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Original Article

Mapping inshore fishing activity using aerial, land, and vessel-based sighting information

Patricia Breen[1], Koen Vanstaen[1]*, and Robert W. E. Clark[2]

[1]*Centre for Environment, Fisheries and Aquaculture Science (Cefas), Pakefield Road, Lowestoft, Suffolk NR33 0HT, UK*
[2]*Sussex Inshore Fisheries and Conservation Authority, 12a Riverside Business Centre, Shoreham-by-Sea, West Sussex BN43 6RE, UK*

**Corresponding author: tel: +44 1502 524489; e-mail: koen.vanstaen@cefas.co.uk*
‡*Present address: Southern Inshore Fisheries and Conservation Authority, 64 Ashley Road, Parkstone Poole, Dorset BH14 9BN, UK*

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Information on the distribution and intensity of inshore fishing activity is needed to inform marine spatial planning and to assess fisheries interactions with the environment and other industries. Although fishing vessels under 15 m (overall length) account for 98.4% (2011 value) by the number of the European fleet, information on inshore fishing activity in Europe is very limited as there is no statutory satellite monitoring of smaller vessels (<15 m length before 2012, <12 m thereafter). Here, we develop, present, and apply a method which uses sightings-per-unit-effort (SPUE) estimates calculated from fisheries enforcement data to describe the distribution and intensity of inshore fishing activity off the coasts of England and Wales. For the larger inshore vessels, the SPUE estimates of activity were validated with vessel monitoring system (VMS) data and showed good agreement at the scale of analysis. Fishing activity estimates from SPUE are presented with an assessment of uncertainty, to account for spatial differences in enforcement activity. Our estimates of the distribution and intensity of inshore fishing activity and will complement estimates of offshore fishing activity based on VMS.

Keywords: data, fishing activity, inshore, sightings, spatial planning, sustainable management.

Introduction

Reliable information on human use of the marine environment is needed to understand interactions between industries and the environment and to inform marine management activities, including spatial planning (Eastwood *et al.*, 2007; Douvere, 2008). This need is particularly acute for fisheries use as, in the process of supplying food and generating income, fisheries can have a widespread impact on the marine environment, leading to interactions with other industries and the environment. Fisheries and their impacts often need to be assessed, and their activities managed, to meet policy commitments (Oliver and Metzner, 2005; OSPAR, 2010). In Europe, these commitments include the development of marine protected areas (MPAs) and MPA networks under legislation such as the UK Marine and Coastal Access Act and the EU Habitats Directive (92/43/EEC). It is also feasible that additional spatial management of fisheries will be needed to achieve good environmental status under the Marine Strategy Framework Directive (2008/56/EC).

Assessment of fisheries impacts and their interactions with other industries or proposed MPAs requires up to date and reliable data on the distribution and intensity of fishing activity. The nomadic nature of fisheries is a significant obstacle to mapping their footprint in the marine environment (Stewart *et al.*, 2010). Following the advent and use of vessel monitoring systems (VMS), high-resolution data on fishing activity for all European vessels over 15 m have been available since 2005 (Lee *et al.*, 2010) and recent EU regulations have required the introduction of VMS for vessels over 12 m from 1 January 2012 (EC No. 1224/2009). Current maps of fishing activity based on VMS imply that there is minimal fishing activity within 12 nautical miles of the coast but, in reality, this reflects the limited use of the coastal-zone by larger vessels. Vessels <15 m dominate the European fleet, accounting for 98.4% of vessels by number (15% of landings and 16% of capacity), and predominantly fish in coastal waters (MMO, 2011). The number of UK fishing vessels <10 m in length was reported as 5021 compared with 1479 >10 m vessels in 2009 (MMO, 2009). In December 2009, of the 1479 >10 m vessels, 723 of these were >15 m and therefore fitted with VMS. Given the influence of inshore fleets on coastal communities and their economy and the multiple uses, including for conservation, of the coastal waters, understanding fishing patterns of the inshore fleet is important (Symes and Phillipson, 2009).

Previous efforts to describe the distribution of inshore fishing activity have been based on "distance from port" rules, seabed maps as proxies for possible fishing grounds, logbook data, and interviews of fishers (Béné, 1996; Gribble and Robertson, 1998; Caddy and Carocci, 1999; Gendron and Brethes, 2002; Hall and Close, 2007; Dunn *et al.*, 2010; Witt *et al.*, 2012). Although these approaches provide useful data, they may not provide sufficient information on the intensity of the activity to inform management advice (e.g. information on locations but not frequency of fishing) or describe activity at smaller scales than the management regions. Furthermore, some approaches can be limited in their ability to provide annual updates which can be used to assess the effectiveness of the management decisions. Information on intensity is usually needed to support management advice because it identifies areas where pressures, impacts, or the risk of potential conflicts among industries are most intense (Eastwood *et al.*, 2007). It is also important from a socio-economic perspective to know the proportion of total activity that might be affected by management measures (Jennings *et al.*, 2012) and to be able to identify areas that account for a large proportion of total activity, which may be prioritized as fishing grounds in marine spatial plans (Jennings and Lee, 2012).

With no systematic VMS monitoring of inshore fleets, other methods of describing the distribution and intensity of fishing activity are needed. Fisheries protection vessels and aircraft routinely patrol many inshore waters and record sightings of fishing vessels. Sightings-based data have previously been used to estimate the amount of recreational pot fishing (Kleiven *et al.*, 2011) and illegal trawling intensity (Dunn *et al.*, 2010), but, in both these examples, the surveys were specifically designed to estimate fishing effort. Clark (2003) used a similar approach to describe fishing activities at a local scale. To obtain broad coverage of fishing activity requires data on much larger scales. Here, we build on these previous approaches to develop, present, and apply a method which uses sightings-per-unit-effort (SPUE) estimates calculated from data routinely collected during fisheries enforcement activities to describe the distribution and intensity of inshore fishing activity in England and Wales. Records of vessel sightings are logged by fisheries protection vessels operated by regional Sea Fisheries Committees [SFCs; these became the Inshore Fisheries and Conservation Authorities (IFCAs) in 2011] and by the Marine Management Organisation (MMO, UK). Further sightings data are available from MMO aerial surveys. As well as recording sightings, we estimated surveillance intensity by patrol vessels and aerial surveys, so that fishing activity could be reported as SPUE. The methods provide information on fishing activity attributed to the 94.1% of English and 98% of Welsh vessels not monitored using VMS which accounts for 15% of landings and 16% of capacity (MMO, 2011).

Methods

Study area and data

Fishing activity was estimated for areas within 20 nautical miles of the coasts of England and Wales. Records of sightings of fishing vessels by fisheries protection vessels, land-based, or aerial surveys in this area from 1 January 2007 to 31 December 2009 were provided by the 12 SFCs of England and Wales and the MMO (Figure 1). A sighting was only recorded by the SFC or MMO when a vessel was actively fishing; therefore, all recorded sightings are actual fishing events. Sightings were included in the analysis if they were accompanied by records of date, time, fishing vessel location (latitude and longitude), fishing method (gear type), and vessel name and registration (optional for privacy reasons to allow analysis stratified by vessel length and engine power). A total of 90 733 fishing vessel sightings were available for the analysis period.

Gear types were aggregated and classified into the following groups: dredging, trawling, netting, potting, and lining and commercial angling (Table 1). Sightings of gear types which did not fit this classification, e.g. hand gathering or recreational angling, or which were located outside the study area, were excluded from further analysis, leaving 58 376 sightings. Not all SFCs recorded vessel registration. Where vessel registration details were available, links were made to vessel characteristics databases to obtain information on vessel length and engine power. Sightings which could not be linked to a vessel were excluded from length and power analysis. In total, 56 858 sightings were included in the vessel length and engine power analysis. Fishing activity was estimated for different gear type, engine power, and vessel length categories.

Sightings and surveillance effort were allocated to a spatial grid with a resolution of 0.05° in the longitudinal direction and 0.025° in the latitudinal direction ($\sim 3 \times 3$ km at 50°N). The grid was located, so that 400 cells aligned with each ICES rectangle. This was required to link landings data, which are reported at the ICES rectangle scale, to estimates of fishing activity. Around west and north Wales, slightly larger grid cells were used, due to low data density and poor positional accuracy (mainly land-based sightings) of the sightings data collected. Grid cells here measured 0.1° longitude and 0.05° latitude (i.e.6×6km) and 100 mapped on to each ICES rectangle. Grid resolution was selected to meet the reporting and management needs of the SFCs and the resolution of the available data. Clearly, the choice of resolution will influence the reported distribution and intensity of fishing activity, with lower resolutions leading to increased estimates of spatial footprint and lower estimates of peak intensity (Mills *et al.*, 2007; Piet and Hintzen, 2012; Gerritsen *et al.*, 2013)

Calculating relative fishing effort

Patrol vessel tracks

Tracks were created for all patrol vessels and aircraft using data recorded from their on-board navigation systems. These logged positions are at intervals ranging from 30 s to 2 h. When position logging was infrequent, we assumed straight line tracks between consecutive position records. This will introduce an error in the track locations, 30 min intervals reduced accuracy by 20% and at 1 h intervals, accuracy is reduced by 30%. Land-based sightings were taken as points and buffered as described below.

A 2 km buffer (±1 km) was applied to vessel and aeroplane tracks to account for the ability of observers to record fishing activity. Two kilometres were chosen based on feedback from SFC observers and a preliminary spatial analysis of the positions of sightings in relation to the patrol vessel track (Figure 2a). Land-based sightings were buffered using a 6 km buffer (±3 km) to seaward, based on feedback from SFC observers (Figure 2a). The Eastern SFC only recorded an observation every hour. Therefore, to avoid overestimation of effort, a buffer was applied around the hourly vessel position.

Using GIS software package ArcGIS 9.3, buffered tracks and points were overlaid with the relevant spatial grid (0.05° longitude by 0.025° latitude or 0.1° longitude by 0.05° latitude). The number of buffered tracks and points which intersected with each

Figure 1. The 12 Sea Fisheries Committee (SFC) districts of England and Wales. The dark grey area along the coastline denotes the area the SFC is responsible for. The dark boundary line shows where each SFC area ends and the next one begins. Other locations discussed in the results are labelled in italics. NB: As of 2011, SFC's are now called IFCA and local boundaries have changed.

grid cell was summed to determine surveillance effort per grid cell (Figure 2b).

Number of sightings

At sea, positions of sighted vessels were recorded by patrol vessels and aircraft using on-board radar linked to GPS. For land-based sightings, positions of fishing vessels were estimated based on bearing and distance from the observation point. Each individual sighting was assigned to the spatial grid and the number of sightings per grid cell was calculated (Figure 2c).

The number of sightings per grid cell was calculated for 2007, 2008, and 2009 individually and as a mean for these 3 years. The 3-year mean reduced the effect of in-year outliers and improved spatial coverage of surveillance effort.

Sightings-per-unit-effort

Using GIS software, the surveillance effort grid and the number of sightings grids were overlaid. A raster calculator was used to calculate the SPUE as (Figure 2d):

$$\text{Sightings-per-unit-effort (SPUE)} = \frac{\text{number of sightings}}{\text{surveillance effort}}.$$

Confidence assessments

The distribution of the surveillance effort indicated that some areas were infrequently or never visited by fisheries protection vessels. In these cases, the intensity and distribution of fishing activity would be more uncertain or unknown. A confidence

Table 1. Descriptions and codes used by MMO and SFC's for categorizing fishing activities.

Fishing activity	Main gear class	Main category
Pelagic side trawler	Trawling	Mobile
Side trawler (pelagic/demersal)	Trawling	Mobile
Pelagic stern trawler	Trawling	Mobile
Stern trawler (pelagic/demersal)	Trawling	Mobile
Demersal side trawler	Trawling	Mobile
Demersal stern trawler	Trawling	Mobile
Beam trawler	Trawling	Mobile
Longliner: mechanically hauled	Lining	Static
Longliner: hand hauled	Lining	Static
Vessel purse-seiner	Trawling	Mobile
Beach purse-seiner	Trawling	Mobile
Bottom seiner (anchor/danish/fly/scots)	Trawling	Mobile
Gillnetter: trammel-nets	Netting	Static
Gillnetter: demersal medium gauge gillnets (cod/sole)	Netting	Static
Gillnetter: skate/turbot nets (large gauge)	Netting	Static
Gillnetter: fixed beach nets/enclosures seafish	Netting	Static
Gillnetter: fixed beach nets/enclosures salmonids	Netting	Static
Potter: lobster and edible crab	Potting	Static
Potter: whelk	Potting	Static
Potter: prawn (nephrops)	Potting	Static
Potter: prawn (non-nephrops species)	Potting	Static
Potter: velvet crab (specific pots)	Potting	Static
Potter: cephalopod trap (e.g. cuttlefish)	Potting	Static
Potter: fish trap	Potting	Static
Driftnetter: pelagic (mackerel/herring, etc.)	Netting	Static
Driftnetter: bass	Netting	Static
Driftnetter: salmonids	Netting	Static
Scallop dredger (french/newhaven)	Dredging	Mobile
Rod and line: commercial	Angling	Static
Rod and line: charter recreational	Excluded	
Rod and line: private recreational	Excluded	
Shrimper	Trawling	Mobile
Klondyker	Excluded	
Industrial trawler (sandeeler)	Trawling	Mobile
Freezer trawler (pelagic/demersal)	Trawling	Mobile
Trawler: single rigged	Trawling	Mobile
Trawler: twin rigged	Trawling	Mobile
Trawler: triple rigged	Trawling	Mobile
Trio trawler (all)	Trawling	Mobile
Pairtrawler (all)	Trawling	Mobile
Suction dredger: mussel	Dredging	Mobile
Suction dredger: cockle	Dredging	Mobile
Suction dredger: razor shell	Dredging	Mobile
Suction dredger: unidentified bivalves	Dredging	Mobile
Unknown	Excluded	–
Handgathering	Excluded	–

Main gear class and main category show how MMO and SFC gear codes were grouped for this analysis.

assessment was therefore developed to provide a simple measure of uncertainty. Confidence was linked to surveillance effort with two class boundaries between high–medium and medium–low confidence based on discussions with SFC personnel who knew the fisheries operating in the areas surveyed. The three confidence classes (Table 2) were further subdivided based on the quality of the underlying positional data, where "+" indicates good quality positional data (data based on radar and/or GPS) and "−" indicates a lower accuracy of positional data (records based on non-GPS systems, e.g. bearings and distance estimate from landmark).

Validation

To validate the estimates of activity, we compared estimates per grid cell of SPUE for >15 m vessels with the number of hours fished by these vessels as determined from VMS data (Figure 3). This was possible because a proportion of the >15 m fleet fish in inshore waters. Cells with activity for static and mobile gears were separated for this analysis. Only areas where confidence was moderate to high were used for correlation. The correlation coefficient showed strong positive correlation for both gear types, although stronger for static gears than for mobile, *R*-values were 0.9 and 0.82, respectively. In many cells, VMS recorded fishing activity where the sightings data recorded no activity; this is possibly due to the different assumptions used for each method. The sightings records actual fishing activity while VMS uses a speed-based rule to assume fishing. This was particularly obvious for mobile gears (Figure 3).

Furthermore, a review process with SFCs requested feedback on the validity of the maps, particularly on spatial distribution, intensity levels, and level of confidence. Responses indicated that the maps portrayed an accurate picture of inshore fishing activity around the SFC districts. Together, these processes validate that the methods used are a true reflection of real fishing patterns.

Results

Data density for sightings

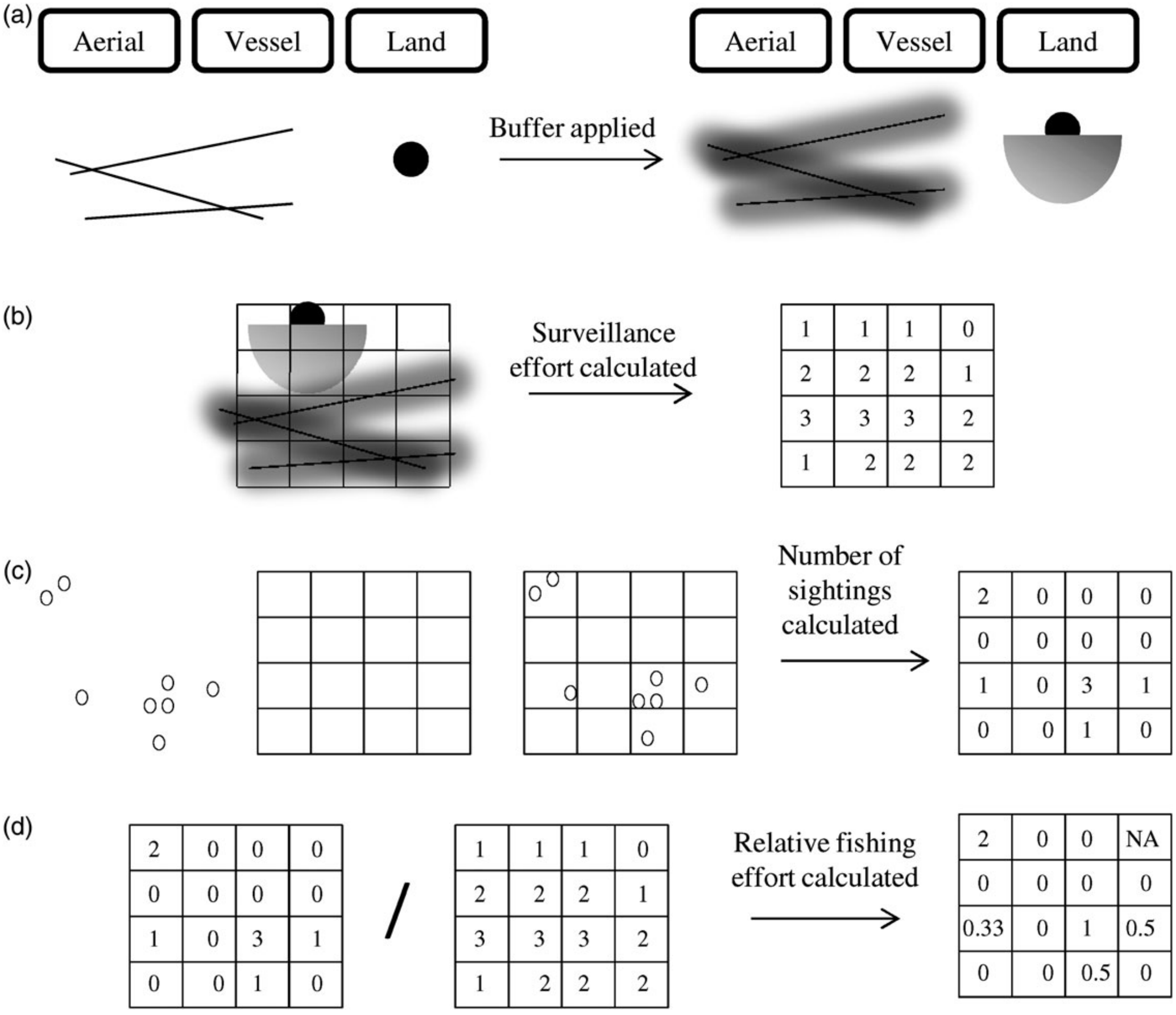
Sightings data density varies within and among SFC districts; higher densities were typically observed closer to the home ports of the fisheries protection vessels. Generally, there were more sightings along the South coast, the Northwestern and Northeastern coasts of England, while lowest data densities were found along the East coast of England and North Wales (Figure 4).

Confidence

The confidence map for all data is shown in Figure 4. Confidence maps refer to the density of surveillance by land, aircraft, and vessels. Confidence is typically moderate or high within the 0–6 nautical mile limit and low to moderate outside. Surveillance effort usually decreased with distance from home port. There was no surveillance effort in several small areas and so fishing activity levels could not be calculated. Fishing activities may still take place within these areas. In Northwestern and North Wales, Cumbria and Southern SFC districts a lower confidence was assigned, due to a reduced spatial accuracy of sightings and surveillance effort data provided.

Relative fishing activity

In total, the area of the English and Welsh coastline within 20 nm affected by fishing at the resolution of this analysis was 38% for mobile gears and 20% for static gears. Fishing activity maps (Figures 5–8) are shown for each gear class listed in Table 1. There were hot spot areas of dredge activity in areas where clams and cockles are harvested, such as the Solent, the Wash, and off the coast of Essex (Figure 5b). Trawling is widespread within the 0–6 nm zone (Figure 5c). The main trawling grounds are located east of Newcastle, the Wash, Sussex coast, western Lyme Bay, and the Cumbrian coast. Potting and netting (Figure 5d and e) activities were often most intense closest to shore. Netting is most intense along the south coast and the northeastern coast, while potting



1	1	1	0
2	2	2	1
3	3	3	2
1	2	2	2

2	0	0	0
0	0	0	0
1	0	3	1
0	0	1	0

2	0	0	NA
0	0	0	0
0.33	0	1	0.5
0	0	0.5	0

Figure 2. Schematic outlining the methodology presented in this paper. (a) Buffering patrol tracks, (b) calculating surveillance effort, (c) plotting and calculating number of sightings, and (d) calculating relative fishing effort.

Table 2. Confidence classifications used for the confidence assessment.

Average surveillance effort over 1 year	Quality of source data	Confidence class
More than once in 2 weeks	Sightings and GPS based	High +
Less than once in 2 weeks, but more than once in 2 months	Sightings and GPS based	Moderate +
Less than once in 2 months	Sightings and GPS based	Low +
More than once in 2 weeks	Non-GPS based	High −
Less than once in 2 weeks, but more than once in 2 months	Non-GPS based	Moderate −
Less than once in 2 months	Non-GPS based	Low −
No surveillance effort	No data	No data

takes place along most of the UK and Welsh coastline but at highest intensity along the south coast and the Northumberland coast. Lining and commercial angling (Figure 5a) is the least frequent fishing activity recorded and is predominantly observed around Cornwall. When the results were summarized by mobile and static gears (Table 1), mobile gears fishing was shown to take place both inside and outside the 6 nm limit (Figure 6a). Static gears, on the other hand, tended to be used close to shore and rarely outside the 6 nm limit (Figure 6b).

Fishing activity for smaller vessels is highest close to shore, in particular for vessels <6 and 6–8 m in length (Figure 7). The <6 m vessels also showed their highest activity level very close to home ports. As vessel size increases, relative activity gradually gets more widespread, out to the 6 nm limit and beyond. Where activity is summarized for >15 and <15 m vessels (Figure 6c and d), most activity of <15 m vessels is shown to be within the 6 nm limit and most activity for >15 m vessels is beyond the 6 nm limit.

Results for engine size show a similar pattern to that recorded for vessel length (Figure 8). Vessels with smaller engines tend to operate close to shore within the 6 nm limit. Vessels with engines <100 kW also tend to stay closer to their home ports (Figure 8a). As engine size

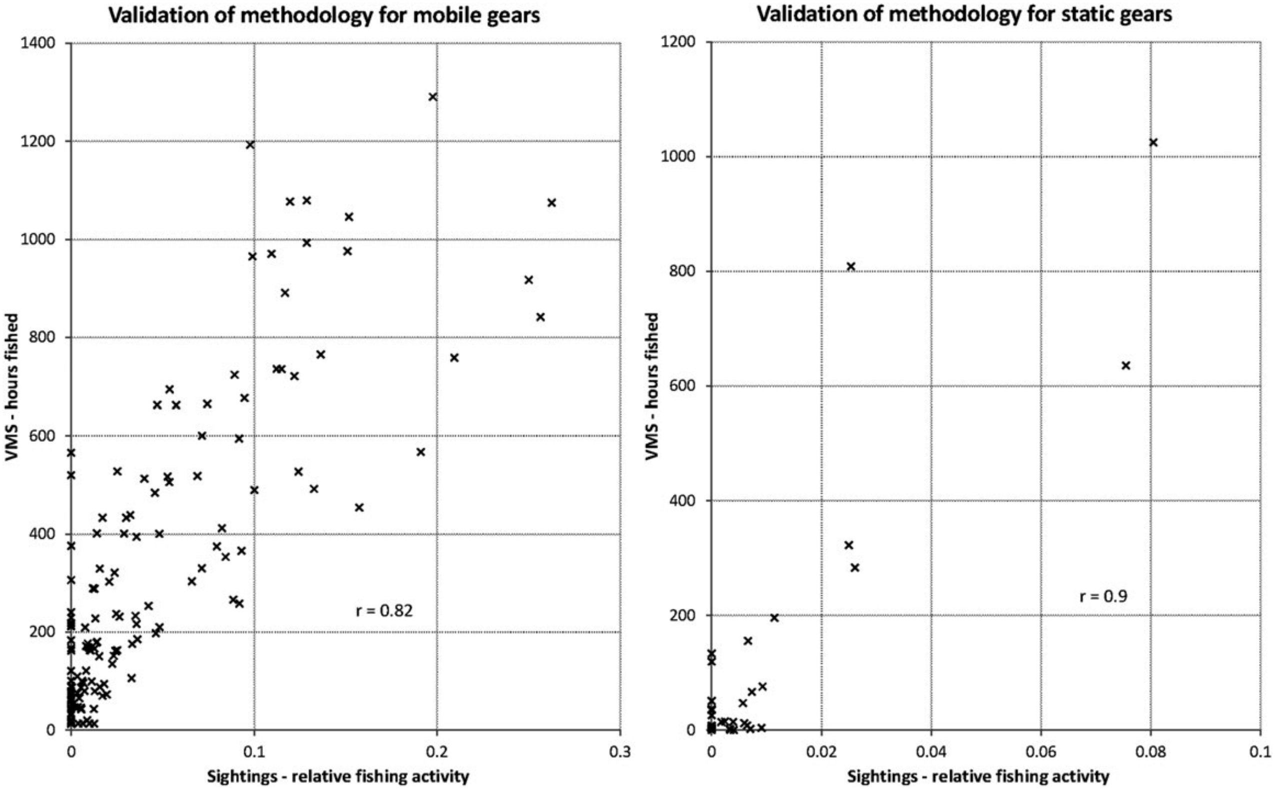


Figure 3. Correlation co-efficient validating the >15 m fleet sightings data with VMS for both static and mobile gears.

increases, activity becomes more widespread and, for the >221 kW engines, most fishing activity occurs beyond the 6 nm limit (Figure 8d).

Discussion

Our results show that existing datasets from fisheries regulatory authorities can be used to describe the distribution and intensity of inshore fishing activity in the absence of dedicated VMS monitoring. By providing information on fishing activity not monitored with VMS, our results contribute to developing a more comprehensive assessment of total fishing activity. This is needed to inform marine spatial planning and to assess fisheries interactions with the environment and other industries. Given that 98.4% of European fishing vessels are <15 m length and that VMS monitoring was only extended to vessels of 12–15 m in 2012, our method provides one means of better describing EU fishing activity. The collation of the required data can be achieved using records from existing fisheries protection vessels and does not require new dedicated infrastructure or surveys. Data layers can also be updated regularly as the collection of sightings data is expected to continue to meet fisheries protection needs.

Personal communication with the SFCs during the review process indicated that a large proportion of vessels under 15 m length will spend most of their time fishing within the 6 nautical mile limit. Based on search effort, this is also the area where we expect confidence in our results to be highest. It is recommended, therefore, that the approach is used primarily to assess the under 15 m fleets fishing within the 0–6 nautical mile zone.

The observation that the smaller vessels stay close to the coast was consistent with the results of Tzanatos *et al.* (2006) in Greece who found similar trends when fishing trip times. They found that, for smaller vessels (<6 m), the average fishing voyage was around 2.2 h and for vessels of 6–9 m length was 2.1 h. This increased to 4.5 h for the over 15 m fleet, with several vessels conducting fishing trips of >24 h. These results suggest that these vessels are moving further from their home ports to fish.

In addition to the validation of the methods using VMS, SFC officers reviewed maps with their knowledge of the fishing activities within their local area. Whereas this confirmed the extent of the main fishing areas, assessment of the relative intensity levels could not be achieved in this way. The trends presented by the maps of relative fishing activity by vessel length confirmed expectations that, as vessel length increased, the distribution of the area around ports affected by fishing increased. Although not a validation of the outputs in itself, it provides evidence that the data are able to display general trends in the distribution and intensity of inshore fishing activities.

The confidence assessment used was developed to give end users a better understanding of potential biases in the activity estimates. Individual sightings are true records of fishing activity, so we have high confidence that fishing was occurring in all areas where it was reported. However, if fishing was not reported in an area and the area was visited infrequently by fisheries protection vessels or aircraft, then confidence would be "low" or "moderate". In these cases, the absence of information on fishing activity does not allow us to infer that no fishing is occurring. If the absence of fishing activity were an important consideration for managers then we recommend that our data for "low" and "moderate" confidence areas should be corroborated with other information. We recommend that activity estimates from any area where confidence is

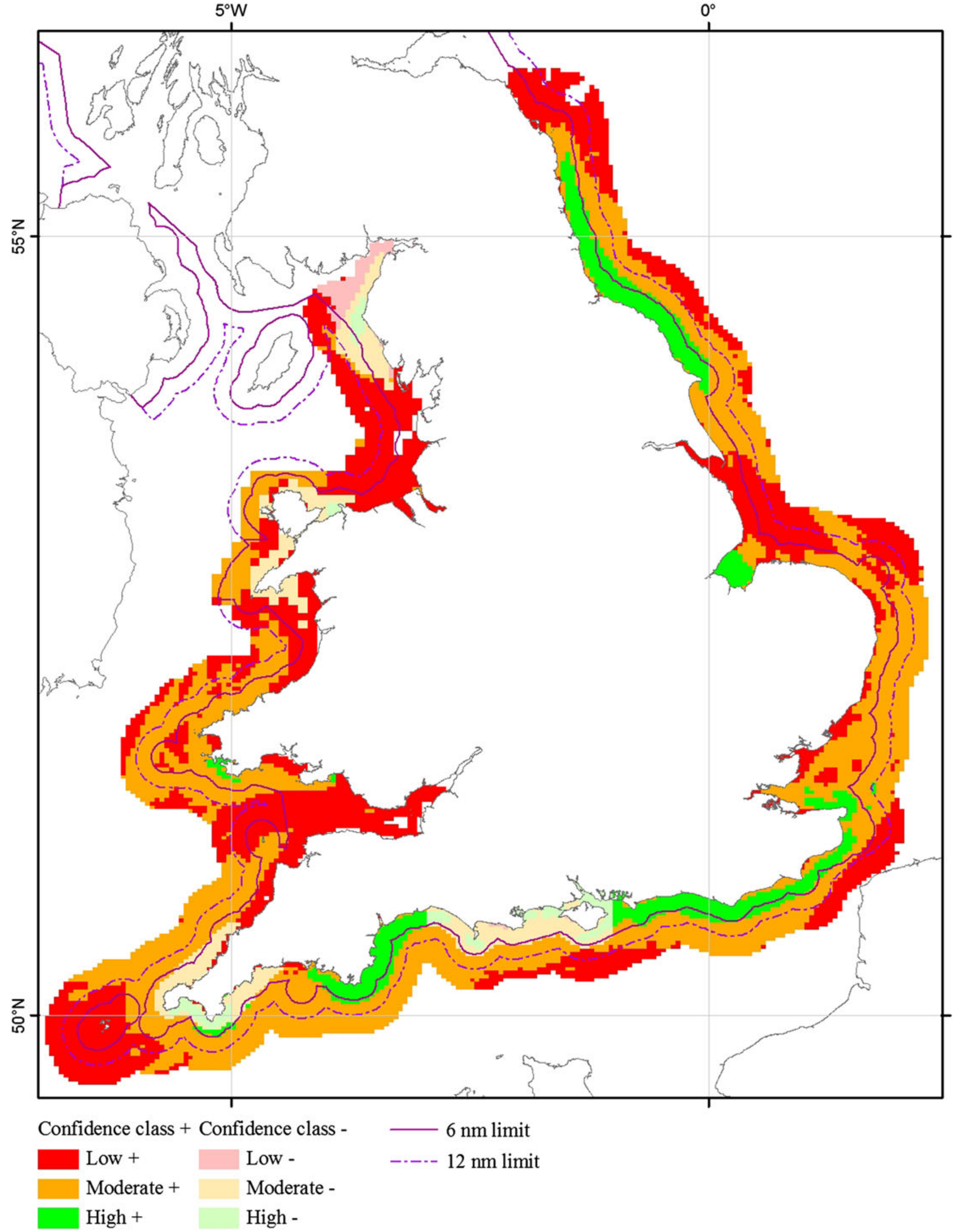


Figure 4. Confidence data layer for the relative fishing effort maps. Data confidence is defined by the frequency of patrol visits to each grid cell and the quality of the source data. White blocks indicate where there was no patrol effort at all.

low should be treated with caution and results should always be interpreted alongside the confidence assessment. There is opportunity for management authorities such as IFCAs and the MMO to use these “low confidence” areas to target future observation effort and improve knowledge of the distribution and intensity of fishing activities in those areas.

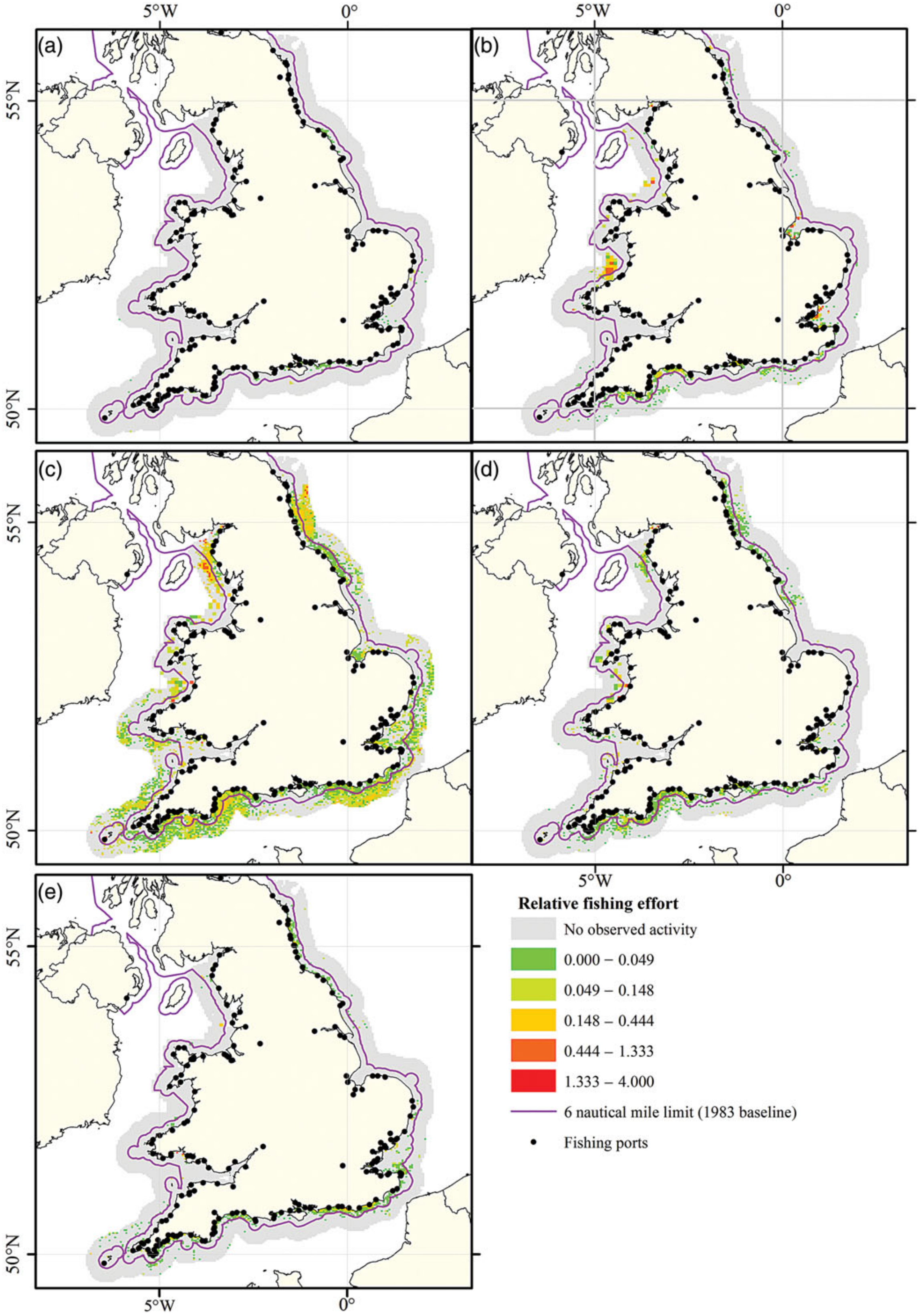


Figure 5. Relative fishing effort distribution for all gear types: (a) lining and commercial angling, (b) dredging, (c) trawling, (d) potting, and (e) netting. Class intervals were applied to maps using a geometric sequence where each class upper limit is three times larger than the upper limit of the previous class. Grid cells measured 3 × 3 km (at 50°N). 1/400th of an ICES rectangle. The outer data area denotes the 20 nm limit.

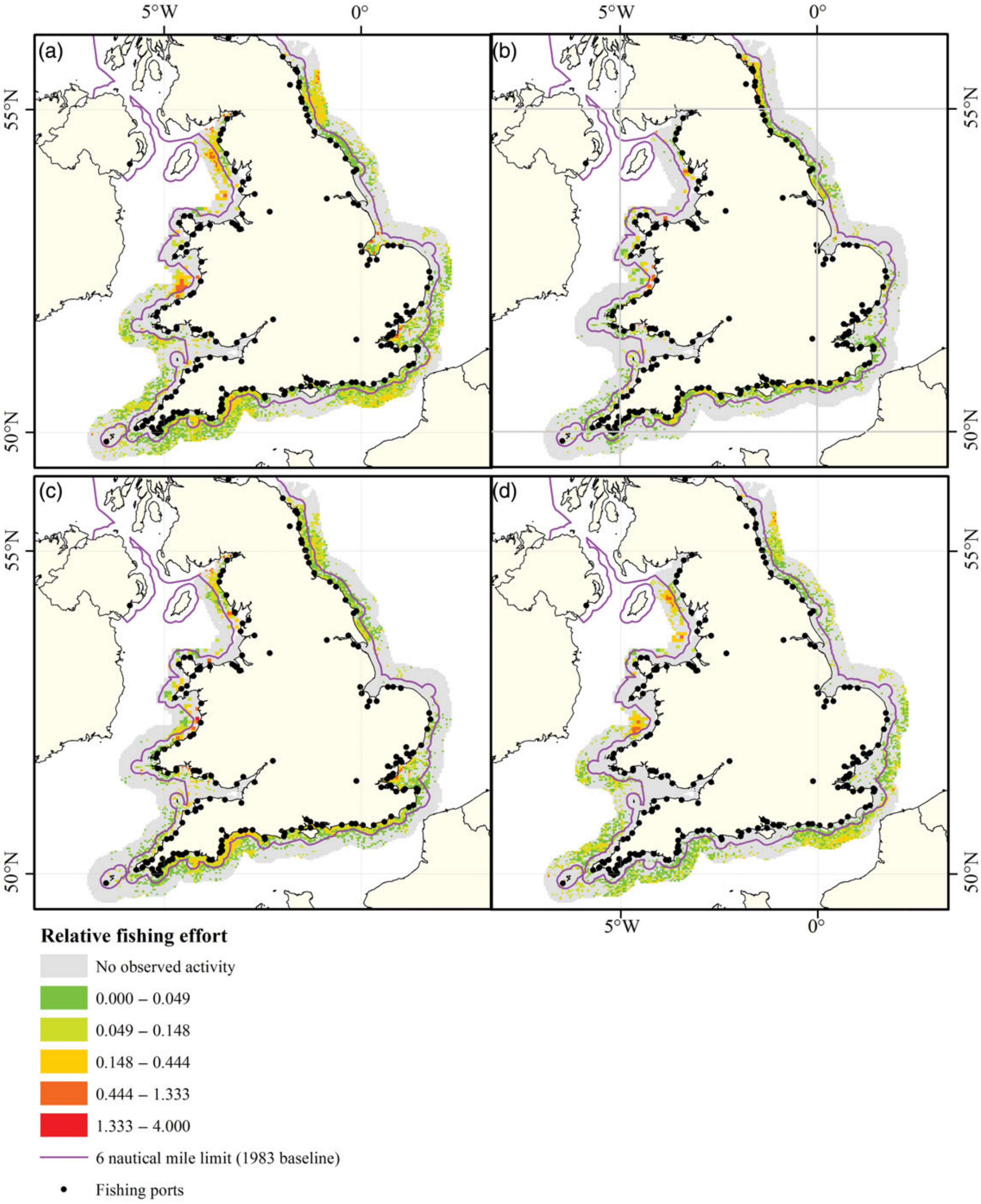


Figure 6. Relative fishing effort distribution for summarized gear types and vessel lengths: (a) mobile gears, (b) static gears, (c) under 15 m vessels, and (d) over 15 m vessels. Class intervals were applied to maps using a geometric sequence where each class upper limit is three times larger than the upper limit of the previous class. Grid cells measured 3 × 3 km (at 50°N). 1/400th of an ICES rectangle. The outer data area denotes the 20 nm limit.

Sightings data were collected opportunistically by the SFCs while conducting their core duty of fisheries enforcement. Within England and Wales, SFCs operated as independent authorities and there was limited standardization in the approaches used for data collection or coordination of the patrols to maximize spatial coverage. In such cases where data collection is fragmented over different

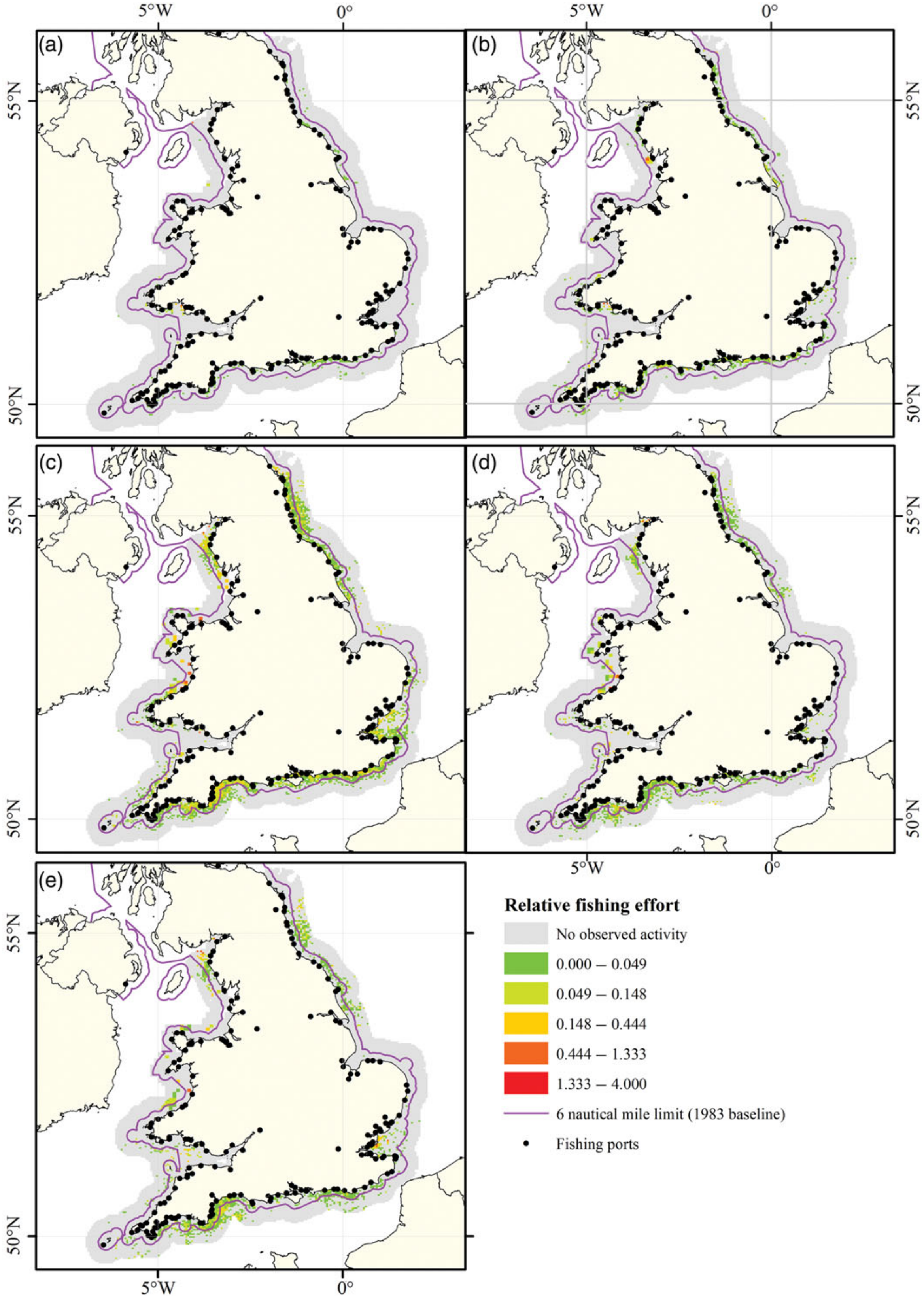


Figure 7. Relative fishing effort distribution for vessel lengths: (a) under 6, (b) 6 – 8, (c) 8 – 10, (d) 10 – 12, and (e) 12 – 15 m. Class intervals were applied to maps using a geometric sequence where each class upper limit is three times larger than the upper limit of the previous class. Grid cells measured 3 × 3 km (at 50°N). 1/400th of an ICES rectangle. The outer data area denotes the 20 nm limit.

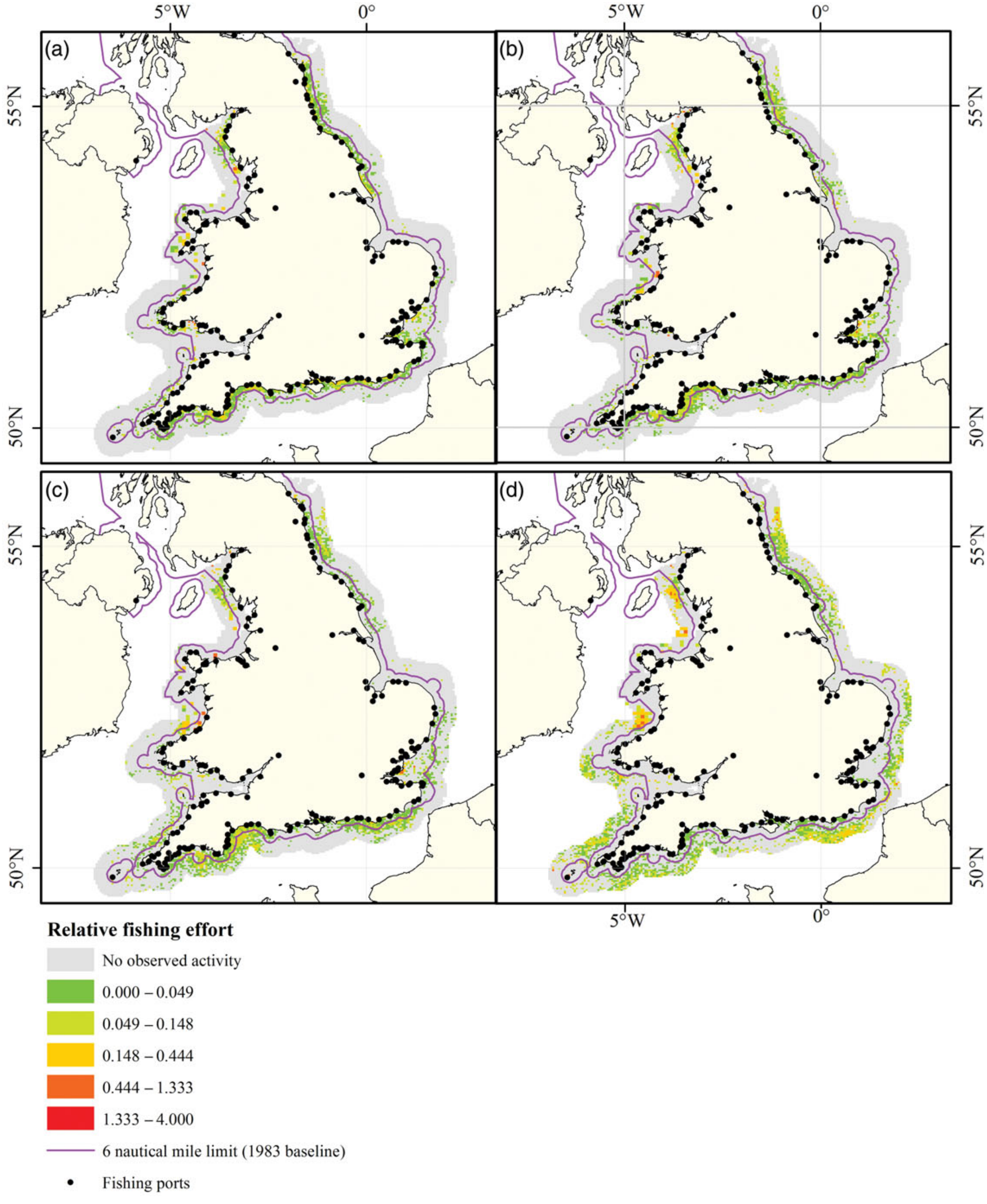


Figure 8. Relative fishing effort distribution for registered vessel power: (a) under 100, (b) 100 – 150, (c) 150 – 221 kW, and (d) over 221 kW. Class intervals were applied to maps using a geometric sequence where each class upper limit is three times larger than the upper limit of the previous class. Grid cells measured 3 × 3 km (at 50°N). 1/400th of an ICES rectangle. The outer data area denotes the 20 nm limit.

management authorities, standardization of the approaches used for data collection is essential, and coordination of the patrols to maximize spatial coverage is desirable. The lack of standardization led to some data being excluded from the analysis, as it could not be integrated with the other available data. As a result, we used only MMO sightings data in some areas. A future move to establish standard practices among enforcement agencies collecting fishing vessel sightings and surveillance effort data would ensure that more accurate and standardized maps could be produced. The use of data from opportunistic surveys such as in this study means that an over- or underestimation of fishing effort is possible depending on how often a patrol vessel or aircraft visit an area, introducing selection bias in the results (Jessup, 2003). Considering our need for information on the activities of the inshore fishing fleet, these data and the analysis provided herein still fill a valuable gap in our knowledge. However, care must be taken when interpreting these results and the confidence values reported for the relative fishing effort maps must be taken into account alongside intensity values.

Our approach for estimating fishing activity does not have the high resolution and high specificity that can be achieved within dedicated studies (Pedersen *et al.*, 2009; Dunn *et al.*, 2010) but does have the advantage that it provides long-term large-scale information on previously unreported and unassessed fishing activity. Furthermore, most countries with a large fishing sector will carry out some form of enforcement of fisheries management and could therefore capture data from patrol vessels or surveillance aircraft.

We aggregated activity data by averaging for the period 2007–2009. This approach is relevant for informing aspects of marine spatial planning and assessing potential for interactions with the environment and static industries, but provides limited information on fleet responses to management actions and on interactions with other industries that may be transient. The analysis could be carried out annually, but this would cause an increase in uncertainty. Individual yearly percentages of grid cells, where confidence was classified as medium, ranged between 5 and 31%, but this increased to 50%, when the 3 years were considered together. Aggregation across years therefore is important to provide robust maps of fishing patterns across the area.

Since the introduction of VMS for >15 m vessels, the ability to produce high-resolution fishing activity maps for these fleets has increased dramatically (Lee *et al.*, 2010). Bez *et al.* (2011), Chang (2011), Jennings and Lee (2012), and Gerritsen *et al.* (2013) provide just a few examples of this. Methods and tools for the processing and analysis of such data have been widely published and are easily accessible (Pedersen *et al.*, 2009; Hintzen *et al.*, 2012). VMS records are also regularly updated and reprocessed. Recently, there has been a move to extend the requirement for VMS to be installed in all vessels between 12 and 15 m overall length and, in Wales, a 2012 order requires all scallop dredgers to carry a tracking device and transmit a location every 10 min while at sea. Since VMS is a monitoring and enforcement tool, there are practical and economic challenges to be overcome when rolling this system out to the entire fleet. From a research and management point of view, the more vessels which are fitted with the VMS system, the more accurately we can map human activities in the marine environment. This is important as, for example, from a socio-economic perspective, the data presented here demonstrate that small-scale vessels do not generally travel far to their fishing grounds and therefore may be more vulnerable in the busy inshore marine environment where competing demands exist between users and where conflicts exist between stakeholders. The more accurately we can map activities in these areas, the greater our ability to reduce conflict and develop successful marine spatial plans (Dalton *et al.*, 2010).

Modelling is a growing method for scientists to explore spatial patterns in the marine environment. Studies employed to develop distribution maps for cetaceans using sightings information could be adapted for use on the presented data, for examples, see Mannocci *et al.* (2013) and Torres *et al.* (2013). General linear models (GLMs) and generalized additive models (GAMs) are two examples of approaches which could be used to create an accurate predicted distribution map for inshore fishing activity. It would be useful in the future to explore these types of analysis. Nevertheless, even with improved VMS monitoring and/or the use of modelling, the approach presented here can still provide value for looking at longer term patterns of fishing activity and/or for providing a historical baseline of recorded fishing activity.

Ultimately, this paper provides a simple and repeatable methodology for the mapping of inshore fishing activity and so will help to fill a significant knowledge gap. This type of information is important for fisheries management, management of pressures on the seabed, and to help reduce conflict between competing marine sectors (Katsanevakis *et al.*, 2011). Integration of such data layers with the highly useful VMS data layers will provide a holistic assessment of fishing activity. Future effort will go into understanding temporal changes and displacement of fishing activity by inshore vessels to improve the link to socio-economic aspects of coastal communities. This will also allow us to establish how often these results would need to be updated. Yearly patterns on fishing activity would be useful information for fisheries and conservation management.

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