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Fisheries, Marine Conservation, Marine Renewable Energy and Displacement: A Fresh Approach

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Fisheries, Marine Conservation, Marine Renewable Energy and Displacement: A Fresh Approach

by

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A thesis submitted to Plymouth University in partial fulfilment for the degree of **Doctor of Philosophy**

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At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the graduate committee.

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A record of my individual contribution to this collaborative research specifically relating to my PhD is provided as part of this thesis.

Refereed journal publications:

Campbell, **M**. **S**, Stehfest, K. M., Votier, S. C., Hall-Spencer, J. M. (2014) Mapping fisheries for marine spatial planning: gear-specific vessel monitoring system (VMS), marine conservation and offshore renewable energy. *Marine Policy,* **45**: 293-300.

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Publications currently in preparation*:*

Campbell, **M**., Ashley, M., de Groot, J., Hall-Spencer, J., Attrill, M., Abbott, V., Rodmell, D. & Rodwell, L. (*In Prep*) The assessment of fishing effort displacement: a review of methodologies, *Fish & Fisheries*.

Campbell, **M.**, Attrill, M., Abbott, V. & Hall-Spencer, J. (*In Prep*) The 'natural' variability of trends in fishing effort in the South West of the UK: Defining a baseline for detecting displacement, *ICES Journal of Marine Science.*

Campbell, **M.**, Hartwell, L. & Hind, E. (*In Prep*) How simple technological advances in data sharing can increase fishermens' participation in fisheries management, *Fish & Fisheries* (Ghoti).

Campbell, **M.**, Hind, E., de Groot, J., Ashley, M., Hartwell, L., Rodmell, D. Hall-Spencer, H., Attrill, M., Abbott, V. & Rodwell, L. (*In Prep*) Lost at sea: Assessment of fishing effort displacement without inclusion of Fishers' Knowledge (FK), *ICES Journal of Marine Science.*

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Conference Presentations:

2014. International Conference on Ocean Energy (ICOE), Halifax, Nova Scotia, Canada. Poster entitled '*The Fisheries and Marine Renewable Energy Working Group: An agenda for improved co-existence*'.

2014. Marine and Coastal Policy Forum, Plymouth University, Plymouth, UK. Talk entitled '*Fisheries and marine renewable energy: Creating a mitigation agenda for improved co-existence*'.

2013. South West Marine Ecosystems, Marine Biological Association of the UK, Plymouth, UK. Talk entitled '*MRE and fishing effort displacement in the South West UK'*.

2012. Invited Keynote Heligoland Celebratory Roads Symposium, Heligoland, Germany. Talk entitled '*The global significance of the CPR Survey'*.

2012. 6th World Fisheries Congress, Edinburgh, UK. Talk entitled '*Minimising fisheries displacement in offshore MPA design'*.

2012. South West Marine Ecosystems, Marine Biological Association of the UK, Plymouth, UK. Talk entitled '*Vessel monitoring system (VMS) data and fishing effort assessment'*.

2011. ICES Annual Science Conference, Gdansk, Poland. Talk entitled '*Mapping fisheries for marine spatial planning using VMS data'*.

2011. Marine and Coastal Policy Forum, Plymouth University, Plymouth, UK. Talk entitled '*Mapping fisheries for marine spatial planning using VMS data'*.

2010. Deep-sea Biology Symposium, Reykjavik, Iceland. Talk entitled '*Deep-sea corals of the UK and Ireland*'.

2009. Plymouth Marine Sciences Partnership, Plymouth, UK. Talk entitled '*The protection of deep-sea corals within the continental shelf limits of the UK and Ireland*'.

2008. Porcupine Marine Natural History Society Annual Conference, Bangor, Wales, UK. Talk entitled '*Marine protected area monitoring tools*'.

2008. 4th Deep-sea Coral Symposium, Wellington, New Zealand. Talk entitled '*The protection of deep-sea corals within the continental shelf limits of the UK and Ireland*'.

2008. International Network on Offshore Renewable Energy (INORE), Brest, France.

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Signed…………………………………………

Date……………………………………………

Abstract

Fishers are among the biggest commercial resource users in the marine environment. In order to meet international, national and local policies, the UK has to designate a suite of marine protected areas (MPAs) and reach marine renewable energy (MRE) targets. Inevitably, there will be conflict between these two industries and marine conservation. This study uses a multi-disciplinary approach to examine evaluate the suitability of various sources of data, which could be used to detect, assess, and ultimately predict, fishing effort displacement within the different sectors of the > 15 m fleet in the South West of the UK. Gear-specific Vessel Monitoring System (VMS) data from 2005-2008 was used to assess potential effort displacement due to Haig Fras, a proposed MPA and Wave Hub, a marine renewable energy installation (MREI). The spatial distribution of fishing activity was highly heterogeneous and distinct areas of intense fishing could be identified for all gear-types. A closure of Haig Fras would have the greatest impact on gillnetters. Scallop dredgers also occasionally use the area. The current closure at Wave Hub has the greatest impact on potters and whelkers whose geographic specialisation is most pronounced and who use the area extensively. Longliners also use the area disproportionately would be affected. A simple index of variability was developed in order to determine baselines and two other sources of data were used. High resolution seabed data and low resolution catch data. A semi structured interview was conducted with forty fishers to elicit further information on the challenges, barriers to progress and priority issues in relation to MRE those fishers face. The theme of discontent with the consultation process scored highly throughout. Fishers' Knowledge (FK) another source of data also scored highly, although further work must be carried out to identify what aspects of this data are useful in assessment of fishing effort displacement.

Chapter 1 Table of Contents

List of Illustrations

Chapter 1 Thesis overview

“Hark, now hear the sailors cry, smell the sea, and feel the sky let your soul & spirit fly, into the mystic...”

Van Morrison, Into the mystic, Moondance, 1970.

1.1 Thesis aim

The aim of this thesis is to evaluate the suitability of various sources of data, which could be used to detect, assess, and ultimately predict, fishing effort displacement due to implementation of marine conservation objectives and the development of the marine renewable energy (MRE) sector (Figure 1.1). This will be achieved by looking at one area - the South West of the UK – at the highest possible detail. The principal data sources that will be critically assessed come from the satellite Vessel Monitoring System (VMS) and interviews and workshops with fishers themselves, information on aspects of fishing behaviour and strategies that can be termed Fishers’ Knowledge (FK).

The key objectives of this work are to:

- Detect, identify and highlight ways in which the UK fishing fleet could be affected by the development of marine conservation efforts and MRE development, and how that might translate into the displacement of vessels into new fishing grounds.

- Carry out this work at varying resolutions, from the individual vessel, through assemblages of vessels with the same gear types, to fishing fleets operating out of individual ports, and finally to whole fleets operating wholesale out of all ports in the South West of the UK;
- Assess what data and analysis methods would be required to detect such a displacement of fishing effort, and at what resolution and scale would such a detection be possible; and
- Assess the potential of these data and methodologies to predict which fisheries in the > 15 m sector are at risk of fishing effort displacement.

During the course of this work, some important developments influenced the direction the thesis research was to take. Firstly, deployment of Wave Hub, the first of the marine renewable energy installations (MREIs) in the South West did not occur until late 2010. Secondly, major data changes to access to VMS data for non-fisheries institutes (including Plymouth University) within the EU occurred from 2009-2011, meaning that restrictions are placed on the level of access for the whole data set and non-access to individual vessel data. In consequence, the only data available to me at sufficient resolution to carry out the above thesis objectives at the finest possible detail are from 2005 to 2008 inclusive. Additional, lower resolution data are available from 2009 and 2010. Only fisheries institutes can access this high resolution VMS data thereafter. This meant that any changes to fishing effort during installation, operation and post operation of this MREI could not be elucidated and this is highly significant. The widespread implications of this policy in studying and managing fisheries displacement are a major theme of this work and are discussed at length during the course of this thesis. An additional important development occurred in 2011, when a fisheries and MRE interactions workshop was held at the

UK's first Marine & Coastal Policy Forum in Plymouth. This event spurred the development of a Natural Environment Research Council MRE Knowledge Exchange Programme (NERC MREKEP) (Rodwell *et al*., 2012, 2013), of which I became a principal member, and which involved a questionnaire at the Environmental Impacts of Marine Renewable Energy (EIMR) in Orkney in 2012, a scoping and expert panel workshop which included fishers, fishing body representatives, scientists, practitioners, policy makers and MRE industry representatives from all over England, Wales, Northern Ireland and Scotland, and which led to the design of a mitigation agenda and a set of actions to take forward (de Groot *et al*., 2014). This mitigation agenda specifically refers to fishing effort displacement due to MRE developments, and conflict between different sectors of the UK fleet. Certain priority actions were taken forward: the development of efficient and cost-effective methods for overcoming data issues for assessing fishing effort displacement; the development of appropriate methods of assessment; and the development of an acceptable consultation protocol between MRE and fishing sectors agreed on by all stakeholders. A subsequent fisher survey was designed and used primarily in the South West, however was extended to select fishers around the remainder of the UK using various techniques; social media outlets including Twitter, and Through the Gaps fisheries blog, meetings and fisher orientated events such as industry expos and activities in the ports. In light of the limitations made to VMS data and catch data access the activities and research that was undertaken under the auspices of NERC MREKE Programme created an opportunity to address three further objectives, specifically related to MRE, and which were not originally planned:

- To develop a list of data collection and activities that would enable assessment of the degree and impact of fishing effort displacement;
- To make recommendations to improve both the collection and use of FK for the assessment of fishing effort displacement; and
- To validate a mitigation agenda brought forward during MREKE Programme workshops.

This thesis is presented as a compendium of research Chapters, each containing more narrowly defined aims and objectives for the component of the study that the Chapter seeks to address, a full review, description of methodologies used, a discussion and summary conclusions. Most of the research was undertaken in a case study area, i.e. the South West of the UK. However, Chapter 5 also includes research which is national in scope. A significant part of Chapter 5 was the result of a combined effort with others within our MREKE Programme team, which resulted in the publication mentioned above (de Groot *et al*., 2014). A portion of material from that publication pertaining to stakeholder views on data has been both reproduced and expanded upon in Chapter 5.

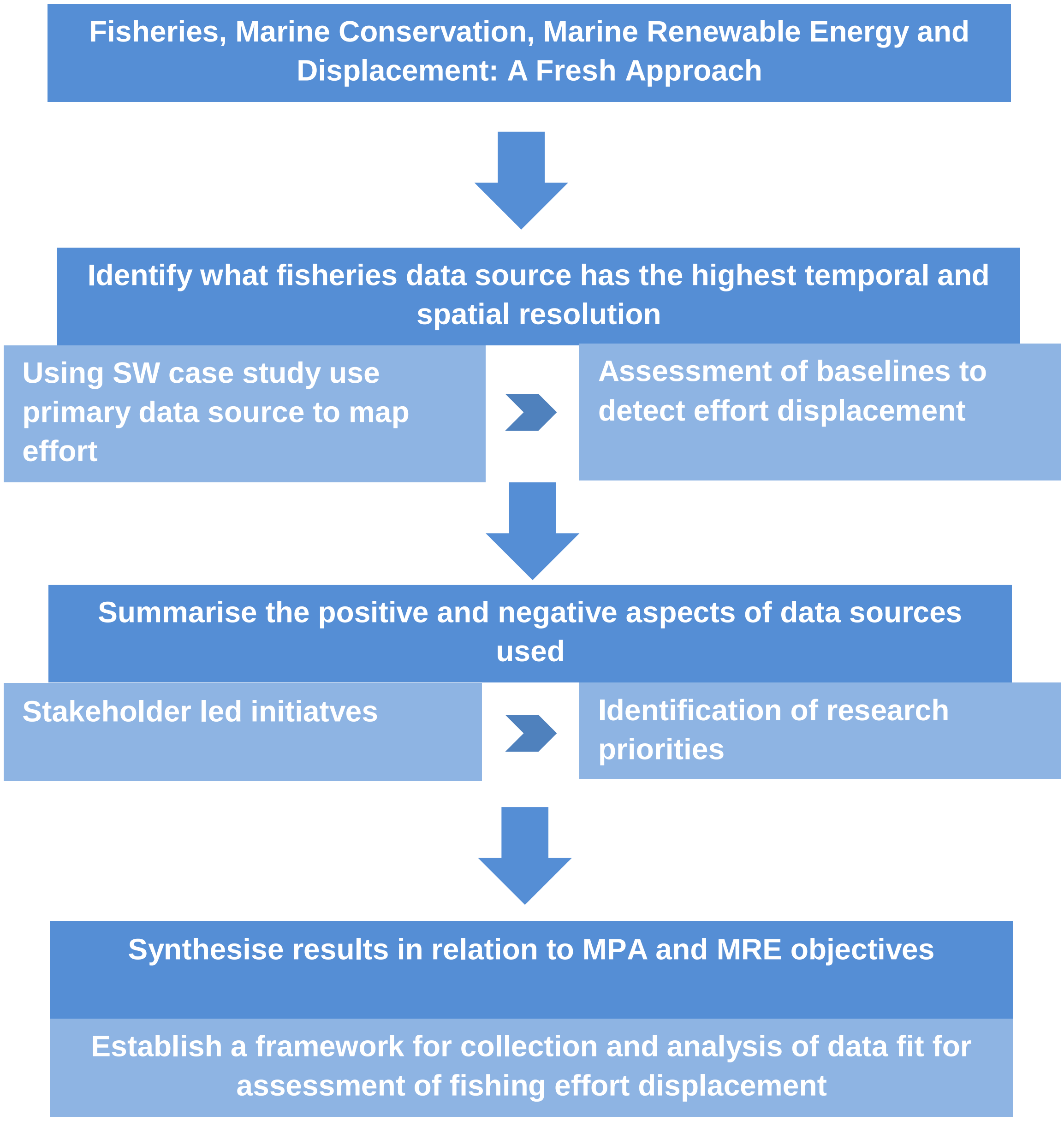

Figure 1.1: Schematic of research pathway

Schematic of research pathway to investigate the research question 'What various sources of data could be used to detect, assess, and ultimately predict, fishing effort *displacement due to implementation of marine conservation objectives and the development of the marine renewable energy (MRE) sector?'*

1.2 Rationale for the case study site and survey

1.2.1 MREI developments in the South West

The South West has great potential in relation to MRE resources (PMSS, 2010a). Named the South West Marine Energy Park in 2012[1], continual investment will see this region grow as a global industry leader. For example, recent funds obtained via an EU Horizon 2020 bid, has secured the testing of a WEC developed by the Finnish company Wello[2]. There is also a large offshore proposed Marine Protected Area (MPA), thus providing fertile territory for analysis of the potential for fishing activity displacement and the assessment of suitable baselines.

Shown below in Figure 1.2 are the most up to date active and proposed MRE sites in the UK. This figure is provided in order to place the South West of the UK in context with the rest of the country.

[1] https://www.gov.uk/government/news/south-west-makes-splash-as-first-marine-energy-park

[2] http://www.wavehub.co.uk/latest-news/eu-horizon-2020-programme-grants-eur17-million-for-wave-power-research-proj

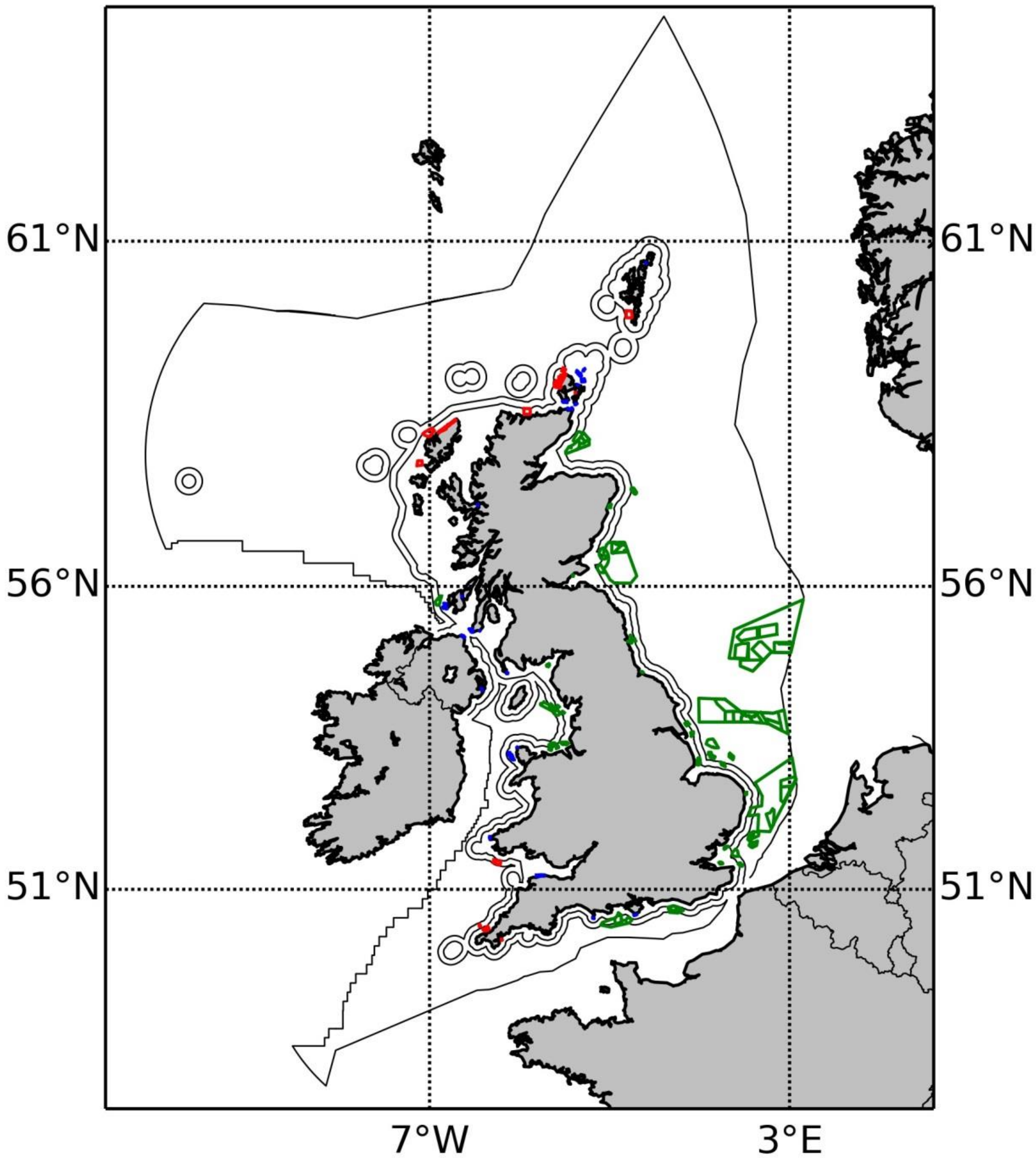

Figure 1.2 Active and proposed UK Marine Renewable Energy Installations (MREI).

Data obtained from the UK Crown Estate (accessed January 2015 from http://www.thecrownestate.co.uk/energy-and-infrastructure/downloads/maps-and-gis-data/). Red polygons are wave energy sites, blue areas are tidal energy sites, and green polygons are wind energy sites.

Shown below are the current Marine Renewable Energy (MRE) developments in the South West[3]. These are also represented in Chapter 4, Figure 4.4:

- Wave Hub, a MREI, a facility for testing prototype Wave Energy Converters (WECs) located 10 NM from Hayle, North Cornwall. This closure will result in an 8 km^2 exclusion zone initially, but with visions for increasing berth numbers;
- Pembrokeshire Wave Energy Test site is managed by Wave Hub Ltd with a total area of 90 km^2 and has a generating capacity of up to 30 MW when at full array level and is located 7-12 NM offshore;
- North Devon Tidal Zone, also managed by Wave Hub Ltd is located in the Bristol Channel. Measuring a total area of 35 km^2 it has a generating capacity of up to 30 MW when at full array level and is located 2-5.5 NM offshore;
- North Cornwall Demonstration Zone, a new wave energy site has the potential to produce 30 MW when at full array level and is located 2-6 NM offshore of Hayle;
- FaBTest is a 2.8 km^2 nursery facility located in Falmouth Bay between 1-3 NM offshore; and
- Tidal Energy Developments South Wales Ltd (TEDSWL) has two sites off the Pembrokeshire coast. One, a preliminary site in Ramsay Sound, will develop into a small array off the coast at St. David's Head in 2017. Both sites are approximately 1-5 NM offshore, and it is proposed the array when fully functional has the potential to produce 10 MW.

[3] https://www.regensw.co.uk/7283018298372873/wp-content/uploads/2015/05/South-West-MEP-Statement-of-Ambition.pdf

- Tidal lagoon at Swansea Bay. The world’s first, man-made, energy-generating lagoon, with a 320 MW installed capacity.

1.2.2 Fisheries in the South West of the UK

Figures 1.3-1.6 show landings in tonnes and GBP of all mobile gears, and static gears respectively. These Figures are based on data attained from the Marine Management Organisation (MMO), which is classed as Level 2 data. This data was attained when requesting VMS data for the period 2007-2010. Figure 1.7 shows the demersal, pelagic and shellfish landings at 21 of the major ports in England and Wales, clearly showing the dominance of the South West fleet especially in the pelagic and demersal sectors.

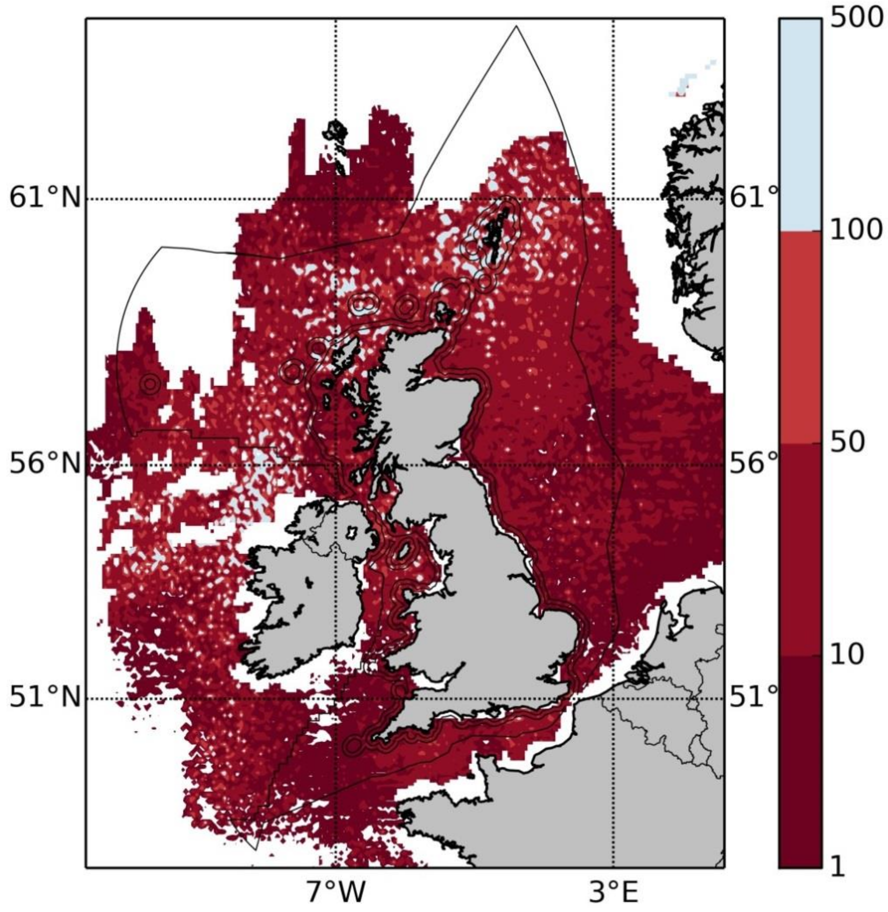

Figure 1.3 Total quantity (in tonnes) liveweight of fish landed by all vessels with mobile gear types.

Data have been gridded to a 0.1 degree regular grid (Data supplied by MMO, Level 2 data)

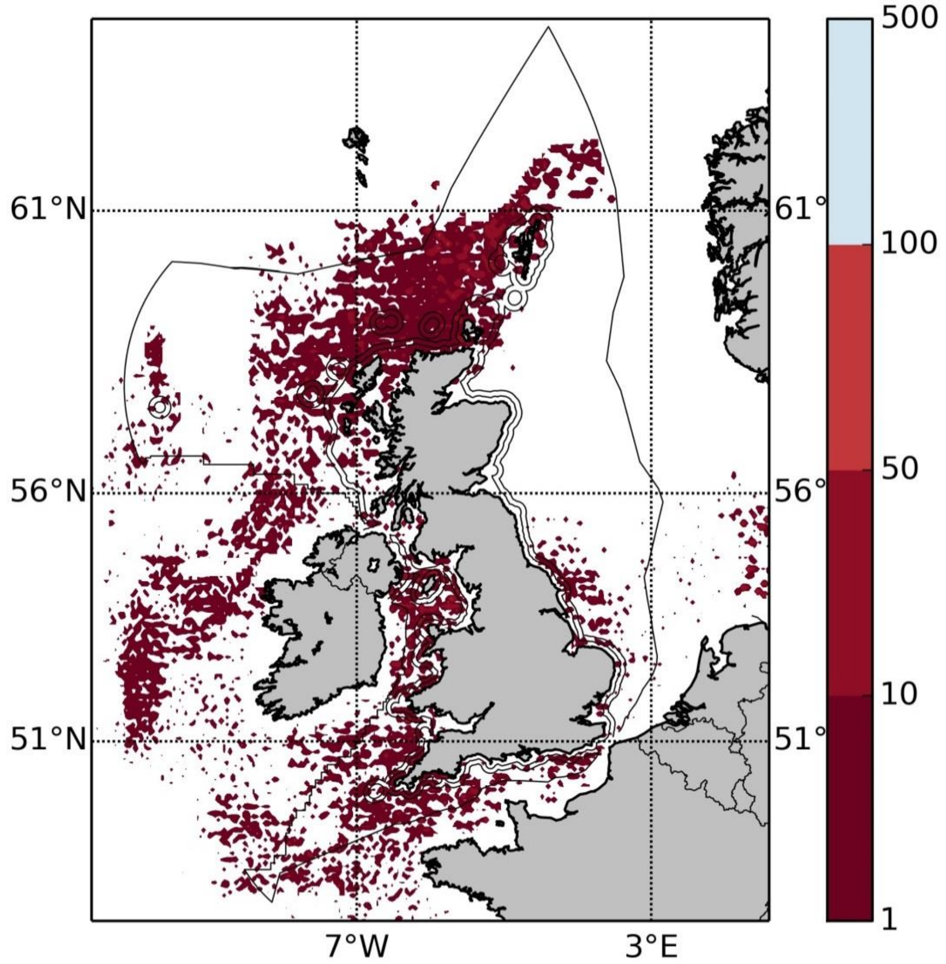

Figure 1.4 Total quantity (in tonnes) liveweight of fish landed by all vessels with static gear types.

Data have been gridded to a 0.1 degree regular grid (Data supplied by MMO, Level 2 data)

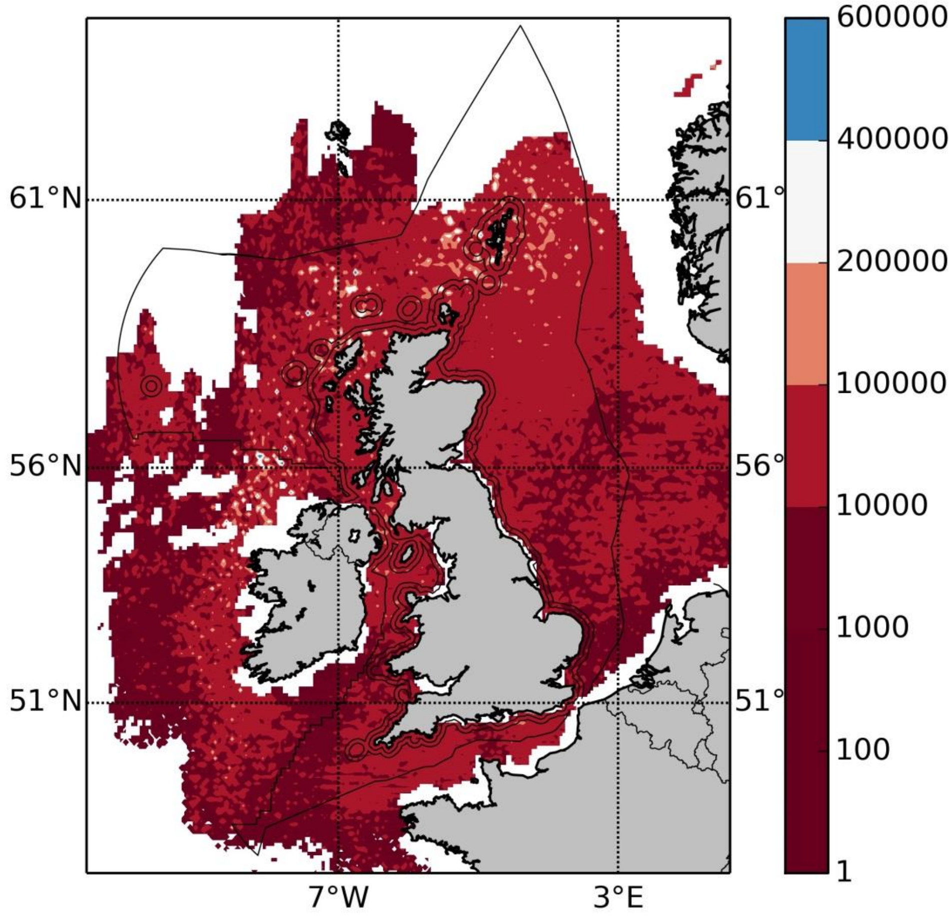

Figure 1.5 Total value (GBP) of landed fish by all vessels with mobile gears.

Data have been gridded to a 0.1 degree regular grid (Data supplied by MMO, Level 2 data)

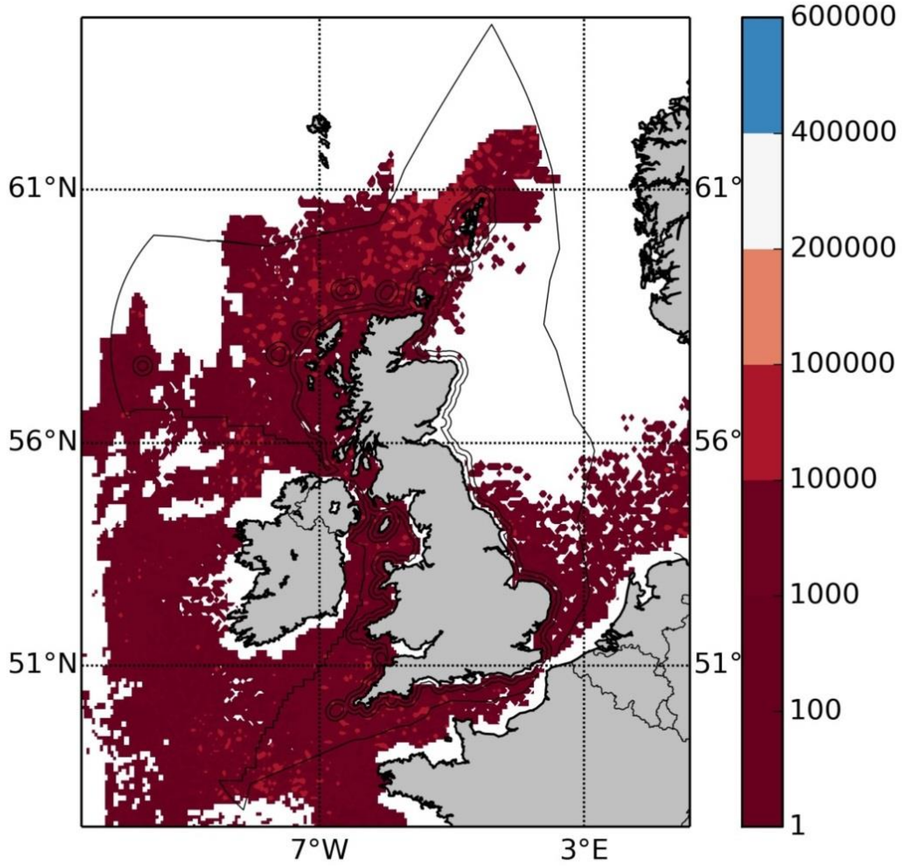

Figure 1.6 Total value (GBP) of landed fish by all vessels with static gears.

Data have been gridded to a 0.1 degree regular grid (Data supplied by MMO, Level 2 data)

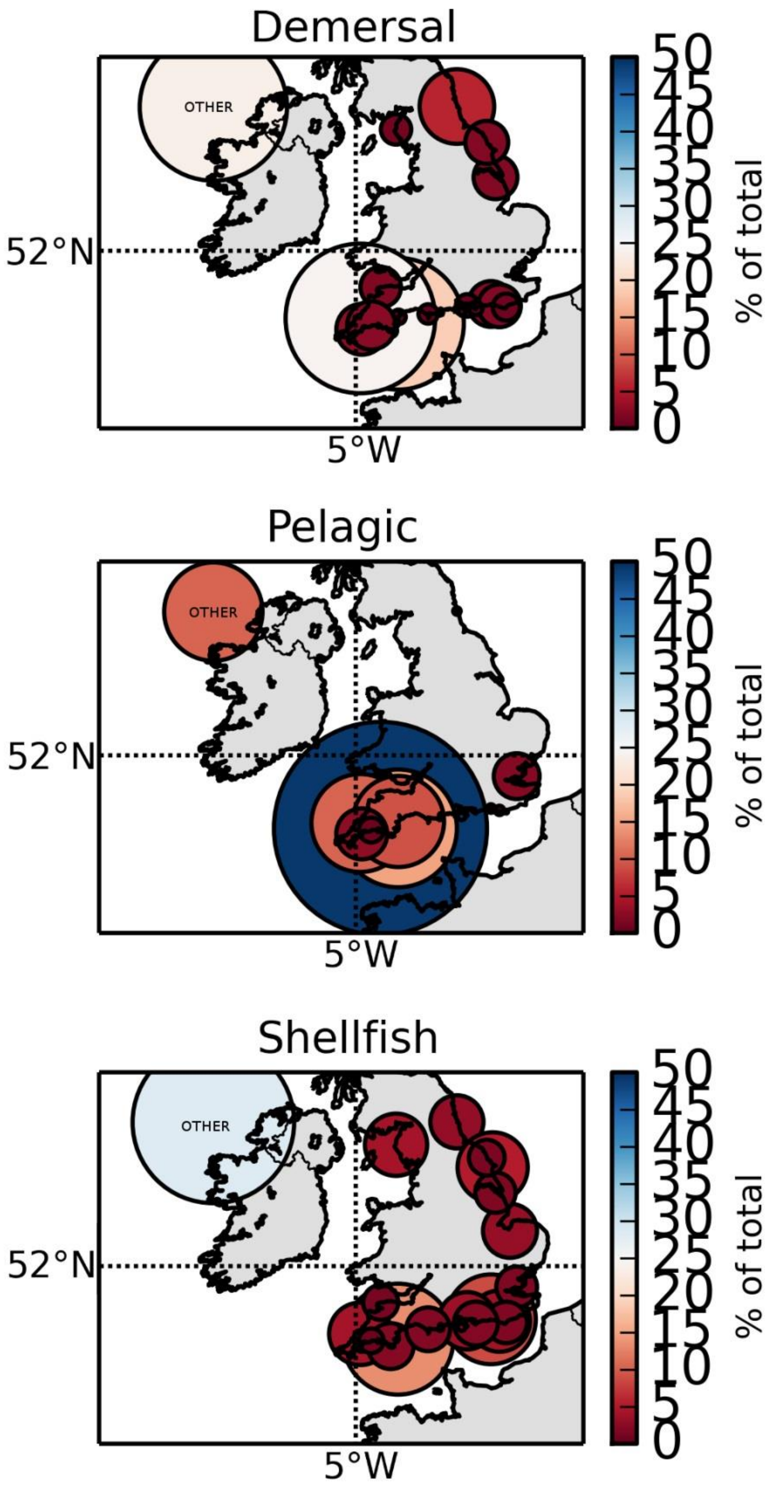

Figure 1.7 Landings in the 21 major ports in England from demersal, pelagic and shellfish fisheries, expressed as a percentage of the total in that respective group.

The category 'other' represents the rest of the ports in England. (Data provided by MMO UK Sea Fisheries Statistics (2007-2010))

1.3 Thesis outline

Chapter 2 is a literature review and scene setting exercise. This Chapter outlines the use of certain data sources in the assessment of fishing effort displacement

Chapter 3 chooses the most appropriate method for assessing effort displacement using gear-specific VMS data for > 15m vessels and seeks to evaluate the potential of effort displacement on different segments of the South West fleet due to a proposed marine protected area (MPA), Haig Fras, and a marine renewable energy installation (MREI) Wave Hub. Patterns in fishing effort are elucidated by the use of statistical techniques, and visualised using multidimensional scaling and hotspot analysis is included in order to ascertain high level activity for each gear type from 2005-2008.

Chapter 4 addresses the question: how might the background variability of fishing effort is described, so that a displacement can be assessed? The approach is twofold. First, fishing effort in South West UK waters is described and quantified relative to arguably the most dominant physical control on the spatial distribution of fishing: seabed substrate. Secondly, a generalised linear model (GLM) analysis was performed, in order to model fishing effort as a linear combination of available independent, or explanatory, variables: depth, wind strength, wave strength, substrate type, and gear type, year and fish value. Thirdly, a simple technique, based on the coefficient of variation is developed that can be used to describe and quantify variability. This technique can be compared across any number of gear types and across any number of years, and can be interpreted using standard statistical methods. This Chapter also Investigates the relationship between fish catch data (derived from low-resolution, less-access-restricted level 2 VMS data) and the background variability of fishing effort, in order to explore the potential role of broad scale catch data (weight and economic value of fish) as a simple proxy for baseline fishing effort. Level 2 data are: available on a 4 year aggregated basis contains fishing type split into simple static vs mobile. Landings values are not at the individual vessel level but are at the level of an ICES square, any area containing less than 10 vessels are removed from the dataset due to confidentiality issues and there is no access to vessel logbook information. The Level 2 vs Level 3 data will be discussed in more detail in Chapter 3.

Chapter 5 focuses on responses of fishers to the challenges of marine renewable energy (MRE). This Chapter is the product of semi-structured interviews with forty fishers around the UK. It is primarily South West based due to financial constraints. In addition, sections of the UK in Scotland, Northern Ireland and Wales fleet were successfully approached using various social media outlets including Twitter, meetings and fisher orientated events such as industry expos and port-side activities. Validation of a mitigation agenda for fishing effort displacement developed by de Groot *et al*. (2014) is presented along with the establishment of a debate about the application of Fishers' Knowledge (FK) in the assessment of fishing effort displacement. A set of recommendations are presented on how to incorporate FK in a systematic way in order to assess fishing effort displacement and a debate is initiated on how to innovate how we engage with fishers and improve the consultation process.

Chapter 6 is a concluding Chapter which brings together the results from each Chapter to provide an overview of the constraints and opportunities for the development of this field of research. Data provision and access are two fundamental themes running throughout the whole of this thesis; this Chapter reviews current data policies within the UK and the EU and discusses future ideas on how to improve data issues within the context of MRE and MPA objectives and data policy climate. It is important to remember that this thesis is one of the first theses to address fishing effort displacement in relation to MRE, and evaluate a potential mitigation agenda designed during the period of study. Considering the data access challenges presented, this Chapter attempts to make some high level recommendations about the assessment of fishing effort displacement and initiates a debate about the formation of an ICES Study Group on assessment of fishing effort displacement.

Chapter 2 Literature Review and Conceptual Framework

Work presented in this Chapter will be incorporated into the following manuscript which is currently in preparation:

Campbell, **M**., Ashley, M., De Groot, J., Hall-Spencer, J., Attrill, M., Abbott, V., Rodmell, D. & Rodwell, L. (In Prep) ‘The assessment of fishing effort displacement: a review of methodologies’, *Fish & Fisheries*.

“Up jumps a herring, the king of the sea

He jumps up on deck saying "helms a-lee!"

Singing, blow the wind westerly, blow the wind

By a gentle nor-wester, how steady she goes”

‘Blow the wind westerly’, Newfoundland Sea Shanty

2.1 Introduction

Of all the extractive processes that occur in our marine realm, fisheries have one of the greatest spatial footprints of all (Eastwood *et al.,* 2007). Professor Ray Hilborn, one of the leading marine scientists of the 21st Century, who has changed our contemporary thinking on fisheries management, once stated “*managing fisheries is managing people*” (Hilborn, 2007) and in a world with an increasing population and competition for space in our coastal and offshore realms, the need for improved analysis of fishers’ behaviour should be high on the agenda. Understanding what drives fishing fleet dynamics (van Putten *et al.,* 2012) and fine scale effort, in order to delineate what influences the choices they make in response to closures, and in particular the effects of displacement due to these closures, respective of region, inshore vs. offshore and gear-type, is paramount.

The study area of fishers’ behaviour is not new to science, having been around since at least the late 1970’s and the key to successful fisheries management is knowledge of this area (Wilen, 1979; Hilborn & Walters, 1992). During this time, major technological advances in vessel efficiency, fish capture and storage, leading to greater diversification in gear types, fishing further offshore, introduction of new and changing economic markets for different fish species has resulted in the introduction of even greater layers of complexity in fisheries analysis. However, due to concerns about global fish stock viability, sustainability and illegal unreported and unregulated (IUU) fishing, new systems of monitoring, enforcement and enhanced stock assessments have meant that data availability, quality and resolution have improved dramatically. This has helped progress the development of scientific methodologies and models to unravel these layers of complexity, to stimulate debate about and contribute to better fisheries management.

One of these enforcement measures was the introduction of *de jure* Marine Protected Areas (MPAs) as a means to not only mitigate for fisheries in peril, but also to limit the degradation of the benthic environment, biodiversity loss and therefore ecosystem function. A set of international commitments; Convention on Biological Diversity (CBD), Oslo-Paris (OSPAR) Convention and the World Summit for Sustainable Development (WSSD), calls for networks of MPAs, known as Marine Conservation Zones (MCZs) to be introduced in 2012, 2010 and 2012 respectively. Sites have been selected to protect areas that are important to conserve the diversity of nationally rare, threatened and represented habitats and species and ecological coherence or connectivity. They will exist alongside already established MPAs, i.e. Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) protecting habitats and birds respectively. However, in the UK the process for establishing a network of MCZs has been extended, in order to improve the robustness and reliability of evidence provided to underpin site selection.

For the UK, the implementation of the Marine and Coastal Access Act in 2009, was both a turning point for campaigners and a positive change leading to improved management of the marine realm: the establishment of a new Marine Management

Organisation (MMO), a new system of marine spatial planning through the development of the Marine Policy Statement, new mechanisms for MCZ designation, and, streamlining and modernisation of licensing and enforcement powers. Another change, is the replacement of Sea Fisheries Committees with 10 regional Inshore Fisheries Conservation Authority (IFCA), a new type of regulator with extended responsibilities; achieving sustainable fisheries objectives while at the same time meeting conservation objectives.

The current MCZ process has caused much debate among the fishing communities across the UK, and not all of it positive. The formation of an MPA Fishing Coalition (MPAC) took place to deal with issues surrounding the designation of MCZs and the stakeholder-led process in particular, and one of the main reasons for establishment of the Coalition, was the issue of displacement of fishers from their customary fishing grounds. It considered that inadequate attention was being given to the consequences of displacement, for vessels directly affected and adjacent or distant areas into which fishing effort is displaced. In the siting of MCZs, the National Federation for Fishermen's Organisations (NFFO) briefly outlined a list of the unintended consequences that should, from a conservation perspective, be avoided and offered some 1st stage strategies to mitigate against conflict. This is shown in Table 2.1, below.

Table 2.1: NFFO list of consequences of displacement and strategies in selecting sites for closure for conservation purposes[4].

Consequences	Strategies
Displacement to areas that have been subject to less pressure and are	Do not select sites upon prime fishing grounds located on relatively resilient

[4] NFFO news item 22/03/13 Marine Conservation Zones and Fisheries displacement

therefore more likely to be in a pristine state, or to less resilient habitats from those areas where fisheries take place	habitats
Displacement to less productive fishing areas where a greater amount of fishing effort is required in order to catch equivalent quantities of fish	Avoid areas where the greatest catches are harvested
The locking up of significant productive resources that undermines the productivity of the remaining accessible resource and prevents maximum sustainable yields from being achieved	Aim to avoid prime fishing grounds, particularly for those fisheries that are limited in their distribution

Coupled with marine conservation is the need for renewable energy for a sustainable future. Presently, the world's oceans are increasingly being tapped as a source of renewable wind, tidal and wave energy (Jones *et al*., 2008; Clément *et al*., 2002) to address the decline in fossil fuel reserves and reduce the rates of environmental changes, i.e. ocean acidification caused by anthropogenic carbon dioxide emissions (Hall-Spencer *et al*., 2008; Shields *et al*., 2009). The UK as an island community holds great potential as a source of marine renewable energy and as a result, the UK Government has set a target for approximately one third of its electricity production coming from marine renewable sources by 2020 (House of Lords, 2008). Commercial offshore wind energy is already well established but the technology for wave, tidal and deep-water offshore wind energy is still in its infancy (Witt *et al*., 2012). Marine Renewable Energy Installations (MREIs) also have the capacity to cause further displacement of fishers from traditional fishing grounds, from both construction and operational phase perspective (Inger *et al*., 2009). However, MREIs also have the potential to become *de facto* MPAs, because at present fishers will not risk damage to fishing gear by fishing in these areas, thus the areas are free of fishing activity. . But on the other hand, MREIs, in particular wind turbine arrays have the potential to benefit fisheries, by enhancing shellfish and seaweed aquaculture, and this idea of the potential for co-location of the above, and co-location of MREIs and MCZs are the subjects of intense scrutiny right now (Yates *et al*., 2015b). However, matters of health and safety and liability issues have precedence here (de Groot *et al*., 2014) and the respective technology and the law must keep up with the pace of both MREI developments and MCZ designations, but what are important here are the issues of mitigation of displacement and co-location. Mitigation and specifically the research and design required to provide mitigation for the life cycle of marine renewable energy projects and MCZs is at the centre of debate when it comes to fisheries displacement.

This increase of human activities in the marine environment calls for a more integrated approach to management rather than a purely fragmented and sector based one (Smith & Wilen, 2003; Crowder *et al*., 2006; Tyldesley, 2006; Douvere, 2008). Marine spatial planning (MSP) is a term which originated from the Government's overarching vision for the marine environment as set out in the first Marine Stewardship Report (Defra, 2002). MSP involves delivering a more ecosystem-based approach to managing and planning of marine activities. As defined by Defra (2004) MSP is a '*strategic, forward-looking planning for regulating, managing and protecting the marine environment, including through allocation of space, that addresses the multiple, cumulative, and potentially conflicting uses of the sea*'. In summary, MSP will provide a framework that will minimise losses for both industry (i.e. energy and resource needs) and conservation, and should, in effect address effort displacement and the context within which industry and conservation rests.

Hence, the questions arise: how to effectively measure displacement? How to separate it from change brought about by regulations and outside economic considerations for example? Are there gear-specific differences and do these differ from region to region? Are there differences within similar métiers? Do the decisions fishers make operating inshore differ from larger offshore vessels? How do we quantify these decisions and apply to displacement analysis among the fleets? Can we predict where fishers will move if areas are closed? If so at what scales are we assessing fishing activity, and what is the appropriate level of data resolution? What are the ecological, social and economic consequences of closures, reallocation of effort and competition between fishers? How do we deal with the paucity of data for the inshore fleet? How do we separate short-term vs. long-term behaviour? Which leads to: what data are currently available or could be made available?[5]

This might include data such as: vessel characteristics, i.e. age, length and engine size (power and capacity), home port and registration port, main gear type, operation of multiple gears, ownership/ management of vessel, crew size; Vessel Monitoring System (VMS) data (> 15 m vessels); detailed logbook access; mobile VMS for < 15 m; catch/ landing data via ICES database; Joint Nature Conservation Committee (JNCC) substrate layers/marine landscape types; MMO quota statistics for gears and regions; qualitative methods via questionnaires on fishers' life at sea, the fish they catch, their strategies, their behaviour due to external economic changes, i.e. quota changes, fuel costs.

What is key to all these questions is; the elucidation of normal practice for fishers, defining of fishing activity baselines taking into account their short-term and long-

[5] The use of some of the data requires the explicit permission of the fishers involved. Written agreement is provided by the fisher, given to the MMO who then contact the fishers involved to verify and then requested data will be released.

term behaviour, using both quantitative fishers capture information and both quantitative and qualitative social science techniques to delineate factors which underpin individual fishers' strategies and thus fleet dynamics. The increased use of Fishers' Knowledge (FK) which is a combination of tacit knowledge, Fishers' Ecological Knowledge (FEK), and Local Ecological Knowledge (LEK) or defined by Hind (2015) as "the experiential knowledge that fish harvesters accumulate while operating in their respective fisheries". It is mainly qualitative in content and has been absent from fisheries management for a long time, however it is becoming integral to the reform of the CFP and will underpin management decisions for the foreseeable future, if aspects of the reform are to be successfully introduced. Careful consideration is of FK required here of the question is whether FK can be a serious contender regarding the identification of mitigation strategies that deal with fishing effort displacement? Hind (2012, 2015) believes this to be the case and suggests using FK as one of the central information pillars to achieving ecosystem-based management. A pilot project *Annual Fisheries Reports* using FK initiated by the NFFO and the Cornish Fish Producers' Organisation (CFPO) in 2010 has led the way with other POs getting involved and has been viewed by many scientists as where the future of the industry lies. This 'mixed-method approach' as discussed by Urquhart *et al.* (2012) is an approach that combines both qualitative and quantitative research in a single study, and if really encouraged across research areas, it has the potential, illuminate and expand the field of fishing effort displacement.. What is emerging from recent research also, e.g. Hind (2015) and Stephenson *et al*. (2016) is that the use of FK coupled with the active participation of fishers in assessment and management may help improve fisheries governance.

Never has there been a more genuine urgency to advocate unique and innovative ways of quantifying and mitigation against, fisheries displacement and its consequences for inshore and offshore fishers. Assessing VMS and catch data for example is only the first step in investigating fishing effort, but fishing is a way of life, processes are complex, what factors influence the decisions that fishers make are multifarious, hence, the investigation of FK alongside all of the other data sources as listed above, may be imperative to gaining any momentum in the resolution of conflict in the multiple uses of marine space and one of our last 'hunter-gatherer' traditions, i.e. fishing.

2.1.1: Understanding effort distribution in fisheries

2.1.1.1: Vessel Monitoring System (VMS) data

The use of VMS as a valuable tool for assessing the distribution of fishing effort is well established (e.g. Dinmore *et al*., 2003; Eastwood *et al*., 2007; Mills *et al*., 2007; Stelzenmüller *et al*., 2008; Hall-Spencer *et al*., 2009; Lee *et al*., 2010; Gerritsen and Lordan, 2011, and references therein) and its availability has revolutionised analyses of the spatial and temporal distribution of fishing effort. However, owing to the array of data collection and treatment (there is no agreed single method in assessing fishing effort from VMS data) that previous researchers have employed globally to ascertain fishing effort among different fleets using VMS, including, speed based rules to identify actual fishing from non-fishing, grid cell sizes, VMS intervals (minutes), conversion of points to a measure of activity, Lee *et al*. (2010) proposed a method, based on known fishing activity that could be a step towards standardization of methods. This is extremely useful as a means to improve data sharing between different nations occupying shared fishing space, and the "audit trail" of various stages from raw data format to the production of fine scale maps of fishing effort, supports international collaboration (Lee *et al*., 2010). In Lee *et al*. (2010), the analysis is supported by actual observer data from a discard monitoring program to assess accuracy of speed values used to delineate fishing vs. non-fishing activity in the VMS dataset. On this topic, observers recorded the timing, location of fishing activity catch and discard rates. Lee *et al*. (2010) discuss how local or sectorial differences in speed of vessels may be observed when fishing and the fact that only 0.5- 1% of fishing trips of English and Welsh vessels have observers on board (Cotter *et al*., 2006) reinforces the idea that in order to assess risk better, more detailed information of the dynamics of local fleet activities (Lee *et al*., 2010) could be attained through increased use of observers? Murawski *et al*. (2005), in analyses of effort distribution and catch patterns adjacent to MPAs, also used observer data, and its inclusion meant that assessments of spatial allocation behaviour could be captured at a much finer resolution.

In the analysis by Lee *et al*. (2010), their access to logbooks meant that any the gear type of any vessel with VMS could be established by linking the national logbook data to the unique vessel identifier and time. Using a speed, distance, time triangle, and known speeds of vessels fishing, they used a point summation method by applying a grid cell size of latitude 3- min/ 0.05° to all VMS point locations, thus allowing the cells to be mapped directly to the scale of ICES rectangles and catch based reporting in logbooks.

The authors also developed an index of difference in spatial pattern to assess the difference in effort between years for the same gears and with different gears. Activity vs. effort, especially in relation to static gears, i.e. VMS data can result in an analysis of activity but information on the size, soak time of nets or traps and hauling times is missing so in order to fully assess effort data these factors are needed. As mentioned briefly above, a point summation method was employed and the reasoning is in part due to the polling frequency of VMS, i.e. 2 hours. Track based approaches may be more appropriate if the polling interval decreases, or if one is researching a small area with fewer vessels, however work by Hinzten *et al*. (2010) may be a step towards improvement in track reconstruction in order to capture the true distribution of fishing activity. In the case of mobile fisheries, “e.g. Deng *et al*. (2005) and Lambert *et al*. (2012)” suggested the use of polling intervals that vary between different sectors of the fleet may be more prudent, , especially when considering fishing impacts on seabed biota and habitats.

Another important caveat associated with VMS data, is the fact that the activity of smaller vessels (< 15 m), which constitute a major part of the UK fishing fleet is not captured. However, from 1st January 2012 vessels < 12 m had to install VMS and there are discussions about extending the systems to towed gear vessels < 8 m in length (EC, 2011b). This combined with the suggestions of reduction of polling intervals, actual logging of fishing activity and non-fishing activity and access to VMS data for international fleets operating in a shared space, may go some way further increase the value of VMS as a source of high resolution fishing effort data (Lee *et al*., 2010).

Jennings and Lee (2012) took this a step further and compared different methods to define fishing grounds by assessing fleets at regional and national scales, with the aim of assessing “*how the choice of criteria for defining fishing grounds influences (i) size, shape and location, (ii) overlap among fishing grounds, and (iii) the extent to which annual and multiannual patterns of fishing activity describe ground used seasonally or by individual fishers*”. VMS analysis of this study by Jennings & Lee (2012) followed that of Lee *et al*. (2010). Analysis was carried out in three sections:

- Individual vessels of the South-west beam trawl fleet
    - Spatial extent of fishing effort, contribution of fishing grounds to annual fishing effort and landings
    - Definition of boundaries encompassing 70, 80, 90 and 100 % of total activity of each vessel and ranking of cells from low to high activity
    - Cumulative activity and area calculations
    - Assessment of consistency of extent of grounds used by fleet on an annual basis with extent used on a monthly basis and by individual vessels
- Fleets at the regional scale, i.e. the scale of ICES VII
    - Description of fishing grounds encompassing 70, 80, 90 and 100 % of total activity of each fleet; beam and otter trawl, dredge, net, potting
    - Definition of boundaries encompassing 70, 80, 90 % of total activity
    - Cumulative activity and area calculations
    - Landings weight and value of bottom fleets compared to landings weight and value of all UK vessels
- The main fleets in the Northwest Atlantic
    - Description of fishing grounds encompassing 70, 80, 90 and 100 % of total activity of each fleet; beam and otter trawl, dredge, net, potting and seine
    - Definition of boundaries encompassing 70, 80, 90 and 100 % of total activity of each vessel and ranking of cells from low to high activity

Other methods were also employed:

- A modified version of the index of difference in spatial pattern developed by Lee *et al*. (2010) was employed to assess spatial patterns of different fleets and overlap of fishing grounds
- Proportional overlap of fishing grounds also calculated when grounds defined as covering 70, 80, 90 and 100 % of total activity
- Weight and value of landings reallocated from scale of reporting to scale of the grid cell used for estimated fishing activity (if required)

From 2006-2009, the grounds fished by individual beam trawlers had extensively but infrequently fished margins. For all fleets in the South West lightly fished areas accounted for 10 % of activity and overlap of ground decreased when exclusion of low activity areas occurred. Analysis of the relationship between cumulative area and activity revealed that most fishing activity was recorded in relatively small proportion of the total area fished. Overlaps between fishing grounds used by all UK fleets decreased as threshold for defining grounds reduced.

This work highlights the importance of stimulating discussion about definition of fishing grounds for all UK fleets and encourages the development of further studies. For all gears across various scales used, fishing activity concentrated in core areas, with the presence of extensive but infrequently fished margins. Therefore exclusion of these margins when defining areas has wide implications, for example when trying to inform the siting of activities in shared space and assessment of the impact of various activities on seabed features (Jennings *et al*., 2012). This analysis gives an insight into the possible trade-offs between different sea interests and a range of approaches to fisher access to core areas. Since 2009 changes to access to VMS data, and the level of data resolution allowed for researchers due to EU Council regulation interpretation (EC 2009; ICES 2010) may prove severely disadvantageous to accurate assessment of fishing fleet activity, the complexities of impact on the seabed, and the consequences of displacement for these fleets, thus having the potential for societal implications (Hinz *et al*., 2012). Outlined here in the comprehensive review by Hinz *et al*. (2012) are the concerns raised by the research team and the potential consequences of limited access to high resolution datasets:

- Aggregated data at 3 NM scale may be to coarse,, to assess impacts on marine habitats which are at best patchy, in particular in the assessment of biogenic reefs or other features of concern. This scale is currently the adopted scale used in MSP (Lee *et al*., 2010)
- Issues arise with the proposed format of data and inability to link with logbooks.
- Aggregation of data on proposed scale may lead to consequences of under or over estimation of fishing activity
    - Lambert *et al*. (2012) assessed the scallop fishing effort using a 3 NM 1.5 NM scales, the latter requiring non-aggregated data. Using the coarser resolution, impact was estimated to be 17 % greater.
    - This has consequences for the accurate assessment of the impact on fauna, especially in the context of displacement of effort.
    - There is difficulty in separating impacts on each species in areas where mixed fishing occurs
    - Delineating habitat fishery interactions is also a problem when designating areas suitable for each sector of fishing fleets.
- Risk of increased uncertainty in management advice due to low resolution data hampering assessment of ecosystem level effects of fishing

- Risk of development of suboptimal pressure indicators, indicators that are requested within EU legislation

2.1.1.2 Analysing Fishing activity without access to VMS

The calls for a more comprehensive understanding of the spatial distribution and economic importance of our fishing fleets, has stimulated the development of innovative techniques in order to capture this information. Due to the paucity of data and subsequent management and access decisions taken in response to that paucity, a number of schemes have been and are in the process of being implemented.

The integration of FK through mapping exercises including information elicited on socio-economic and operational aspects of inshore fisheries, have added rich value by helping to inform management and policy making. The pilot study carried out in the Pentland Firth and Orkney waters (Marine Scotland, 2013) , where considerable interest lies in terms of renewable energy developments (Crown Estate, 2013 is now being rolled out to other areas in Scottish waters. Through the other regional MCZ projects, Irish Sea Conservation Zones and the Welsh inshore waters MCZ Wales Project, the overall approach is somewhat the same, i.e. to elicit information on areas fished, seasonal usage, target species, methods employed, gear changes, employment and exit/entry into each sector.

Following on from this, initiated in 2012, the Self-sampling of the Inshore Sector (SESAMI) project, managed by Cefas has called for volunteers to take part in this 2 year project. The aims are to effectively collect evidence to support this sector in management decisions and to monitor discards and develop strategies to reduce them. The project will be conducted in two phases; the first phase will involve data collection by skippers and crew, and validation of the data they collect by Cefas observers who will board participating vessels at agreed times with vessel skippers and the second phase, with participating vessels being involved in trials to develop the most selective configurations and strategies for their gear. Also covered in part 2, section 3, are methods put forward by Witt *et al*. (2010), for assessing area coverage by smaller vessels, being dependent on home port and vessel size. This is a crude method, but combined with higher level data which has been obtained by the initial MCZ projects, *ScotMap* (McLay *et al*., 2012) for example and the ambitious future returns from SESAMI, there is a real chance at better elucidation of the consequences of displacement on different segments of the inshore fleet at regional scales.

In order to accurately assess fishing effort in the static gear fleets, further information on the size, soak time of nets or traps, hauling times for example and also area of seabed covered by gear is needed. Pioneering work in Orkney waters has been underway since 2013 in order to sustain the commitment of the inshore creel fisheries. It is the first UK based Fishery Improvement Project (FIP) and as well as monitoring of practices and development of stock assessment, the project with the aid of The Crown Estate, will allow the attachment of GPS on the gear in order to provide mapping of the seabed, thus informing the siting of marine energy developments. Tagging of crabs and juvenile lobsters will also take place, allowing better information on spawning migrations (WWF, 2014).

2.1.1.3 Murawski et al. (2005): All year round and seasonally closed areas NE USA

This study evaluated the changes in effort distribution and concentration over time due to year round and multiple adjacent seasonal closures of the NE USA. The closed areas are large, more than 22000 km^2 in the year round closures and much greater in the seasonal closures. In particular several questions needed to be answered:

- Does effort become concentrated around the boundaries of the closed area?
- What are the effects of seasonal closures on the concentration of fishing effort and catch rates?
- How do year round closures affect the spatial choice dynamics and other aspects of fisher behaviour?

To address the questions, port sampler interviews were used, together with vessel trip reports from logbooks, VMS data and fishery observer data, catch per unit effort (CPUE), a measure of abundance for various species and the value in dollars per unit effort ($PUE) were calculated as explanatory variables describing targeting of fishing effort in relation to distance from the MPAs. Standardization of effort among the three different vessel size classes occurred.

1. Year round closures

Effort displaced by these closures was 31 % of trawling effort mainly attributed to those targeting groundfish stocks. Overall fishing effort reduced by 50 % of pre-1994 levels, hence there could not have been reabsorption of displaced effort into the open areas. Changes in sampling and reporting procedures and the spatial scales at which the data was aggregated confounded these latter results, i.e. effort attraction to the boundaries occurs at local scales 0-5 km so that the 10-min grid size used was too coarse. Altogether, 10 % of trawling effort occurred within 1 km of the MPA boundaries, and approximately 25 % within 5 km and average catch value per unit time trawled was twice as high within 4 km of the boundary. Analyses suggested that “scouting behaviour” and “risk-taking” in their spatial decisions were infrequent, due to a days-at-sea cap. Spatial choice was principally influenced by catch histories and revenues.

2. Seasonal closures

Once the seasonal closures were reopened, an increase in effort was observed. These closures operating out of phase displaced effort among the areas, and the displaced effort is dependent upon the sequence of closure and reopening. What is important to note here is that due to the proximity of multiple seasonal closures operating at various times, any conservation benefit attained may be diluted by the various patterns of effort once the closures are re-opened.

Further work has been highlighted by the authors: detailed bioeconomic modelling to consider factors such as distance to port, effects of trip limits on the myriad of species, catch rates within a single trip for example, more complex analyses of trade-offs in fishing strategies near boundaries, more complex models of spatial behaviour to discern what determines initial targeting choices and the development of models to describe spatial location choice dynamics at scales appropriate to management scenarios. Owing to the fine scale resolution of the use of observer data, interpretation of location choice behaviour was more appropriate to temporal and spatial resolution associated with MPAs and seasonal closures.

2.2 The use of Fishers' Knowledge (FK)

FK the knowledge that fishers accumulate in their day to day operations (Neis, 1992), including the change in techniques and the changing environment (Johannes & Yeeting, 2001). Analysis of FK by Soto (2006) implied that FK is unreliable and inferior to traditional fisheries science, most likely due to it being mainly qualitative in nature. However, other scientists have realised the value of such 'anecdotal' information from fishers, and have used innovative ways of turning qualitative information into a semi-quantitative output, e.g. turning FK into maps that show seasonal migration patterns of cod unknown before the use of FK (Murray *et al*., 2006), and the creation of rules to describe herring shoals based on FK and interviews with fisheries managers (Mackinson, 2001). Dengbol *et al*. (2006) state that fisheries science must prepare for new approaches and the careful integration of FK with traditional science is a strong contender. Daw (2008), concluded from his work on FK within tropical fishery case studies that fisheries management is more effective if FK is translated into scientific output. Wilson *et al*. (2006) also highlight the importance of the interaction of scientists with FK, that this knowledge is a "*product of the fishing community*" thus requiring effective engagement techniques in order to gather it.

2.2.1 Fishers: the last of the hunter gatherers or the new scientists

Research by Hind (2011, 2012, and 2015) focused on the fishery and on how FK is collected, interpreted and organized in Galway Bay and the Aran Islands, Ireland. The thesis was part of a much larger project, the *Irish Fishers' Knowledge Project* and the aim of this project to was to develop a methodology to engage fishers as stakeholders and assess if FK could become part of the Marine Institute's permanent activities, due to scientific uncertainty of stocks in that area.

The work by Hind (2011, 2012, and 2015) showed:

- There is a lack of systematic application of FK, it simply being seen as an object for pilot studies for example.

- Fisheries science could be improved by better combing the qualitative and socio-economic information with standard quantitative information. This is especially relevant in the context of displacement and closures.
- That there is potential for FK becoming more precise, for example asking fishers to use their boat based GPS to draw maps as opposed to drawing them freehand, and this comes back to fishery and other industry collaboration and a hint at a possible mitigation strategy.
- Through the techniques developed to elicit FK, fine scale resolution of local fishing areas of importance were quite precise.
- FK highlighted concerns about top-down policies and price of catches that gave some insight to current and future fishing behaviour and strategies.
- Through the capture of FK, fishers presented ideas on how the fisheries could be better managed.
- That we need to be using the appropriate level of knowledge that matches the scale of the study site, or the research question being asked.
- And finally states that FK should be used across all fleets, both those operating inshore and offshore.

2.2.2 Factors affecting fishers' behaviour: Fuel price

Abernethy *et al*. (2010) undertook a study of the impact of an acute fuel price rise in 2008 on the behaviour of different sectors of the UK fishing fleet in the South-west of the UK. All interviewees were skippers of vessels >10 m in size and a range of vessel owners and company skippers were selected. A cross section of beam trawl, otter trawl, gillnettter, scallop dredger and crab/lobster potters were interviewed. A selection of quantitative information was acquired; namely, fish price change over time, and vessel characteristics, i.e. size, age and power, and further semi structured interviews were used to elicit additional information about vessel characteristics, i.e. maintenance, fuel consumption, fuel cost per trip currently and from 1 year previously and fuel costs were calculated for average trips from 2007-2008. Skippers were then asked a series of open ended questions about the effects of fuel price increase on the decisions they make, how their behaviour has changed since the fuel price and what the future holds. Unstructured surveys were also conducted with members of the wider fishing community, POs, Seafood Cornwall, ex-skippers, market workers and fisheries scientists and observers.

Results showed: fishers towing mobile gears were more affected than static users however fuel efficient static fishers also suffered negative effects on income; higher fuel consumption by towed gears and larger vessels; vessels skippered by owners used less fuel than company skippers; strong interaction between towed gear and ownership, i.e. ownership of vessel makes a difference in fuel efficiency (vessels skippered by owner had newer vessels, newer engines and more regular maintenance). Across all gear types 34% of skippers experience difficulty in recruiting (67% were company skippers). Skipper owners had fewer problems. In effect, fuel price directly changed the way they fished (mainly to reduce fuel consumption):

- Fishing with flow of tide not against it
- Steaming and fishing more slowly
- Fishing in good weather only
- Fishing closer to port
- Less time spent in exploratory fishing
- Reducing gear experimentation

The onshore market value of fish rises as other fishers (15%) take advantage of low number of boats in poor weather, this equates to less fish in market meaning seafood buyers bid higher and drive fish price up. Further work is needed here as some of the behaviour changes discussed may be masked if using only certain types of data, VMS for example. There is the potential to overestimate or underestimate fishing activity, as described by the six main behaviour observations above and this has consequences when assessing true effort displacement among different sectors of the fleet.

2.2.3 The consequences of ignoring FK

A study by Suuronen *et al*. (2010) in the eastern Baltic cod fishery analysed the views of Swedish, Danish and Polish fishers, mainly trawlers and gillnetters in response to closures for marine conservation and MPAs. Closures had taken place between 1997 and 2003, leading to a shift in effort and catch distribution. In 2004-2005 further larger closures had taken place, effectively closing all three major cod spawning areas. However, no positive impacts had been observed in the status of the cod stock and negligible reduction of effort occurred (ICES, 2007). Scientists, with the help of a spatially explicit fishery simulation model ISIS-Fish, suggested that the networks of MPAs performed poorly (Kraus *et al*., 2009). ISIS-Fish, a three part fishery model was designed to simulate and evaluate policies in multi-species multi-fleet fisheries (Mahévas & Pelletier, 2004), taking into account spatial and seasonality differences in both fish species and fishing activities. The Baltic cod population is well known in both biological and ecological terms, and this study by Kraus *et al*. (2009) where fleet models are parameterised based on catch data, was able to show that the MPA design, i.e. the seasonal closures were totally inefficient in reducing cod mortality.

Suuronen *et al*. (2010) explicitly gathered information on fishers' perceptions and attitudes on aspects on the MPAs and other management measures in the Baltic cod fishery, in order to understand their responses to inform better management in the future. Fishers had expressed concerns about rule compliance between different nations and the MPAs and had detailed ideas on use of various other management techniques, i.e. seasonal closures, days-at-sea cap. The main take home point here, is that the study by Suuronen *et al*. (2010) was the first study to capture the views and management suggestions (i.e. FK) of fishers, but they were not incorporated into the MPA design thus ignoring FK, what is observed in this Baltic cod fishery are, increased catch of juvenile cod, as fleets were displaced to areas where smaller fish were more prevalent, and subsequent intensification of competition between fleets and reallocation of fishing effort. All fishers, Danish, Polish and Swedish also expressed worry over unrealistic short-term management decisions that were taken without cooperation of the fishing industry completely jeopardising the long-term vision for this well studied cod population. Thus, further illustrating that better integration of stakeholder views i.e. FK into decision making processes is a fundamental part of successful fisheries management, and in this case across multiple gear-types and Member States.

2.3 Predicting fishing effort displacement

Economic modelling methods exist that provide tools with which to predict short-term choice behaviour in a fishery facing area restrictions but these require input data from consultation. Andersen and Christensen (2005) provide methods to inform models of behaviour in a commercial fishery by including interview derived data on the principal factors leading to the decision of where and how to fish. Economic theories suggest that redistribution of fishing effort within remaining suitable fishing grounds will be determined by the profit return each individual fisherman expects (Gordon, 1954). Andersen and Christensen (2005) use detailed information from interviews and questionnaires to identify important factors influencing the short term decision making process. This knowledge is then utilised to inform the theoretical background of a random utility model (RUM) which models behaviour based on quantitative information from a commercial fishery (such as logbooks data, sale slips and registered vessel data). The model presented by Andersen and Christensen (2005) predicts effort redistribution effectively for a species specific fishery. However for the real life example that was used to validate the model the fishermen actually changed gears and targeted a different species, an outcome that was not available within the model.

It is necessary to consider that behaviour is difficult to model due to the large amount of variables possible. Although the model in this example provides a useful indicator, understanding the options fishermen are likely to take can involve parameters outside those in any given model. Therefore gaining feedback and engagement on the outcomes of modelling exercises and understanding how changes in quota, fishing restrictions and personal choice of fishermen can affect fishing activity patterns is of direct benefit to having confidence in model outcomes.

In the most up to date review van Putten *et al*. (2012) present the main conceptual models that aim to explain and predict the behaviour of fishing fleets. In this review, the majority of studies, mainly in North America and Europe, focused on location choice behaviour, demersal and pelagic species and mainly trawl based fishing method (Rijnsdorp *et al*., 2000, 2001; Hiddink *et al*., 2006). And while a large proportion of studies considered individual characteristics, i.e. vessel attributes and descriptors of fishers and their motivations as key drivers of fishing choice, economic factors dominated. Coupled social and economic behavioural models in explaining observed fishing behaviour remain under developed (van Putten *et al*., (2012), but the road ahead is one of optimism. Recently, Lade *et al*. (2015) carried out an insightful study on how the interaction of social information and ecological processes can be critical if we are to understand the dynamics of a fishery. . With enough attention to issues examined in the above section, getting access to this data will result in improvements in the actual analyses of displaced fishing effort, and of the consequences of this displaced effort in terms of how the fishers are affected and the impact on benthic communities.

Chapter 3 Spatial and Temporal Distribution of Fisheries in the South West of the UK, with reference to the Case Studies of Haig Fras and Wave Hub.

Part of this Chapter has been published in:

Campbell, **M**., Stehfest, K., Votier, S. & Hall-Spencer, H. (2014) ‘Mapping fisheries for marine spatial planning: Gear-specific Vessel Monitoring System (VMS), marine conservation and offshore renewable energy’, *Marine Policy*, **45**: 293-300.

The above publication also includes some elements of Chapter 4, i.e. marine substrate map and descriptors.

"The charm of fishing is that it is the pursuit of what is elusive but attainable, a perpetual series of occasions for hope"

John Buchan, 1874-1940.

3.1 Introduction

Over the last 20 years, management approaches have shifted from the conservation of individual species to the more holistic management of spaces to help reduce damage to ecosystems and the goods and services they provide (Zacharias & Roff, 2000; Roberts *et al*., 2005; Apitz *et al*., 2006; Pedersen *et al*., 2009a). 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 by the year 2012 (United Nations, 2002; Spalding *et al*., 2008; Jones & Carpenter, 2009), however progress has been slow and the year 2020 is a more realistic target. In addition, the world's oceans are increasingly being tapped as a source of renewable wind, tidal and wave energy (Clement *et al*., 2002; Gray *et al*., 2005; Breton & Moe, 2009; Inger *et al*., 2009) to make up for a potential shortfall in fossil fuel reserves, and to help reduce the rates of environmental changes caused by anthropogenic carbon dioxide emissions (Hall-Spencer *et al*., 2008; Shields *et al*., 2009). The UK, has set a target to produce 33 gigawatts from marine renewable sources by 2020, which would meet the EU target of supplying 20 % of its gross consumption of energy from marine renewables by 2020 (United Kingdom House of Lords, 2008). The current political strategy is to stimulate private large-scale, large capital investment in developing the technological means necessary to make wave and tidal energy conversion an economically viable enterprise by making available large offshore areas for marine renewable energy installations (MREIs). However, large scale offshore (> 12 nm) MREIs have the potential to exclude certain fishing gear types from large areas of the sea in both construction and operational phases (Inger *et al*., 2009).

The development of offshore MREIs and designation of marine protected areas are two rapidly emerging demands on marine space that may compete with or displace fishing activities (Gray *et al*., 2005; Stewart & Possingham, 2005). 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 (Rijnsdorp *et al*., 2000; Suuronen *et al*., 2010). To resolve conflicts, marine policymaking has shifted away from sector-by-sector management towards an integrated, multi-sector, ecosystem-based approach with a transparent planning process, known as marine spatial planning (MSP) (Smith & Wilen, 2003; Crowder *et al*., 2006; Tyldesly, 2006; Douvere, 2008; EC, 2008a; Gilliland & Laffoley, 2008; Douvere & Ehler, 2009; Foley *et al*., 2010; Halpern *et al*., 2012). This is intended to help managers optimize 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 (Halpern *et al*., 2012). Decision support, i.e. types of data, information and tools needed to facilitate implementation and advancement of MSP, was identified as a priority need, and key to this is spatially high-resolution and temporally accurate information on the various activities taking place in the marine environment (Eastwood *et al*., 2007; Halpern *et al*., 2012).

Until relatively 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 (Witt *et al*., 2007). These data lacked temporal and spatial coverage and resolution, preventing full integration of fisheries data into marine spatial plans (Pedersen *et al*., 2009a) at the level of detail recommended by Halpern *et al.* (2012). Satellite vessel monitoring systems (VMS) are increasingly being used to overcome these limitations. Introduced in the 1990s in various parts of the world (Marshall & Robert, 1998), VMS were originally established to allow fisheries administrators to control and monitor fishing activity (Davies *et al*., 2007; Witt *et al*., 2007). 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 identity and position every two hours to a Fisheries Monitoring Centre (EC, 2003). Vessel speed values have also been obligatory since 2005. From 1st January 2012, there were plans for all vessels > 12 m to install VMS (EC, 2011a). These smaller vessels are mostly inshore. However, there have been major delays, and full implementation of this system now called Inshore VMS or I-VMS, may not occur until late 2015 after further trials have taken place (MMO, 2014a). The system is being introduced through a collaborative effort between the MMO, Cefas, IFCAs and Seafish, and is being designed to specifically deal with MPAs and fisheries displacement in inshore areas (MMO, 2012). A number of developers are also involved, including Selex® and Succorfish®, who are both leaders in vessel tracking and satellite communications, thus fit for fishing industry purposes. The main aim is to provide a system which is cost effective, gives fishers access to their own data (stewardship issues), and which allows fishers to collect a greater variety of physical and environmental data and through the use of sensors on gear records when a vessel is fishing or not fishing. Trials in the Lyme Bay area have proven a great success[6]. The MMO are also offering grant-in-aid of up to £2000 for vessels >15 m to update or replace their current VMS terminals[7]. There are even discussions about extending the systems to towed gear vessels > 8 m in length (EC, 2009a), however as described above until test windows have closed and lengthy consultation with fishers has occurred, there will most likely be further delays. What is clear is that VMS has become an established monitoring practice and its use and perceived importance to fisheries studies is on the increase.

VMS data have proven valuable in spatial analyses of fishing activity (Deng *et al*., 2005; Davies *et al*., 2007; Witt *et al*., 2007) to the extent that these data have even been used as a proxy for the distribution of target fish stocks (Bertrand *et al*., 2008). Such data can also be used to show how spatial closures can displace fisheries activity (Murawski *et al*., 2005; Hiddink *et al*., 2006). 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 (Rogers *et al*., 2008; Hall-Spencer *et al*., 2009). In addition, gear-specific VMS analyses have been carried out within the German EEZ (Fock, 2008; Pedersen et al., 2009a), the Irish EEZ (Gerritsen & Lordan, 2011), the UK EEZ (Stelzenmüller *et al*., 2008; Lee *et al*., 2010; Jennings & Lee, 2012; Lambert *et al*., 2012) and for the Danish fleet (Bastardie *et al*., 2010) which greatly improve the assessment of fisheries impacts in those areas. Such work has considerable implications for management of local fishing grounds, as different

[6] http://www.seafish.org.uk/about-seafish/news-and-events/news/seafish-invites-industry-to-demonstration-day-at-brixham-to-find-out-how-innovative-inshore-vessel-monitoring-system-technology-works

[7] http://www.fishnewseu.com/index.php?option=com_content&view=article&id=13549:vms-grants-available&catid=44:uk

fishing sectors (defined by catch or gear type) have specific responses to different management measures such as closures.

3.1.1 ICES divisions VII e-h, and case studies Haig Fras and Wave Hub

In this Chapter, VMS data are used to provide an overview of the distribution of fishing activity by gear type in ICES divisions VII e-h (Figure 3.1), which borders the coasts of Ireland, the UK and 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 (Witt & Godley, 2007; Halpern *et al*., 2008). This Chapter details a VMS data-driven analysis of how two fisheries closures, one a MREI and the other a proposed MPA, may affect the distribution of both static and mobile gear users. This is done by mapping fishing effort by all gear types onto a regular grid within the entire area in order to look for spatial and temporal trends with which to draw inference about the nature of fishing within and adjacent to the two areas.

The first of the closures is Wave Hub, a MREI, a facility for testing prototype Wave Energy Converters (WECs) located 10 NM from Hayle, North Cornwall within the South West Marine Energy Park (MEP), and the first of its kind in the UK. This closure will result in an 8 km^2 exclusion zone. The project was due to be deployed in 2008, however lengthy delays meant that construction, installation and operations did not commence until 2010. Coupled with this, due to the nature of the exclusion zones associated with MRE developments, there is a great deal of interest in the formation of *de facto* MPAs (Inger *et al*., 2009), so-called because the closure of the MPA is due to development but might aid conservation efforts. And it is hoped that efforts at Wave Hub will provide great insight into this phenomenon (Witt *et al*., 2012).

The other closure is a proposed MPA. Haig Fras, a 45 km long granite reef that is the only substantial area of rocky reef in the Celtic Sea (Rees, 2000) was put forward as a Natura 2000 conservation area in 2008 (JNCC, 2008). In 2009, the site was approved by the EC as a Site of Community Importance (SCI), however due to the fact that it is located beyond the UK's 12 NM limit, any management decisions will have to be taken under the EU CFP. Therefore, the site is now awaiting these management measures to be put in place due to the reform of the CFP which began in January 2014, and which is discussed in the previous Chapters.

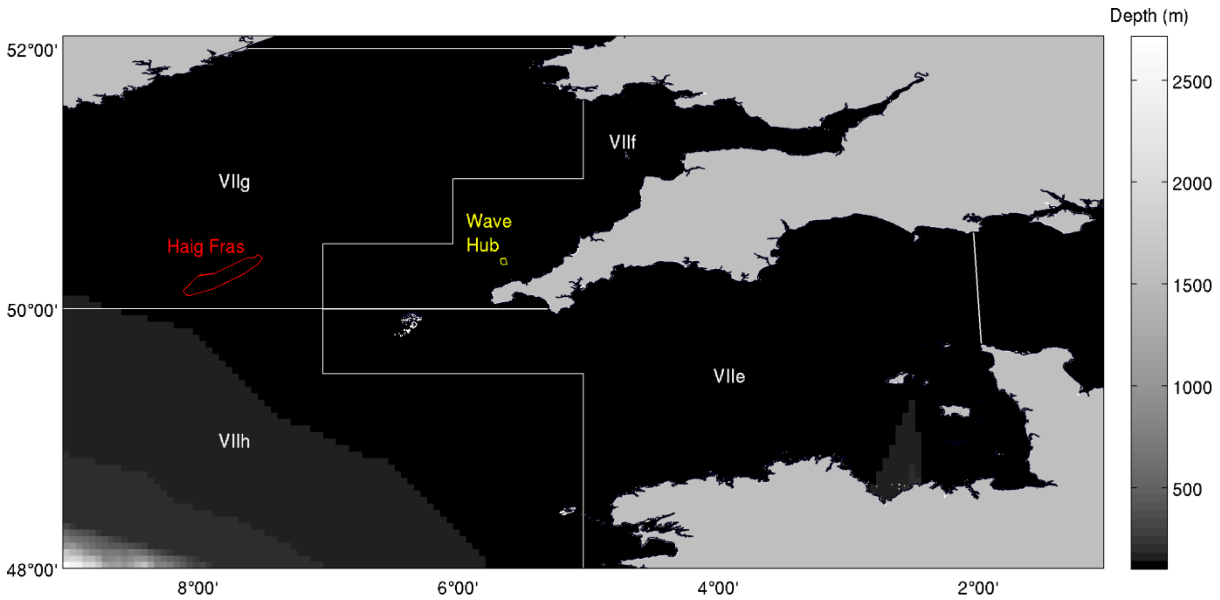

Figure 3.1: Study area showing ICES divisions, Haig Fras Natura 2000 site and Wave Hub

Study area showing ICES divisions VII e-h boundaries, the location of the proposed Haig Fras Natura 2000 site in ICES VIIg and the location of the Wave Hub deployment area in ICES VIIf.

3.1.2 Primary objectives

The objectives of this Chapter are as follows:

- To calculate and visualise the distribution of fishing effort by UK vessels > 15 m in ICES subarea VII which encompasses the offshore waters of the South West UK, at the highest available resolution, for the years 2005 – 2008 inclusive;
- To examine the applicability of methods proposed for the calculation of fishing effort from VMS data;
- To make a broad assessment of the patterns of fishing effort across gear types and areas within ICES subarea VII, in particular divisions e-h by using a variety methods;
- To make a broad assessment of the scale of fishing effort, and its distribution across gear types, in the Wave Hub, an MREI and Haig Fras proposed MPA;
- To examine the added value of high resolution VMS data to assess questions regarding fisheries displacement related to the spatial resolution of the data; and
- To examine the added value of high resolution VMS data to assess questions regarding fisheries displacement related to the temporal resolution of the data.

3.2 Methodology

3.2.1 VMS Data

Raw, unfiltered VMS data for all UK registered vessels >15 m in length that were active in ICES subarea VII, divisions e-h in 2005-2008 were obtained from the Marine Management Organisation (MMO), formerly the UK Marine and Fisheries Agency. As was explained in the introductory Chapter, such high resolution data is currently only accessible to fisheries agencies. Access to post 2008 data was not available in the same high-resolution format as earlier data. Access to gear type information was not available for non-UK fishing vessels fishing in UK waters, thus these vessels 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 together with the date and time of transmission. Access to individual 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, gillnetter, potter/whelker, beam trawl and demersal otter trawl, all which conform as close as possible to European Union level 3 and 4 Data Collection Regulation (DCR) (EC, 2008b; EC, 2008c) considering the level of data made available for this study (this 'level of data' is discussed in detail in Chapter 1). For the purposes of this study, in order to meet the objectives outlined in Chapter 1, the highest possible obtainable resolution is required to examine its information content with respect to fisheries displacement, and to make an assessment of what loss of information occurs when aggregation or averaging is made over scales and gear types. When data aggregated to the extent to which it is when served to the public and non-fisheries agencies, the sorts of questions that can be answered using it changes compared to the higher resolution data. Only by comparing the sorts of information relevant to assessing fisheries displacement between high and low resolution data sets, is it possible to evaluate the added value of the higher resolution data. This is essential to understand the potential utility of the lower resolution data served to non-fisheries research institutes and the general public, including the fishers themselves. The resolution of the data is a fundamental control on what specific questions about fisheries displacement can be answered using it.

3.2.1.1 Access to raw VMS data post-2008

This issue has been explained briefly in the preceding Chapters however, it is important to explain here in depth the nature of the issues with data access. Presently, EU VMS data for purposes other than those relating to the Common Fisheries Policy (CFP) are "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')" (ICES, 2010). 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 (ICES, 2010).

When VMS data from 2009 onwards was requested from the MMO, access was initially denied as they had been going through a major overhaul due to the change in EU regulations concerning the data. Numerous repeat attempts resulted in an initial dataset, 2007-2010 that was presented as an aggregated 4 year dataset, vessel gear type separated into static and mobile with no classification provision, and any areas with less than 10 vessels operating records were removed. This level of data is known as 'Level 2' clearance. Subsequent attempts at explaining the nature of the work being carried out and the need for higher resolution data in order to assess displacement resulted in 'Level 3' clearance. This data set did contain areas with less than 10 vessels operating, did split fishing activity by gear type and included live weight landings from each gear classification; however data was presented only on a yearly basis (i.e. aggregated or averaged over a period of 1 year). This is the highest level of data resolution currently authorised by the MMO and is not sufficient for assessing fishing effort displacement, especially in a discrete region, for example the study region: ICES subarea VII divisions e-h.

3.2.2 Fishing activity analyses

3.2.2.1 VMS

VMS data analysis followed the approach for estimating fishing activity established by Lee *et al*. (2010). In summary, records without an associated gear type; within 3 NM of ports, and duplicates are all removed. To identify *bona fide* fishing activity, the interval between each successive record was calculated and only those vessels travelling at a speed less than 6 knots were deemed to be actively fishing. This methodology was applied to all gear types. Summaries of totals per area at each processing stage are provided in Table 3.1 a-h. Between approximately 15 and 60% of raw records are removed depending on the ICES division and the year. The number of duplicate records is very small compared to those records removed because of speed or proximity to port.

A point summation method followed, using a grid cell size of 0.05° (or 3 arc minutes), equating to 3 NM, the resolution of fishing data considered necessary to inform MSP in the UK (Jennings & Lee, 2012). In summary, every 2 hours, a vessel with a known unique identifier sends a ‘ping’ or a signal to the satellite, thus position in latitude and longitude is known. Between successive positional information, the distance that the vessel covers and the time that has passed is known, thus by using a simple distance-speed- time relationship, the speed value of each successive position can be calculated. By using speed values of known fishing, active fishing and steaming can be separated. Thus, fishing activity (hours) in each grid cell can be calculated by summing the single points that have been deemed to be actively fishing.   Fishing activity in each of the ICES division VII e-h was calculated separately because vessels that move between ICES divisions are assigned new unique identifiers, thus each division has to be taken as a separate study area. The vessels are assigned these new unique identifiers as an extra means of ensuring confidentiality.

Table 3.1 Data processing stages and summaries: a) number of raw records; b) number of unique records; c) number of duplicate records; d) number of records near a port; e) the number of records remaining after filtering for duplicates and proximity to port; f) number of records removed based on high speed; g) number of records left after filtering for duplicates, proximity to port, and speed; and h) % of raw records left after all filtering.

(a) Number of raw records/ ICES division					
	e	**f**	**g**	**h**	**all areas**
2005	194429	65876	25210	54862	340377
2006	182543	74347	28116	39975	324981
2007	193313	84485	20924	32900	331622
2008	185477	82644	22120	27347	317588

(b) Number of unique records/ ICES division					
	e	**f**	**g**	**h**	**all areas**
2005	194242	65681	25195	54831	339949
2006	182009	74074	28050	39897	324030
2007	192954	84378	20901	32872	331105
2008	182232	81073	21895	26980	312180

(c) Number of duplicates (removed)/ ICES division					
	e	**f**	**g**	**h**	**all areas**
2005	187	195	15	31	428
2006	534	273	66	78	951
2007	359	107	23	28	517
2008	3245	1571	225	367	5408

(d) Number of records near port (removed)/ ICES division					
	e	**f**	**g**	**h**	**all areas**
2005	56071	3388	4183	0	63642
2006	60120	3697	8129	0	71946
2007	69693	3457	3693	0	76843
2008	59871	3767	5865	0	69503

(e) Number records left after filtered for duplicates and near port/ ICES division					
	e	**f**	**g**	**h**	**All**
2005	138171	62293	21012	54831	276307
2006	121889	70377	19921	39897	252084
2007	123261	80921	17208	32872	254262
2008	122361	77306	16030	26980	242677

(f) Number records removed based on speed/ ICES division					
	e	**f**	**g**	**h**	**All**
2005	56261	11751	8954	14257	91223
2006	51245	11189	8601	11191	82226
2007	49493	12167	6977	7438	76075
2008	37408	7494	5185	5264	55351

(g) Number records left after filtered for duplicates, near port, and speed/ ICES division					
	e	**f**	**g**	**h**	**All**
2005	81910	50542	12058	40574	185084
2006	70644	59188	11320	28706	169858
2007	73768	68754	10231	25434	178187
2008	84953	69812	10845	21716	187326

(h) % records total raw records left after all filtering/ ICES division					
	e	**f**	**g**	**h**	**All**
2005	42.12	76.72	47.83	73.95	54.37
2006	38.69	79.61	40.26	71.80	52.26
2007	38.15	81.38	48.89	77.30	53.73
2008	45.80	84.47	49.02	79.40	58.98

3.2.2.2 Differences in spatial patterns of fishing activity

Maps of fishing effort were created by gridding data by linear interpolation at a resolution of 3 square NM, and presented using a Mercator projection. The data were gridded with the distortion in this projection accounted for, by using non equal grid increments in latitude and longitude, in order to grid fishing effort onto a regular square grid of 3NM. In each map (Figures 3.4 to 3.9 inclusive) the 6 NM and 12 NM limits are shown, as well as the UK Exclusive Economic Zone (EEZ) limit.

Differences in spatial patterns of fishing activity were quantified 1) between pairs of gear types and 2) within same gear types but between pairs of years. The index of difference in spatial pattern developed by Lee *et al*. (2010) was used whereby, in brief, "*the absolute differences in proportion of fishing activity in each cell were calculated, so that the total activity in ICES VII e-h was equal to 1.0. To compare two maps, the per-cell absolute differences in the proportion of fishing activity were calculated and summed for the entire ICES VII e-h then divided by 2 resulting in an index of difference in spatial pattern varying from 0 to 1, i.e. 0 representing identical spatial fishing patterns in the same cells and 1 representing no activity in the same cells".* This metric can be thought of as an index of spatial coherency: 1 would indicate no coherence in the spatial distribution between 2 data sets (for example, comparing 2 years) and a value of 0 would indicate full coherence or identical spatial distributions. Notice that this method of quantifying changing spatial distribution would be highly dependent on the size of the cell and thus only meaningful comparisons can be made between data sets with identical cell size (i.e. spatial resolution) and is dealt with in Section 3.3.2.

3.2.2.2.1 Multidimensional Scaling (MDS)

In order to further display the overall compositional patterns in the high-dimensional (space and time) data, i.e. between-year and between-gear differences (both indices) in fishing effort, they are further analysed using two-dimensional non-metric multidimensional scaling (MDS) which produces data ordinates that can be visualised on a simple two-dimensional scatter plot (Kenkel & Orlóci, 1986). These indices correspond perfectly to distances, and it would be possible to construct a matrix of pair-wise comparisons between all combinations of gear and year, with an MDS plot to illustrate the main patterns in a compact way. This is shown is Figure 3.2.

3.2.2.2.2 How concentrated is fishing effort across each gear type and ICES VIIe-h? The use of Moran's I and Getis-Ord Gi statistic

Clustering, or concentratedness, or fishing effort was examined at two scales; global and local. A global analysis involves studying the entire map of fishing effort. In order to assess the degree of effort concentration (visualised in Figures 3.4-3.9), a global Moran's I analysis (Moran, 1950) was carried out in order to compute autocorrelation in the spatial distribution of the number of hours fished. This analysis was carried out per-gear and per-year, with the fishing effort data kept in the same spatial resolution of grid cell ($3NM^2$). The metric has ranges in value from -1 (indicating a much dispersed or totally random pattern) to +1 (indicating a much clustered pattern). Once this 'global' pattern is the dataset was calculated, a local analysis explores within the global pattern to identify clusters or so-called 'hotspots' that show localised intense fishing effort. The 'local' Getis-Ord Gi statistic (Ord & Getis, 1995) was used to determine which areas with the highest number of hours fished, or 'hotspots' on a per-year, per-gear basis. The statistic was computed over a range of scales, on a per-grid-cell basis. The calculations were carried out using the PySAL toolbox.

3.2.2.3 EU defined fleet effort analysis

Fishing effort of fleets is defined in the Basic Regulation of 2002 (Article 3(h)) (EC, 2002a) as the product of capacity and activity. Capacity of a vessel is measured in terms of its gross tonnage (GT) or engine power (kW), and activity is commonly measured as the period of time in which a vessel is active, i.e. days-at- sea. In this study, capacity is presented as number of vessels, which is an accepted, albeit approximate, method when GT or kW is not available. Each ICES division VII e-h was analysed separately for the same reasons as outlined in section 3.2.2.1. All analyses were performed using MATLAB (Matlab, 2007).

3.2.2.3.1 Two dimensional non-metric Multidimensional Scaling (MDS)

In order to further display the overall compositional patterns in the data, i.e. number of days-at-sea, and especially as a simple means with which to identify any seasonality in fishing trends, they are further visualised using two-dimensional non-metric multidimensional scaling (MDS). This is shown is Figure 3.14, and was performed in order to further visualise seasonality between gear-type and area by showing the month-by-month pattern in fishing effort. These plots also show, at-a-glance, which gear-types display a greater or lesser degree in seasonality than others.

3.2.2.4 Effects of spatial and temporal resolution

VMS data needs to be interpolated onto a regular grid in order for comparative analyses (between gears, over space, and in time). The spatial resolution at which VMS data is analysed partially dictates the level of uncertainty that applies to any inferences made using it. An advantage of having data at the highest possible available resolution, such as here, is that it can be analysed at varying resolutions in order to assess at what spatial resolution is appropriate, by examining how the value of metrics change with different grid sizes (both up- and down-sampling).

In order to demonstrate this, the effect of spatial grid resolution on our ability to interpret indices of relative difference in pattern of fishing activity was investigated. Maps of this fishing effort (similar to Figures 3.4 – 3.9) were prepared for each gear and for each of the following grid sizes: 1) 0.025 degrees (1.5 NM); 2) 0.05 degrees (3 NM); 3) 0.1 degree (6 NM); 4) 0.2 degrees (12 NM); and 5) 0.4 degrees (24 NM). This was carried out for data collected in 2005 to 2008 inclusive. As before, the proportion of fishing effort in each cell was again calculated such that the sum over the entire study area, ICES VII e-h was 1.0. For each gear type, and for each grid size, the per-cell absolute differences in the proportion of effort in 2005 and 2008 were calculated, summed for the entire grid, and divided by 2. This produced an index of difference in spatial pattern, varying from 0 to 1, over the period 2005 to 2008, for each gear types, and for varying spatial resolutions. To examine the effect of spatial resolution, the percentage change in this index was calculated for 0.05, 0.1, 0.2, and 0.4 degrees, respectively, relative to 0.025 degrees.

3.3 Results

3.3.1 Spatial and temporal analyses

The spatial distribution of fishing activity was highly heterogeneous and distinct areas of intense fishing could be identified for all gear types (Figures 3.4 – 3.9). Spatial patterns were more consistent within gears between 2005 and 2008 for mobile gears (scallop dredge, beam and otter trawls), with the index of difference in spatial distribution ranging from 0.122 to 0.654 (Table 3.2) representing high to intermediate spatial coherence (or low to intermediate change) in spatial pattern of fishing effort. For the static fleet (longline, gillnetter and potters/whelkers), smaller ranges were observed, ranging from 0.195 to 0.362. For static gear types, the spatial patterns within gears between successive years tended to be more similar than dissimilar (non-random spatial patterns, indicative of non-transient fishing). However, for the scallop dredging fleet, spatial patterns from 2005-2008 ranged from 0.613 to 0.654, indicating a slight shift in spatial distribution from the previous year and more transient fishing behaviour.

Table 3.2 Indices of relative difference in spatial pattern, calculated according to the method of Lee et al. (2010), within gear between 2005 and 2008.

Year	Scallop Dredge	Longliner	Potter/ Whelker	Gillnetter	Beam trawl	Otter trawl
2005 - 2006	0.613	0.211	0.195	0.320	0.129	0.407
2006 - 2007	0.654	0.276	0.215	0.274	0.122	0.434
2007 - 2008	0.654	0.214	0.233	0.362	0.141	0.501

0= total equality; 1= maximal difference

Patterns of fishing activity between pairs of gears ranged from 0.648 to 0.998, indicating a high degree of dissimilarity in the spatial distributions of fishing effort by vessels with different gear types (Table 3.3 a-d).

Table 3.3 Indices of relative difference in spatial pattern, calculated according to the method of Lee et al. (2010), between gears between (a) 2005, (b) 2006, (c) 2007 and (d) 2008.

(a) 2005	**Dredge**	**Longliner**	**P/W**	**Gillnetter**	**Beam**	**Otter**
Dredge	x	0.958	0.986	0.823	0.914	0.955
Longliner	x	x	0.965	0.905	0.749	0.867
P/W	x	x	x	0.964	0.898	0.937
Gillnetter	x	x	x	x	0.798	0.848
Beam	x	x	x	x	x	0.861
Otter	x	x	x	x	x	x

(b) 2006	**Dredge**	**Longliner**	**P/W**	**Gillnetter**	**Beam**	**Otter**
Dredge	x	0.971	0.990	0.851	0.899	0.965
Longliner	x	x	0.945	0.907	0.648	0.848
P/W	x	x	x	0.948	0.867	0.955
Gillnetter	x	x	x	x	0.827	0.875
Beam	x	x	x	x	x	0.855
Otter	x	x	x	x	x	x

(c) 2007	**Dredge**	**Longliner**	**P/W**	**Gillnetter**	**Beam**	**Otter**
Dredge	x	0.960	0.992	0.954	0.923	0.985
Longline	x	x	0.954	0.936	0.669	0.897
P/W	x	x	x	0.953	0.905	0.913
Gillnetter	x	x	x	x	0.803	0.922
Beam	x	x	x	x	x	0.890
Otter	x	x	x	x	x	x

(d) 2008	**Dredge**	**Longline**	**P/W**	**Gillnetter**	**Beam**	**Otter**
Dredge	x	0.994	0.998	0.936	0.942	0.995
Longliner	x	x	0.933	0.947	0.596	0.92
P/W	x	x	x	0.971	0.928	0.911
Gillnetter	x	x	x	x	0.843	0.962
Beam	x	x	x	x	x	0.961
Otter	x	x	x	x	x	x

0= total equality; 1= maximal difference

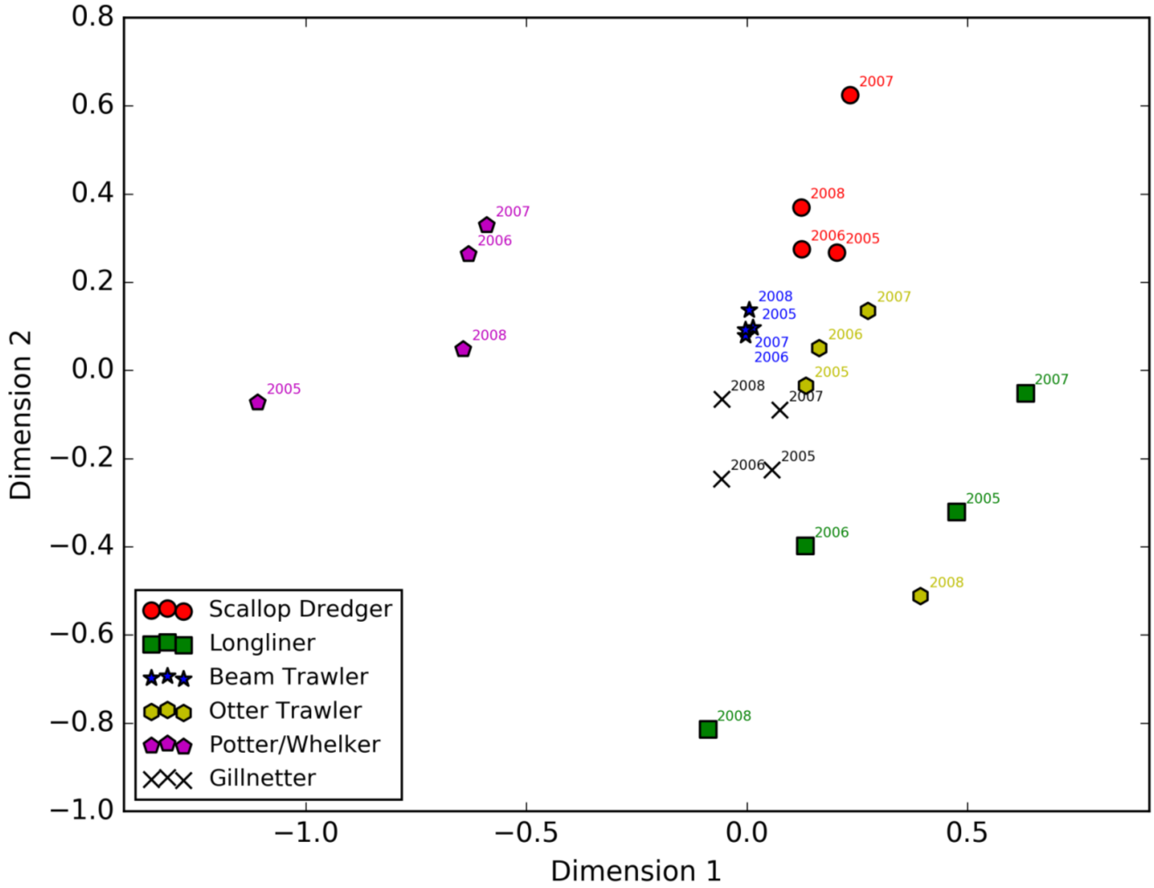

Figure 3.2 2-D MDS ordination of fishing activity of scallop dredgers, longliners, beam trawlers, otter trawlers, potter/whelkers and gillnetters between gears and between years.

Fishing effort has been aggregated across regions, in order to differentiate the clustering of fishing effort on a per-gear and per-year basis.

Firstly, the MDS plot shows that each particular gear-type distinctly cluster together, and that there is significant dissimilarity between the gear-types, meaning they each have their own spatial patterns which are distinct from one another. This is very similar to the first result of the index of spatial difference between pairs of gear-types as presented in Table 3.3. However, it is easier to spot broad trends at-a-glance compared to this data in map time-series form, which enables analysis of fishing effort in a particular region or time. The MDS plot shows that the only exception to the general trend of non-overlap between gear types is an overlap between otter trawling in 2008, and the longlining fleet, which is also observed in the index of spatial difference of otter trawling in 2008 (Table 3.2). Examination of the relevant maps of fishing effort, the cause is apparent: namely, there was a major shift in otter trawling in 2008, which is shown in Figure 3.3 as a Northwest extension to the fishing grounds, east of the Bristol Channel which is not observed in any other year. The highest clustering is observed within the beam trawl fleet, which suggests very little change in fishing grounds from 2005-2008, this is also illustrated in Table 3.2. This illustrates that the use of multiple visualisation tools is necessary to observe any nuances between fishing activity between gear-type and year. The MDS plot is also a useful way to see any outlier years with each fishing gear-type. This may have the potential to be a really useful simple first-order tool in assessment of effort displacement. It could be also be used to assess fishing activity by gear-type in any given month, thus looking at seasonality differences. It should be noted however, that the stress value, which is the measure of how the distances in the configuration ordinally fit the data, was estimated at 2.4, much greater than the threshold of 0.2 which corresponds to 'good data fit' (Kruskal, 1964). This may also be due to the high number of data points, and in a 24* 24 matrix of 6 gear-types over 4 years of data, the number of data points is extremely high. Thus caution is needed in taking the stress value at face value. In cases like these, advice states that we could increase the dimensionality, of 3 or 4 for example but in doing so we increase the level of complexity to beyond what the human mind can readily comprehend (Wickelmaier, 2003).

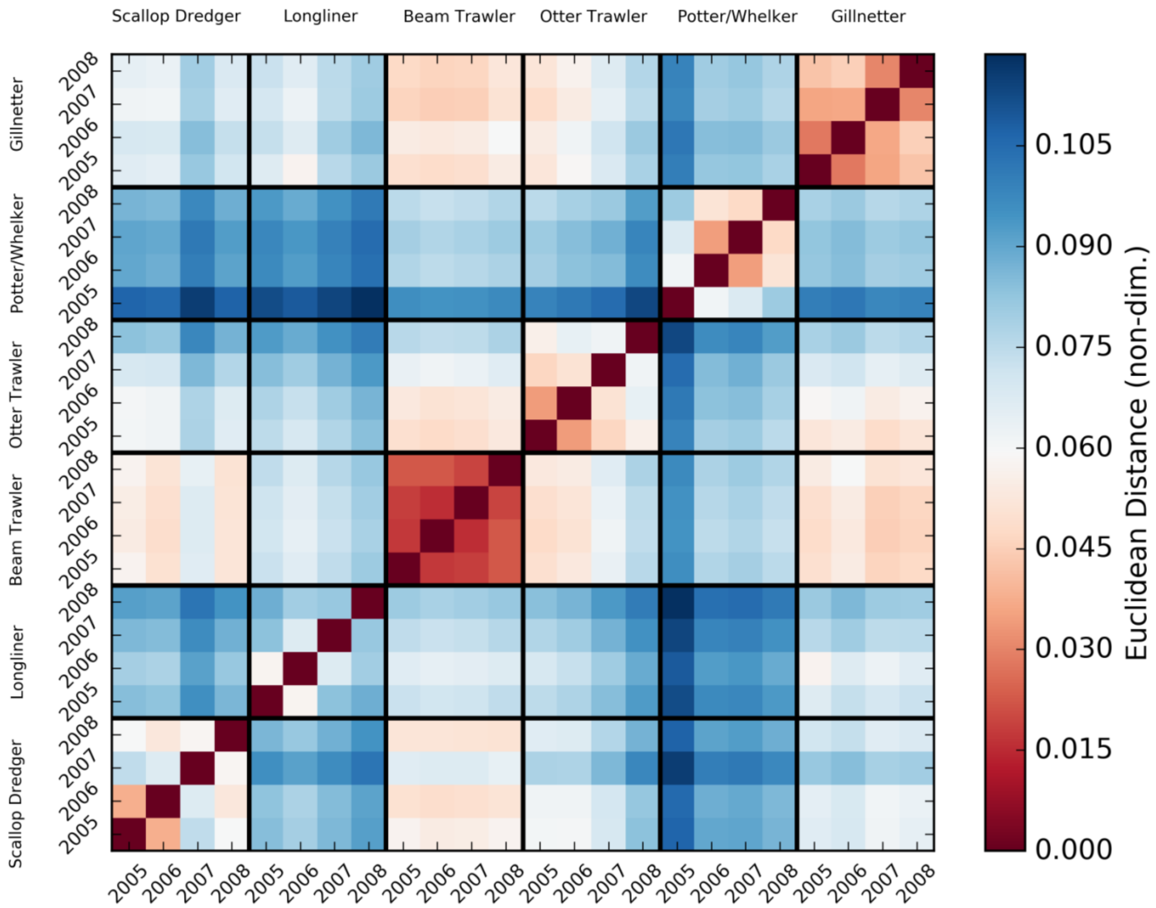

Figure 3.3 The Euclidean distance matrix between all gears and all years. *Cold colours show large differences between pairs of data, and hot colours show relatively small differences. The diagonal of the matrix is zero because it compares one data set with itself.*

Figure 3.3 is the actual input into the MDS ordination, is displayed simply as an extra visualisation tool. Low values of Euclidean distance (red) correspond to greater similarity, with zero being identical and high values of Euclidean distance (blue) correspond to greater dissimilarity. Both beam trawlers and to a certain extent gillnetters have a high degree of self-similarity in fishing activity from 2005-2008. It is also clear that each gear-type is distinct from one another. This Figure is not normally included in analyses, as it is the MDS plot that is the final product, but nonetheless, this is a good visual tool that serves as the link between the MDS plot, which is an abstraction of the data in non-dimensional units, to the map forms of fishing effort, which are more readily understood but are harder to summarise.

Fishing effort of the fleets as described by EC (2002) are presented in Table 3.4. ICES VII f (which contains Wave Hub), represents an area with some of the highest potting and whelking and gillnetting effort, in comparison to other ICES divisions, although some heterogeneity was observed over the present study period 2005-2008. Even for the gear-types that show least heterogeneity, the variations are such that if a particular location is not necessarily well matched by the larger trends, and it depends on location and gear-type. A detailed analysis of fishing effort within the confines of the Wave Hub MREI (Figure 3.1), summarised in Tables 3.5 and 3.6, revealed that beam trawling was most dominant in terms of vessel numbers and fishing effort, but that of all static gear types, gillnetting was by far the dominant and in fact was the dominant fishing activity when normalised by the number of vessels. Potting and whelking was less prevalent relative to area VII f as a whole. A comparison of effort between the Wave Hub MREI and area VII f as a whole reveals that regional estimates only go so far in being able to accurately describe the distribution of fishing effort among different gear types within Wave Hub, which suggests that analysis at the scale of an entire ICES region is too coarse in scale to indicate fishing effort within small MREIs or MPAs in that region.

According to Table 3.4, ICES VII e represented the highest scallop dredging effort. ICES VII g, which contains the Haig Fras MPA site, also represented high fishing effort values for gillnetting and scallop dredging, in comparison to other fishing gears in the area. Again, a comparison between regional fishing efforts (Table 3.4) and localised efforts within the Haig Fras area (Tables 3.5 and 3.6) is instructive. Gillnetting within Haig Fras broadly reflects the trend for the region; however scallop dredging only features in 2005 and 2006 within Haig Fras whereas the region as a whole does not see the same trend. However, estimates in fishing activity within Haig Fras are highly volatile owing to the very few numbers of UK vessels that operate there. It is known in the industry that French demersal vessels use the area heavily, however those non-UK vessel data are not available therefore not amenable to the same analyses (Cornish Fish Producers Organisation (CFPO), pers. comm., August 2012). Beam trawling and otter trawling are widespread throughout the study area with highest effort in ICES VII e and f, but almost absent from Haig Fras (Figures 3.4, 3.3; Tables 3.5 and 3.6). Again, these results suggests that analysis at the scale of an entire ICES region is too coarse in scale to be indicative of fishing effort within small MREIs or MPAs in that region.

Table 3.4 Capacity (no. vessels) and activity (days at sea) of UK fleets in ICES VII e-h from 2005-2008. Wave Hub is within ICES VII f, and Haig Fras within ICES VII g and is highlighted within the table.

Year/gear type	e		f		g		h	
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
Longliner	5	51	5	5	7	20	9	64
Gillnetter	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	**No.**	**Days**	**No.**	**Days**	**No.**	**Days**	**No.**	**Days**

	vessels	at sea	vessels	at sea	vessels	at sea	vessels	at sea
SD	29	125	23	26	23	23	20	31
Longliner	4	42	3	4	5	15	5	102
Gillnetter	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	No. vessels	Days at sea	No. vessels	Days at sea	No. vessels	Days at sea	No. vessels	Days at sea
SD	27	134	18	18	16	35	17	12
Longliner	1	156	1	1	2	1	4	51
Gillnetter	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	No. vessels	Days at sea	No. vessels	Days at sea	No. vessels	Days at sea	No. vessels	Days at sea
SD	19	86	16	17	19	23	9	12
Longliner	2	19	2	0	2	1	4	12
Gillnetter	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

Table 3.5. Fishing activity of UK fleets in (a) Wave Hub MREI and (b) Haig Fras from 2005 to 2008.

(a) WAVE HUB				
Number of hrs fished	**2005**	**2006**	**2007**	**2008**
Otter trawl	103	71	36	82
Beam trawl	301	167	179	140
Gillnetter	137	173	146	104
Longline	64	36	70	25
Scallop dredge	9	7	1	0
Potter/Whelker	18	19	36	19
(b) HAIG FRAS				

Number of hrs fished	2005	2006	2007	2008
Otter trawl	5	1	2	1
Beam trawl	3	1	1	1
Gillnetter	13	15	9	4
Longline	0	0	0	0
Scallop dredge	7	7	0	0
Potter/Whelker	0	0	0	0

Table 3.6. Number of unique UK fishing vessels in (a) Wave Hub MREI and (b) Haig Fras from 2005 to 2008.

(a) WAVE HUB				
Number of unique vessels	**2005**	**2006**	**2007**	**2008**
Otter trawl	2	3	3	5
Beam trawl	21	28	25	13
Gillnetter	4	2	5	3
Longline	2	6	1	1
Scallop dredge	1	2	1	0
Potter/Whelker	3	3	4	4
(b) HAIG FRAS				
Number of unique vessels	**2005**	**2006**	**2007**	**2008**
Otter trawl	2	1	2	1
Beam trawl	1	1	1	1
Gillnetter	12	10	10	6
Longline	0	0	0	0
Scallop dredge	1	1	0	0

Potter/Whelker	0	0	0	0

Fishing with mobile gear was more widely distributed (Figures 3.4, 3.5 & 3.8): beam trawling occurred over the largest part of the study area (Figure 3.4) closely followed by otter trawling which was also widespread (Figure 3.5). The distribution of static gear fishing was focused in fewer, smaller and more isolated areas (Figures 3.6, 3.7 & 3.9). These broad trends are a logical consequence of these broad gear classifications; however the changing nature of these spatial patterns year-on-year, as well as patterns within the various mobile and static gear types are a crucial form of decision support, i.e. types of data, information which are classed as priority and needed to facilitate implementation and advancement of MSP, as defined in section 3.1 (Halpern *et al*., 2012). In general, otter trawlers (Figure 3.5) tended to venture further afield from port than beam trawlers (Figure 3.4) and occupied a greater proportion of the Celtic sea than the western English Channel and Atlantic. Gillnetters showed most geographic spread, occupying most areas more equally except a few ‘hot spots’ of activity (such as Haig Fras). Longliners were confined almost exclusively to the western English Channel whereas scallop dredgers became increasingly concentrated in both the Channel and the Atlantic regions during the study period, losing their presence in the Celtic Sea by 2008. Finally, the distribution of potters and whelkers strongly reflected the relatively small number of ports that they operated from, showing a high degree of geographic specialisation. One dominant area for that gear type is within the boundaries of Wave Hub.

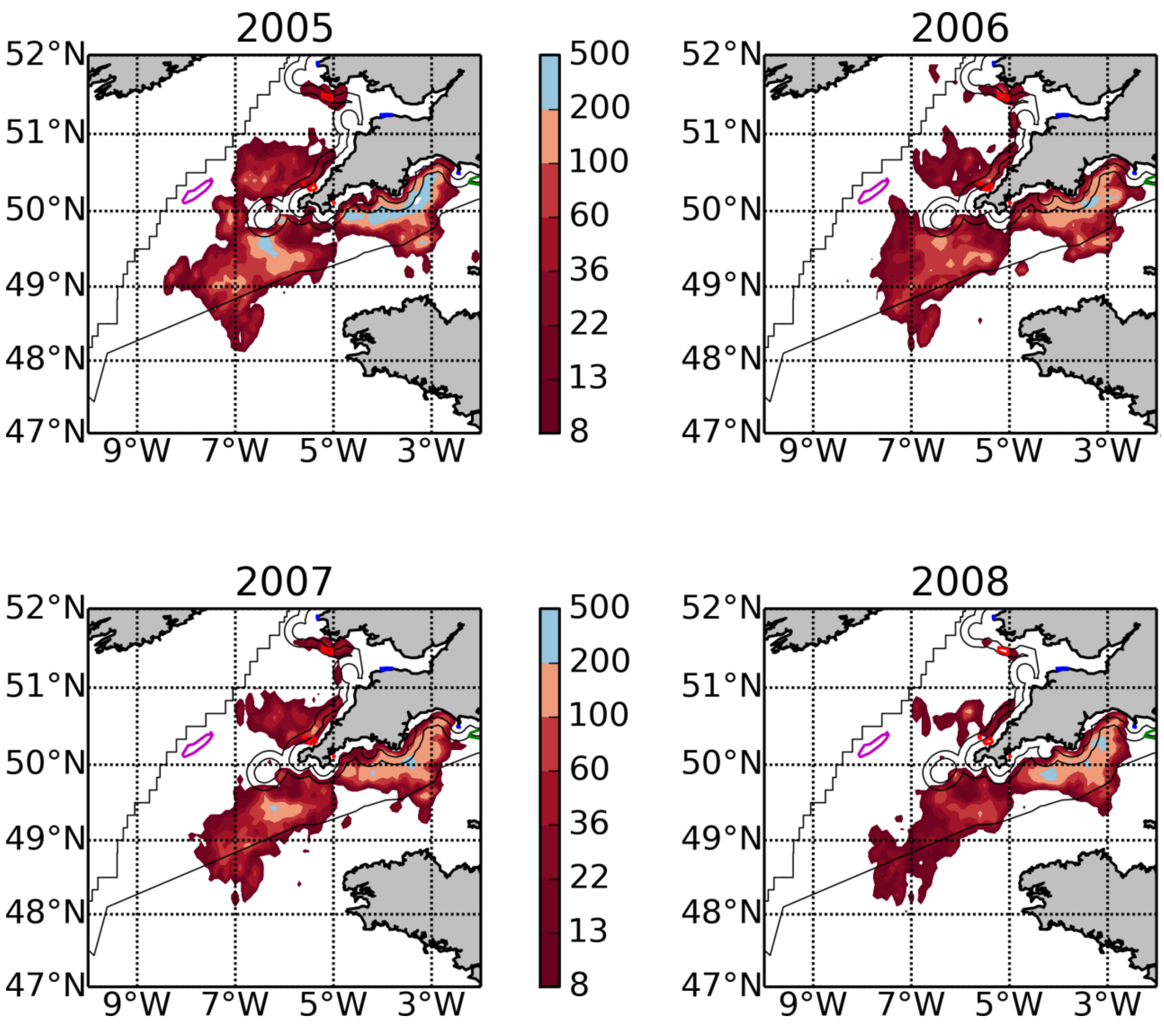

Figure 3.4 Fishing activity for beam trawlers

Fishing activity (number of hrs fished) distribution of UK vessels >15 m in length in ICES divisions VII e-h from 2005-2008 for beam trawlers. Haig Fras and Wave Hub MREI are identified.

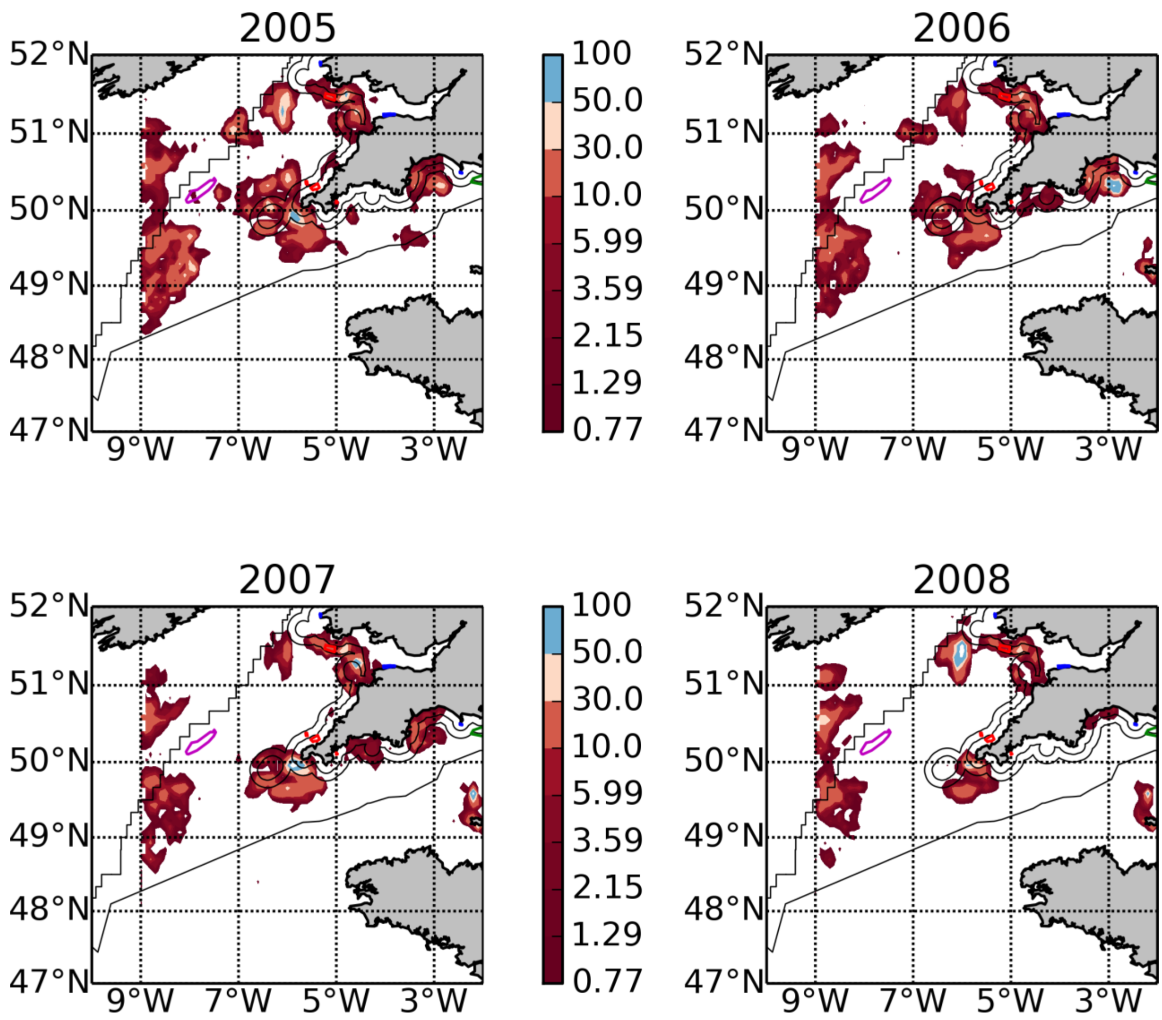

Figure 3.5 Fishing Activity for demersal otter trawlers

Fishing activity (number of hrs fished) distribution of UK vessels >15 m in length in ICES divisions VII e-h from 2005-2008 for demersal otter trawlers. Haig Fras and Wave Hub are identified.

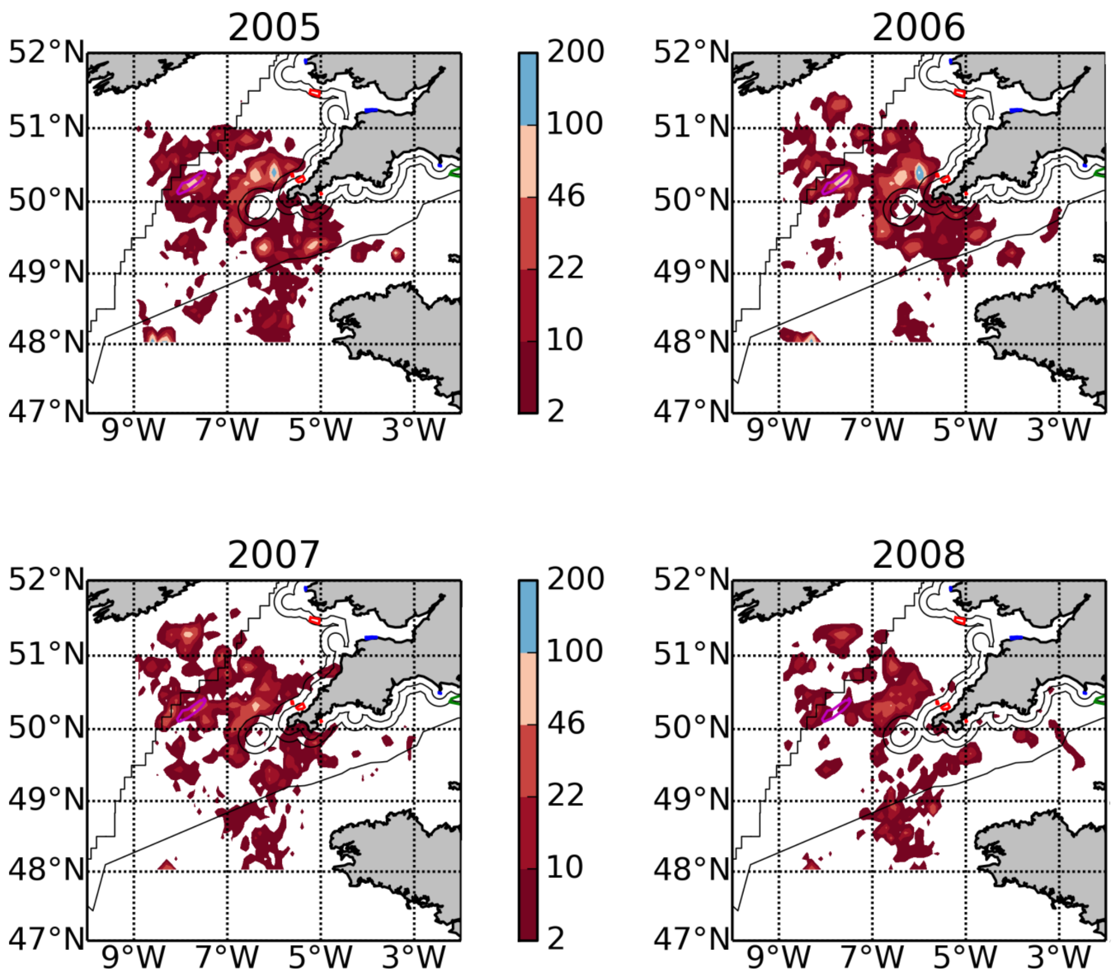

Figure 3.6 Fishing activity for gillnetters

Fishing activity (number of hrs fished) distribution of UK vessels >15 m in length in ICES divisions VII e-h from 2005-2008 for gillnetters. Haig Fras and Wave Hub are identified.

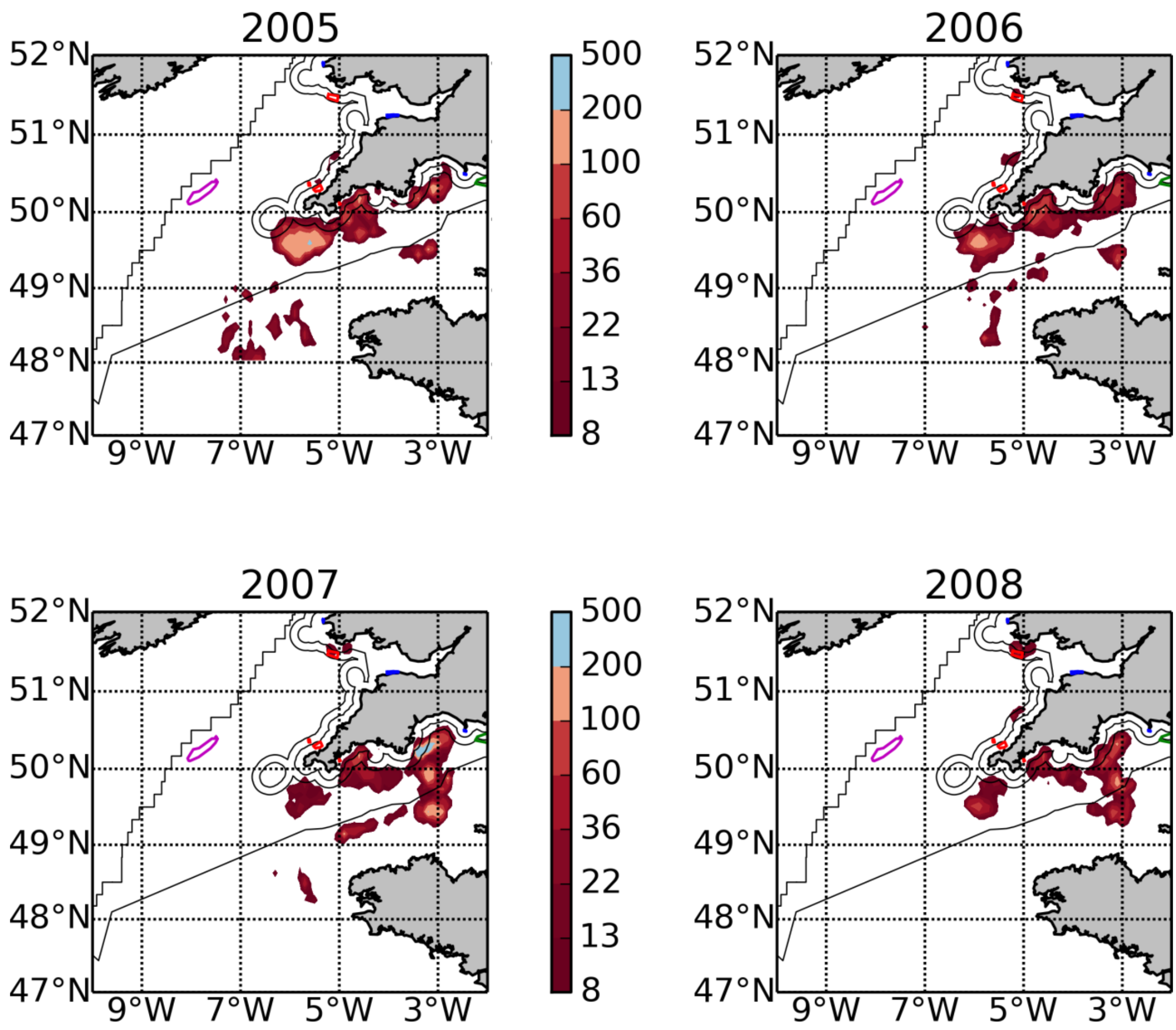

Figure 3.7 Fishing activity for longliners

Fishing activity (number of hrs fished) distribution of UK vessels >15 m in length in ICES divisions VII e-h from 2005-2008 for longliners. Haig Fras and Wave Hub are identified.

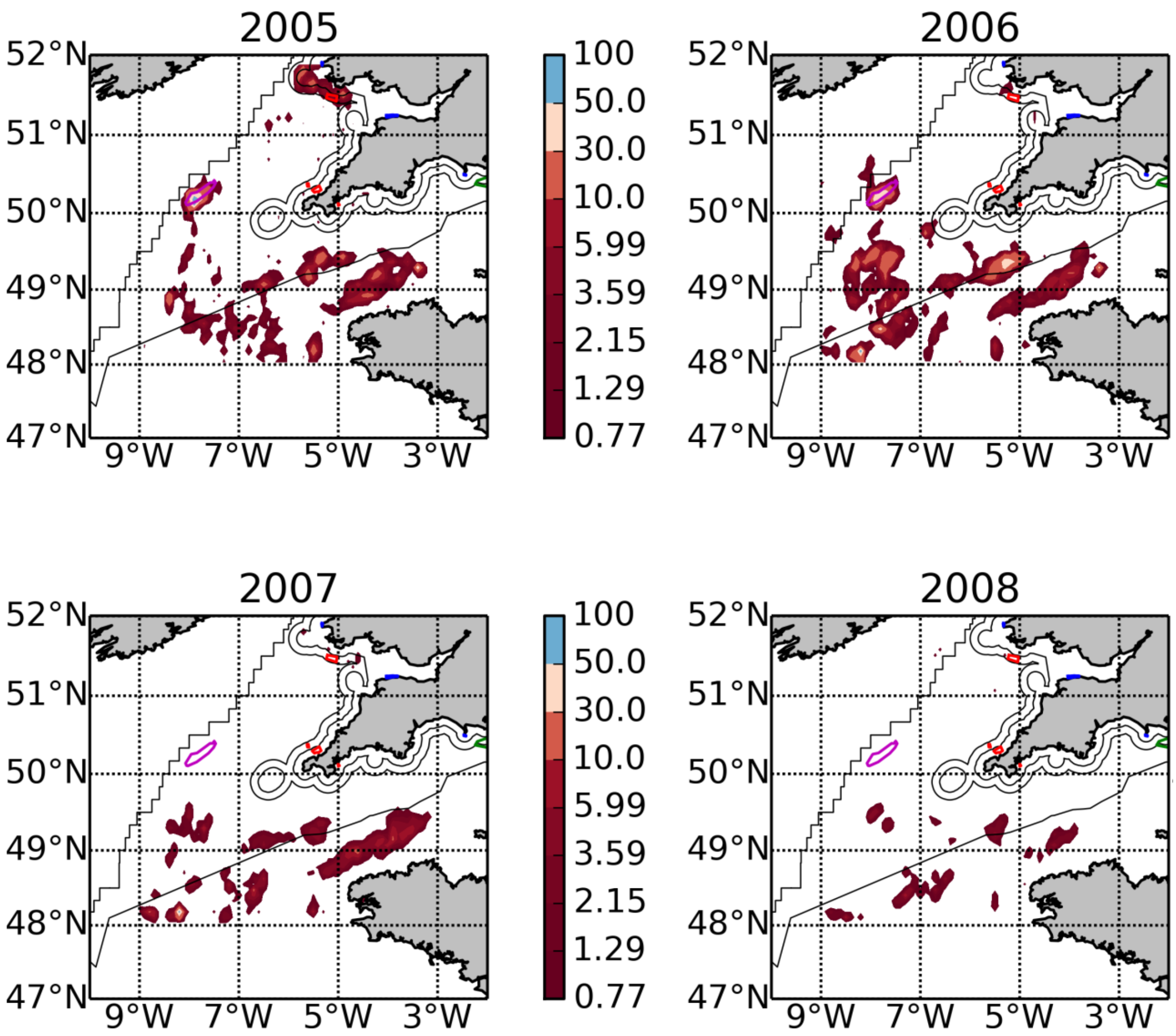

Figure 3.8 Fishing activity for scallop dredgers

Fishing activity (number of hrs fished) distribution of UK vessels >15 m in length in ICES divisions VII e-h from 2005-2008 for scallop dredgers. Haig Fras and Wave Hub are identified.

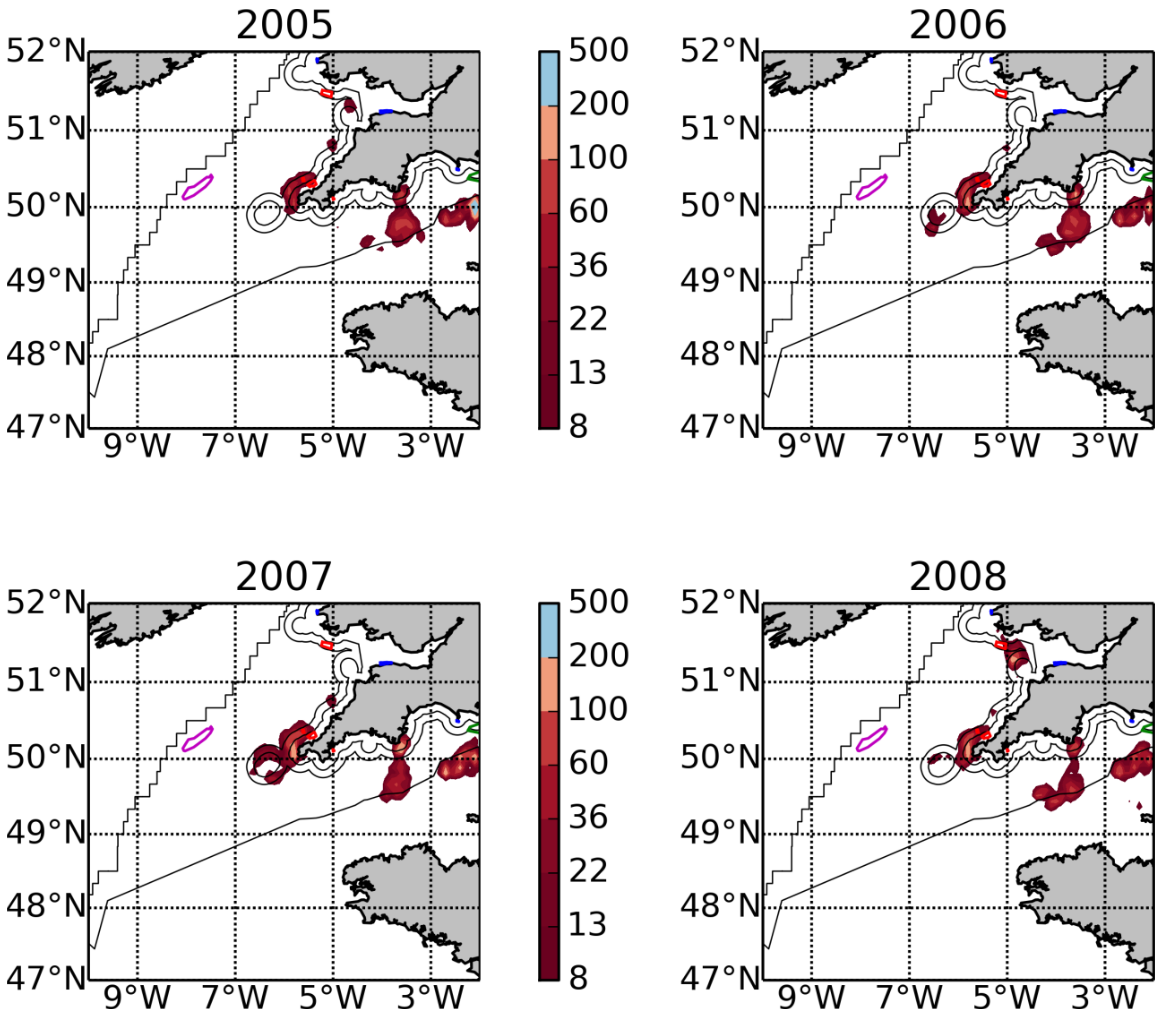

Figure 3.9 Fishing activity for potters and whelkers

Fishing activity (number of hrs fished) distribution of UK vessels >15 m in length in ICES divisions VII e-h from 2005-2008 for potters and whelkers. Haig Fras and Wave Hub are identified.

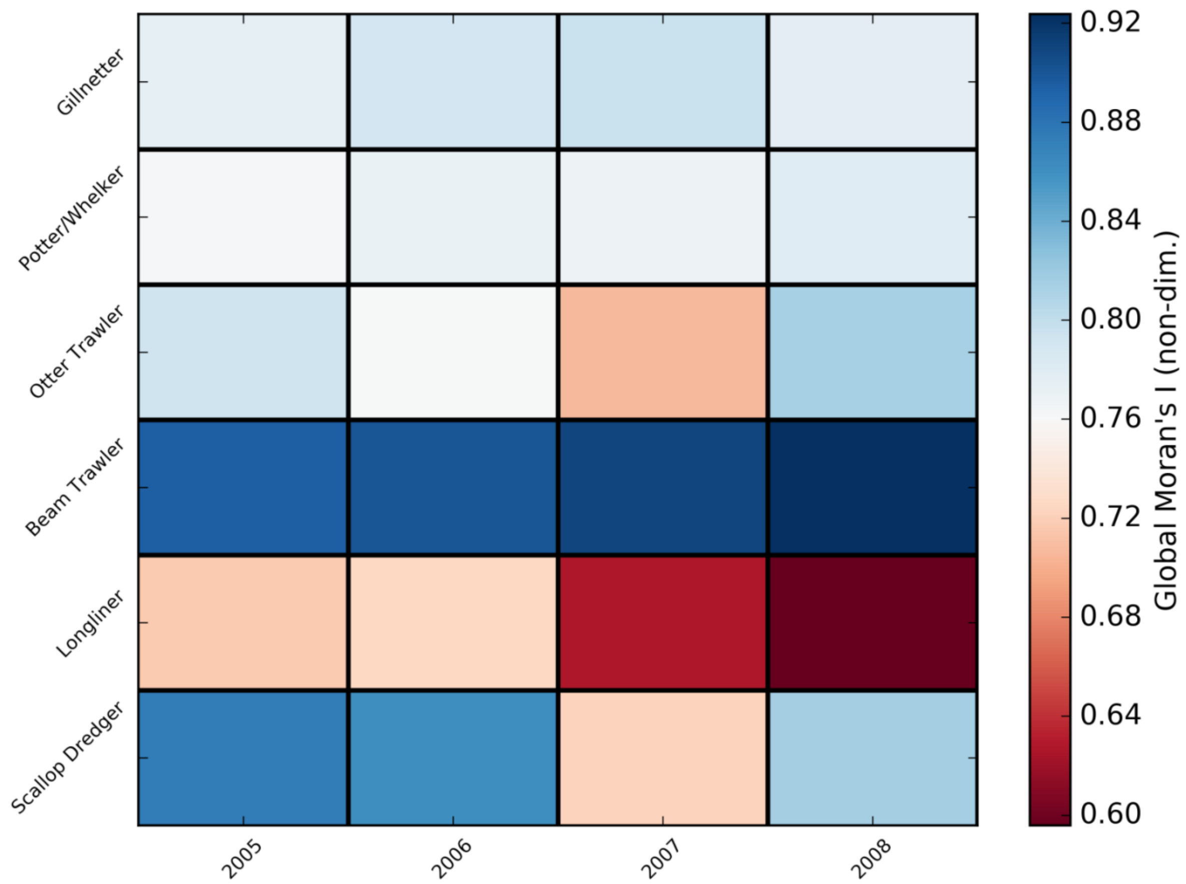

Figure 3.10 Global Moran's I

Figure showing autocorrelation of fishing activity (number of hours) per gear-type and year. Cold colours indicate a high degree of spatial clustering in fishing effort, over all regions. Hot colours show a relatively dispersed pattern in fishing effort.

Results show that different gear-types have different degrees of spatial clustering, but also that some variability in this clustering occurs in time. The Moran's I analysis (Figure 3.10) shows that the global pattern for beam trawling in particular, shows a high degree of clustering. In contrast, the distribution of fishing effort by longliners is much more dispersed. Other gear-types lie between these two end member cases. While the analysis (Moran's I, Figure 3.10) shows broadly the same patterns that you can discern from the maps of fishing effort (Figures 3.4-3.9), the power of such an analysis is that it provides an objective statistical means to compare gear-type and analyse spatial distributions of fishing effort over time. For example, the variability in Moran's I between 2005 and 2008 was sensitive enough to pick up the same changes in spatial distributions for longliners and scallop dredgers in particular, that could be discerned by eye, but provides an objective means to evaluate subsequent changes.

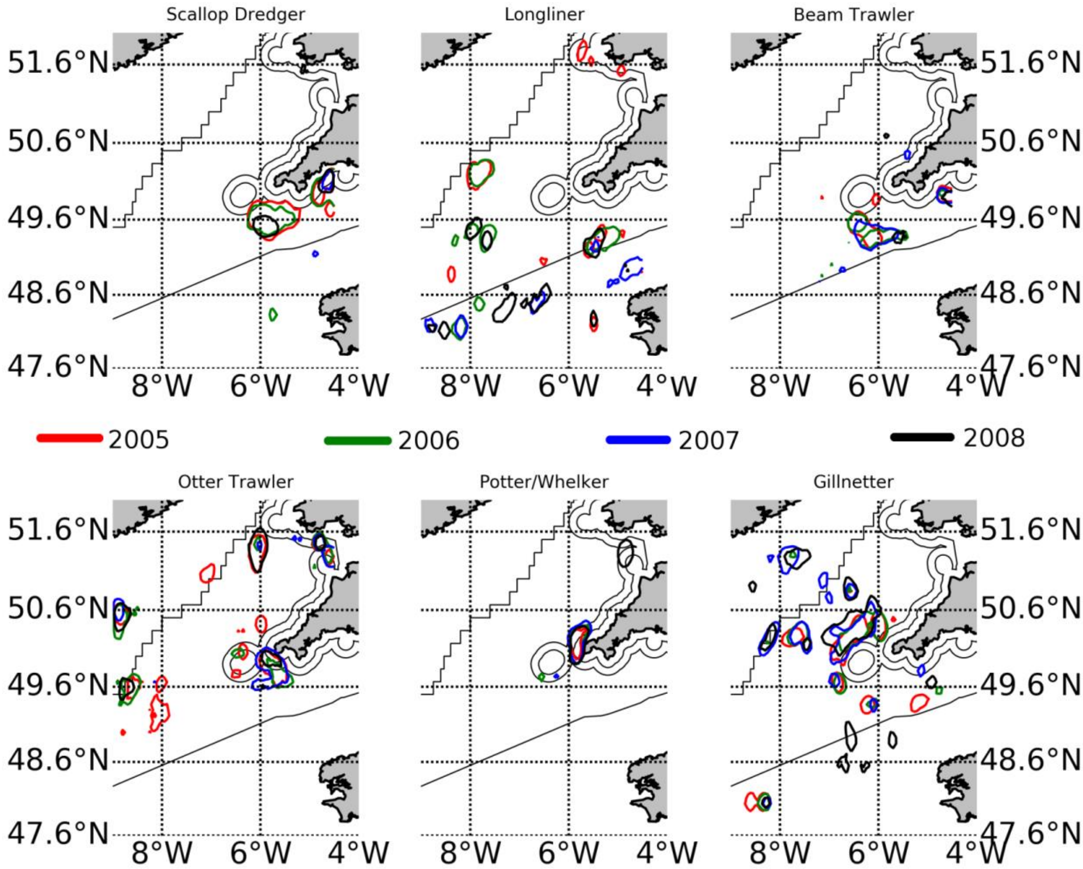

Figure 3.11 Getis-Ord Gi Statistic for all gear-types between 2005-2008. *Contours show the areas of very intense fishing effort, colour-coded by year. The contours represent the areas with a standardised local Getis-Ord Gi statistic of greater than 10. Contours that overlap indicate areas that are hotspots over multiple years. Contours in isolation represent areas that are intensively fished in only some years.*

High values of the G statistic show very high localised autocorrelation in fishing effort, which corresponds to a very spatially clustered pattern in fishing. To demonstrate these fishing hotspots in map form, the areas within which the G statistic was greater than 10 were contoured (Figure 3.11), for each fishing gear type. The value 10 was chosen as an appropriately high value that demonstrated fishing hotspots across all gear types. Similar statistical analyses were conducted by Jalali *et al*. (2015) to demonstrate hotspots in fishing effort. These maps (Figure 3.11) show that fishers tend to fish intensely at very specific sites year upon year, but that the distribution of these localised areas varies considerably with gear type. There is almost no overlap between the gear-specific hotspots. Such analyses could be extremely useful for identifying areas that only occasionally intensely fish, areas that are overfished, or areas most vulnerable to displacement.

3.3.2 Effects of spatial and temporal resolution

VMS data needs to be interpolated onto a regular grid in order for comparative analyses (between gears, over space, and in time). The spatial resolution at which VMS data are analysed partially dictates the level of uncertainty that applies to any inferences made using it. An advantage of having data at the highest possible available resolution, such as here, is that it can be analysed at varying resolutions in order to assess what spatial resolution is appropriate, by examining how the value of metrics change with different grid sizes.

The results (Figure 3.13) suggest in general that relatively small (<5 %) relative changes are to be expected for grid sizes of less than 0.2 degrees, and that up to 20% relative changes would be expected up to 0.4 degrees. It is recommended that a spatial resolution of no more than 0.1 degree was appropriate. No evidence was found that a resolution of less than 0.05 degrees (Lambert *et al*., 2012; Hinz *et al*., 2013) was necessary in this case. This pattern varied per gear type: for example, the spatial resolution made relatively little difference to data from scallop dredge vessels and beam trawlers. Spatial resolution had much greater effects of the spatial pattern indices of otter trawlers and potters/whelkers.

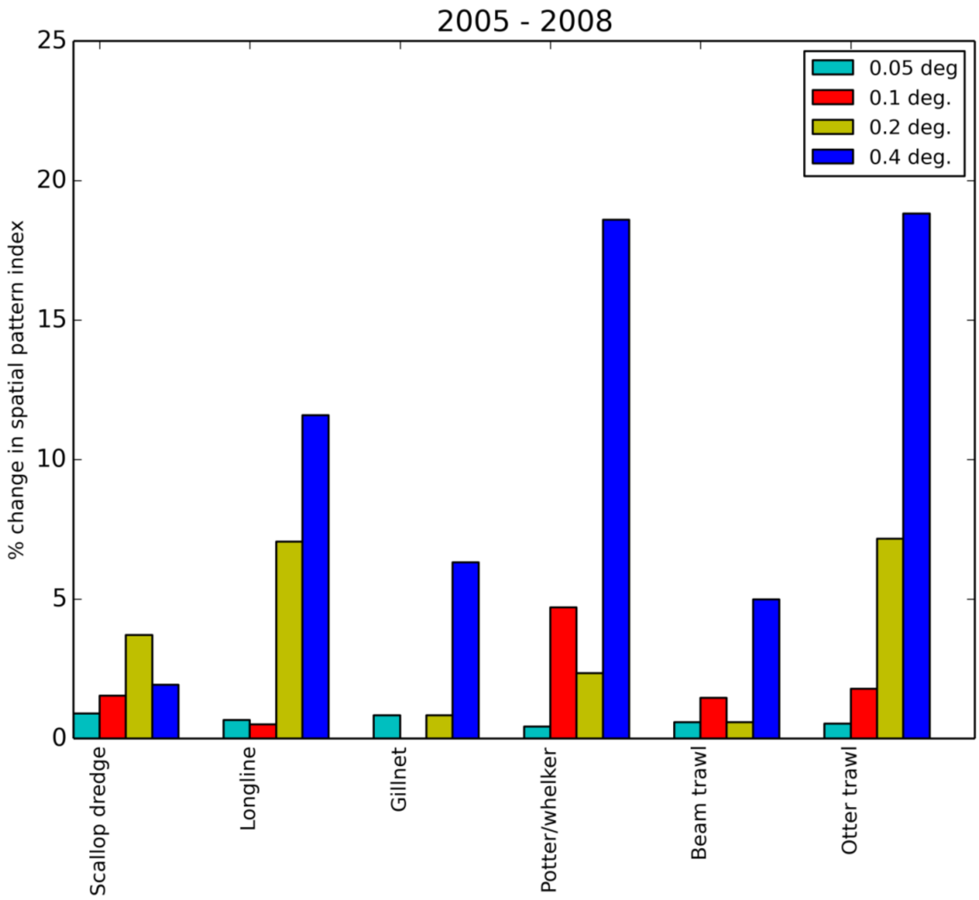

Figure 3.12 Percentage absolute change in index of relative difference in pattern of fishing activity for different grid sizes

Percentage absolute change in index of relative difference in pattern of fishing activity for a grid size of 0.05 (cyan), 0.1 (red), 0.2 (yellow) and 0.4 (blue) degrees respectively, relative to a grid of 0.025 degrees, over the period 2005 – 2008, for each of the 6 gear types.

Table 3.4 summarises the number of days fished in total per year, per gear and per ICES division. Having data at a high temporal resolution is beneficial for also looking at seasonality in the fishing effort. Displacement of fishing effort need not only occur in space: it might also have a temporal component if closures mean that fishing intensifies in certain areas at certain times of the year. It is therefore important to examine in trends in fishing effort by various fleets throughout the year, on a month-by-month basis. Detecting the effects of fisheries displacement might be possible by looking at how the seasonality of fishing effort changes in an area following a closure. In order to detect a change, a baseline needs to be established. Here, this is done using 2005 – 2008 as the pre-displacement baseline.

Figure 3.13 summarises fishing effort per calendar month, per ICES VII division, e-h, for each of the gear types. The average number of days per vessel was calculated as the total number of hours fished, divided by 24 hours, and divided by the number of unique vessels with a certain gear type. Strong seasonality is in evidence in longliners and potters/whelkers. Closures would presumably therefore disproportionately affect these gear types during the summer months when relatively more fishing is carried out. It might intensify summer fishing effort elsewhere. The relative impacts on benthic ecosystems would vary seasonally from these fishing types. In contrast, only weak seasonality is in evidence for scallop dredging, gillnetting, beam and otter trawling. The pattern in seasonality between gears also varies strongly across ICES VII e-h (Figure 3.14). The effects of closures on fishing effort needs to take into account, at some level, whether or not fishing is physically, biologically and economically viable throughout the year (like trawling), or only in certain seasons. It is likely that longliner and potter/whelker fishers, without adaptation, would be disproportionately affected by closures and displacement because the fishing season is short. All this points to that, fishing is more concentrated at particular times of the year, thus displacement potentially causes more intense impacts than if it was distributed evenly through the year. It is important to note that these conclusions could not be drawn using data at a coarser temporal resolution.

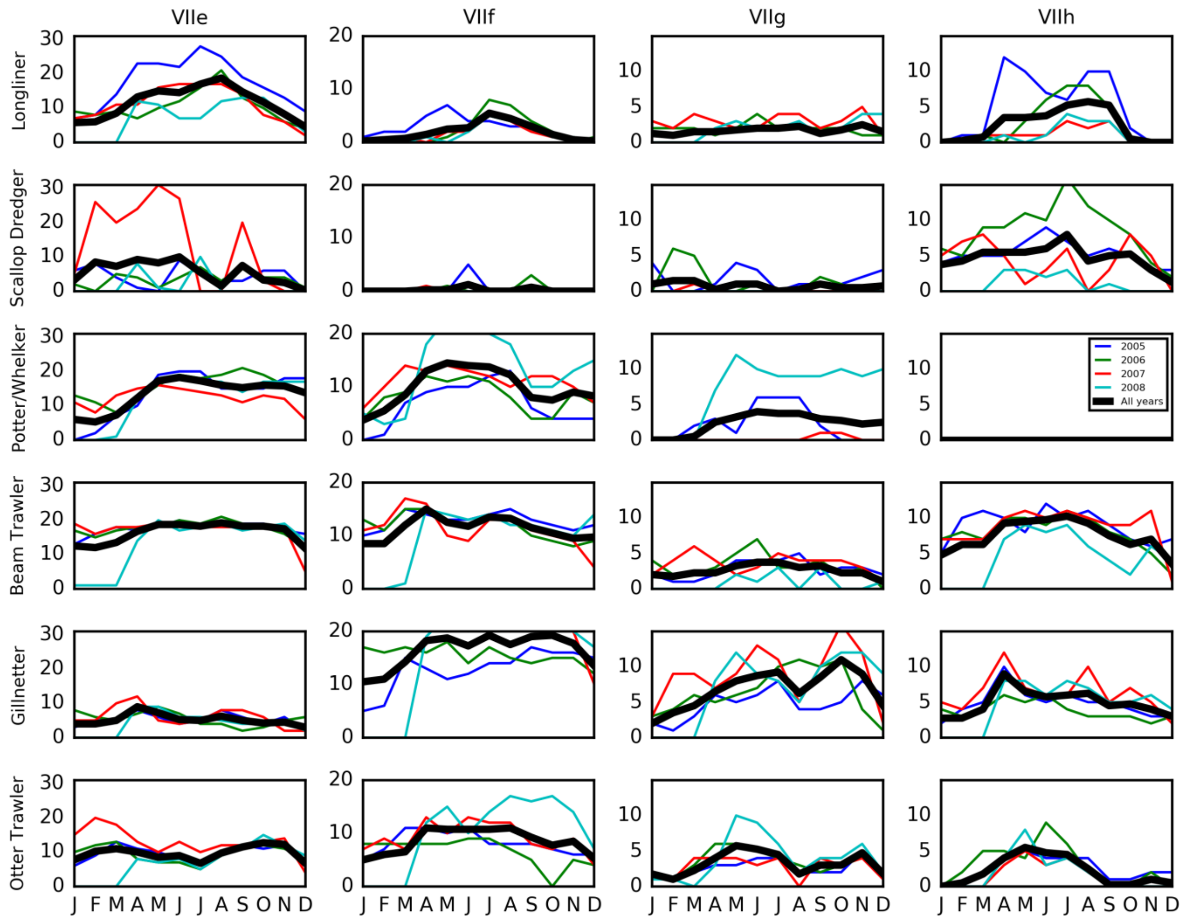

Figure 3.13 Average number of days at sea by UK vessels >15 m in length and average per calendar month in total per ICES divisions VII e-h

Average number of days at sea by UK vessels >15 m in length 2005-2008 (coloured lines) and on average (heavy black line) per calendar month, in total over ICES divisions VII e-h.

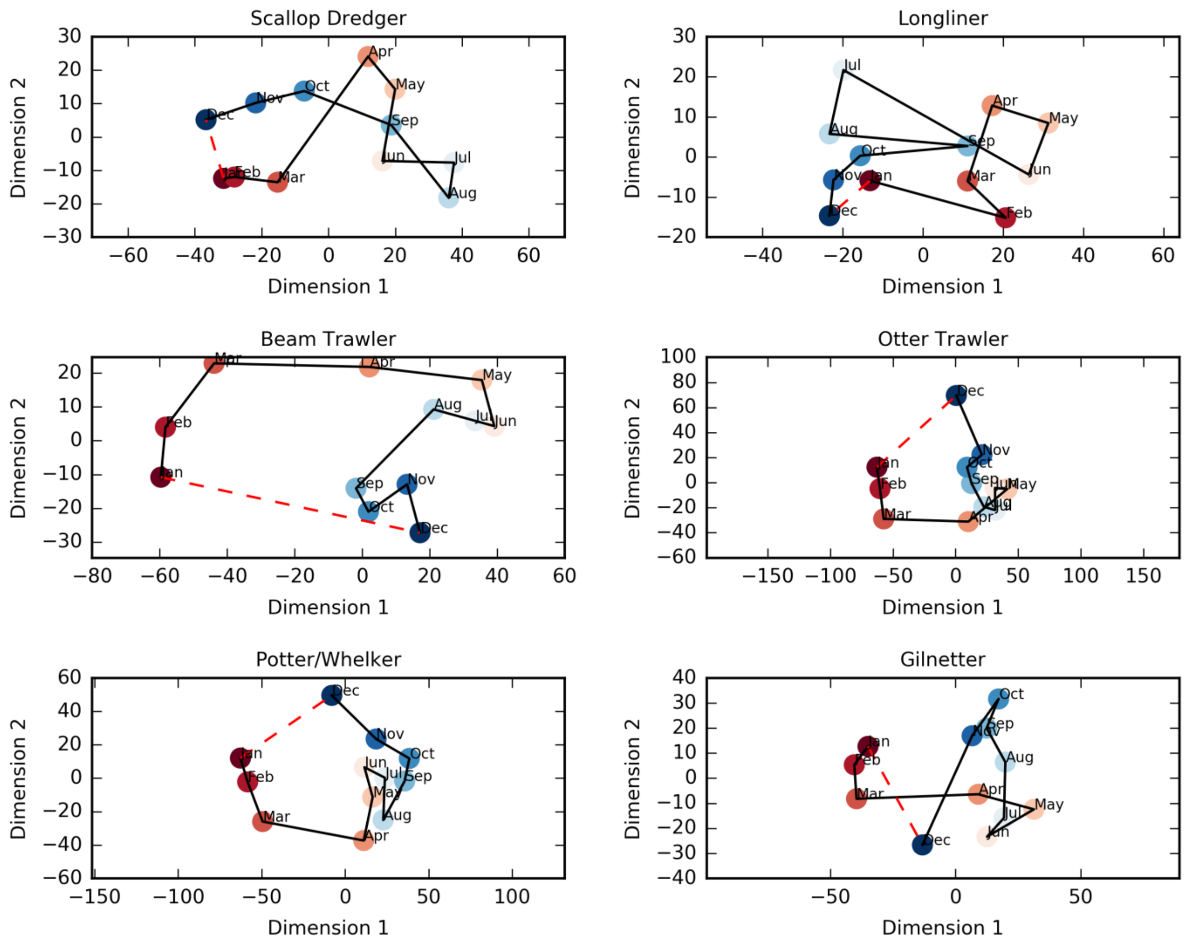

Figure 3.14 2-D MDS ordination of number of days at sea, for each gear-type with all years and ICES VII e-h aggregated.

Each dot represents a different month of the year.

Figure 3.14 clearly shows seasonality in each fishery, because there is a regular trend in the values of the ordinates month by month, which manifests as a circular pattern. This seasonality is strongest for beam trawler, otter trawler, and potter/whelker, and to a lesser extent with the others which show slight departures from the circular pattern in the plot. This analysis has been conducted by aggregating over years and regions but displays similar patterns for each region and year (not shown)

3.4 Discussion

3.4.1 Winners and losers in terms of fishing effort displacement: initial insights

The presented analyses of Vessel Monitoring Scheme data from South West UK reveal clear gear-specific differences in spatial and temporal patterns of fishing activity and allow detailed 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, for example towed gears avoiding Haig Fras. When gear type is not analysed then useful information (e.g. seasonal patterns in the locations of areas that are intensely used by sectors of the fleet – Figures 3.9 and 3.10) is lost and the overall impression of fleet activity is dominated by the most common fishing method (Witt *et al*., 2007). As such, detection of differences in other than the most dominant fishing gear type would be difficult. Previously, VMS data have been used to plan offshore marine protected areas, designed to minimize displacement of activity and to identify areas that were most likely to have untrawled biogenic habitats (Hall-Spencer *et al*., 2009). Gear-specific fishing activity was not analysed for the design of these offshore MPAs because such data were not made available by the authorities. Given the diversity of fishing gears used in inshore waters (< 12 nm), a lack of gear-specific information could lead to poor marine spatial management decisions. Results presented here illustrate that gear-based VMS analyses can offer greater detail on fleet activities than traditional sources of fisheries data, such as overflight data, and provides an opportunity to improve marine spatial planning, but could be substantially improved if higher level data, i.e. access to logbooks, and further years of data were available (for example, Lee *et al*., 2010; Jennings & Lee, 2012). This is particularly important in the South West UK as this area currently harbours most of the English and Welsh fishing fleets (Defra, 2007).

The effects of fishery closures (e.g. for nature conservation or offshore renewable energy developments) will vary considerably between different sectors of the fishing industry owing to the spatial heterogeneity in fishing effort. In the present study, beam trawling was the most widespread type of fishing, closely followed by demersal otter trawling. This sector of the fleet exploited such large areas that effects of two small area closures (Haig Fras and Wave Hub) are unlikely to have detectable environmental impacts outside the closures as mobile gears are rarely used within the these closures. However, if more (or different) areas off South West UK were closed, displacement of towed demersal gear activity might have the potential to increase pressure on benthic habitats unless seldom fished parts of a region are closed to towed demersal gear (Hall-Spencer *et al*., 2009) 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 jeopardized" (National Federation for Fishermen's Organisations (NFFO) pers. comm., July 2012). It may seem that this fear is not proportional to the scale of likely closures, however the risk of other vessels moving into other users territory is something that is discussed by various fishers (Chapter 5) and it is why a potential risk analysis of variability in fishing effort causing displacement is much needed (Chapter 4). Conversely, closed areas can sometimes benefit mobile gear users through 'spillover' (Gell & Roberts, 2003) or enhanced recruitment through larval export (Beukers-Stewart *et al*., 2005). 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 gillnetters, then their activity could likely be displaced onto other areas, potentially increasing competition between fishers and pressure on these habitats (for example, Rijnsdorp *et al*., 2000; Suuronen *et al*., 2010). Potters and whelkers, who often compete for space with mobile gear users (Blyth *et al*., 2002), may also be more affected by the small closures than mobile gear users. 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 MRE developments (Gray *et al*., 2005; Berkenhagen *et al*., 2010). We can use the outcomes of hotspot analysis in order to observe statistically derived hotspots for each given gear-type in any given year (Figures 3.10, 3.11). In the case of Wave Hub, initial impact assessments were deemed completely inappropriate and fishing effort highly underestimated, leading to conflict at the beginning of an important process. A solution was reached and fishermen were compensated, however, in order to come to this point, 18 months of new stakeholder negotiations had to take place and considerable damage had occurred between these two industries (Wave Hub fisheries liaison officer, pers. comm., October, 2013). This study has shown that, given the spatial and temporal heterogeneity of fishing effort in South West UK waters, detecting and assessing fisheries displacement requires high-resolution data and spatially distributed analyses, especially given the complexity caused by the interaction of factors involved.

3.4.2 Potential wider ecological impacts

3.4.2.1 Apex predators

Given that different fisheries have different environmental impacts, spatial management plans require high-resolution information on the distribution of different types of fishing activity (Stelzenmüller *et al*., 2008). For example, apex marine predators may benefit from feeding/scavenging on discards (Furness, 2003; Votier *et al*., 2004; Bicknell *et al*., 2013) or be at risk from accidental bycatch in long-lines or nets (Lewison *et al*., 2004) with discard rates and bycatch risk varying greatly as a function of gear type (Lewison *et al*., 2004; Furness *et al*., 2007). The VMS dataset used here 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 (Mitchell *et al*., 2004) given that individual seabirds appear to adjust their foraging behaviour when overlapping with bottom trawling VMS tracks in the Celtic Sea (Votier *et al*., 2010, 2013). A further 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 (Shephard *et al*., 2012). However, as described above, changes to fisheries management, in particular fisheries area closures may negate this effect, if fishers' behaviour is altered and fishing activity displaced. There is scope for modelling this type of uncertainty based on the types of datasets available (e.g. Stelzenmüeller *et al*. (2015), Zhang *et al*. (2015))

3.4.2.2 Seabed features

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 (Kaiser *et al*., 2006; Pedersen *et al*., 2009b), with scallop dredging known to cause more damage to seabed habitats than potting, for example (Hall-Spencer & Moore, 2000; Tyler-Walters *et al*., 2009). A spatially explicit analysis of which fishing gears are used is important, combined with evidence of the spatial distribution of those susceptible benthic communities, to both assess the cumulative likely impacts on these marine ecosystems but also in the context of marine planning, given the potential of MPAs and marine renewables to displace fishing effort into smaller areas, thereby potentially intensifying impacts elsewhere (Halpern *et al*., 2008; Stelzenmüller *et al*., 2008; Hinz *et al*., 2009; Stelzenmüller *et al*., 2010a, 2010b; Hiddink *et al*., 2011). Given the spatial and temporal variability in fishing effort that we have demonstrated in this Chapter, it is important that the spatial resolution of the VMS data be of equal or higher spatial resolution than information on the spatial distribution of the seabed habitats of vulnerable benthic communities. This is especially important if those habitats exist in relatively small or isolated/fragmented pockets. In other words, if the threat to a given habitat is evaluated using fishing data from VMS at a cell size greater than the habitat area (or outside of the habitat's spatial extent), then the uncertainty in assessing the potential impacts of fishing in that area would be prohibitively large to draw meaningful conclusions.

Marine reserve planners and renewable energy developers are increasingly using multi criteria decision analysis tools such as Marxan to optimize site selection (Baban & Parry, 2001; Villa *et al*., 2002; Bruce & Elliott, 2006; Prest *et al*., 2007), as this allows consideration of a variety of different spatially explicit selection objectives. While the main consideration is the distribution of the natural resource in question, the inclusion of gear-specific high-resolution fisheries data can minimize environmental costs of closures incurred by activity displacement (Dinmore *et al*., 2003), minimize the effects of accidental bycatch, discarding and trawl damage and increase the economic benefits of closures to fishers (Richardson *et al*., 2006), one of the main stakeholders in the marine environment (Gray *et al*., 2005), thereby making closures more politically feasible (Richardson *et al*., 2006).

3.4.3 VMS under the microscope

Although, in general, gear-type-specific VMS data analyses need to be carried out to sensibly manage the marine environment, there are exceptions. 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. So this stresses the need for new approaches, and one which has shown potential uses a behavioural rule approach at the level of the home port of each vessel (Vanstaen *et al*., 2010). The rule follows that vessels of a certain size will have a maximum limit of distance to where they can travel to from their home port; hence we can obtain a broad scale picture of the extent of inshore fisheries in a given area, by creating buffer layers on a map indicating maximum extent of fishing area. However, in the case of assessment of fishing effort displacement, as this study has demonstrated, a broad scale is not sufficient to detect changes in fishing effort. More data on < 15 m behaviour could have been obtained via one of the regional MCZ projects, Finding Sanctuary, however all stakeholders had signed a confidentiality clause meaning any third party not involved in the initial project would not get access to data. Successive attempts to access this data throughout the study period met without success, until 2013 when large aggregated polygons were made available through another research project. However, no meaningful analyses in relation to fishing effort displacement could be made with these aggregated 1 year datasets. This was a substantial amount of work at a fine scale performed by the regional MCZ projects, and it could have been put to better use once the projects were finished. VMS still provides the highest resolution data if raw records can be obtained and, as described above, current updates to the I-VMS project carried out by the MMO, Cefas, Seafish and the Inshore Fisheries and Conservation Authorities (IFCAs) will lead the way for inshore fishing analysis in the future.

Data on non-UK vessels was unavailable for this study; however even if it had been available, concerns over data inaccuracies, in particular the lack of information on gear type (Lee *et al*., 2010) would have precluded its use. As described above, the fact that Haig Fras is an important site for French demersal vessels and some UK vessels (Table 3.6 a & b) means that in relation to fishing effort displacement and indeed the impacts of displacement, the discussion is limited in scope unless we have a complete dataset that includes all fishing activity from all Member States operating in the same region. 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. The analyses are based on records that are transmitted every 2 hours, and there are risks in production or propagation of errors; misclassification of fishing vs. non-fishing; and 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. In this analysis, a point summation method is used but underestimations of activity are a risk (Jennings & Lee, 2012). Reconstruction of tracks is an alternative option (Mills *et al*., 2007), but vessels rarely travel in straight lines and again, it may not be appropriate for those using static gear.

Regardless of using point summation or tracks, the 2 hour polling frequency is an issue (Jennings & Lee, 2012). In terms of track reconstruction, a nonlinear interpolation technique like a spline (Hintzen *et al*., 2010; Russo *et al*., 2011) might help reconstruct a more plausible track than linear interpolation would, but the fundamental problem is that 2 hrs is too long between successive samples (Lambert *et al*., 2012). In the case of reducing VMS polling frequency, seminal work by Lambert *et al*. (2012) has suggested polling at intervals specific for each gear-type is optimal, supporting more accurate assessments of fishing activity and resulting impacts on the seabed. This work was carried out directly with the fishermen in the Isle of Man scallop fishery, and this work must be encouraged further in other areas and fisheries in order to ascertain if both mobile and static gears would need different polling regimes, i.e. making sure the polling regime is fit for purpose for that particular gear classification. This would require high effort on the part of the scientific and fishing communities and the formation of strategic collaborations in order to encourage any change to be initiated at the EU level, who oversees any changes to VMS policies.

The quality of VMS data is generally good: the number of duplicate records is very small compared to those records removed because of speed or proximity to port. Of the data filtering methods employed, most uncertainty is assigned to the filtering of records based on speed. This is in part due to a necessarily somewhat arbitrary threshold (6 knots) beyond which a vessel is deemed to be fishing, but mostly due to uncertainty surrounding the representativeness of recorded speed value in each 2-hourly VMS record. In January 2005, transmission of speed data became compulsory in EU VMS but a reliance on these data could underestimate fishing activity if it falls between 2-hourly VMS records (Witt *et al*., 2007; Fock, 2008) A simple speed filter such as used here allows the correct identification of a high percentage of both steaming and fishing activity (Lee *et al*., 2010; Jennings & Lee, 2012). The speed filters used, although necessary to indicate fishing gear deployment, could however potentially overestimate fishing activity in a situation where vessels slow down, for example, due to bad weather or treacherous terrain, or to reduce fuel costs (Abernethy *et al*., 2010). In addition, local or sectorial differences in fishing speeds of individual vessels or at fleet level may occur (Lee *et al*., 2010) which would call into question the 6 knot threshold for all gear types, areas, and weather conditions. As was stated above, testing various polling intervals would help identify an appropriate speed threshold for each fishing fleet type. Technological aspects of VMS will continue to improve, but if marine spatial planning is to mature as a discipline there is a compelling argument to be made to include fishers' knowledge (FK) which includes the biological, sociological and psychological influences on fishing fleet behaviour (for example, Murray *et al*., 2011; van Putten *et al*., 2011; Rees *et al*., 2013) with VMS and logbook data in order to predict the movement of vessels across metiérs and fleets, in both the short-term and long-term. This topic is explored in detail in a later Chapter.

3.4.3.1 Investigation of other technologies: Automatic Identification System (AIS) technology in lieu of VMS?

AIS, a self-reporting messaging system, was developed by the International Maritime Organisation (IMO) to ensure safety and collision avoidance at sea and is mandatory for all sea going vessels of 300 gross tonnage (GT) and upwards on international voyages, and 500 GT and upwards for vessels not engaged in international voyages and passenger ships (SOLAS, 2002). In addition, fishing vessels of 15 m length and above within the water of EU Member States are required to have AIS (EC, 2011b). Unlike VMS, which is usually based on point-to-point satellite communications between the ship and the ground centres, AIS messages are broadcasted by the vessels omnidirectionally and can be received by other ships in the neighbourhood, by ground based receivers and by satellites. The AIS system provides the possibility for ships to exchange, in near-real-time, vector information on its current state (position, speed, course, rate of turn etc.), static information about the vessel (vessel identifiers, dimensions, ship-type etc.) and voyage related information (destination, ETA, draught etc.) at variable refresh rates of seconds while in motion to 2-5 minutes while at anchor (ITU-R, 2014). Over the past few years, these data has been transmitted to various regional and national data centres with varying levels of data stream success and changing levels of coverage over time and space.

AIS might never be able to replace VMS but they could be used in tandem. Although AIS has potential and is generating interest from the scientific community, robust methods for data manipulation and analysis are still in their infancy (for example, Pallotta *et al*., 2013; Mazzarella *et al*., 2014). AIS do not come under the same control restrictions as that of VMS, and with all EU vessel uptake of the system, there are no trans-boundary issues between Member States, therefore data should be much widely available. For example, regarding availability, AIS recently made headlines with an initiative between Skytruth, Oceana and Google, with 'fishing vs 'non-fishing' behaviour explicitly presented that aims to tackle global overfishing by simple vessel monitoring[8]. As described above the polling frequency of VMS is something that needs to be explored, having a lower polling frequency than 2 hours may be much more advantageous in the assessment of fishing effort and AIS

[8] Global Fishing Watch http://www.globalfishingwatch.org

provides significantly lower polling frequencies. However it was not specifically introduced with fisheries control in mind, and the technical aspects of the AIS signal, i.e. intermittent communication represents limitations in ensuring a complete and systematic coverage. Other aspects include, inclusion of only the >15 m fleet and the difficulty of assessing vessels that engage in static fishing.

3.5 Summary

- The spatial distribution of fishing activity was highly heterogeneous and distinct areas of intense fishing could be identified for all gear types;

- The methods of Lee *et al.* (2010) are the most appropriate, straight forward to implement, and therefore most valuable for the calculation of fishing effort from VMS data. These methods in summary: records without an associated gear type, within 3 NM of ports and duplicates are all removed. To identify *bona fide* fishing activity, the interval between each successive record was calculated and only those vessels travelling at a speed less than 6 knots were deemed to be actively fishing. This methodology was applied to all gear types. A point summation method followed, using a grid cell size of 0.05° (or 3 arc minutes), equating to 3 NM, the resolution of fishing data considered necessary to inform MSP;

- In lieu of data on vessel gross tonnage (GT) or engine power (kW), fishing effort was defined in terms of number of vessels and number of hours fished. Further work could be carried out to establish the importance, or otherwise, of factoring in the vessel's size and/or engine power in fishing capacity;
- An index of spatial difference in spatial distributions revealed that scallop dredgers were the most spatially variable fleet in South West UK waters, and

they were the only gear type whose shift in geographic spread was easily noticeable by eye at a large scale, moving their efforts from the Celtic Sea (including Haig Fras) further south into the western English Channel and Atlantic during the study period;

- Mobile gear types have a high to intermediate spatial coherence (or low to intermediate change) in spatial pattern of fishing effort between years, despite their mobility. This might be because they remain active almost year-round. The claim that the VMS data and analysis methods employed were sufficient to capture displacement is supported, for example, by this analysis capturing the changing pattern of fishing effort by scallop dredgers which underwent significant shifts in spatial distribution between years;
- There was a high degree of dissimilarity between the spatial distributions of fishing grounds by vessels with different gear types. The two gear types most closely matched according to an index of spatial difference in spatial distributions were longline and beam trawlers, but it is suggested that this is only the case because of the wide geographic spread of beam trawlers and the relative isolated patches of activity by longliners;
- The index of spatial similarity is a robust method of quantifying changing spatial distribution but is highly dependent on the size of the cell. Therefore, care should be taken to report this cell size because meaningful comparisons can only be made between data sets with identical cell size. If this method proves popular in subsequent research, a standard cell size should be adopted;
- A closure of Haig Fras would have the greatest impact on gillnetters. Scallop dredgers also occasionally use the area; however they exhibited much more

spatially variable behaviour during the study period so it is less clear whether their occasional use of the area reflected long term usage trends. It is important to note that this analysis is Uk vessel centric, and we know that a large number of French vessels use this area, and we cannot say anything about the likely impacts of these;

- The G statistic maps show that fishers tend to fish intensely at very specific sites year upon year ‘hotspots’, but that the distribution of these localised areas varies considerably with gear type. There is almost no overlap between the gear-specific hotspots. Such analyses could be extremely useful for identifying areas that are only occasionally intensely fished, areas that are overfished, or areas most vulnerable to displacement.
- The current closure at Wave Hub has the greatest impact on potters and whelkers whose geographic specialisation is most pronounced and who use the area extensively. Longliners also use the area disproportionately and would be affected. In contrast, the potential impacts of beam and otter trawlers seem less clear given their much wider spatial distributions in fishing;
- Relatively small (<5 %) relative changes in calculated statistics of fishing effort are to be expected for grid sizes of less than 0.2 degrees, and that up to 20% relative changes would be expected up to 0.4 degrees. It is recommended that a spatial resolution of no more than 0.1 degree is appropriate. No evidence was found that a grid resolution of less than 0.05 degrees was necessary;
- The spatial resolution made relatively little difference to data from scallop dredge vessels and beam trawlers. Spatial resolution had much greater effects of the spatial pattern indices of otter trawlers and potters/whelkers.

These two fishing types are very different, in general, in terms of spatial coverage and clustering, so it is suggested that the grid resolution effects are due to capturing, or otherwise, the nature of intense fishing in a relatively small number of highly localised areas;

- Longliners, potters and whelkers show the greatest seasonality in fishing effort with disproportionately greater effort in summer months. Closures and any expansion to those closures might therefore disproportionately affect those gear types during the summer months when relatively more fishing is carried out.

Chapter 4 Determining Variability in Fishing Effort Trends in the South West of the UK: Defining a Baseline for Detecting Displacement.

Work presented in this Chapter will be incorporated into the following manuscript which is currently in preparation:

Campbell, **M**., Attrill, M., Abbott, V. & Hall-Spencer, J. (*In Prep*) 'The 'background' variability of trends in fishing effort in the South West of the UK: Defining a baseline for detecting displacement', *ICES Journal of Marine Science.*

“The fishermen know that the sea is dangerous and the storm terrible, but they have never found these dangers sufficient for remaining ashore”

Vincent Van Gogh, 1853-1890.

4.1 Introduction

4.1.1 Detecting baselines

In order to detect and evaluate a change in fishing effort directly attributable to Marine Renewable Energy (MRE) or Marine Protected Areas (MPAs) associated closures, it is necessary to establish baselines by mapping fishing effort. For this, there must be access to high-resolution temporally and spatially explicit data about what the fisheries community are now calling the “anatomy” of fishing grounds (Jennings & Lee, 2012) to assess fishery footprints (Jennings *et al*., 2012). Recent work by de Groot *et al*. (2014), elements of which will be discussed in detail in the next Chapter, highlighted the insufficiency of base line monitoring thus far in assessing interactions between MREIs and fisheries. In particular there were numerous examples of under estimations of fishing effort, hence inaccurate baselines, and this is a concern when attempting to plan and predict any displacement of effort, or mitigate against it. In addition, in relation to impacts of Offshore Wind Farms (OWFs), Ashley (2014) found that in many cases only one year sampling was conducted pre-closure, giving no indication of natural patterns of variation, due to insufficient baselines and making any meaningful comparison for impacts post-closure difficult.

It is imperative, therefore, that the background variability in fishing effort is understood and quantified. Assessing fishing effort pre-displacement will allow a change in fishing behaviour caused by displacement to be identified because it will be a forced behaviour outside the background pattern. Long time series are also important due to the fact that marine ecosystems go through cyclical patterns and shifts that can extend over long periods. For the purposes of monitoring, this is required to answer questions regarding how long after a displacement change might be detectable. This is a fundamental prerequisite in any studies into the causes and effects of fisheries displacement. This Chapter addresses the question: how might the background variability of fishing effort be described, so that a displacement can be assessed? The approach is twofold. First, fishing effort in South West UK waters is described and quantified relative to arguably the most dominant physical control on the spatial distribution of fishing: seabed substrate. Given the seabed substrate is a straightforward quantity to measure and varies relatively slowly over long time scales and large spatial scales – indeed, potentially much more slowly than ecological and socio-economic factors and even changes in waves and tides - any relationships that can be made between fishing trends and substrates is useful for first-order description and prediction of fishing effort. Second, a simple technique is developed that can be used to describe and quantify variability. This technique can be compared across any number of gear types and across any number of years, and can be interpreted using standard statistical methods. It is argued that compiling this metric over sufficient time will provide a baseline against which the spatial distribution in fishing effort in a given year can be compared and, by extension, the potential effects of fisheries displacement detected. This variability index is necessary in order to make associations between fishing effort and an explanatory variable that would explain that variability when information sources and drivers in fishing effort are not collected on a frequency comparable to VMS data (such as policy changes, socio-economic study findings, substrate, specific benthic ecology studies, etc.).

Seabed substrate type at a given location is controlled predominantly by broad-scale supplies in sediment and energy at the seabed (Figure 4.1), which in turn is strongly controlled by water depth (Figure 4.2). Some studies suggest that there can be strong relationships between the spatial distributions of seabed substrates and fish of individual species (Maravelias *et al.*, 2000; van der Kooij *et al.*, 2008; Chatfield *et al.*, 2010).

4.1.1 Primary Objectives

The objectives of this Chapter are as follows:

- Assess the potential role of substrate in explaining the spatial distribution of UK fishing effort in South West UK waters;
- Determine the significance of a suite of explanatory variables: depth, wind strength, substrate type, gear-type and fish value for fishing effort;
- Determine the gear types with which fishing effort is significantly different;
- Develop an objective means to assess the background variability of fishing effort, as a baseline against which to assess displacement; and
- Investigate the relationship between fish catch data (derived from low-resolution, less-access-restricted level 2 VMS data) and the background variability of fishing effort, in order to explore the potential role of broad scale catch data (weight and economic value of fish) as a simple proxy for baseline fishing effort.

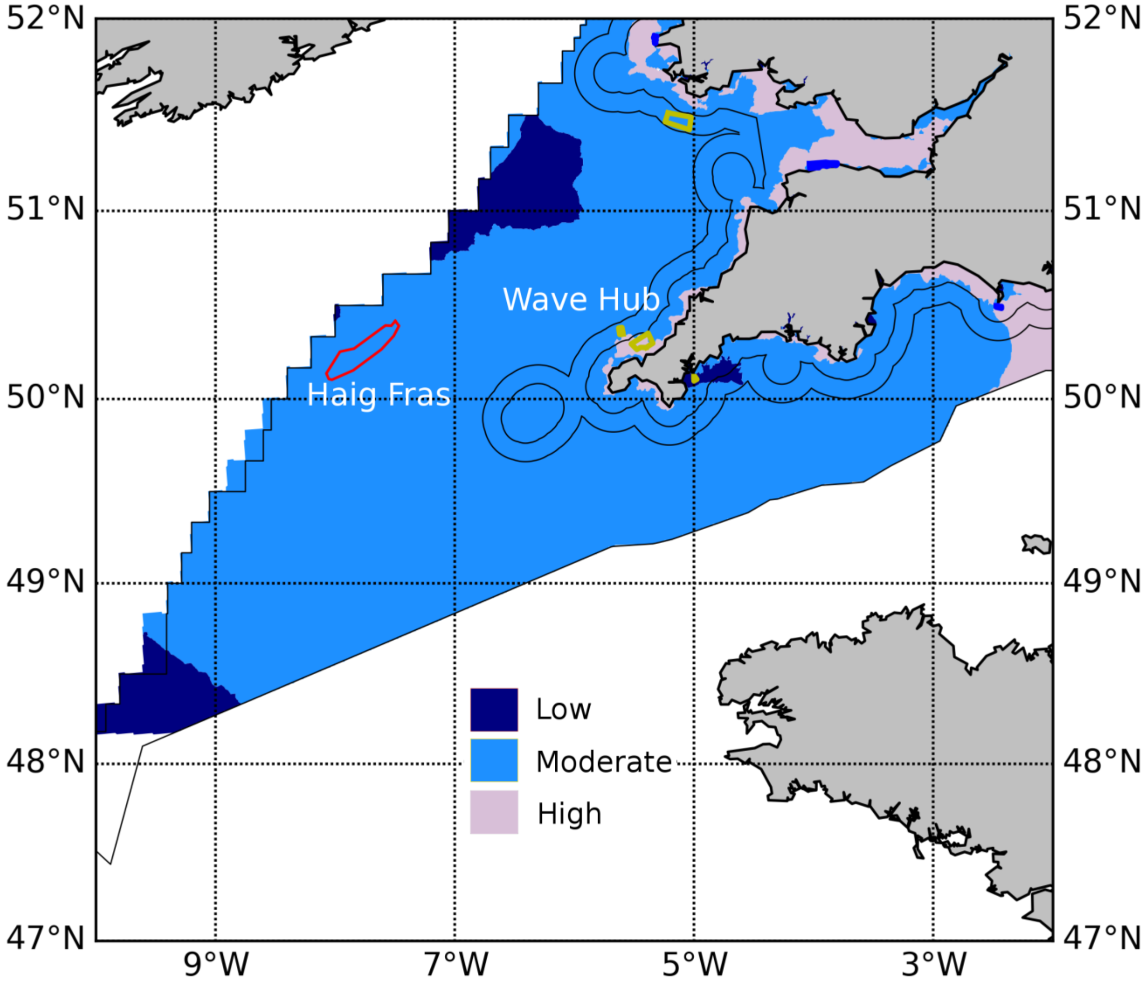

Figure 4.1: Kinetic energy at the seabed in the South West UK waters

Kinetic energy at the seabed (Nm^{-2}) in the South West UK waters. Major proposed MREIs (wave developments in yellow, tidal developments in blue) and Haig Fras (red) are also shown. (McBreen et al., 2011)

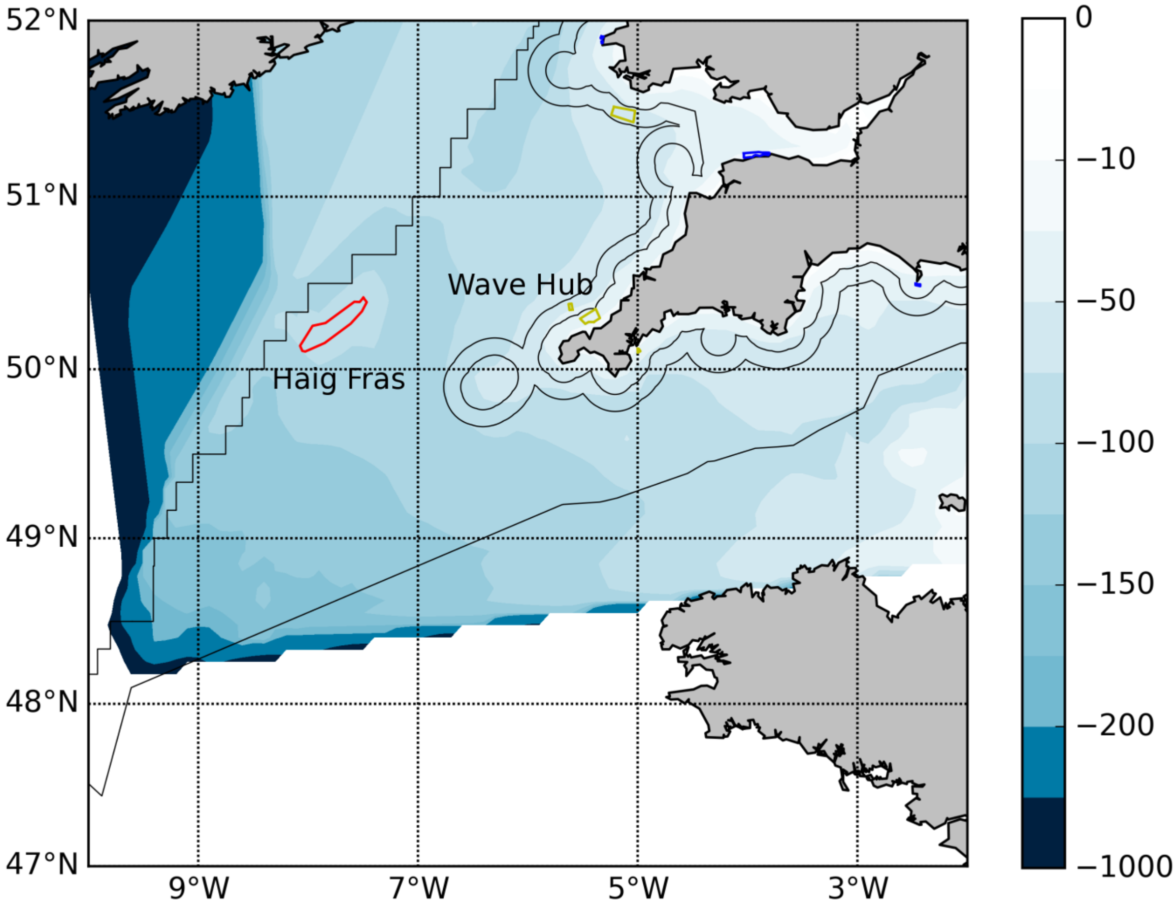

Figure 4.2: Bathymetry of the South-west UK waters

Bathymetry of the South-west UK waters. Coloured filled contours correspond to depth in metres at 7 isobaths. Major proposed MPAs (red) and proposed/ active (wave developments in yellow, tidal developments in blue) are also shown (source: ABPmer Atlas of MRE).

4.2 Methodology

4.2.1 VMS data and analysis

The methods for VMS data, access and analysis are outlined in section 3.2.1, Chapter 3. As described in the previous Chapter, VMS confidentiality issues have affected this study, and also others.

4.2.2 Fishing activity and marine substrate

Seafloor composition should, at some level, have some bearing on explaining the distribution of fishing effort for certain gear-types, to the extent that Seafish used seabed type as a proxy for fishing activity and intensity (Seafish representative, pers., comm, January 2015). Seafish are a levy body that represent the UK seafood industry (www.seafish.org).

Here, the distribution of fishing activity was assessed with respect to five ‘marine landscape’ types (following the EUNIS 2007-2011 classification scheme) derived from UK SeaMap 2010 data, a predictive model based on inputs of observed substrates, biological zone, energy, salinity and biogeographic region (McBreen *et al*., 2011) with additional categories on deep-sea areas provided by Howell (2010). Outputs are at a resolution of 0.0025 decimal degrees (about 300 m). The five substrate categories used were: sand, mixed sediment, coarse sediment, mud and rock (including rias, sealochs and mounts). Substrates are considered to be invariant over the study period (2005 – 2008). To assess seabed type as a driver of fishing activity, average number of fishing hours per 1 km^2 of the different marine landscape was calculated, following the methods described in section 3.2.2.1, Chapter 3. The seabed map only covers the UK continental shelf Exclusive Economic Zone (EEZ), whereas ICES divisions VII e-h have a greater geographic area (Figure. 3.1., Chapter 3). Therefore the relationship between substrate and fishing effort could only be assessed within the EEZ. Fortunately, however, division VII f is entirely contained within the EEZ boundary, and at least half by area of each of the remaining ICES VII divisions are within the EEZ. Given that most fishing effort of beam trawlers (Figure 3.4., Chapter 3), otter trawlers (Figure 3.5., Chapter 3), gillnetters (Figure 3.6., Chapter 3), longliners (Figure 3.7., Chapter 3), and potters/whelkers (Figure 3.8., Chapter 3) are within the EEZ, it is argued that the substrate analyses are unbiased. Only scallop dredgers (Figure 3.8., Chapter 3) show significant fishing activity outside the EEZ; therefore conclusions drawn regarding the relationship of scallop dredging and substrate are to be considered tentative. It is also pertinent to point out that all UK MPAs and MREIs are within the UK EEZ, so any fishing-substrate relationships outside the EEZ are of contextual interest only.

4.2.3 Statistical Analyses

A generalised linear model (GLM) analysis was performed, in order to model fishing effort as a linear combination of available independent, or explanatory, variables: depth, wind strength, wave strength, substrate type, gear type, year and fish monetary value. The response (dependent) variable was the aggregated fishing effort data for all gear-types and all years. Since the numbers of hours fished is a form of count data, being the number of fishing hours in a fixed spatial area, the appropriate statistical model is a Poisson distribution, which is a very good fit to the data (Figure 4.11). The GLM model was constructed using a log link function which is standard practice for Poisson-based GLM analyses (Zeileis et al., 2008; O'Hara and Kotze, 2010). The predictor matrix was composed of, each per grid cell, a) water depth; b) annual mean wind speed; c) annual mean significant wave height; d) substrate type (coded 1 to 5 inclusive for, respectively, sand, coarse, mixed, rock, mud); e) gear type (coded 1 to 6 inclusive); f) year (coded 1 to 4 inclusive); and g) total value of fish landed by all vessels (derived from the MMO level 2 data, 2007-2010, described further in section 4.3.3). The rationale behind using fish value is that fishers might be likely to return to known profitable grounds. The GLM was constructed using the 'statsmodels' package (http://statsmodels.sourceforge.net/devel/glm.html). The total number of observations was derived from the fishing effort, substrate, wind, wave, bathymetry, and fish value data sets gridded onto the same regular grid.

4.2.4 Fishing effort variability index

A simple metric was developed to characterise the background variability in fishing effort. Given that fisheries displacement is inherently a spatial problem (that cannot meaningful be summarised in space, only in time) and the spatial distributions of fishing effort differ markedly between gear types (Chapter 3), it is important that variability is spatially explicit (i.e. not averaged or aggregated over space). In developing such a metric it is also important that it is 1) simple (therefore easy to apply), 2) does not differ in its application as a function of the amount of data available (so can be re-calculated as more data becomes available over time) and 3) calculated in such a way that its statistical validity can be easily assessed.

One approach that satisfies the above criteria is as follows. For each gear type, the per-cell coefficient of variation (CV) in fishing effort is computed across the 4 years available (2005 – 2008 inclusive) as the ratio of the standard deviation and mean effort (across years) per cell, expressed as a percentage. This coefficient of variation is used as a simple measure of the variability in fishing effort which can be specified on a per-grid-cell basis and assumes nothing about the distribution of the data. Because it is calculated per gear and per location, calculated relative to, and expressed as a percentage of, the mean fishing effort, valid comparisons can be made between gear types, between locations, and over time. This quantity when mapped gives an indication of the variability in fishing effort over space, with small values of this index indicating small fluctuations in per-grid variability in fishing effort relative to the mean fishing effort for the same grid cell, which is in turn indicative of a region which is stable, or a ground fished with similar intensity year-to-year. High values of this index indicate highly variable, sporadic fishing effort not indicative of a stable, regularly fished area.

4.3 Results

4.3.1 Substrate

Figure 4.3. shows the seabed map derived for the ICES VII subarea for the UK EEZ. The general pattern of clastic substrates (sand, mixed and coarse sediments) follows the general distribution of depth (Figure 4.2.) and kinetic energy at the seabed (Figure 4.1.): sandy in moderate energy locations, and coarse and mixed sediment in higher energy regions. Locations of rock are generally more spatially isolated and are controlled by bedrock geology rather than wave energy (Connor *et al*., 2006). Haig Fras is predominantly rocky with some small patches of coarse and mixed sediment. At this spatial resolution, the Wave Hub region is coarse sediment exclusively (Figure 4.4.). There is a wide variety in substrate types for the proposed MREI sites in the South West of the UK (Figure 4.4.).

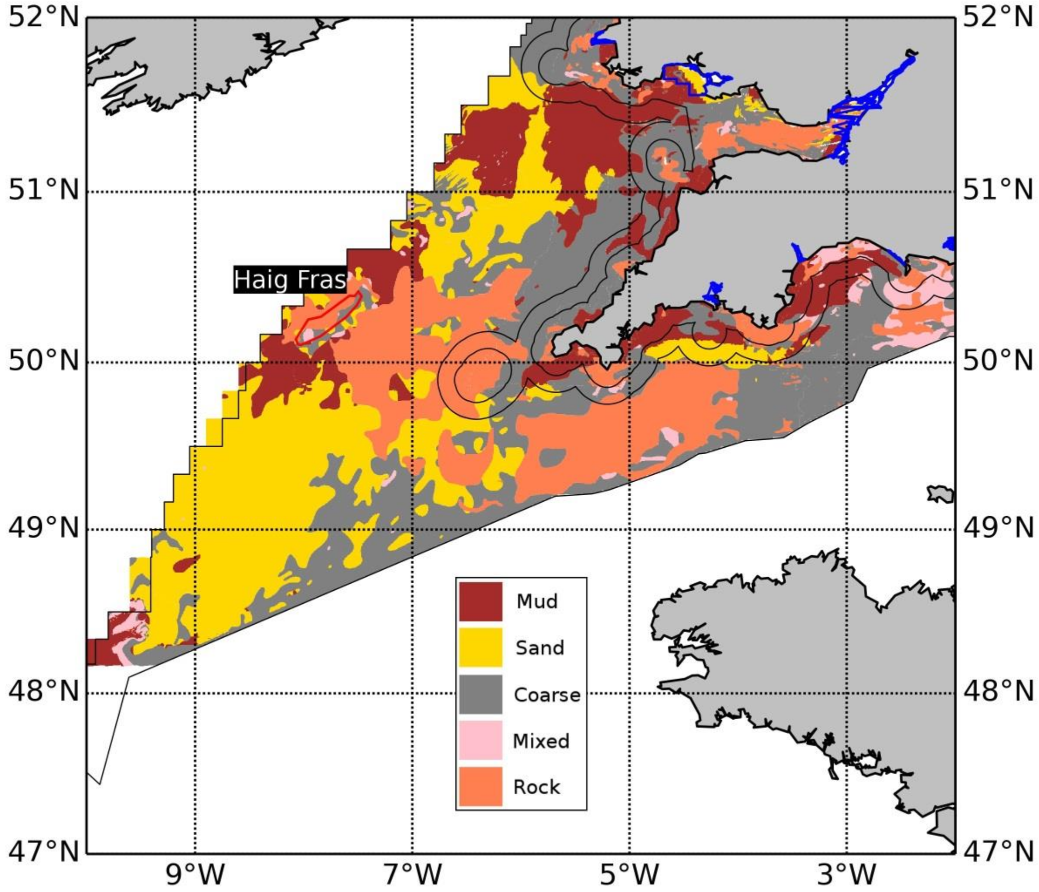

Figure 4.3: Five substrate types derived from UK Seamap data

Five substrate types derived from UK Seamap data (McBreen et al., 2010; Howell, 2010) within the UK continental shelf covering the ICES divisions VII e-h. The location of Haig Fras is also noted.

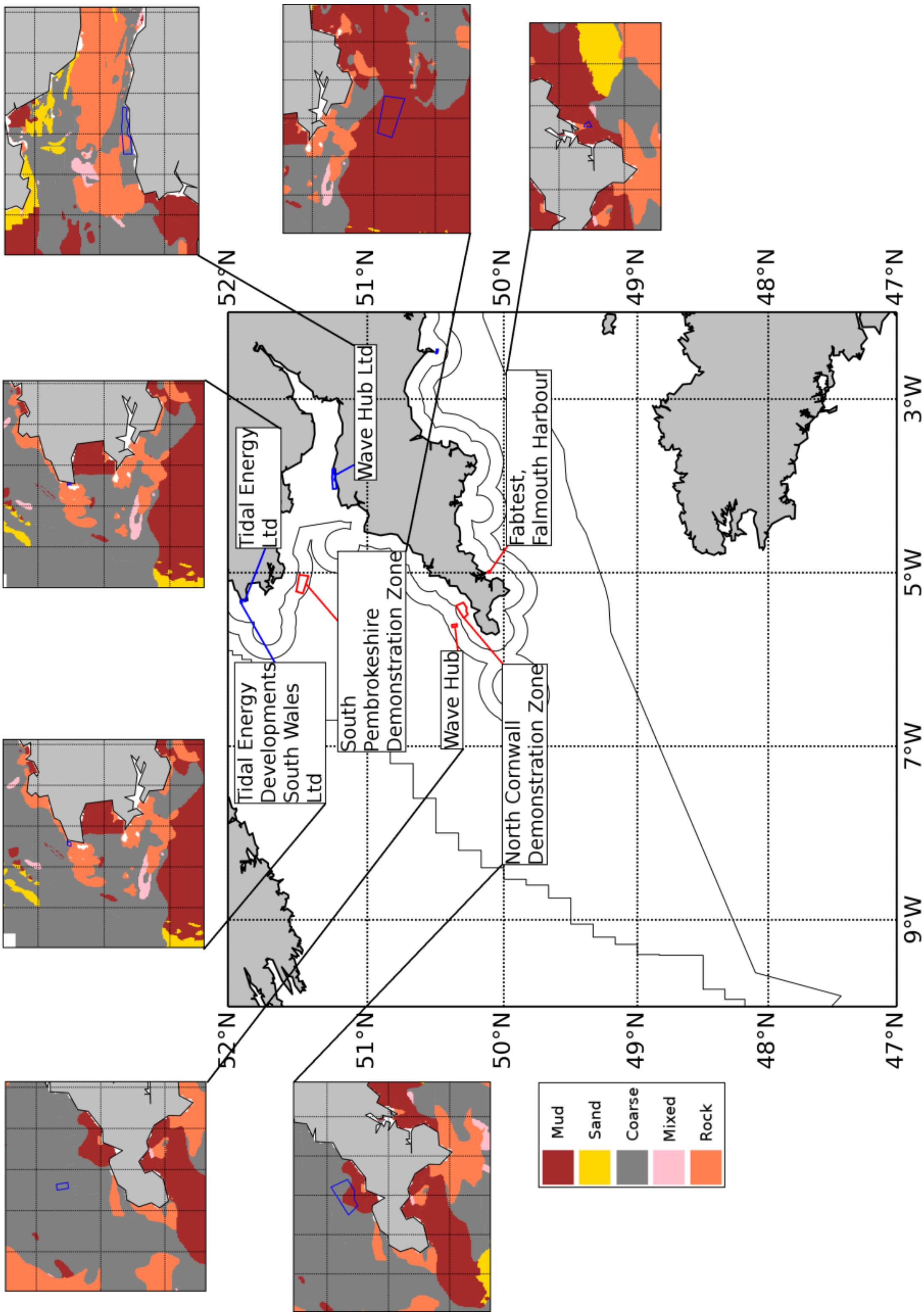

Figure 4.4: The location of proposed/active MREIs in the South West UK

The location of proposed/active MREIs (wave energy developments are red, and tidal energy developments are blue) in the South West UK, in relation to substrate types derived from UK Seamap data.

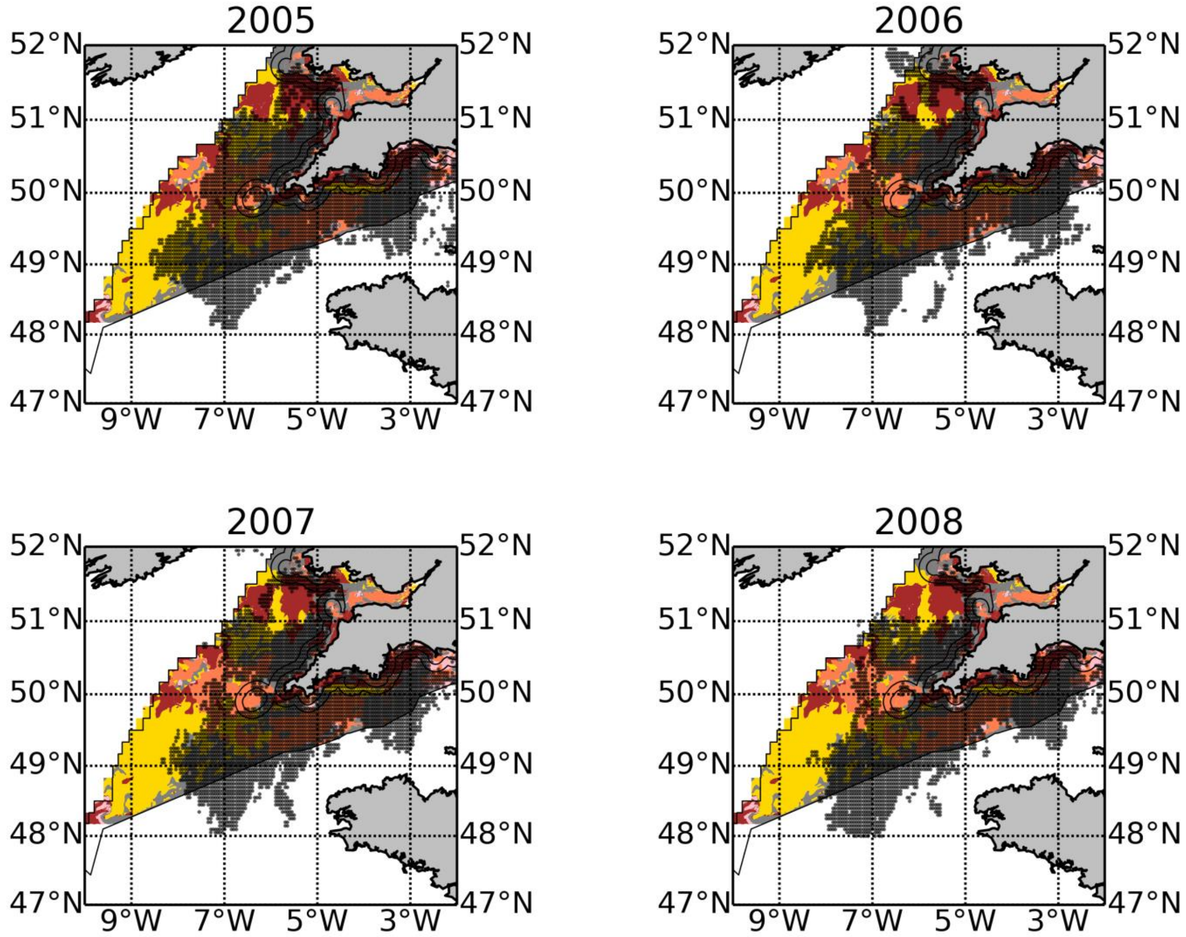

Figure 4.5: Substrate map overlain with the spatial distribution of beam trawl effort

Substrate map overlain with the spatial distribution of beam trawl effort 2005-2008 (see Figure 4.3 for key to substrates).

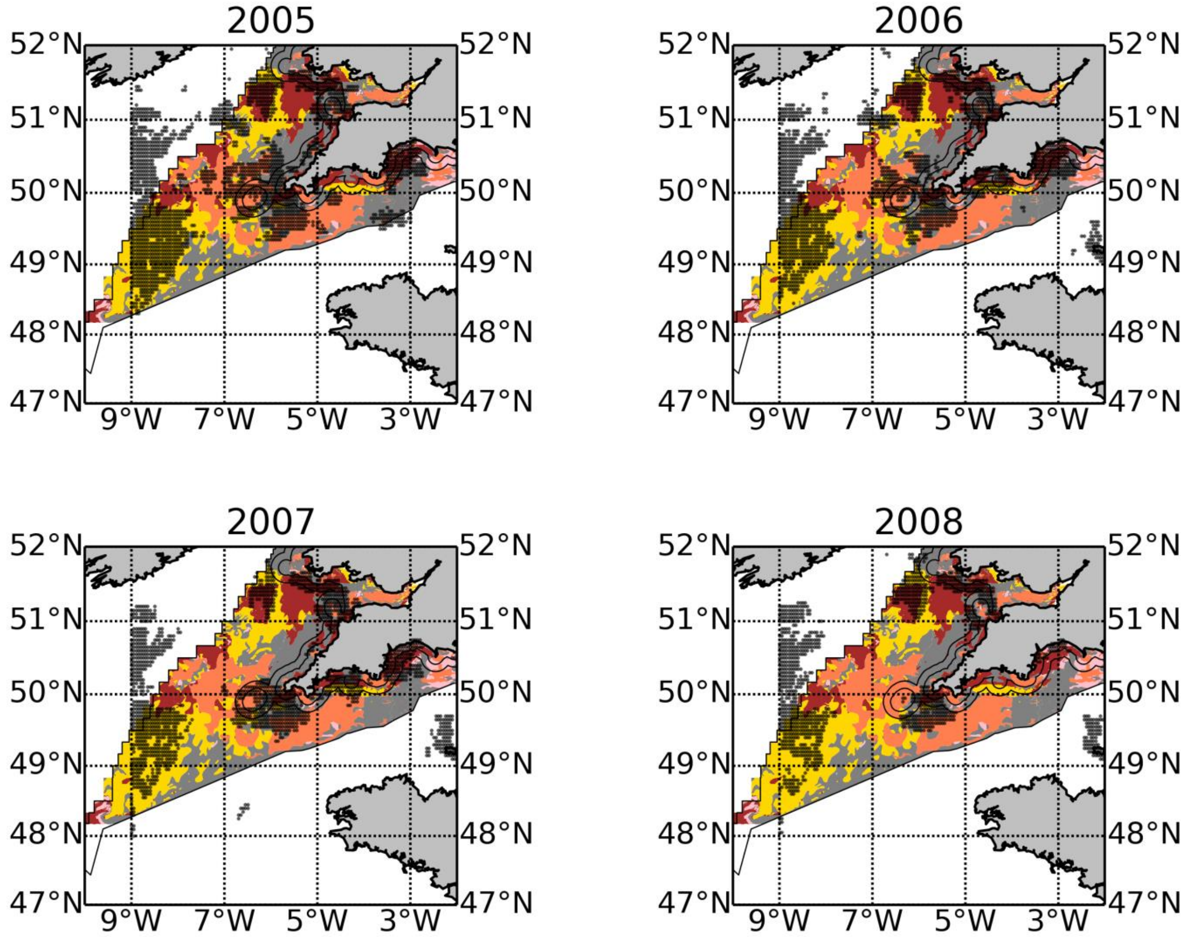

Figure 4.6: Substrate map overlain with the spatial distribution of demersal otter trawl effort

Substrate map overlain with the spatial distribution of demersal otter trawl effort 2005-2008

(see Figure 4.3 for key to substrates).

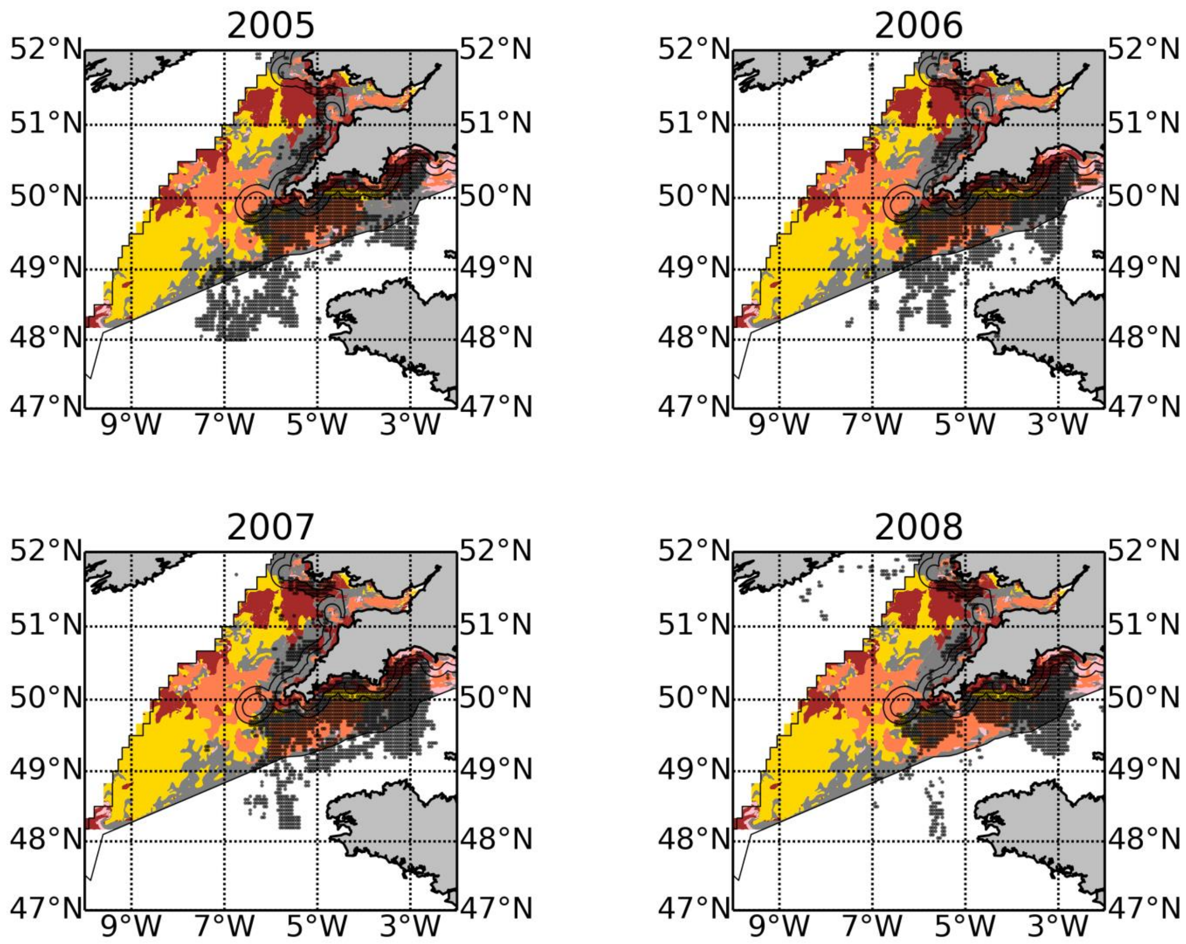

Figure 4.7: Substrate map overlain with the spatial distribution of scallop dredge effort

Substrate map overlain with the spatial distribution of scallop dredge effort 2005-2008 (see Figure 4.3 for key to substrates).

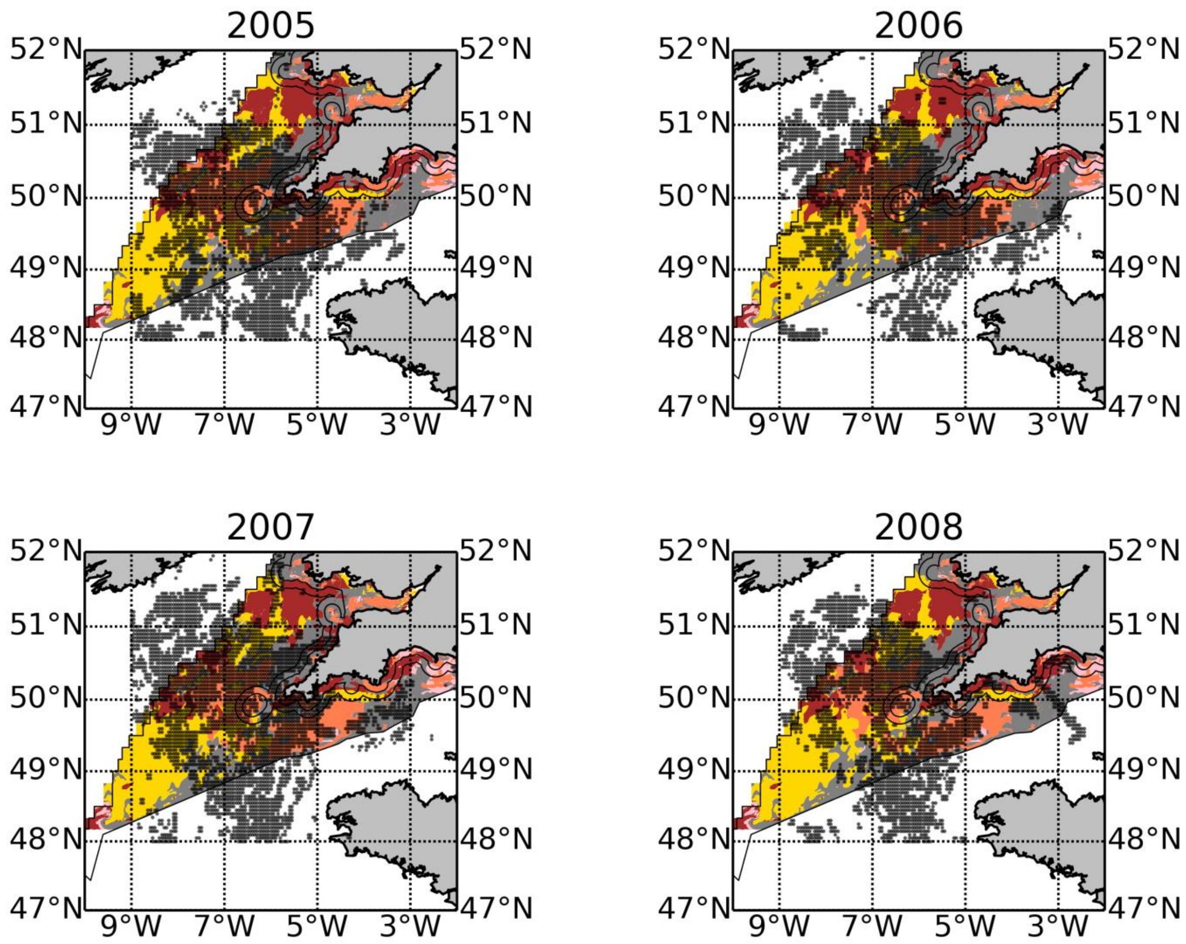

Figure 4.8: Substrate map overlain with the spatial distribution of gillnetter effort

Substrate map overlain with the spatial distribution of gillnetter effort 2005-2008 (see Figure 4.3 for key to substrates).

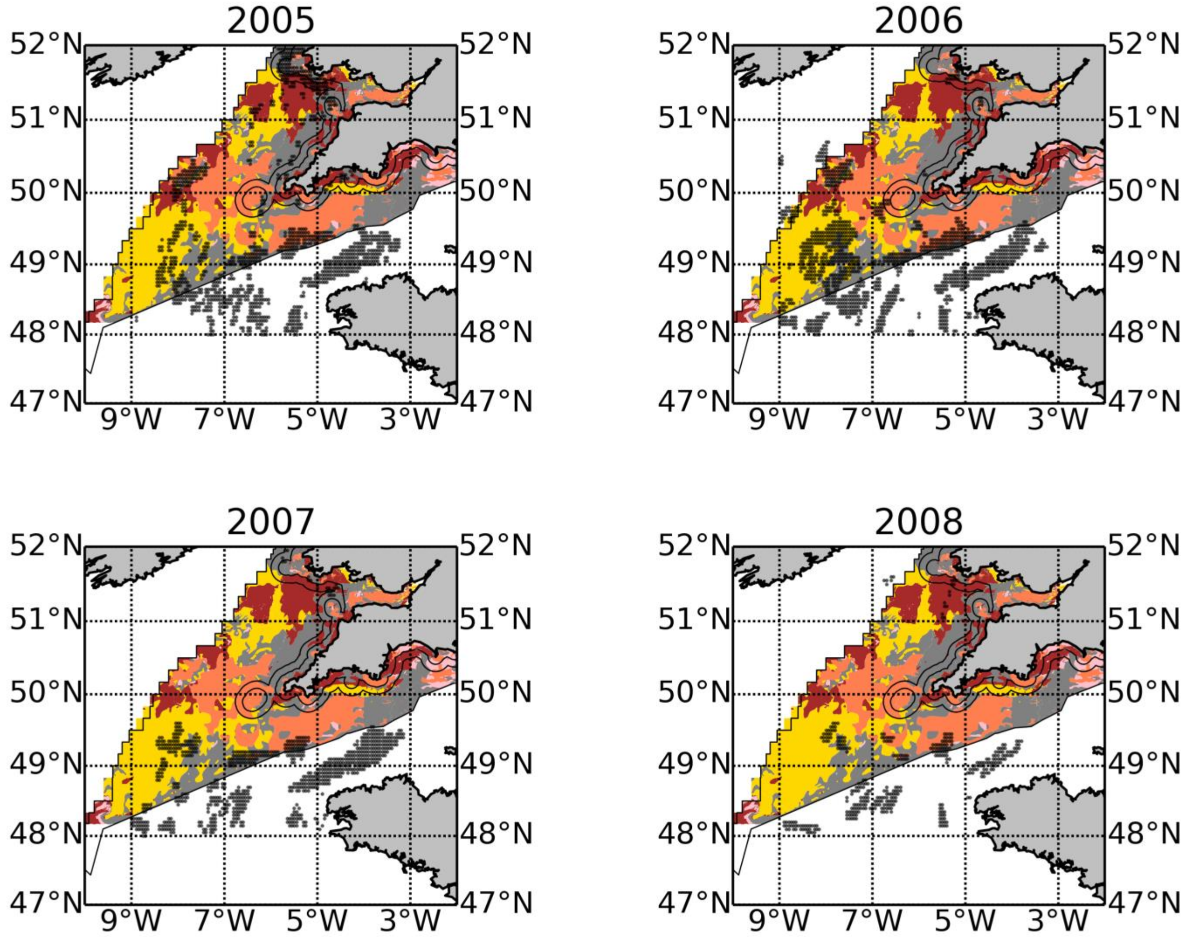

Figure 4.9: Substrate map overlain with the spatial distribution of longliner effort

Substrate map overlain with the spatial distribution of longliner effort 2005-2008 (see Figure 4.3 for key to substrates).

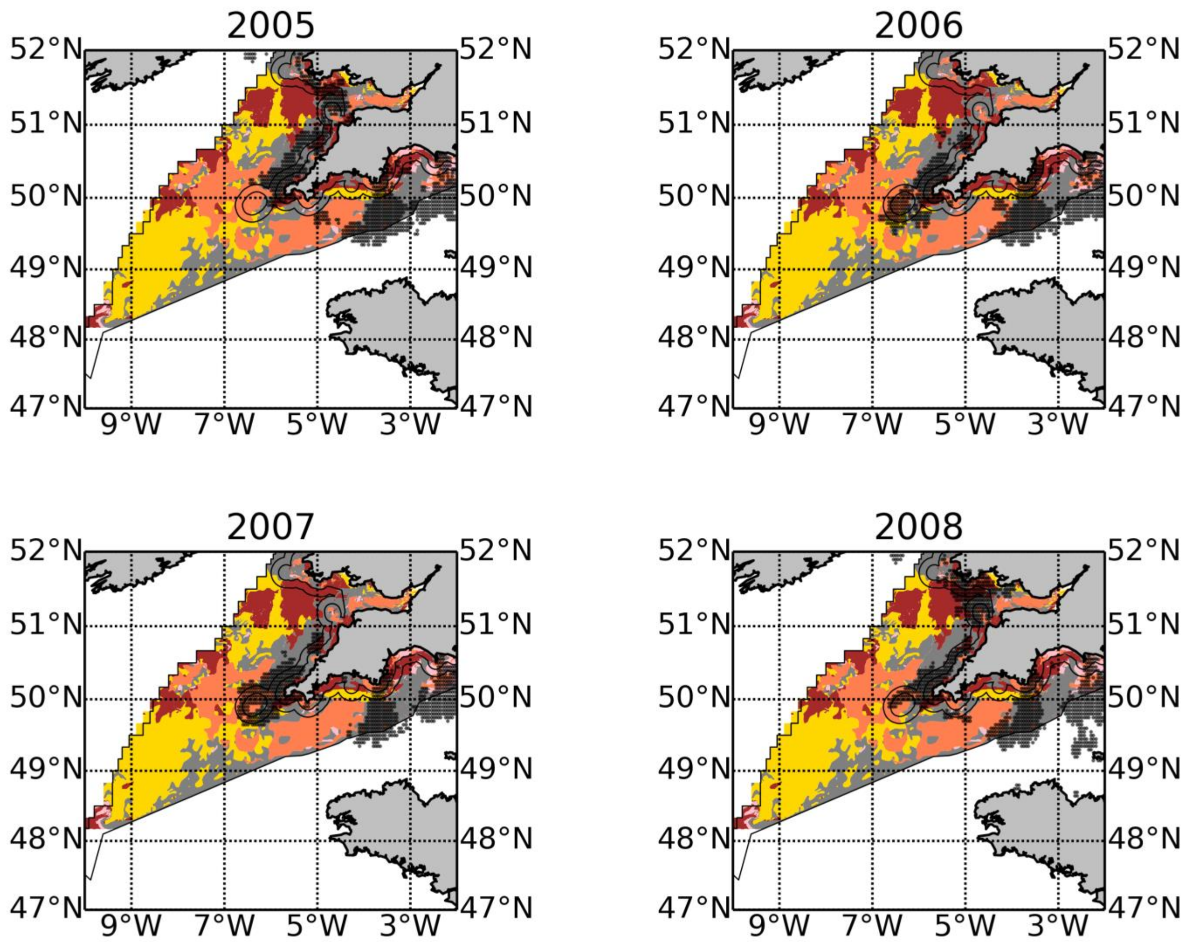

Figure 4.10: Substrate map overlain with the spatial distribution of potter/whelker effort

Substrate map overlain with the spatial distribution of potter/whelker effort 2005-2008 (see Figure 4.3 for key to substrates).

For static gears, in particular, the potting and whelking fleet but also to a certain extent gillnetting, this broad qualitative pattern in spatial distribution of fishing effort is clearly linked to the ability of the vessels to travel to areas of suitable marine substrate type (Figure 4.10.) within the range capabilities of the craft, since fishing activity is concentrated on rocky areas (Tables 4.1 and 4.2), which covered the smallest percentage of the study area (Figure 4.3). Longlining activity per unit area was highest over mud; 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 mixed sediment or mud, and beam and otter trawling mainly in muddy areas with high coverage per unit time in mixed and sand respectively. Some overlap with rocky areas did occur with the mobile fleets (Tables 4.1 and 4.2).

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

*Table 4.1. Activity (hrs/ km^2 * 10^{-5}) of all UK fleets respective of substrate type from 2005 to 2008.*

Gear type/substrate	Sand	Coarse	Mixed	Rock	Mud		Totals
Mobile							
Scallop dredge	11.026	9.555	38.196	26.158	40.09		125.025
Beam trawl	61.424	42.332	63.597	21.147	355.34		543.84
Otter trawl	8.315	2.654	4.179	21.183	246.671		283.002
Static							
Longline	1.174	1.58	4.281	1.727	11.162		19.924
Gillnetter	11.624	5.203	10.637	23.562	143.617		194.643
Potter/Whelker	2.441	5.837	4.967	15.623	7.332		36.2
Totals	96.004	67.161	125.857	109.4	804.212		

Table 4.2. Percentage of activity (Table 4.1) per substrate type.

Gear type/substrate	Sand	Coarse	Mixed	Rock	Mud
Mobile					
Scallop dredge	8.81	7.64	30.55	20.92	32.06
Beam trawl	11.29	7.78	11.69	3.88	65.33
Otter trawl	2.93	0.93	1.47	7.48	87.16
Static					
Longline	5.89	7.93	21.48	8.66	56.02
Gillnetter	5.97	2.67	5.46	12.10	73.78
Potter/Whelker	6.74	16.12	13.72	43.15	20.25

4.3.2 Generalized Linear Model Results

The GLM model was constructed to explore the multivariate response of fishing effort to a suite of potentially explanatory, independent variables. It is able to simultaneously account for the variance in spatially distributed fishing effort explained by multiple independent variables and their interactions (covariances) mapped onto the same spatial grid. The MDS analysis presented in Chapter 3 was able to reveal that different fishing gear-types have distinct patterns, which serves as justification for the GLM analysis which seeks to explain the underlying cause of these spatial patterns, at the present spatial resolution and given the temporally limited data set, given plausible explanatory variables. As mentioned above, the data have a Poisson form (Figure 4.11). The results from the ‘global’ GLM analysis on all fishing effort data (all gears, all years, and all regions) are summarized in Table 4.3.

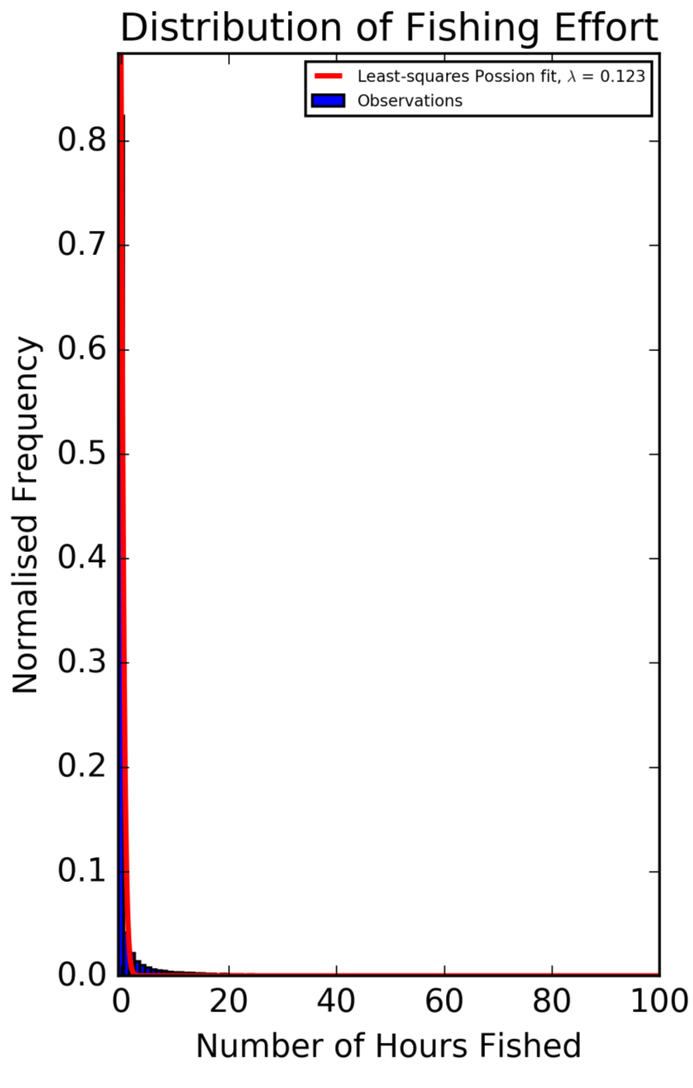

Figure 4.11 Distribution of per-grid, number of hours fished, aggregated over regions and years.

The frequencies have been normalized, and a Poisson distribution has been fitted to the data using a least-squares method. The lambda parameter for this example is

0.123. All gear types, years and regions have a similar statistical distribution in fishing effort, with similarly good Poisson model fits.

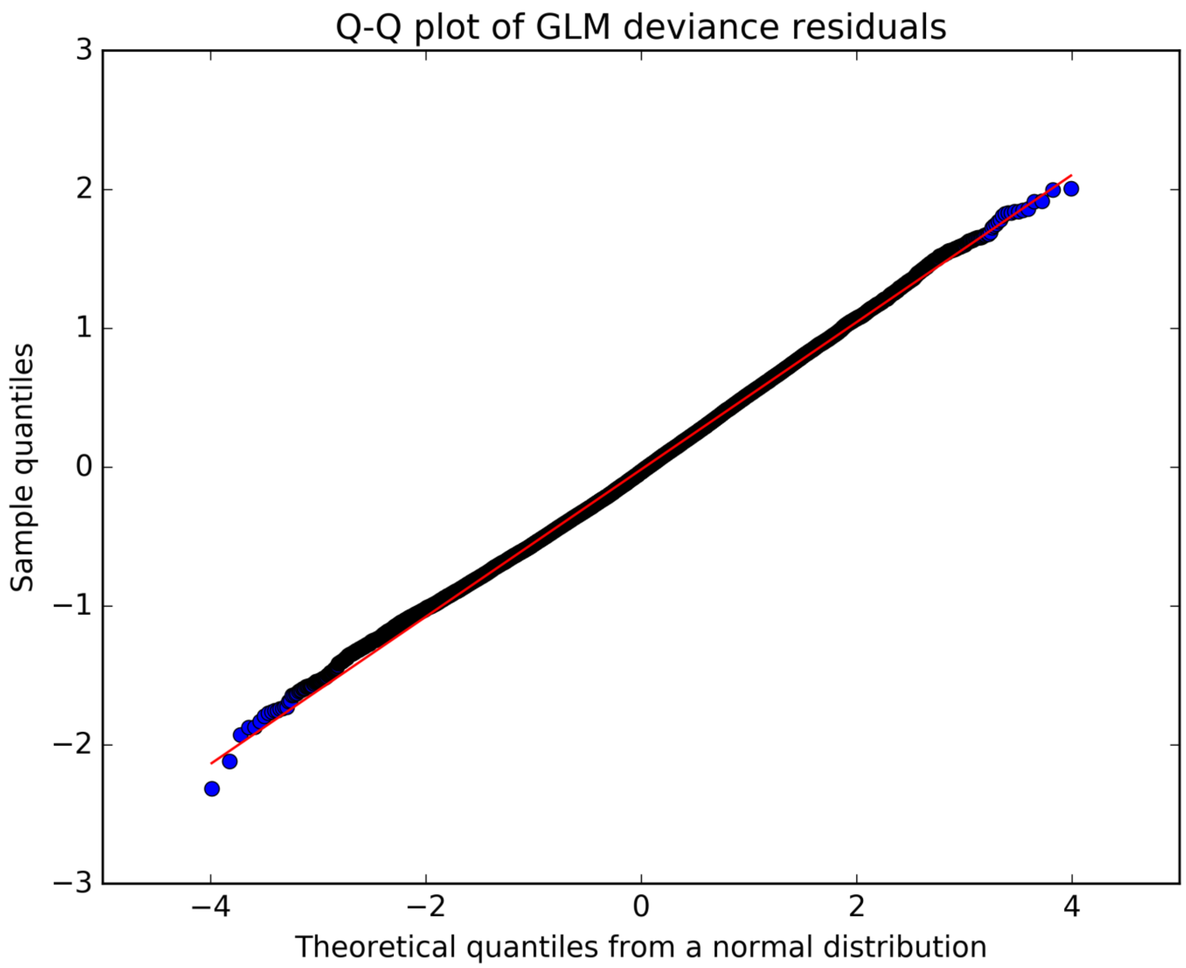

Figure 4.12 Quantile-Quantile plot of the residuals in the model

This shows that the model resultant from the GLM analysis had normally distributed residuals.

Table 4.3 Generalized Linear Model Regression Results for aggregated fishing effort data. Significant p-values (at the 95% level) are highlighted in bold

Variable	Model coefficient	Standard error	z value	P>|z|	[95.0% Conf. Int.]
Depth	0.0025	0.004	0.687	0.492	-0.005 , 0.010

Wind Speed	-9.575e-11	2.38e-11	-4.021	**0.000**	-1.42e-10, -4.91e-11
Wave Height	-0.0106	0.004	-2.704	**0.007**	0.018 , -0.003
Substrate	-0.0051	0.004	-1.391	0.164	-0.012 , 0.002
Gear Type	-0.0057	0.001	-3.963	**0.000**	-0.009, -0.003
Year	-0.0046	0.003	-1.738	0.082	-0.010, 0.001
Fish value	-0.0194	0.001	-35.854	**0.000**	0.021, -0.018

The model residuals were normally distributed (Figure 4.12) which means the model is amenable to a chi-square goodness-of-fit test, based on the residual deviance of 8530 and 7 degrees of freedom (6 model parameters plus a constant term). The test suggested that the model did not fit the data well (p = 0.0, the null hypothesis that the model is not a good fit to the data is accepted), despite the residuals between the model and the data being normally distributed. Therefore, subsequent analyses using the model to predict mean fishing effort based on individual explanatory variables, and pairwise comparisons between gears and years, was not carried out. However, the model has value in identifying the strength of the relationship between the dependent variable (fishing effort) and the chosen explanatory variables. For example, the model suggests that neither the depth, nor the substrate, nor the year variable were significant at the 95% level (with p-values on Z scores of, respectively, 0.492, 0.164, and 0.082) whereas gear type, wind and wave energy, and total fish value were all highly significant at the 95% confidence level. The results from simple ANOVA tests (not shown) evaluating the variance in fishing effort explained the same suite of explanatory variables showed very similar dependencies as the GLM results presented here, which corroborates the choices behind the GLM construction.

Identical analyses were constructed for each of the 6 gear types (by aggregating data over years and regions), with the same suite of explanatory variables except gear type. The results of this analysis are summarised in Tables 4.4 to 4.9 inclusive, and summarised in Table 4.10 which summarises the most important information in Tables 4.4 to 4.9, which is what explanatory variables were statistically significant for each gear type.

Table 4.4 Generalized Linear Model Regression Results for fishing effort by scallop dredgers

model	coefficient	std err	z value	P>|z|	[95.0% Conf. Int.]
Depth	0.1249	0.034	3.686	**0.000**	0.058, 0.191
Wind	-1.05e-07	1.87e-08	-5.610	**0.000**	-1.42e-07, -6.83e-08
Wave	-0.0677	0.187	-0.361	0.718	-0.435,, 0.300
Substrate	0.1872	0.215	0.871	0.384	-0.234, 0.608
Year	-0.2482	0.106	-2.348	**0.019**	-0.455, -0.041
Fish value	1.1495	0.103	11.213	**0.000**	0.949 , 1.350

Bold indicates significance at 0.05 level

Table 4.5 Generalized Linear Model Regression Results for fishing effort by longliners

Variable	Coefficient	Std. err.	z value	P>|z|	[95.0% Conf. Int.]
Depth	-0.0727	0.034	-2.147	**0.032**	-0.13, -0.006
Wind	-4.267e-08 -	1.69e-08	-2.518	**0.012**	-7.59e-08, -9.46e-09
Wave	1.4884	0.234	6.367	**0.000**	1.030 , 1.947
Substrate	0.2481	0.184	1.350	0.177	-0.112, 0.608
Year	-0.7888	0.125	6.310	**0.000**	-1.034, -0.544
Fish value	0.1078	0.065	1.654	0.098	-0.020 0.235

Bold indicates significance at 0.05 level

Table 4.6 Generalized Linear Model Regression Results for fishing effort by beam trawlers

Variable	Coefficient	Std. err	z value	P>|z|	[95.0% Conf. Int.]
Depth	0.0346	0.015	2.241	**0.025**	0.004, 0.065
Wind	-3.803e-08	8.45e-09	4.500	**0.000**	-5.46e-08, -2.15e-08
Wave	0.1396	0.085	1.652	0.099	-0.026, 0.305
Substrate	-0.0973	0.099	-0.986	0.324	-0.291 , 0.096
Year	-0.2575	0.051	-5.063	**0.000**	-0.357, -0.158
Fish value	0.9235	0.041	22.435	**0.000**	0.843 1.004

Bold indicates significance at 0.05 level

Table 4.7 Generalized Linear Model Regression Results for fishing effort by otter trawlers

Variable	Coefficient	Std. err	z value	P>|z|	[95.0% Conf. Int.]
Depth	-0.0141	0.017	-0.833	0.405	-0.047, 0.019
Wind	4.043e-08	1.15e-08	3.504	**0.000**	1.78e-08, 6.3e-08
Wave	0.1490	0.114	1.307	0.191	-0.074 , 0.372
Substrate	-0.3858	0.132	2.928	**0.003**	-0.644, -0.128
Year	-0.2761	0.079	-3.508	**0.000**	-0.430 -0.122
Fish value	0.4834	0.049	9.800	**0.000**	0.387 0.580

Bold indicates significance at 0.05 level

Table 4.8 Generalized Linear Model Regression Results for fishing effort by potters/whelkers

Variable	Coefficient	Std. err	z value	P>|z|	[95.0% Conf. Int.]
Depth	0.0317	0.043	0.742	0.458	-0.052, 0.115
Wind	8.745e-09	1.85e-08	0.473	0.636	-2.75e-08, 4.5e-08
Wave	-0.9679	0.222	-4.358	**0.000**	-1.403, -0.533

Substrate	0.7825	0.242	3.232	**0.001**	0.308 , 1.257
Year	0.0414	0.120	0.344	0.730	-0.194, 0.277
Fish value	0.5268	0.070	7.574	**0.000**	0.390, 0.663

Bold indicates significance at 0.05 level

Table 4.9 Generalized Linear Model Regression Results for fishing effort by gillnetters

Variable	Coefficient	Std. err	z value	P>|z|	[95.0% Conf. Int.]
Depth	-0.1138	0.027	-4.225	**0.000**	-0.167, -0.061
Wind	3.329e-08	1.17e-08	2.842	**0.004**	1.03e-08, 5.63e-08
Wave	0.9687	0.150	6.458	**0.000**	0.675 , 1.263
Substrate	0.4301	0.136	3.159	**0.002**	0.163 , 0.697
Year	-0.2010	0.083	-2.426	**0.015**	-0.363 , -0.039
Fish value	0.3926	0.052	7.533	**0.000**	0.290, 0.495

Bold indicates significance at 0.05 level

Table 4.10 Statistically significant explanatory variables (marked with an 'x'), collated from GLM Regression results for fishing effort by each gear type. n/a means 'not assessed'.

	All gears	Scallop Dredger	Longliner	Beam Trawler	Otter trawler	Potter/ whelker	Gillnetter
Depth		X	X	X			x
Wind	x	X	X	X	x		x
Wave	x		X			x	x
Substrate					x	x	x
Gear	x	n/a	n/a	n/a	n/a	n/a	n/a
Year		X	X	X	x		x
Fish value	x	X		X	x	x	x

4.3.3 Variability in Fishing Effort

Figures 4.13 to 4.18 inclusive show the index of variability (coefficient of variation) in fishing effort, as described in section 4.2.3 for respectively, beam trawl, otter trawl, scallop dredge (collectively, the mobile gears), longline, gillnetter, and potters/whelkers. Cold colours (blues) represent a large variability (less regularly fished, or not regularly fished with the same annual intensity) in fishing effort and warm colours (reds) represent small variability (more regularly fished, or regularly fished with the same annual intensity).

The distribution of this index for beam trawl (Figure 4.13) strongly follows proximity to port, with greater variability in effort the further out to sea being the general pattern. Fishing grounds in VII e are the most stable (show the least variability) in general and grounds in VII g and h show the greatest variability. Using this metric it is possible to tell at-a-glance which areas are routinely fished (deep red colours) and those areas that are rarely fished (deep blue colours). The areas coloured red are most stable (similar intensity of fishing effort year on year) and, all other factors – such as proximity to port - being equal, would be greatest affected by displacement. Closure of Haig Fras would not affect beam trawling. Within Wave Hub, variability is moderate.). Wave Hub area is a moderately important fishing ground for the fleet within the region but not nearly as intensively or routinely fished with this gear as other grounds nearby. Displacement of fishing effort in this area would cause greater variability because areas once fished with moderate intensity and stability would no longer be fished. Therefore incorporating data from subsequent years would turn those areas more blue if displacement had occurred.

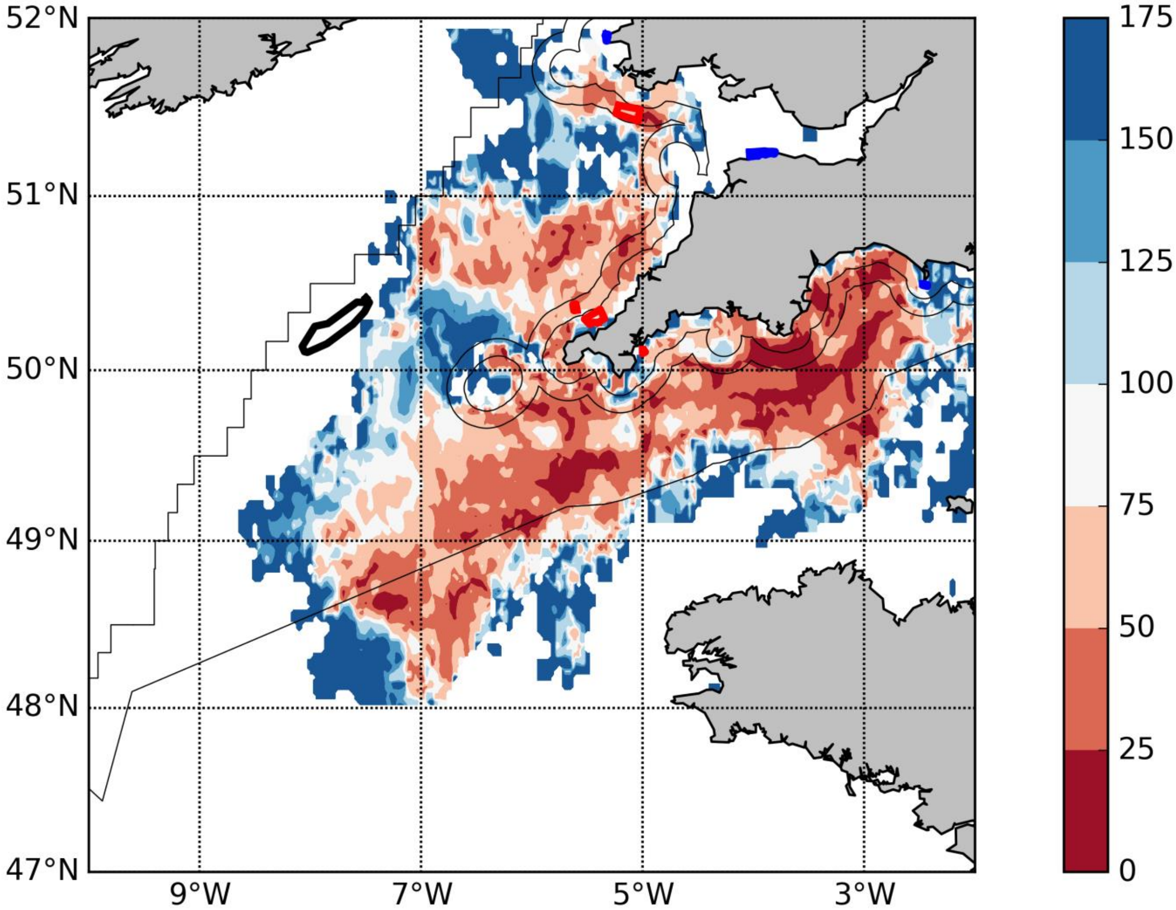

Figure 4.13 Coeffficient of variation (CV) of beam trawl fishing effort per grid cell, over 2005-2008

Coefficient of Variation of beam trawl fishing effort per grid cell, over 2005-2008. Haig Fras (black polygon) and MREIs (red/blue polygons) are marked.

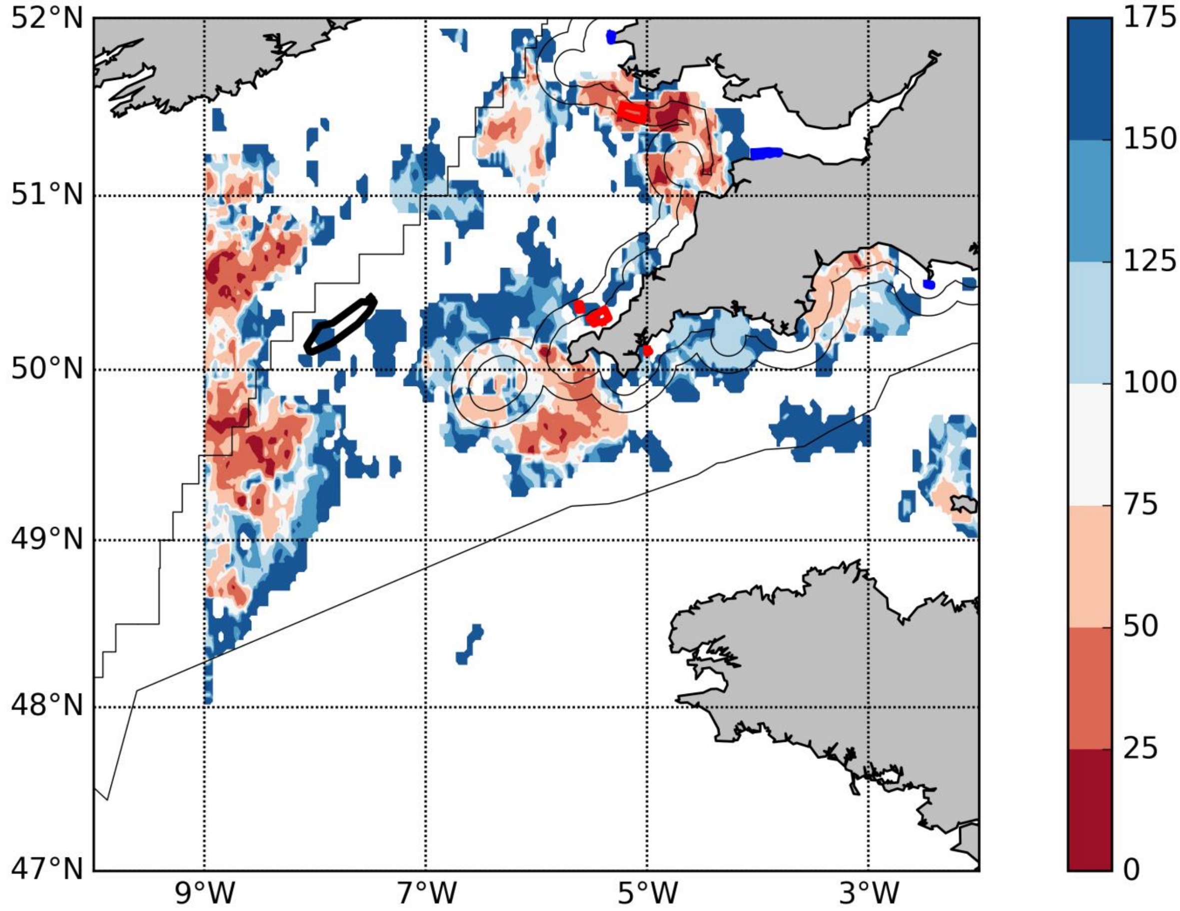

Figure 4.14 Coefficient of variation (CV) of otter trawl fishing effort per grid cell, over 2005-2008.

Coefficient of Variation of otter trawl fishing effort per grid cell, over 2005-2008. Haig Fras (black polygon) and MREIs (red/blue polygons) are marked.

The spatial distribution of the variability index for demersal otter trawl (Figure 4.14) is more complicated than for beam trawl, with ‘hotspots’ of stable fishing grounds at the edges of VIIg and h, around Lands’ End and the Scilly Isles, South Wales and Lyme Bay. The variation in intensity of effort in parts of Haig Fras and Wave Hub is very high because of infrequent visits to those areas by this gear type. Proposed wave energy developments at FaBTest (near Falmouth) and offshore of Pembrokeshire would affect otter trawling to a greater degree, given the relative stability of fishing in those areas by otter trawlers.

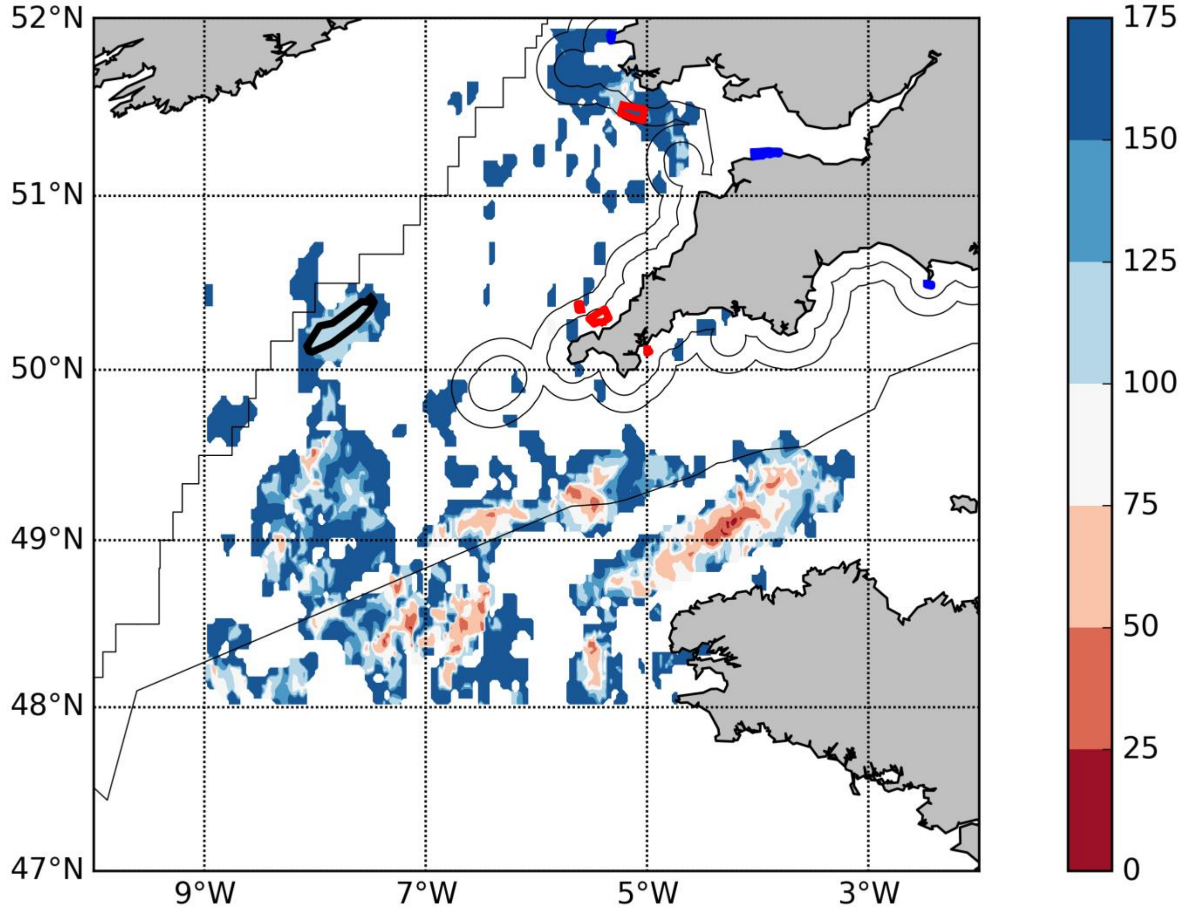

Figure 4.15 Coefficient of variation (CV) of scallop dredge fishing effort per grid cell

Coefficient of Variation of scallop dredge fishing effort per grid cell, over 2005-2008. Haig Fras (black polygon) and MREIs (red/blue polygons) are marked.

The spatial distribution of the variability index for scallop dredging (Figure 4.15) shows very high variability almost everywhere, which aligns with the results from

Chapter 3. Scallop dredging within Wave Hub is non-existent, and highly variable within Haig Fras. Unlike with beam trawlers and otter trawlers whose preferred grounds are identifiable from the hotspots of warm colours of their respective maps, more years of data would be required to assess the preferred fishing grounds of scallop dredgers. Alternatively, it could be concluded that the effects of displacement would be more variable between years, thus more years are required to estimate the average long-term consequences. The most stable areas are to the north of Brittany.

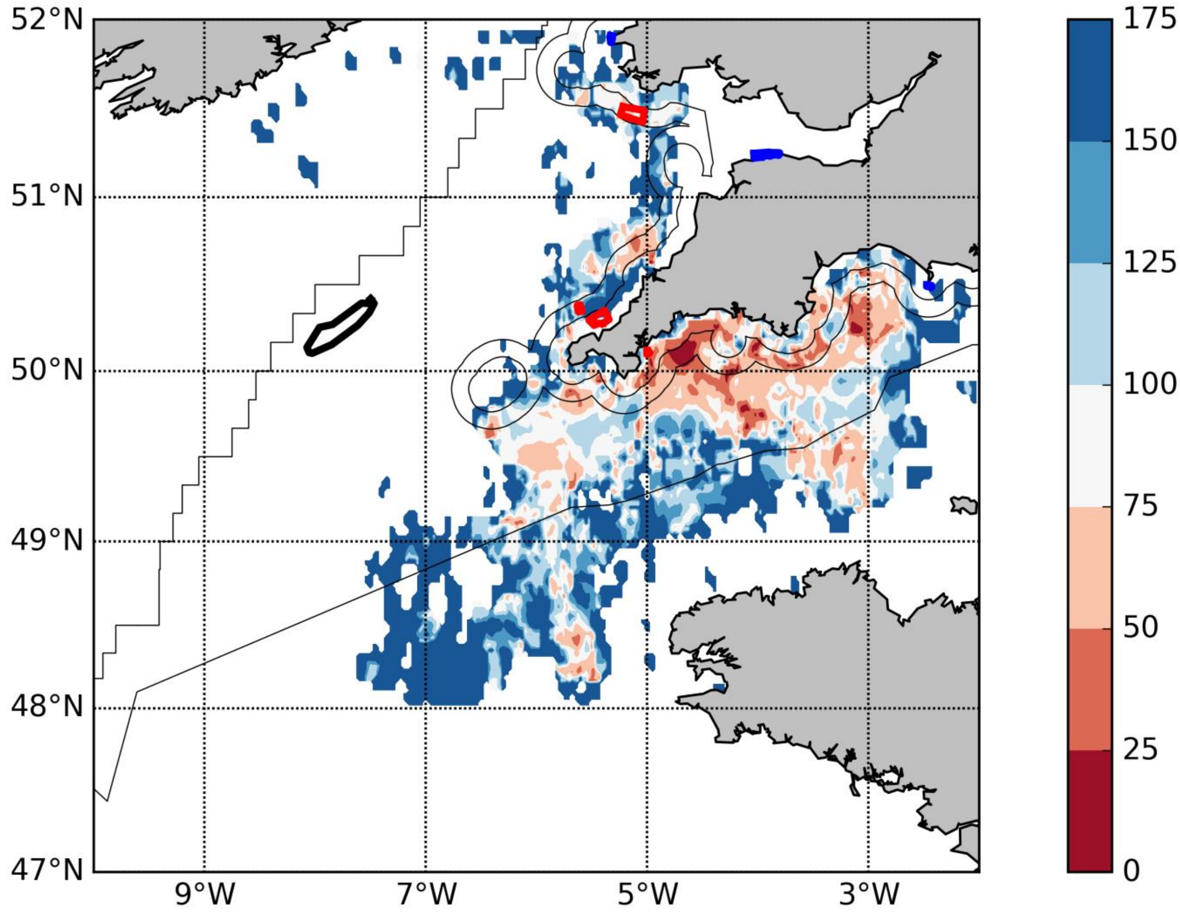

Figure 4.16 Coefficient of Variation (CV) of longliner fishing effort per grid cell

Coefficient of variation of longliner fishing effort expressed as a percentage of the mean fishing effort per grid cell, over 2005-2008. Haig Fras (black polygon) and MREIs (red/blue polygons) are marked.

The spatial distribution of the variability index for longliners (Figure 4.16) shows that the most stable grounds are proximal to southern Cornwall and Devon ports. In general, variability increases with greater distance to port. The exception is a small stable area to the west of Brittany. Longliners are absent from Haig Fras, and their fishing effort is highly variable within Wave Hub and Pembrokeshire MREIs. Longliners would potentially be greatly affected by any South West extension to

FaBTtest which is an area of low variability in fishing effort, indicative of a preferred ground.

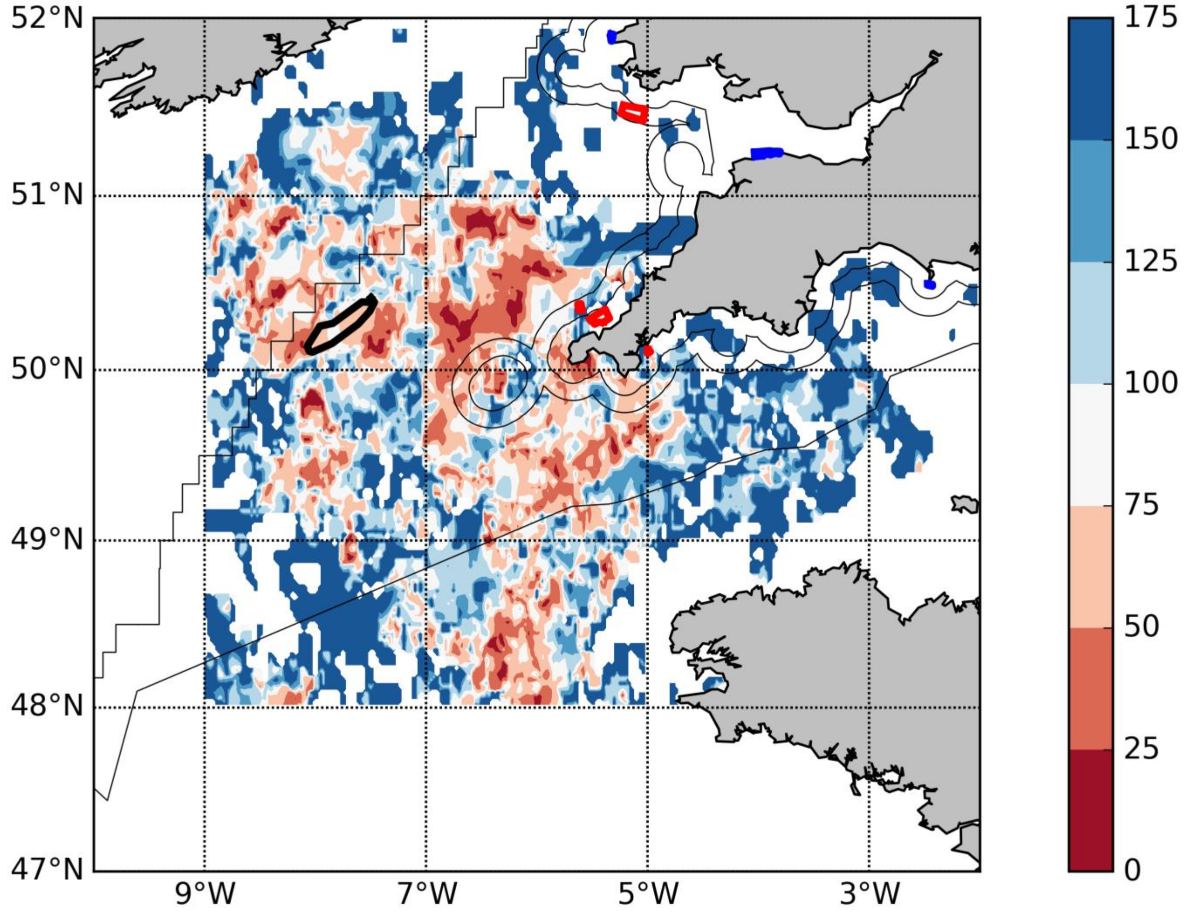

Figure 4.17 Coefficient of Variation (CV) of gillnetter fishing effort per grid cell,

Coefficient of variation of gillnetter fishing effort per grid cell, over 2005-2008. Haig Fras (black polygon) and MREIs (red/blue polygons) are marked.

Gillnetters show a wide variation in both areas fished, and the fishing effort variability index (Figure. 4.17). The most stable areas are identified within a broad band that stretches from the western tip of Britanny in the Atlantic to the southern coast of Ireland in the Celtic Sea, with the most stable areas in the central Celtic Sea between Haig Fras and Wave Hub. Haig Fras is a stable fishing ground for gillnetters and therefore might be disproportionately affected by a closure. Gillnetting within Wave Hub is much more variable. An interesting trend is how localised variability is: small patches of intense and stable effort (reds) are found adjacent to less stable areas (blues). The substrate type is uniformly coarse in this region (Figure 4.4). This ubiquitous heterogeneity is not observed in the other gear types to the same degree, perhaps because the other gears do not cover nearly the same spatial extent, or perhaps this reflects the same spatial variability in target fish populations.

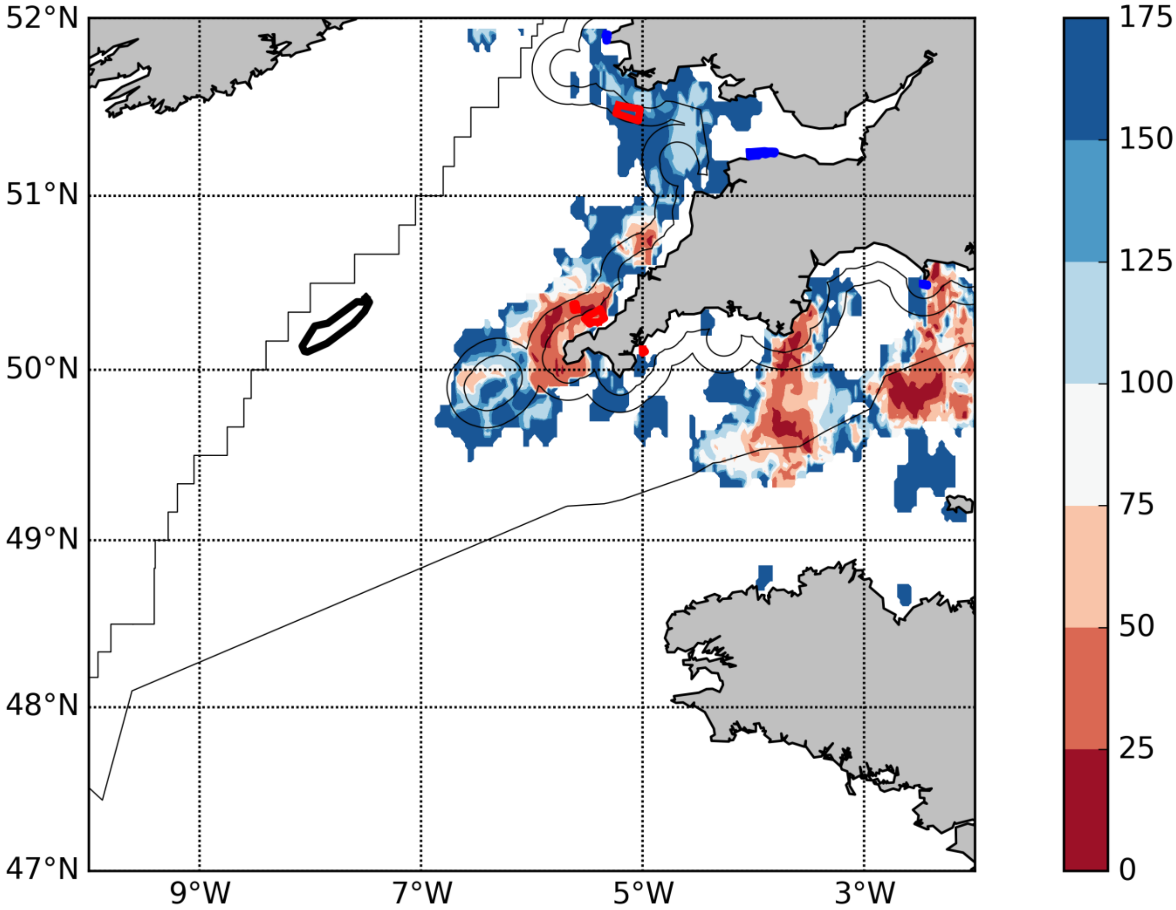

Figure 4.18 Coefficient of variation (CV) of potter/whelker fishing effort per grid cell

Coefficient of variation of potter/whelker fishing effort expressed as a percentage of the mean fishing effort per grid cell, over 2005-2008. Haig Fras (black polygon) and MREIs (red/blue polygons) are marked.

In contrast to the heterogeneous spatial pattern of fishing effort variability displayed by gillnetters, potters and whelkers (Figure 4.18) show much more localised and invariant fishing effort, especially adjacent to the major ports that these fleets operate out of (especially Plymouth, Poole, Padstow and Newlyn). As with beam trawlers, there is a clear general pattern of high variability in fishing effort (sporadic occasional visits and effort rather than frequent and prolonged activity) with increasing distance from port. There are stable grounds within the Wave Hub area but not within Haig Fras.

4.3.3 Relationship between Catch and Variability in Fishing Effort

The final objective of this Chapter, as listed in section 4.1.1, is to investigate the relationship between fish catch data (derived from low-resolution, less-access-restricted level 2 VMS data) and the background variability of fishing effort. In Chapter 1, maps (Figures 1.3 to1.6, where contours are in order of magnitude increments) were presented showing UK fishing effort in terms of total quantity of landed catches (in tonnes liveweight) and total economic value (in GB£), derived from MMO level 2 VMS data aggregated over gears and over the years 2007 – 2010 inclusive. Here, the relationship between these bulk statistics on a broad scale and the variability in fishing effort (derived from higher resolution VMS data) is explored. This analysis is an attempt to utilise the catch statistics in order to further characterise fishing effort, in order to explore the potential role of broad scale catch data (weight and economic value of fish) as a simple proxy for baseline fishing effort. This is important because of the access restrictions imposed on the level 3 VMS data which have already been discussed at length.

Owing to the limitations imposed by the level 2 VMS data, the above is only possible at a broad scale: from data aggregated across gears (but still separated into mobile and static gear types) and across multiple years. Fishing variability index was calculated for all mobile gears on aggregate and all static gears on aggregate, and compared qualitatively to maps of economic value and gross weight of fish caught by mobile and static gears, respectively, derived from the VMS level 2 data (presented in Chapter 1). The comparison was of different, but overlapping, periods of time (2005-2008 compared with 2007-2010), however the analysis was conducted over the same spatial extent and at the same spatial grid resolution.

Level 2 VMS data are separated by mobile and static gears, so first, the variability in fishing effort for mobile gears (scallop dredgers, beam trawlers and otter trawlers) and static gears (potters/whelkers, longliners, and gillnetters) were computed by summing fishing effort obtained using the high-resolution VMS data from 2005 – 2008 inclusive, and calculating the coefficient of variation using the same procedure described in section 4.3.2. These results are presented as Figures 4.19 and 4.20 for mobile and static gears, respectively. Note that Figure 4.19 is the aggregate of data presented in Figures 4.13 to 4.15, and Figure 4.20 is the aggregate of data presented in Figures 4.16 to 4.18.

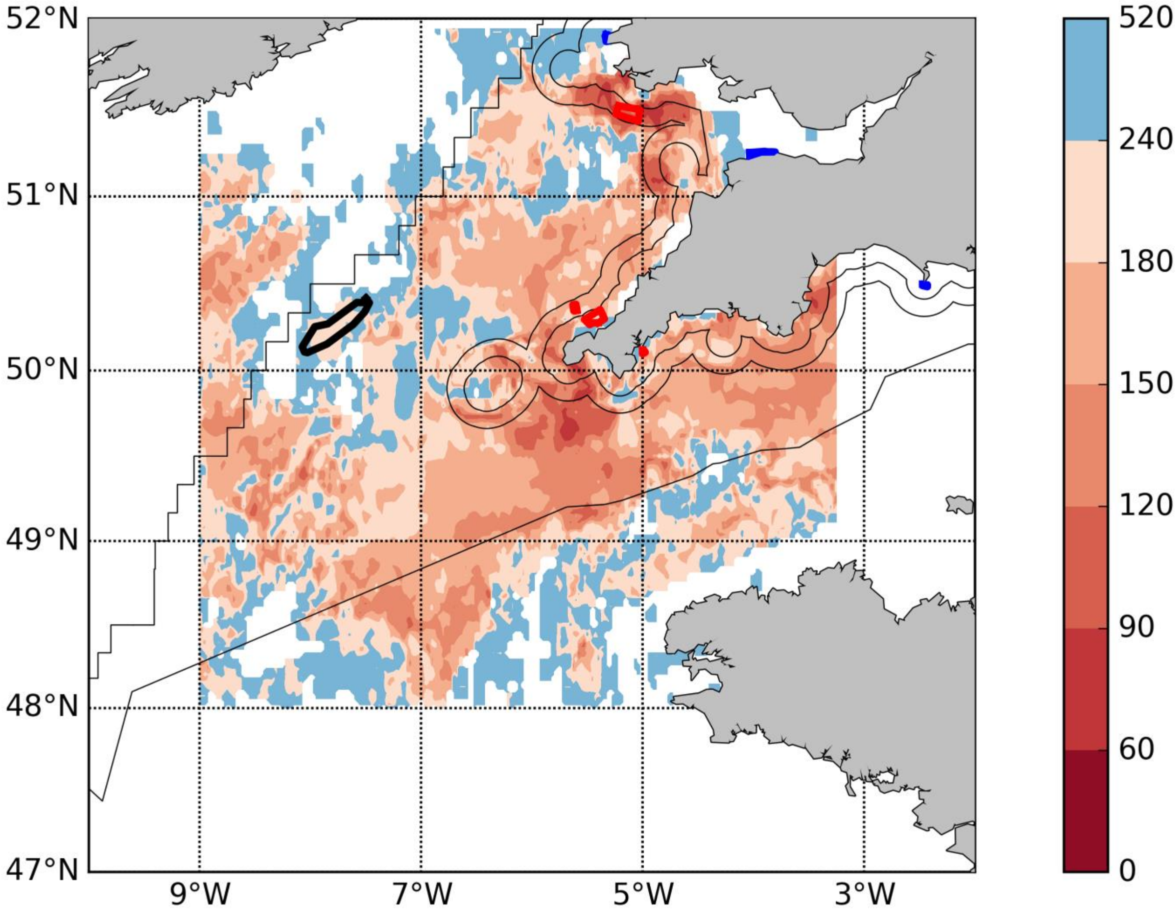

Figure 4.19 Coefficient of variation (CV) of fishing effort by all the mobile gear types per grid cell

Coefficient of variation of fishing effort by all the mobile gear types per grid cell, over 2005-2008. Haig Fras (black polygon) and MREIs (red/blue polygons) are marked.

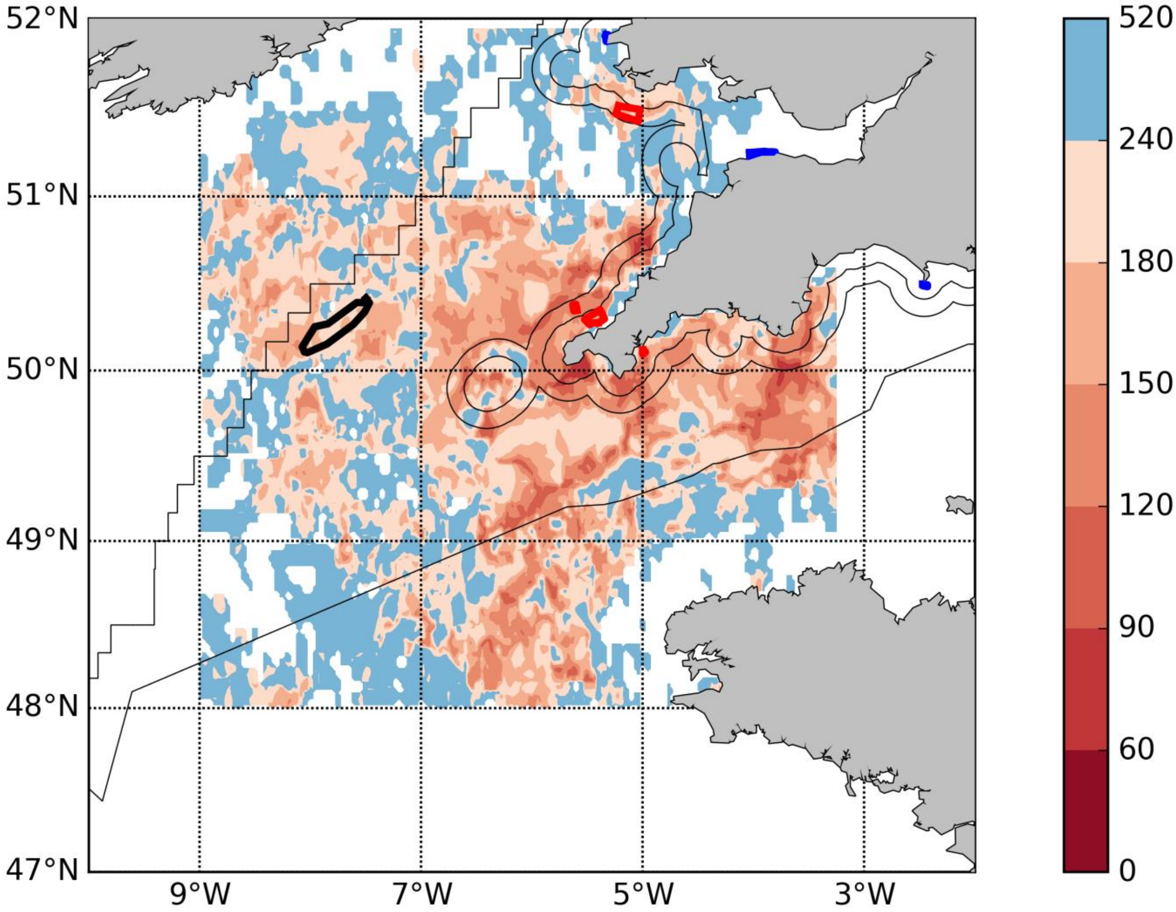

Figure 4.20 Coefficient of variation of fishing effort by all the static gear types per grid cell

Coefficient of variation of fishing effort by all the static gear types per grid cell, over 2005-2008. Haig Fras (black polygon) and MREIs (red/blue polygons) are marked.

The map of variability in fishing effort by mobile gears in South West UK was overlain with contours of the data presented in Figures 1.3 (Chapter 1, total quantity in tonnes of fish landed by mobile gear vessels) and Figure 1.5 (Chapter 1, total value in GB£ of fish landed by mobile gear vessels) and these are presented as Figures 4.21 and 4.22 respectively. Both datasets are per grid 0.05 degree square cell. While the data represent different periods of time (catch data over the 4 year period 2007-2010 and fishing effort data over the period 2005-2008), the two data sets are comparable in that they are defined over the same spatial extend and at the same resolution and aggregated to the same, albeit very broad, gear types. The 50% overlap in time between the two periods was deemed to be sufficient for qualitative comparative purposes.

As expected, those stable grounds that are fished frequently (with low variability indices) also tend to yield higher catches, in terms of both liveweight tonnage and economic value. Those grounds with less stable, perhaps less reliable, fishing (with high variability indices) yielded less catch. There is a very close correspondence between the 1 tonne liveweight contour (Figure 4.19), the 1000 GB£ contour (Figure 4.22), and the contour representing up to a CV of 240 % in fishing effort, in all areas.

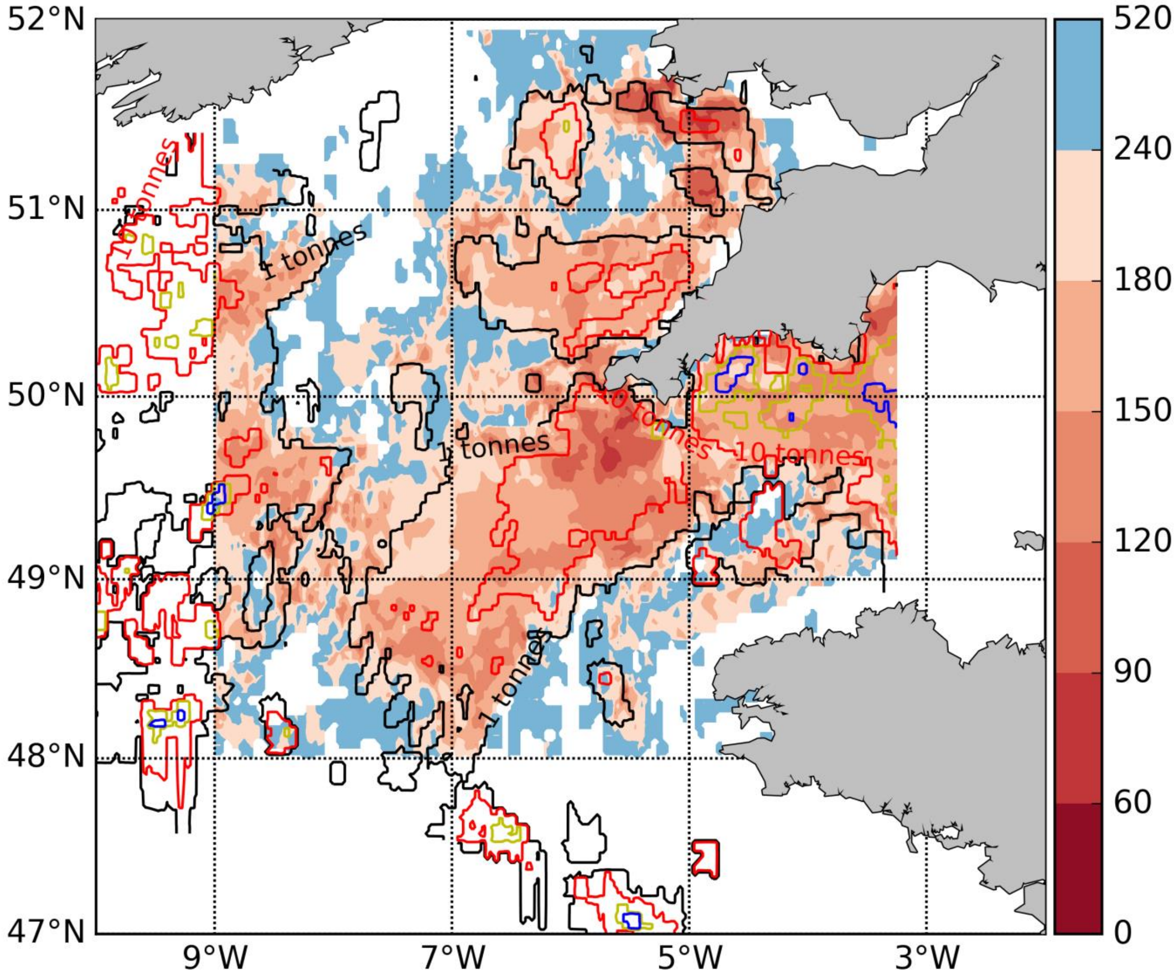

Figure 4.21 Colour-filled contour map of the coefficient of variation (CV) of fishing effort by all the mobile gear types grid cell overlain with contours of gross tonnage of landed fish

Colour-filled contour map of the CV of fishing effort by all the mobile gear types per grid cell, over the 4-year period 2005-2008, overlain with contours of gross tonnage of landed fish from the 4-year period 2007-2010. The contour lines shown are 1 tonne (black), 10 tonnes (red), 50 tonnes (yellow) and 100 tonnes or greater (blue).

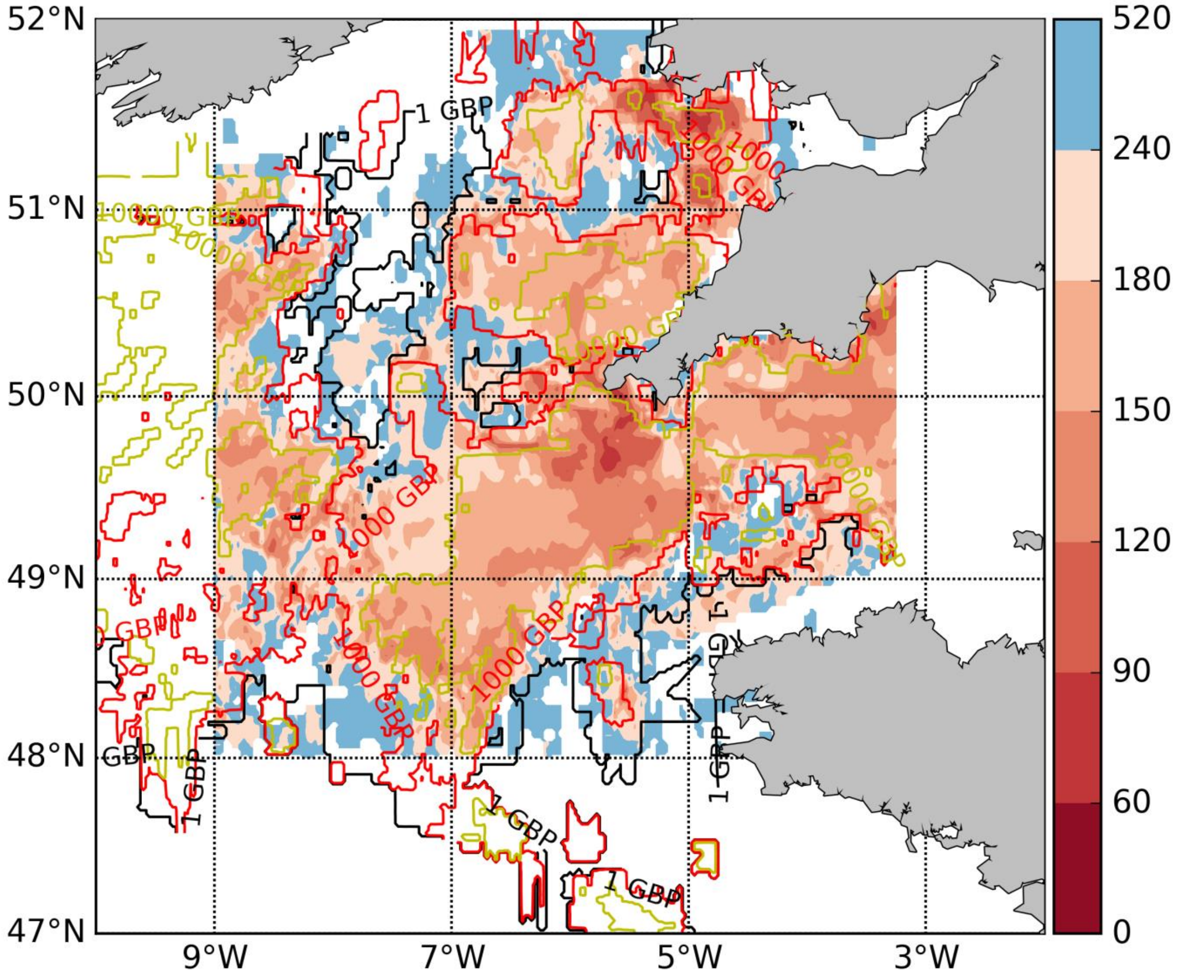

Figure 4.22 Colour-filled contour map of the coefficient of variation of fishing effort by all the mobile gear types per grid cell overlain with contours of gross value of landed fish

Colour-filled contour map of CV of fishing effort by all the mobile gear types over the 4-year period 2005-2008, overlain with contours of gross value of landed fish from the 4-year period 2007-2010. The contour lines shown are GB£1 (black), GB£1000 (red), and GB£10,000 or greater (yellow).

The same analysis was carried out for static gear types. The map of variability in fishing effort by mobile gears in South West UK was overlain with contours of the data presented in Figure 1.4 (Chapter 1, total quantity in tonnes of fish landed by static gear vessels) and Figure 1.6 (Chapter 1, total value in GB£ of fish landed by static gear vessels) and these are presented as Figures 4.23 and 4.24 respectively. As with mobile gear types, there is a close correspondence between the 1 tonne liveweight contour (Figure 4.23), the GB£1000 contour (Figure 4.24), and the contour representing up to 240% coefficient of variation, in all areas.

As a rule of thumb, it is therefore suggested that fish catches over 1 tonne and greater than GBP£1000, are concentrated in areas where the variability in fishing effort was less than 240% coefficient of variation fishing effort. This pattern is broadly the same for both mobile and static fishing gears. It would be interesting to apply a similar analysis to other regions and time periods to see how general, if at all, this trend is. If a relationship such as this proves to be sufficiently general that specific threshold values of either fish catch weight, or value, or both, could be used as proxies to specific thresholds of fishing effort, then that would be enormously beneficial as 1) contextual information for analyses of lower-resolution VMS data (with which it is not possible to compute indices of fishing effort, or variability in fishing effort); and 2) input variables in behavioural modelling of fishing and fisheries displacement.

This analysis bolsters the plausibility of the fishing variability metric described in section 4.2.3 and presented in section 4.3.3 insomuch that it captures the spatial variability fishing effort that help explain trends revealed by an independent data and set of metrics (fish catch weight and value).

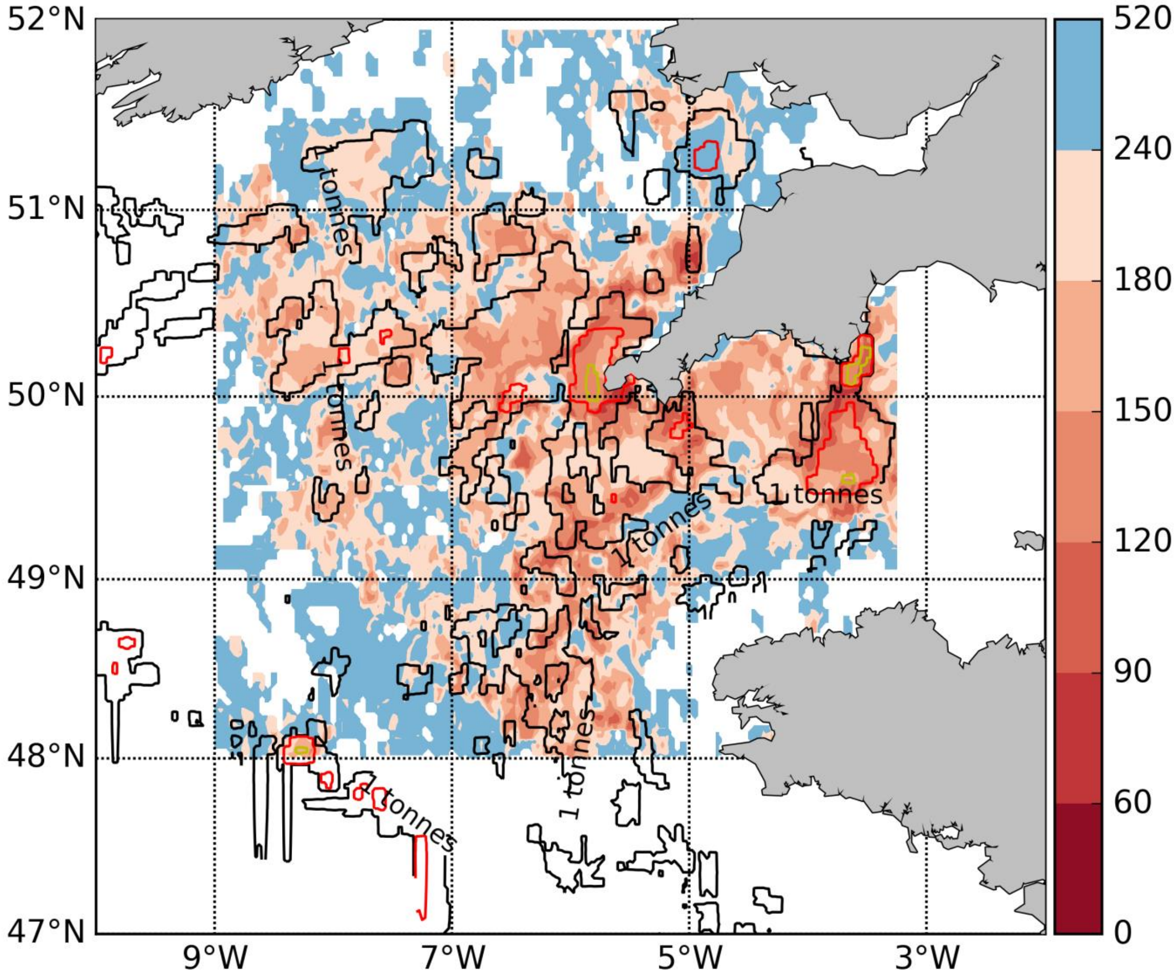

Figure 4.23 Colour-filled contour map of coefficient of variation of fishing effort by all the static gear types per grid cell, over the 4-year period 2005-2008, overlain with contours of gross tonnage of landed fish

Colour-filled contour map of the CV of fishing effort by all the static gear types per grid cell, over the 4-year period 2005-2008, overlain with contours of gross tonnage of landed fish from the 4-year period 2007-2010. The contour lines shown are 1 tonne (black), 10 tonnes (red), and 50 tonnes or greater (yellow).

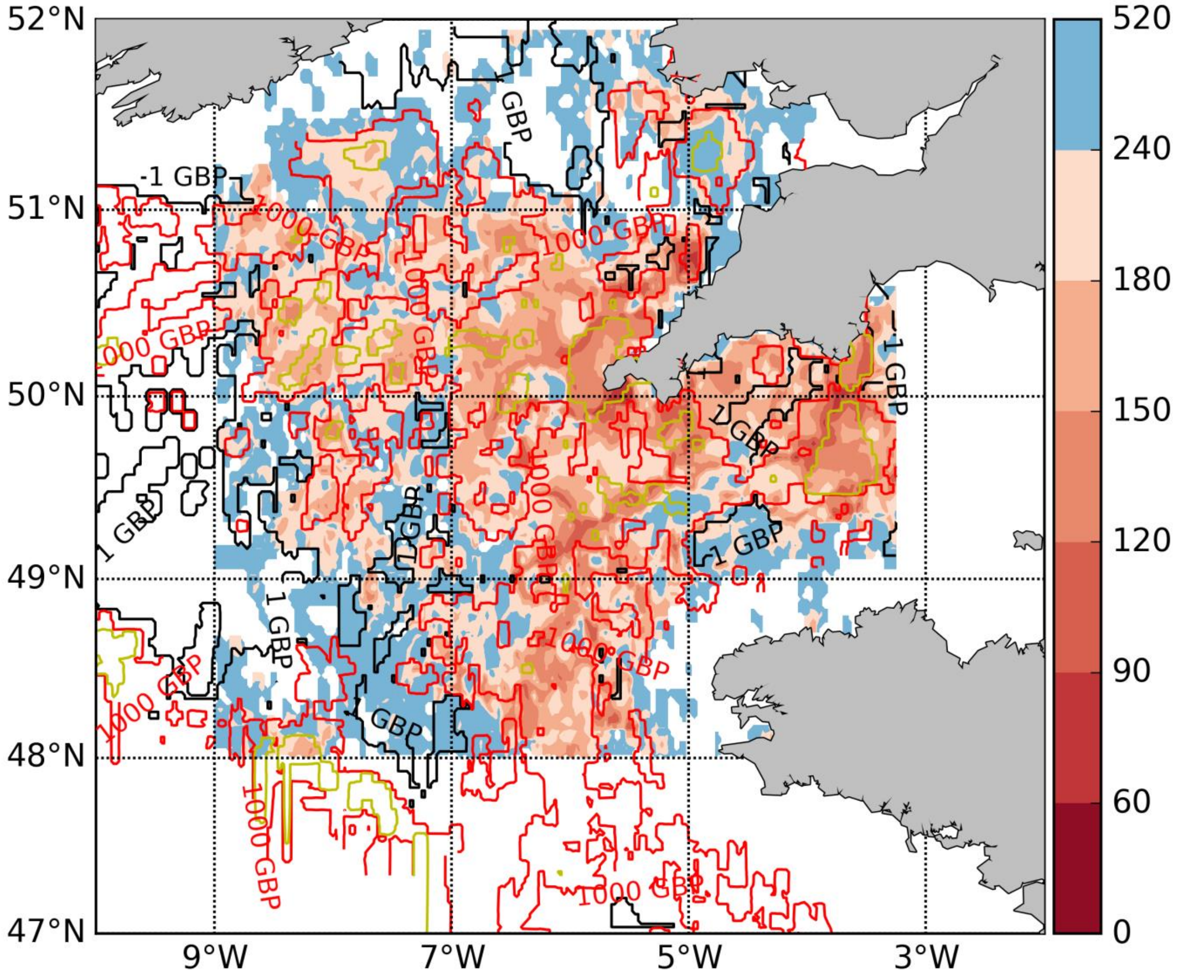

Figure 4.24 Colour-filled contour map of the coefficient of variation of fishing effort by all the static gear types per grid cell, overlain with contours of gross value of landed fish

Colour-filled contour map of the CV of fishing effort by all the static gear types per grid cell, over the 4-year period 2005-2008, overlain with contours of gross value of landed fish from the 4-year period 2007-2010. The contour lines shown are GB£1 (black), GB£1000 (red), and GB£10,000 or greater (yellow).

4.4 Discussion

The over-arching question of this part of the study was: do we expect average intensity of fishing to vary between substrates more than between gears and over time? Based on the evidence presented in Tables 4.4–4.10, the answer is, statistically speaking, no. What all of this analysis points to is the fact that either substrate only has a very subtle role in fishing effort when viewed at large scales and/or aggregated over gear types, or that substrate plays a role at scales smaller than the 3 NM scale at which fishing effort was calculated and assessed. This makes sense given the fact that substrate is only one factor in the spatial distribution and population dynamics of different fish. Substrate only plays a significant role depending on specifics of place and gear type, and possibly time, other investigations would have to include other environmental factors. Disentangling the relative contributions of substrate and other factors in examining both the causes of a particular fishing effort in a particular place requires modelling a whole suite of substrate and other factors. What the analysis in this study shows is examining what role of substrate plays is only meaningful at the smallest possible scale.

Thus, using this simple variability index provides a means to investigate the footprint of vessels using a specific gear type, helping to define fishing grounds further giving a map of low variability corresponding to stable grounds or ‘hot spots’, and high variability grounds corresponding to infrequently fished margins. This variability index acts much like a broad-scale risk analysis, and could be used by agencies when dealing with issues of siting of MREIs and the formation of an MPA.

There are caveats associated with the substrate analysis which analysed fishing effort per substrate type by aggregating data from all ICES divisions. There are no doubts as to the value of the analysis at a broad scale, i.e. ICES divisions VII e-h as a whole; however, a finer scale analysis would be needed to assess the seasonal movements of the fleets. In addition, when we consider that we cannot take into account vessels changing gear (at present is no access to logbook information), then we reach a limit to the certainty with which VMS data can be used to explore fishing effort per gear type, at least at this spatial resolution. Further analysis should include defining fishing grounds to assess space allocation by various fleets (Jennings & Lee, 2012) and impacts of various fleet activities on the seabed (Jennings *et al*., 2012; Gerritsen *et al*., 2013).

More recently attempts have been made to predict regional fishing grounds of commercially important static fishery using remotely sensed LiDAR and catch data (Ali Jalali *et al*., 2015). With the use of these techniques and their input into a MaxENT model, accurate estimations of suitable fishing grounds based on habitat complexity and bathymetry were achieved. However, they highlighted the need to down scale regional analyses and the use of GPS located catch data to generate habitat suitability models, especially where there are limitations with other spatially important data. Having access to daily catch records from logbooks along with associated gear-type VMS (e.g. Gerritsen & Lordan, 2011), both at a high resolution, is what is needed if we are to truly assess predict and plan for effort displacement.

4.5 Summary

- Qualitatively, for static gears the relationships with substrate are most obvious. The gillnetting and potting and whelking fleet concentrated significantly on rocky areas. Longlining activity per unit area was highest over mud, however high values were also observed over mixed sediment and rock. For mobile gears activity per unit area of substrate type varied considerably, to the point that it was hard to discern any relationship; in general, it might be true that scallop dredging occurring mixed sediment or mud, and beam and otter trawling mainly in muddy areas with high coverage per unit time in mixed and sand respectively, but there was large variability in these trends;

- The potential role of substrate and a suite of other potentially explanatory were assessed by statistically testing the relationship between fishing effort and substrate in South West UK waters. This was achieved using a Generalised Linear Model (GLM) approach that attempted to model the spatial distribution in fishing effort as a function of physical variables (wind, waves, depth, and substrate), gear type, year, and the monetary value of fishing grounds. The approach was also used to construct models for each individual gear-type. The results showed that substrate almost always was an insignificant predictor of fishing effort. The relative importance of wind and waves, depth and substrate, gear, year and fish value varied significantly depending on gear type. This result reinforced the building line of evidence presented in this thesis that when it comes to assessing fishing intensity, and fisheries displacement, this must be done at the highest possible spatial and temporal resolution, and most importantly, always carrying out the analyses on a per-gear basis;
- Within a given year, there was an unequal average fishing effort per substrate type. This suggests that only data aggregated over very large scales (an entire ICES subarea, e.g. VII) does it become evident that substrate plays a non-gear-specific role in fishing effort;
- In ICES divisions VIIe and VIIh, and as a whole, within a given year there was an unequal average fishing effort per gear. This suggests that data aggregated over smaller scales can be sufficient to demonstrate that gear

type can be a significant driver in fishing effort, and can be identified irrespective of the substrate type;

- Fishing effort with a given gear type is statistically more similar over time than over different substrates, and fishing effort across all gear types does not significantly change over time;
- Fishing effort over mud is almost always significantly different than all other substrate types. Fishing effort over rock is almost always significantly different than other substrate types but only in ICES divisions VIIf, VIIg and VIIh. Fishing effort over sand, coarse and mixed substrates tends not to differ significantly;
- Pairwise comparisons of fishing effort between different gears almost always show significant difference, but the details depend on the specific ICES divisions. The notable exception is otter trawlers who tend not to differ significantly in fishing effort compared to other gear types except for in ICES VIIe and h;
- An objective means was developed to assess the background variability of fishing effort, as a baseline against which to assess displacement. This index is the coefficient of variation, which quantifies of intensity about the mean fishing effort, expressed as a percentage of the mean fishing effort. Because it is calculated per gear and per location, calculated relative to, and expressed as a percentage of, the mean fishing effort, valid comparisons can be made between gear types, between locations, and over time. Small values of this index indicate small fluctuations about the mean, which is in turn indicative of a regularly fished region, or a preferred fishing ground. High values of this

index indicate highly variable, sporadic fishing effort not indicative of a stable, regularly fished area;

- The distribution of this index for beam trawl strongly follows proximity to port, with greater variability in effort the further out to sea being the general pattern. In contrast, otter trawling occurs in more localised 'hotspots' of stable fishing grounds. Scallop dredging shows very high variability almost everywhere. Unlike with beam trawlers and otter trawlers whose preferred grounds are identifiable from the hotspots of warm colours of their respective maps, further years of data would be required to assess the preferred fishing grounds of scallop dredgers;
- For static gears, longliners had very stable grounds proximal to southern Cornwall and Devon ports and in general, variability in fishing effort increases with greater distance to port. Gillnetters show a wide variation in both areas fished. Small patches of intense and stable effort (reds) are found adjacent to areas (blues) but this ubiquitous heterogeneity is not observed in the other gear types. Finally, there is much more localised and invariant fishing effort, especially adjacent to the major ports that these fleets operate. As with longliners, variation in fishing intensity increases strongly with distance from port; and
- Fishing variability index was calculated for all mobile gears on aggregate and all static gears on aggregate, and compared qualitatively to maps of economic value and gross weight of fish caught by mobile and static gears, respectively, derived from the VMS level 2 data. Both data sets were aggregated over a 4 year period.

- Overlying contours of fish catch weights or monetary value onto maps of aggregated fishing effort variability index revealed coherent spatial patterns: as expected, those stable grounds that are fished frequently (with low variability indices) also tend to yield higher catches, in terms of both liveweight tonnage and economic value. Those grounds with less stable, perhaps less reliable, fishing (with high variability indices) yielded less catch. This analysis bolsters the plausibility of the variability metric presented here, insomuch that it captures fishing effort that help explain trends revealed by an independent data and set of metrics (fish catch weight and value).
- As a rule of thumb, it was revealed that catches over 1 tonne and greater than 1000 pounds sterling were concentrated in areas where the variability in fishing effort has a coefficient of variation of less than 240%. This pattern was broadly the same for both mobile and static fishing gears. Further analyses in other areas and time periods might prove this relationship to be sufficiently general that specific thresholds of fish catch statistics could be used as proxies to specific thresholds of fishing effort (Figures 4.23, 4.24).

Chapter 5 Assessing the possibility of co-existence between fisheries and marine renewable energy: The results of a national fisher survey helping to put the spotlight on fishers and fishers' knowledge (FK)

"You've got to want to do the job, it's not a job you do for the money, you wouldn't do it in all honesty. You've got to love the job, want to do the job and then the money's secondary you know. That's the way I see it. ... fishing is a way of life, a completely different way of life"

Craig, fisherman, Cadgwith Cove.

5.1 Introduction

There is the overarching public opinion that global fisheries management has thus far failed (Beddington *et al*., 2007; Worm *et al*., 2009). Urquhart *et al*. (2014) discusses the need for application of the 'mixed method' approach i.e. that combines both qualitative and quantitative research in a single study, in some way to help with the fishing industries problems. Assessment of fishing effort displacement is one of those major industry problems. Symes & Phillipson (2009) highlight the fact that the social dimension in fisheries is lacking, and in ignoring this data, the complexity of fishing industry is under-represented. In the case of this research thesis, this may result in the potential under-estimation in the consequences of fishing effort displacement on different sectors of the UK fleet, because we fail to shed light on these complexities within fishing behaviour. Chapter 3 and 4 highlight how aspects of spatially and temporally explicit data can inform certain aspects of resource use, but in order to get a true representation of fisher behaviour, these semi structured interviews have the potential to be a way of eliciting much more significant information. Fishers' Knowledge (FK), as outlined in Chapter 2 is a data source that is both highly under-utilised, not greatly understood by the more traditional marine science community, and it has certainly has not been considered when capturing data in order to inform the fishing effort displacement and MRE debate, nor has it been applied to any discussions on marine spatial planning. It is fisher specific, and because fisheries are about managing fishers (Hilborn, 2007), this Chapter by using the questionnaire enables some gaps to be filled in reference to fishers views on current fisheries management fisher behaviour which is the fundamental basis of understanding displacement and ensuring minimal socio-ecological impacts of MRE.

5.1.1 Primary objectives

The objectives of this Chapter are as follows:

- To develop a list of data collection and activities that would enable assessment of the degree and impact of fishing effort displacement;
- To attempt to validate a mitigation agenda developed by stakeholders involved in MREKE Programme; and
- To make recommendations to improve both the collection and use of FK for the assessment of fishing effort displacement.

5.2 Methodology

5.2.1 National survey of fishers and marine renewable energy

The questionnaire designed for fishers around the UK is shown in Appendix 1. Table 5.1 details the rationale for each question which followed the example of Rees *et al*. (2013b). All fishers interviewed were skippers of a vessel, and operated a particular gear type, shown in Tables 5.2-5.3. A semi-structured interview was used according to Bernard (2006) and fishers were asked a series of closed questions to elicit information about regional and local fishing activity and general vessel characteristics etc., and open –ended questions to elicit more information about fishing behaviour. Triangulation, i.e. comparing the points of view of three or more independent sources to determine accuracy of information (Bruce *et al*., 2000) was also employed in order to increase the accuracy of the responses provided. Informal, unstructured surveys were also carried out with other members of the fishing communities: crew, Producer Organisations (POs), fleet managers, fish merchants, fisheries consultants, members of fishing communities. These were conducted in order to gain a better understanding of the array of issues that are of relevance to the wider fishing community.

Due to the nature of the case studies that are in Chapter 3 and 4, most face to face interviews were conducted in the South West of the UK. Due to financial constraints, in order to reach other fishers in other regions; England ((SW), (NE), (SE), (NW)), Northern Ireland (NI), Scotland (Sc) and Wales (Wa), the survey was emailed to a wide array of fishing associations and Producer Organisations (POs) along with the outputs of the MREKE Programme. Social media was also used to establish contact with the fishers and telephone interviews followed. The survey had a large geographical scale and an attempt was made to include only those areas where MREIs have been developed or have been proposed. However, given the nature of social media, and the rapid uptake of information, other fishers interested in the subject matter also requested to be interviewed, they may not be directly affected by MREIs but had in-depth knowledge and opinions on the subject matter. A brief overview of the aims and objectives of the survey was published in *The Skipper,* a monthly publication *produced by* Mara Media, a publishing and event management company in Ireland. Interviews were also conducted at a Mara Media Skipper Expo International event in Bristol. Regular Defra and Cefas fisheries meetings held in Newyln were also attended in order to understand fishing industry issues, and elicit contacts for further interviews. One interview was conducted with a Dutch fisher and fleet owner who fishes in the North Sea. Key responses from this fisher are included as a separate section as this questionnaire was designed for UK fishers only in order to assess gear-type and regional differences. However, this fisher who is both a skipper and fleet owner had very valid suggestions that could illuminate the debate about co-existence of MRE and fisheries and in particular FK.

Qualitative data were extracted and analysed using the text analysis software NVivo8 (QSR International, 2010), which enables the analysis of open ended questions and allows coding of themes and key quotes extracted. This package allows the analysis of text-rich research such as interview outputs. Data from each interview are organised in separate files, and then using ‘text search queries’, the use, context and meaning of words can be explored. For example, some expressions can be associated with particular demographics, or can be found several times in each separate interview and this can be found using particular key word searches, and they can be counted. If the text search query returns some interesting content, this can be saved as a ‘node’, hence it is these nodes that enable the organisation of content into broad themes that can be interrogated.

Table 5.1 Rationale behind the questions for the fisher survey on fishing activity and marine renewable energy

Section/ Question no.	**Rationale**
Section A	Questions designed to define local/regional fishing activity of interviewees
1	Scoping question to identify priorities

2	Scoping question to determine experienced/perceived barriers to progress
3, 4	Visioning questions to aid management
5	Visioning question to aid research objectives
6	Visioning question to identify research priorities
7, 8, 9	Scoping questions to identify potential impacts
10	Scoping question to identify potential fisher adaptations/ to aid management
11	Scoping question to identify gaps/ aid management

5.3 Results

5.3.1 National survey of fishers and marine renewable energy interactions: Fishers identifying issues, challenges, priorities and helping evaluate agendas

5.3.1.1 Description of respondents

Forty skippers were interviewed for the purpose of this study, which is a low response rate, i.e. a low number of questionnaire returns. The age range represented in this study is shown in Table 5.2. The average number of years each fisher has spent in the fishing industry is 23 years (sd=+/- 10). The number of fishers from each region and the type of fishing activity they are engaged in is shown in Table 5.3.

Table 5.2 The age range of respondents

Age	18-30	31-40	41-50	51-60	Over 60
No. fishers	2	10	17	11	0
Time spent in the industry (sum)	18	150	387	369	0

Table 5.3 The number of skippers interviewed and main type of fishing activity and area fished (some fishermen in different seasons use a different gear-type and these are included also)

Gear-type	Scallop	Beam trawl	Otter trawl	Longline	Pots/whelkers	Gillnetter
No. skippers	1	12	5	4	11	7
Fishing area	1 (Wa)	1 (S) 3 (SW) 5 (SE) 3 (NI)	2 (SW) 1 (SE) 2 (Sc)	3 (SW) 1 (SE)	6 (SW) 3 (SE) 1 (NE)	5 (SW) 2 (NE)

Key: England ((NW), (NE), (SW), (SE)); Scotland (Sc); Northern Ireland (NI); Wales (Wa)

5.3.1.2 Priority issues and barriers to progress

A thematic analysis of fishers' responses to questions on priority issues and barriers to progress is presented below in Table 5.4. The results of these questions are important as they underpin not just the consultation process but also any future research agenda.

Table 5.4 Thematic analysis of fishers' response to priority issues and barriers to progress to inform future management

Themes for barriers to progress	No./ (%)fisher response	Themes for priority issues	No./ (%) fisher response
1. Policy	11 (28)	1. Displacement/loss of access	18 (45)
1. Consultation	11 (28)	2. Cable disturbance	11 (28)
2. Lack of Trust	9 (23)	3. Timing of installation/ repairs	10 (25)
3. Lack of knowledge	7 (18)	4. Co-location	9 (23)
3. True representation of all fishers	7 (18)	5. Inshore fishers- limited range	8 (20)
4. Science and fisher observation Mismatch	4 (10)	6. Effects on seabed	6 (15)
5. Timescales	3 (8)	6. Policy of OWF siting	6 (15)

5.3.1.3 Consultation process

The question regarding the consultation elicited quite negative responses from the fishers overall, however, one fisher expressed one positive opinion. The results of dominant themes are shown in Table 5.5.

Table 5.5 Thematic analysis of fishers' responses on the consultation process

Consultation theme	No. /(%) of fisher responses
1. Not fit for purpose	14 (35)
2. Disconnect with management	10 (25)
3. The lack of the fishers voice	9 (23)
4. Lack of Trust	7 (18)
5. Lack of long-term vision	5(13)
6. Ineffective Communication	3 (8)
6. Legitimacy	3 (8)
7. Lack of knowledge sharing	2 (5)
8. Efficient on a local basis	1 (3)

In total, 35% of fishers agreed that in this current climate, the consultation process is simply 'not fit for purpose'. In relation to this theme, one fisher stated '*we are presented with fait accompli, we're not involved in the planning stages, plans are done, then we come in, what* then? *This didn't happen with the oil industry, so why with renewables?*' One fisher alluded to a completely closed consultation process, in particular to an ongoing but opposed development off the North East coast. A group of fishers using their years of knowledge, i.e. FK suggested alternative sites, but were ignored by the OWF developer. This lack of confidence in a pivotal process directly relates to how fishers can feel disconnected with management, and in this case one quarter of fishers interviewed expressed this view. This is discussed in detail in section 5.4.2. This loss of confidence in a process, feeds this disconnect with those making decisions about marine plans, and may help to explain why 18%

of fishers have a lack of trust in not just the process of a consultation but also the outcomes. Following on from this, 8% of fishers interviewed expressed views on the actual legitimacy of the consultation process. FK scored highly here, with 23% of fishers actively acknowledging the lack of inclusion of their knowledge. The one fisher, who expressed positivity about the consultation process, was referring directly to consultation processes at the smallest local level, and this is something to highlight, can much smaller focus groups work better than large industry meetings?

5.3.1.4 Research agenda

Fishers were asked to give three examples of research areas that could aid in the improved co-existence of fisheries and MRE. Table 5.6 shows the top three in rank order.

Table 5.6 Fisher identified research priorities in rank order

Research Priority/ Rank	**No./ (%) fisher responses**
1. Use of fishers' knowledge	17 (43)
2. Siting of MREIs	7 (18)
3. Vulnerability of stocks	5 (13)

There were a low number of opinions on this subject. Some fishers had multiple answers while others did not answer the question at all. Some fishers mainly in the North Sea were concerned with stocks and climate change, and if more MREIs are planned they felt that the area would become much more encroached. More than one fisher expressed an interest in how the research community can try and predict effects of different scenarios with one fisher asking 'can the researchers *inform areas for siting and predict effects?* One fisher stated that '*now fishermen and scientists have the same opinion on certain stocks and we are working better with ICES now*' but that '*younger researchers are more open to new ideas but there is still a way to go'.* The same fisher also stated that *"back in 1987, when I started I thought the sea was mine, but now we all need each other'*, referring to scientists. Fishers' Knowledge (FK) was a theme that was recorded in every interview, and was stated in many guises, e.g. '*our knowledge*', '*our opinions*', '*all the years at sea*', '*our voice*'. Therefore there needs to be a framework designed for the capture of this data source, and designed in a systematic way with specifically fishing effort displacement in mind.

One gillnetter in the NE stated that '*our knowledge targets the aspirations of the fisheries, of the fishermen for the long-term',* and in this case, this fisher is referring to FK. One of the many negative aspects of the consultation process experienced by fishers was the lack of long-term vision; hence FK integration may be a solution to better reception of and participation in the consultation process. Siting of MREIs was also one of the top research areas mainly because fishers felt '*alternatives sites are there, we just are not being listened to'.* A query about fisher incentives was brought up here '*is there some way of trying to figure out with scientists how we could come up with incentives for us at sea, like a rewards scheme?*". This subject of incentives is not new (Hilborn et al., 2005) but it has been discussed by many fishers, and it would form a good research project, especially considering the level of conflict being experienced between both the MRE and fishing industry.5.3.1.5 Mitigation agenda validation

A thematic analysis of fishers responses to the mitigation agenda are shown in Table 5.7.

Table 5.7 Fisher responses to aspects of the mitigation agenda developed by de Groot et al. (2014) and number of fishers who provided responses

Mitigation agenda/ action points	No./ (%) fisher responses	Top three emerging themes by rank
Overcoming data issues for assessment of fishing effort displacement ➢ **Variety of data gathered using appropriate methodologies** ➢ **Data to be made available and shared freely while respecting commercial sensitivity** ➢ **Direct involvement of fishers**	15 (38)	1. Trust issues between fishers and managers/scientists 2. Data management issues 3. Previous failures
The need for the development of assessment guidelines and methods ➢ **A variety of fishing effort analysis methods exist, but are not specifically designed for assessment of effort displacement** ➢ **Distributed on a national basis**	10 (25)	1. More Collaboration needed 2. Guidance from scientists 3. Timeframes differ between a fisher and managers/scientists
Analysis of case studies to inform behaviour rules of various gears, vessels and skippers ➢ **Further analysis of MRE case studies to identify successes and failures**	23 (58)	1. Who will start process/how to initiate 2. Improved Communication 3. The need for the fisher' voice

The urgent need for the sharing of best practice ➢ **The set-up of a Mitigation Toolkit, hosted on the NERC portal** ➢ **Both industries to contribute and a facilitator required**	14 (35)	1. Improved Communication 2. Trust issues between fishers and managers/scientists and between two industries 3. The need for the fishers' voice

Collaboration of fishers and MRE developers ➢ **Direct involvement of fishers in collaborative projects with developers and researchers to further technologies, methods and plans to maximise fishing opportunities within and around energy sites.** ➢ **This requires improved coordination between fishers and science funders.**	27 (68)	1. Lack of understanding between two industries 2. Process fatigue 3. Funding issues

Development of standards across UK and Member States ➢ **Reform the Marine Industry Liaison Group (MILG) to operate at a more strategic level, and ensure involvement of the fishing industry.** ➢ **Research initiatives a priority across Europe**	30 (75)	1. Existence of trans-boundary issues 2. Mistrust of other EU countries 3. Pessimism about timeframes

Development of a new consultation protocol between MRE and fishing sectors ➢ **New design of appropriate methods to engage fishers** ➢ **Ensure consistency in procedures and be sensitive to differences in discourse between the two industries** ➢ **Improve communication in consultation and engagement processes and develop**	29 (73)	1. Timeframe 2. Political issues-MRE Policy driving 3. Historic lack of fisher voice inclusion

specific protocols for these		

5.3.1.6 Dutch fisher responses

Although not taken into account in the analysis of fishers from the UK, as this last Chapter was UK-centric, the decision to include the responses of this fisher as a separate section, are based on the suggestions for the consultation process and the use of FK, which very much aligned with what UK fishers were expressing. This is very important, because it illustrates that across boundaries and Member States, fishers are experiencing the same conflict between MRE and fisheries, and if so then, sharing this knowledge might in some way help to tackle the issues highlighted in fishers' evaluation of the mitigation agenda developed by de Groot *et al*. (2014) (Table 5.7).

This fisher has amassed 34 years' experience in the fishing industry, and as described above, is an active skipper and vessel owner, and his vessel is the largest in the Dutch fleet. The MRE development most commented upon here was Dogger Bank Offshore Wind Farm (OWF). One of the biggest issues this fisher commented on most was the consultation process between fishers, fisheries managers and scientists how it could be dramatically improved. This is in alignment with approximately 73% of UK fishers who felt that as part of a mitigation agenda to work, the consultation process needs to be improved. In addition to this, two key themes that emerged from analysis shown in Table 5.5 that hindered a positive consultation process; the lack of use of FK and MRE policy driving the process. This directly matched the opinions of this fisher, '*political decisions are taken before consultation takes place'*. He also included a lack of choice when it came to what was offered when the consulting process was underway, and was directly referring again to the

MRE policy drivers not being considered alongside fisheries policy. The improved use and application of FK, was also a strong theme. In particular, this fisher detailed FK about; fish populations, currents and detailed observations on ecological and environmental changes that need to acknowledged. He referred to the change of currents and fish populations and in particular spawning patterns of commercially valuable fish since OWFs have been built on Dogger Bank, and how this has remained ignored for the most part. In addition, MRE repairs were taking place at sensitive times for two major species here, Plaice and Sole. This kind of information has to be a priority when conducting the consultations. This is also in line some of UK fishers' responses to FK, in that 23% feel that FK has to be considered in consultations for them to be meaningful and aid in reducing conflict between the industries. Regarding the top three research topics, the fisher, in order of importance stated, 'quota and stocks, FK and knowledge sharing', key themes which also emerged from discussions with UK fishers. In terms of aiding fisheries management, which was one of the visioning questions (Q3, Appendix 1, Table 5.1), this fisher focused on the '*lack of long-term planning for MRE not taken into account alongside the need for long-term survival of fish in the North Sea*', and in not aligning both MRE and fisheries objectives in the long-term, effort displacement is an issue.

5.4 Discussion

5.4.1 Data needs

Through a collaborative process at the UK's first Marine and Coastal Policy Forum, Rees *et al*. (2013a) sought to identify priority questions that could shape the marine and coastal policy agenda. In relation to data and MSP, the majority of questions from participants related to how to use data effectively. This is in line with barriers to progress from this survey; fishers have concern over what they are seeing in their environment on a daily basis in comparison to what scientists are reporting and are questioning if data are being used in the right way. What is surprising from the forum participants is the lack of questions regarding what data are needed or how it can be collected, which is a concern of fishers. This may be a reflection of the attendance of different sectors, of which fishing industry representation was lacking. Fishers identifying data needs and the priorities, barriers and challenges of collecting this data for the purposes of assessing fishing effort displacement must not be a static process. The scale and pace of change in the marine and coastal policy of the UK, and overarching changes to the CFP mean that fishers must find ways to adapt at the same rate of change, thus affecting resource use estimates on various temporal and spatial scales. It must be an iterative process and at every stage, be transparent and be subject to stakeholder consultation (Shucksmith & Kelly, 2014), in this case with the fishing industry.5.4.2 Incentives and the consultation process

Fisher incentives were highlighted in these interviews, and it is significant. Beddington *et al*. (2007) stated that for fisheries management to work, among other practical solutions were incentives for fishermen, so clearly there needs to be a discussion on how to make this work. A theme that emerged from the consultation process with fishers was this ‘disconnect with management’, this was a strong theme also in the research carried out by de Groot *et al*. (2014), termed the ‘fisheries disconnect’. Another way to describe it was the lack of a fishers’ voice, a feeling expressed by the fishing community (Gray *et al*., 2005). Within the fisher validation of the mitigation agenda, the timeframe was the most important aspect. The mitigation agenda developed by de Groot et al. (2014) identified MSP as a way to tackle the conflict between both industries. Because fishers expressed the view that there is a lack of long-term vision when considering fisheries objectives alongside those of MRE, then MSP could provide a more integrated approach for mitigating fishing effort displacement. Why? Because defining timeframes is an integral part of the MSP process (Douvere, 2008), and considers short-term and long-term components, i.e. a base year to assess 'current conditions' and target years that defines the planning period and identification of future year scenarios. Timeframe designation has to be a fundamental part of the consultation process. In the early COWRIE reported by Blyth-Skyrme *et al*. (2010) early engagement with fishers at the beginning of a planning process was explicitly explained as being of the highest priority. , In conducting surveys with fishers across multiple MRE sites, Ashley (2014) found that fishers felt they were not involved in the process from the beginning. These surveys were carried out four years after the initial COWRIE work, thus signifying there is something inherently wrong with the current consultation process. This is further reinforced by the outcomes of this study. Clearly, there has to be a paradigm shift in how we engage with fishers in the consultation process as it is the basic building blocks of a successful MRE development and in designing a new process fishers must be involved. Perhaps one way of mitigating against displacement, for example, could be certain incentives put in place for fishers that do not simply involve compensation.

Maxwell *et al*. (2015) in discussing a new way to manage our marine resources via 'dynamic ocean management' highlights the need for innovation. If the UK is to reach its target to produce 33 gigawatts from marine renewable sources by 2020 (United Kingdom House of Lords, 2008), then some innovation is needed in how to approach the consultation process. This paradigm shift in fisher engagement and the need for innovation are considered in section 5.4.4.

5.4.3 The need for further investigation

5.4.3.1 Where to next for NERC MREKE Programme Marine Renewable Energy and Fisheries Displacement Working Group?

Cvitanovic *et al*. (2015) identified that knowledge exchange must improve between scientists and policy-makers, thus the research undertaken under the NERC MREKE Programme (de Groot *et al*., 2014) which was one of the first of its kind for the UK, is a step in the right direction. Harnessing the power of all actors from all regions, including active fishers, fishing association representatives, MRE industry representatives, scientists, practitioners and policy-makers, means that scientists have greater opportunity to conduct policy focused and relevant science (Halpern *et al*., 2012).

Fishers responded positively to the mitigation agenda that was developed by the working group. Of particular interest was the development of a consultation protocol actively involving fishers in its design. But progress has been slow to initiate action plans and activities, hence there needs to be an analysis of the impact of the NERC MREKE Programme on each stakeholder group and overall impact of the project thus far. All of the research outputs generated through NERC MREKE Programme migrate to the International Council for the Exploration of the Sea Working Group on Marine Renewable Energy (ICES WGMRE). There may be potential to create an ICES Study Group (SG) within ICES WGMRE specifically addressing fishing effort displacement assessment and mitigation.

A significant section on the interrogation of data priorities which was outlined in Chapter 1 requires further study, however discussions are currently underway in order to attempt to continue the questionnaire across multiple regions of the UK

5.4.3.2 An extension to the national fishers' survey

As explained in the results, there were not enough data to suggest gear-type or regional differences, mainly due to financial constraints in gaining face to face interviews, but there are plans to extend this questionnaire in conjunction with any further work carried out under NERC MREKE Programme. To conduct a national questionnaire of this size was rather ambitious. The idea could be to allocate each region to an array of ex-fishermen, much like that used by Rees *et al*. (2013b), who have experience of the industry, or endeavour to get the involvement of Seafish, or active fishermen for that matter. Likert scale analysis could have been used to investigate perception statements, like that used by Rodwell *et al*. (2014b) of fishermen in different regions, because there may have been further information about each fisher in that area that this survey did not elicit.

Another fisher survey was carried out by Rees *et al*. (2013b) in on the social impacts of MCZs on the North Devon inshore fishing fleet. Given the fact that it also included responses about an MREI, the Atlantic Array, and the proposed installation subsequently being cancelled, it would be prudent to evaluate the responses in greater detail in order to elicit any further information about fishers' knowledge (FK). And it would also be useful to set up a meeting with developers and fishers in order to document why the Atlantic Array project failed, anecdotal evidence points to fisheries conflicts, thus this is very important for both consultation process redesign and application of FK. A fundamental part of the mitigation agenda (de Groot *et al*., 2014) is to document successes and failures in MRE and fisheries and share best practice, this is vital information for inclusion in the Mitigation Toolkit, and should be a priority.

5.4.4 The consultation process: Paradigm shifts, innovation and incentives

The fact that 35% of fishers felt that the current consultation process for fisheries and MRE is not fit for purpose signifies that there has to be a complete paradigm shift in how it is designed. However, before discussions on reinventing the consultation process can occur, the whole culture of how scientists, fisheries managers and MRE developers engage with fishers has to change. There are two keys words that need to be acknowledged, creativity and innovation. De Groot *et al*. (2010) show weak valuation of ecosystem services, conservation fisheries and MRE, for example is a major impediment to informing the decision- making process. Thus the key is bringing fishers closer to the subject matter by way of training, education for example. Cooke *et al*. (2013) provide some interesting ideas on 'formal and non-formal strategies'. One formal strategy proposed is the development of training manuals, which would be fisher specific, and use of non-formal strategies such as social media. What is illustrated here in this thesis is the value of social media as an effective means of engagement with fishers. Social media works by generating interest in a topic, more fishers are engaging in social media, mainly Twitter and Facebook and there are research projects now being initiated e.g. ResponSEAble[9] that aim to directly investigate social media as a tool for fisher engagement. A new charity Fishing into the Future (FitF) are working with an industry led Steering Group consisting of active fishers along with scientists, processing and retail and government representatives *'Focusing on sharing knowledge, key outcomes include a comprehensive scheme for UK fishermen to contribute data into the science which*

[9] http://www.responseable.eu

underpins fisheries management; training and education initiatives ,including broadening the scope of skippers' training to include fisheries biology, management and marketing, and establishing regional knowledge exchange workshops for fishermen and other seafood industry businesses'. These are really great strides forward to achieving full representation of fishers in the consultation process. The key word here is capacity building, and since consultations are a stakeholder led process, providing this training etc. may in a way help fishers feel more inclusive. One fisher in this study attributed consultation process success with the design being of a local nature. There could be the formation of small focus groups from each gear-type per region beginning the consultation process, and then representatives from each gear-type per region could be paid to attend larger consultations. The key is investment; much more funding should be invested in the consultation process.

During a number of informal discussions on the topic of innovation, one fisher pointed to marine planning consultations with fishers in the Mull of Kintyre by Alexander *et al*. (2012). Researchers used interactive pads with mapping software and invited fishers for a series of sessions, conduced questionnaires and mapping exercises. Fishers were very receptive to this and the use of such technology was hailed as a success. Recent work by Mayer *et al*. (2013) involving simulation gaming (SG), i.e. gaming software designed for marine spatial planning showed that taking scientists, agencies and industry representatives out of the 'normal' consultation protocol led to a deeper understanding of the issues that each representative faces in their work environment in the context of spatial planning. The use of online streaming technology, i.e. Bambuser was piloted at the last meeting of the Gap2 project, a consortium of researchers who focus on stakeholder engagement. This software was used to stream a conference live, with fishers in the

UK logging on from their laptops, and a conference that was capped at 150 attendees reached almost 400. It has since been used to stream Marine Scotland fisheries and CFP meetings (Katrina Borrow, Mindfully Wired Comms).[10] This might be termed revolutionary in terms of gaining greater fisher participation in consultations, because fishers who rely on their commercial catch for their living can participate remotely.

During the course of the interviews with fishers, this idea of Incentives was a popular discussion element among fishers. This idea of incentives in fisheries is not new (Hilborn *et al*., 2005), but the fact that fishers are interested and it is motivating them, it should be considered. Fishers considered extra days-at-sea as a possible rewards route for good environmental stewardship. Others considered the chance to work with researchers and carry out research as an incentive providing capital could be made available to update vessels etc. Interesting conversations with some fishers in Newyln occurred regarding the 'fisher as a consultant', and incentives around these possibilities. Clearly fishers are interested in working with the research community, so there needs to be some planning as to how this could be as successful as the fisher and science partnership in Lyme Bay.

5.5.5 Establishment of a framework for the collection and analysis of FK

In section 5.3.1.4, the improved inclusion of FK was identified as a priority in terms of directing a research agenda. The first reform of the CFP in 2002 promised greater inclusion of FK (EC, 2002), but what is being observed among the fishers interviewed for this study and from other important studies (e.g. Griffin, 2009, Stöhr & Chabay, 2010) is that more than a decade later, fishers still feel FK is not included in

[10] http://www.mindfullywiredcomms.org/

decision-making and management. The most important aspect to be considered in designing a framework for the collection and analysis of FK, is that it should be systematic in its approach (Daw, 2008, Tesƒamichael et al, 2014). This was a method which was employed in this study and showed as an example in questionnaires conducted with the North Devon inshore fishers by Rees *et al*. (2013b). In this study by Rees *et al*. (2013b) an ex-fisher who was employed in order to conduct the surveys altered how the questions needed to be asked to fishers, e.g. asking for exceptional experiences as opposed to general or vague questions. This is also an important point linking why fishers could be employed to lead consultation processes on a local level as described above in section 5.4.4.

Table 5.8 below illustrates a potential systematic approach for the collection and analysis of FK in the assessment of fishing effort displacement. This has been compiled using an array of published work and advice on the subject (Daw, 2008, Tesƒamichael et al, 2014, Leopold et al., 2014, Hind, 2015)

Table 5.8 A potential systematic approach for the collection and analysis of FK in assessment of fishing effort displacement

Step	Methods	Rationale
1.	Formation of small local focus groups to discuss surveys. First step of engagement with the community is very important. Potential to employ a fisher/ scientist fisher combination to carry out surveys	From interviews with fishers, more success seems to stem form locally orientated groups who can feed into larger association, regional meetings See Rees *et al*. (2013b) ref above
2.	Designing the survey: • Aim is to create experiential questions as well as	Fishers find it easier to answer these easier than general or vague questions. Semi-structured survey with

	demographics and attitudes to and perceptions of subject matter • Semi-structured, open –ended questions • Use Likert Scale questions when dealing with attitudes or perceptions	open ended questions allow a better flow of conversation
3.	Random and targeted sampling of fishers and triangulation with other members of the wider fishing community, e.g. processors, managers, PO's	Most of the time surveys can be opportunistic. But sometimes, fishers can recommend someone who may know more on a subject or someone beneficial to talk to
4.	Elicit information on FK of fishing areas and catch size through maps either digitally or on paper Info on: species, home port, distance, gear-type, month, year, seasonality, other factors that might affect fishing behaviour	The use of digital maps, or a computer is best with mapping software
5.	Input data in a spatial database	Use of GIS
6.	Mapping of catch, effort, CPUE Follow up with methodologies outlined in Chapters 3 and 4 of this thesis Analysis of Likert Scale analysis of perceptions/attitudes Textual language analysis (NVivo) to identify themes for management	Standard in any fisheries analysis

5.6 Summary

- Barriers to progress, in order of the most important theme included: policy, consultation, trust, lack of knowledge, true representation of all fishers, science vs. fisher observation mismatches and time scales;
- Priority issues identified in order of importance were: displacement or loss of access, cable disturbance, timings of installation/repairs, effects on the seabed and specifically offshore wind farm (OWF) siting;
- The consultation process caused a lot of discontent among fishers across all gears. The three top themes identified were: not fit for purpose, management disconnect and the lack of the fishers voice;
- Fishers identified incentives as an important part of mitigation strategies;
- Initial validation of a mitigation agenda developed by de Groot *et al*. (2014) highlighted themes of trust in relation to trans-boundary issues, data management and the consultation process;
- Lack of understanding, process fatigue and funding themes emerged when validating a collaborative effort with MRE as part of the mitigation agenda;
- In order of the most important: use of FK, siting of MREIs and vulnerability of stocks were the three areas that scientists should focus their research upon;
- The response rate of the importance of gathering FK was high, fishers felt this data source was an important aspect of trying to assess impacts on the UK fleet due to MRE;
- A framework for the collection and application of FK is suggested, but more development is needed;
- Due to the small number of fishers interviewed, further study into regional and gear-type differences of fishers responses needs to be conducted;

- Due to the small number of fishers interviewed and the fact that more research needs to be conducted, this means that results are indicative rather than conclusive.

Chapter 6 Conclusion

"There is increasing recognition of the benefits of combining spatial analysis with more qualitative research strategies to uncover the complexities of fisheries… Mixed methods are likely to prove fruitful in exploring an integrated strategy which is both iterative and reflexive…"

*Urquhart et al. (2014) Fisheries Research, **108**, 240-247.*

6.1 Introduction

Balancing nature conservation objectives, reaching MRE targets and sustaining an industry that provides livelihoods and social good is a complex and often conflicted arena. The UK is to reach its target to produce 33 gigawatts from marine renewable sources by 2020 (United Kingdom House of Lords, 2008), move towards the establishment of a representative and coherent network of MPAs by the year 2012 (Jones & Carpenter, 2009), of which progress has been slow and the target is closer to 2020. Alongside these objectives, there is fisheries policy, i.e. the CFP, the new changes of which were initiated in 2014 with also a new vision for European fisheries by 2020 (EC, 2009b). Displacement of fishing effort has implications for the conservation of habitats, species population on remaining grounds (Dinmore *et al*., 2003, Kaiser et al., 2006). In respect to the actual fishers involved, displacement has caused fishing conflict between gear-types occupying shared space (Murawski *et al*., 2005, Suuronen *et al*., 2010) and has perceived implications, costs, safety risks due to more time at sea, poorer catches and increased impact on already vulnerable areas (Mackinson, 2006). Finding the right balance that can address fisheries policy and achieve sustainability, maintain conservation features in 'a favourable condition’ and bring about the ability to harness our own energy in order to meet climate change targets is a difficult road to venture upon. Thus, this thesis afforded the opportunity to truly interrogate available fisheries data, and add research to a sparsely populated research area, fishing effort displacement. The key points from each element of study reported in this thesis are discussed below and are considered in relation to the overall aim of the thesis and recent developments in this area of research into fishing effort displacement and fisheries and data policy development within the EU.

The overall aim of the thesis was to evaluate the suitability of various sources of data, which could be used to detect, assess, and ultimately predict, fishing effort displacement due to implementation of marine conservation objectives and the development of the marine renewable energy (MRE) sector. The key objectives of this work were to:

- Detect, identify and highlight ways in which the UK fishing fleet could be affected by the development of marine conservation efforts and MRE development, and how that might translate into the displacement of vessels into new fishing grounds. Carry out this work at varying resolutions, from the individual vessel, through assemblages of vessels with the same gear types, to fishing fleets operating out of individual ports, and finally to whole fleets operating wholesale out of all ports in the South West of the UK;
- Assess what data and analysis methods would be required to detect such a displacement of fishing effort, and at what resolution and scale would such a detection be possible; and

- Assess the potential of these data and methodologies to predict which fisheries in the > 15 m sector are at risk of fishing effort displacement

And in light of major limitations made to data access, the activities and research that were undertaken under the auspices of NERC MREKE Programme created an opportunity to address three further objectives, specifically related to MRE, and which were not originally planned:

- To develop a list of data collection and activities that would enable assessment of the degree and impact of fishing effort displacement;
- To make recommendations to improve both the collection and use of FK for the assessment of fishing effort displacement; and
- To validate a mitigation agenda for fishing effort displacement brought forward during MREKE Programme workshops.

6.1.1 Research in a changing policy and data climate

The initial literature review identified a range of research requirements to assess fishing effort displacement (Chapter 2), however it was not until the MREKE Programme opportunity arose, as described above, that made it apparent that an interdisciplinary approach would be needed, and a new set of research objectives created, and various sections added to Chapter 2.

This thesis was conducted in a changing policy and data climate. The data changes to data access were discussed at length in Chapters 1 and 2. Policy wise, the development of MSP to balance competing interests in the use of the marine environment, i.e. fisheries management, biodiversity and MRE development (Qui &

Jones, 2013) occurred during the study period. Alongside this, the enactment of the Marine and Coastal Access Act in November in 2009 required the newly formed Marine Management Organisation (MMO) and the existing Welsh Government to produce plans for their inshore and offshore waters. Within this, the overarching Marine Policy Statement (MPS) which guide these marine plans had some fundamental statements laid out, one of which states '…*to reduce real and potential conflict, maximise compatibility between marine activities and encourage co-existence of multiple uses'.* From the conclusions drawn from this thesis, we are still a long way from reducing the conflict when it comes to MRE and conservation plans. And, it is now ironic as the conclusions of this thesis are being drawn, that the EU is set to change some Fisheries Control Regulations and fisheries data collection methods from 2017-2020. The current Fisheries Control Regulation 1224/2009. (EC, 2009a), is now .under consultation and all stakeholders have the opportunity to respond, of particular interest to this thesis concerns information on '*new instruments of the EC to ensure the implementation of the CFP by Member States*' (EC, 2016a). This same Fisheries Control Regulation, which when amended in 2009, blocked VMS data access, hence this is an important consultation. Thus the changes to these policies will have a direct impact on the direction of research into fishing effort displacement.

6.2 Chapter 2

This Chapter shows that there are currently no prescribed methodologies for the assessment of fishing effort displacement. This Chapter presents the various methods used to assess fishing activity and illustrates a number of important case studies that deal with different data sources. Central to all these case studies is the type of data needed. Currently, in the EU there is another stakeholder consultation underway in trying to establish *'where are we, and where are we going with our fisheries'* (EC, 2016b). This Chapter set out the methods that would be appropriate for the analysis of displacement, and the information contained and research questions generated would feed directly into this consultation.

6.3 Chapter 3

The methods of Lee *et al.* (2010) were used to analyse 2-hourly, level 3 VMS data to derive a number of important parameters to quantify fishing effort in the South West UK (ICES areas VII e-h inclusive), the most important being fishing activity, defined in terms of the number of hours fished. In summary, the methods by Lee *et al*. (2010): records without an associated gear type, within 3 NM of ports and duplicates are all removed, to identify *bona fide* fishing activity, the interval between each successive record was calculated and only those vessels travelling at a speed less than 6 knots were deemed to be actively fishing. This methodology was applied to all gear types. A point summation method followed, using a grid cell size of 0.05° (or 3 arc minutes), equating to 3 NM, the resolution of fishing data considered necessary to inform MSP. The spatial distribution of fishing activity in South West UK was not only highly heterogeneous, with distinct areas of intense fishing that could be identified for all gear types, but also varied significantly in time.

These maps were used to assess the variability of individual fleets. Variability was here is defined in terms of the degree to which the spatial pattern of fishing effort for a particular gear type changed over time, quantified by an index of spatial difference in the distributions of fishing effort. This index revealed that scallop dredgers were the most transient fleet in South West UK waters, and whose gear type whose shift in geographic spread between years was easily noticeable by eye on large scale maps, moving their efforts from the Celtic Sea (including Haig Fras, a Natura 2000 site) further south into the western English Channel and Atlantic during the period 2005 to 2008 inclusive. It was revealed that other mobile gear types (beam and otter demersal trawlers) tend to have a high to intermediate spatial coherence (or low to intermediate change) in spatial pattern of fishing effort between years, despite their mobility. This might be because they remain active almost year-round and cover large areas more uniformly than static gears for which the spatial distribution conforms to ‘hotspots’ of more intensely fished areas. Variability may be an important component in assessing economic impact, depending on what drives that variability

Fishing effort was assessed with specific reference to two major case studies: one proposed MPA (Haig Fras); and one MREI (Wave Hub). A closure of Haig Fras would have the greatest impact on gillnetters. Scallop dredgers also occasionally use the area; however they exhibited much more transient behaviour during the study period so it is less clear whether their occasional use of the area reflected long term usage trends. The current closure at Wave Hub has the greatest potential impact on potters and whelkers whose geographic specialisation is most pronounced, i.e. fishing small areas most intensely, and who use the area extensively. Longliners also use the area disproportionately and would be affected. In contrast, the potential impacts of beam and otter trawlers may be minimal given their much wider spatial distributions in the nature of their fishing activity.

The index of spatial similarity is a robust method of quantifying changing spatial distribution but is highly dependent on the size of the cell. Therefore, care should be taken to report this cell size because meaningful comparisons can only be made between data sets with identical cell size. If this method proves popular in subsequent research, a standard cell size should be adopted when conducting regional scale analyses. Much more research would need to be carried out on cell size when trying to ascertain spatial similarities at much smaller local scales. In order to promote such a move, the analyses were carried out at a number of different spatial resolutions (grid sizes) in order to evaluate the effects of spatial resolution on the computed fishing activity metric. The effect of spatial resolution on calculated statistics on fishing effort varies markedly with gear type, which is suggested to be due to capturing, or otherwise, the nature of intense fishing in a relatively small number of highly localised areas. For example, the spatial resolution made relatively little difference to data from scallop dredge vessels and beam trawlers, but had much greater effects of the spatial pattern indices of otter trawlers and potters/whelkers. Despite the variability between the gear-types, however, some general recommendations can be drawn from the analysis. Relatively small (<5 %) relative changes in calculated statistics of fishing effort are to be expected for grid sizes of less than 0.2 degrees, and that up to 20% relative changes would be expected up to 0.4 degrees. It is recommended that a spatial resolution of no more than 0.2 degree is appropriate, and that statistics should be computed at resolutions no coarser than 0.4 degrees. In this study, no evidence was found that a grid resolution of less than 0.05 degrees was necessary, which contradicts what was previously reported in the literature (e.g. Lambert *et al*., (2013), Hinz *et al*. (2012)), however these studies focused on single mobile fisheries in much smaller localised areas, so there is still some debate on what grid size is appropriate when we conduct regional scale analysis compared to local scale analysis. It also fuels the debate about assigning different grid cell sizes for each specific gear-type.

The analyses suggest that high-resolution, 2-hourly VMS data, and the analysis methods employed, would be sufficient to detect and quantify the changing nature of fishing effort. In particular, due to the spatial extent of the study area, i.e. regional ICES VII e-h, this 2-hour polling rate is satisfactory. For example, this analysis captured the changing pattern of fishing effort by scallop dredgers which underwent marked shifts in spatial distribution between years. However, in order to detect a displacement in fishing effort caused by closures, appropriate baselines need to be established which quantify the variability in fishing effort, as determined from VMS data analysis methods, which would be expected to occur whether or not a closure takes place. Given the spatial and temporal variability in fishing effort, and the variability among fleets, establishing baseline conditions against which a change due to displacement could be detected and evaluated, needs to be as spatially explicit as possible, which requires high resolution data and appropriate statistics. Developing protocols for establishing baseline fishing effort, and understanding this 'natural' variability, were the subjects of Chapter 4. An MDS analysis was fund to be a very powerful means with which to visualise differences in fishing effort between different gear types. A localised index of spatial autocorrelation, Getis-Ord G statistic, was a very powerful way to capture intensity in fishing effort in a spatially distributed sense, which should be explored by other researchers in future evaluation of fisheries displacement in any context.

In a meeting with the ICES Working Group on Fisheries Spatial Data (WGSFD) (ICES, 2015) participants agreed that the future direction of the WG should be the '*streamlining of the analytical process and development of robust methodologies'* in assessing the spatial effort of fishing activity. This also forms one of the high level recommendations in assessment of fishing effort displacement in section 6.7 at the end of this Chapter, thus illustrating how aligned this thesis is with the objectives of a pan-European WG with key experts in this field. Another key component to data analysis, being taken forward by this WG is the standardising of methodologies across Member States, which is also a key finding of this thesis. The same issues are still arising in data availability, security and coverage, which are discussed in great length in Chapter 2 and 3, and the WG some good suggestions on assessment of data quality, and development of data quality control standards, which this thesis did consider as part of high level recommendations on assessment of fishing effort displacement (section 6.7). What is interesting is that the WG submitted a questionnaire to users of VMS data at the end of 2015 detailing the need for knowledge on methods and software used and this would be a valuable component to the Mitigation Toolkit idea described by de Groot *et al*. (2015) and in fact the first ToR for a potential ICES Study Group on Fishing Effort Displacement (SGFED) (Table 6.1, section 6.5.2).This Chapter and Chapter 4 focused on the types of data which are fundamentally important in the assessment of fishing effort displacement, as stated by the objectives outlined in Chapter 1. It is promising to observe that in the EU Implementing Decision (EC, 2016c), through an evaluation of the framework for the collection, management and use of data in the fisheries sector, a new multiannual programme should focus on what data are required from Member States. Regarding data value, there is also high priority on the collection of social and economic data, which aligns with the findings of Chapter 5.

6.4 Chapter 4

In order to detect and evaluate a change in fishing effort directly attributable to MRE or MPA associated closures, it is necessary to establish baselines by mapping fishing effort. In order to detect, plan for and predict fishing effort displacement due to spatial plans, it is imperative that we develop systematic, repeatable and applicable methods for determining baselines at the smallest possible scale and resolution that are adequate for each gear-type.

A simple, objective means was developed to assess the natural variability of fishing effort, as a baseline against which to assess displacement. This index is the confidence interval of the variation of intensity about the mean fishing effort. Because it is calculated per gear and per location, calculated relative to, and expressed as a percentage of, the mean fishing effort, valid comparisons can be made between gear types, between locations, and over time. Being expressed as a percentage of the mean allows valid comparisons to be made over time, even if the absolute magnitude of fishing effort changes over time. Small values of this index indicate small fluctuations about the mean fishing effort, which is in turn indicative of a regularly fished region, or a preferred (or 'stable') fishing ground. High values of this index indicate highly variable, sporadic fishing effort not indicative of a stable, regularly fished area.

Maps of fishing variability index were prepared, for each gear type classification, for the South West UK region using the same VMS level 3 data from 2005-2008 used in Chapter 3. For each grid cell, the standard error on the mean fishing effort over the period was computed and, assuming a normal distribution of fishing effort in that cell, a coefficient of variation which was expressed as a percentage. It is argued that this is an intuitive metric which is easy to understand, reproduce and extend to any other area and time period where VMS level 3 data are available. Maps were created for each mobile and static gear type, and for mobile and static gear types on aggregate. The analysis could, and should, easily be extended to more years if the data are available (which it was not in this instance).

The distribution of this index for beam trawl strongly follows proximity to port, with greater variability in effort the further out to sea being the general pattern. In contrast, otter trawling occurs in more localised ‘hotspots’ of stable fishing grounds. These hotspots are not clearly visible when looking at the mean fishing maps. Scallop dredging shows very high variability almost everywhere. Unlike with beam trawlers and otter trawlers whose preferred grounds are identifiable from the hotspots of activity of their respective maps, further years of data would be required to assess the preferred fishing grounds of scallop dredgers.

For static gears, the spatial distributions of fishing effort variability were different than mobile gears. Longliners had very stable grounds proximal to southern Cornwall and Devon ports and in general, variability in fishing effort increases with greater distance to port. Gillnetters show a wide variation in both areas fished. Small patches of intense and stable effort are found adjacent to more variably used areas almost everywhere, but this ubiquitous heterogeneity is not observed in the other gear types. This implies that establishing baselines and therefore detecting displacement will not be equally easy for all gear types: some gear types, such as gillnetters, show greater spatial heterogeneity in fishing variability and therefore might need longer time periods over which to evaluate statistics in order to establish both baseline and significant change.

Fishing variability index was calculated for all mobile gears on aggregate and all static gears on aggregate, and compared qualitatively to maps of economic value and gross weight of fish caught by mobile and static gears, respectively, derived from the VMS level 2 data (described in Chapters 1 and 3). The comparison was of different, but overlapping, periods of time (2005-2008 compared with 2007-2010), however the analysis was conducted over the same spatial extent and at the same spatial grid resolution. Overlying contours of fish catch weights or monetary value onto maps of aggregated fishing effort variability index revealed coherent spatial patterns: as expected, those stable grounds that are fished frequently (with low variability indices) also tend to yield higher catches, in terms of both liveweight tonnage and economic value. Those ground with less stable, perhaps less reliable, fishing (with high variability indices) yielded less catch. This analysis bolsters the plausibility of the variability metric presented here, insomuch that it captures fishing effort that helps explain trends revealed by an independent data and set of metrics (fish catch weight and value). As a rule of thumb, it was revealed that catches over 1 tonne per unit time and greater than 1000 pounds sterling were concentrated in areas where the variability in fishing effort had a coefficient of variation of less than 240%. This pattern was broadly the same for both mobile and static fishing gears. Further analyses in other areas and time periods might prove this relationship to be sufficiently general that specific thresholds of fish catch statistics could be used as proxies for specific thresholds of fishing effort. It is suggested that proxies such as this could be useful in situations where access to level 3 VMS data are restricted – level 2 data in this case (aggregate catch data) can be used as a broad-scale proxy for variability in fishing effort, which would otherwise only be gleaned using (access-restricted) level 3 VMS data. Relationships such as these might also act as inputs to predictive models of fisheries behaviour, to allow modelling of displacement using simple data-driven scenario-based analysis. For these reasons, given the sensitive nature of high-resolution VMS data and the limited utility of lower-resolution data in assessing gear-specific, time-specific, trends in fishing effort, it is suggested that future work should explore any further relationships between indices that can be estimated using low-resolution level 2 VMS data (with less access restrictions) that could be used as proxies for fishing effort otherwise only revealed by higher-resolution data.

Another potential proxy for, or explanatory variable for, seabed substrate could be fishing effort. The co-variation of substrate type and fishing effort per gear type was investigated qualitatively, and quantitatively using a General Linear Model (GLM) analysis. Qualitatively, for static gears, the relationships with substrate are most obvious: the gillnetting and potting and whelking fleet concentrated significantly on rocky areas. Longlining activity per unit area was highest over mud, however high values were also observed on mixed sediment and rock. For mobile gears activity per unit area of substrate type varied considerably; in general, scallop dredging occurring on mixed sediment or mud, and beam and otter trawling mainly in muddy areas with high coverage per unit time in mixed and sand respectively, but there was large variability in these trends. The GLM revealed that substrate was generally a poor explanatory variable for fishing effort. This might be due to the mismatch in spatial resolutions between the substrate information (approximately every 300 m) and the fishing effort (every 3 nautical miles).

As described in section 6.1.1, important changes to Fisheries Control Regulation 1224/2009 may potentially be underway after an extensive consultation period (EC, 2016a). This Chapter illustrated the need for appropriate baseline data, and the outcomes of this analysis in this Chapter were akin to a type of 'risk analysis approach' using different metrics to assess the variation in fishing effort per gear-type over time. One potential area of assessment in this new consultation is the identification of new instruments to ensure the implementation of the CFP. Within the draft statements is '*The first main thrust in this context is the introduction of a systematic risk analysis approach and the introduction of a comprehensive* *traceability system as the basis for fisheries control. The new approach aims at making the best possible use of modern technologies. In particular data have been automated as far as possible and are subject to comprehensive and systematic cross-checks with a view to identifying areas where there is a particularly high risk of irregularities'.* This further reinforces the significance of the methods developed in this Chapter, i.e. the risk of effort displacement due to different conservation or MRE developments and their importance in informing this consultation.

6.5 Chapter 5

One of the first questions in the survey for fishers (Appendix 1, Q 2) was the identification of the barriers to progress with regard to the co-existence of marine renewables and fisheries. One of -the major themes emerging as a barrier to progress was the displacement of fishing effort or loss of access. Priority issues identified in order of importance were: displacement of fishing effort or loss of access, cable disturbances to fishing grounds and fish populations, the timings of installation/repairs, negative effects on the seabed and specifically OWF siting.

The consultation process caused a lot of discontent among fishers across all gear-types and regions. The three top themes identified were: the process being completely inadequate or not fit for purpose, a feeling of disconnection with management and lack of inclusion in decision making and the lack of the inclusion of FK in planning. Fishers identified incentives as an important part of mitigation strategies. Initial validation of a mitigation agenda developed by de Groot *et al*. (2014) highlighted themes of lack of trust in relation to trans-boundary issues and Member States, data management and confidentiality issues and inherent problems with the consultation process that fishers felt did not include them. A Lack of understanding, process fatigue and uncertainty in funding themes emerged when validating how an improved collaborative effort between fisheries and MRE would work as part of the mitigation agenda.

In order of importance: the increased use of FK in planning and management, better informed siting of MREIs and vulnerability of stocks were the three areas that fishers felt scientists should focus their research upon. The response rate of the importance of gathering FK was high and fishers felt this data source was an important element of trying to assess impacts on the fleet due to MRE. An initial framework for the collection and application of FK remains was developed.

6.5.1 Consultation process: A new dawn?

Considering the investment in marine renewable energy, it is somewhat disillusioning to be gaining responses from fishers on how the consultation process is still inadequate, six years after initial COWRIE work established that early and continued engagement with the fishing community was essential in order to secure success for the life cycle of MRE developments. Further work must be carried out in order to: determine what aspects of this process do not work, examine success and failures across MRE and conservation and examine best practice examples in order to ascertain what can be changed. Chapter 5 has presented initial ideas on how the consultation could be improved through innovation, incentives and working examples. Investing in technology and engagement techniques for the consultation process has been identified as the best way forward. The use innovative tools such as interactive smart pads with mapping software e.g. Alexander *et al*. (2012) used in initial marine spatial planning solutions in response to proposed MRE development in the Mull of Kintyre is one of the best examples of innovative technology. Giving fishers the tools with which to become more informed about the objectives of other ecosystem services such as MRE and conservation has been identified as a priority, using examples from freshwater conservation and engaging the public (Cooke *et al*., 2013), such as formal teaching methods and development of training manuals that scientists have a direct input in. The importance of charities like Fishing into the Future (FiTF) collaborating with Seafish, scientists and fisheries managers which have been discussed at length in Chapter 5, section 5.4.4 is also part of this innovative engagement and consultation process. In summary[11]: FitF are working with an industry led Steering Group consisting of active fishers along with scientists, processing and retail and government representatives *'Focusing on sharing knowledge, key outcomes include a comprehensive scheme for UK fishermen to contribute data into the science which underpins fisheries management; training and education initiatives ,including broadening the scope of skippers' training to include fisheries biology, management and marketing, and establishing regional knowledge exchange workshops for fishermen and other seafood industry businesses'*. These are really great strides forward to achieving full representation of fishers in the consultation process, which was highlighted in the mitigation agenda by de Groot *et al.* (2014).

6.5.2 Establishment of an International Council for the Exploration of the Sea Study Group (ICESSG) on fishing effort displacement: Suggested Terms of Reference (ToR)

Finally, the study aims to stimulate debate on whether there should be an ICES SG on fishing effort displacement (SGFED). This SG could be organised within the Working Group on Marine Renewable Energy (WGMRE), or the Working Group on Spatial Fisheries Data (WGSFD) alongside the Strategic Initiative on the Human

[11] http://www.seafish.org/about-seafish/blog/2013/7/29/fishing-into-the-future

Dimension (SIHD). This thesis has shown that assessment of fishing effort displacement is complex, and the variety of data sources required to quantify it and the impacts of it, involves the human dimension and data sources such as FK, thus the SG would have to be aligned between the WG's shown above. Table 6.1 below makes an attempt to generate ToRs for this potential SG.

Table 6.1 Table showing ToR Descriptors for the Study Group on Fishing effort Displacement (SGFED)

ToR	Description	Background
a	Provide summaries of data sources to assess fishing effort displacement. 'Horizon scanning' to identify future data sources	1) Science requirements: The science community need to be updated on what sources of data are valuable 2) Advisory requirements: Advice to WGMRE and SIHD
b	Report on methods and tools that are being developed by research teams across the EU/ globally considering cumulative impacts and application of risk-based approaches Horizon scanning to identify future methods	As above
c	Identify cross-sectoral issues of MRE with MCZs, co-location	As above
d	Foster strong collaborative working relationships with other ICES groups but also research groups across EU/Globally	As above
e	Manage NERC Portal Mitigation Toolkit	As above

6.6 The potential of the 'mixed method approach'

VMS data remains one of the most powerful information sources for analysis of fishing activity; however, there is room for improvement, such as including smaller vessels, of which is being progressed slowly through the I-VMS project (Chapter 2), and facilitating easier access to the data for researchers and spatial planners across EU Member States. Since 2009, changes to access to VMS, and the level of resolution available due to EC Council regulations as described in detail in Chapters 2 and 3, changes which have affected this study, may prove severely disadvantageous for accurate assessment of fishing fleet activity and the consequences of displacement for these fleets, may have societal implications (Hinz *et al*., 2012). However as described in the above sections in this Chapter: consultations are underway in order to assess Fisheries Control Regulations (EC, 2016a) and proposed changes to data collection methods 2017-2020 are currently being discussed in EU Parliament (EC, 2016c), the elements of which are the basis of EC Regulation 199/2008 (EC, 2008c). This is promising in terms of pushing the data needs agenda in relation to assessment of fishing effort displacement, because as stated in the proposal '*The new streamlined rules will pave the way for gathering more and better data to help close persistent gaps in our knowledge. They will give scientists and decision-makers a better idea of how fisheries are affecting marine and maritime ecosystems'* (EC, 2016b).

As described in Chapter 1, the consultation of the second tranche of MCZs in the UK has now closed. In comparison to the results on the first consultation and designation of MCZs in 2013, the fishing industry has hailed this second tranche site selection and consultation a success due to the fact that they believe this time it is a process "based on building a solid knowledge base on which to make these important decisions" (Barrie Deas, Chief Executive NFFO, pers. comm., January, 2015). This knowledge base equates to robust, high resolution data and the fishing industry must become more involved in provision of its data, analysis and interpretation given the fact that some MCZ proposals in the South West and Irish Sea are still being deferred mainly due to issues of fishing effort displacement.

As detailed in Chapter 1, given the high level of potential resources for MRE in the South West and forecasts showing that the MRE industry by 2030 will be 5 times the size of the fishing industry (PMSS, 2010a, 2010b), and in an area of highly productive commercially important seas, it is imperative that data access and sharing becomes a much higher priority than it currently is, and it will take much better communication and engagement between the actors involved than currently exists. Another way of eliciting important data are the use of social science techniques, and the design of semi-structured interviews to gather information on general aspects of their trips at sea and their opinions and perceptions on priorities, challenges, barriers and perception of impacts due to closures for, in this case marine renewable energy (MRE) and producing semi-quantitative value maps, e.g. ScotMap (McLay *et al*., 2012) which can be used to assess fine scale changes in fishing effort.

6.7 Further work and high level recommendations on assessment of fishing effort displacement

Further clarification of any effects of gear-type and geographical location on fisher response must be achieved. The small number of fishers interviewed and the fact that more thematic analyses have to be performed means that results are indicative rather than conclusive. A lack of access to high-resolution gear-specific fisheries data raises scientific and socio-economic concerns about the underpinning of ongoing marine spatial management decisions. Given the rapid current 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 that gear-specific

VMS and other high resolution fisheries data are made available and used in conjunction with each other to predict and plan for the likely effects of spatial restrictions on fisheries.

One such company making waves in fisheries data capture and analysis are Succorfish**.** Gaining access to trial data in Lyme Bay that is involved in I-VMS is a priority. Individual fishers are trialling an app that has the capacity to store meta-data about each trip as well as a larger suite of environmental data. The vessel also operates a 2 minute ping rate, out-performing the standard 2 hour ping rate. This has the potential to revolutionise assessing fisheries displacement, as it operates on the smallest scale possible and can provide information on individual fisher behaviour across a range of time scales, which then can be rescaled to sector level and then fleet level to enable the input of more precise data in order to train current models in use is the assessment of fisher behaviour. It would be prudent to elucidate further responses from fishers, or an extension to the original questionnaire in this study (Appendix 1) in order to further validate a mitigation agenda developed by de Groot *et al*. (2014) and gain insight into the value and application of fishers' knowledge (FK). Perhaps an even greater priority is to assess the actual impact of the MREKE Programme outcomes and mitigation agenda on each of the actors involved. There is also the idea to perform research on development of performance monitoring and assessment of spatially and temporally explicit data. This thesis does not deal with cumulative impacts of displacement, there must be research into the development of a suite of tools that are fit for purpose, i.e. are designed with fisheries displacement in mind but which is not currently in place;

One of the themes in both mitigation and research priorities is trans-boundary issues. A funding call via INTERREG Europe 2014-2020 with the first round of proposals mid-summer brings a chance for collaboration between Member States on the issue of fishing effort displacement in a shared sea space.

As a final conclusion to this thesis, there needs to be some high level recommendations about the assessment of fishing effort displacement. This subject is complex and throughout the development of MRE, there has been conflict between the fisheries industry and MRE, and considering the UK will have to reach its target to produce 33 gigawatts from marine renewable sources by 2020 (United Kingdom House of Lords, 2008). Due to the nature of MRE developments underway and updates to rMCZ designations, the recommendations below in some way contribute to the need for this joined up approach between stakeholders to provide a cost-effective means of collecting more extensive baseline data (Chapter 4) (MMO, 2013).

- Data access changes: Firstly, changes need to come from the top down, but they need to be a discussion from the bottom up. Data access policy from the EU has got to change. As discussed in section 6.2-6.3, there are underway a suite of consultations on Fisheries Regulation and data collection in the EU, but in order for actual changes a lot more collaboration is required between scientists working with individual fishers, fishing associations or create new focus groups within each region in order to provide evidence to the ICES Groups, who in turn provide advice to OSPAR for example. The impetus is there, this thesis has captured the attitudes, perceptions and suggestions from fishers, and the fact that loss of grounds is a priority issue for most of the fishers interviewed, means that meaningful spatial and temporal analyses have to be performed. There also has to be some method of MRE developers having to release their data, this was discussed during the MREKE Programme, but no further action has been taken. The level of physical data that MRE developers hold is immense, and the data collected is quite large, why are we duplicating research effort and spending funds that could otherwise be channelled somewhere else.

- Funding: There has to be some investment in initiatives such Fishing into the Future (FitF) which was discussed at length in Chapter 5,section 5.4.4, who train fishermen and provide them with educational opportunities, and there has to be investment in the design of a new consultation process. There may be a way of MRE developers funding providing much needed investment here considering the cost of projects, after all it is in their interest to work on the ground with fishers due to the fact that displacement of fishing effort, or underestimation of effort can impinge on a projects development. This funding issue needs to have a long-term vision
- NERC MREKE Programme, Fisheries and MRE Displacement Working Group (WG): Firstly, there needs to be an evaluation of the impacts of this WG on the 34 invited participants across both the fishing and MRE industry, fishing associations, conservation practitioners and scientists in order to produce outputs. This was the first and only of its kind in the UK. Due to funding, there has not been any development. This WG had three workshops, a report and publication, and much more engagement needs to occur. This WG has the potential to contribute greatly to the suggested ICES WGFED detailed section 6.5.2 and as the first organised WG of its kind, has also the potential to need to continue to exist, facilitate, provide workshops and conduct research for the life cycle of MRE developments.

- Capacity building: There has to be a priority to equip fishers with the knowledge of scientific methods and training in order to foster better awareness of other ecosystem services. Assessment of fishing effort displacement has to be a stakeholder led endeavour, due to the importance of fisher sources of data, i.e. FK which is discussed at length in Chapter 5. Fishing into the Future (FitF) as described in Chapter 5, section 5.4.4 are only one charity who are doing just that, however the key word here is charity, and that means needed investment. Under this term capacity building, there must also be an attempt to provide enough training so that fishers can be employed as consultants, liaison officers for example and work alongside managers and scientists.
- Methods: Lee *et al*. (2010) made the first attempt to standardise VMS analysis, and others across Member States have conducted the same analysis, and developed their own, have however not much development of methods specifically for fishing effort displacement has occurred since. This needs to change, and begin standardising other methods and steps are currently being taken by the ICES Working Group on Fisheries Spatial Data (WGSFD) (ICES, 2015).
- Collaboration: There has to be a drive for the fostering of more strategic collaboration, between research groups across member states who are involved in the analysis of fishing effort displacement. An idea would be to hold a meeting, or conference as a potential Kick-off event, perhaps through ICES channels.
- NERC Mitigation Toolkit: It has been discussed throughout this thesis, but this is very important. There is no one data, methods, best practice and advice

repository that includes submission of relevant items by both MRE and fishing industries, conservation practitioners and scientists. Underpinning this is the discussion on the development of data protocols and data quality controls as we are still dealing with sensitive data, and this conversation has to occur now. Discussed in section 6.2-6.4, a new Danish initiative DISPLACE model has aspects of what this repository would look like, but overall it is a sharing platform. Funding is needed in order to employ individuals to begin work on this.

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Appendix 1: Questionnaire

MARINE RENEWABLE ENERGY WITH PLYMOUTH UNIVERSITY

Marine Renewable Energy Knowledge Exchange Programme (MREKEP)/ NFFO Fishing Energy Survey

I am working on a national project funded by the Natural Environment Research Council (and SEAFISH / NFFO) to find out the main issues concerning how renewable energy developments affect fishing and the best course of action to solve the problems that are identified.

This short survey is being conducted with individual fishermen and fishing representatives around the coast of the UK. We aim of collect views from each region to the central questions that will be discussed and reported to government, industry (fishing and renewables) and planners. I would like to develop this questionnaire once I have analysed all the responses, I aim to conduct further research and would hope that I could contact you again regarding this also.

We have already led a workshop in Orkney and an expert panel in York. One of the main issues that had come up already is that fishermen do not have the time and support from a large company or organisation to attend these national meetings. This leaves decisions being made in isolation from the local fishermen who are affected most. Our aim is therefore to record your views alongside other fishermen around the coast of the UK, in order to have greater representation in this project.

The survey is being led by Plymouth University. As part of the ethical procedure followed by the university the information you provide will be reported anonymously, each survey will be allocated a number and date so it can be identified if you wish to withdraw the information you provide at a later date.

Please contact me at **maria.campbell@plymouth.ac.uk** or phone **07814745926** if you have any concerns or wish to withdraw the information you provide in the future. Once the survey is completed and we have not heard from you by 31st September 2014 we will assume you are happy to have your views included (anonymously aggregated with all other interviewees) in the final report.

ID No:
Date:

Respondent details

How many years have you been fishing?

Which areas do you fish the most (general locations such as Bristol Channel, within twenty miles of Hayle etc.):

Where is your home port?

What gears do you use and in which seasons? What species?

	Spring	Summer	Autumn	Winter
Gear				
Species				

Is your vessel over or under 10 m?

How old is the vessel?

Are you a vessel owner or company skipper?

Gender: Male O Female O
Age: 18-30 O 31-40 O 41-50 O 51-60 60+ O

Fishing and Energy developments:

1. What are the **priority issues** to aid the co-existence of marine renewable and fisheries? (i.e. What issues have you encountered related to the interaction of marine renewables and fishing industries).

2. What are the **barriers to progress** with regard to the co-existence of marine renewables and fisheries?

3. How can we **mitigate problems** associated with marine renewables and fisheries? What mitigation strategies would be best suited to aid local fisheries (i.e. funding stock enhancement, better research of construction and operation effects, siting developments more carefully in relation to fishing grounds)

4. What are your thoughts on the **consultation process** with regard to new marine renewable developments?

Interaction of marine renewables and fishing industries

5. If you could choose three research topics or projects to aid fishing and renewable energy development co-existence, what would they be? Why?

i. …………………………………………………………………
ii. …………………………………………………………………
iii. …………………………………………………………………

6. Which one of these three would you consider to be the most important?

Effort Displacement:

Displacement of fishing effort has been raised in the initial project meeting and also by SEAFISH and NFFO as a major issue (whether fishermen forced to lose existing grounds or new additional effort appearing in remaining grounds). The following questions are intended to record your views on this subject.

7. How do you think you will personally be interacting with the marine renewables industry?

8. Do you think your fishing activity will be affected by the marine energy industry?

9. If yes, how do you think you will be affected? (e.g. either by losing ground or new boats entering the grounds you currently fish)

10. What suggestions do you have to reduce the negative effects of displacement?

11. What are your thoughts on a mitigation agenda developed by NERC MREKE Programme?

Thank you very much for your participation in this scoping survey. Are there any other issues that you would like to raise? Could you recommend anyone else that I could contact regarding this research?

Name……………………………………..

Telephone……………………………….

Email……………………………………..

Do you have any comments on the interview that you would like to add?

……………………………………………………………………………………………………
……………………………………………………………………………………………………

Appendix 2: Statement of contribution to co-authored papers

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

Maria S. **Campbell**[a,b], Kilian M. Stehfest[c], Stephen C. Votier[d] and Jason M. Hall-Spencer[a]

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This paper was written by me, with written and GIS contributions by Kilian Stehfest under the supervision of Professor Jason Hall-Spencer and Dr Stephen Votier. This paper combines analyses from Chapters 3 and some elements of Chapter 4 of the thesis, and provides not only one of the most comprehensive spatial and temporal analyses of fishing effort in the South West of the UK using gear-specific Vessel Monitoring System (VMS) data, but also one of the first detailed analysis of risk of effort displacement due to marine conservation and marine energy. Dr Victor Abbott from my supervisory team, an anonymous reviewer from one of my research groups, the Centre for Marine and Coastal Policy Research (MarCoPol) and an additional anonymous reviewer provided comments of drafts of this paper. This paper was published in the journal Marine Policy in 2014.

Investigating the co-existence of fisheries and offshore renewable energy in the UK: identification of a mitigation agenda for fishing effort displacement.

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This paper was a concerted effort under the NERC funded MREKE Programme. The paper is a synthesis of scoping workshop and questionnaire in Orkney, and an expert panel held in York. It was written overall by Jiska de Groot but with equal writing content by me as second author under the supervision of Dr Lynda Rodwell. The publication identifies as three key priority areas for this agenda: developing efficient and cost-effective mechanisms for overcoming data aresues for assessment of fishing effort displacement; the development of appropriate methods of assessment; and the development of an acceptable consultation protocol between MRE and fishing sectors agreed on by all stakeholders. Two anonymous reviewers commented on drafts of the paper. This paper was published in the journal Ocean and Coastal management in 2014.

Marine and coastal policy in the UK: Challenges and opportunities in a new era

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p Natural England, Pydar house, Pydar Street, Truro, Cornwall TR1 1XU, United Kingdom

This paper was written by Dr Lynda Rodwell, and each co-author contributed a section and summary highlight from their presentation. The paper was the product of the UK's first Marine and Coastal Policy Forum, and is the introductory paper in a

Special Issue from this forum. In this introductory paper the global context of marine policy changes and the themes which emerged from the forum, forming the basis of the articles in this special issue, are outlined. I was the coordinator of this forum and assisted on all drafts. Two anonymous reviewers commented on drafts of the paper. This paper was published in the journal Marine Policy in 2014.

Priority questions to shape the marine and coastal policy research agenda in the United Kingdom.

Siân Rees[a], Steve Fletcher[a,b], Gillian Glegg[a], Charlotte Marshall[c], Lynda Rodwell[a], Rebecca Jefferson[d], **Maria Campbell**[a,e], Olivia Langmead[a], Matthew Ashley[a,f], , Helen Bloomfield[g], Daniel Brutto[h], Andrew Colenutt[i], Alexandra Conversi[a], Bob Earll[j], Imman Abdel Hamid[k], Caroline Hattam[f], Simon Ingram[a], Emma McKinley[l], Laurence Mee[m], Jenny Oats[n], Frances Peckett[o], Jim Portus[p], Martin Reed[a], Stuart Rogers[q], Justine Saunders[r], Kylie Scales[s], & Russell Wynn[t].

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t National Oceanography Centre, Southampton University, European Way, Southampton, S014 3HZ.

This paper was written by Siân Rees and was the result of a workshop held at the UK’s first Marine and Coastal Policy Forum in 2011. Thirty four priority research questions within six broad themes were identified by delegates who attended the 1st marine and coastal policy Forum, hosted by the Centre for Marine and Coastal Policy Research at Plymouth University in June 2011. I and six members of the research group analysed the responses to the workshop and synthesised them. Two anonymous reviewers as well as myself and others in the research group commented on drafts of the paper. This paper was published in journal Marine Policy in 2013

The design of Marine Protected Areas on High Seas and Territorial waters of Rockall.

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This paper was written by Professor Jason Hall-Spencer. Both Marta Soffker and I performed all the analyses and I prepared all the figures. I also wrote a section about the coral data used and commented on all reviews. Two anonymous reviewers also commented on the manuscript. The paper summarise how remote fisheries closures were designed to protect *Lophelia pertusa* habitat in a region of the NE Atlantic that straddles the EU fishing zone and the high seas. This paper was published in the journal Marine Ecology Progress Series in 2009.

Appendix 3: Published papers and presentations

Campbell, **M**. **S**., Stehfest, K. M., Votier, S. C. & Hall-Spencer, J. M. (2014) Mapping fisheries for marine spatial planning: gear-specific vessel monitoring system (VMS), marine conservation and offshore renewable energy. *Marine Policy,* **45**: 293-300.

de Groot, J., **Campbell**, **M**., Ashley, M. & Rodwell, L. (2014) Investigating the co-existence of fisheries and offshore renewable energy in the UK: Identification of a mitigation agenda for fishing effort displacement. *Ocean and Coastal Management*, **102**, 7-18.

Campbell, **M**., de Groot, J., Ashley, M. & Rodwell, L. (2014) The Fisheries and Marine Renewable Energy Working group: Creating an agenda for improved co-existence. In, *5th International Conference in Ocean energy (ICOE)*, Halifax, Nova Scotia, Canada, 4-6th November 2014.

Rodwell, L., Fletcher, S., Glegg, G. A., **Campbell**, **M**., Rees, S. A., Ashley, M., Linley, E. A., Frost, M., Earll, B., Wynn, R. B., Almada-Villela, P., Lear, D., Stanger, P., Colenutt, A., Davenport, F., Barker-Bradshaw, N. J. & Covey, R. (2014) Marine and coastal policy in the UK: Challenges and opportunities in a new era, *Marine Policy*, **45**, 251-258.

Rees, S., Fletcher, S., Glegg, G., Marshall, C., Rodwell, L., Jefferson, R., **Campbell, M.**, Langmead, O., Ashley, M., Bloomfield, H., Brutto, D., Colenutt, A., Conversi, A., Earll, B., Abdel Hamid, I., Hattam, C., Ingram, S., McKinley, E., Mee, L., Oats, J., Peckett, F., Portus, J., Reed, M., Rogers, S., Saunders, J., Scales, K. & Wynn, R. (2013) Priority questions to shape the marine and coastal policy research agenda in the United Kingdom. *Marine Policy*, **38**, 531-537.

Hall-Spencer, J. M., Tasker, M., Soffker, M., Christiansen, S., Rogers, S., **Campbell, M.** & Hoydal, K. *et al*. (2009) The design of Marine Protected Areas on High Seas and Territorial waters of Rockall. *Marine Ecology Progress Series*, **397**: 305-308.

Journal Publications

Mapping fisheries and assessing displacement due to closures for the purposes of marine conservation and marine renewable energy using gear-specific Vessel Monitoring System data in the South-west of the UK

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Abstract

Vessel Monitoring System (VMS) data from 2005-2008 in ICES areas VII e-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, in terms of all marine activity on the planet. We analyzed the distribution of the UK fleet of large

(>15 m length) fishing vessels and, as expected, found clear gear-specific temporal and spatial differences in activity. Mobile demersal gears had the highest intensity and widest distribution of activity in the study area, and so these gear types might be expected to have the most widespread effects on ecosystems of this region. We describe 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). Our maps indicate that if the mobile demersal gear fleets were excluded from these proposed closures they would be little affected but if the static gear fleets were excluded this would likely result in displacement of certain vessels and increase fishing pressure on other rocky grounds and other fishers who use these areas. Predictions concerning the effects of fisheries displacement can be improved through the use of high-resolution gear-specific activity data. Our study shows that VMS can provide an invaluable source of such data, provided that gear information is made available to fisheries managers and to scientists.

Keywords: Marine protected area, marine renewable energy, marine spatial planning, gear type, displacement, vessel monitoring system.

1. Introduction

Over the last 20 years, management approaches have shifted from the conservation of species to the more holistic management of spaces to help reduce damage to ecosystems and the goods and services they provide [1,2,3,4]. 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 by the year 2012 [5,6,7], however progress has been slow and we now look to the year 2020. In addition, the world's oceans are increasingly being tapped as a source of renewable wind, tidal and wave energy [8,9,10,11] 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 to produce 33 gigawatts from marine renewable sources by 2020, meeting the EU target of supplying 20 % of its gross consumption of energy from marine renewables 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 offshore marine renewable energy and designation of marine protected areas are two rapidly emerging demands on marine space that compete with use by certain types of fishing activities [9,15] and are likely to alter spatial patterns of fishing activity. In examples from the North Sea and Baltic cod fishery, beam trawling, could be forced to concentrate activity onto smaller grounds, leading to increased competition, reallocation of activity and lower catch [16, 17]. To resolve conflicts, marine policymaking 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]. This is intended to help managers optimize 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]. Decision support, i.e. types of data, information and tools needed to facilitate advancement of MSP was identified, and key to this; high-resolution spatially and temporally accurate information on the various activities taking place in the marine environment [26, 27].

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 respectively, 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 identity, position every two hours to a Fisheries Monitoring Centre [31]. Vessel speed values were included from 2005. From 1st January 2012 vessels > 12 m 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 greatly improve the assessment of fisheries impacts. Such work has considerable implications for management, as different fishing sectors have specific responses to different management measures e.g. closures.

Here, VMS data are used to provide an overview of the distribution of fishing activity by gear type in ICES areas VII e-h (Fig. 1a), which borders the coasts of Ireland, the UK and 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]. Descriptions are provided of how two potential fisheries closures may affect the distribution of activity of both static and mobile gear users. Investigations are made of the potential effects of displacement and the influence of bathymetry and seabed type on fisheries activity. 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 km2 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 the formation of 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 for all UK registered vessels >15 m in length that were active in ICES areas VII e-h in 2005-2008 were obtained from the Marine Management

Organisation (MMO), formerly the UK Marine and Fisheries Agency. Access to post 2008 data was not available in the same high-resolution format as earlier data. 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 together with 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 which conform as close as possible to European Union level 3 and 4 Data Collection Regulation (DCR) [EU 2008a, EU 2008b] [50,51] considering the level of data made available for this study.

2.2 Fishing activity analyses

2.2.1 VMS

VMS data analysis followed the recently established approach for estimating fishing activity by Lee et al. [43]. In summary; removal of records without an associated gear type, within 3 nm of ports and duplicates occurred, the interval between each successive record calculated and a speed based rule of 1-6 knots was applied to identify actual fishing activity for all gear types. A point summation method followed, using a grid cell size of 0.05° or 3 mins, the resolution to provide fishing data to inform marine spatial planning in the UK [44]. Fishing activity in each of the ICES areas VII e-h was calculated separately, the reasoning being that the dataset provided meant that as each vessel moved between ICES areas the unique identification number changed and without access to logbook information or other higher level information, it would have been impossible to know which vessel this was, causing potential over representation of activity. All analyses were performed using Mathworks programming software, MATLAB 12.

To quantify the differences in spatial patterns of fishing activity between gear types and within same gear types 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 VII e-h was one. To compare, the absolute differences in proportion of activity in each cell were calculated, summed for ICES VII e-h then divided by 2, resulting in an index of difference in spatial pattern varying from zero to one, i.e. zero representing identical spatial fishing patterns in the same cells and one representing no activity in the same cells [43].

2.2.2 EU defined fleet effort analysis

Fishing effort of fleets is defined in the Basic Regulation of 2002 (Article 3(h)) [52] as capacity * activity. Capacity is measured in terms of the size of vessels gross tonnage (GT) or engine power (kW) and activity commonly measured as the period of time in which a vessel is active, i.e. days at sea. In this study, we presented capacity as number of vessels, which is an accepted, albeit rough method, GT or kW was not made available for this study. Each ICES area VII e-h were analysed separately.

2.2.3 Fishing activity and marine landscapes

The distribution of fishing activity with respect to 5 marine landscape types derived from UK SeaMap data [53].   The 5 categories were; sand, mixed sediment, coarse sediment, rock and mud. Fishing activity and not fishing impact on seabed was assessed here, thus average number of fishing hours per 1 km2 of the different marine landscape was calculated. The region, ICES VII e-h was analysed as a whole.

3. Results

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 for mobile gears ranging from 0.2698 to 0.5151 (Table 1). For the static fleet, similar consistencies were observed for both potting and whelking and gillnetting from 2005-2008, ranging from 0.3837 to 0.5025 and in longlining from 2005-2006. However, for the longlining fleet, spatial patterns from 2006-2008 ranged from 0.6629 to 0.721, indicating perhaps a slight shift in spatial distribution from the previous year. Patterns of fishing activity between pairs of gears ranged from 0.8472 to 0.9979, indicating the heterogeneity in activity as discussed briefly above (Table 2), although some lower values were observed between beam trawling and scallop dredging across all years ranging from 0.6089 to 0.6832, possibly indicating a slight overlap of fishing activity.

Fishing effort of the fleets as described by (Table.3), showed some very interesting results with Wave Hub, ICES VII f, representing an area with some of the highest potting and whelking effort, as well as gillnetting, although some heterogeneity occurred from 2005-2008. Ices VII e represented the highest scallop dredging effort. Haig Fras, ICES VII g also represented high fishing effort values for gillnetting and longlining, in comparison to other fishing gears in the area. Beam trawling and otter trawling are widespread throughout the study area with highest effort in ICES VII e and f.

Fishing with mobile gear was more widely distributed (Fig. 2a, e, f) with beam trawling occurring over the largest part of the study area (Fig. 2e) but also widespread otter trawling (Fig. 2f), whereas static gear fishing was focused in fewer areas (Fig. 2b, c, d). For static gear, in particular, the potting and whelking fleet, this pattern is clearly linked to the availability of suitable marine landscape type (Fig. 3), with fishing activity concentrated on rocky areas (Table 4), which covered the smallest percentage of the study area (Fig. 3), but also to a certain extent gillnetting (Table 4). Longlining activity per unit area, was highest over mud 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 mixed sediment or mud, and beam and otter trawling mainly in muddy areas 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 southwestern corner of the study area was a hotspot for gillnetting and longlining. Furthermore, Hurd's Deep (49º 30' N: 3º 34' W), a narrow channel at which depths drop below 100 m to the North of Jersey is targeted by beam trawling.

4. Discussion

Vessel Monitoring Scheme data from South-west 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 gear type is not analysed then useful information (e.g. 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 offshore marine protected areas, designed to minimize 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. Our 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, but could be improved if higher level data were available (for example, [43,44]. This is particularly important in areas such as South-west UK as this area currently harbors most of the UK fishing fleet [54].

The effects of fishery closures (e.g. for nature conservation or 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 and to a certain extent demersal otter trawling. This sector of the fleet exploited such large areas that effects 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 South-west 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 jeopardized” (NFFO pers. comm., July 2012). On the other hand, 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 our study, VMS analyses showed that longlining activity, and to a lesser extent gillnetting activity, was 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. 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 [9,58]. There are caveats associated with the marine landscape analysis. There are no doubts as to the value of the analysis as a broad brush approach, i.e. ICES areas VII e-h as a whole, however, a finer scale analysis would be needed to assess the seasonal movements of the fleets and as we cannot take into account vessels changing gear, then these issues which do need to be addressed. Further analysis, by using the methods of defining fishing grounds to assess, not only space allocation by various fleets [44] and impacts of various fleet activities on the seabed [59,60] would improve this current 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]. Our VMS dataset indicates only modest longlining activity in the region but high levels of bottom trawling with discards that likely benefit certain seabird populations in the region [65] given that individual seabirds adjust their foraging behavior 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' behavior is altered and fishing activity displaced.

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 of MPAs and marine renewables to concentrate impacts into smaller areas [42,47,74-77].

Marine reserve planners and renewable energy developers are increasingly using multi criteria decision analysis tools such as Marxan to optimize site selection [78-81], as this allows consideration of a variety of different spatially explicit selection objectives. While the main consideration is the distribution of the natural resource in question, the inclusion of gear-specific high-resolution fisheries data can minimize environmental costs of closures incurred by activity displacement [82], minimize the effects of accidental bycatch, discarding and trawl damage and increase the economic benefits of closures to fishers [83], 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 trialed throughout the EU, and 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 Conservation Authorities (IFCAs) will lead the way for fine scale inshore fishing analysis. Data on non-UK vessels was not made available for our study, however concerns over inaccuracies in this data in particular the lack of gear type provided [43], meant that it could not have been used. 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. The analyses are based on records that are transmitted every 2 hours, and there are risks in production or errors or misclassification of fishing vs. non-fishing and in 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. In this analysis a point summation method is used as it is deemed more transparent but underestimations of activity are a 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 hour polling frequency is an issue [44]. In terms of track reconstruction, recent work has helped improve VMS analysis using cubic Hermite splines for beam trawl [86] and subsequently other gear types [87]. In the case of reducing VMS polling frequency, seminal work by [45] has suggested 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 but a reliance on these data could underestimate fishing activity if fishing activity falls between VMS records, typically sent every 2 hours. 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, treacherous terrain or to reduce fuel costs [88] or local or sectoral differences in fishing speeds of individual vessels or at fleet level may occur [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 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].

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 rapid current 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 that gear-specific VMS and other high resolution fisheries data are used to predict and plan for the likely effects of spatial restrictions on fisheries.

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Tables

Table 1. Indices of relative difference in spatial pattern within gear between 2005 and 2008 Lee *et al*. 2010 [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 Lee *et al*. 2010 [43].

2005	Dredge	Longline	P/W	Gillnet	Beam	Otter
Dredge	0	0.9393	0.9319	0.9009	0.6832	0.8576
Longline	0	0	0.9717	0.7746	0.8956	0.9378
P/W	0	0	0	0.9733	0.8728	0.9179
Gillnet	0	0	0	0	0.8129	0.8472
Beam	0	0	0	0	0	0.8606
Otter	0	0	0	0	0	0

2006	Dredge	Longline	P/W	Gillnet	Beam	Otter
Dredge	0	0.956	0.8966	0.9152	0.6261	0.852
Longline	0	0	0.9939	0.8698	0.8987	0.9659
P/W	0	0	0	0.9464	0.8467	0.9464
Gillnet	0	0	0	0	0.8438	0.8794
Beam	0	0	0	0	0	0.867
Otter	0	0	0	0	0	0

2007	Dredge	Longline	P/W	Gillnet	Beam	Otter
Dredge	0	0.9583	0.8977	0.9492	0.6089	0.9013
Longline	0	0	0.9905	0.9581	0.932	0.9875
P/W	0	0	0	0.9554	0.8874	0.9141
Gillnet	0	0	0	0	0.8348	0.9308
Beam	0	0	0	0	0	0.8938
Otter	0	0	0	0	0	0

2008	Dredge	Longline	P/W	Gillnet	Beam	Otter
Dredge	0	0.9927	0.9174	0.9489	0.6529	0.9331
Longline	0	0	0.9979	0.9371	0.9562	0.9903
P/W	0	0	0	0.9512	0.8919	0.9332
Gillnet	0	0	0	0	0.8681	0.9678
Beam	0	0	0	0	0	0.9632
Otter	0	0	0	0	0	0

0= total equality; 1= maximal difference

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

Year/gear type	e		f		g		h	
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				

Table 4. Activity (hrs/ $km^2 * 10^{-5}$) 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

Figures

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

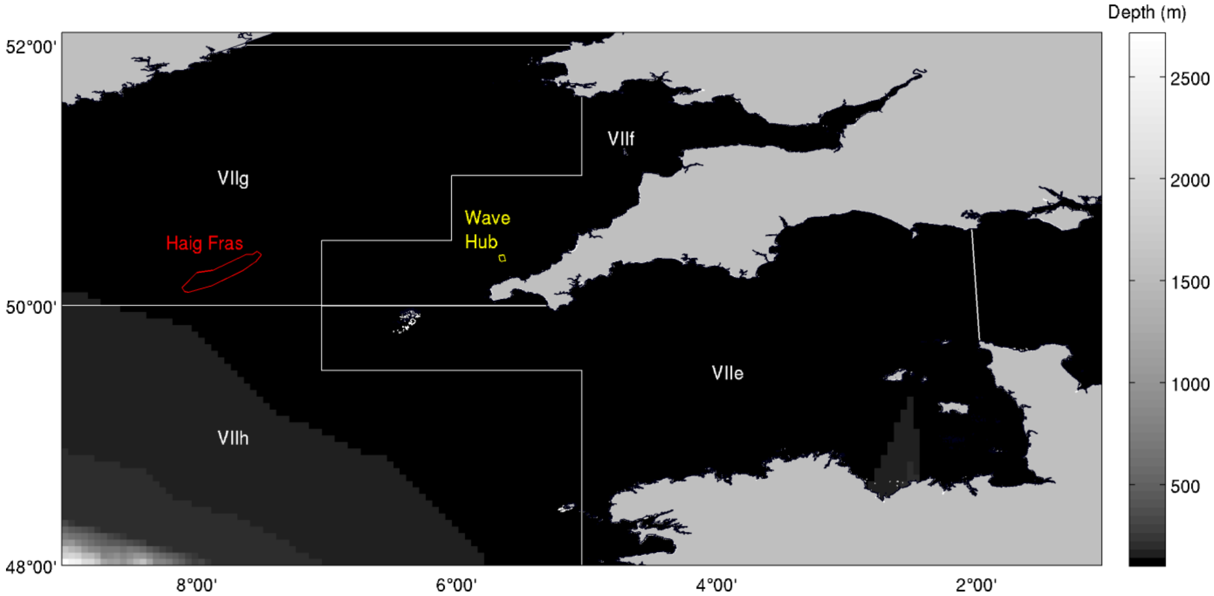
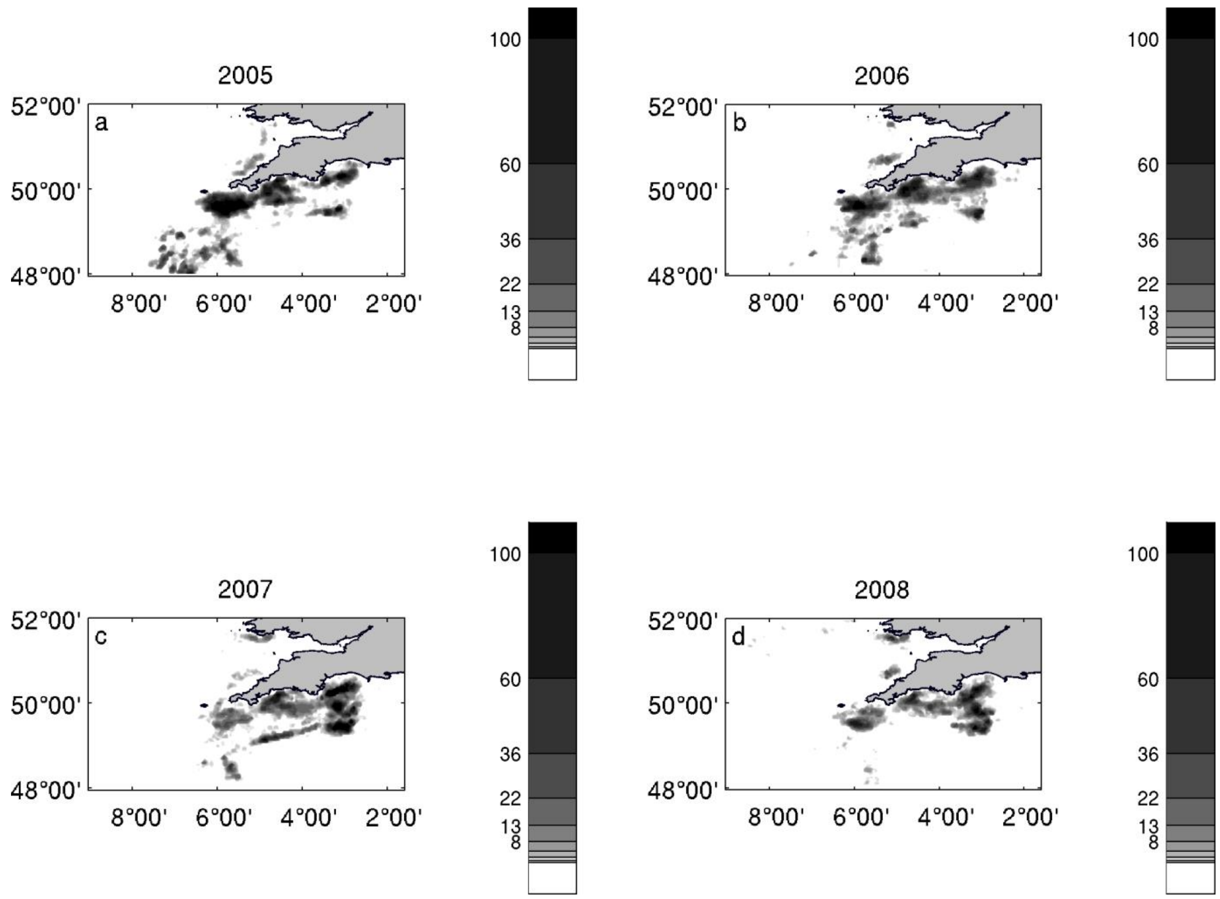


Fig. 2. Fishing activity distribution of UK vessels >15 m in length in ICES areas VII e-h from 2005-2008 (a) scallop dredge (b) longline (c) gillnet (d) potters/whelkers (e) beam trawl (f) otter trawl. Logarithmic scale bar (hrs) is shown.

(a)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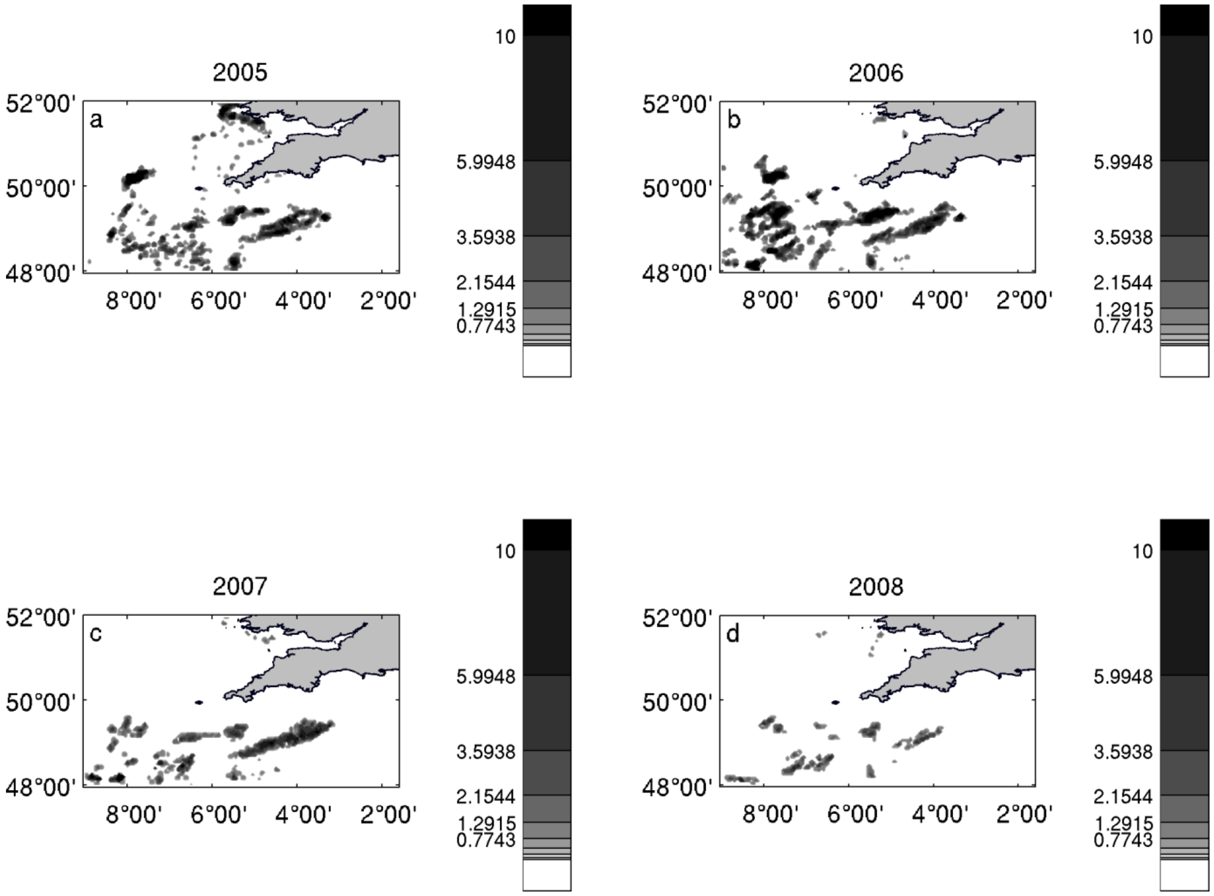
(b)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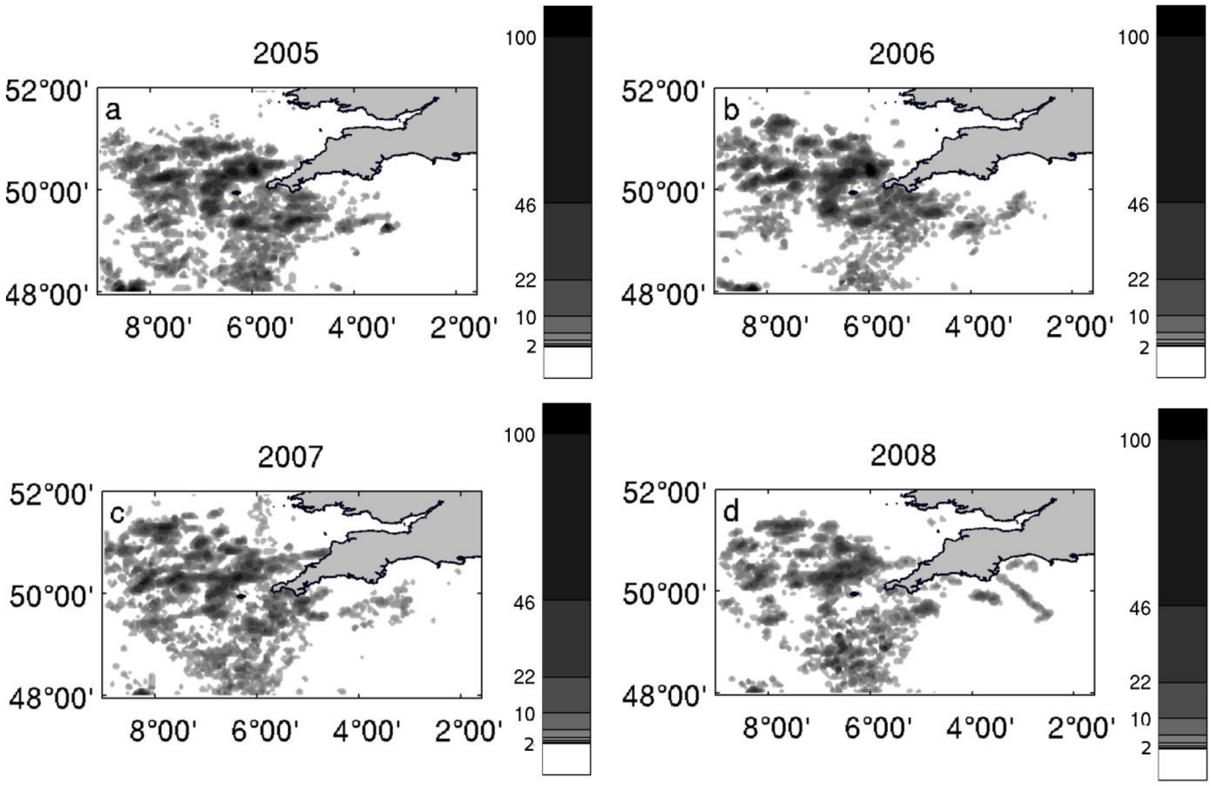

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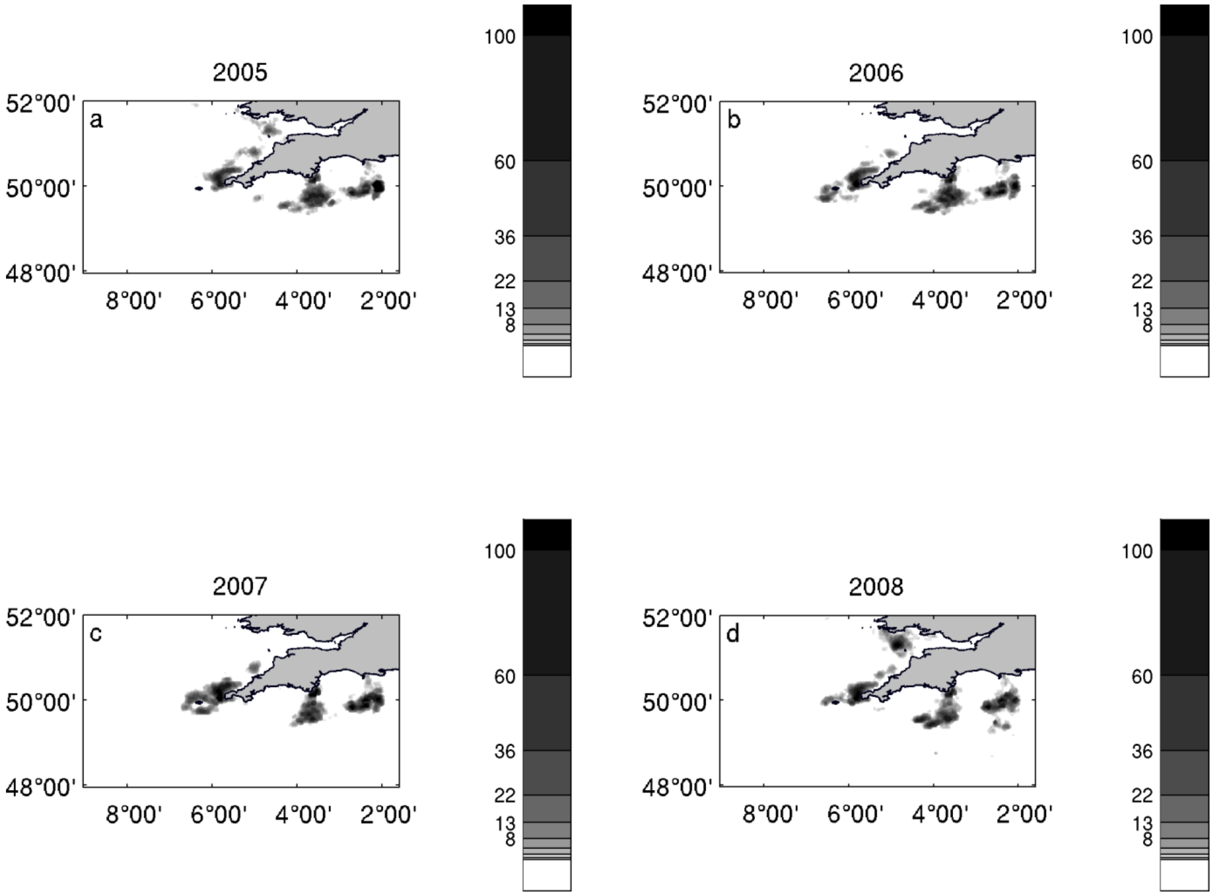
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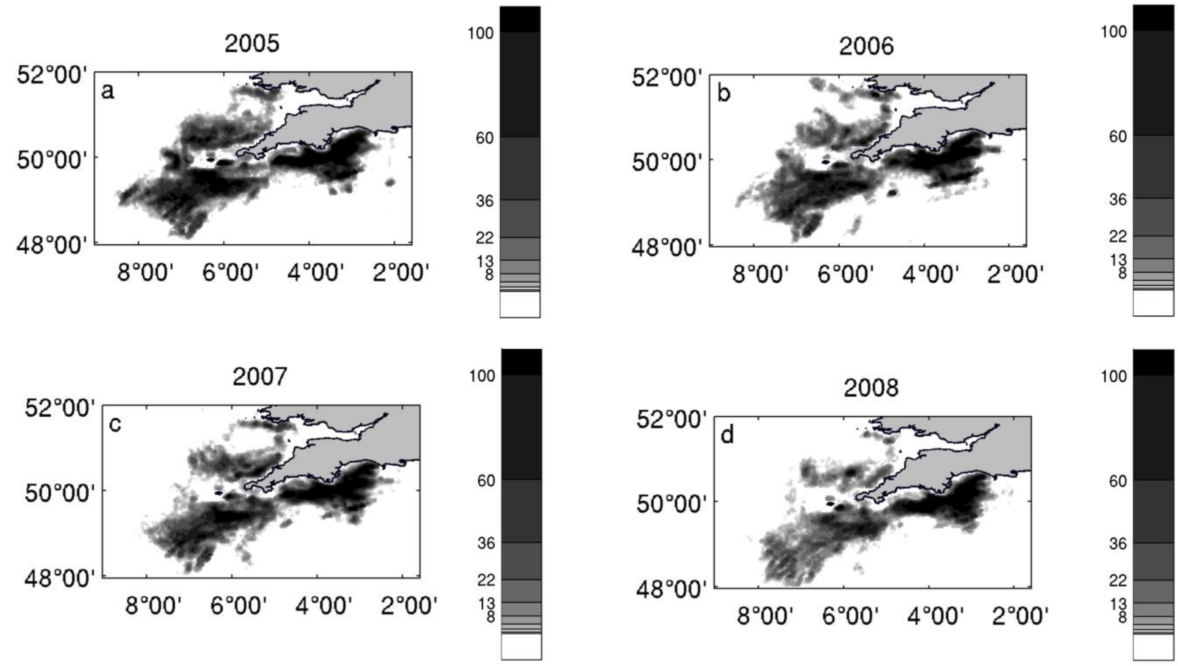
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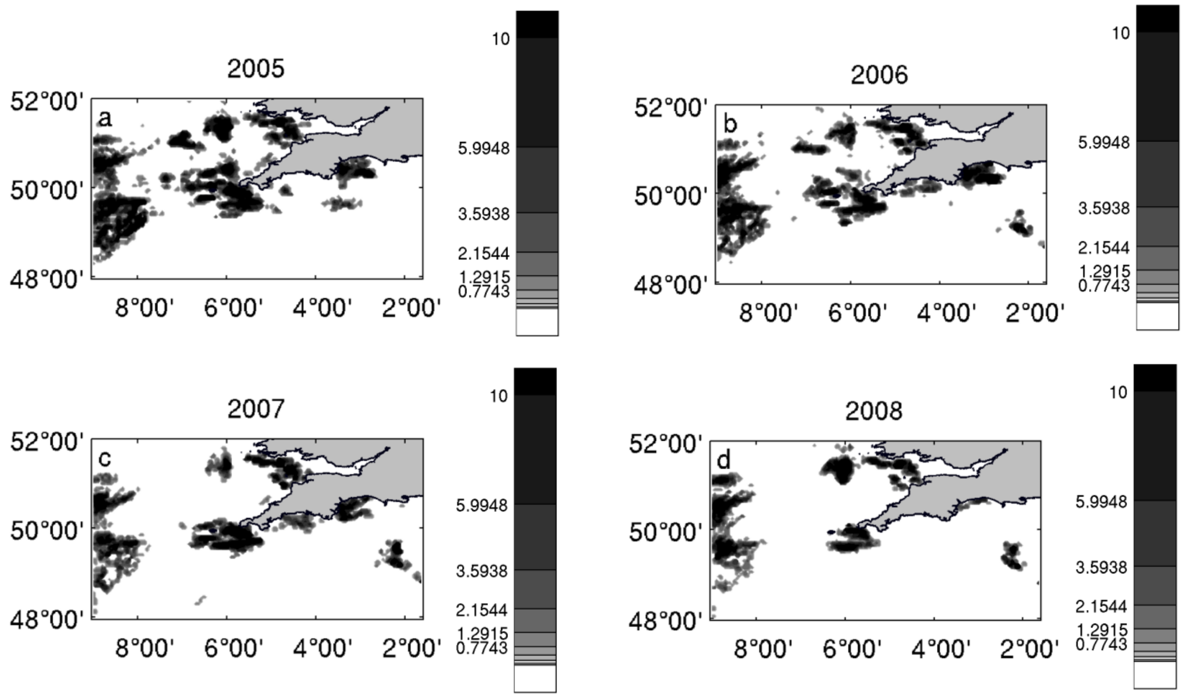
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(g)

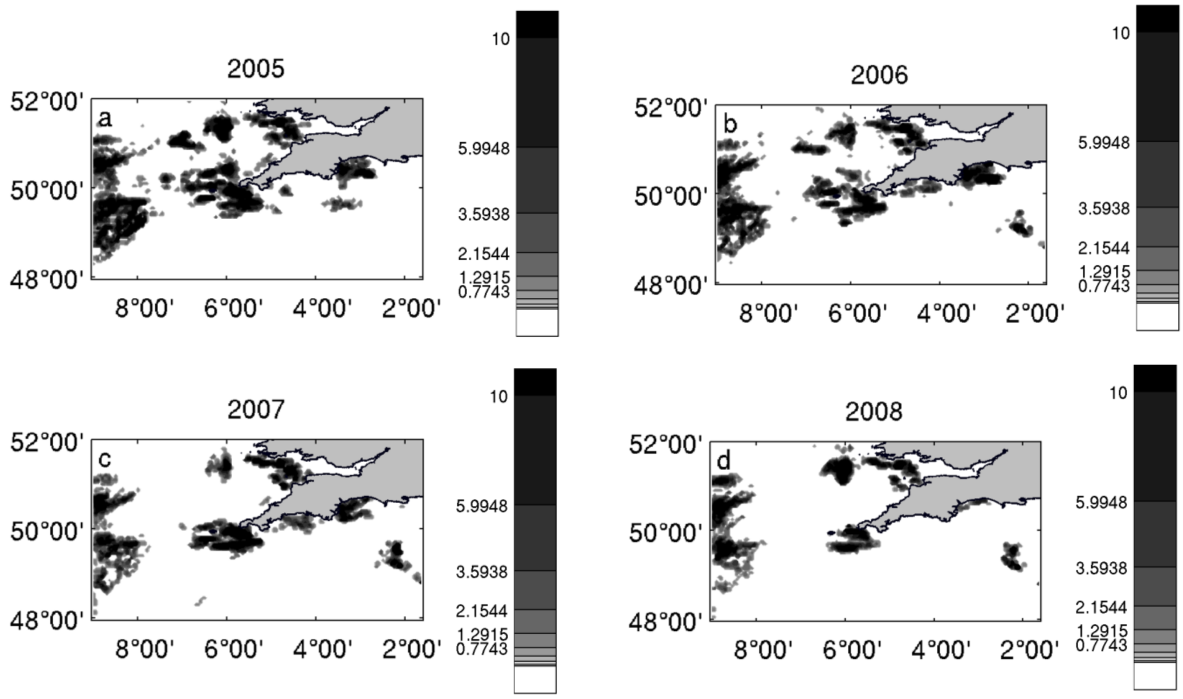
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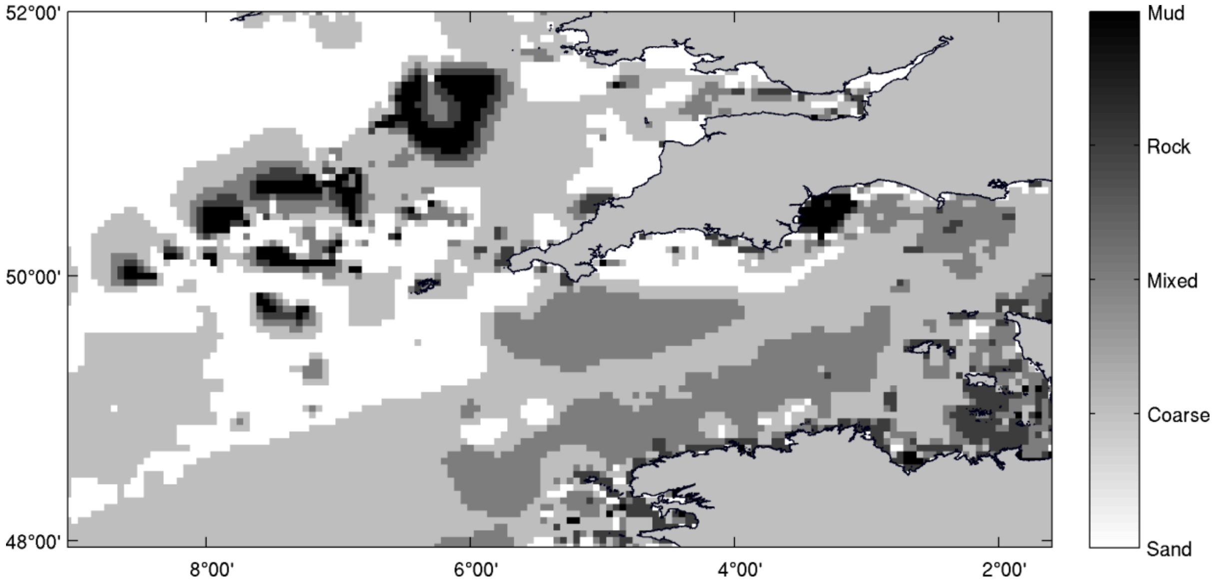
Fig. 3. Five marine landscape types derived from UK Seamap data [48](Connor et al., 2006) within the boundaries of ICES areas VII e-h.



Investigating the co-existence of fisheries and offshore renewable energy in the UK: Identification of a mitigation agenda for fishing effort displacement

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Abstract

The increased demand for sea space for marine renewable energy (MRE) developments and marine conservation will have impacts on the fishing sector. As a consequence, it is imperative to understand the ways in which fisheries and renewable energy interact and explore the potential for co-existence. In this paper we investigate the challenges of co-existence between the two sectors and explore a mitigation agenda for fishing effort displacement in the UK. Data were collected through stakeholder questionnaires and two stakeholder workshops. Thematic analysis was carried out to identify the key challenges faced by stakeholder groups. The research identifies, as main points of this agenda: developing mechanisms for overcoming data issues for assessment of effort displacement; the development of appropriate methods of assessment; and development of a consultation protocol between MRE and fishing sectors.

Keywords: conflict management, stakeholder engagement, consultation, fisheries management, marine renewable energy, ecological data, environmental monitoring, fishing effort displacement.

1. Introduction

1.1. Increasing demand on sea space

Extensive fisheries management and policy has been developed responding to growing concerns about depletion of commercial fish stock due to overfishing. Management measures such as area closures and fishing quota, as a way to control fishing effort, have been implemented, which as has resulted in displaced effort (for example, Suuronen *et al*., 2010). In the UK, the Common Fisheries Policy (CFP) is the main mechanism to deliver sustainable fisheries and economic strength to the fishing sector. It consists of four interrelated policies addressing: markets, structures, external fishery relations and conservation. Originally created in 1983, the CFP was part of the Common Agricultural Policy (CAP) in the 1970s and used until the CFP was formally created in 1983. However, when part of the CAP, the CFP was used avoid conflict with other nations over competing claims on fish stocks (European Commission, 2009). However, the CFP has failed to deliver on these objectives due to lack of compliance; communication problems; lack of transparency; lack of integration of scientific evidence into decision making as well as weak integration of environmental concerns into the CFP (Khalilian *et al*., 2010; Osterblom *et al*., 2011; Qui and Jones, 2013; Rodwell *et al*., 2013b). Several decades after the CFP was put in place, the issue now is not so much nations competing for access to the sea but competing activities and priorities such as conservation and renewable energy generation. This is the result of the growing concern about fossil fuel depletion, its supply and impacts on the environment, which has led governments around the world to introduce measures to increase the proportion of energy produced from renewable sources, and enter into agreements to deploy renewable energy (Sustainable Development Commission, 2007).

1.2. Fisheries in the UK

Current fisheries statistics, provided by the Marine Management Organisation (2013), place the over 10 m fleet vessel number at 1374, and the number of vessels 10 m and below active were 5 032. The composition of the approximately 12 450 vessels operating in the UK in 2012 consisted of: 5 950 in England; 4 700 in Scotland; 800 Northern Ireland; and 1 000 Wales. In 2012, vessels landed approximately 627, 000 tonnes of fish (including shellfish) into the UK and abroad with a market value of £770 million. Pelagic and shellfish landings increased from 2011 to 2012, with shellfish constituting the majority of landings, however average price of pelagic fish decreased from the previous year, hence the value landed is 7% less than 2011. Most of the Scottish and Northern Irish fleet landings consist of pelagic fish; Welsh catches consist of mainly shellfish; and the English fleet land predominantly pelagic fish. In 2012, more than half of all landings made by the UK fleet were caught in the Northern North Sea and West of Scotland. Falling catches of cod and haddock have contributed to the fall in demersal catches since the mid 1990's, however mackerel and herring catches have continued to rise. Since 2008, scallop landings have increased while both crab and Nephrops have shown some decline. The UK has the 4th most powerful fleet in the EU (Marine Management Organisation, 2013), which underlines the need for careful consideration of MRE interaction with the fishing sector. The greatest share of larger vessels is based in Scotland whereas the higher number of smaller vessels, i.e. below 10 m are based in English waters. The reason for these differences; the Scottish fleet are responsible for the targeted catches of herring and mackerel and fish mainly in the North Sea and west of Scotland. The English fleet mainly target Channel fisheries for Sole and Plaice, but with a higher proportion of smaller vessels, these also target inshore areas.

1.3. Offshore renewable energy development and effort displacement

The UK has made commitments to ensure that an overall 15% of energy demand is met from renewable sources by 2020 (DECC, 2011), with more ambitious targets set by the devolved administrations. Since 1998, increased powers were given to the governments in Northern Ireland, Scotland and Wales, within the UK as a whole. As a result, many of the administrative, executive and legislative authorities operate only within these administrations. There areas have their own ministers, priorities and mandates to different degrees, resulting in a variety in policies and procedures in each administration, for issues such as energy, fisheries, and marine planning. Energy policy, for example, is fully devolved in Northern Ireland; in Scotland, it is executively devolved, which provides Scottish Minsters with full control over major consents and planning as well as operational control over market and support systems; and Wales, which as the least devolved power, oversees planning and consents for smaller renewable emerging facilities. Regarding renewable energy, this has resulted in different targets: 100% of demand for electricity from renewable energy by 2020 in Scotland (Scottish Government, 2011); 40% in Northern Ireland (DECC, 2011); and 22.5 Gigawatts of installed capacity from different renewable energy technologies in Wales by 2020E2025 (Welsh Assembly Government, 2010).

To achieve targets, the UK must strongly increase its renewable energy deployment and comprehensive energy policies, and strategies were established to abate to increase the use of energy from renewable sources. As a consequence, the marine area around the British Isles increasingly functions as a location for energy generation, because offshore there are better resources (Pelc and Fujita, 2002), the possibility of larger scale developments, as well as perceived increased acceptance and higher consenting rates (Haggett, 2008; Jay, 2010).

Large, high capacity wind farms are being planned, whilst other more nascent technologies, such as wave and tidal technologies, are on the rise, increasing the competition for ocean space. Since 2000, the owner of the seabed, the Crown Estate, has leased large areas of the UK seabed for development with a generating capacity of up to 40 GW (Crown Estate, 2013a). Six rounds have been announced for offshore wind, increasing in scale and technical complexity as the industry developed. In September 2008, the first leasing round took place in the Pentland Firth in Scotland for wave and tidal energy, which resulted in six wave project development sites and four tidal stream sites to be leased with a potential up to several 100 MWs (Crown Estate, 2013b).

Marine renewable energy (MRE) development may lead to large impacts on the fisheries sector. If the developments proposed around the country go ahead, it is expected that exclusion zones will be established around the developments, resulting in displaced effort of fishers (Alexander *et al*., 2013; Mackinson *et al*., 2006), and together with the planned suite of marine conservation zones (MCZs), the problem of displacement is compounded even further (Campbell *et al*., 2014). Although area closures and controls of fishing effort have been widely used as fisheries management tools, and it is known that they affect the distribution of fishing effort (Hiddink *et al*., 2006), the scale and extent of the offshore renewables industry as well as other area closures (e.g. as a result of marine protection) is unprecedented. This increased pressure on the marine space is recognised in both the UK and beyond, and in order to improve the stewardship of our seascapes and reduce conflict, a forward-looking, ecosystem-based and transparent process known as Marine Spatial Planning (MSP) is being promoted; frameworks being developed; experiences documented; criteria tested; and future priorities envisioned (Douvere and Ehler, 2009; Foley *et al*., 2010; Halpern *et al*., 2012; Stelzenmüller *et al*., 2013).

In the UK, the Marine and Coastal Access Act (MCAA) (hereafter the Marine Act), a system for MSP gaining Royal Assent in 2009 and now enacted into law, was established, which aims to rationalise the use of the marine area. However, little is known about offshore renewable energy generation and its interaction with fishing effort. Even less is known about the social, economic and environmental impacts of effort displacement or the cumulative impacts that multiple area closures will have (Hilborn *et al*., 2004; Mangi *et al*., 2011; Punt *et al*., 2009; Sale *et al*., 2005). As a result of increased development in the sea space it is imperative to understand the ways in which fisheries and renewable energy interact and explore potential for co-existence.

In this research we investigate the challenges in resolving interactions between fisheries and marine renewable energy. We focus on the improved co-existence between the two sectors and developing a mitigation agenda for fishing effort displacement in the UK. This research was carried out as part of the work of the Fisheries and Marine Renewable Energy Working Group (FMREWG), and consists of a scoping survey and two workshops, funded by the Marine Renewable Energy Knowledge Exchange Programme (MREKEP), a Natural Environment Research Council (NERC) project and coordinated by Plymouth University.

2. Methods

The primary focus of the research was the interaction of fisheries and the MRE sector in the UK context. Focusing on the UK as a case study enabled an in-depth investigation of the issues around fishing effort displacement and renewable interactions in this specific area. Robson (2002) described this approach "as a strategy of research which involves an empirical investigation of a contemporary phenomenon in its real life context using multiple sources of evidence". This focus also allowed for the application of multiple methods, including a questionnaire survey and two workshops based on the Delphi-method.

2.1. Data collection

2.1.1. Questionnaire survey

The first method applied consisted of a questionnaire survey, which was conducted at the EIMR (Environmental Interactions of Marine Renewable energy) Conference in Orkney in May 2012. Around 200 delegates participated in this event, including representatives from business, policy and academia from a variety of backgrounds including ecology, engineering, policy and fisheries. The survey was aimed as a scoping exercise for exploring the range of knowledge exchange options between the areas of marine energy development and fisheries, to identify priority research issues, knowledge gaps and collaboration needs. Not all delegates had relevant activities or knowledge areas for this topic, and therefore not all delegates felt like they could not contribute to this debate.

2.1.2. Workshops

Workshops were used as the main technique to explore the range of issues associated with effort displacement as a result of offshore renewable energy deployment. The nature of the participants and the aim of the research to develop a mitigation agenda lent itself to a Delphi-approach. This method generally consists of various techniques, but typical features include: an expert panel, rounds with questions through which information is collected from those in the panel, the information is analysed and fed back, which provides participants with an opportunity to revise their judgements (Okoli and Pawlowski, 2004; Mullen, 2003). The approach aims to achieve consensus on a complex problem. Although modified to fit the aim and circumstances of the research, the approach provided an opportunity for knowledge exchange be-tween multiple stakeholders as well as consensus on a mitigation agenda. To enable discussion and knowledge exchange to take place, participants from different backgrounds and regions were divided into groups. Each group thus consisted of a mix of people from different backgrounds and administrations, and the results must be taken in the context of these groups working together. To ensure confidentiality of the participants' comments to a wider audience, no specific comments were allocated to persons.

2.1.2.1. Workshop 1- Scoping

The second part of the MREKEP activities concerned a scoping workshop which aimed to identify key issues and research topics in the fields of fisheries and marine renewable energy interactions (Rodwell *et al*., 2012). In May 2012, 29 delegates of the EIMR Conference in Orkney attended the scoping workshop. The participants included academics, regulators, and the offshore renewables and fisheries sectors. The workshop took a focus group approach, a form of group interview which employs the interaction between research participants to generate data. This method is considered to be “particularly useful for exploring people's knowledge and experience” (Kitzinger, 1995), and enables to explore participants to explore issues of importance. Participants were divided into 4 groups of 7-8 people with a facilitator attached to each group. The groups covered four questions each between 5 and 10 min, and were asked to brainstorm their ideas to create a mind map or produce list of key ideas. The groups would rotate so they were able to read the previous' group work and add to their ideas. The four questions were:

1. What are the priority issues to focus on with regard to the interaction of marine renewable and fisheries?

2. What are the barriers to progress with regard to the interaction of marine renewable and fisheries?

3. How can we mitigate problems associated with the interaction of marine renewable and fisheries?

To provide the opportunity for reflection and achieving consensus, the facilitator of each group would present the key ideas of each round. An open discussion followed to ensure appropriate coverage of ideas. Furthermore, participants were asked to use post-it notes to add anything that was not covered in this work-shop, but was deemed important to include in the expert work-shop. Extensive notes were taken during the discussion and mind maps, key ideas and post-it notes were collected, all of which provided additional input for the analysis.

2.1.2.2. Workshop 2 -Expert Workshop

The final activity consisted of an expert workshop which brought together 33 representatives from all devolved administrations covering: academia, the offshore renewable energy industry, regulators and delegates involved in marine conservation and fisheries. The workshop took place over one and a half days. The aim of the expert workshop was to examine the issues raised in the scoping workshop in more detail or expand on them, as well as to contribute to secure positive future interactions between fishing and offshore renewables industry, and so addressing the issue of fishing effort displacement as a result of development of an offshore energy industry. Table 1 provides a summary of the sectors represented at the workshop.

The workshop was designed in four separate sessions, which aimed to move from the present situation towards development of positive actions in the future. The sessions covered:

1. A review of past research and work
2. Case study experience and practical implementation
3. Moving forward and recommendations for action
4. Achieving consensus on action

During both workshops, each group was moderated by a facilitator, and notes were taken during the discussions. The second workshop was recorded.

2.2. Data analysis

2.2.1. Questionnaire survey

The returned questionnaires were entered into SPSS. Descriptive statistics were used to summarize the sample and the number of respondents that identified particular research gaps and priority issues. The number of completed questionnaires collected, a total of 24, was too low to conduct in-depth statistical analysis. Instead, to assess the most urgent needs for data and collaboration, survey responses were assigned a score according to the respondent's indicated appropriate level of data and collaboration needs. The data needs score was developed based on the ranking of importance of issues. The scores were weighted and high data needs were assigned a score of 3, medium of 2, and low of 1. For example, the identified data needs score of 51 for ecological data (Fig. 1), is based on 14 respondents indicating high data needs, 4 medium and 1 low. The calculated data score therefore is: (14*3) + (4*2) + (1*1) = 51. A high data needs score means that respondents thought that there is a data need and that this data need is urgent. An indicated low data need means that in comparison to others the data are needed but not most urgent. When a type of data was not marked, this indicated that the respondent thought there were no data needs. Correspondingly, priorities for research collaboration needs were assessed by assigning a score to the appropriate level of collaboration needs, with high collaboration needs scored as 3, medium as 2 and low scoring 1. The collaboration needs score was calculated in the same way as the data needs score.

Table 1. Affiliations of the delegates attending the MREKEP expert workshop in York.

Sector	Number of delegates
Offshore renewable energy sector (e.g. developers, utility company, non-profit renewable energy trade association)	5
Fishing sector (e.g. fishing organisations, industry groups, conservation authorities)	10

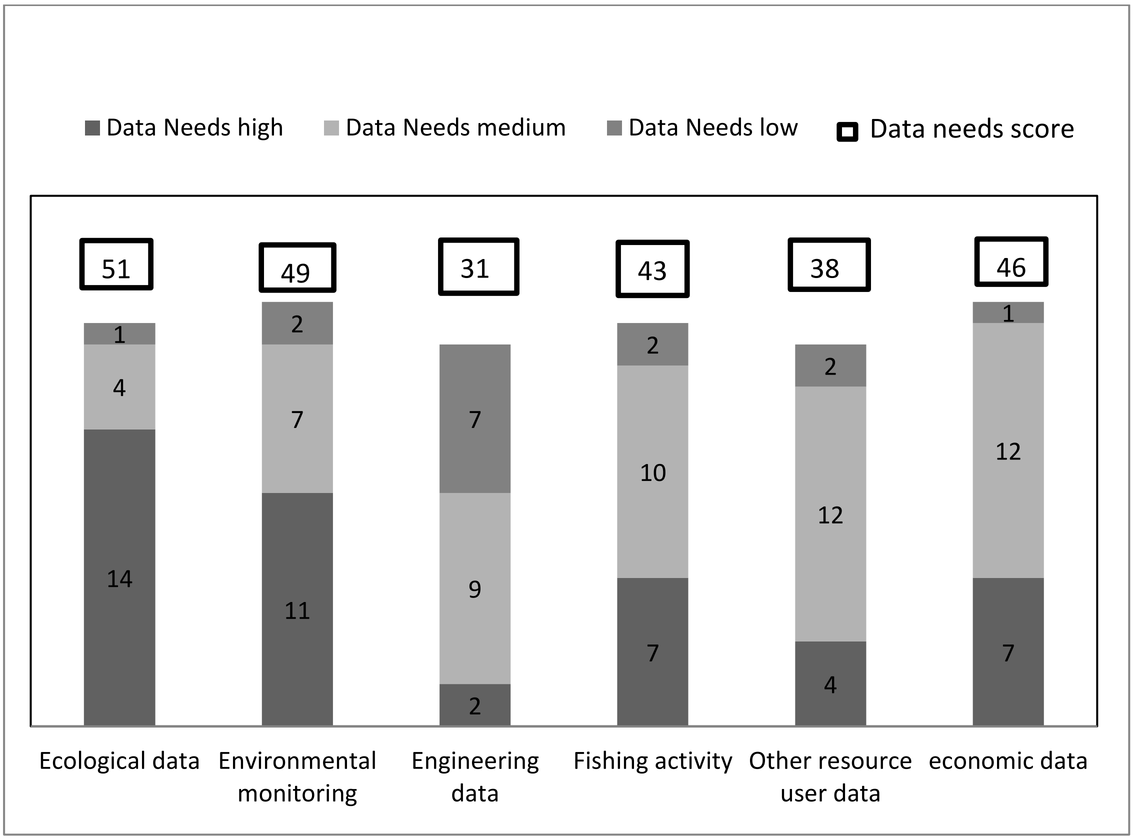
Planning and management (e.g. non-departmental, public bodies, government representatives, government advisory body)	10
Academia	8

2.2.2. Workshops

The data resulting each of the workshops were coded, which is the process of categorising the data. Open coding, an inductive approach to coding that is not based on pre-defined themes, was used to identify key themes. Thematic analysis was applied to the codes from the scoping workshop which in qualitative research involves identification of recurrent issues in the data (Joffe and Yardley, 2004; Creswell, 1994). Themes are clusters of linked categories which convey similar meanings, and allowed for the nuances of the themes to be explored in-depth. Although software is available (such as NVivo), to aid the process of searching through the data, the identification of themes remains dependent on human effort, and was achieved through systematic reduction of the texts and notes into separate units. Once reduced, data issues, assessment methods, and communication were identified as the three overarching themes, each with a set of sub-themes, based on population of the codes. The presentation of the key themes and their in-depth exploration are discussed in the next section as the challenges for coexistence of fisheries and offshore renewable energy.

Data analysis of the expert workshop focused on examining the issues and themes raised in the scoping workshop, and to contribute to secure positive future interactions between fishing and offshore renewables industry by achieving consensus on actions. Because the themes for discussion were identified through analysis of the first workshop, the data from the expert workshop were coded through a process of deductive coding, which analyses the data based on existing codes that can be based on previous research or a pre-existing theoretical framework (Joffe and Yardley, 2004; Creswell, 1994). This provided further insight into the existing codes and contributed to the practical components of the mitigation agenda.

Fig. 1. Data needs identified by survey respondents



3. Results: identification of key challenges for coexistence of fisheries and offshore renewable energy development

Inductive analysis of the coded data from both workshops found three key overarching challenges that a mitigation agenda should address; Data issues, assessment of fishing effort displacement, and issues around consultation and communication. Early identification of these themes in the survey and scoping workshop, enabled elaboration on the themes in more detail in the expert workshop. Reoccurrence of the themes throughout the research activities confirmed their importance. The key challenges and results presented below are the results from the two workshops. Where indicated, the results discussed are specifically from the survey. These key challenges will provide the basis for the mitigation agenda. underlying themes identified in all activities are discussed below. The main results presented below are the results from the two workshops. Where indicated, the results discussed are specifically from the survey. These key challenges will provide the basis for the mitigation agenda.

3.1. Challenge: data issues

A first challenge identified was issues surrounding data. The main issues discussed included: different types of data needs, availability of data and data sharing.

3.1.1. Data needs

Participants indicated a large data gap for assessing effort displacement. This is supported by evidence from the literature, where few studies have sought to balance the benefits that may result from closed areas against the cost that results from the displacement of fishing effort (Halpern *et al*., 2004; Hiddink *et al*., 2006; Kaiser, 2005). The data showed that once core fishing areas are accurately identified more research and development should go into understanding the dynamics of these areas in various research fields (for example, Jennings and Lee, 2012). Similar work by Bastardie *et al*. (2010, 2014) has shown that access to single vessel data and combining more than one data set, leads to more accurate predictions of fisher behaviour, profits and stock abundance for example. Participants were cognisant of the difficulties of obtaining funding for research and monitoring, and questions were raised on who could provide this additional research funding.

The survey results showed the different areas in which respondents thought more data were needed (Fig. 1). Survey respondents were asked to prioritise data needs for research into MRE and fisheries interactions and indicate the appropriate priority level assigned to the type of data. The final data needs score is given above each data column (Fig. 1).

3.1.1.1. Ecological data and environmental monitoring

Despite well-developed methods for assessing the effects of management actions of fish stocks (Quinn II and Deriso, 1999), assessment methods of the effects on other components and attributes of the ecosystem is not as well developed (Hiddink *et al*., 2006; Sainsbury *et al*., 2000). This also showed in the survey results. The need for ecological data was considered highly important by survey respondents as well as how fisheries and fishing impacts the existing resource and locations. Ecological data was mentioned by 14 respondents as having a high need for data (Fig. 1). The need for ecological data was also mentioned by workshop participants although to a lesser degree. This difference is likely to be explained through the different balance between the types of actors present at the workshop compared to the initial conference. Environmental monitoring was also identified as having high data needs with a data needs score of 49. Survey respondents were also invited to explain their opinion, which resulted in identification of research gaps regarding: potential effects of displaced fishing activity on ecology; opportunities for co-location; behavioural case studies, long term impacts on marine organisms; changes in fish behaviour and migration; and fish mortality.

3.1.1.2. Engineering data

Participants thought that design level mitigation by the developer and research on engineering solutions is lacking. Although engineering data needs did not show in the survey as critically lacking with a data needs score of 31, it was considered that tackling design level mitigation by research on engineering solutions is a gigantic leap forward for overcoming effort displacement.

Research should be conducted on construction techniques, such as scour protection and armouring to aid discussions about mitigation and potential fishery benefits following construction. For the successful development of a mitigation strategy, fishers' representatives indicated that fishers should ideally be involved in the research, because there may be displacement for some fisheries but potential benefits to others. Examples included Holderness, Bangor and Lyme Bay, and participants indicated that these benefits could be more widespread.

3.1.1.3. Fishing activity, cumulative impact and spatial scale

The results found a gap in data on fishing activity, cumulative impact and spatial scale. This is consistent with the academic literature, which identified that the aggregate environmental effects of closing large areas of the seabed to fishing have rarely been investigated (Halpern *et al*., 2004; Hiddink *et al*., 2006; Murawski *et al*., 2005; Steele and Beet, 2003). Data needs for fishing activity scored high in the survey, with a data needs score of 43. The data gaps identified in the survey for fishing activity include: the spatial distribution of commercial fisheries in scales (temporal, spatial, and gear specific); spatial displacement; key areas for life stages of commercial species; and cumulative and in combination effects of MRE and MCZs on fishing opportunity.

A need for a greater understanding of spatial scale issues was indicated as well as assessment of cumulative displacement. A further lack of guidance was identified on how to assess cumulative displacement, which was recognised as something that must be addressed with immediate effect. Assessment of cumulative effects was deemed important, particularly in relation to the spatial scales regarding inshore and offshore zones and the combination of activities. The need to understand the cumulative effects on the multiple sectors operating in marine and coastal areas has also been identified in the literature (Rodwell *et al*., 2012; Stellzenmüller *et al*., 2010). The importance of clear identification of activities in the marine space also shows from the survey where data needs regarding other resource users received a data needs score of 38. It was agreed that spatial scale issues and cumulative impacts of developments requires the best possible spatial data for both habitats and fishing activity. However, constraints to access of this data were recognised as a barrier to timely evidence gathering, and ways must be found to overcome this issue.

3.1.1.4. Socio-economic data

Economic data received a data needs score of 46, making it the third highest ranked data needs priority. Research gaps indicated were: importance of each fishing ground (economic and productive); actual economic impacts upon fishers in terms of displacement/loss of access; potential employment for fishers from MRE; supply chain issues; community benefits of MRE; and social impacts on fishers.

Discussions raised the importance of greater emphasis on socio-economic research to build up a greater evidence base. There also are insufficient mitigation solutions for developments in the consenting stage. There is a lack of information for fishing communities on potential employment or spin-off effects of the renewable energy sector, or on potential impacts. Because decisions on these issues (e.g. which port to use) are rarely being made until after the consenting process, communities are kept in the dark.

3.1.2. Availability of data

There was consensus among participants from all sectors that there is a large amount of data in existence, from both industry and individual vessels and in electronic format (e.g. VMS data) or paper format (e.g. catch and landing data). Participants raised that there is a wealth of information that is not or not entirely recorded on paper and consists of fishers' local knowledge (FK), which is increasingly being recognised as important data (For examples in the literature see Close and Brent Hall, 2006; Hind, 2012; Johannes *et al*., 2000). It was agreed that these types of data can collectively be used to assess displacement.

However, participants pointed to the difficulties of accessing these data, and for these data to be used, methods must be further developed to translate knowledge into evidence. Development of best practice guidelines to achieve close collaboration on research project between academics, professionals, fishers and the MRE industry during all phases of planning and development was suggested. The time delay between the actual research and its translation into advice and policy was considered too long, and 'any measures that can speed up the process should be considered'(Rodwell *et al*., 2012).

3.1.3. Data sharing

Participants were divided on the topic of data sharing, in particular if the data are commercially sensitive. Some resistance from the fishing industry was considered justifiable. Others emphasized the rationality of sharing the data because it will improve the assessment of effort displacement and correspondingly the outcome of the assessment. Nevertheless, there was general consensus that to overcome issues related to inaccessibility of data, there needs to be appropriate sharing of this data (Rodwell *et al*., 2012). Processes of data sharing should follow a strict protocol in which the user guarantees its use for specific purposes, and safeguards confidentiality. Furthermore, benefits of releasing the information should be communicated clearly along with possible negative consequences of not providing the data. Holderness was seen as an example of good practice in data sharing. It was mutually agreed that trust and communication are key factors for data sharing to take place.

Strong opinions were voiced on regulator responsibility: the power of the regulator was considered underused. There was a call for a coordinated approach which would include multiple bodies; Government, marine authorities, the fishing industry and MRE industry. Regulators could impose more stringent conditions upon industries and help to establish memorandum of understanding (MOU) between industries. This underlined the need for general consensus on a UK wide approach to data utilisation and establishment of a MOU between all relevant bodies, for example the Triton Knoll project and the Statement of Common Ground (SoCG) developed by both the fishing and MRE industries.

Participants identified an urgent need for careful development of access and consent protocols. This was considered to be the result of dented trust in the appropriate use of the data, which as caused by negative press surrounding the misuse of fisheries data by NGOs which had resulted in the prosecution of fishers involved in voluntary logbook schemes. This issue was also flagged in a fisheries and offshore wind energy interactions report by Mackinson *et al*. (2006).

A data case study repository was suggested to enable quick access to data and avoid repetition. Data should be easy to access and it should become a requirement that all data are freely available. Suggestions included that data provision could be part of the consents process for developers. It was considered an issue that the data belong to a developer, who paid for this. If no consent is given, another can take the data it needs. In some cases may be possible to sell on the data. It was considered that the issue required further attention. A national database or repository, however, was not seen as a replacement for dialogue.

3.2. Challenge: assessing fishing effort displacement

Another challenge identified relates to assessment of fishing effort displacement and appropriate methods and tools. There was also considered to be a need to understand the rationale for assessing fishing effort displacement, and to clearly define what needs to be assessed and to what level. Before dealing with specific site issues, the scientific questions that are sought to be answered should be clear, and clarity is needed around the scientific aspects of issues such as monitoring before starting a discussion on ‘higher level issues’. For example, there was a general consensus that it must be clear whether the scientific aspect to be researched addresses monitoring or outstanding scientific knowledge. Once the rationale of the research is clear, it is important to start the process of selecting what to monitor immediately, as well as decisions upon targets. This baseline research and monitoring is currently lacking for appropriate site selection.

3.2.1. Assessment methods

Irrespective of the state of development of the methods, there was general agreement among participants that there needs to be a standard methodology for assessing effort displacement across all UK administrations and Member States of the European Union. Research should be directed towards investigating cross-boundary issues, as both fishers and developers will be sharing cross boundary space. With fisheries management largely regulated through policies at a European level, there is merit in approaching effort displacement measurement through a standard methodology that can be applied by all Member States. This is particularly relevant because fishing effort displacement as a result of offshore renewables is currently unassessed.

The data showed that comprehensive methods for assessing fishing effort displacement are missing. Research is needed on specific gear interactions and the dynamics of fishing areas. With reference to data gaps, it was felt that Plotter data should be used first and foremost when assessing fishing effort, although VMS remains the first port of call for many and must not be undervalued. Data restrictions on VMS have reduced its resolution, but pressure must be increased from the academic community and industry for better regulated access. This issue needs immediate attention, as is supported by the academic literature in this field (Campbell *et al*., 2014; Hinz *et al*., 2013, and references therein).

An important weakness identified by participants was that most methods are not specifically developed to assess fishing effort displacement. Therefore, although there are several methods in existence through which effort displacement could be measured, when determining choice of method, it must be taken into account that these methods are not developed specifically for this task. This is also discussed in the literature where it is indicated that interpretation of such data only represents a partial view of real activity as measuring activity is not the same as measuring effort (Jennings and Lee, 2012; Lee *et al*., 2010). There are still unknowns in the compatibility of fishers sharing the same area, and these are the complexities we must research further. In addition to the development of models the suitability of a variety of tools and technologies that are currently in use for various purposes were discussed for assessing displacement.

3.2.1.1. 'Traditional' VMS (vessel monitoring system) and IVMS (inshore vessel monitoring systems)

Vessel monitoring systems are used for monitoring of fishing vessels. All fishing vessels in the UK over 15 m in length[1] are required to have a VMS on board, which transmits the geographical position every two hours. Although this data exists,

[1] On January 1st 2012 vessels over 12 m in length were obliged to install VMS. There are also discussions on towed vessels over 8 m in length installing VMS systems.

unprocessed VMS data are considered personal data under the Data Protection Act and can therefore not be released by the management authorities; hence an aggregated, anonymised format is released to non-fisheries agency personnel, and this is a significant problem (Nolan, 2006). VMS data are considered valuable at the first stage of assessing fishing activity in a general area, but care must be taken when selecting a particular analytical method, e.g. grid cell resolution (for example, Lambert *et al*., 2012). Potential overestimates or underestimates may occur, and the grid cell resolution recommended and used to inform MSP may not be adequate. However, further work by Kafas *et al*. (2012) and the Scottish case studies, are trying to overcome traditional gridded analyses and use other forms of fishing density analyses. The sys-tem also only polls every two hours. Research carried out Lambert *et al*. (2012) suggest a polling of 30 min, hence further work with fishers is needed in order to assess these suggestions among different mobile vessels with different gear types. Furthermore, data inconsistencies exist with certain data unavailable as a result of changes in certain EU legislations, i.e. UK researchers needing EU (non-UK) data may find incomplete data sets, hence cannot use the data to assess shared space use by Member States. Because only vessels over 15 m are currently assessed, there may be an under-estimation of fishing effort, resulting in potential misinterpretation of data. However, developments are occurring, the IVMS project (Marine Management Organisation, 2012), a low cost method using mobile phone technology, which was trialed in 2011 and 2012 in Lyme Bay, was considered to be a promising tool for assessing displacement, however improvements must be made, including the range of service and compliance by individuals.

3.2.1.2. Plotter data

Moving on from 'traditional' VMS methodologies towards improved methods to monitor vessels, fisher plotter data were discussed. This included highly accurate GPS chart plotting data and the Succorfish SC2 vessel monitoring system technology (Succorfish, 2014), which could include the footprint of fishery, the time in which fishing activities are carried out, key activity areas and seasonal variances. The technologies, which are being tested in several places, including Shetland and the South West of England, were considered to be very precise methods for providing the data necessary to assess displacement. Although promising, it was emphasized that these methods are still in development and current knowledge and experience with their implementation was considered far from ideal

3.2.1.3. Mapping tools

Scotmap is a Marine Scotland project which provides information of fishing activity of fishing vessels under 15 m of length. The data set is based on interviews with fishermen to define their fishing areas, and is used to provide information on monetary value, relative importance and space usage of the Scottish marine area (Scottish Government, 2013). Scotmap was indicated as moving towards the ideal standard methodology for assessing displacement. Finally, modelling was thought to have great potential, but participants questioned the knowledge and multiple variables that would have to feed into the model before it could assess fishing location choice. Therefore, mapping exercises were considered a more fruitful endeavour.

3.2.1.4. Marine Spatial Planning

Although not a direct tool or method for measuring assessment, a system of MSP, introduces strategic approaches to account for marine uses, and enable a variety of uses that are compatible with each other (Douvere, 2008; Jay, 2010). MSP therefore, was regarded as a valuable integrated approach for mitigating displacement. Survey respondents indicated that methods that should be developed were habitat resilience and vulnerability tools, particularly at the start of the mapping process that is currently taking place as part of MSP.

3.3. Challenge: communication, consultation and collaboration

It became evident during the discussions across all groups and areas of expertise that it is important to have realistic expectations of what can be achieved through engagement: there will always be some degree of displacement. However, there must be a general acceptance net. This creates a clear imperative to provide guidance on management of displacement and its impacts. There are clear differences between fishers' perceptions and the perceptions of developers. This section describes the challenges of interaction between fisheries and MRE, focused around three main issues: legitimacy of consultation practices, communication protocols and collaboration.

3.3.1. Legitimacy of consultation practices

The legitimacy of consultation practices was discussed on multiple occasions, in particular issues around the moral responsibility of consulting versus consultation as a legal requirement. Respondents indicated that ‘If you are conducting engagement, you must be interested in the result’, and you ‘should not practice tokenism purely because engagement is required by the regulator’ (Rodwell *et al*., 2013a). Fishers explained that this recalls similar feelings of powerlessness they experienced with the MCZ process and consultation regarding leasing rounds for energy developments, which had taken place two years after 11 sites had been announced (Rodwell *et al*., 2012).

A genuine belief that participation in the process will make a difference and can contribute something to the process will increase willingness to participate from the side of the fishers. Participants, and fishers' representatives in particular, emphasized that the merit of the consultation should be clear, and those consulting should be clear about the degree of influence that can be exercised. Fishers should thus only be consulted if they have the power to influence the outcome, otherwise it was considered disingenuous to ask for their participation. At a more practical level, it was deemed important to realise that fishers give up their time when going to consultations and research exercises. Participants should be allowed either monetary compensation for lost days at sea or allowed some flexibility in allocation of quotas (Rodwell *et al*., 2012).

There was general agreement that suitable methods for consultation with the fishing sector must be better identified and used, and it was recognised that these methods might be different for consultation on MSP and licensing of individual developments. It is important to clearly communicate the difference between these two issues as well as the different degrees of influence that can be exercised during these processes. For example, during MSP processes, stakeholders have the opportunity to be involved during the planning phase, which provides stakeholders with the opportunity to provide input at strategic level, as is described by Pomeroy and Douvere (2008). Participants felt that good engagement during this process could potentially mitigate problems during the licensing stage. At this stage it is still possible to emphasize the importance of particular fishing grounds and have these incorporated in the MSP, as is the case in Shetland, where high and low constraint sites are mapped for the renewables sector in relation to fishing grounds (Shetland Islands Council and NAFC Marine Centre, 2013). Consultation at the licensing stage was considered a different matter, as plans are further ahead and moved to a concrete proposal. A need for guidance on improvement of selection process for renewable development zones was identified, and concern was voiced about what policies the MMO put in place if it is not possible to alter the spatial extent of a site.

Participants indicated that consultation with the fishing sector in the past had been too ad hoc and not focused on the issues hand (Rodwell *et al*., 2012), and it was proposed that consultation regarding effort displacement consultation should be framed in terms of: identification of locations where the displaced fishers go; assessment of new activity in the displacement area and; assessment of changes in the pressure on fish stocks.

The issues described above relate to four elements in the literature that Portman (Portman, 2009) describes that relate to communication in consultation practices: process presentation, transparency, clarity of message and communicated at the appropriate level to facilitate understanding of those that will have to read it, and accessibility. The author further indicates that the second and third elements may be particularly challenging for MRE projects, which employ nascent technologies.

A final issue participants identified under consultation was representation of fishers in the decision making process, and a careful consideration of the initiation of consultation. Consultation should be inclusive instead of inviting key figures or the loudest members, because they do not necessarily represent the voice of the majority and potentially polarize the consultation discussion. The use of local representatives was considered important as they are regarded as having the knowledge and trust within communities to foster effective consultation. Correspondingly, the cost implications for conducting good and inclusive consultation were recognised as a barrier for the renewables sector. Energy and resources should be aimed at fostering meaningful consultation to mitigate or solve problems.

3.3.2. Communication protocols

Communication protocols should be a two-way stream of in-formation, in which consultation on collaborative efforts are arranged in a reciprocal way and not dictated by one party. This was perceived by members of the fishing sectors as sending out the message that ‘if you want to have your say, you will have to give up your time to suit our meeting’ (Rodwell *et al*., 2013a). The site designation for MCZs was given as an example of a difficult communication process in which two-way communication was not functioning well. Because of the perceived lack of influence in the site designation, some fishers responded by refusing to participate. A positive side effect of this negative experience was that it united the fishermen because they felt they could not influence the process. This resulted in establishment of the MPA Coalition, which aims to maximize the influence of the fishing industry in the designation of MPAs and the management measures required within them (NFFO, 2010).

3.3.2.1. Representation of fishers during decision making processes

Fishers will get the most from engagement and negotiation opportunities if joined up as a group from the start with central point of contact, and legal aid such as a solicitor to negotiate and record business to business agreements. Participants supported the use of a unified body to represent local fishers and speak for them in MRE decisions and development. The establishment of Fisheries Groups for different gear and vessel types was discussed. It was considered important that fishers create groups that have: a clear point of contact; an agreed aim; and objective and legal representation. In the Fisheries Groups, requirements of individuals could be dis-cussed and agreed before entering into negotiations with the developer.

Negotiations can be supported with documented case studies of existing successful mitigation practices. These studies, based on UK, European and international examples can provide reference, sup-port and guidance for site specific negotiations. The power of communities and effective communication with communities was highlighted with reference to Shetland. By using the Council as a mediator there was successful resolution to the conflict and the first test of a wave development. Requirements for sharing best practice could be built into the consent requirements, along with data sharing, and again the idea of inputting this into the 'toolboxes' is a positive step forward.

3.3.2.2. Inter-jurisdictional communication

Inter-jurisdictional communication was considered by participants as part of the process of creating good communication protocols. The importance of communicating across borders was emphasized because renewable energy siting sometimes moves across jurisdictional boundaries, for example the proposed

Dogger Bank wind farm and the wind farms in the Irish Sea being fished by Belgian, Irish, English and Welsh fishing vessels. In these cases, multiple administrative boundaries need to be integrated. In the future, the boundaries of marine plan zones will be added to these. Before consultation or engagement, it was deemed important to determine who is operating in the particular area of a development. Furthermore, there needs to be a greater awareness of what is going on in the various areas of the UK among research organisations.

The fishing sector identified a need for a clear understanding of why and how their input is being used. Central to efficient communication protocols, communication between the MRE sector and the fishing sector, and those initiating the communication should consider carefully what information is requested and the way the information is requested (Rodwell *et al*., 2013b). Enhanced dialogue was advocated particularly in the early part of consent process.

Particularly poignant here with multi-jurisdictional, cross-border, national and international members is the need for the development of innovative techniques to help engage stakeholders and practitioners, especially in the context of MSP, was identified. Recent work involving simulation gaming (SG) between scientists, policy-makers and MSP practitioners by Mayer *et al*. (2013) offered new possibilities for management between sectors, was shown to improve understanding of issues and foster stronger collaborations between individuals and agencies. Encouraging this kind of approach using SG for use by the sectors discussed here both early in the consenting process and for the life cycles of MRE projects may be a step in the right direction, or at least stimulate ideas.

3.3.2.3. Consistency in procedures

The participants emphasized that trust needs to be built at the local level but is also dependent on nationwide consistency in procedures and processes, for example the provision of consistent points of contact in both industries to maximise the benefits from communication. Further-more, in the exchange of information that is taking place the consulting body must deliver on promised outputs from the consultation.

It was considered crucial that particularities of the fishing and renewables sectors were taken into account when engaging. In particular, the differences in discourse and practice between the two sectors were considered a potential barrier for engaging with fishing communities. Information should be kept simple at all stages. For example, participants from the fishing sector indicated that few fishers would be likely to read a long and technical report, whereas a single page leaflet with a clear and straightforward message would greatly benefit them. The outputs must be easily available and understandable. Outputs solely produced in paper format were not considered sufficient because of differences in the way individual's acquire and process information.

3.3.3. Collaboration

An important difference was identified between consultation and collaboration. Instead of only consultation, participants agreed that there should be collaboration between the fishing and MRE sectors from the earliest possible opportunity. The single most important message was that working together is crucial for over-coming fisheries displacement issues. ‘Working together requires collaboration and communication at different levels, and between stakeholders’, during which ‘the marine renewable energy industry, the fishing sector and spatial planners must work together based on trust and respect' (Rodwell *et al*., 2012). This was acknowledged by representatives of both sectors.

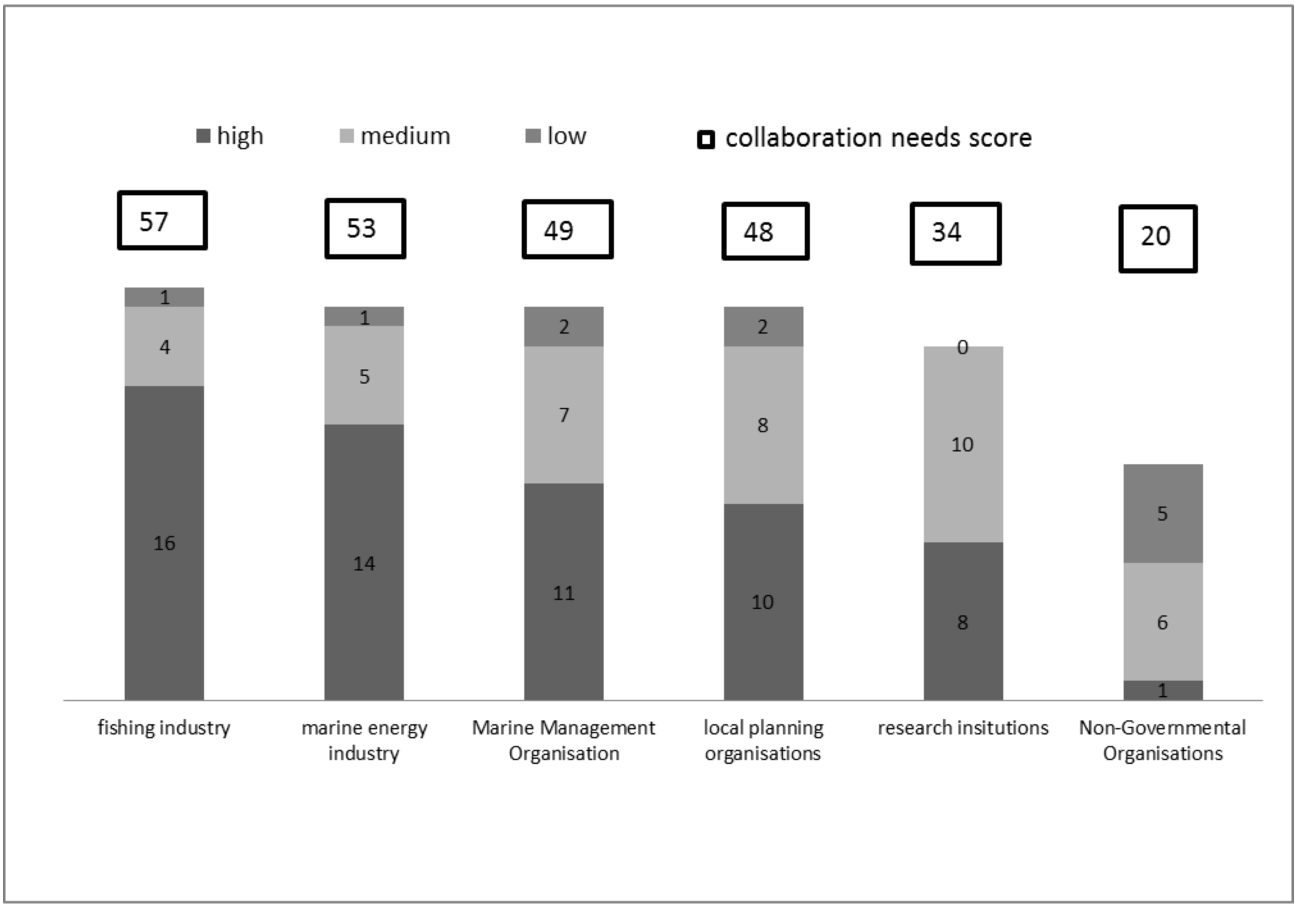
Survey respondents were asked to identify priorities for research collaborations into MRE and fisheries interactions. The final collaboration needs score is given above each data column (Fig. 2). The results demonstrate that the highest need for research collaboration was considered for the fishing industry (with a score of 57) and MRE industry (53), closely followed by the marine management organisation (49) and local planning organisations (48).

Collaborations between energy companies and the fishing sector should be promoted, and guidance could be beneficial for dealing with fishing effort displacement (Rodwell *et al*., 2012). Furthermore, it was argued that some fishers should be directly involved in collaborative projects with developers and researchers. For example projects in which fishers work with developers and research to further develop technologies, methods and plans to maximise fishing opportunities within and around energy sites. For this to take place however, improved coordination is required be-tween fishers and science funders. Development of fisheries led initiatives involving developers and researchers was also seen as a way to open up constructive communication whilst addressing trust and power balance issues, which were identified as key barriers in fisheries and renewables interaction.

Several cases of collaboration are already taking place. An example of practical collaboration taking place and being documented is the Fishermen and Scientists Society in Halifax, Nova Scotia. This is a partnership based on effective communication and common goals between fishermen, scientists and the general public. The Society facilitates both collaborative research and the collection of relevant information that promotes the conservation of North Atlantic fisheries stock. It is aimed at establishing and maintaining a network of fishermen and scientific personnel that are concerned with long-term sustainability of the marine fishing industry in the Atlantic region (Fishermen & Scientists Research Society, 2012). Through the society, fishers participate in research, communication and establishment of a knowledge base which can be used to better manage and conserve the resource.

Industry led projects also exist in the UK. For example, the European Marine Energy Centre (EMEC) is working together with Herriot Watt University's International Centre for Island Technologies, Seafood Scotland and industry input from the Orkney Fishermen's Society and Orkney Fishermen's Association. In this project, fishers are involved in monitoring activities around the Bilia Croo wave test site in Orkney (EMEC, 2012). There is an opportunity for developers, fishers and the industry authority, Seafish, to work together to survey and identify hazards. This collaboration could obtain mutually beneficial information on hazards and gear obstructions unknown to developers and fishers. Currently available chart updates accessible through the seafood authority's website (Seafish, 2013) provide opportunities for effective updates of new hazards and infrastructure. Identification of new seabed hazards provides an opportunity to apply the communication protocols discussed above utilising consistent group representatives and legal recording to agree mitigation and safety considerations.

Fig. 2. Priorities for research collaborations identified by survey respondents



At a national level, the FLOWW (Fisheries Liaison with Offshore Wind and Wet Renewables) group meets four times a year with the aim of advancing the relationships between the fisheries and offshore renewable energy industries through dialogue. FLOWW developed best practice guidance to aid offshore renewable energy developers with fisheries liaison, such as establishing and managing contacts, guard vessels, information for construction and maintenance personnel, providing assistance to fishers, entangled fishing gear, and dealing with claims for loss or damage of gear (FLOWW, 2014). To improve liaison between the renewable energy and fisheries sectors, the initial FLOWW guidelines should be disseminated as widely as pos guidelines available as a link on relevant sites (such as on the Crown Estate website). This requires co-ordination on a national level. Other suggestions included making FLOWW guidelines a legal requirement, execution of these requirements would remain with the Crown Estate (Rodwell et al., 2013a). Further solutions were suggested to reform the Marine Industry Liaison Group (MILG) to operate at a more strategic level, and ensure involvement of the fishing industry.

4. Towards a mitigation agenda for fishing effort displacement

The results from the workshops presented above bring about a set of activities and action points to mitigate fishing effort displacement as a result of marine renewable energy development. A workshop recommendation was that a Mitigation Toolkit should be developed, to open up a way of sharing research and ideas and allowing for more efficient targeting of research and reversing the current trend of holding back mitigation solutions.

4.1. Overcoming data issues for assessing effort displacement

Better guidelines and procedures to quantify displacement are urgently needed. If displacement is assessed at an early stage the developer can then shape the development accordingly. This in turn leads to promotion and understanding the need for fishers to share data, addresses specific protocols on how to respect commercial sensitivity and can aid developers to inform decisions and activity. This will require multiple partner support and should be initiated immediately. This would require project funding and protocols developed in order to share the data, and identification of the various bodies that could take on this responsibility (Rodwell *et al*., 2013a).

For assessing fishing effort displacement there is a need for:

- A variety of accurate data gathered through appropriate assessment methodologies
- Data to be made available and shared freely whilst respecting commercial sensitivity
- Assessment guidelines to be developed and distributed at a national level.
- Case studies need to be analysed to inform behaviour rules of various gears, vessels, and skippers.
- Best practice of displacement assessment to be shared.
- Direct involvement of fishers in collaborative projects with developers and researchers to further technologies, methods and plans to maximise fishing opportunities within and around energy sites. This requires improved coordination between fishers and science funders.

4.2. Development of appropriate methods for assessing displacement

Although a variety of methods exists that have the potential to assess fishing effort displacement, these methods are not specifically developed for this purpose. Therefore it is important that:

- When determining choice of method, it must be taken into ac-count that they are not specifically developed for this task.
- Comprehensive methods are developed for assessing effort displacement, including tailoring of existent methods.
- Models for displacement should be developed as well as habitat resilience and vulnerability tools, particularly at the start of the mapping process that is currently taking place as part of MSP
- MSP could provide an integrated approach for mitigating displacement.

- A standard methodology is developed for assessing effort displacement across all UK administrations and Member States of the European Union.

4.3. A consultation protocol between MRE and fishing sectors

Beginning engagement and negotiation for upcoming projects at the earliest possible stage provides a significant opportunity for least impact on existing fishing activity. This, however, requires collaboration and communication between all stakeholders. This study has shown that it is necessary to formalise negotiation procedures, and develop appropriate methods for approaching fishers. To mitigate effort displacement as a result of marine renewable energy development it is necessary to:

- Clearly communicate the merit of the consultation and the de-gree of influence that can be exercised.
- Ensure consultation is inclusive and all sectors are represented, and a practical solution was suggested to reform the Marine Industry Liaison Group (MILG) to operate at a more strategic level, and ensure involvement of the fishing industry.
- Improve communication in consultation and engagement processes and develop protocols; and ensure inter-jurisdictional communication. Develop the current FLOWW guidelines into a legal requirement.
- Ensure consistency in procedures, and be sensitive to differences in discourse and practice between the two sectors.
- Determine mitigation options on evidence of success and agreements with stakeholders.

- Analyse case studies of marine renewable developments to identify successes and failures of mitigation options, and learn from case studies on conflict resolution.

5. Conclusion

In this paper we investigated the challenges for co-existence between the fisheries and renewable energy sectors, and explored a mitigation agenda for fishing effort displacement resulting from MRE development in the UK. The workshops, which provided the primary input for this paper, brought together key experts (both academic and practitioners) in the field of marine renewable energy and fisheries. The research, which was the first of its kind to exist in the UK, demonstrated the need for a collaborative effort to overcome the potential difficulties associated with the co-existence of marine industries within limited marine space. There was an overwhelming sense of genuine desire for the two industries to work together to find solutions. The main points identified for a mitigation agenda consisted of: developing efficient and cost-effective mechanisms for overcoming data issues for assessing effort displacement; the development of appropriate methods of assessment; and development of an acceptable consultation protocol between MRE and fishing sectors agreed on by all stakeholders. It was considered that with appropriate interaction, through effective communication and the use of transferable in-formation such as the mitigation toolkit, data and case study repositories, real progress can be made in mitigating conflict between the fisheries sector and the MRE industry. Although this information will be largely applicable in a UK context, appropriate methods of assessment, consultation protocols, and data issues, can be adapted to the context of other countries facing similar challenges.

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Marine and coastal policy in the UK: Challenges and opportunities in a new era

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Abstract

Marine and coastal policy in the UK has faced a number of significant changes in recent years, most notably the passing of the Marine and Coastal Access Act in 2009. These changes have brought significant challenges and opportunities for all those involved in the management and use of the UK's marine and coastal environment. This new era of marine policy inspired the UK's first Marine and Coastal Policy forum held in June 2011. In this introductory paper the global context of marine policy changes and the themes which emerged from the forum, forming the basis of the articles in this special issue, are outlined. It is concluded that there is a high level of engagement, capacity and willingness of key stakeholders to work collaboratively to address the environmental, social and economic complexities of managing the marine and coastal environment. It is both evident and encouraging that progress is being made and the many challenges faced in this new era give rise to a number of opportunities to develop new ideas and effective mechanisms for finding solutions.

1. Introduction

In November 2009 the Marine and Coastal Access Act (MCAA) [1] was passed, which marked the beginning of a new era in the management and protection of the marine and coastal environment in the UK[2]. This ambitious and complex legislation brings with it both opportunities and challenges for policy makers, coastal managers and practitioners. It has eight main components which include: the establishment of the Marine Management Organisation (MMO); a marine planning system; a reformed marine licensing system; a new mechanism for marine nature conservation; modernising of inshore fisheries management and marine enforcement; a new

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[2] The Marine and Coastal Access Act is focused on England and Wales. The Scottish Government passed devolved legislation in the form of the Marine (Scotland) Act, 2010. Northern Ireland will have its own policy approach with supporting legal instruments.

authorisation scheme for migratory and freshwater fisheries; improvement in coastal access; and a more ‘joined up’ approach to coastal and estuarine management. It is the opportunities and challenges that this act brings with it which inspired the UK's first Marine and Coastal Policy forum, 22–24th June 2011. The forum was hosted by the Centre for Marine and Coastal Policy Research, based within the Marine Institute, Plymouth University. It aimed to bring together marine experts to explore the key influences, approaches and techniques within what is a changing policy climate for the sustainable use of the marine and coastal environment.

The aim of this paper is to outline the main challenges and opportunities for marine policy which were first highlighted at this forum and that have subsequently been developed into research articles to form this special issue. In the following section, the global context of policy surrounding the marine and coastal environment is established. Then the four cross-cutting themes covered by the forum and related research articles are presented and discussed in brief. These themes are: management and planning of the marine environment e.g. [2–8]; science-policy integration and communication e.g. [9,10]; social and economic issues e.g. [11–14] and marine conservation and ecosystem services e.g. [15,16]. The key findings of forum workshops directly linked to these themes are described in boxes. The challenges and opportunities are then put in the context of sustainability and solutions which can be generated by better communication are discussed. Finally a number of overarching conclusions as to the future of marine policy in the UK are drawn.

2. The global context

The global context and the key ideas that are driving work in the marine environment from a global to a local scale were outlined in the keynote talks by Laurence Mee (Scottish Associa-tion of Marine Science (SAMS) and Dan Laffoley (International Union for Conservation of Nature (IUCN). In his talk entitled ‘Designer seas or stewardship, a people's choice?’ Professor Mee, Director of SAMS discussed: the changing use of the marine environment; the increasing demands for exclusive and shared use of marine space which is triggering conflicts; and the designation of access and property rights through marine spatial planning. Mee illustrated his point with the example of the Dogger Bank in the North Sea where conservation and wind farm interests are juxtaposed. Coupled with this problem, there is a change in human perception about our seas, sometimes coloured by the phenomenon of slipping ecological baselines where standards and expectations of natural environmental quality gradually decline with each generation. A survey carried out in seven EU countries as part of the EU funded Knowseas project demonstrated that popular perceptions of the problems afflicting the marine environment do not always coincide with those held by scientists [17]. In this example the foremost popular concern of respondents was found to be industrial pollution even though the worst polluters are regulated or have moved to Asia. Mee concluded that it is difficult to deal with or communicate complexity and political systems tend to focus on the linear causality of ‘easy wins’ rather than the complex, ‘wicked’ problems related to trade-offs and human values. Furthermore, there is no simple mechanism to balance the prerogative to conserve natural capital whilst optimising economic return and maintaining human well-being. Adaptive management, which offers one mechanism to set environmental and social objectives and work towards them, is at the heart of the EU Marine Strategy Framework Directive. This new strategy requires ‘buy in’ from the public but opinion surveys have shown low confidence in current institutions and efforts to build public understanding have been minimal. There is no way to return to pristine marine systems of the past and the mix of conservation and ‘designer seas’ projected for the future will require clear benchmarks, new human values and a common understanding of stewardship.

Continued emphasis on the global scale of problems and potential solutions, was given by Professor Dan Laffoley, Senior Advisor, Marine Science and Conservation for the Global Marine and Polar Programme in the IUCN. Laffoley focused on the use of new technologies in communicating key messages about how to achieve a positive future for the marine environment. He showed how the IUCN is making great strides in bringing information about the marine environment to the general public and policy makers through media using tools such as Google and how in the future ‘apps’ for mobile handheld devices may be developed to make information more accessible [9]. It was proposed that through better communication, people can develop their knowledge and understanding, so that they could become more involved in the decision making processes which should lead to better informed decisions being made. He emphasised the need to inspire people to care enough so that change, in the form of better protection of the marine environment, can become a reality.

3. Management and planning of marine resources

With the variety of emerging legislation and policy such as the Marine and Coastal Access Act 2009 and the EU Marine Strategy Framework Directive and the formation of the MMO, there is now a stronger mandate than ever before for marine planning. The UK Marine Policy Statement published in March 2011 [18] establishes the policy framework for marine planning and decision making for the whole of the UK's marine environment. Its aim is to help achieve the UK Government's vision for clean, healthy, safe, productive and biologically diverse oceans and seas. The evolution of the coastal and marine governance framework in recent years has been both significant and pronounced. This is the focus of the paper by Fletcher *et al*. [2] which highlights the main changes in how England's marine and coastal spaces are governed. The evolving governance framework is a response to the multitude of management challenges facing the marine environment in the coming years, such as the management of historic marine sites in the face of increasing use of the marine and coastal environment [3]. Marine management and planning requires a robust under-standing of a variety of disciplines and their interactions with natural and anthropogenic activities in a given area. Potential approaches to help find sustainable solutions include the use of effective fisheries management tools, ocean front modelling, Vehicle Monitoring Systems (VMS) tracking and mapping, innovative technologies, predictive modelling, decision support tools and stakeholder engagement. In all these approaches data access is deemed to be a common and crucial issue (Box 1).

Using Cefas Observer Data, Harriet Condie and colleagues [4] have analysed the potential impact of implementing a fisheries discard ban, in conjunction with effort restrictions or catch quotas, on otter trawlers operating in the North Sea. They found that a discard ban in isolation will not incentivise more selective fishing. However, if suitable market size regulations are in place, a discard ban in conjunction with effort restrictions can generate a small incentive to fish more selectively. Research identified that whilst catch quotas can create strong incentives for fishers to operate more selectively, they may not be suitable for all vessel segments due to dramatically shortened fishing seasons that may render fishing unprofitable.

Gear-specific VMS data have been employed by Campbell and colleagues [5] to map fishing effort in and around the Western English Channel from 2005 to 2008. The resulting maps highlight potential effects of fisheries closures around a renewable energy installation, Wave Hub in Cornwall, and at a candidate offshore Marine Protected Area, Haig Fras, on the distribution of an international fishing fleet of large (>15 m length) vessels and spatial differences in the intensity of fishing by different gear types. Patterns in fishing effort reflect the suitability of different substrata for each gear type and the availability of target species and the data clearly show that intensely fished 'hot-spots' varied between gear types. The key findings of the study demonstrate the value of gear-specific VMS for spatial management planning.

There is a growing demand for fit-for-purpose maps of the UK's offshore area, and in the recent financial climate increased co-operation is crucial to delivering this. One example is the UK Marine Environmental Mapping Programme (MAREMAP), a new partnership of UK public sector organisations which is responsible for seafloor geological and habitat mapping [20]. By sharing resources and best practice, the MAREMAP partners are attempting to address the under-sampling of UK seas (only about one-third of the UK offshore area is mapped with multibeam bathymetry). The products generated through this multi-disciplinary programme such as high-resolution seafloor habitat maps, are underpinning policy in several ways. For example, the maps are influencing the location and size of potential Special Areas of Conservation (SACs) in the UK offshore area and contributing to UK actions under the EU Habitats Directive. The MAREMAP partners are also developing new technologies and techniques to increase the spatio-temporal resolution and cost-effectiveness of marine mapping and monitoring. A recent study commissioned by Defra investigated the application of marine autonomous systems to mapping and monitoring of the future UK MPA network [21].

Box. 1. Summary of the ‘Data Access’ workshop

Data access

Data access is recognised as an important issue that requires a concerted effort from the marine community to solve. Currently, there is no definitive route to accessing many datasets and participants were unsure of how to request some of the data. There are issues on location, access and licensing restrictions; lack of consistent standards and formats; incomplete or lacking metadata; quality of data and gaps in data availability. There are concerns that while it is necessary to request data from a wide variety of sources, more effort is needed to standardise or harmonise access to data within the UK and Europe. It was suggested that there is a need for high level support in resolving these issues and that the Marine Science and Coordinating Committee could provide such support.

The activities of Marine Environmental Data and Information Network (MEDIN) were discussed with regard to data exchange formats and metadata standards, and the linkages to the UK Location Programme, which transposes the EU INSPIRE Directive [19] to improve the sharing and re-use of public sector location information. Important issues raised include enabling adequate data discovery and access and ensuring confidence in the data by utilising metadata including details such as how data were collated, by whom and for what original purpose. Only with this information was it felt that sufficient confidence could be ascribed to allow reuse. The MMO’s approach to ensuring the quality assurance processes of data providers to assign a level of confidence to data has been criticised as being too academic. However, a high priority must be given to building a robust evidence base for all to use.

There is still a need to overcome barriers to data access. The UK government is working towards making public data available to all. However, there are still obstacles to achieving this such as licenses on some datasets, compliance to regulations on disclosure of personal data and commercially sensitive data.

Despite a number of remaining challenges, significant progress has been made over a relatively short time. There is now a much greater emphasis placed on data standards, collection and management and there is recognition that data management beyond the life of specific, short-term projects is vital.

Further tools for the management and planning of marine resources include predictive modelling and software tools such as Marxan. Marshall and colleagues have applied species distribution models (SDMs) to marine conservation and planning [6]. They offer practical considerations for discussion and propose recommendations for best practice of application of SDMs to support marine conservation planning, including combining model out-puts with other data layers, metadata standards and model error. Tools, such as Marxan, have been developed to support the identification of areas for conservation. However, it has been shown that the successful selection of appropriate areas for conservation can depend upon the availability of data. Using the case study of Lyme Bay in UK, Peckett and colleagues assess the effectiveness of currently available substrate data to designate marine reserves to meet conservation objectives [7].

Miller and colleagues have shown how the distribution of oceanic fronts observed by satellite may be used as a proxy for enhanced pelagic biodiversity [8]. These maps of ocean fronts can then be applied to assist in the designation of Marine Protected Areas (MPAs), fisheries management and site selection for marine renewable energy installations. Frequently fronts between different water masses are associated with higher plankton abundance and diversity and with certain pelagic fish and megafauna. A front climatology of the UK continental shelf was generated showing the regions where strong fronts are most frequently observed during each season. These results have already been used by the UK government to advise the selection of potential MPAs.

The Crown Estate has extensive experience of managing activities within the marine environment and of balancing economic activity with stewardship of natural resources for future generations to use and enjoy. Olivia Burgess presented case study examples of offshore wind, aggregates and coastal assets emphasising the experience of the Crown Estate's in managing its business assets in the context of emerging policy and legislation [22]. Given the Crown Estate's stewardship role in the conservation of the marine environment, the need for well-balanced relation-ships with key stakeholders and policy makers was noted. The development of marine renewable energy creates numerous opportunities and challenges which were further discussed (Box 2).

4. Science-policy integration and communication for coastal and marine governance

The integration of scientific knowledge and understanding into policy making can supports improved policy decisions on the management of the marine and coastal environment. The key questions to shape policy for the future were investigated in one of the forum workshops (Box 3, [10]). The challenges of bridging the gap between policy and science were discussed in a parallel workshop (Box 4). Some of the successes, failures and challenges in attempts at integration are detailed below.

Communicating science to stakeholders including the public was the focus of some discussion at the forum. Piers Stanger discussed the overarching strategy for their management through Shoreline Management Plans (SMPs) and discussed the inclusion of climate change science [24]. One of his key findings was that much work is needed to improve the effectiveness of science communication within this process.

Andrew Colenutt focused on the high quality of data provided by Channel Coastal Observatory data management centre [25] and the role it plays in underpinning policy. The national network of regional coastal monitoring programmes (funded by Defra, and in partnership with maritime local authorities and Environment Agency regional teams) provide high quality topographic, bathy-metric, hydrodynamic and remote sensing data. These datasets were essential to the production of the North Solent SMP [26], which used analytical and visualisation techniques to raise awareness and understanding of the potential implications from present and future risks of tidal flooding and coastal erosion, to vulnerable coastal communities. Such techniques, he claimed, proved extremely effective consultation and communication tools. Further to the national planning guidance relating to development and coastal change, Colenutt suggested that Local Planning Authorities use the flood and erosion risk assessments produced through the SMP process when designating Coastal Change Management Areas.

Franca Davenport of the Science Communication Unit in University of West of England highlighted the increasing reliance of EU policy makers on scientific knowledge and opinion in order to produce evidence-based policy. The topics covered by European-level marine and coastal policy covers a broad range of topics which have widely differing time frames and research needs. In order to feed effectively into European policy, research should aim to be either policy-framed with direct connections to specific legislation or policy-relevant with findings that have implications for current or future policy making and implementation. To have an impact, Davenport argued, research needs to reach policy makers at an appropriate time within the policy cycle which is often difficult to synchronise. Consultancies may play an important role in collating scientific evidence and evaluating the implementation of policy. By developing relationships with consultancies or taking on the role of the consultant, researchers and academic centres can facilitate the transfer of their research to the policy community. She identified multiple routes to influencing policy, that range from personal contact to publication of consultancy reports, and using several of these pathways could have the largest impact.

Natasha Barker of WWF-UK noted that SMPs are a leading example of how to apply the ecosystem approach to policy. She also agreed with the need for better communication between scientists, policy makers and stakeholders is becoming more apparent identifying the range of emerging initiatives to support this such as NERC Knowledge Exchange programme [27], DG Env Science for Environ-mental Policy news and EC funded projects such as PISCES [28]. Whilst recognising science-policy integration is a two-way process, she emphasised that since policy makers have little available time to go looking for relevant science, the most pressing need is for scientists to report their work in a way that clearly links it to the relevant policy context.

There was mixed opinion concerning the success of SMPs in underpinning policy, indicating that some coastal regions may still have a lot to learn from the good practice of others. There was a clear message that the onus should be on scientists to be pro-active in communicating their science effectively to policy makers. Scientists need to communicate the constraints of marine and coastal research and the answers that can be realistically provided to policy makers. Furthermore, they should be aware of potential conflicts between policies and how to effectively position their science so it can provide an objective view. Lastly, it was high-lighted that communicating science is something that natural and social scientists often feel uncomfortable or ill-equipped to do and as such, it presents a significant challenge for scientific community in the future.

Box. 2. Summary of ‘Fisheries and Marine Renewable Energy Interactions Workshop’

Fisheries and Marine Renewable Energy Interactions

Conflict often arises during the development and operation of offshore marine renewable energy (MRE) projects. This workshop brought together a variety of interested stake-holders who, in a round table discussion, highlighted a number of key reasons and possible solutions.

The lack of broad scale datasets on the displacement of species at MRE sites (including cabling areas) was discussed by Stuart Rogers from the Centre for Environment, Fisheries and Aquaculture Science (Cefas). He identified the need to introduce monitoring programmes to observe the impact and assess the likely consequences of developments and to determine how fisheries and MRE can best work together.

The lessons learnt from the Wave Hub EIA process with regard to fisheries were outlined by Colin Cornish. During community consultation, it emerged that the financial impacts on the fishery had been grossly underestimated. Mitigation was found to be the preferred option for fisheries groups, rather than financial compensation. A Strategic Mitigation Fund was established which feeds into the community rather than individuals. This funds projects such as a local fuel supply. Local boats are now used for survey work.

During consultations with fisheries during the environ-mental impact assessment process for Atlantic Array, Tim Golding found that relations were generally good with organisations and groups and these consultations provided a broad overview. Consultations were also undertaken with individuals to provide finer detail. It was highlighted that messages from groups to individuals differ, as often a few strongly opinionated people can dominate in a group. Therefore, it is essential to pursue individual engagement. As with the Wave Hub, mitigation was preferred to compensation as this invested in a long term future. Currently there is very little scientific fisheries evidence available for windfarm sites to allow constructive engagement and mitigation planning [16] although the effects on biodiversity of Wave Hub were investigated as part of the PriMARE project [23].

There is a need for better engagement with not only fisheries but also with coastal communities. Development of marine renewables needs to be seen as a positive opportunity. Better research methods, tools and application of new technologies are also required. However, much better base-line data are required across all species in order to inform better mitigation. Two specific problems identified were the electro-magnetic field effects on elasmobranchs and the noise effects on all species. Unknown shifts in ecosystems mean that further research in this area is also required. A fisheries mitigation working group is now being funded by a Natural Environment Research Council Knowledge Exchange Programme (MREKE) [27] as a direct result of this workshop.

Box 3. Summary of ‘Questions to shape Marine Policy’ (See [10] for full outputs of this workshop)

Questions to shape marine policy
(See Rees et al. [10] for full outputs of this workshop)

UK and European policy is rapidly developing to meet international targets for the sustainable use and protection of the marine environment. To inform this process, research needs to keep pace with these changes and research questions must focus on providing robust scientific evidence. To this end, a collaborative methodology for identifying priority questions that are pertinent to recent changes in marine policy was developed by members of the Centre for Marine and Coastal Policy Research at Plymouth University, UK.

One hundred and fifteen primary questions were generated by the forum delegates. Twenty three participants nominated themselves to take part in a facilitated workshop to sort and combine the primary questions into a set of 38 priority questions. These research questions were then subject to a process of review, validation and quality control by a working group from the Centre of Marine and Coastal Policy Research.

The priority research questions identified at the forum are timely and closely linked to current policy processes in the UK such as the development of a UK network of Marine Protected Areas and the introduction of marine planning. The data requirements to support these processes were identified, including building capacity for a centralised data collection and monitoring framework. Discussions also identified a need to gain a greater understanding of the relationship between ecosystem function and the delivery of ecosystem services, particularly for use within a management context, and research to further understanding of the emerging concept of marine citizenship. Questions relating to governance are dominated by the need to review the current policy framework to streamline efforts, avoid duplication, and ensure that national policy is fit for purpose.

The final priority questions provide a research focus to address the current challenges. They are interdisciplinary and will require cross sectoral partnerships. The results of this research are not restricted to a UK audience. Some of these questions are local in nature, for example those concerning a UK network of Marine Protected Areas, but some have a global element e.g. carbon sequestration as an ecosystem service. Individual countries or regions are progressing their own timelines towards international policy goals. There is much to be gained from international efforts to share experiences to inform progress.

Box 4. Summary of ‘Helping to Bridge the Gap between Marine Science and Policy’ workshop

Helping to bridge the gap between marine science and policy

In order to bridge the gap between marine science and policy is it important to first identify: what the gap or perceived gap between marine science and policy is; what obstacles are preventing us from bridging the gap; and what are possible solutions?

The participants of this workshop, representing a diversity of backgrounds such as fishing, NGOs, scientific research, statutory organisations and local councils, identified a number of key gaps including: communication, collaboration, experienced manpower, funding, data accessibility and knowledge of the marine environment. They also identified some possible underlying reasons (and in some cases obstacles) such as a mismatch in agenda between science and social values, changing methodological standards, mismatch in spatial and temporal scales of science and policy, preconceived notions and inconvenient truths.

It was generally agreed that in order to cross the existing gap a positive approach is needed—‘not just doom and gloom’. All stakeholders need to be prepared to suggest solutions and simplify language used thereby improving good science communication. Collaboration and integration are needed at an appropriate scale. A credible advocate is required along with good leadership and accountability and adaptive institutions.

Research councils are now making it very clear that in all proposals for funding the social impact of any study should be demonstrated. This illustrates that some headway is being made in connecting science and policy. However, some participants felt that this requirement was just an addendum rather than integral to the rationale for carrying on the project. Likewise, the social impact is also becoming more prominent in Research Excellence Framework which demands that academics consider the implications of their research to society. Many academics feel lost as how to address this. There is clearly a need for training of specialists in the area of science communication. The general consensus was that, though gaps and obstacles do still exist, there is some success in starting to bridge them.

5. Social and economic considerations in marine policy

Until relatively recently, marine scientists have tended to focus on marine environmental issues when considering and engaging with marine policy, with economists and social scientists working separately to the marine science community. There are now, however, increased efforts to integrate natural, social and economic considerations more in keeping with the ‘ecosystem approach’. For example, the 2010 State of Seas Assessment, Charting Progress 2 [29] was the first to include a full socio-economic analysis in the form of a ‘Productive Seas Evidence Group (PSEG)’ chapter and the 2011 National Ecosystem Assessment includes chapters on the socio-economic use and value of UK marine and coastal ecosystems [30]. Some of the latest developments in estimating value for the marine environment and looking at some specific applications of this type of thinking are discussed below.

Stephen Hull from ABPMER outlined a framework for assessing the change in value of the marine estate under different management options [11]. This framework has used the Charting Progress 2 Productive Seas Evidence Group report [31] to develop ‘static’ baseline values of ecosystem services as at 2008 and considers how these baseline values might change up to 100 years into the future. Knowledge in this area is developing rapidly as new information becomes available along with more refined models.

An area-focused example of socio-economic impacts of environmental policy in the form of the 2008 Lyme Bay closures to mobile fishing gear was presented by Caroline Hattam of Ply-mouth Marine Laboratory. This case showed that there is a wide range of opinion on whether this policy intervention had been beneficial or not depending on the stakeholder group being asked. Mobile gear fishermen were expectedly negative in their assessment, whereas static fishermen in the closure area were more positive [12]. It could be many years before the full environmental and socio-economic implications will be truly known. There were lessons learned on displacement of activities and the communication processes used by managers, which could be applied to the ongoing MCZ process in England and Wales. Research identified that some stakeholders in Lyme Bay did not seem fully aware of the reason for the closure. It was advocated that every effort should be made to anticipate the likely results of area closures such as the pressure of relocation and new areas of potential conflict.

Julie Urquhart, of the Society, Economy and Environment Research Group (SEERG) at the University of Greenwich, considered the contribution of inshore fisheries to a community's sense of place using Sussex and Cornwall as examples. This reflects the fishing communities' long, often multi-generational, history of interacting with the local sea area whereas environmentalism can be perceived as the relatively new concept. The integration of marine conservation and fisheries objectives through the establishment of Inshore Fisheries and Conservation Authorities (IFCAs) remains a challenge though there is a general sense of optimism that they are an improvement on their predecessors, the Sea Fisheries Committees, and they provide an opportunity for better integration and communication between fisheries and conservation sectors [13].

Michael Clark of the University of Central Lancashire high-lighted that tourism and recreation, while undoubtedly important elements of the marine and coastal economy with environmental implications, need to be managed in a positive way. A case study example of economic and social impacts of establishing an artificial surf reef at Boscombe to encourage surf tourism demonstrated that careful consideration is needed of the promises made to local communities about the potential economic and social benefits of the establishment of such constructions when there is little evidence available [14]. Benefits to local communities may be achieved through coastal regeneration schemes alone. However, the potential benefits of the marketing provided to an area by such a novel scheme should not be overlooked.

There is clearly a challenge to both those responsible for setting policy for UK seas and to marine scientists to have a comprehensive view of the range of interests and activities in the marine environment. The traditional divide between those focused on environmental aspects of UK seas and those with an economic interest needs to be bridged to ensure sustainable use of UK seas for future generations. Furthermore, potential policy success is highly dependent on the engagement of stakeholders. The implications of marine related policy for society were the focus of one of the forum workshops (Box 5).

6. Marine conservation and ecosystem based management

Having a strong evidence base for selection, designation and management of Marine Protected Areas is fundamental in making decisions that all stakeholders can trust. Incorporating ecosystem services into marine conservation planning can play an important role in informing decision makers of the best sites for protection (Box 6). Many new techniques and approaches are being developed and were discussed at the forum, including methods for the identification of biodiversity hotspots to support the MCZ selection process in England and the scope to apply this in data poor offshore regions [32]. However there was a strong warning from Caroline Chambers (from Marine Ecological Surveys Ltd) about the need to ensure that data quality is known and made explicit, using confidence measure to explain the likely implications of data presented. Research has found that the closure of the Lyme Bay reefs to mobile fishing gear caused understandable concern within the mobile fishing sector, who felt the closure was unwarranted and unjustified. Results of ongoing monitoring presented by Tim Stevens may go some way to demo three showed clear recovery trends, and these were difficult to link unequivocally to the closure. However, data analysis over community information showed the new closure areas were developing communities which were similar to the closed control areas over time. Further monitoring of the closed area will be essential in determining whether exclusion of demersal fishing gear is an appropriate management action to conserve marine biodiversity. Of the 16 indicator species surveyed, only three showed clear recovery trends, and these were difficult to link unequivocally to the closure. However, data analysis over community information showed the new closure areas were developing communities which were similar to the closed control areas over time. Further monitoring of the closed area will be essential in determining whether exclusion of demersal fishing gear is an appropriate management action to conserve marine biodiversity.

Mobile marine species present special challenges to marine conservation, shifting across borders and potentially needing a range of locations during various life stages. There are clear difficulties in identifying geographic areas which are consistently important for particular mobile species. Clare Embling presented methods to determine habitat use by mobile species [33–35], and use habitat modelling to identify critical areas which could be defined as Marine Protected Areas [33]. In both case studies, clear environmental factors drove the distribution of the mobile species which enabled geographic areas to be defined, and equally important gave clear information on the environmental factors which need to be maintained to conserve those mobile species [33–35]. Such an approach will be critical in defining and managing MPAs where they are a suitable tool for mobile species conservation.

demonstrating the environmental benefits of the closure through recovery of benthic fauna, but trends are variable [15].

Box 5. Summary of 'Marine Policy and Society' workshop

Marine policy and society

The aim of this workshop was to investigate what current trends such as globalisation, demographic change, climate change and peak oil mean for planning and policy and what research needs exist in order for us to meet the challenges we currently face. For each of these trends, participants considered the questions: What are the impacts of this trend for the management of the marine and coastal domain? What does this mean for marine planning/policy? What research is needed to support policy making?

In terms of marine planning and policy, participants identified that themes need to be translated into local actions. Sometimes the problem appears too large to be addressed but often there are things that can be done locally that can make a difference, for example, a change to consumption patterns. Trends are often case study dependent. This was particularly the case for demographic change where some areas are positively affected and others negatively. Each case must be considered in turn. It was also proposed that for effective policy making more appropriate training and a wider skillset are needed. Weaknesses in the skillset must be identified and training provided in order to successfully address key issues. Policy must be adaptive—one size does not fit all. Constantly changing problems mean that policy makers need to be able to adjust to changes in an appropriate and timely fashion. Often there is a mismatch between the scale of the problem and the policy 'solution'. Awareness of appropriateness of scale is vital. Some problems need to be tackled at all scales; local, regional, national and global.

The research needs identified were numerous and included some generic issues such as increasing funding, standardising data collection and monitoring, sharing data, international collaboration, improved communication and cultural understanding. More specific topics identified, which cut across all themes, included the transition to a green economy, sustainable lifestyles, social attitudes and valuing ecosystem services such as aesthetics.

Box 6. Summary of ‘Towards a Systematic Approach to Ecosystem Services in Marine Conservation planning in the UK’ workshop

Towards a systematic approach to ecosystem services in marine conservation planning in the UK

The aim of this workshop was to discuss how the ecosystem services approach could contribute systematically to marine conservation planning in the UK. It was highlighted that the key benefit of incorporating ecosystem services into marine conservation planning was its potential role as an integrative factor in decision and policy making. This would allow marine conservation planning to be undertaken within a single holistic decision making framework which transparently showed: causality relationships; trade-offs between different policy and planning choices; and identified the relationships between key variables in marine conservation planning. More broadly, workshop participants considered that using ecosystem services in marine conservation planning provided a clear link between societal well-being and the marine environment, and as such, provided a potentially powerful mechanism to improve public and policy-maker understanding of the marine environment.

The two key challenges of using ecosystem services in marine conservation planning related first, to the methodology of identifying, classifying and valuing marine ecosystem services; and second, to the data gaps that currently exist in the evidence base to support ecosystem service assessment. Specific concerns focused upon the potential for over-simplification in current classifications, difficulties in measuring intangible ecosystem services, difficulties in linking monetary values to ecosystem services, and how to ensure that any assessment of ecosystem services met the needs of a range of policy-making processes. The lack of data concerning ecosystems and associated services was the second dominant theme. At present there is a considerable lack of evidence concerning the existence of ecosystem services. This makes an accurate assessment or valuation of them impossible.

In order to improve incorporation of ecosystem services into marine conservation planning, a multi-disciplinary research agenda must be mapped and prioritised. This should include: a consistent ecosystem service classification suited to the marine environment; the identification and systematic filling of data gaps; learning from experience elsewhere and from other environments how to enhance the application of ecosystem services in the marine environment; and finding an effective way of measuring intangible benefits. More broadly, finding mechanisms to better engage relevant stakeholders and the public in debates about the social benefits of marine conservation was also highlighted as important. Overall, the workshop saw significant value in incorporating ecosystem service approaches into marine conservation planning, but felt that at present, this was difficult due to methodological concerns and a lack of evidence. However, with focused research, the benefits could be realised.

7. Sustainability- From ideas to practice

In the final keynote speech of the forum Bob Earll (Director of Communications and Management for Sustainability) focused on two key themes, delivering sustainability and the ways that conferences can promote and generate ideas. He proposed that sustainability is the key idea that provides the focus for much of the policy and technical world. The central idea of sustainability is simply stated but fundamental. It involves a clear view of the future, a vision which includes social, environmental and economic elements and people. The generation of new and realistic ideas is crucial to the development and implementation of sustainability. A two-way discourse between academics and practitioners is also essential to meet the very real challenges we face including meeting environmental, economic and social challenges.

Earll highlighted that the scale and complexity of the issues can be discouraging but also demonstrate the need for action [36,37]. The need to present and communicate complicated ideas like sustainability much more clearly, by using systems diagrams such as the periodic table, was advocated [38]. Important ideas like ecosystem services need to be operationalised, with the context of informing decision making; there are scientific limits to this approach [39]. Fishing remains a major challenge not least from its decline and failure to provide an important food source but also because of the level of environmental damage that can be caused. Society needs to normalise the way fishing operates, at present; its position relative to every other sector is quite exceptional for reasons that are unclear and disproportionate to its performance. Constructive opportunities such as scallop ranching need to be found, however, their limits must be recognized.

Earll concluded that networking and the building of networks to help tackle critical issues is very important and conferences, such as the Marine and Coastal Policy forum, have an critical role to play in helping to generate and promote ideas which are key to developing a more sustainable future.

8. Conclusions

In this special issue the key challenges and opportunities regarding marine policy in the UK as identified by the expert participants of the UK's first Marine and Coastal Policy Forum are highlighted. The forum demonstrated a high level of engagement, capacity and willingness of the research, academic, professional and practitioner communities to grapple with the environmental, social and economic complexities associated with the very difficult realities of managing the marine and coastal environment.

Several important and prominent issues stood out. Better socio-economic research input is needed in the process of managing our marine environment to enable us to evaluate the full extent of activities in the marine and coastal environment. The ecosystem services approach can provide a useful framework for linking social and ecological systems and bringing a fuller range of issues into the valuation process. There is a clear need for effective mechanisms of societal engagement within the decision making process and policy cycle. Furthermore, marine management tools such as predictive modelling require further development and implementation to assist effective decision making.

Effective management of commercial fishing is one of the biggest challenges of the 21st Century. Given the huge geographical range and scale of commercial fleets, an increasing global population, conflict with other sectors and the decline of ecosystems, urgent action needs to be taken. Conferences can provide information about the problems caused but they must also galvanise fisheries managers and governments to take robust, effective action to address the issues identified.

The introduction of the MCAA and the associated management bodies has provided the UK with a real opportunity to implement a range of new tools and techniques to enhance marine governance and learn from the outcomes. For example, the process of MCZ establishment and the establishment of the new IFCAs provide us with clear opportunities but also challenges in incorporating a diversity of stakeholder views whilst still being successful in achieving conservation and fisheries objectives.

A clear issue which needs to be addressed is that of conflict management due to multiple uses of the marine environment. One such example is the interactions between marine renewable developments and fisheries. The first steps in this process were achieved at this forum with the establishment of a marine renewables and fishing working group (funded by NERC). In this special issue the key outputs from the forum are synthesised. It is intended that these outputs will contribute to developing UK-specific responses to both domestic and EU marine policies.

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Priority questions to shape the marine and coastal policy research agenda in the UK

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Abstract

United Kingdom (UK) and European Union policy is rapidly developing to meet international targets for the sustainable use and protection of the marine environment. To inform this process, research needs to keep pace with these changes and research questions must be focused on providing robust scientific evidence. Thirty four priority research questions within six broad themes were identified by delegates who attended the 1st marine and coastal policy Forum, hosted by the Centre for Marine and Coastal Policy Research at Plymouth University in June 2011. The priority questions formed through this research are timely and reflect the pace and change of marine policy in the UK in response to international, European and national policy drivers. Within the data theme, the majority of questions seek to find improved procedures to manage and use data effectively. Questions related to governance focus on how existing policies should be implemented. The marine conservation questions focus entirely upon implementation and monitoring of existing policy. Questions related to ecosystem services focus on research to support the conceptual links between ecosystem services, ecosystem function, and marine management. Questions relating to marine citizenship are fundamental questions about the nature of societal engagement with the sea. Finally, the marine planning questions focus upon understanding the general approaches to be taken to marine planning rather than its detailed implementation. The questions that have emerged from this process vary in scale, approach and focus. They identify the interdisciplinary science that is currently needed to enable the UK to work towards delivering its European and international commitments to achieve the sustainable use and protection of the marine environment.

Keywords: Marine Conservation, Marine Planning, Marine Citizenship, Ecosystem Services, Data, Governance

1. Introduction

The need to identify research priorities is important because a robust evidence base is critical to support informed policy change. However, it is a complex issue as national policy for the marine. and coastal environment is not created in isolation and is driven, at least in part, by the need to meet international commitments. These include global treaties, such as the Ramsar Convention on Wetlands and the Convention on Biological Diversity, and regional agreements, such as the OSPAR Convention of the Protection of the North East Atlantic [1–3]. These policies provide a frame-work for both UK and European Union (EU) marine policy through the definition of important over-arching principles and criteria for species and habitat protection. The EU translates many of these principles into more concrete objectives through its directives and it is the responsibility of the member states to ensure the requirements of these directives are met.

Central to the management of the European marine environment are the Habitats Directive (92/43/EEC) and the Birds Directive (79/409/EEC) which together create a network of protected areas for a number of listed species and habitats native to member states in the terrestrial and marine environment. These directives require the designation of European Marine Sites as either Special Areas of Conservation (SACs) or Special Protection Areas (SPAs) and subsequently protection of these sites from harmful development [4]. More recently the Marine Strategy Framework Directive 2008/56/EC (MSFD) has been introduced to provide broader marine environ-mental protection in European waters [5]. This Directive, which constitutes the environmental component of the EU's Integrated Maritime Policy (IMP), aims to achieve good environmental status in all EU marine waters by 2020 while protecting the resource base for economic and social activities. This brings the marine environment in line with the EU's Water Framework Directive's (WFD) requirements for inland and coastal waters. In addition, the IMP, which advocates an integrated approach to governance of marine and coastal waters, has proposed the introduction of marine or maritime plans, working in close association with integrated coastal zone management.

To support the UK Government in meeting these international and European commitments and to achieve the Government's aim of 'clean, healthy, safe, productive and biologically diverse oceans and seas' [6], the Marine and Coastal Access Act 2009 (MCAA) [7], the Marine (Scotland) Act 2010 [8], and the forthcoming Northern Ireland Marine Bill 2012 are providing the framework to stream-line the way the marine environment is managed in the UK. Along with developing legislation from the devolved administrations [9] these new provisions include the legal frameworks to develop Marine Plans (guided at a national level by the Marine Policy Statement [10]), provide powers to set licensing controls for development proposals in the marine area, and enable the designation of a new type of Marine Protected Area (MPA) called Marine Conservation Zones (MCZs).

The scale and pace of change in European and national policy presents challenges in managing the marine environment for its sustainable use. These changes in the governance of the marine environment place considerable demands on the marine community to work together to provide the necessary information and understanding to fulfill the set objectives. Decision makers need access to scientific evidence that is targeted to their needs [11,12]. To this end, academic research in the science-policy arena must be integrated and interdisciplinary. It must also be timely by framing research activities within the context of the general trends in that field [13,14]. Collaborative exercises to identify priority areas for research and management have demonstrated a metho-dology for identifying relevant areas of research to scientists, policy makers and practitioners [15–22]. However, none has focused on the interdisciplinary research requirements needed to achieve the sustainable use and protection of marine environment in the UK. To fill this gap in knowledge the aim of this study was to work with policy makers, practitioners and academics to identify priority questions to shape the marine and coastal policy research agenda in the UK.

2. Methods

In his taxonomy of horizon-scanning methods, Sutherland [16] identifies the methods used in this research as ‘expert workshops’ which ‘‘bring together experts to suggest possible future issues based on their own experience and knowledge’’ (p. 524). Sutherland identifies the advantages of this approach as the credibility provided by experts and that the iterative nature of the work-shops draws out key issues and provides opportunities to refine the outcomes. The disadvantages are that the findings are always constrained by who was (or was not) involved in the workshops and by the precise process that was followed. The authors recognised these qualities in this study and specifically sought to minimise the disadvantages inherent to the method through the application of a rigorous research process described below, yet inevitably some effect will remain. Any variation in the methods used and in participation in the workshop would have resulted in a slightly different list of research questions; however, this is the case for all such processes.

The development of this research involved four stages (Fig. 1). The central focus for undertaking this research was the 1st marine and coastal policy Forum which was hosted by the Centre for Marine and Coastal Policy Research (MarCoPol) at Plymouth University, UK in June 2011.

Fig. 1. Process diagram that shows the stages undertaken for developing the priority questions to shape the marine and coastal policy research agenda in the UK. n= the number of questions at each stage of the process.

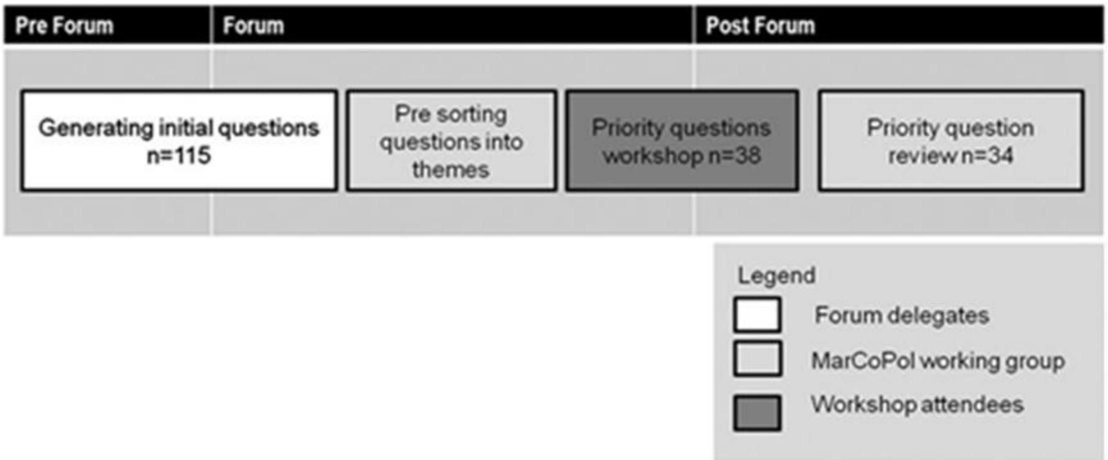

Table 1. Delegates to the Marine and Coastal Policy Forum shown by sector.

Sector	Number of forum delegates
Consultant	12
Charity representative (e.g., National Trust, The Wildlife Trust)	12
Government advisory body (e.g., Joint Nature Conservation Committee)	6
Industry representative	3

Local government authority representative	3
Research institute member (e.g., University, Plymouth Marine Laboratory, Marine Biological Association)	52
Student (MSc & BSc)	6

2.1.Stage 1: Generating initial questions

Forum delegates were asked to identify the key questions that they felt were needed to be addressed by the research community to fully meet the challenges posed by recent policy developments to achieve the sustainable use and protection of the UK coastal and marine environment. Delegates were invited to submit questions by email prior to the Forum and during the first two days of the meeting. One hundred and fifteen initial questions were generated in total. Table 1 provides a summary of the sectors represented by Forum delegates. The majority of delegates to the Forum were representatives of research institutions within the UK, many of whom are experienced in providing research to support marine governance and policy decisions. In addition, there was representation from all key stakeholder sectors active in the UK's marine and coastal governance framework.

2.2.Stage 2: Pre-sorting questions and workshop

In order to make the best use of time available during the Forum meeting, the questions initially submitted were pre-sorted into thematic categories by a working group from the Centre for Marine and Coastal Policy Research. The thematic categories were: data, the ecosystem approach, human impacts, MPAs, marine spatial planning, policy, and social issues.

2.3.Stage 3: Priority questions workshop

Twenty three delegates attended the Forum workshop, during which they were asked to work in small groups to review the initial, themed, pre-sorted questions. Delegates were asked to keep the following criteria in mind when writing, reviewing, and combining research questions. The criteria, adapted from Sutherland et al. [16], were that each question should:

a) be answerable through realistic research design;

b) be SMART (specific, measurable, attainable, realistic and timely);

c) allow a factual answer that does not depend on value judgements; and

d) be of relevance to the UK.

Each group was moderated by a facilitator who kept the group to task and recorded the process through which decisions were made, primarily in order to maintain a clear audit trail between the initial questions generated by the wider Forum delegates and the refined questions identified by delegates at the workshop. The outcome of the workshop was 38 priority questions to take forward to the next stage.

2.4.Stage 4: Priority question review

A working group from the Centre for Marine and Coastal Policy Research undertook a final review of the priority questions in order to remove duplication and validate the audit trail between the initial questions and the final set of priority questions. This process resulted in the removal of four duplicated questions. A final set of 34 priority questions was agreed.

3. Results

The research questions were grouped into the following six broad categories: marine conservation, marine planning, marine citizenship, ecosystem services, data and governance. The questions were divided into these categories in order to provide a coherent structure for presentation. However, it should be recognised that an individual question may have relevance under one or more categories. The final 34 questions are not ranked. The results are presented and discussed according to their categories.

3.1.Data

1. What are the minimum data requirements (range of datasets and quality thresholds) for effective marine planning?

2. What lessons have been learned from the recent Marine Conservation Zone (MCZ) process to improve the incorporation of scientific and stakeholder data into marine conservation planning?

3. What elements are required to coordinate a national data collection and monitoring framework to support marine management?

4. How can confidence in stakeholder sourced data be assessed?

The need for a robust evidence base to inform marine decision making is apparent in questions 1–4. All four questions are forward thinking and, ultimately, aim to identify ways in which the collation and provision of data can be improved to support marine environmental management. Questions 1 and 4 reflect upon the development of the UK MPA network, in particular with regard to improving the incorporation and quality of data into the decision making process (question 1). Data initiatives such as the Ocean Biogeographic Information System (OBIS), and the Marine Environmental Data and Information Network (MEDIN), have developed in response to the fragmented nature of marine environmental data holdings in the UK and have worked to increase the availability of marine environmental data to end-users. Yet lack of data has been cited as a common impediment to progress in conservation, especially in offshore environments [23]. The questions posed here recognise the extent of data gathering (consolidation of ecological data and gathering of social and economic data) required to determine the location of MCZs (question 2) and support the development of marine plans (question 1). Question 3 also identified that the development of a central data body, monitoring framework and a protocol for the assessment of stakeholder sourced data (question 4) could serve to support robust policy delivery.

3.2.Ecosystem services

5. What are the links between marine ecosystem function and ecosystem services?

6. How can marine ecosystem services (e.g., climate regulation) be incorporated into marine management?

7. What are the research priorities to improve our understanding of marine ecosystem services?

Marine ecosystems provide a number of essential ecosystem services, such as the provision of food and climate regulation, which are essential to maintain human wellbeing [24–26]. The development of descriptors [24] to translate the complexity of marine ecosystem functions into marine ecosystem services has broadened the inclusion of marine ecosystem services into policy and planning [27,28]. As such, the consideration of eco-nomic, social and ecological values in decision making (the ecosystem approach) via defining ecosystem services has become integral to marine conservation planning and policy in the UK [5,7,10,29]. The questions raised under the category of ecosystem services (questions 5–7) demonstrate that greater understanding is needed of the concept, particularly with regard to the links between ecosystem functions and the delivery of ecosystem services (question 5), in order for it to be used in a management context (question 6). As this is a broad area of research it is suggested that setting research priorities within the subject area may improve its practical application (question 7).

3.3.Governance

8. How can marine heritage priorities (e.g., wrecks) be integrated into coastal and marine policy?

9. How can the current marine and coastal policy framework adapt to drivers of change?

10. Can the current marine and coastal policy framework in the UK be streamlined and duplication reduced?

11. How do sectoral interests (e.g., fisheries, conservation, energy) influence marine and coastal policy at different scales?

12. How does the current marine and coastal policy framework enable the sustainable management of the marine environment?

13. To what extent is the Marine Policy Statement effective and how can this be assessed?

14. To what extent is the national capacity for marine and coastal governance appropriate for the scale of the challenge(s)?

The UK marine and coastal governance framework mediates policy derived from a number of scales into tangible actions, usually at the national, sub-national, or local level. The priority research questions developed related to governance all address specific issues related to the implementation of current policy, either as standalone policy themes or through integration with other policy frameworks. The coastal and marine governance framework has been the subject of on-going debate in the UK for the last five years during the development of new marine legislation, therefore many of the questions about what the legislation should contain have been resolved. The emphasis in questions 8–14 reflects this evolution; they are directed at assessing the suitability of the current policy framework to deliver overarching policy objectives. Given that the questions refer to a system which has very recently been developed and not yet fully implemented, this can be read as the participants' observation that there is both an opportunity and need to build in mechanisms for review and adaption of that system as the challenges of implementing the policy become apparent. Questions are posed as to whether current policy is adaptive to drivers of change (question 9), whether duplication can be reduced between policies (question 10) and whether current policies incorporate all sectors fairly (questions 8 and 11).

3.4. Marine citizenship

15. How are people's perceptions of the marine environment influenced by media?

16. What are the barriers to engaging the public with the marine environment and how can these be overcome?

17. What is the role of the 'Big Society' in the marine environment?

18. What public behaviours could be encouraged to change in order to improve the health of marine ecosystems?

19. What role do retailers and consumers play in the use and management of marine resources?

Questions 15–19 all relate to aspects of marine citizenship, the emerging paradigm that encompasses an individual's responsibility to make informed choices about their impact on the marine environment [30]. In common with other citizenship principles, marine citizenship recognises that individual members of society have a responsibility to contribute to solving marine environ-mental problems through their personal behaviour, particularly related to everyday consumer and lifestyle choices [31–33]. Multiple factors, including knowledge, values and experience, can influence public engagement with environmental issues [34] and the relationship between the public and the marine environment is also likely to be influenced by similar factors

[35]. Better understanding of these factors, and the channels through which information about the marine environment flows will support future action to increase the level of marine citizenship in a target population (questions 15 and 16). Elements of marine citizenship and the UK's 'Big Society' (the current Government agenda of greater individual involvement in civic activity in policy areas where Government has reduced or retracted direct support) are potentially aligned, therefore question 17 is significant, but potentially UK specific. At present, the desirable individual pro-environmental behaviours that might be considered as expressions of marine citizenship in order to reduce human pressures on marine environmental health are uncertain, hence question 18. Finally, question 19 focuses on the role retailers can play in influencing the choices of consumers and therefore indirectly contributing to the governance of marine resources. These questions highlight the potential of marine citizenship as an emergent policy channel in the UK, but also identify some of the challenges which need to be overcome in order to support its realisation.

3.5. Marine conservation

20. What are the impacts (social, economic and ecological) and extent of recreational fishing within UK seas?

21. How can ecological change in the UK MPA network be monitored from a baseline to demonstrate performance against conservation objectives at varying scales?

22. Can non-statutory management measures deliver the conservation objectives of the UK MPA network?

23. To what extent do the conservation objectives of the UK MPA network help achieve wider good environmental status for UK seas as defined in the EU MSFD?

24. What are the relationships between socio-economic and ecological change in the MPA network?

25. What are the socio-economic impacts of the UK MPA network and how can they be monitored?

26. What are the thresholds and criteria for implementing statutory management measures in an MPA?

27. Does the size, shape and number of MPAs influence their social, ecological and economic effectiveness?

28. What are the relative costs and benefits of statutory and non-statutory management and enforcement measures for marine management?

29. How can the conservation needs of highly mobile marine species be addressed within the current policy framework?

The UK administrations are tasked to substantially complete an ecologically coherent network of MPAs by 2012 [10]. Recommendations for MCZs in English and offshore

Welsh waters were published in September 2011 [36–39]. These recommendations have been reviewed by an independent scientific advisory panel and the statutory nature conservation agencies. Final recommendations will be put forward to Government in 2012. Questions 20 to 29 all relate to this policy development and delivery. The questions identified under this category recognise that in order to improve decision making a greater understanding is required of the human impacts on marine resources e.g., does recreational angling have a significant impact on marine resources (question 20). At present, the future management of activities within the MPA network is under review, based on the statutory conservation objectives for each site. As such, questions 22, 26 and 28 highlight the need to assess the suitability of different management measures to deliver the conservation gains for which the MCZ network was designed and to set thresholds for the management of activities to be reviewed. In addition, the priority questions identify a need to make provisions to monitor and manage the network of MPAs from a baseline economic, social and ecological perspective (questions 21, 24, 25 and 27) against which the success of the MPA in delivering conservation objectives both locally, regionally and internationally can be reviewed. Question 29 specifically addresses the provisions for the conservation needs of highly mobile marine species within the current marine conservation policy framework.

3.6. Marine planning

30. How can the net environmental impact of marine planning be measured?

31. What are the mechanisms and criteria (ecological, economic and social) for identifying and negotiating trade-offs between human activities in marine planning?

32. How can the representation of stakeholders be quality assured in participative marine management?

33. How can marine planning integrate with the existing policy framework and management processes at varying scales?

34. What are the implications of applying a precautionary approach to marine planning?

Marine spatial planning is considered to be a critical step to implementing an ecosystem based approach to managing the multiple uses of the marine environment [40]. The EU IMP [41], the EU MSFD 2008/56/EC, the UK MCAA (2009), the Marine (Scotland) Act (2010), and the UK Marine Policy Statement have collectively set the course for delivering marine plans in the UK. This policy impetus has shaped the development of the priority research questions 30–34. Question 30 identifies the need for developing methods to determine the net environmental impact of marine planning and one reason for this could be to determine the impact of the planning process itself on our use of the marine environment. It is possible that the introduction of marine planning will increase human impacts on the marine environment or facilitate better protection, and such a study would enable the impacts to be assessed and compared with the goals of the Marine Policy Statement. It is recognised that decision making within this ecosystem based context of marine planning requires trade-offs to be made between multiple users [42,43]. Therefore, questions 30 and 31 require the identification of these activities, potential trade-offs, and a mechanism to review the net environmental impact of the marine plans to deliver broader marine resource use objectives.

The representation of stakeholders in the decision making process is addressed by question 32. The task of ensuring that appropriate representation is maintained may be more challenging for offshore areas, than for example for estuaries or terrestrial environments where user groups are more easily defined, as there could be a lack of democratic representation, given that it is remote to the general population. Questions 33 and 34 require an overview of the policy and to identify whether the objectives can be integrated with other concurrent polices and management (question 33), including those existing at sea and those on land, and if the application of the precautionary approach should be reasserted (question 34). A lack of data is particularly acute in offshore areas [23] but there is a need to provide plans in the immediate future. Where insufficient data exists to make informed choices the precautionary principle requires that there is a presumption in favour of environmental protection. This is relatively straightforward when considering new activities but can be more challenging when reviewing and approving existing activities which may be causing harm and determining their future maintenance or growth. Hence, exploring the application of the precautionary principle to marine planning offers many interesting research questions particularly with regard to balancing social and economic factors within a precautionary approach.

4. Discussion

This research priority setting process was focused on the needs of marine and coastal policymakers in the UK; therefore the questions form an explicitly applied research agenda largely specific to the UK. It is anticipated that policymakers will benefit from the development of a research agenda that supports their information needs [22] and which therefore underpins the development of policy. The questions that emerged from this process varied in scale, approach and focus, which potentially reflected the interdisciplinary nature of marine and coastal research [44] and the mix of participants in the process (e.g., the notable lack of questions relating to coastal processes) [22]. The balance of questions between each category varied, with an emphasis towards marine conservation, governance, and marine planning. However, as topicality is an important influence in the selection of questions, this is unsurprising, as the development of an MPA network within a marine planning framework are the central developments in the UK's current marine and coastal governance framework.

The specific nature of the questions presented under each category broadly reflected the stage of that theme or topic in the policy cycle (Table 2). The number and composition of each stage in the cycle varies, but a typical policy cycle includes the following stages: (1) identification of a policy challenge; (2) evidence collection to understand the characteristics of the policy challenge; (3) analysis of the evidence in order to understand the cause and effect relationships involved in the policy challenge; (4) identification of potential policies to address the policy challenge; (5) selection of favoured policies; (6) implementation of favoured policies; and (7) monitoring of implemented policies to evaluate success and con-sider the need for policy adaptation. Table 2 broadly summarises the approximate connection between the question categories and stages of the policy cycle.

Within the data category, the majority of questions sought to find improved procedures to manage and use data effectively rather than focus on what data is needed or how it should be collected. These questions were concerned with the implementation of data policy, which perhaps reflects data management as a long-standing concern in the UK. Similarly, the questions related to governance reflected the advanced stage of governance issues within the policy cycle, and focused on how existing policies should be implemented. The marine conservation questions demonstrated the furthest progression through the policy cycle as they were, in general terms, focused entirely upon implementation and monitoring of existing policy. These questions were also rather specific, targeting existing gaps in knowledge that, if filled, would support the delivery of existing policy, rather than the development of new policy. In contrast, the questions related to ecosystem services were much more fundamental in nature, focused on conceptual links between ecosystem services, ecosystem function, and marine management. The current policy frame-work related to ecosystem services reflects the need to understand the issues surrounding how ecosystem service ideas could be formulated and applied to the marine environment and its management. The questions related to marine citizenship illustrated a similarly early position in the policy cycle as they related, in general terms, to fundamental questions about the nature of marine citizenship rather than its implementation or monitoring. Finally, the marine planning questions reflected a mid-stage in the policy cycle by focusing upon understanding the key approaches to be taken to marine planning rather than focusing upon its detailed implementation.

It was notable that although all questions were intended to be focused on the UK, some of the questions, if successfully answered, would provide insight into issues at other geographic scales. For example, answers to the question ‘What are the mechanisms and criteria (ecological, economic, and social) for identifying and negotiating trade-offs between human activities in marine planning?’ (question 31) would also be of benefit at the European scale, to inform the implementation of the European Roadmap for Maritime Spatial Planning [45–47] and in more general terms as a contribution to the delivery of the European IMP [48]. In addition, recent studies focused on the Mediterranean and the Black Sea highlight data needs for the integration of science into policy [49]. The development of research related to those questions derived under the marine conservation theme would benefit from international collaborations with scientists in countries where networks of MPAs are more advanced (e.g., [50–52]) or where studies on MPA impacts are already in effect (e.g., [53,54]).

That the potential usefulness of the answers to some questions extends beyond the UK highlights that some questions transcend national boundaries and are potentially salient questions applicable to other countries, to regional seas, or globally. Given the influence of the EU in particular on UK marine and coastal policy, the applicability of certain questions at a variety of scales was perhaps to be expected. The observed interdependence does highlight the potential for the development of a European or even global collaborative research agenda that is tailored to answering specific questions of shared relevance.

The impact of research priority setting exercises such as this one is discussed by Sutherland et al. [22], who make the point that the connection between science and policy is sometimes slow and ambiguous, making impact rather difficult to determine. However, it is also noted that in previous exercises of a similar nature [16,17,19–21], policy makers have been keen to engage and the exercises have been successful in encouraging discussion and debate, as has this process.

Table 2. The relationship between question category and policy cycle stage.

Policy Cycle	Question Category Marine Conservation	Marine Planning	Marine Citizenship	Ecosystem services	Data	Governance
1.Identification of policy challenge			X	X		
2.Evidence collection			X	X		
3.Analysis of evidence			X	X		
4.Idenitification of potential policies		X				
5.Selecetion of favoured policies		X				
6.Implementation of favoured policies	X				X	X
7.Monitoring of implemented	X				X	X

policies						

5. Conclusion

The priority questions formed through this research reflect the pace and change of marine and coastal policy in the UK in response to international, European and national policy drivers. They also represent a ‘to date’ snapshot of issues pertinent to the science-policy research community. By using a collaborative process to identify priority questions the results will enable scientists to be more effective and efficient at delivering policy focussed science [15]. The results will also encourage collaborations between sectors and academic fields. The questions have identified the science that is currently needed to inform policy that will enable the UK to deliver its European and international commitments to achieve sustainable use and protection of marine environment.

Identifying questions that are pertinent to the UK does not however exclude a wider European and international audience from engaging with this research. Answers to some of these questions are local in nature but others, including ecosystem service questions, have global relevance (e.g., carbon sequestration), and research must be focussed at an international scale. With a global trend towards integrated approaches to managing ecosystems at appropriate scales [55], the sustainable management of the oceans requires science to be integral to current policy requirements. Developing priority questions to focus research is not a static process. To maintain relevance within this fast-moving subject base, the science-policy research community would benefit from regular revisions of this process and the inclusion of a broader sample group. Developing priority questions is therefore an iterative exercise and one which must (like policy) reflect the trends, values and needs of society.

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Design of Marine Protected Areas on high seas and territorial waters of Rockall Bank

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Abstract

Fisheries closures are rapidly being developed to protect vulnerable marine ecosystems worldwide. Satellite monitoring of fishing vessel activity indicates that these closures can work effectively with good compliance by international fleets even in remote areas. Here we summarise how remote fisheries closures were designed to protect *Lophelia pertusa* habitat in a region of the NE Atlantic that straddles the EU fishing zone and the high seas. We show how scientific records, fishers' knowledge and surveillance data on fishing activity can be combined to provide a powerful tool for the design of Marine Protected Areas.

Keywords: *Lophelia pertusa*, MPA, Fisheries, Offshore Marine Protected Area, NE Atlantic, Vessel monitoring system, VMS

Introduction

The past few years have seen rapid development in the use of fisheries closures to protect deep-water coral habitats from destructive fishing practices throughout the North Atlantic. The world's first deep-water coral protected area came into effect in 1984, but did not prevent trawling damage to *Oculina varicosa* reefs off the Atlantic coast of Florida due to lack of enforcement (Reed *et al*. 2005). Surveys in the late 1990s revealed that bottom trawling and long-lining was also causing widespread and long-term damage to more northern coral communities on both sides of the Atlantic (Jones & Willison 2001, Hall-Spencer *et al*. 2002). This met with rapid responses by the authorities, with the establishment of cold-water coral protected areas first in Scandanavia and Canada (Fosså *et al*. 2002, Mortensen *et al*. 2005) followed by closures in EU waters, the USA and Iceland. The first areas in the

Atlantic high seas to be closed to protect deep-water habitats entered into force on 1 January 2005 and were recommended by the North East Atlantic Fisheries Commission (NEAFC), followed by closures in the NW Atlantic by the Northwest Atlantic Fisheries Organization (NAFO) from 1 January 2007 (Table 1). Satellite monitoring of fishing vessel activity has indicated that these closures can work effectively with good compliance by international fleets even in remote areas such as the Darwin Mounds, a coral-rich area 180 km off the NW coast of Scotland (Davies *et al*. 2007).

Here we summarise how deep-water *Lophelia pertusa* habitats were selected for closure on Rockall Bank (see ICES 2002, 2006, 2007a). The Bank lies to the west of Scotland in the NE Atlantic and straddles the boundary between the fishing zone managed by the EU and the high seas, where fishing is managed by NEAFC. The Bank supports important fisheries for haddock and other shallower water species on the upper slopes and top of the bank, together with deeper-water species such as monkfish and blue ling on the lower slopes.

Table 1. Areas closed to bottom trawl fishing in the North Atlantic to protect deep- and/or cold-water habitats (adapted from ICES 2007a). Note Gilkinson & Edinger (2009) provide an update on Canadian closures since 2007. NEAFC: North East Atlantic Fisheries Commission; NAFO: Northwest

Closed area	Region	Year closed
Oculina Bank	USA	1984
Sula Reef	Norway	1999
Iverryggen Reef	Norway	2000
Selligrunnen Reef	Norway	2000
Sacken reef	EU (Sweden)	2001
Spiran reef (degraded)	EU (Sweden)	2001
Vadero reef (degraded)	EU (Sweden)	2001
Northeast Channel	Canada	2002
Tisler Reef	Norway	2003
Fjellknausene Reef	Norway	2003
Røst Reef	Norway	2003
The Gully	Canada	2004
Stone Fence	Canada	2004
Darwin Mounds	EU (UK)	2004
Azores, Madeira, Canary Islands	EU (Spain/Portugal)	2004
Reykjanes Ridge (part of)	NEAFC	2005
Hekate Seamounts	NEAFC	2005
Faraday Seamounts	NEAFC	2005
Altair Seamounts	NEAFC	2005
Antialtair Seamounts	NEAFC	2005
Oceanographer Canyon	USA	2005
Lydonia Canyon	USA	2005
Hornafjar□ardjúp	Iceland	2006
Skaftárdjúp	Iceland	2006
Reynisdjúp	Iceland	2006
Orphan Knoll	NAFO	2007
Newfoundland Seamounts	NAFO	2007
Corner Seamount	NAFO	2007
New England Seamounts	NAFO	2007
Hatton Bank	NEAFC	2007
NW Rockall Bank	NEAFC/EU (UK)	2007
W Rockall Mounds	NEAFC	2007
Logachev Mounds	NEAFC/EU (Eire)	2007
NW Porcupine Bank	EU (Eire)	proposed
Hovland Mound Province	EU (Eire)	proposed
SW Porcupine Bank	EU (Eire)	proposed
Belgica Mound Province	EU (Eire)	proposed

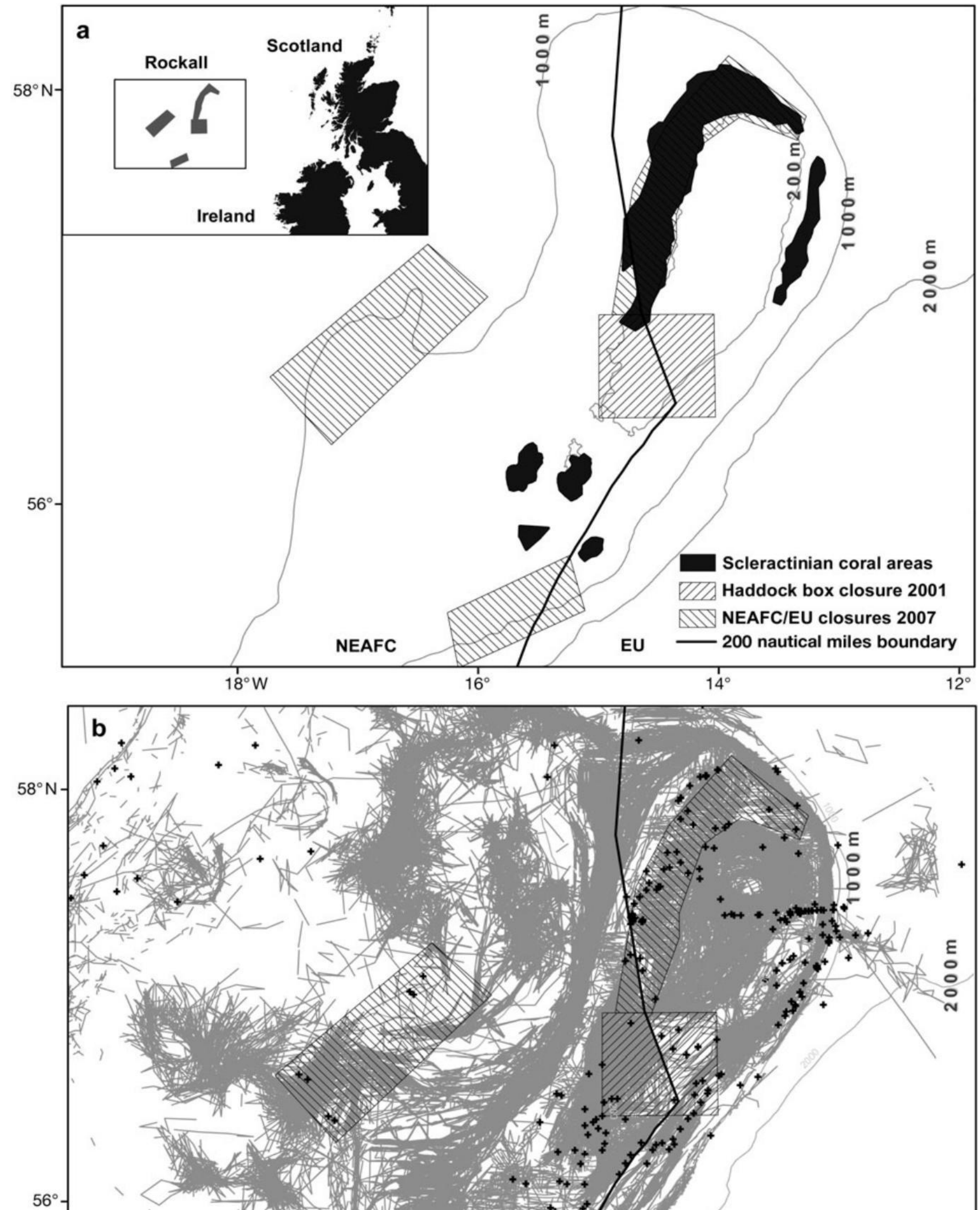
Methods

Based on evidence presented by the World Wildlife Foundation, the Convention for the Protection of the Marine Environment in the North Atlantic (OSPAR) communicated to NEAFC its concern about the conservation of *Lophelia pertusa* reefs on the Bank. NEAFC then requested the International Council for the Exploration of the Sea (ICES) to indicate appropriate boundaries of any closure of areas where cold-water corals are affected by fishing activities. Three sources of information were used by the ICES Working Group on Deep Water Ecosystems (WGDEC) to identify such boundaries. These were: (1) records in the scientific literature and elsewhere of the occurrence of *L. pertusa*; (2) the knowledge of fishers using the Bank on the distribution of *Lophelia*; and (3) records of fishing activity derived from satellite-based vessel monitoring systems (VMS).

Each of these sources had their advantages and dis-advantages. Scientific records may be very old, and historical records of coral occurrence may now be inaccurate, as may be the geographical locations of records due to poor position fixing or if the data are from long dredge hauls (Hall-Spencer et al. 2007). In contrast, fishers' knowledge is recent and therefore may be more 'believable' to the fishing industry, but may not be complete or fully accurate. VMS records showing the location of trawling activity are generally comprehensive and unbiased, but there are several reasons for an area of the seabed to remain unfished; notwithstanding the presence of net-damaging corals, other seabed obstructions may exist or it may be too deep for trawling to take place. These sources could not necessarily be relied upon individually to identify suitable closure areas, but when used together provided a powerful tool indicating where such closed areas should be established.

VMS positions were provided by NEAFC, the Irish Navy and the UK Department of Environment, Food and Rural Affairs for 2005, the most recent year of comprehensive available information on the distribution of fishing fleets in the area. VMS data were filtered to remove non-trawling activity by only including vessels travelling between 1.5 and 4.5 knots. Note that this filter did not remove all pelagic trawling tracks from the plot and may include some vessels travelling slowly in the area, but not fishing. These records were combined with data on coral distribution provided by WGDEC reports, and new information on *Lophelia* distribution from surveys carried out by the UK Government in 2005 and 2006 (Davies *et al*. 2006, Howell *et al*. 2009), a Fisheries Research Services (FRS) monkfish survey in November 2006 (FRS unpubl. data) and data from the EU HERMES programme (van Duyl & Duineveld 2005). The final analysis (Fig. 1) combined information on the spatial distribution of coral records and data describing fleet distribution to select potential sites for closure where the conservation benefit of closures was maximal and the displacement effect on fishing was minimal.

Fig. 1. North East Atlantic Fisheries Commission/EU closures (hatched) around Rockall off Scotland and Ireland in 2007;(a) Deep-sea scleractinian areas noted by fishers (black shading) and (b) scientific records with overlay of filtered vessel monitoring system (VMS) tracks for 2005 showing the patchy distribution of fished areas around Rockall Bank.


a
Rockall
Scotland
Ireland
58° N
56°
18° W
16°
14°
12°
1000 m
200 m
2000 m
Scleractinian coral areas
Haddock box closure 2001
NEAFC/EU closures 2007
200 nautical miles boundary
NEAFC
EU
b
Scleractinian records
VMS tracks 2005
Haddock box closure 2001
NEAFC/ EU closures 2007
200 nautical miles boundary

Results and Discussion

Following ICES advice, areas of Rockall Bank in NEAFC- and EU-controlled waters were closed to fishing effective from March 2007 (ICES 2007a). Fig. 1 shows the North West Rockall, Logachev Mounds and West Rockall Mounds areas that were closed to protect coral habitat in 2007, in addition to an area that was closed to protect haddock stocks in 2001 which has the additional benefit of helping protect benthic habitats.

The process of designing and enforcing a network of offshore Marine Protected Areas is ongoing and has made significant progress in recent years. A new tranche of deep-water coral closures has been pro-posed within the Irish EEZ, also based on a combination of scientific surveys, fishers' knowledge and VMS (ICES 2007b). Further challenges to designing an eco-logically robust network of closures remain, such as the need for an increased understanding of cold-water coral food webs and of larval transport to and from pro-posed closures, which could be tackled using molecular approaches (Le Goff-Vitry *et al*. 2004, van Oevelen *et al*. 2009). Effective surveillance and enforcement are critical to the protection of coral in these areas, which will be helped by VMS records which include data on the gear in use and vessel activity. Boundaries will also need to be designed to account for gears used and the frequency of transit.

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The Fisheries and Marine Renewable Energy Working Group: creating an agenda for improved co-existence

MARINE & COASTAL POLICY WITH PLYMOUTH UNIVERSITY

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Introduction

As an emerging industry, Marine Renewable Energy (MRE) is expected to play a major contributory role if the UK is to successfully reach its desired target of renewable energy production by 2020 (DECC, 2011). However, due to the competing objectives and priorities of MRE and other industries, for example fisheries, and in the delivering of conservation measures, the demand for space within our marine landscape is increasing, and interactions are inevitable. In this research we investigate the challenges in resolving interactions between fisheries and marine renewable energy. We focus on the improved co-existence between the two sectors and developing a mitigation agenda for fishing effort displacement in the UK. This research was carried out as part of the work of the Fisheries and Marine Renewable Energy Working Group (FMREWG) and funded by the Marine Renewable Energy Knowledge Exchange Programme (MREKEP), a Natural Environment Research Council (NERC) project and co-ordinated by Plymouth University.

Methods

The first method included a scoping survey questionnaire conducted at the Environmental Interactions of Marine Renewable Energy (EIMR) in Orkney May 2012. Participants responses to questions were given a data needs score based on their ranking of importance of certain issues presented, resulting in priority areas and research gaps being identified. A Scoping workshop followed (Rodwell *et al*., 2012) and data was coded according to an inductive process in order to identify key themes and challenges. Individuals were selected for the final expert workshop, held in York in April 2013 (Rodwell *et al*., 2013). Data from this workshop was coded according to a deductive process, as themes had already been identified from the initial workshop. This provided further insight into the existing codes and contributed to the practical components of the mitigation agenda. Both workshops were based on the Delphi- method and in order to enable discussion participants from different backgrounds and regions were divided into groups.

Results

Questionnaire Survey

To explore the range of knowledge exchange options between MRE & fishing sectors and Identify research gaps/ priority areas

Scoping Workshop

1. What are the priority issues?
2. What are the barriers to progress?
3. How can we mitigate problems?
4. What are your thoughts on consultation process?

Key themes & challenges identified

Data issues

- Data needs
- Monitoring
- Fishing activity, spatial scale &cumulative impact
- Socio-economic data
- Data sharing & availability

Assessment methods

- Choice of appropriate method (Plotter, VMS, Mapping tools)
- Marine Spatial Planning?

Communication, consultation & collaboration

- Legitimacy of consultation practice
- True representation of fishers
- Inter-jurisdictional communication

Expert workshop

1. Review of past research
2. Case study review
3. Recommendations for action
4. How to achieve consensus on action

Mitigation Agenda

ACTION

Overcoming data issues in assessment of displacement

Development of consultation protocol between MRE and fishing sectors

Development of methods for assessing displacement

Figure 1. Flow chart outlining the basic process of this project from survey to the final workshop, and an overview of key themes, challenges and recommendations for action

Discussion

This research has enabled the authors and members of this Working Group to bring about a set of activities and action points to mitigate fishing effort displacement as a result of MRE development. One of the final recommendations was the development of a Mitigation toolkit, in order to open up research channels and share ideas and case studies among various practitioners, academics and industry representatives. Collaboration needs to be more strategic and will require multiple partner support in order to target issues of communication, full representation of the fishing industry and inherent problems in data availability and utility.

Conclusions

This Working Group, the first of its kind in the UK, brings together individuals from a nationally diverse group of academics, regulators, policy makers and representatives from fisheries, MRE sectors and conservation bodies. It has the potential, for the first time, to develop effective guidelines and protocols for both mitigation and assessment of displacement of fishing effort, for the entire life cycle of MRE projects, and has further potential to adapt to the needs other countries facing similar challenges.

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