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Mapping fisheries for marine spatial planning: Gear-specific vessel monitoring system (VMS), marine conservation and offshore renewable energy

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A B S T R A C T

Vessel Monitoring System (VMS) data from 2005 to 2008 in ICES Divisions VIIe-h were used to assess the distribution and intensity of fishing activity in and around the western English Channel, one of the most intensively used marine areas on the planet. The distribution of the UK fleet of large (> 15 m length) fishing vessels was analysed and clear gear-specific temporal and spatial differences in activity were found. Mobile demersal gears had the highest intensity and widest distribution of activity in the study area, and so might be expected to have the most widespread ecosystem-level impacts. The potential effects of two proposed fisheries closures; a planned wave energy testing facility (Wave Hub) and a candidate offshore Marine Protected Area (Haig Fras) are described. Maps indicate that mobile demersal gear fleets would be little affected if they were excluded from these proposed closures, but if the static gear fleets were excluded this would likely result in displacement of certain vessels, increasing fishing pressure on other rocky grounds and other fishers. Predictions concerning the effects of fisheries displacement can be improved through the use of high-resolution gear-specific activity data. This study shows that VMS can provide an invaluable source of such data, provided that gear information is made available to fisheries managers and scientists.

1. Introduction

Over the last 20 years, management approaches have shifted from the conservation of species to the more holistic management of spaces, designed to help reduce damage to ecosystems and the goods and services they provide [1–4]. Marine protected areas (MPAs) are emerging as a central tool for this approach, with the World Summit for Sustainable Development calling for the establishment of a representative and coherent network of MPAs [5–7]. In addition, the world's oceans are increasingly being tapped as a source of renewable wind, tidal and wave energy [8–11] to address the decline in fossil fuel reserves and reduce the rates of changes caused by anthropogenic carbon dioxide emissions [12,13]. The UK has set a target of producing 33 gigawatts from marine renewable sources by 2020, meeting the EU target of supplying 20% of its gross consumption of energy from marine renewable sources by 2020 [14]. However, large scale offshore marine renewable energy installations (MREIs) have the potential to exclude certain fishing gear-types from large areas of the sea, from construction to operational phases [11].

The development of MREIs and the designation of marine protected areas are two rapidly emerging demands on marine space that compete with or displace fishing activities [9,15] and are likely to alter spatial patterns of fishing activity. For example, in relation to MPAs, North Sea and Baltic beam trawl cod fisheries could be forced to concentrate activity onto smaller grounds, leading to increased competition, reallocation of activity and lower catch [16,17]. To address conservation and economic activity and to aid in the resolution of stakeholder conflict, marine policy-making has shifted away from sector-by-sector management towards an integrated, multi-sector, ecosystem-based and transparent planning process, known as marine spatial planning (MSP) [18–25,26]. This is intended to help managers optimise sustainable use of the sea, for example by avoiding long-term damage to benthic habitats or the wasteful bycatch of non-target species. Recently, a group of international experts met to devise priority needs for the successful practical implementation of MSP [26]. One of the key elements identified, high-resolution, spatially and temporally accurate types of data and information on the various activities taking place in the marine environment [26,27].

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Until recently, marine managers had to rely on surveillance data from observer planes/vessels or logbook catch data to determine the spatial distribution of fishing activity [28]. These data lacked temporal coverage and spatial resolution, preventing full integration of fisheries data into marine spatial plans [4]. Satellite vessel monitoring systems (VMS) are increasingly being used to overcome these limitations. Introduced in the 1990s in various parts of the world [29], VMS were originally established to allow fisheries administrators to control and monitor fishing activity [28,30]. In European Union waters, VMS were introduced in 2000 when all vessels >24 m in length (and all vessels >15 m in length since 2005) were required to submit information on their position every 2 h to a Fisheries Monitoring Centre [31]. Vessel speeds have been included since 2005. From 1st January 2012, vessels >12 m in length will have to install VMS [32] and there are discussions about extending the systems to towed gear vessels >8 m in length [33]. VMS data have proven valuable in spatial analyses of fishing activity [28,30,34] and have been used as a proxy for the distribution of target fish stocks [35]. Such data can also show how spatial closures can displace fisheries activity [36,37]. VMS is now being used to inform the design of MPAs to avoid displacement of destructive fishing activities onto vulnerable marine ecosystems in the deep sea [38,39]. In addition, gear-specific VMS analyses have been carried out within the German EEZ [4,40], the Irish EEZ [41], the UK EEZ [42–45] and for the Danish fleet [46] which have the potential to greatly improve the assessment of fisheries impacts. Such work has considerable implications for management, as different fishing sectors have specific responses to various management measures for example closures.

Here, VMS data are used to provide an overview of the distribution of fishing activity by gear type in ICES Divisions VIIe-h (Fig. 1a), which borders the south-eastern coast of Ireland, the south-western coast of the UK, and the north-western coast of France. This area covers parts of the English Channel, Celtic Sea and Atlantic Ocean and is one of the most highly used marine areas in terms of all marine activity on the planet [28,47]. How two potential fisheries closures may affect the distribution of both static and mobile gear users is described. The potential effects of displacement and the influence of bathymetry and seabed sediment type on fisheries activity are also investigated. One of the proposed closures is for an MREI, a facility for testing prototype Wave Energy Converters (WECs), Wave Hub the UK's first marine energy park located 10 NM from Hayle North Cornwall resulting in an 8 km^2 exclusion zone. Coupled with this, due to the nature of the exclusion zones associated with offshore marine renewable energy developments, there is a great deal of interest in these sites as *de facto* MPAs [11]. The other proposed closure is Haig Fras, a 45 km long granite reef that is the only substantial area of rocky reef in the Celtic Sea [48] and was put forward as a Natura 2000 conservation area in 2008 [49].

2. Materials and methods

2.1. VMS data

VMS data were available for all UK registered vessels >15 m in length that were active in ICES Divisions VIIe-h from 2005 to 2008 and were obtained from the Marine Management Organisation (MMO), formerly the UK Marine and Fisheries Agency. In addition, access to gear-type information was not available for non-UK fishing vessels fishing in UK waters, thus were excluded from analyses. The UK vessel VMS dataset contained vessel records, each consisting of a randomly created vessel identification number (to separate individual vessels while retaining their anonymity), speed, vessel position in decimal degrees, and the date and time of transmission. Access to logbook information was not permitted by the MMO for this study, although gear-type information was extracted from logbooks by the MMO and submitted with the initial VMS dataset. The following fishing gear-type classifications were used: scallop dredge, longline, gillnet, potter/whelker, beam trawl and demersal otter trawl, all of which conform as close as possible to European Union level 3 and 4 Data Collection Regulation (DCR) [50,51] considering the level of data made available for this study.

2.2. Fishing activity analyses

2.2.1. VMS

VMS data analysis closely followed the recently established approach for estimating fishing activity by Lee et al. [43]. In summary, the removal of records: (1) without an associated gear type, (2) within 3 NM of ports, and (3) duplicates. The interval between each successive record was calculated and a vessel was deemed to be engaged in fishing activity if its speed was between 1 and 6 knots (for all gear types). This filtered data was subject to a point summation method, using a grid cell size of 0.05° or 3 mins WGS84, this is the resolution to provide fishing data to inform marine spatial planning in the UK [44]. Fishing activity in each ICES Division VIIe-h was calculated separately.

Fig. 1. Study area showing ICES Divisions VIIe-h boundaries, the location of the proposed Haig Fras Natura 2000 site and the location of the proposed Wave Hub deployment area.

To quantify the differences in spatial patterns of fishing activity between gear types and within the same gear type but between years, the index of difference in spatial pattern developed by [43] was used. In brief, “activity in each cell was calculated so that the sum of all activity in ICES Divisions VIIe-h was one. To facilitate comparison, the absolute differences in proportion of activity in each cell were calculated, summed for ICES Divisions VIIe-h then divided by 2, resulting in an index of difference in spatial pattern varying from zero to one. In this way, zero represents identical spatial fishing patterns in the same cells, and one represents no common spatial pattern in the same cells” [43].

2.2.2. EU-defined fleet-effort analysis

Fishing effort of fleets is defined in the EC Regulation of 2002 (Article 3(h)) [52] as the product of capacity and activity. Capacity can be measured roughly in terms of the number of vessels or more precisely, the size of vessels (either gross tonnage (GT) or engine power (kW)) and activity is commonly measured as the period of time in which a vessel is active, for example the number of days at sea. In this study, capacity is presented as number of vessels, because neither GT nor kW was made available and calculated days at sea for each vessel within the specified gear types. Each ICES Division VIIe-h were analysed separately.

2.2.3. Fishing activity and marine landscapes

The distributions of fishing activity were analysed with respect to five marine landscape types, which were derived from UK SeaMap data [53]. The five categories were; sand, mixed sediment, coarse sediment, rock, and mud. Fishing activity was assessed by calculating the average number of fishing hours per 1 km^2 of each marine landscape. By aggregating all fishing effort by gear type it was possible to assess fishing activity on a regional level (ICES VIIe-h) rather than sub-divisional as before.

3. Results

The spatial and temporal distributions of fishing effort per ICES Division (Fig. 2), particularly with reference to seabed sediment type (Fig. 3) and bathymetry (Fig. 1), reveal a great deal of insight into factors governing fishing site selection by various gear types. For the purposes of brevity here we outline some of the major findings, whereas a more exhaustive analysis is the subject of ongoing work.

The spatial distribution of fishing activity was highly heterogeneous and distinct areas of intense fishing could be identified for all gear types (Fig. 2). Spatial patterns were more consistent within gears between 2005 and 2008, with the index of difference (Section 2.2.1) for mobile gears ranging from 0.2698 to 0.5151 (Table 1). For the static fleet, similar consistencies between years were observed for both potting and whelking and gillnetting from 2005 to 2008, ranging from 0.3837 to 0.5025, and in longlining from 2005 to 2006. However, for the longlining fleet, spatial patterns from 2006 to 2008 ranged from 0.6629 to 0.721, indicating a slight shift in spatial distribution from the previous year. Patterns of fishing activity between individual pairings of gears ranged from 0.8472 to 0.9979, indicating distinct spatial zonation by gear type (Table 2), although some lower values were observed between beam trawling and scallop dredging across all years ranging from 0.6089 to 0.6832, indicating an overlap of fishing activity.

Fishing effort of the fleets (Table 3), showed some very interesting results within ICES Division VIIf, with some of the highest potting and whelking effort, as well as gillnetting, although some variation in this effort occurred over the study period. ICES Division VIIe represented the highest scallop dredging effort. Haig Fras, in ICES Division VIIg, also represented high fishing effort by gillnetting and longlining fleets, in comparison to other fishing gears in the area, with Haig Fras being the main gillnetting ground for these vessels 2005–2008. Beam trawling and otter trawling are widespread throughout the study area, with highest effort in ICES Divisions VIIe and f.

Fishing with mobile gear was more widely distributed (Fig. 2a, e and f) with beam trawling occurring over the largest part of the study area (Fig. 2e) but also widespread otter trawling (Fig. 2f). Static gear fishing was focused in fewer areas (Fig. 2b–d). For static gear, and in particular the potting and whelking fleet, this pattern is clearly linked to the availability of suitable seabed sediment (Fig. 3), with fishing activity concentrated on rocky areas (Table 4), which covered the smallest percentage of the study area, but also to a certain extent coarse sediment (Fig. 3). This pattern was also present, to a smaller extent, for gillnetting (Table 4). Longlining activity per unit area was highest over muddy substrates, however high values were also observed over mixed sediment, and rock. Mobile gear activity per unit area of marine landscape type varied between all marine landscape types: scallop dredging occurring over mixed sediment or mud; beam and otter trawling mainly in muddy areas, and with high coverage per unit time in mixed and sand respectively. Some overlap with rocky areas did occur with the mobile fleets (Table 4).

In addition to marine landscape type, bathymetry also influences the distribution of intensely fished areas for some gear types. For example, the continental shelf break in the south-western corner of the study area was a hotspot for gillnetting and longlining. Furthermore, Hurd's Deep (49° 30′N: 3° 34′W), a narrow channel at which depths drop below 100 m to the north of Jersey is preferentially targeted by beam trawlers.

4. Discussion

Vessel Monitoring Scheme data from southwest UK reveal clear gear-specific differences in spatial patterns of fishing activity and allow analyses of the use of shared resources by UK fleets. As expected, the VMS data show that intensely fished areas vary between gear types with towed demersal gear users generally avoiding the rocky grounds that are targeted by other static gear fleets. When the data is not analysed per gear type, useful information (for example seasonal patterns in the locations of areas that are intensely used by sectors of the fleet) is lost and the overall impression of fleet activity is dominated by the most common fishing method [28]. Previously, VMS data have been used to plan the sites of offshore marine protected areas, designed to minimise displacement of activity and to identify areas that were most likely to have untrawled biogenic habitats [39]. Gear-specific fishing activity was not analysed for the design of these offshore MPAs as such data were not released by the authorities. Given the diversity of fishing gears used in inshore waters, a lack of gear specific information could lead to poor marine spatial management decisions. Results illustrate that gear-based VMS analyses can offer greater detail on fleet activities than traditional sources of fisheries data, such as over flight data, and provides an opportunity to improve marine spatial planning. However, insight could be significantly improved if higher level data were available (for example, [43,44]). This is particularly important in areas such as southwest UK as this area currently harbours most of the UK fishing fleet [54].

The effects of fishery closures (for example for nature conservation, or for offshore renewable energy developments) will vary considerably between different sectors of the fishing industry. In the present study, beam trawling was the most widespread type of fishing, followed by demersal otter trawling. ' areas that effects

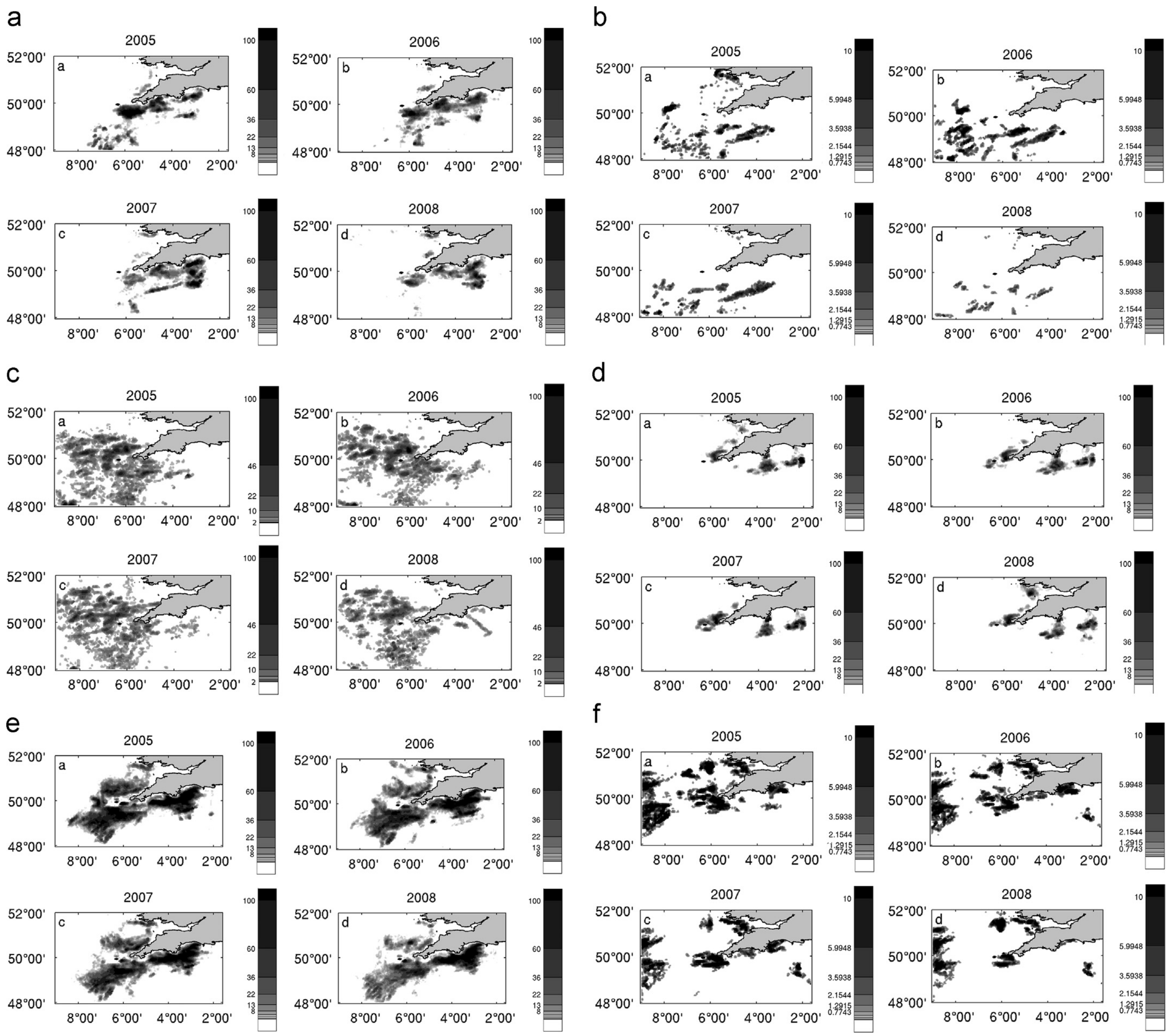

Fig. 2. Fishing effort distribution of UK vessels > 15 m in length in ICES Divisions VIIe-h from 2005 to 2008 (a) scallop dredge (b) longline (c) gillnet (d) potters/whelkers (e) beam trawl and (f) otter trawl. Logarithmic scale bar (h) is shown.

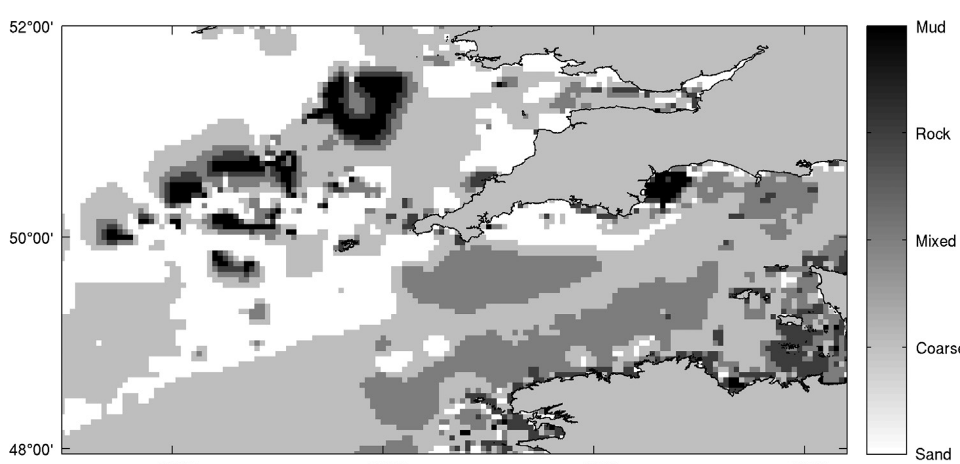

Fig. 3. Seabed type derived from UK Seamap data [53] within the boundaries of ICES Divisions VIIeh.

Table 1
Indices of relative difference in spatial pattern within gear between 2005 and 2008 using method developed by Lee et al. [43].

Year	Scallop dredge	Longline	Gillnet	Potter/ whelker	Beam trawl	Otter trawl
2005–2006	0.4591	0.5199	0.3955	0.3837	0.2698	0.4311
2006–2007	0.5151	0.6629	0.4438	0.3096	0.2949	0.4568
2007–2008	0.4393	0.721	0.5025	0.3988	0.2913	0.5031

0 = total equality; 1 = maximal difference.

Table 2
Indices of relative difference in spatial pattern between gear types for all years using the method developed by Lee et al. [43].

2005	Dredge	Longline	P/W	Gillnet	Beam	Otter
Dredge	–	0.9393	0.9319	0.9009	0.6832	0.8576
Longline	–	–	0.9717	0.7746	0.8956	0.9378
P/W	–	–	–	0.9733	0.8728	0.9179
Gillnet	–	–	–	–	0.8129	0.8472
Beam	–	–	–	–	–	0.8606
Otter	–	–	–	–	–	–
2006	Dredge	Longline	P/W	Gillnet	Beam	Otter
Dredge	–	0.956	0.8966	0.9152	0.6261	0.852
Longline	–	–	0.9939	0.8698	0.8987	0.9659
P/W	–	–	–	0.9464	0.8467	0.9464
Gillnet	–	–	–	–	0.8438	0.8794
Beam	–	–	–	–	–	0.867
Otter	–	–	–	–	–	–
2007	Dredge	Longline	P/W	Gillnet	Beam	Otter
Dredge	–	0.9583	0.8977	0.9492	0.6089	0.9013
Longline	–	–	0.9905	0.9581	0.932	0.9875
P/W	–	–	–	0.9554	0.8874	0.9141
Gillnet	–	–	–	–	0.8348	0.9308
Beam	–	–	–	–	–	0.8938
Otter	–	–	–	–	–	–
2008	Dredge	Longline	P/W	Gillnet	Beam	Otter
Dredge	–	0.9927	0.9174	0.9489	0.6529	0.9331
Longline	–	–	0.9979	0.9371	0.9562	0.9903
P/W	–	–	–	0.9512	0.8919	0.9332
Gillnet	–	–	–	–	0.8681	0.9678
Beam	–	–	–	–	–	0.9632
Otter	–	–	–	–	–	–

0 = total equality; 1 = maximal difference.

Table 3
Capacity (no. vessels) and activity (days at sea) of UK fleets in ICES Divisions VIIe-h from 2005 to 2008.

Year/ gear type	VIIe		VIIf		VIIg		VIIh	
2005	No. vessels	Days at sea	No. vessels	Days at sea	No. vessels	Days at sea	No. vessels	Days at sea
SD	17	207	14	33	6	0	12	59
Longline	5	51	5	5	7	20	9	64
Gillnet	22	62	23	154	24	58	26	58
P/W	10	62	7	80	5	26	0	0
Beam	58	210	48	153	43	33	45	106
Otter	18	114	15	98	41	32	16	29
2006								
SD	29	125	23	26	23	23	20	31
Longline	4	42	3	4	5	15	5	102
Gillnet	22	66	21	186	19	78	24	46
P/W	11	186	7	99	3	0	0	0
Beam	60	210	49	141	36	38	44	94
Otter	17	113	13	79	30	41	15	35
2007								
SD	27	134	18	18	16	35	17	12
Longline	1	156	1	1	2	1	4	51
Gillnet	16	72	14	261	13	106	13	76
P/W	14	147	9	133	3	2	0	0
Beam	53	203	47	135	29	42	38	103
Otter	8	154	9	111	25	34	8	71
2008								
SD	19	86	16	17	19	23	9	12
Longline	2	19	2	0	2	1	4	12
Gillnet	13	50	13	184	10	85	12	57
P/W	13	149	6	160	3	85	0	0
Beam	48	159	34	116	23	10	39	55
Otter	7	84	5	122	24	48	8	21

of two small area closures (Haig Fras and Wave Hub) are unlikely to have detectable environmental impacts outside the closures as mobile gear is rarely used within the proposed closures. However, if more areas off southwest UK were closed, displacement of towed demersal gear activity has the potential to increase pressure on benthic habitats unless seldom fished parts of a region are closed to towed demersal gear [39], or in response to new measures being discussed for deep-sea fisheries leading to "a displacement of a fleet of large capacity demersal vessels into areas in Western Waters such as the Celtic Sea where an ongoing recovery of demersal stocks would be jeopardised" (NFFO pers. comm., July 2012). Conversely, closed areas can sometimes benefit mobile gear users through 'spillover' [55] or enhanced recruitment through larval export [56]. An example is the increase in scallop dredging activity on areas surrounding large towed demersal gear closures in the NW Atlantic [36]. In this study, VMS analyses showed that longlining activity, and to a lesser extent gillnetting activity, were concentrated in much smaller areas than mobile demersal gear-types in South-west UK. If the Haig Fras Natura 2000 site were to be closed to longline and gillnet fisheries then their activity would likely be displaced onto other areas, potentially increasing competition between fishers and pressure on these habitats (for example [16,17]). Potters and whelkers, who often compete for space with mobile-gear users [57], may also be more affected by the proposed small closures than mobile gear users because their activities are so highly localised. The loss of even relatively small fishing grounds might incur economic costs for the potting/whelking fleet that need to be weighed against any long-term benefits of 'spillover' during compensation claims if closures are related to commercial ventures such as marine renewable energy developments [9] and [58]. Further analysis, by using the method of defining fishing grounds to assess fishing activity, not only space allocation by various fleets [44] and impacts of various fleet activities on the seabed [59,60], would improve this study and the questions it raises regarding consequences of fishing activity displacement.

Given that different fisheries have different environmental impacts, spatial management plans require high-resolution information on the distribution of different types of fishing activity [42]. For example, apex marine predators may benefit from feeding/scavenging on discards [61,62] or be at risk from accidental bycatch in long-lines or nets [63] with discard rates and bycatch risk varying greatly as a function of gear type [63,64]. The VMS dataset indicates only modest longlining activity in the region but high levels of bottom trawling may generate large quantities of discards that may benefit certain seabird populations in the region [65], given that individual seabirds adjust their foraging behaviour when overlapping with bottom trawling VMS tracks in the Celtic Sea [66,67]. A study in the Celtic Sea has pointed at the creation of *de facto* refugia for elasmobranchs due to the spatial heterogeneity of fishing activity among the fleets [68]. However, as described above, changes to fisheries management, fisheries area closures may negate this effect, if fishers' behaviour is altered and fishing activity displaced.

Table 4
Activity (h/km^2 $\times$ 10^{-5}) of all UK fleets respective of marine landscape type from 2005 to 2008.

Gear type/Marine landscape	Sand	Coarse	Mixed	Rock	Mud
Mobile					
Scallop dredge	11.02615	9.555377	38.19663	26.15827	40.09043
Beam trawl	61.42465	42.33229	63.59778	21.14759	355.342
Otter trawl	8.3149726	2.6548399	4.179753	21.18380	246.67104
Static					
Longline	1.1745026	1.5800855	4.2812401	1.7274331	11.162576
Gillnet	11.624799	5.2034432	10.637948	23.562868	143.6178
Potter/whelker	2.441716	5.8374971	4.9672157	15.623484	7.332280

Another example where mangers require gear-specific fishing activity information is in mitigating the impacts of certain types of fishing activity on the seabed. Areas of strong fishing activity by mobile gear types can modify the magnitude of natural sediment transport and sedimentation patterns by waves and currents [69]. In a hitherto unique study from the continental shelf in the Gulf of Lions, the impact of bottom trawls on fine sediment resuspension was found to be comparable with that of the largest storms, and is responsible for more than 30 per cent of the total erosion of sediment from that area.

When managing seabed habitats for biodiversity conservation, or for the commercial protection of nursery areas and brood stock, gear specific VMS data will prove useful in spatial planning since mobile demersal gear types have major impacts on certain benthic communities [70,71], with scallop dredging known to cause more damage to seabed habitats than potting, for example [72,73]. An analysis of which fishing gears are used where is important, both in assessing the cumulative impacts on marine ecosystems but also in the context of marine planning, given the potential for MPAs and MREIs to cause displacement of fishing activity [42,47,74–77].

Marine reserve planners and renewable energy developers are increasingly using multicriteria decision analysis tools such as Marxan to optimise site selection [78–81], as this allows consideration of a variety of different spatially explicit selection criteria. While the main consideration is the distribution of the natural resource in question, the inclusion of gear-specific high-resolution fisheries data can minimise environmental costs of closures incurred by activity displacement [82] and increase the economic benefits of closures to fishers [83], who are one of the main stakeholders in the marine environment [9], thereby making closures more politically feasible [83].

Although gear-type-specific VMS data analyses need to be carried out to sensibly manage the marine environment, there are caveats. The fact that only vessels >15 m length are presently included in VMS means these data cannot be used to predict effects of inshore marine renewable energy installations on the distribution of inshore fishing activity. However, mobile phone VMS for small inshore vessels are being trialled throughout the EU, and initial results suggest that fishing vessels of certain lengths tend to follow predictable patterns of fishing activity [84]. Current work being carried out by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) in conjunction with the Inshore Fisheries and Conservation Authorities (IFCAs) will lead the way for finer scale inshore fishing analysis. Data on non-UK vessels was unavailable for this study and concerns over data inaccuracies, in particular the lack of gear-type [43], precluded its use. Clearly, accurate assessment of the environmental impacts of international fisheries activity requires knowledge of activity distribution of all vessels, regardless of their length and nationality. Other issues arise in the VMS analyses. For example, the analyses are based on records that are transmitted every 2 h, and there are risks in misclassification of fishing vs. non-fishing. When interpreting fishing activity in the smaller area of Wave Hub, this is an issue which needs to be explored further, especially in the case of static gear use, where more data is needed on net and trap characteristics and soak times, in order to fully gage fishing effort [43]. In this analysis, a point summation method is used as it is deemed more transparent, but underestimations of activity are a potential risk [44]. Reconstruction of tracks is an option [85], but vessels rarely travel in straight lines and again, it may not be appropriate for those using static gear and the 2 h polling frequency is an issue [44]. In terms of track reconstruction, recent work has helped improve VMS analysis using spline polynomials rather than linear segments for tracks of beam trawl [86] and subsequently other gear types [87]. However, no interpolation technique will overcome the basic necessity for more frequent polling, prompting [45] to suggest polling at intervals of 30 min, supporting more accurate assessments of fishing activity and resulting impacts on the seabed.

In January 2005, transmission of speed data became compulsory in EU VMS. A simple speed filter allows the correct identification of a high percentage of both steaming and fishing activity [43,44]. The speed filters used, although necessary to indicate fishing gear deployment, could overestimate fishing activity as vessels might slow down due to bad weather or to reduce fuel costs for example [88], and/or local or sectoral differences in fishing speeds of individual vessels or at fleet level [43]. As marine spatial planning advances there is an opportunity to include fishers' knowledge (FK) with VMS and logbook data as well as studies of the biological, sociological and psychological influences on fishing fleet behaviour [89–91] in order to predict the movement of vessels across fleets in both the short-term and long-term.

There is room for improvement in the VMS, such as including smaller vessels and facilitating easier access to the data for researchers and spatial planners across EU Member States. Presently, EU VMS data for purposes other than those relating to the Common Fisheries Policy (CFP) is "constrained by a combination of human rights law; data protection law; the law of confidence and EU law, in particular the EU confidentiality obligation under Article 113 of EC Regulation 1224/2009 (the 'Control Regulation')" [92]. VMS are considered to provide personal data obtained via surveillance although if data analyses are for marine planning purposes, and if such analyses are integral to the CFP, then anonymized, aggregated data may be released [92]. Since 2009, changes to access to VMS data, and the level of resolution due to EU Council regulations, changes which have adversely affected this study, may prove severely disadvantageous to accurately assessing fishing fleet activity and the consequences of displacement for these fleets, hence having societal implications [93].

5. Conclusions

A lack of access to high-resolution gear-specific fisheries data for analyses raises scientific and socio-economic concerns about the underpinning of ongoing marine spatial management decisions. Given the current rapid expansion in European marine space leased to marine renewable energy, and plans for a network of MPAs that restrict certain fishing gear types, it is imperative to predict and plan for the likely effects of spatial restrictions on fisheries.

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