fishermen, whose fishing areas were generally mapped as one or two large polygons. In total, 72% of the vessels initially targeted for the study were interviewed. Some fishermen declined to take part or others could not be contacted. The response rate varied regionally (Fig. 4). Overall, interviewed vessels accounted for 74% of the Scottish annual under 15 m fleet reported

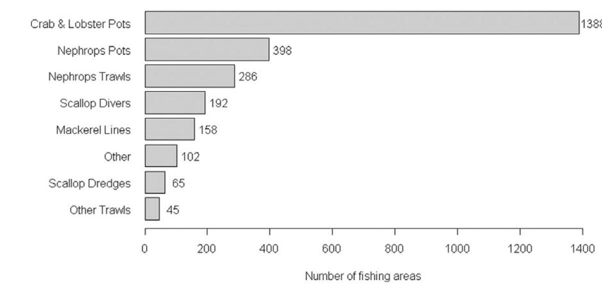

Fig. 3. Number of gear/species polygon combinations representing the main fisheries prosecuted by the Scottish under 15 m fleet as recorded in ScotMap.

landings value (averaged for 2010 and 2011). Eighty six of the skippers interviewed (10%) declined to disclose vessel earnings information. The monetary value mapped outputs were therefore based on information from 1004 interviews.

The quantitative evaluation of interview coverage on the basis of reported landings for individual ICES statistical rectangles indicated considerable variation in spatial coverage (Fig. 4). Poor vessel response rates (Ayr & Campbeltown, Portree, Ullapool, Kinlochbervie) and high decline rates (South West & Clyde area, West Highlands) were reflected in the spatial coverage. However, the total value of annual landings varies greatly between ICES rectangles (£1 K < value ≤£5.5 M). As a result, low percentage coverage for some rectangles is associated with a very small quantities and value of landings (e.g. rectangle 48E6 – 8% of ca. £11 K; Fig. 4) rather than poor vessel response rates.

3.2. Mapped outputs

Mapped outputs for all ScotMap interviews show the distributions of the monetary value, relative economic value, and number of vessels and crew (Fig. 5). The distribution of monetary value (Fig. 5A1) provides useful synopsis of the economic importance of different sea areas around Scotland to the Scottish under 15 m commercial fishing fleet. However, the value map under-represents value in regions where interview coverage was low or a high proportion of interviewees declined to give earnings information. An alternative representation of value, which incorporates landings value from all interviewed and non-interviewed vessels as officially reported in FIN is shown in Fig. 5A2. Superficially, the distribution of value indicated by the two maps is very similar. Fig. 5A2 indicates higher value in the Firth of Tay and Moray Firth areas and the North Minch west of Ullapool than Fig. 5A1. At finer spatial scales more differences are evident.

Areas closer to the coast are generally more economically important

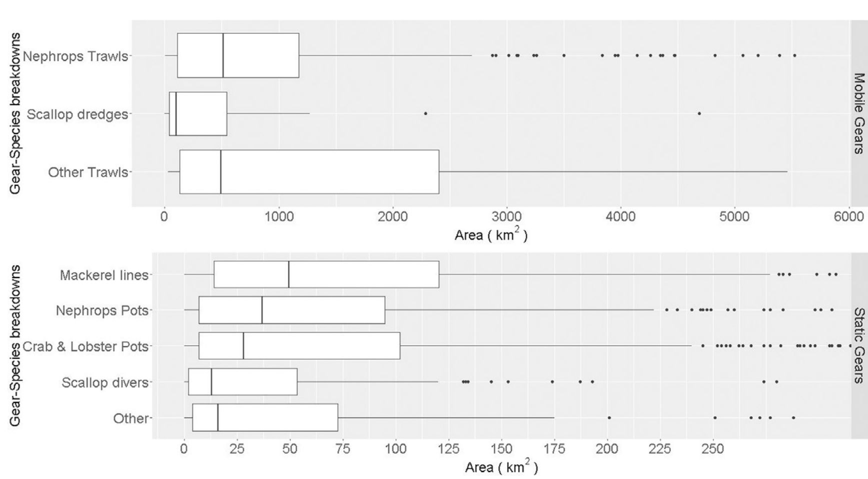

Fig. 2. Size of fishing areas per vessel by gear/species combinations grouped by mobile and static gear types representing the main fisheries prosecuted by the Scottish under 15 m fleet as recorded in ScotMap. Some outliers have been excluded for visualisation purposes. A boxplot with all fishing areas are shown in Supplementary materials (Supplementary 1).

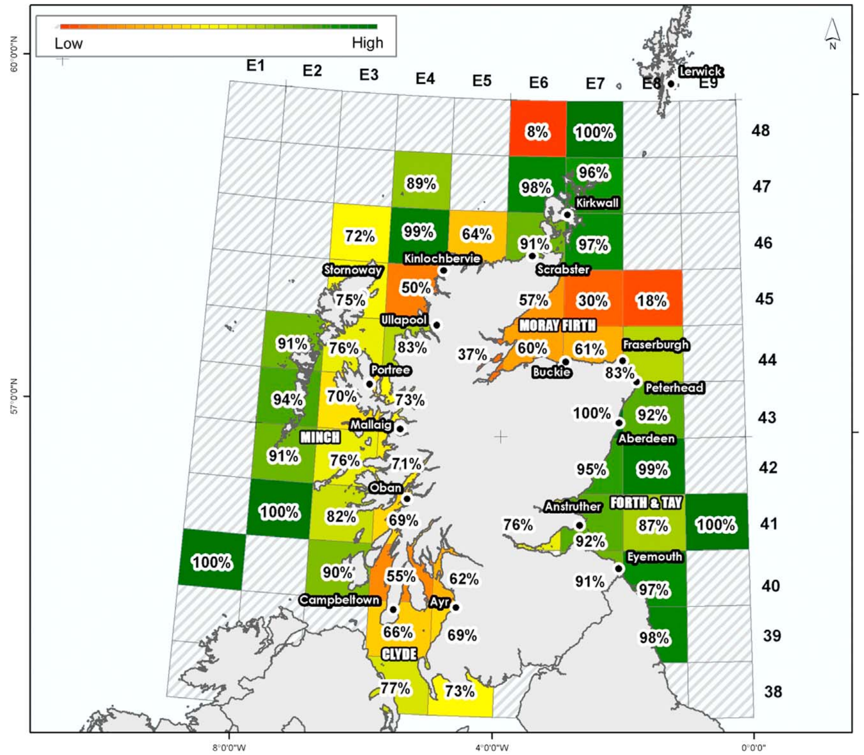

Fig. 4. Percentage of the total annual value of under 15 m vessel landings as reported on FIN (averaged 2010/2011) by ICES rectangle accounted for by vessels successfully interviewed for ScotMap Locations of Scottish fishery district offices and marine area names are also shown.

for the under 15 m fishing fleet with the highest value fishing areas within 3 nautical miles (NM) of the coast (Fig. 6).

The distribution of the relative economic value (Fig. 5B) provides an alternative representation of the importance of fishing. Similar to the monetary value map, it shows that the grounds which are most important to the inshore fishing community are located close inshore, within 3 NM.

Vessel number (Fig. 5C) indicates that under 15 m vessels fish all around the coasts of Scotland, and in some cases more than 12 NM from the coast. The main foci of activity (i.e. extensive areas with relatively high numbers of vessels per cell) were 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 was concentrated within 6 NM of the coast.

The number of employees per cell is essentially a function of number of vessels. As a consequence, the number of vessels and the number of employees mapped outputs (Fig. 5D) were very similar. The typical number of crew recorded for smaller creel vessels (< 10 m), is one or two as compared to between three and five on larger (> 10 m) trawlers and dredges and scallop dive vessels.

3.3. Validation

Mapped outputs from ScotMap for individual fisheries and for all gear/species combined were presented to fisheries stakeholders at consultation events. Attendees generally had good local knowledge and were able to offer informed comments. There was good agreement at most meetings about the main fisheries identified, their location and the foci of activity. The feedback received provided reassurance that mapped activity was representative of the under 15 m vessel national fishing activity (Figs. 7–14).

Concerns most commonly expressed at consultation meetings related to the privacy of individuals' data, interview coverage, and the effects of missing earnings data and non-interviewed vessels on the monetary value maps. Some attendees queried the spatial precision of the mapped areas and whether fishermen had reliably estimated gross earnings. Subsequent to the meetings, fisher self-reported estimates of average annual gross earnings were checked against the respective independent administrative data Generally, there was a good fit between interview estimates and official landings. There was evidence of both over and underestimation with a slight tendency of gross vessel earnings overestimation (see Fig. 14 in Supplementary material). It is possible that the timing of interviews, e.g. in respect to proposed policy measures or developments, may have influenced interview responses (Tables 2 and 3).

In general it was agreed that numerous factors in combination could resulted in imprecise mapping of fishing activity or contradict local knowledge, particularly at fine spatial scales. Consultee feedback varied between regions. Table 3 in Supplementary materials summarises feedback received from different regions.

4. Discussion

ScotMap outputs provide information on the location of inshore fishing activities and the economic importance of different fishing areas in Scotland at a much higher spatial resolution than was previously possible. The data collected show that Scottish registered vessels under 15 m in length fish in all inshore marine areas around Scotland and in some cases, beyond 12 NM from the shore. The most important fishing areas, both in terms of usage and value, are closer to shore (< 3 NM from the coast; Fig. 6) possibly due to a range of factors such as fishing range restriction of smaller vessels, distribution of and value of targeted species, nature of the grounds, and grounds available to creels given the competition with mobile gears. Areas of high value reflect the distribution of fisheries for high value species (e.g. lobster, scallops and creel-caught *Nephrops*), areas of high vessel activity and, in some cases, relatively small areas where the larger, higher-earning vessels fish for lower value species. As a result, ScotMap national mapped outputs are probably best interpreted in conjunction with outputs of gear/species combinations (see Supplementary material), particularly

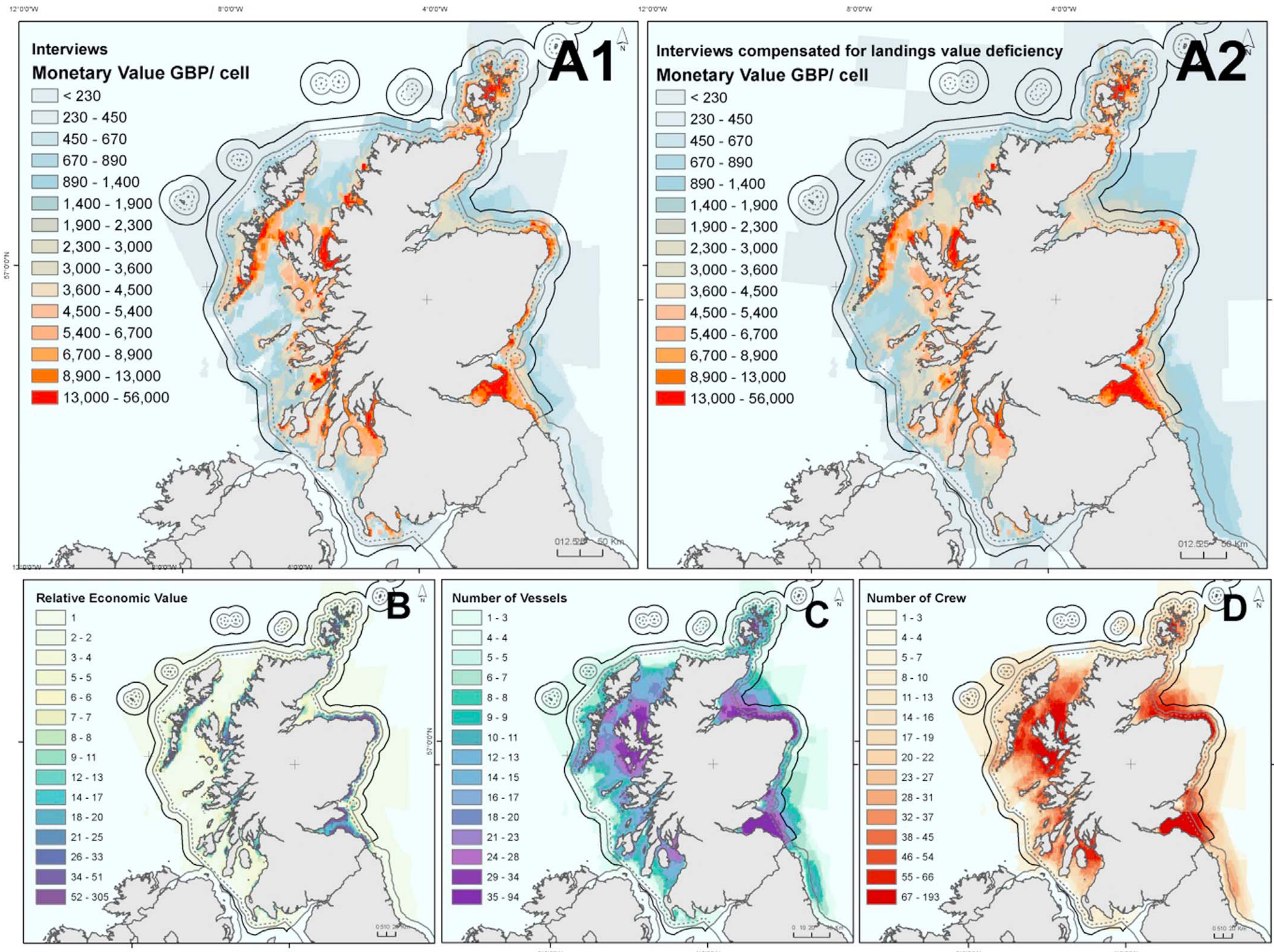

Fig. 5. Distribution of (A1) monetary value from all ScotMap interviewed vessels using fisher self-reported estimates of average annual gross earnings and (A2) Distribution of monetary value for all Scottish registered commercial fishing vessels under 15 m in overall length for the period 2007–2011, derived using official landings value data for interviewed and non-interviewed vessels, distributed according to interview spatial extents and/or across ICES rectangles (see text for details). The same classification system are used to aid comparison. Distribution of (B) Relative Economic Value (C) Number of Vessels, and (D) Number of Crew from all ScotMap interviewed vessels. Administrative limits of 3, 6, and 12 NM from baselines also shown with dotted grey, solid grey and solid black lines respectively.

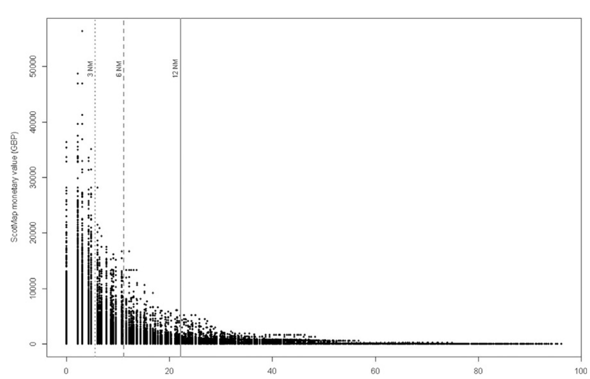

Fig. 6. Monetary value as a function of distance from coast. Raster cells closer to the coast have higher monetary value. Distances of 3, 6 and 12 nautical miles from the coast are shown with dotted, dashed, and solid lines respectively.

if working in a regional context. The size of fishing areas as mapped varies between fisheries, with mobile gears typically occupying a much greater area than static gears e.g. towing in larger areas (Fig. 2). The size of various fishing areas illustrate the current spatial extent of different fishing activities and should be considered with receptor sensitivity characterisation in fisheries management and environmental impact assessments.

The project was considered successful at various levels. The interview approach enabled a rapid compilation of spatial usage over a relatively short period of time. Questionnaire methodology obviated the need for years of monitoring and, for many vessels, has offered more attribute information than traditional GPS loggers (e.g. activity type, gear, species etc.). The verification process put in place ensured the high quality of the outputs. The project had very good uptake from the people involved and helped build rapport with fishing industry stakeholders. The project achieved an impressive interview coverage compared to other participatory mapping studies (e.g. Brown & Kytta 2014 [35]), accounting for 75% of Scottish inshore landings and 72% of the under 15 m vessels in Scotland.

Mapped outputs have already made an important contribution to the evidence provision for marine spatial planning in Scottish waters. Data have been used to support national marine planning in Scotland [18], the sustainable development of offshore renewable energy in Scottish waters [36], and the assessment of impacts on the fishing sector from the management measures of the Scottish Marine Protected Areas [16, 17, 37].

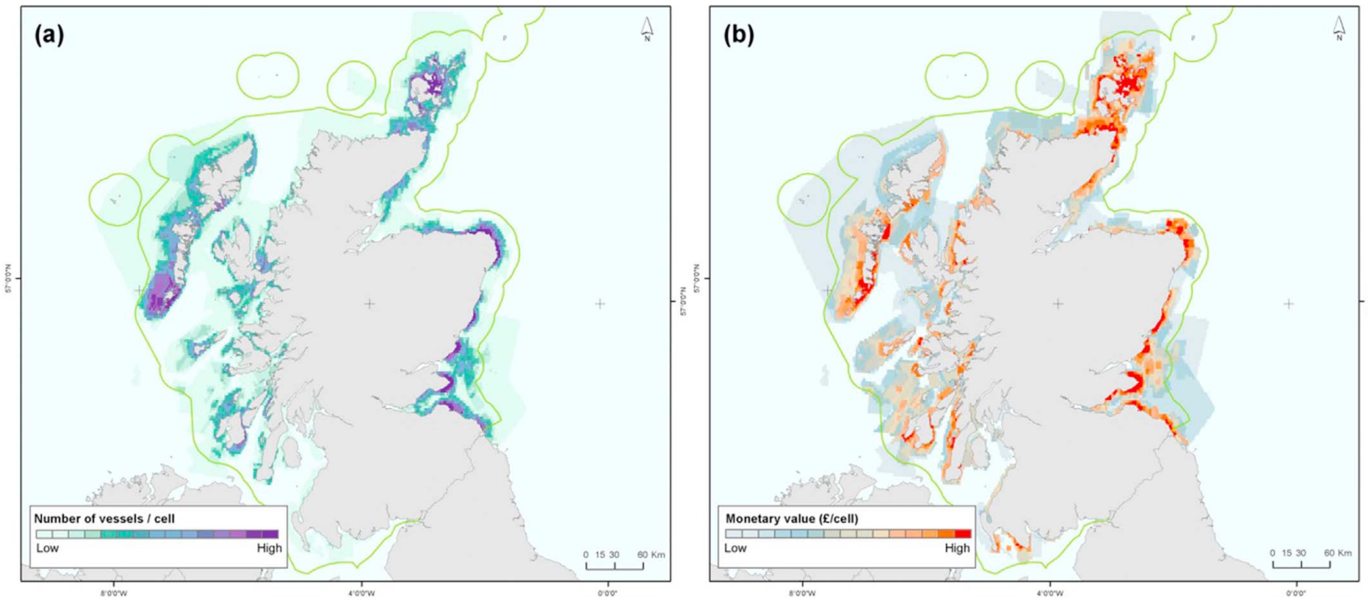

Fig. 7. Vessel number (a) and monetary value distribution (b) for creel (pot) fishing for crab and lobster all species. From polygons identifying crab and/or lobster (brown crab and/or velvet crab, green crab, spider/ spiny crab, common lobster, crawfish, squat lobster) as the primary or secondary target species where the fishing gear is pots.

4.1. Critique of mapped outputs

As with other socio-economic studies [20,29], the robustness of the representation is contingent on survey response rate and low coverage can compromise the accurate representation of fishing areas. As a result, the interview derived value map under represents value in regions where interview coverage was low or a high proportion of interviewees declined to give earnings information. To compensate for missing earnings information a layer of the missing landings value from non-interviewed vessels was added to a landings value layer from interviewed vessels constructed using official landings value data (Fig. 5 A2). The methodology developed helped approximate full coverage in all areas. However, as with any combination of heterogeneous datasets, the layer should be used with caution due to different spatial accuracy of the combined datasets (interview data vs. official landings in ICES rectangles). The layer is also based on the assumption that missing landings value for interview fishing areas identifying Nephrops trawling is sourced from the same areas identified from ScotMap interviews.

The distribution of the relative economic value is a useful indicator of the most important grounds in different sea areas around Scotland. It can highlight areas of importance to local boats and remote communities, e.g. north of Kirkwall and around Westray and North Ronaldsay (less evident on the monetary value map). The relative economic value is based on the percentage contribution of fishing areas to gross vessel earnings. As a result, it is less influenced by high-value species or high-earning vessels, and is also robust to missing earnings data (but not missing vessels).

The numbers of vessels analysis provides information on the spatial extent of fishing and where activity is concentrated (where most boats fish). However, it is not an accurate indicator of fishing effort or associated environmental pressures, since the analysis does not take account of measures of nominal effort (e.g. number of creels or hours fished), and seasonality of fishing which will vary between vessels and according to the targeted fishery. Although provisions to collect this information during interviews were made, the data collected were incomplete in this regard. Relating the spatial footprint derived in this project to, for example, the sea bed abrasion pressure exerted by the activity would require detailed information on the number and frequency of gear deployments.

Overall, the relatively coarse time scale adopted for ScotMap (five year period 2007–2011) 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 due to limited suitable deployment areas, it is less so for mobile gears e.g. trawling, due to vessels ability to move between fishing grounds to meet seasonal variation of target species and adapt to fisheries management measures. In both cases, the value of landings and the distribution of value are likely to change over time in relation to internal factors such as markets, stock abundance, alternative fishing opportunities, fisheries

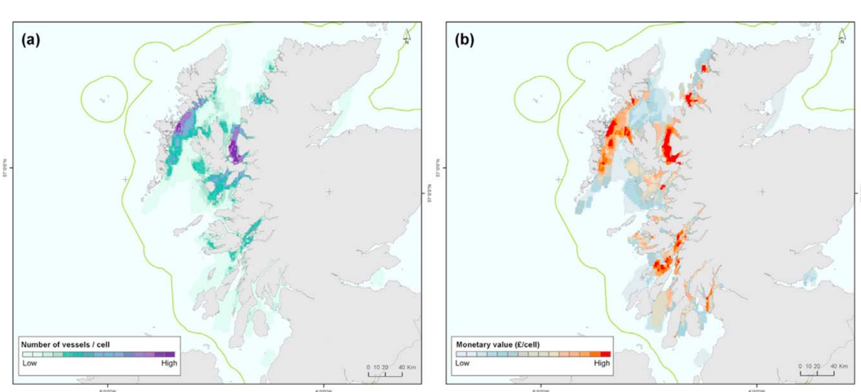

Fig. 8. Vessel number (a) and monetary value distribution (b) for Nephrops creel (pots) fishing.

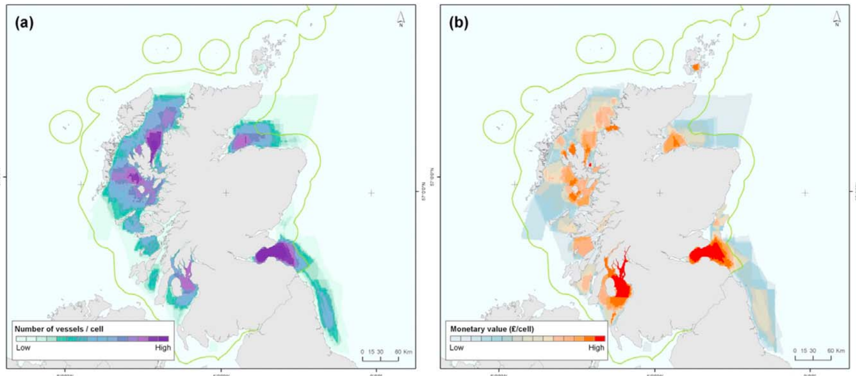

Fig. 9. Vessel number (a) and monetary value distribution (b) for Nephrops trawling.

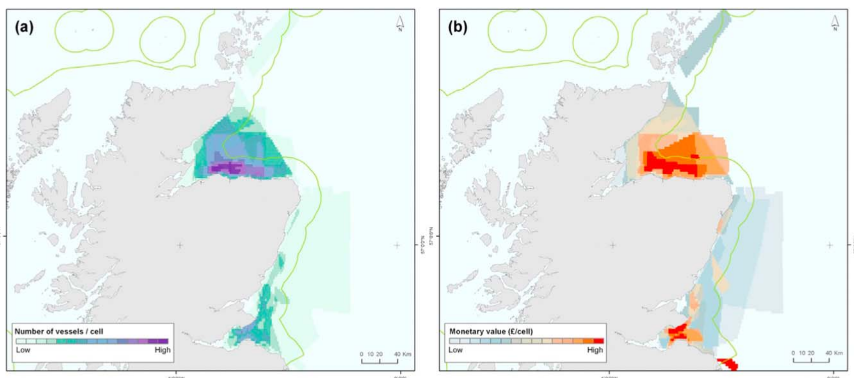

Fig. 10. Vessel number (a) and monetary value distribution (b) of vessels deploying trawl as fishing gear with various target species. Includes common squid predominant target species, as well as haddock, plaice and other flatfish.

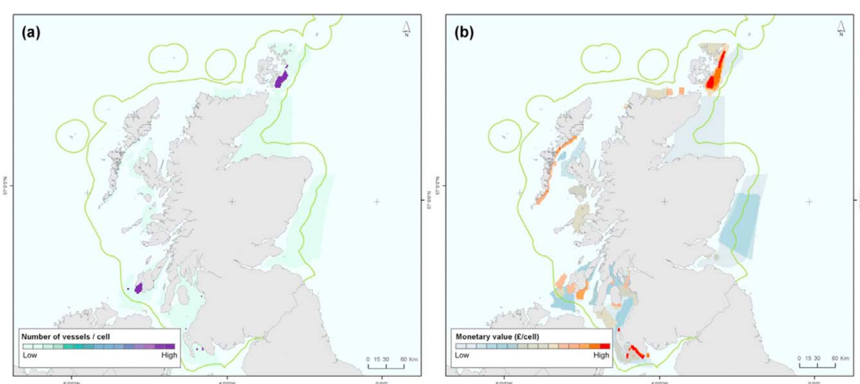

Fig. 11. Vessel number (a) and monetary value distribution (b) for king scallop fishing using towed dredges.

policy interventions and external pressure from wider marine policy e.g. MPAs and other marine users. As a result, the relevance of ScotMap data outputs is likely to decrease over time. It is also expected that outputs for the more dynamic fishing activities e.g. fisheries for species like velvet crabs, or fisheries which are susceptible to boom and bust become less reliable over time.

4.2. Methodological considerations & improvements

The large number of participants and interviewers involved in ScotMap resulted in many logistical challenges and inevitably introduced inconsistencies and variation in data completeness, accuracy, and precision between different interviewers.

The interview methodology is labour intensive and requires significant financial and human resources. Manually compiling and maintaining an up-to-date target list of vessels proved problematic due to the dynamics of the vessel registry and multiple definitions based on administrative harbour, source and/ or location of landings. The process could be improved and the end product could be more complete, if a system of tracking interview returns in real time had been operated, and a means of targeting key vessels for interview had been developed.

Some interviews were missing information. Data on fishing effort and seasonality were sought in the interview questionnaire, but most responses were incomplete (e.g. missing creel numbers, or hours fished). It is thought the lack of information reflects insufficient emphasis being given to collection of these data during interviews. This could be improved by the introduction of mandatory fields and pre-loaded drop down menus in the data collection software. Moreover, one in ten skippers interviewed declined to disclose (see Results section). If the exercise was to be repeated, the use of official reported data could overcome these issues. The use of official data would, however, need to be properly reflected in the consent form so fishermen can have a better understanding of the process.

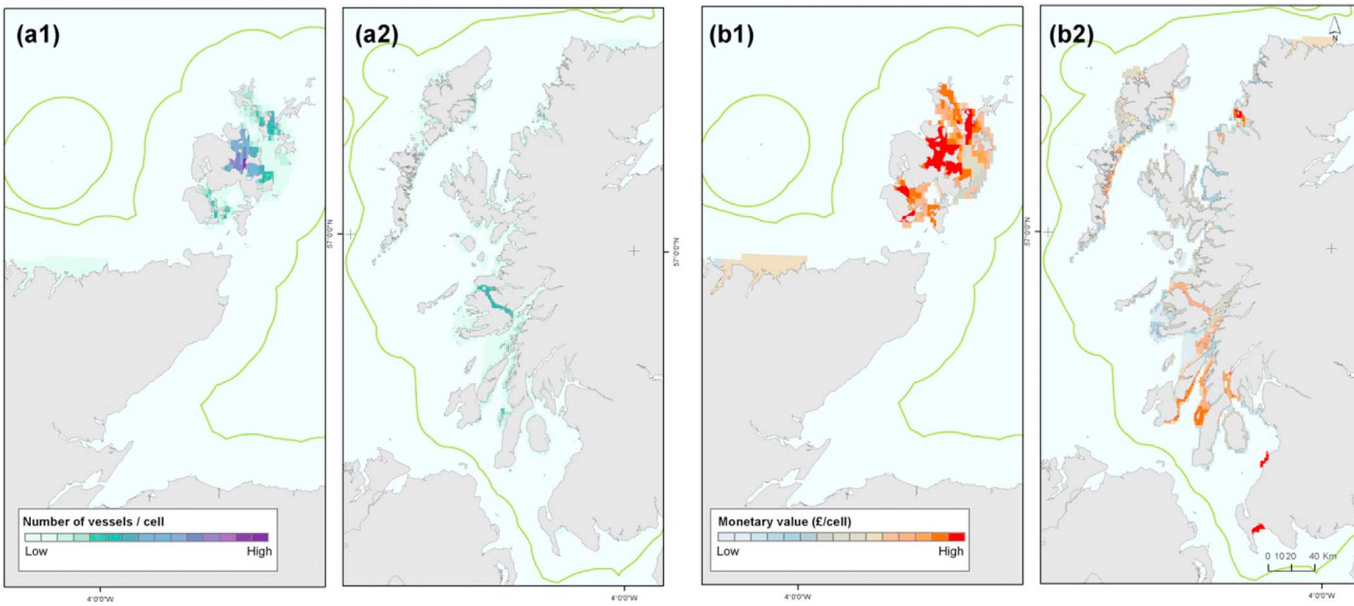

Fig. 12. Vessel number (a1 & a2) and monetary value distribution (b1 & b2) king scallop diving.

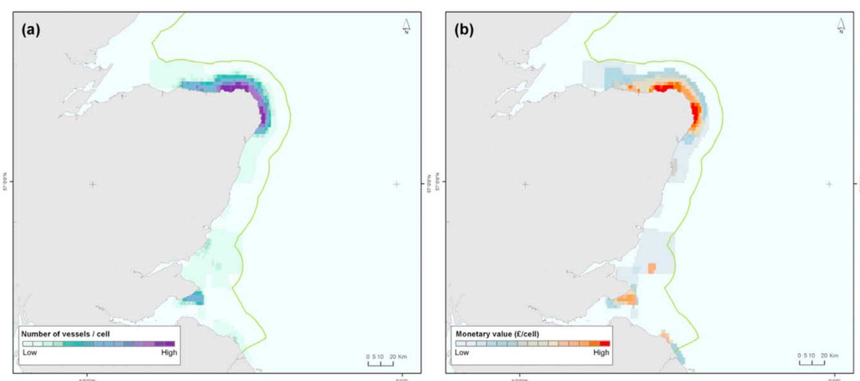

Fig. 13. Vessel number (a) and monetary value distribution (b) for mackerel line fisheries.

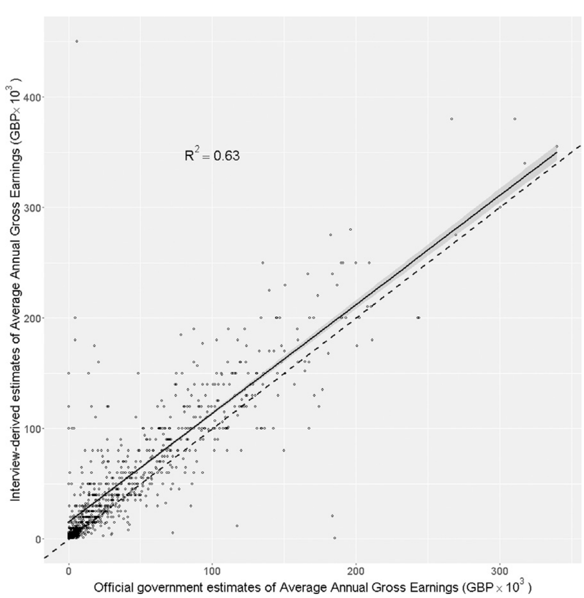

Fig. 14. Comparison of Interview-derived estimates of average annual gross earnings from ScotMap project versus respective official landings data (GBP ×103). 45o diagonal line (dotted) and linear regression line including 95% confidence region (solid) are also plotted to illustrate earnings overestimation.

Accuracy of individual polygons, particularly at fine scales, may be limited. No analytical validation of the spatial accuracy of the data was possible, there being no alternative source of information at such fine spatial scales. Arguably, information on habitats could be used but habitat data at fine spatial scales are also limited. A qualitative verification process, including feedback provided at the consultation meetings, was established instead. Mapping accuracy can be aided by further software improvements including additional map features appearing during data compilation (e.g. near shore bathymetry, zones subject to fisheries or other restrictions, and activity from larger fishing vessels).

Furthermore, fishermen delineated their fishing areas with variable precision (see variance of polygon areas for gear-species combinations; Fig. 2) potentially compromising the precise representation of the extent of certain fisheries in fine spatial scales and sometimes resulted in unrealistic extents. e.g. fishing, albeit at low intensity, taking place on grounds which are known to be unsuitable for particular species or fishing method. Varying precision of area delimitation may reflect some fishermen intentionally protecting the precise location of their fishing activities. Interviewees were given full flexibility of the map scale under which they recorded their spatial information. Software flexibility may have contributed to the variable precision and resulted into inconsistencies between interviews. Data precision could be improved by standardising zoom levels in the ScotMap GUI when recording fishing areas.

Lastly, restricting the number of interviewers to a smaller, specialist

Table 2
Gear-species combinations equate to the main fisheries prosecuted by the Scottish under 15 m fleet. Gear-species combinations were defined by polygons identifying primary target species and a particular gear as listed here.

Gear-species combinations	Target species	Gear used	Remarks
Crab and Lobster Pots	Brown crab (*Cancer pagurus),* Velvet crab (*Necora puber*), Green/ shore crab (*Carcinus maenas*), Spider/spiny crab (*Maja squinado*), Common lobster (*Homarus gammarus*), Crawfish (*Palinurus elephas*), and Squat lobster (*Munida rugose*)	Creels (pots)	In most cases, areas that had any crab species as the primary target species also had lobster as the secondary target species and vice versa. Therefore, polygons targeting crab and lobster were combined together as a mixed fishery.
Nephrops Pots	Norway Lobster (*Nephrops norwegicus*)	Creels (pots)	–
Nephrops Trawls	Norway Lobster (*Nephrops norwegicus*)	Trawls	–
Scallop Divers	King scallop *(Pecten maximus)*	Diving	–
Mackerel Lines	Atlantic mackerel *(Scomber scombrus)*	Lines	–
Scallop Dredges	King scallop	Towed dredges	–
Other Trawls	Common squid (*Loligo vulgaris*; predominant target species), Haddock (*Melanogrammus aeglefinus*), Plaice *(Pleuronectes platessa)* and other flatfish.	Trawl	All other trawl targeted species but *Nephrops*
Other	Whelks *(Buccinum undatum)*, Razorfish *(Ensis spp.)*, Surf clams, Brown shrimps *Crangon crangon)*, Pollack *Pollachius pollachius)*, Cod (*Gadus morhua*), Haddock, Plaice, Salmon *(Salmo salar)*, Herring *(Clupea harengus)*, Mackerel, Skates and rays, Wrasse *(Labridae spp.)*, Bass *(Micropterus salmoides)*, Cockles *(Cerastoderma edule)*, Spotted dogs, and/ or unusual gear/species combinations,		Polygons relating to fishing for other species 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.

Table 3
Consultee feedback by areas around districts.

Areas around districts	Feedback
South East areas (Anstruther and Eyemouth districts)	Fishing activity was captured accurately and was consistent to stakeholder knowledge.
Western Isles (Stornoway districts), Moray (Buckie and Fraserburgh districts) and Pentland Firth & Orkney areas (Kirkwall and Scrabster districts)	Most fishing activity was captured accurately and was consistent to stakeholder knowledge. Activity from creelers in the north coast of the Moray Firth was inaccurate due to high decline rate.
Clyde area (Campbeltown and Ayr districts)	Fishing activity was mostly under represented and was inaccurate at places. Stakeholders felt there was considerable room for improvement. *Nephrops* trawling was mostly representative except between Campbeltown and Girvan. Identified gaps included scallop dredge fishing in the Argyll and Clyde regions, creek activity in the Clyde Sea and Solway Firth areas.
East of Campbeltown, west of Islay, and south of Jura areas (Oban district)	Fishing activity inaccurate at places.
West coast area (Kinlochbervie, Ullapool, Portree, and Mallaig districts)	Fishing activity within lochs was under represented.
North East area (Peterhead and Aberdeen districts)	Fishing activity from mackerel line fisheries was thought to be accurate.

group could positively influence overall data quality. Overall, the above recommendations would be expected to reduce the effort required for data collection/ pre-processing/ and cleansing and reduce the data work-up period of any similar future project and improve the quality of the outputs. However, as with any interview based approach, getting buy in from stakeholders is critical.

4.3. Current developments & future uses of the data

Despite verification efforts, the collected individual data remain fundamentally soft in nature (i.e. data accuracy cannot be guaranteed). Uncertainty makes the data potentially subject to challenge in marine planning. To overcome this limitation, other technological vessel tracking approaches are currently under development. Due to recent changes in legislation [38,39], VMS and Automatic Identification System (AIS; European Council 2000) loggers will be fitted to smaller vessels [41–43], but it will be some time before such data are available and a substantial number of < 12 m vessels will still not be covered by tracking units. However, as with ScotMap, these approaches are likely to come with limitations in terms of fleet and geographic coverage, data analysis and interpretation. A combination of approaches might be required in the future for accurate representation of the use of ocean space by commercial fisheries in marine spatial planning.

The potential of the public participatory mapping data collected to inform marine spatial planning and fisheries management has yet to be fully explored. Future analyses to map fishing effort, seasonality, areas of gear conflict, and alternative ways of representing the relative importance of fishing grounds at the regional level are being considered. The ScotMap methodology could be used to map historic fishing patterns or offer information about areas that fishermen propose to fish in the future. Moreover, it would be of scientific interest to assess the capability of participatory mapping for detecting change rather than offering a single snap shot of a dynamic marine activity. This could be achieved by interviewing the same target list again in the future.

5. Conclusion

Data outputs from the ScotMap project provide information on the location of inshore fishing activities and the importance of different fishing areas in Scotland at a much finer spatial scale, compared to the more landings data derived from logbooks aggregated at the level of ICES statistical rectangles… The study illustrates how participatory mapping can generate useful resources on the location of inshore fishing activities and the economic importance of different fishing areas, that can directly inform marine planning at both national and regional scales. Within Scotland, project outputs have been used to support various policyareas, including national planning, sectoral planning for offshore renewable energy developments and marine conservation.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2017.01.009.

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