UNIVERSITY OF SOUTHAMPTON

FACULTY OF ENGINEERING, SCIENCE
AND MATHEMATICS
School of Ocean and Earth Science

HUMAN ACTIVITIES IN THE DEEP NORTH ATLANTIC

by

Angela Benn

Thesis for the degree of Doctor of Philosophy

October 2011

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

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SCHOOL OF OCEAN & EARTH SCIENCES

Doctor of Philosophy

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To achieve long-term planning and whole-ecosystem management of the oceans requires data on the extent of human impacts and the wider availability of data on human activities. This study, which aimed to provide the first detailed assessment of the extent of human activities in the deep North East Atlantic, OSPAR Maritime Area, revealed that during 2005 bottom-trawl fisheries affected an area of seafloor at least one order of magnitude greater than all the other the activities in the study combined. It was also found that identifying data sources, access to data and data quality presented significant barriers to implementing whole-ecosystem management and governance in the North East Atlantic.

Additional work, in the North West Atlantic, to investigate the availability of data on human activities and to identify examples of best practice, revealed similar problems to those encountered in the North East Atlantic.

Legal and policy frameworks and reporting requirements for human activities in the North East Atlantic were reviewed and recommendations made.

This study identified access to fisheries' vessel-monitoring data (VMS) and data quality as particular problems. Currently the location of bottom-trawling can only be identified by analysis of these data. This information is vital for ecosystem management. Current European Commission legislation, regarding access to environmental data and more specifically fisheries data, were discussed and the responses to applications made to European Member States for VMS data were analyzed. The results revealed a variety of interpretations of the Regulation.

While the ecosystem approach is incorporated into many conventions and agreements, its implementation is not straightforward. For whole-ecosystem governance and management of the oceans, it is necessary to move beyond the traditional sector-based, piecemeal approaches. To do so requires significant improvements in availability and management of human-activities data and a shift in thinking towards a more integrated approach.

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DECLARATION OF AUTHORSHIP

I, Angela Benn, declare that the thesis entitled *Human activities in the deep North Atlantic* and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
- where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly attributed;
- where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all main sources of help;
- where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
- parts of this work have been published as Benn, A. R., Weaver, P. P. E., Billett, D. S. M., van den Hove, S., Murdock, A. P., et al. 2010. *Human Activities on the Deep Seafloor in the North East Atlantic: An Assessment of Spatial Extent*. PLOS One, 5(9)

Signed: ....Angela Benn..........................

Date: ....19th October 2011................................

Acknowledgements

I wish to acknowledge the HERMES project (EC contract no GOCE-CT-2005-511234, funded by the European Commission's Sixth Framework Programme under the priority 'Sustainable Development, Global Change and Ecosystems'); the Continental Margin Ecosystems (COMARGE) project of the Census of Marine Life initiated by the Alfred P. Sloan Foundation and the HERMIONE project (EU contract 226354 funded by the European Commission's Seventh Framework Programme under the priority 'Deep-Sea Ecosystems'), for funding this work.

I owe a debt of gratitude to my supervisors Phil Weaver, David Billett and Sybille van den Hove and my panel chair, Paul Tyler, for their encouragement, support, enthusiasm and the opportunities they have made available to me during my studies. Thanks are also due to many colleagues both within and outside NOCS for help and advice. They are Jeff Ardron, Steve Bennett, Brian Bett, Ben Boorman, Douglas Burnett, Robert Carney, Richard Caslake, Sarah Dacre, Poul Degnbol, Gemma Doneghan, Jan-Allan Ede, Alan Evans, Dick Ferro, Matthew Gianni, Vikki Gunn, Kerry Howell, Kjartan Hoydal, Alan Hughes, Peter Hunter, Tore Indreiten, Colin Jacobs, David Johnson, Tim Le Bas, Debbie Milton, Andrew Murdock, Abi Pattenden, Robin Plumley, John Reynolds, Rowland Rogers, Karen Rolfe, Darren Sanders, Carla Sands, Mark Tasker and Mikis Tsimplis.

It has been a very difficult journey at times and special thanks go to my family - Piers, Tom, Kazimir, Flo and Eileen for their endless patience and support and for not allowing me to give up. Thanks also to my mother who is no longer around to see the end of this journey.

List of acronyms

ABNJ	Areas Beyond National Jurisdiction
AoA	Assessment of Assessments
BODC	British Oceanographic Data Centre
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
CBD	Convention on Biological Diversity
CFP	Common Fisheries Policy
CHS	Canadian Hydrographic Service
COP	Conference of the Parties
CSR	Cruise Summary Report Inventory
DECC	Department of Energy and Climate Change
DFO	Department of Fisheries and Oceans Canada
DG MARE	Directorate-General for Maritime Affairs and Fisheries
DSCC	Deep Sea Conservation Coalition
EC	European Commission
EEA	European Environment Agency
EEZ	Exclusive Economic Zone
EIA	Energy Information Administration
ERS	Electronic reporting system
ESSIM	Eastern Scotian Shelf Integrated Management Initiative
FAO	United Nations Food and Agriculture Organization
FCO	Foreign and Commonwealth Office
FEPA	Food and Environment Protection Act
FOI	Freedom of Information Request
GEBCO	General Bathymetric Chart of the Oceans
GES	Good Environmental Status
GRAME	Global Assessment and Reporting of the Marine Environment
ICES	International Council for the Exploration of the Seas
ICPC	International Cable Protection Committee
IEA	International Energy Agency
IMO	International Maritime Organization
IOC	Intergovernmental Oceanographic Commission
IODE	International Oceanographic Data and Information Exchange
ISA	International Seabed Authority
IUCN	International Union for the Conservation of Nature
IUU	Illegal, unregulated and unreported fishing
MA	Millennium Ecosystem Assessment
MEDIN	Marine Environmental Data and Information Network

MMO	Marine Management Organisation
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
MSP	Marine Spatial Planning
NAFO	Northwest Atlantic Fisheries Organization
NCEM	NAFO Conservation and Enforcement Measures
NEAFC	North East Atlantic Fisheries Commission
NGO	Non-Governmental Organization
NPD	Norwegian Petroleum Directorate
NOAA	National Oceanographic and Atmospheric Administration
OSPAR	Convention for the Protection of the Marine Environment of the Northeast Atlantic, 1992
POGO	Partnership for Observation of the Global Oceans
RFMO	Regional Fisheries Management Organization
SAC	Special Areas of Conservation
SPA	Special Protection Areas
UKDEAL	United Kingdom Digital Energy Atlas and Library
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea, 1982
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFSA	United Nations Fish Stocks Agreement, 1995
UNGA	United Nations General Assembly
VMS	Satellite-based vessel monitoring system
WHOI	Woods Hole Oceanographic Institute
WWF	World Wide Fund for Nature

1 Introduction

This thesis focuses on human activities on the seafloor in waters deeper than 200 metres in the North Atlantic. It estimates the spatial extent of human activities on the seafloor and reviews the regulations governing such activities. Whilst most of the work focuses on the OSPAR Maritime Area of the North East Atlantic this thesis also examines issues concerning the availability of data on human activities in the North West Atlantic. In addition, it investigates the implementation of European Commission Regulation 199/2008 which addresses, *inter alia*, access to fisheries data in the North East Atlantic, the Baltic and the Mediterranean.

The primary question the thesis asks is “What is the extent of human activities on the seabed of the North East Atlantic?” In carrying out this research an important secondary question has arisen, “Do we have sufficient data on human activities for the effective governance and sustainable management of deep-sea ecosystems?” The hypothesis tested is that “We have sufficient information on human activities to enable the effective implementation of ecosystem-based governance and management in the deep North East Atlantic”.

This chapter focuses on the background to current governance and management approaches. It defines the United Nations Convention on the Law of the Sea (UNCLOS) maritime zones (UN, 1982) and summarises the rights and duties of States within each zone. It briefly reviews the goods and services which are provided by the deep sea and the human activities impacting on deep-sea ecosystems. Various approaches to management and management tools are described, including the ecosystem-based approach, the precautionary principle, marine spatial planning (MSP), marine protected areas (MPAs) and integrated assessments. The chapter concludes by discussing the role of information on human activities and introduces the remaining chapters of this thesis.

1.1 Background

1.1.1 Governance and management

Olsen defines governance: “Governance sets the stage within which management occurs … (and) … encompasses formal and informal arrangements, institutions and mores that structure and influence i) how resources or an environment are utilized; ii) how problems and opportunities are evaluated and analysed; iii) what behaviour is deemed acceptable or forbidden and iv) what rules and sanctions are applied to affect the pattern of use” (Olsen et al., 2006).

Over the past three decades a paradigm shift in the approach to the management of natural resources has resulted in the emergence of ecosystem-based management as the dominant approach (Olsen et al., 2006). At the level of discourse, if not yet in practice, this is replacing traditional sectoral-based management approaches. Olsen suggests that this paradigm shift would be more appropriately defined as ecosystem-based governance as it requires a profound reassessment of i) how change within ecosystems is analysed, ii) how goals are set and iii) how human activities are regulated. Once the shift has been made, the day-to-day operations can assume the characteristics of management (ibid.). The need for the translation of this paradigm shift from theory into practice is supported by the current study.

The achievement of ecosystem-based governance and management requires i) clear objectives and a strategy to implement them, ii) an effective monitoring regime and iii) appropriate, accurate and timely information. These are three key requirements but other important requirements include, for example, sufficient resources, a willingness to act and agreed indicators of environmental status.

Governance of the deep sea is achieved through a set of interacting components (Figure 1.1). These include i) governments and policies, ii) non-governmental organisations (NGOs), iii) markets and industrial lobbies, and iv) agencies and networks that provide advice. These influencing components are modified by a variety of pressures: legal, political, social, cultural, environmental and economic (Olsen et al., 2006).

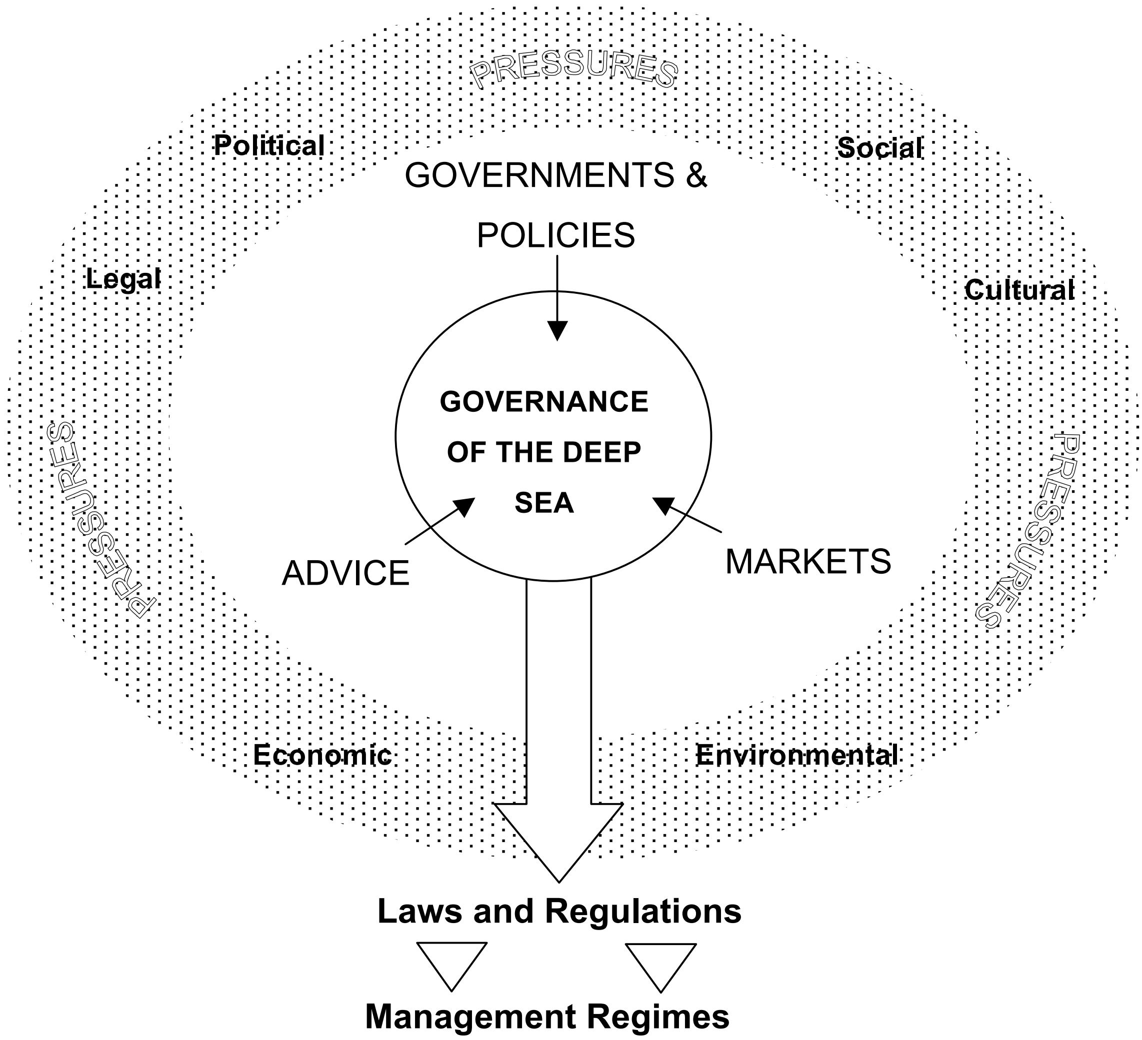

Figure 1.1 The components that influence governance of the deep sea (adapted from Olsen et al., 2006).

Governance of the deep sea is complex. For the North East Atlantic, the range of actors and institutions includes:

- Supra-national (United Nations), regional (European Commission) and national policy-makers;
- Advisory bodies, such as the International Council for the Exploration of the Sea (ICES) which advises governments and international regulatory bodies on the marine environment, ecosystem and living resources in the North Atlantic;
- Management organisations, for example the North East Atlantic Fisheries Commission (NEAFC) which sets conservation and management measures for the fisheries within the regulatory area or the International Maritime Organization (IMO) – the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships;

- The International Seabed Authority (ISA), through which the seabed and subsoil beyond the limits of national jurisdiction are managed. However, while mining is managed through the ISA, it does not control oil and gas exploration and production.
- The wider scientific community – providing advice to policy-makers via such mechanisms as the HERMIONE Science-Policy Panel[1];
- Non-governmental organisations (NGOs), for example, the Worldwide Fund for Nature (WWF) and the Deep Sea Conservation Coalition (DSCC) or institutions, such as the International Union for the Conservation of Nature (IUCN), which conduct research, lobby and contribute advice to support policy formulation. Olsen et al., (2006) note that NGOs can provide "eyes and ears" to ensure that policies and actions are put into place and are implemented;
- International institutions such as OSPAR (the Oslo-Paris Convention for the Protection of the Marine Environment of the North East Atlantic)[2];
- Industries which operate in the deep sea –including the submarine cables industry, the oil and gas industry and fisheries. The actors include many different individuals including, for instance, in the case of fishing, vessel owners and investors (who may be only indirectly involved in operations and remote from controls), offshore oil and gas companies and their technical subcontractors, cable operators and industry organisations such as local fishermen's organisations and the International Cable Protection Committee (ICPC).

For governance and management to be effective clear objectives are needed (van den Hove and Moreau, 2007). This is particularly challenging in such a complex natural, political and economic environment. The achievement of clear agreed objectives may be hindered or complicated by the time-frames over which ecological systems, policy, scientific research, technology, industry and business operate. Governmental processes are slow in contrast to developments in technology. Science continuously adds to our understanding - which is inevitably incomplete (*ibid.*). The former extends the reach of particular interests - exploiting goods and services, while the latter

[1] HERMIONE Science-Policy Panel page: http://www.eu-hermione.net/hermione-science-policy-panel

[2] OSPAR comprises fifteen Governments of the western coasts and catchments of Europe, together with the European Community and is the mechanism through which they cooperate to protect the marine environment of the North-East Atlantic. OSPAR started in 1972 with the Oslo Convention against dumping and was broadened to incorporate the Paris Convention of 1974 which covered land-based sources of pollution and the offshore industry. These two conventions were unified, up-dated and extended by the 1992 OSPAR Convention. However, OSPAR has no jurisdiction over fisheries or shipping.

introduces new information adding to our understanding of the ecosystems of the deep sea and the impacts of human activities on them. The process of the Darwin Mounds' designation as a marine protected area is a good example of such a time lag.

The Darwin Mounds, discovered in 1998, lie approximately 180 km to the north west of Scotland at a depth of around 1,000 metres. The Mounds are colonised by a diverse fauna of *Lophelia pertusa* and other suspension feeding organisms (Masson et al., 2003). The designation of a closed area around the Darwin Mounds did not occur until five years after their discovery, during which time damage from deep-water trawlers became evident (De Santo and Jones, 2007). In 2003, at the UK's request, the European Commission imposed a ban on trawling in a 1,380 km^2 area around the mounds (EC, 2003a; 2004a). The ban became permanent in 2004 (EC, 2004b). While at first sight it appears that the process from a temporary ban to a permanent ban on bottom trawling was relatively quick, De Santo and Jones (2007) point out that it required a careful, step-wise approach by the UK and involved a degree of compromise over the extent of the area to be closed. Davies et al., (2007) suggest that it is possible that the announcement of the closure may have led to increased trawl effort in the Darwin Mounds protected area in the month prior to the closure.

The deep sea is remote and there is a multiplicity of interests and of jurisdictions (Vierros et al., 2006), most of whose boundaries are based on legal or administrative requirements rather than the ecological requirements of living systems (Olsen et al., 2006; Douvere and Ehler, 2008). Ecosystem boundaries are more subtle, defined by, for example, temperature, currents or depth (Laffoley et al., 2004). Beyond the challenges of establishing clear objectives, (for example the sustainable use of resources and protection of the marine environment) and the strategies to meet them, monitoring their implementation and effectiveness is also difficult. The question of who is responsible for monitoring developments and enforcing compliance is an important question – particularly for the open-ocean and deep sea (Vierros et al., 2006).

Policies, laws and regulations governing the deep sea operate at all levels – supra-national, regional and national. However control is difficult to achieve. The legal jurisdiction for the deep sea is complex. The majority of areas deeper than 200 metres water depth lie outside the jurisdiction of individual States. While many human activities take place within waters which fall under the jurisdiction of coastal States, many also take place in areas which lie beyond national jurisdiction, in the high seas and the Area. UNCLOS lays down the fundamental rights and duties of States and establishes jurisdictional zones (UN, 1982) (Figure 1.2).

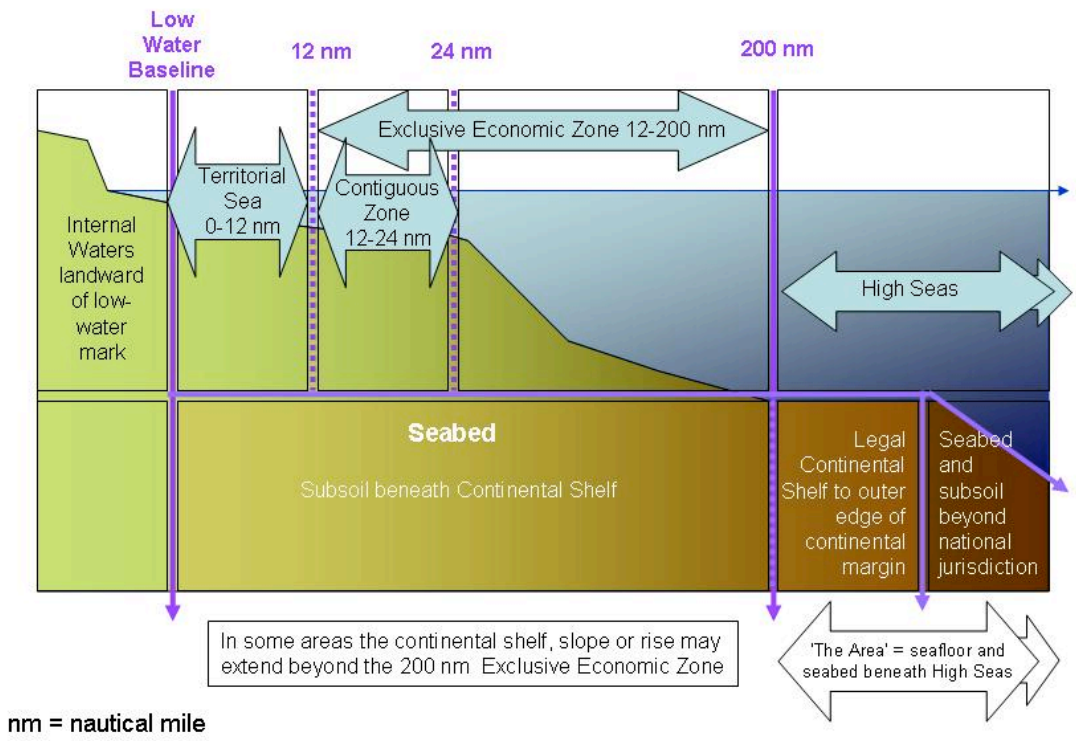

Figure 1.2 Marine zones under UNCLOS 1982. (Based on Churchill and Lowe, 1999, page 30 and UNEP, 2006, page 9).

The following is a summary of the rights and duties of coastal States within the UNCLOS zones (based on Churchill and Lowe, 1999).

Internal waters. A coastal State has sovereignty over its internal waters. Internal waters lie to the landward side of the baseline from which the other maritime zones are measured. The "normal baseline", from which the outer limits of the territorial sea and other coastal State zones are measured "is the low-water line along the coast as marked on large-scale charts officially recognised by the coastal State" (UNCLOS, Article 5). While this applies for coastlines that are relatively straight and un-indented, alternative rules apply under other geographic conditions[3].

[3] UNCLOS Articles 6 to 13 lay down particular rules for establishing baselines in specific geographical conditions : i) reefs; ii) straight baselines for coasts deeply indented or fringed with islands; iii) mouths of rivers; iv) bays; v) ports; vi) low-tide elevations; vii) islands.

Territorial Sea. A coastal State has sovereignty over its territorial sea which extends up to 12 nautical miles (nm) measured from the baseline. However, vessels of other States are allowed "innocent passage" through territorial waters for purposes of peaceful navigation.

Exclusive Economic Zone (EEZ). Within its EEZ a coastal State has sovereign rights over natural resources and economic activities, for example fishing and hydrocarbon exploration and production. Within the EEZ a coastal State also has jurisdiction over marine science research and environmental protection. Other States, however, have freedom to lay submarine cables and pipelines, freedom of navigation and of over-flight.

The inner limit of the EEZ is the outer limit of the territorial sea while the maximum extent of a coastal States' EEZ is 200 nm from the baseline. However, for many States the extent of their EEZ is restricted by the presence of EEZs of neighbouring States.

There is, however, no obligation on States to claim an EEZ. The main exceptions are States bordering the Mediterranean and other semi-enclosed seas. The reluctance of Mediterranean States to establish EEZs may lie in the problems of delimitation which remain unresolved in this relatively narrow sea and the desire of most States to preserve freedom of navigation, naval mobility and access to fisheries (Cacaud, 2005).

Continental Shelf. A coastal State has sovereign rights over the continental shelf (the seabed and subsoil) measured to 200 nm from the baseline for the purposes of exploration and exploitation of resources. The coastal State's rights beyond the 200 nm limit, "the outer shelf", differ from those within the 200 nm zone as the superjacent waters are the high seas and not part of the coastal State's EEZ. The same freedoms of cable and pipeline laying and navigation and over-flight exist as in EEZs. While sedentary species remain exclusively under the control of the coastal State, non-sedentary species fall under fishing as one of the freedoms of the high seas. The coastal State also retains the exclusive rights to exploitation of non-living resources on the outer shelf, but a proportion of the value or volume of the production must be shared with the international community via payments to the International Seabed Authority (ISA)[4].

[4] After the first five year's production, the coastal State must pay to the International Seabed Authority (ISA) either part of the value or a proportion of the volume of the production. In the sixth year the rate of payment is one per cent of the value or volume of production at the site and increases by one per cent for each subsequent year until year twelve, after which payments remain at seven per cent. Payments are distributed

UNCLOS Article 76 permits States to submit a request to the United Nations for the extension of their EEZ beyond the 200 nm with a maximum to the 350 nm limit if they can prove that their continental shelf reaches beyond 200 nm. At 7 December 2010 fifty four submissions had been received[5].

High Seas. All States are permitted the traditional freedoms of the high seas, namely the freedoms of navigation, over-flight, scientific research, construction of artificial islands and other installations, laying and maintenance of submarine cables and pipelines, and fishing. The exercise of freedoms remains the subject of a "due regard" obligation which requires that these "freedoms shall be exercised by all States with due regard for the interests of other States in their exercise of the freedom of the high seas, and also with due regard for the rights under this Convention with respect to activities in the Area" (UNCLOS, Article 87.2). Additionally, States engaging in fishing in the high seas have a duty to negotiate and agree upon measures to conserve living resources (UNCLOS, Articles 117-119). Further obligations under UNCLOS are:

- the requirement that the highs seas "be reserved for peaceful purposes" (UNCLOS, Article 88);
- the requirement that flag States ensure the safety at sea of vessels flying its flag, and the duty to keep a register of vessels (UNCLOS, Article 94);
- the duty to render assistance (UNCLOS, Article 98);
- the duty to cooperate in the repression of piracy (UNCLOS, Article 100);
- the duty to cooperate in the suppression of illicit traffic in narcotic drugs and psychotropic substances (UNCLOS, Article 108);
- the duty to cooperate in the suppression of unauthorized broadcasting from the high seas (UNCLOS, Article 109).

The Area. The seabed which lies beneath the high seas is governed by ISA, which was established under UNCLOS. Activities within the Area involved in the exploitation of sea-bed resources fall under the control of ISA. However pipeline, cable laying and scientific research may be undertaken without the Authority's permission.

As well as requiring an understanding of jurisdictions, the setting of clear objectives for governance and management and their implementation and regulation requires a diverse range of other information and knowledge, in particular, knowledge of:

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by the Authority to States Parties to the Convention "on the basis of equitable sharing criteria ..." UNCLOS, Article 82.

[5] Submissions to the UN Commission on the Limits of the Continental Shelf: http://www.un.org/Depts/los/clcs_new/commission_submissions.htm

- Ecosystem function and structure
- Status and trends of ecosystems
- Natural drivers and evolution of ecosystems
- Geographical occurrence of species and their abundance
- Direct human interactions with ecosystems (anthropogenic drivers)
- Existing institutional framework and its potential for evolution
- Actors and power distribution
- Uncertainties and scientific disagreements
- Individual and social values and value conflicts
- Effects of decisions on valued outcomes

(van den Hove and Moreau, 2007).

Although complex governance and regulatory frameworks are in place, lacunae exist. Gjerde (2008) describes global and regional agreements as forming "a web of obligations for states regarding biodiversity". She also asserts that inadequacies exist in both the implementation of existing legal requirements, the "implementation gap" and in the coverage of existing conventions and organizations, the "governance gap" (ibid). For example, Rogers and Gianni, (2010) report wide variations in the implementation of UNGA Resolutions 61/105 and 64/72 relating to deep-sea fisheries on the high seas. Gjerde (2008) identifies seven key governance gaps covering coordination, oversight, accountability, assessment, responsibilities, compliance and enforcement and clarity over appropriate regimes (Gjerde, 2008).

A further concern, raised by De Santo (2010), is "whose science" is used as a basis for decision making. The essential role of science in governance and management, identifying objectives and indicators, monitoring, assessing and evaluating impacts, is well established. However, differences in the outcomes of policy decisions relating to fishing closures were suggested to depend upon "whose science was more highly valued, trusted and more effective in getting the message across" (ibid.). The perceived value attached to science and scientific advisors has major implications for policy making.

1.1.2 Goods and services in the deep sea

The deep sea is a provider of many ecosystem goods and services. Goods and services (for example food and waste assimilation) can be defined as representing the benefits that humans derive either directly or indirectly from ecosystem functions (Costanza et al., 1997). In 2005 the Millennium Ecosystem Assessment (MA) identified four categories of services provided by ecosystems: supporting, provisioning, regulating and cultural (Millennium Ecosystem Assessment, 2005). van den Hove and Moreau,

(2007) and Armstrong et al., (2010) identify examples of goods and services provided by the deep-sea (Figure 1.3).

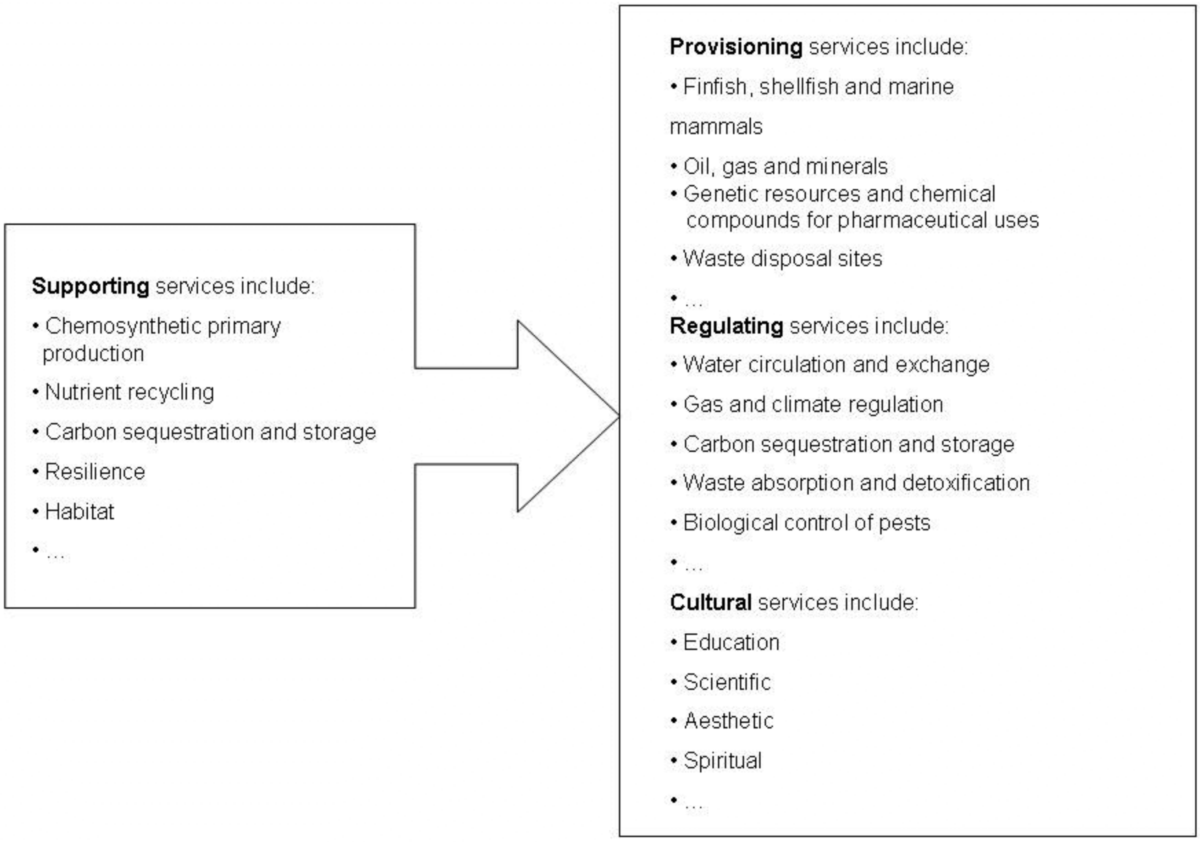

Figure 1.3 Examples of deep-sea goods and services (from van den Hove and Moreau, 2007).

Some goods and services are of obvious commercial value, for example food, fuels and materials. The term also encompasses less obvious but nevertheless essential services such as climate regulation and global biogeochemical cycles. Fluxes of energy and elements to and within the deep sea and the recycling of nutrients are vital components of global biogeochemical cycles upon which all life on Earth depends (Suttle, 2005; 2007; Danovaro et al., 2008; Heip et al., 2009; Lampitt et al., 2010b). Improvements in technology allow increasing exploitation of deep-sea goods and services. However, such exploitation is currently based on incomplete knowledge. Understanding of the occurrence and the function of deep-sea ecosystems and the roles they play in biogeochemical cycles is limited (Cochonat et al., 2007). As a consequence of this uncertainty any activities will involve indeterminate risk which will call for the application of the precautionary principle (Harremoës, 2001; van den Hove and Moreau, 2007).

1.1.3 Human activities in the deep sea

Halpern et al. (2008) estimate that no area of the world's oceans remains unaffected by human activities and that 41 per cent is strongly affected by multiple drivers. The positive relationship between biodiversity and ecosystem functions and services suggests that the accelerating loss of biodiversity in human-dominated marine ecosystems may lead to the collapse of all taxa currently fished by the mid-21st century (Worm et al., 2006). This paper proved very controversial (Hilborn, 2007; Branch, 2008), nevertheless, other evidence supports the prospect of substantial declines in both targeted and bycatch species (Jackson, 2008; FAO, 2010; IUCN 2011). Faced with such consequences, strategies for effective governance and management of human activities in the deep sea have become urgent.

The remoteness of the deep sea has, in the past, limited exploration but not prevented exploitation. Waters deeper than 1,000 metres cover an estimated 62 per cent of the planet (Roberts, 2002). However, only about 0.0001 per cent of it has been the focus of biological scientific investigation (van den Hove and Moreau, 2007). There are very few long-term time series, so predicting the future status of the deep sea is difficult (Glover and Smith, 2003). It is only during the past few decades that developments in technology have enabled knowledge of deep-sea ecosystems and biodiversity to expand (Koslow, 2007). Evidence of the effects of human activities on the deep sea is accumulating. The impacts of fishing are shown to extend deeper than the reach of fishing vessels, with decreased abundance evident in both target and non-target species (Bailey et al., 2009; Priede et al., 2011). The destruction of vulnerable deep-water habitats by trawling is already well documented (Freiwald et al., 2004; Wheeler et al., 2005; Clark et al., 2006). The effects of trawling on deep-coral ecosystems of seamounts have been shown to be long lasting (Althaus et al., 2009). The longevity of plastic debris on the deep seafloor is estimated to be hundreds to thousands of years (Barnes et al., 2009).

Indirect impacts from human activities such as climate change are more uncertain. Evidence suggests that alterations in surface productivity arising from climate change may alter species abundance, distributions and behaviour (Danovaro et al., 2001; Levin et al., 2001; Ruhl and Smith, 2004; Lampitt et al., 2010a). The effects of increasing ocean acidification in the deep sea are, as yet, unknown. However, evidence suggests that the deep sea will not be immune from the effects of a shallower aragonite saturation horizon and changes in species distributions are predicted (Orr et al., 2005; Guinotte et al., 2006; Tittensor et al., 2010).

The same developments in technology that have enabled advances in our understanding of the deep sea also allow access to resources of commercial value. Increasing demand and diminishing or exhausted terrestrial and shallow water resources create pressures, pushing existing human activities ever deeper into the world's oceans (van den Hove and Moreau, 2007). Commercial fisheries are fishing deeper (Morato et al., 2006). Bottom trawlers now fish to depths of around 2,000 metres (Gianni, 2004). Opportunities for new industries are emerging. Commercial mining of massive sulphide deposits in water depths of ~1,600 metres is being licensed in Papua New Guinea (Nautilus Minerals, 2010) and the ISA is currently considering an application by the Russian Federation for approval of a plan of work for exploration for polymetallic sulphides on the Mid-Atlantic Ridge[6]. In May 2010 China filed the first application to the ISA for deep-sea mining in the Indian Ocean. There is also growing commercial interest in deep-sea genetic resources (Leary et al., 2009).

The need for new legislation to be developed is urgent, as well as for improved implementation and the coverage of existing legislation (Gjerde, 2008). This is not only to protect the deep sea, but also to manage emerging issues. Existing governance and management strategies require review and, where necessary, need to be revised to incorporate measures to protect the environment (Hourigan, 2009). An example of such a process is the United States 'NOAA Strategic Plan for Deep-sea Coral and Sponge Ecosystems' designed to integrate existing fragmented regional approaches into a more holistic comprehensive national ecosystem management framework (NOAA, 2010).

New, emergent industries also require legislation. ISA is developing regulations for the prospecting and exploration of polymetallic nodules (ISA, 2000; 2010a). Codes of conduct and mechanisms to ensure the equitable sharing of common benefits arising from commercial exploitation of deep-sea genetic resources are being developed (Arico and Salpin, 2005; UNGA, 2007a). Access to very deep-sea species and new policies for the protection of marine genetic resources is under discussion within the Cartegena Protocol on Biosafety[7] (a supplementary agreement to the Convention on Biological Diversity (CBD) (UNEP, 1992).

Potential impacts from new industries must also be assessed. New impact assessment methods are required to encompass multiple impacts and to ensure transparency and

[6] ISA: http://www.isa.org.jm/en/node/627

[7] Text of the Cartegena Protocol on Biosafety http://bch.cbd.int/protocol/publications/cartagena-protocol-en.pdf

replicability (Halpern et al., 2007a). Work to predict the impacts on biodiversity of deep seabed mining is underway (ISA, 2008).

1.1.4 The ecosystem approach

Humans are a part of the natural environment. The concept that through their actions they also influence and shape it first emerged on to the international political agenda during the United Nations Conference on the Human Environment held in Stockholm in 1972 (UNEP, 1972). In the past, environmental governance and human cultural and socio-economic activities had been considered as separate, conflicting entities. Traditional management practices which had centred on a single use, such as fisheries or mineral exploitation, have resulted in separate governance regimes for each. Individual sectors have become set one against another. It has become increasingly evident that such sector-based approaches, which maximise opportunities and short-term gains for individual sectors (Laffoley et al., 2004), have resulted in conflicts among users and are inadequate to meet the need for sustaining the goods and services that healthy ecosystems provide (Olsen et al., 2006). This realization has led to a shift in governance, at least at the level of discourse. The move is towards a more holistic ecosystem-based approach that incorporates all aspects of environmental problems in which actions are coherently implemented across the relevant social, economic and environmental sectors. Ecosystem-based management has emerged as the dominant approach to managing natural resources and the environment (Olsen et al., 2006).

Despite its emergence as a key objective in environmental governance and management there is not yet an agreed-upon legally binding definition of the ecosystem approach. The CBD defines it as a “strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way”. It also “recognizes that humans, with their cultural diversity, are an integral component of many ecosystems” (UNEP, 2004a). The ecosystem approach calls for adaptive, precautionary and knowledge-based measures across national and administrative borders to protect and restore ecological functions (Backer et al., 2010).

The ecosystem approach has evolved over the past few decades from a vague principle to an overarching objective of environmental governance and management and has been incorporated into numerous international agreements including the 1982 Law of the Sea Convention (UN, 1982), the 1992 Rio Declaration (UN, 1992b) and Agenda 21 (UN, 1992a), the FAO Code of Conduct for Responsible Fisheries (FAO, 1995) and the 1995 UN Fish Stocks Agreement (UN, 1995). In 2002 the Conference of the Parties (COP) to the CBD in Decision V/6 laid down guiding principals for the implementation of the ecosystem approach (UNEP, 2000). COP Decision VII/11 provides further guidance and elaboration on implementation, based on the experiences gained (UNEP, 2004b).

As well as being incorporated into global legislation and agreements the ecosystem approach is also incorporated at a regional level. OSPAR and HELCOM[8] delivered a joint statement on the application of the ecosystem approach to the management of human activities (OSPAR/HELCOM, 2003). Within Europe the ecosystem approach was adopted as one of the underlying principles of the Integrated Maritime Policy (EC, 2007a). The Marine Strategy Framework Directive (MSFD) (EC, 2008b), the environmental component of the Integrated Maritime Policy, promotes the application of "an ecosystem-based approach to the management of human activities while enabling a sustainable use of marine goods and services". The ecosystem approach has also been a guiding principle in the revision of the Common Fisheries Policy (CFP) (EC, 2009b). The European Commission recognizes that the CFP forms part of the integrated management framework necessary to develop an ecosystem approach and describes such fisheries management as striving "to ensure that benefits from living marine resources are high while the direct and indirect impacts of fishing operations on marine ecosystems are low and not detrimental to the future functioning, diversity and integrity of these ecosystems" (EC, 2008a). It also notes that "since fishing interacts with other human activities and their consequences relating to the seas, these interactions must also be considered".

While the ecosystem-based approach has emerged as the dominant approach to management of natural resources and the environment the challenge lies in translating the theory into practice. Effective implementation mechanisms and processes are being sought. A number of organisations are developing guidance. In response to a request made during the seventh meeting of its COP (UNEP, 2004a), the CBD established an online Ecosystem Approach Sourcebook website[9] as a tool to help practitioners implement the ecosystem approach and as a forum within which to share experiences. ICES provides guidance on the application of the ecosystem approach to human activities in the European marine environment (ICES, 2005a). The FAO sets out guidelines on the application of the ecosystem approach in fisheries management (FAO, 2003; EC, 2008a). The IUCN has published a series of documents covering the implementation of ecosystem-based management in a general context as well as in

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[8] The Baltic Marine Environment Protection Commission (also known as the Helsinki Commission or HELCOM).

[9] CBD Ecosystem Approach Sourcebook website: http://www.cbd.int/ecosystem/sourcebook/

relation to, for example, climate change, specific geographical locations, natural disasters and extractive industries in arid and semi-arid zones[10].

1.1.5 Adaptive governance and management

As socio-ecological systems involve "complex, non-equilibrium and self-organising systems characterised by properties of emergence, irreducible uncertainties, non-linear internal causality and indeterminacy" complete knowledge and understanding will not be achieved (van den Hove, 2007). The lack of scientific certainties in natural systems can restrict the formulation of long-term management plans based on modelling or knowledge of only a limited part of the system (Mee, 2004).

Adaptive management allows management to proceed despite uncertainty. It provides a science-based learning process (Figure 1.4). Adaptive management uses the best available multi-disciplinary knowledge to construct a dynamic model to explore how systems might behave under different management regimes. The outcomes are monitored and evaluated and, if necessary, the model refined and new management objectives set (Mee, 2004).

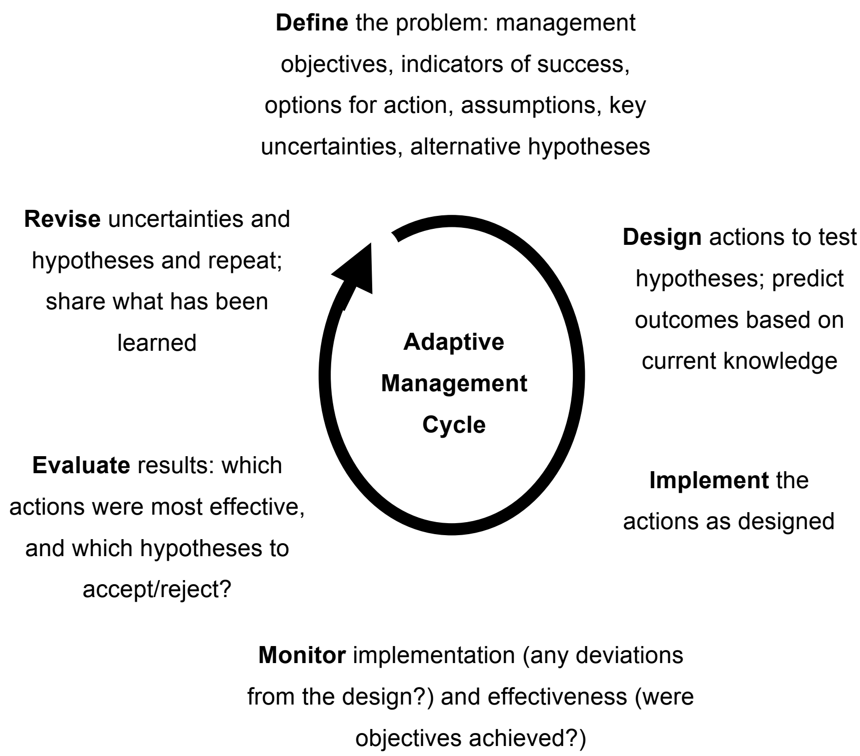

Figure 1.4 The adaptive management cycle (Murray and Marmorek, 2003; 2004 in van den Hove and Moreau, 2007).

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[10] IUCN Ecosystem Management Series: http://www.iucn.org/about/union/commissions/cem/cem_resources/cem_ems/

1.1.6 The precautionary approach (application of the precautionary principle)

The complex nature of ecosystems inevitably results in environmental policy decisions being made in the absence of complete information (van den Hove and Moreau, 2007). This is particularly true in the deep sea where knowledge about the ecosystems and impacts of human activities are only just emerging. The precautionary approach is one of the underlying tenets of environmental governance and management and, like the ecosystem approach, it is incorporated into many international and regional instruments. However, different terms, for example, ‘precautionary principle’, ‘precautionary approach’, ‘precautionary measures’ are used in these treaties and agreements (EEA, 2001). This does not make for clarity.

Principle 15 of the Rio Declaration on Environment and Development, “The Precautionary Principle”, states that: “Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation” (UN, 1992b). The European Environment Agency defines the precautionary approach as “a decision to take action, based on the possibility of significant environmental damage even before there is conclusive, scientific evidence that the damage will occur”[11]. The UN Food and Agriculture Organisation (FAO) Code of Conduct for Responsible Fisheries[12], the UN Fish Stocks Agreement (UNGA, 1995) and the European CFP (EC, 2002a) all promote the application of the precautionary approach to managing resources.

OSPAR defines the precautionary approach for marine ecosystems as a “management approach where preventive measures are to be taken when there are reasonable grounds for concern that substances or energy introduced, directly or indirectly, into the marine environment may bring about hazards to human health, harm living resources and marine ecosystems, damage amenities or interfere with other legitimate uses of the sea, even when there is no conclusive evidence of a causal relationship between the inputs and the effects” (OSPAR, 2010a).

Despite the precautionary principle being taken up as a key component in governance and management Gjerde (2008) argues that there is a lack of institutions to enable its consistent application.

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[11] EEA glossary: http://glossary.eea.europa.eu/terminology/concept_html?term=precautionary%20approach

[12] FAO Code of Conduct for Responsible Fisheries:
http://www.fao.org/docrep/005/v9878e/v9878e00.HTM#2

1.1.7 Marine spatial planning (MSP)

The increasing pressure on the marine environment from human activities has resulted in two kinds of conflict. The first, and lesser, type of conflict is between users competing for space or activities that are incompatible with one another – such as submarine cables and bottom trawling. The second and more pressing conflict is the cumulative impact of all activities on the marine environment – the conflict between users and the environment (Douvere and Ehler, 2008). Activities in parts of the marine environment are currently regulated and zones allocated in which to operate. Examples include licensed blocks for mineral extraction, waste disposal sites, shipping channels and marine protected areas. However, the management is most often *ad hoc*, lacking a strategic and comprehensive framework (DEFRA, 2007).

MSP offers an integrated approach to managing human activities in marine ecosystems and is seen as an essential step towards ecosystem-based sea use management. It moves away from sectoral management – which requires information on a single species or activity, towards an holistic approach to planning. MSP is defined as "analysing and allocating parts of three-dimensional marine spaces to specific uses or non-use, to achieve ecological, economic, and social objectives that are usually specified through a political process" (Douvere and Ehler, 2008).

A number of MSP projects have been undertaken within Europe. The UK Irish Sea Pilot was set up in 2002 to assess the potential for applying the ecosystem approach to managing the marine environment at a regional sea scale (JNCC, 2004). The complexity and range of human activities and management interests in this shallow marine environment is evident from the resulting maps (Figure 1.5). Other MSP projects, for example in Belgium (Maes et al., 2006) and the Netherlands (IMPNS, 2005) have addressed the management of new activities, the expansion of existing ones and the increasing demands for conservation, as well as addressing the conflicts arising from the need to integrate the management of marine and coastal ecosystems (Douvere and Ehler, 2008). In the North West Atlantic, the Massachusetts Ocean Management Plan[13] represents a first step towards integrated marine spatial planning in the USA. The Eastern Scotian Shelf Integrated Management (ESSIM) Initiative[14], completed in 2008, was Canada's first integrated marine management plan.

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[13] http://www.env.state.ma.us/eea/mop/final-v1/v1-complete.pdf

[14] http://www.mar.dfo-mpo.gc.ca/e0010329

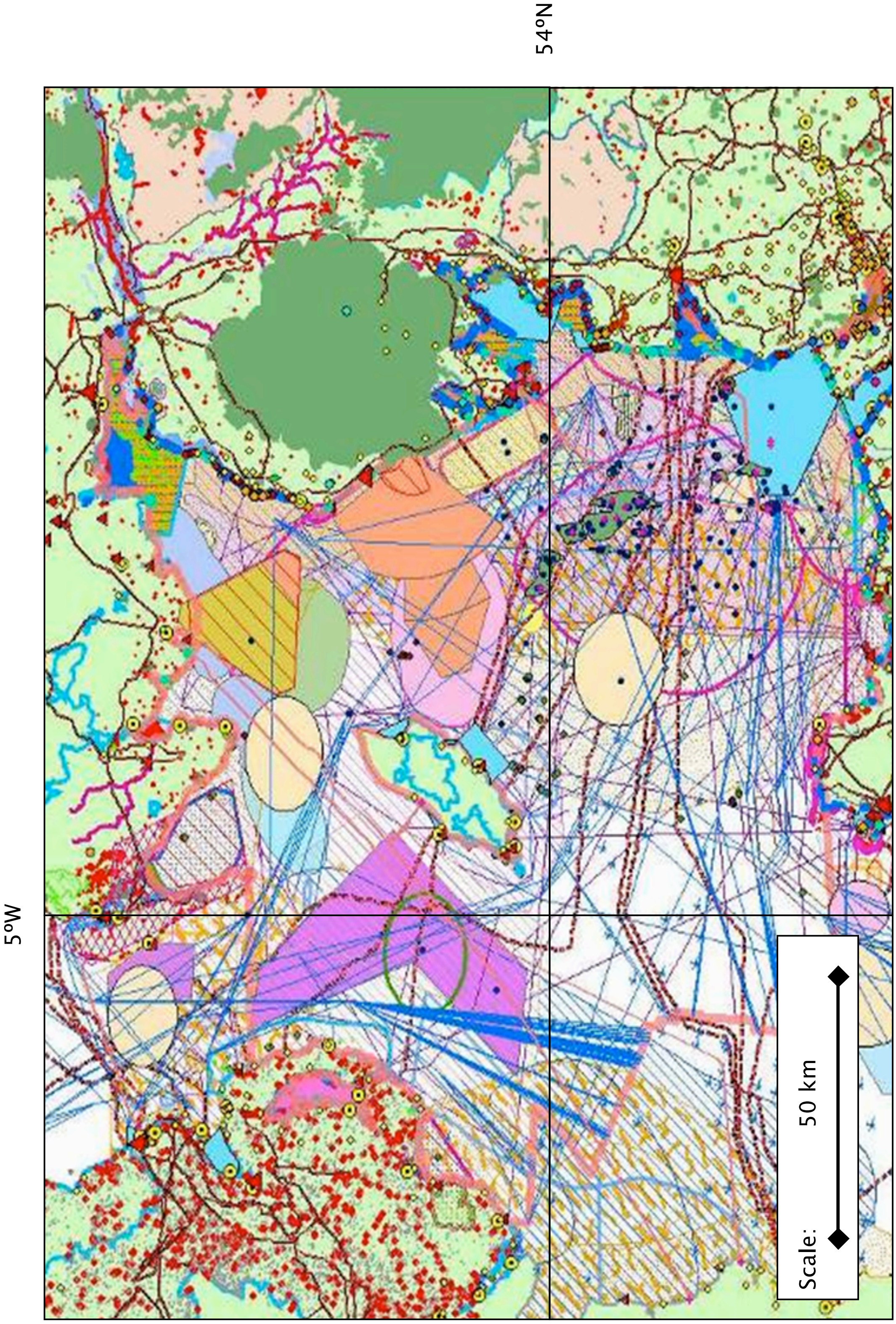

Figure 1.5 The complexity of human activities and management interests in the Irish Sea as revealed by a compilation of the individual maps produced during the Irish Sea Pilot Project (MSPP Consortium, 2005)

Legend for Figure 1.5 (Not shown in legend: Fishing Grounds, Fish Protection Areas, Spawning Areas and Nursery Grounds - by Species)

MSP projects to date have focussed on shelf areas and within the waters of individual States. Even within such contained and defined areas, problems arising from the fragmented governance and mismatches between the scales of governance and ecosystems are evident (Crowder et al., 2006). As human activities extend further offshore and into deeper waters, the implementation of MSP in areas which lie beyond national jurisdictions is likely to present even greater challenges in terms of fragmented governance and mismatches in scale.

1.1.8 Integrated ecosystem assessments

Integrated ecosystem assessments, alternatively known simply as integrated assessments, are becoming established as key management tools for human activities in the marine environment in support of ecosystem-based management (Eastwood et al., 2007). Levin et al. (2009) define an integrated ecosystem assessment as “a formal synthesis and quantitative analysis of information on relevant natural and socioeconomic factors, in relation to specified ecosystem management objectives”. They describe it as “an incremental approach, in which integrated scientific understanding feeds into management choices and receives feedback from changing ecosystem objectives”.

There is no single, definitive approach to integrated assessments and assessments will always need to be adapted to each situation. Nevertheless, work to develop approaches and methods to successfully implement integrated assessments at local, regional and global scales is being undertaken world-wide and the possible processes and mechanisms by which they can be implemented are under discussion and review (ICES, 2004; Choi et al., 2005; ICES, 2005b; Levin et al., 2009; ICES, 2010a; SEAMBOR, 2010).

While a range of approaches to ecosystem assessment are proposed (for example, a five-step process (Levin et al., 2009) or a process based on two steps (ICES, 2005b)) the basic key elements are common to them all – although variously described. These include the current status and trends of ecosystem components (for example biodiversity, structure, function), the human activities known or predicted to occur (including relationships between society, economy, biodiversity and habitats), the mechanisms through which they exert pressure on the ecosystem (the drivers affecting ecosystems’ functioning and biodiversity functioning), the importance of the mechanisms in relation to important ecosystem components and mitigation options in relation to management, conservation and rehabilitation (ICES, 2004; 2005b).

The European Environment Agency (EAA) proposes yet another approach, describing the process of integrated assessments within the framework of DPSIR[15]. DPSIR is a feedback mechanism based on a chain of causal links. The start of the chain are Driving forces, which lead to Pressures, which in turn lead to changes in the State of the environment, leading to Impacts on ecosystems and society which elicit political Responses.

The problem of description is exacerbated by the variety of cultures attempting integration. Sectors whose activities may need to be included in such assessments are diverse and include fisheries, tourism, waste disposal, marine scientific research, the hydrocarbon industry, renewable energy, shipping, submarine cable, military as well as industries generating land-based sources of inputs to the marine environment. While elements of integrated ecosystem assessment processes are being developed and refined, for example ICES, (2004) and OSPAR, (2009b), complete integration of multiple ocean-use and management objectives has yet to be achieved (Levin et al., 2009).

1.1.9 The Assessment of Assessments

Agenda 21, adopted at the Rio Conference on Environment and Development, committed States to improve understanding of the marine environment in order to better assess present and future conditions (UN, 1992a). During 2001-2002, work commenced to explore the feasibility of establishing a regular global process for assessing the marine environment. The findings of the resulting study led the 2002 World Summit on Sustainable Development to support actions at all levels to "establish by 2004 a Regular Process under the United Nations for global reporting and assessment of the state of the marine environment, including socioeconomic aspects, both current and foreseeable, building on existing regional assessments". This was endorsed by the United Nations General Assembly later in 2002 (Resolution 57/141) (UNGA, 2002).

The initial phase of the Regular Process was the Assessment of Assessments (AoA) made in preparation for the first global integrated assessment planned for 2014. The AoA assembled and reviewed existing national, regional and global assessments of the marine environment as well as related social and economic aspects to evaluate their strengths and to identify methods which could contribute to regular and comprehensive overall assessments of the world's oceans and seas. It assessed the products as well as the structures and processes of existing assessments.

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[15] EEA Integrated Assessment Portal:
http://ia2dec.ew.eea.europa.eu/knowledge_base/Frameworks/doc101182

The final report of the AoA (UNEP & IOC-UNESCO, 2009) highlighted a number of issues of particular relevance to this study. These included:

- The assessment coverage in areas beyond national jurisdiction was particularly weak.
  This is significant as most deep-sea areas lie outside national jurisdiction.

- Many existing assessments are produced only once or very occasionally.
  Out of the total 1,023 assessments listed in the GRAME database[16] only 175 (17 percent) are regularly repeated.
  This is of limited use for identifying temporal changes and trends.

- Assessments of individual sectors or ecosystem components are not sufficient for maintaining and restoring ecosystem health where other human activities have an impact.

- Approximately 50 percent of the existing assessments were classified as 'narrow'[17]

The Summary Database[18] reports that only 2 out of the 1,023 assessments provided access to environmental, economic or social data.

1.1.10 Marine protected areas

There is no single definitive definition of an MPA but until recently the most frequently used was that proposed by Kelleher (1999): "Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment".

The most recent definition of a protected area, whether marine or terrestrial, produced in 2007 by the IUCN-WCPA emphasizes the long term-conservation focus: "A clearly defined geographical space, recognised, dedicated and managed, through legal or

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[16] GRAMED Database: GRAMED Database: http://www.unepwcmc.org/GRAMED/DataResults.cfm?report=summary

[17] Definition of 'narrow' from GRAME: "Assessments … that focus on a particular aspect of the marine environment, such as fisheries or climate change …" http://www.unep-wcmc-apps.org/GRAMED/DataResults.cfm?report=summary

[18] GRAMED Summary statistics: http://www.unep-wcmc-apps.org/GRAMED/DataResults.cfm?report=summary

other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Dudley, 2008).

MPAs may be established for a range of reasons from strictly for wilderness values, where extractive activities such as mining and fishing are excluded and only science is allowed, to areas managed more broadly for the sustainable use of natural resources and ecosystems (IUCN, 1994). While the objective of protection from human activities is common to all MPAs, not all activities are necessarily prohibited. Some activities, such as fishing, may be restricted on a temporal as well as a spatial basis (for example spawning closures) (FAO, 2003). Protected area networks should be capable of maintaining biodiversity and ecosystem functioning at large scales (Roberts et al, 2003).

The impetus to establish MPAs has gained momentum over the past decade. Chapter 17 of Agenda 21, The Plan of Implementation of the World Summit on Sustainable Development, Article 32(c) (UN, 2002) invited States to: "Develop and facilitate the use of diverse approaches and tools, including the ecosystem approach, the elimination of destructive fishing practices, the establishment of marine protected areas consistent with international law and based on scientific information, including representative networks by 2012 and time/area closures for the protection of nursery grounds and periods, proper coastal land use and watershed planning and the integration of marine and coastal areas management into key sectors".

In 2003, the Vth IUCN World Parks Congress (WPC) was pivotal in setting the direction for protection of the oceans. WPC Recommendation 5.22 called upon the international community as a whole to greatly increase, by 2012, the marine and coastal area managed in MPAs and that the MPA networks should be extensive and include strictly protected areas that amount to at least 20–30% of each habitat.

In 2004, the Convention on Biological Diversity (CBD, COP 7) agreed, stating that the overall purpose of the programme of work on protected areas was "The establishment and maintenance by 2010 for terrestrial and by 2012 for marine areas of comprehensive, effectively managed, and ecologically representative national and regional systems of protected areas that collectively, *inter alia* through a global network, contribute to achieving the three objectives of the Convention and the 2010 target to significantly reduce the current rate of biodiversity loss at the global, regional, national and sub-national levels and contribute to poverty reduction and the pursuit of sustainable development" (UNEP, 2004c).

COP 7, Decision VII/28 defines the process and deadlines by which the targets should be met. Despite the additional target set by COP 7, later endorsed by COP 8, that by 2010 “at least 10 per cent of each of the world’s ecological regions be effectively conserved” (UNEP, 2004c), concerns have been expressed at the slow rate of progress to define MPAs on a global scale (Wood et al., 2008). With a global annual growth rate in the spatial extent of marine protected areas of 4.6 percent since 1984 it is unlikely that even the most modest targets can be met for several decades rather than within the coming decade (ibid.). The World Database on Marine Protected Areas[19] reports that only 0.7 per cent of oceans are currently protected.

Decision X/2 of COP 10 in 2010 provided a strategic plan for biodiversity in which Target 11 states that “by 2020, at least 17 per cent of terrestrial and inland water areas, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascapes” (UNEP, 2010).

Within the European Union the MSFD (EC, 2008b) requires Member States to prepare national strategies to manage their seas to achieve or maintain Good Environmental Status (GES) by 2020. The Directive requires Member States to prepare marine strategies that comprise an initial assessment, specification of what constitutes GES in state waters, a set of targets and associated indicators, a monitoring programme and a programme of measures. The programme of measures, to be completed in the period 2012-2015 and implemented by December 2016, must include spatial protection measures, which will contribute to coherent and representative networks of MPAs, adequately covering the diversity of the constituent ecosystems.

The "Natura 2000" network, established under the Habitats Directive (EC, 1992), comprises special areas of conservation (SACs) designated by Member States. The network also includes special protection areas (SPAs) classified according to the Wild Birds Directive (EC, 2009a). Natura 2000 applies to both terrestrial and marine environments within Member States’ EEZs. Sites are selected via a three stage process. Member State must undertake assessments of each of the habitat types and species present on their territory. A list of proposed sites, based on standard selection criteria specified in the directive, is submitted to the Commission. The Commission, in agreement with the Member States, must then adopt lists of “Sites of Community Importance”. The proposals for each bio-geographical region are then analysed via a

[19] World Database on Marine Protected Areas: http://www.wdpa-marine.org/#/countries/about

series of seminars. The process is open to Member States, experts representing relevant stakeholder interests including owners, users, and environmental NGOs. Once lists of Sites of Community Importance have been adopted, Member States must designate all of the sites as SACs as soon as possible and not more than six years after the date of adoption. The most recent figures available from May 2010 on the Natura 2000 Barometer[20] listed 1,412 marine sites covering 132,923 km^2.
In 2003 the OSPAR Convention, covering the North East Atlantic, adopted Recommendation 2003/3 on a network of MPAs (OSPAR, 2003) calling for an ecologically coherent network of well-managed marine protected areas to be established by 2010. OSPAR reports that in 2010 there were 159 MPAs covering 147,322 km^2 established in waters belonging to Contracting Parties (OSPAR, 2010b). The majority of these are coastal or in waters <200 metre water depth.

An amendment at the Ministerial Meeting during September 2010 recognised that, despite efforts by Contracting Parties, the network of MPAs was considered to be not ecologically coherent. The amendment acknowledged that further work was needed - in particular to include areas in deeper waters, and also to ensure that the sites are well-managed to achieve the aims for which they have been established (OSPAR, 2010c).

During the 2010 Ministerial Meeting, OSPAR Ministers established six high seas marine protected areas covering a total area of 285,000 km^2. The sites encompass a series of seamounts and sections of the Mid-Atlantic Ridge. The establishment of these MPAs raises a number of issues regarding jurisdiction. The MPAs at Altair Seamount, Antialtair Seamount, Josephine Seamount and Mid Atlantic Ridge north of the Azores are in the high seas. However, they are above the seabed that is subject to a submission by Portugal to the Commission on the Limits of the Continental Shelf. Any seabed that is part of such a submission to UNCLOS comes under the control of the relevant coastal State. Consequently, the water column and seabed may be subject to different jurisdictions. A joint agreement between OSPAR and Portugal harmonises the arrangement for these four MPAs, allowing Portugal to manage the seabed in collaboration with OSPAR who will manage the water column.

This is further complicated by OSPAR's lack of authority over fishing activities, mining or shipping. Hence, before full protection can be accorded to these sites, OSPAR has to reach agreements covering fishing with NEAFC, covering mining with the ISA, and covering shipping with the IMO. NEAFC have already imposed closures for bottom

[20] NATURA 2000 Barometer: http://ec.europa.eu/environment/nature/natura2000/barometer/docs/sci.pdf

fisheries in four of the new MPA locations although Milne Seamount and Josephine Seamount do not have any current protection.

A further issue, identified by van den Hove and Moreau (2007), relating to the designation of MPAs in the deep sea is that lack of knowledge of deep-sea habitats may result in insufficient protection for some habitats because protection may be biased towards those ecosystems and habitats already identified. The World Conservation Union sets out criteria for the selection of MPAs (IUCN, 1994). These include naturalness, biogeographic importance, ecological importance, economic importance, scientific importance, international or national significance and practicality/feasibility (IUCN, 1994).

It is generally accepted that MPA networks should be distributed along environmental gradients and should protect representative species and habitat types. However, the lack of knowledge of the distribution of all deep-sea species makes this problematic. Consequently surrogates are often used as measures of biodiversity (Howell, 2010). Although a number of classification systems, appropriate for the deep-sea, have been developed based on biogeographical province, depth, substrate type, geomorphology and biology Howell (2010) warns, that while the existing systems are suitable for the tasks for which they were designed, none individually, is completely applicable for achieving representation of biological diversity within a deep-sea MPA network. She proposes a hierarchical classification system based on four criteria, biogeography, depth, substrate and biology, shown to be indicators of faunal distribution and representing the principal biological variations in the deep sea.

While there is international political momentum to establish networks of MPAs it can be seen that to do so in the deep sea is not straightforward. Different regimes of legislation and different jurisdictions complicate governance and management. Refinements to existing classification systems are necessary if they are to be applicable to deep-sea biodiversity.

1.1.11 Information on human activities

It is evident that the ecosystem approach is common to many instruments and agreements at all levels and also that human activities are considered in the broader framework of socio-ecological systems. It is also recognised that such activities must be managed in way that does not compromise the structural and functional integrity of the ecosystem. Reliable and comprehensive information about the natural, social, economic, legal and political aspects of the system is fundamental. To achieve this the spatial and temporal distribution of multiple human activities in a specific area need to be known, together with the spatial distribution of important ecosystems, the intensity and location of impacts as well as the responses of the human and non-human components to the combined effects of these impacts (Lester et al., 2010). Studies suggest that the availability of information on these components varies. Such information, when available, is rarely collected for the purpose of fulfilling ecosystem based management, consequently it is often not available at scales or resolutions appropriate to develop assessments of anthropogenic activities (Eastwood et al., 2007; Lester et al., 2010).

Much of the available information on human activities relates to broad scale economic and social aspects or specific species (see for example the European Atlas of the Seas[21], the Irish Sea Pilot Project[22] and The Scotian Shelf: An Atlas of Human Activities[23]). However, detailed data on the location and extent of activities is more difficult to both locate and access. While broad-scale information is necessary, to fully comprehend the extent of human activities and identify trends, detailed data are essential. The situation is compounded by jurisdiction issues in the deep sea where activities often occur both inside national jurisdictions but also extend into the high seas and the Area, which both lie beyond national jurisdictions, or extend across national boundaries and are governed by different legal regimes (Figure 1.1).

Detailed information on human activities, where accessible, can be used to map and assess i) the type and extent of impacts (Eastwood et al., 2007); ii) the relative spatial extent of human activities (Benn et al., 2010); iii) varying intensities of impacts as well as iv) where activities overlap and to assess their cumulative impacts (Lester et al., 2010). Detailed information on the location of activities, for example the location of bottom trawling, can be used to inform planning decisions for marine protected areas (Hall-Spencer et al., 2009) and to monitor compliance with closed areas (FAO, 2003).

It would be reasonable to assume that access to this fundamental information is guaranteed. The availability of detailed data on human activities is vital to the effective implementation of the ecosystem approach. However, previous researchers requiring access to data on human activities in the marine environment have highlighted problems of access and appropriate quality (Eastwood et al., 2007, Lester et al., 2010, Horsman and Breeze, 2006, Lumb et al., 2004, Gerritsen and Lordan, 2010).

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[21] European Atlas of the Seas: http://ec.europa.eu/maritimeaffairs/atlas/maritime_atlas

[22] The Irish Sea Pilot Project: http://www.jncc.gov.uk/pdf/irishseapilot_all.pdf

[23] The Scotian Shelf: An Atlas of Human Activities: http://www.mar.dfo-mpo.gc.ca/e0009693

1.2 The current study

Huge effort is being expended to implement the paradigm shift towards an holistic and integrated approach to governance and management of the marine environment. However, this thesis questions whether the basic information necessary to achieve this is available from the sectors concerned.

While marine spatial planning has been undertaken on the Continental Shelf and within EEZs, no study to date has addressed the issues of the location and extent of human activities within the deep sea – both within and outside areas of national jurisdiction. In order to test the feasibility of this, seven of the main human activities taking place on the seafloor in the deep North East Atlantic are identified from the literature. The availability and quality of data are researched. The locations of deep-sea activities are mapped and estimates are made of the relative spatial extent of each activity as well as the direct physical pressures they exert on the seabed. A further phase of the work assesses data availability for the same activities in the North West Atlantic to identify, if applicable, examples of best-practice. The third element of the thesis reviews the legislation that governs the human activities identified and assesses the reporting requirements for each. The penultimate element of the thesis is an analysis of the responses to requests for VMS data. Finally, a summary of the findings and conclusions is presented together with ideas for further work.

2 Human Activities on the Deep Seafloor in the North East Atlantic

2.1 Introduction

As has been shown in Chapter 1, a paradigm shift in the governance and management of the marine environment is underway. Governance and management are moving away from traditional approaches based on an individual activity, species or component of an ecosystem and towards more holistic and integrated approaches which account for ecosystem processes and socioeconomic processes. The ecosystem-based approach demands knowledge of the spatial and temporal distribution of multiple human activities in a specific area together with the spatial distribution of important ecosystems, the intensity and location of impacts as well as the responses of the human and non-human components to the combined effects of these impacts (Lester et al., 2010).

Continuing degradation of the marine environment is recognised globally (UNEP, 2004a; Millennium Ecosystem Assessment, 2005). Governance and management of the deep sea is of increasing international concern. The United Nations, the Regional Seas conventions and regional organisations, including the European Union, are all developing marine environmental policies as well as monitoring and reporting procedures. Rules and codes of conduct are being established to regulate activities impacting on the deep ocean. The OSPAR Commission has recognised the scientific case for establishing MPAs in areas beyond national jurisdiction in the deep North East Atlantic (OSPAR, 2008b). It has developed a code of conduct for Responsible Marine Research in the Deep Seas and High Seas of the OSPAR Maritime Area (OSPAR, 2008a) (Figure 2.1). NEAFC (Figure 2.1) has adopted procedures and rules for existing and new bottom-fishing areas aimed at the protection of vulnerable marine habitats (NEAFC, 2008; 2009; 2010a; b). NEAFC and the OSPAR Commission have initiated the first efforts towards multi-sectoral management in the high seas in the North East Atlantic. Under a new memorandum of understanding adopted by the two organisations in 2008, an attempt is being made to combine fisheries and conservation management (OSPAR, 2008b).

The past decade has seen initiatives to provide transparent access to standardized data sets on the marine environment collected by oceanographic fleets and automated observation systems including data collected and provided by industry. Within Europe SeaDataNet[24]provides on-line access to marine datasets derived from *in-situ* and

[24] SeaDataNet: http://www.seadatanet.org/

remote observation. In the UK, Marine Environmental Data and Information Network (MEDIN)[25], a partnership between government departments, research institutions and private companies promotes access to and sharing of marine data. Globally, the International Oceanographic Data and Information Exchange (IODE) OceanDataPortal[26] facilitates seamless access to oceanographic data and promotes the exchange and dissemination of marine data and services, aims to facilitate seamless access to oceanographic data and promotes the exchange and dissemination of marine data and services. However, while these databases contain data on the marine environment they rarely, if ever, contain information on the human activities taking place.

Data on human activities are collected and held i) by public institutions and private companies to fulfill regulatory requirements, ii) for commercial and operational purposes and iii) for scientific research. According to the European Union Directive on Public Access to Environmental Information (EC, 2003c), Article 2.1.c environmental information includes measures, (including administrative measures), such as policies, legislation, plans, programmes, environmental agreements and activities affecting or likely to affect the elements and factors listed in the Article. These include water, soil, land, landscape and natural sites, marine areas, biological diversity and its components as well as the interactions among these elements.

The aim of this chapter is to discover the spatial distribution and to estimate the spatial extent of major human activities during 2005 on the deep seafloor of the North East Atlantic within and beyond EEZs. In this study the 'deep sea' is defined as the waters and sea-floor below 200 metres water depth, usually the outer edge of the continental shelf (Gage and Tyler, 1991). The OSPAR maritime area (Figure 2.1) was selected for the study. Of the total 11,032,175 km ^{2} comprising the OSPAR area, greater than 75 per cent (8,517,010 km^2) is deeper than 200 metres.

The marine ecosystems in the North East Atlantic are some of the most heavily impacted by human activities (Halpern et al., 2008). The availability and suitability of data relating to these activities are assessed and the spatial extent of the direct physical impact on the seafloor is quantified. However, the extent of collateral physical impacts, for example smothering caused by sediment plumes and chemical effects on the benthos, for example those related to oil industry cuttings piles, are not assessed. In addition, the wider chemical and biological impacts caused by pollution are not estimated. In the current study, human activities, identified by reference to

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[25] Medin: http://www.oceannet.org/

[26] OceanDataPortal: http://www.oceandataportal.org/index.php?option=com_content&task=view&id=27&Itemid=67&catid=4

literature (OSPAR, 2000; Glover and Smith, 2003; Thiel, 2003; Davies et al., 2007; van den Hove and Moreau, 2007), are defined as intentional human activities occurring directly on the sea floor as well as structures and artefacts present on the seafloor resulting from past activities. Previous studies in shallower waters have examined much smaller areas in detail, (Lumb et al., 2004; Eastwood et al., 2007), or have looked at single activity impacts, for example the impacts of the extraction of aggregates and the oil and gas industry, (de Groot, 1996a; 1996b), whilst other studies have taken a broad global view (Halpern et al., 2008).

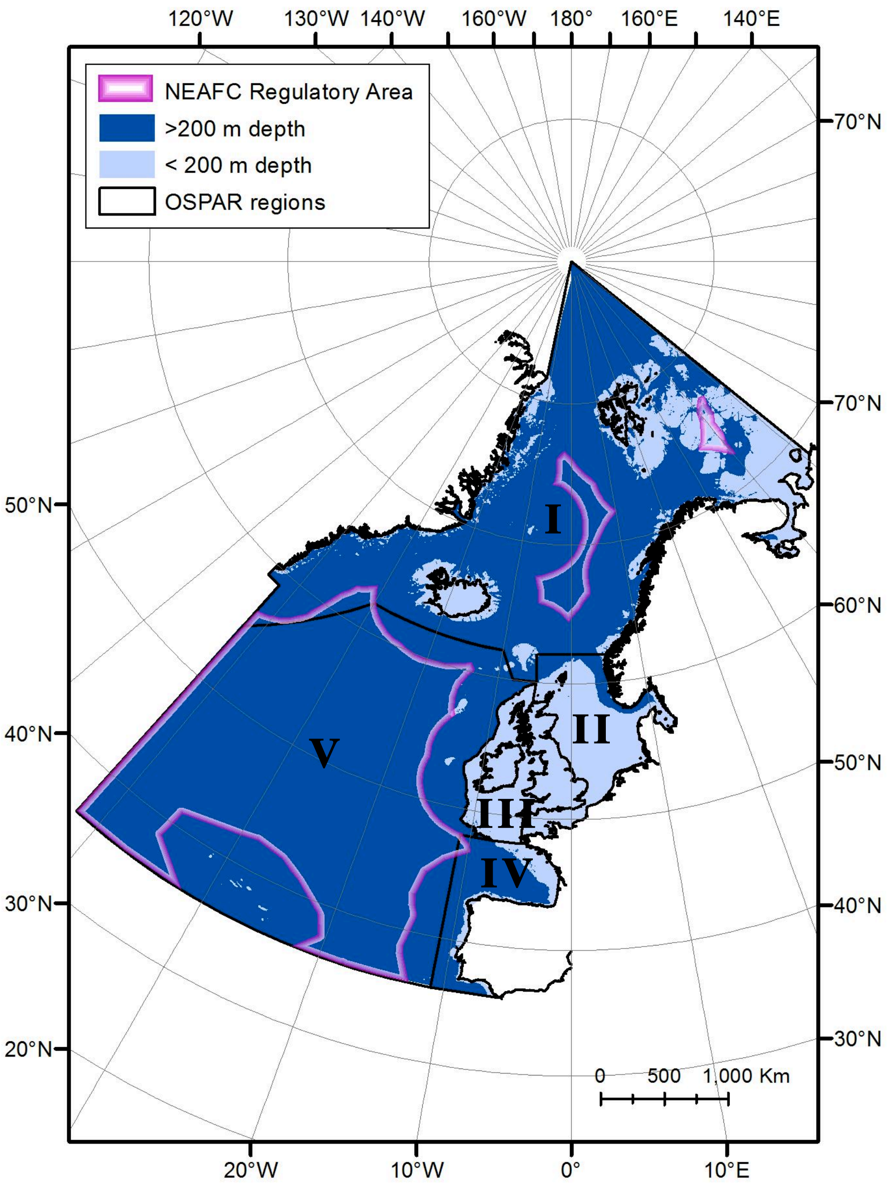

Figure 2.1 OSPAR Maritime Area and the North East Atlantic Fisheries Commission Regulatory Area. OSPAR Regions I: Arctic Waters, II: Greater North Sea, III: Celtic Seas, IV: Bay of Biscay and Iberian Coast, V: Wider Atlantic. (Courtesy of the GeoData Institute, University of Southampton)

2.2 Methods

Data for activities were requested from sources listed in Tables 2.1, 2.2 and 2.3. They were rarely in a format immediately suitable for assessing the spatial extent of each activity. Typically, data were provided as text files or MS Excel sheets with XY point locations of features, for example, marine scientific research sample sites or radioactive dumpsites. In the case of vessel tracks or pipelines, data were either strings of coordinate points (in text files or MS Excel) or actual GIS datasets (polyline features). As such, these have no areal definition but merely describe the route a vessel took based on its GPS track or location of a point on the seabed.

Table 2.1 Sources of data.

Source	Contact information
Marine Scientific Research	
Report of Observations/Samples collected by Oceanographic Programmes (ROSCOP) Cruise Summary Reports	http://www.ices.dk/Ocean/roscop/index.asp
British Oceanographic Data Centre (BODC)	http://www.bodc.ac.uk
Hotspot Ecosystem Research on the Margins of European Seas (HERMES)	http://www.eu-hermes.net/members/cruises.html
Intergovernmental Oceanographic Commission of UNESCO, International Oceanographic Data and Information Exchange	http://www.oceandataportal.org
National Marine Facilities, National Oceanography Centre, Southampton	http://www.noc.soton.ac.uk/nmf
Ocean Information Centre, Research Ship Schedules and Information	http://www.researchvessels.org
Pangaea Publishing Network for Geoscientific & Environmental Data	http://www.pangaea.de
Various individual scientific institutions	
Submarine Cables	
Kingfisher Information Service – Cable Awareness	www.kisca.org.uk/charts.htm#option4
France Telecom SigCables	www.sigcables.com/cgi-bin/index.pl
Waste disposal: Radioactive Waste	
NEA.1985. Review of the Continued Suitability of the Dumping Site for Radioactive Waste in the North-East Atlantic. Nuclear Energy Agency, Organisation for Economic Cooperation and Development, Paris. 448pp.	
Waste Disposal: Munitions and chemical weapons	
OSPAR. 2005. (Revised). Overview of Past Dumping at Sea of Chemical Weapons and Munitions in the OSPAR Maritime Area. Biodiversity Series. OSPAR, London. 13 pp.	http://www.ospar.org/documents%5Cdbase%5Cpublications%5Cp00222_2005%20Revised%20Dumping%20at%20Sea%20of%20chemical%20weapons.pdf
Oil and Gas Industry	
UK Digital Energy Atlas and Library	http://www.ukdeal.co.uk
Norwegian Petroleum Directorate	http://www.npd.no/en/

Table 2.2 Military activities. Sources to which requests were addressed for information on military activities during 2005 in the North East Atlantic.

Source	Contact Information
NATO	mailbox.natodoc@hq.nato.intscience@hq.nato.int
French Ministry of Defence	http://www.defense.gouv.fr/formulaire_de_contact
Norwegian Ministry of Defence	postmottak@fd.dep.no
Portuguese Ministry of Defence	gcrp@defesa.pt
Spanish Ministry of Defence	comunicacion@fn.mde.es
Irish Defence Forces (Freedom of Information request)	foi@defenceforces.ie
UK Ministry of Defence (Freedom of Information request)	http://www.mod.uk/DefenceInternet/ContactUs/ FreedomOfInformationInformationRequest.htm
Government of Greenland	info@gh.gl
Government of Iceland	external@utn.stjr.is

Table 2.3 VMS data. Sources to which requests for VMS data were addressed.

State	Source	Contact
†Denmark	Fiskeridirektoratet	sat@fd.dk
†France	Cross Atlantique	Csp-France.CROSS-Etel@developpement-durable.gouv.fr
Greenland	Fisheries Authority	APNA@gh.gl
Iceland	Ministry of Fisheries and Agriculture	postur@slr.stjr.is
†Ireland	Fisheries Monitoring Centre	nscstaff@eircom.net
Norway	Ministry of Fisheries and Coastal Affairs	postmottak@fkd.dep.no
†Portugal	Direcção Geral das Pescas e Aquicultura, Departamento de Inspecção das Pescas	ccc@ip.dgpa.min-agricultura.pt
†Spain	Secretaría General de Pesca Maritíma	csp@mapya.es
†UK	Marine Fisheries Agency Data and Communications	sat.ops@mfa.gsi.gov.uk

† EC Fishing Monitoring Centres Contact List:
http://ec.europa.eu/fisheries/cfp/control/fmc_contact_list_en.pdf

The geostatistics to estimate the spatial extent of activities were carried out in collaboration with the GeoData Institute at the University of Southampton. Their methodology is described below.

To define a realistic areal footprint for features, the data were processed in ArcGIS v. 9.3 (Environmental Systems Research Institute). This industry standard GIS package has tools for buffering spatial features by a specified width (or range of widths). The output of this processing is a polygon shape which is a proxy for the actual spatial location and extent of the features on the seabed (the footprint). The tools operate on point or polyline features and can be used in a variety of coordinate systems. The geographical distribution of activities was mapped (Figure 2.2).

In order to minimise area distortions, ArcGIS's implementation of the *North Pole Lambert Azimuthal Equal Area Conic projection* was chosen as appropriate for use within the OSPAR regional extent.

Some of the datasets contained the necessary information to create the areal footprint, for example, known diameters of oil industry pipelines. Where this information was unavailable, values were sought from owners of the assets, industry experts or from published literature.

Depth zones were identified by reference to the General Bathymetric Chart of the Oceans dataset (GEBCO) (IOC et al., 2003). GEBCO is a world bathymetry dataset on a 1 arc minute grid and is the most extensive freely available bathymetric dataset.

Buffer polygons were created for each feature and the area values (automatically created by the GIS) were extracted and totalled to estimate the spatial extent of each activity (Table 2.4). A confidence rating relating to the quality of data was applied, based on the method described by Eastwood et al. (2007). A score of 1 denotes an estimated location and extent; 2 denotes a known location but estimated extent and 3, a known location and extent. Where the data used to calculate the estimates did not represent the total extent of an activity in the OSPAR deep water area, (marine research, submarine cables and bottom trawling) a further estimate, extrapolated to represent the total of each activity, was calculated (Table 2.5).

The datasets were drawn from a variety of sources (Tables 2.1, 2.2 and 2.3). They were collected for a variety of purposes. Some data were only indicative. Some were derived from GPS tracking. Others were surveyed precisely. Therefore, positional accuracies varied. This is a broad scale strategic study and while it is important to obtain as accurate information as possible, the study is considering the *relative* spatial extent of these activities in the context of the OSPAR region, and small errors are not likely to be significant to the final values, here. The study quantifies the physical footprint but does not quantify how significant these impacts, whether detrimental or beneficial, might be on the surrounding ecosystems. This study does not tackle contamination that may be spread away from the specific impact, for example leakage of radioactivity.

2.2.1 Marine scientific research

Marine scientific research is carried out by academic institutions or fisheries research laboratories. Research by academic institutions involves a range of equipment on the seafloor to sample the marine environment including moorings, grabs, corers, dredges and trawls. Much of this equipment has only a single impact of a few square metres. While fisheries research also involves the deployment of sampling equipment, such as grabs and moorings, it involves a higher proportion of bottom impact trawling.

Data were obtained from the seven online sources listed in Table 2.1 and individual scientists. Twenty four cruises, which took place in water deeper than 200 metres and carried out activities on the seafloor, were identified from cruise reports and station lists. A further 29 cruises which may have impacted on the seafloor in water deeper than 200 metres were accessed on the ROSCOP website but searches in PANGAEA, BODC and European project databases (for example HERMES) did not locate station lists or cruise reports. Cruises for which data were available represent approximately 45 per cent of the total number of cruises identified during 2005 which may have impacted on the seafloor within the OSPAR area listed on the ROSCOP cruise summary. Where cruise reports and station lists were available, activities on the seafloor were then mapped (Figure 2.2). According to the footprint size of each piece of equipment buffers were applied to estimate the spatial extent on the seafloor. Where the footprint area of each activity was not included in the cruise report (size of equipment deployed, length and width of trawl), it was estimated based on published literature and advice from individual institutions.

2.2.2 Submarine communication cables

Greater than 95 per cent of international communications are routed via submarine fibre-optic cables. In areas where cables are vulnerable to damage from fishing or anchoring (< 1,500 metres water depth) they often have one or more layers of armour and can be up to 50 mm in diameter. In waters deeper than 1,500 metres (generally beyond the reach of fishing), cables are non-armoured and are between 17 mm and 20 mm in diameter (Carter et al., 2009). An alternative protective measure is the burial of cables in water depths shallower than 1,500 metres (ibid.). During the burial operation a plough opens a furrow in the seafloor into which the cable is laid and the sediment replaced. Skids supporting the plough can leave a footprint on the seabed, particularly in zones of soft sediment, potentially increasing sediment compaction and leading to the disturbance of the marine fauna. The overall width of the disturbance strip produced by the plough-share and skids in direct contact with the seabed ranges from 2 to 8 metres width (ibid.). The spatial extent calculated here represents the width of either the unburied cables on the seafloor or, for buried cables, the footprint of the plough based on the minimum and maximum width of disturbance strips (2 metres and 8 metres) (ibid.), although it is unlikely that the disturbance strip is 8 metres wide everywhere.

Geospatial data for submarine cables were obtained from the two sources listed in Table 2.1. The Kingfisher Information Service – Cable Awareness data were available in MS Excel format to an accuracy of 10 metres and France Telecom's SigCables, available as ESRI shape files. These websites, for users of the seabed and, in particular, for skippers of fishing vessels, give cable locations to approximately 25º West, beyond which it was assumed that the water is too deep for the cables to be in danger. As no data were available beyond ~ 25º West, the cable lines were extrapolated by this study from the final data point provided for each cable to a landfall in the United States or Canada, identified from ICPC (2008). The distance to the western boundary of the OSPAR maritime area, 42º West was then calculated. Forty five cables were identified with an approximate total length of 75,055 km, which included all of the current in-service systems as at 2005. However, this does not take into account all systems dating back to the start, in 1850, of telegraphic communications – which remain on the seafloor. The total approximate length of all cables (including coaxial, fibre optic and telegraph cables laid in the past but not including military cables) on the seafloor within the OSPAR area during 2010 is estimated to be 184,200 km (Steve Bennett, Global Marine Systems Limited, personal communication). The spatial extent of cables calculated within this study, based on data from the Kingfisher Cables and France Telecom datasets, is estimated to represent approximately 41per cent of the total area of cables.

Neither dataset reported whether the cables were buried, armoured or non-armoured. Therefore, four scenarios have been considered based on the following assumptions:

1. No cable burial at any water depth. Cable diameter 50 mm in water depths 200 metres – 1,500 metres and 20 mm diameter in water depths greater than 1,500 metres.

2. No cable burial at any water depth. Cable diameter of 50 mm at all water depths (the maximum diameter of modern, double armoured fibre optic cables (Carter et al., 2009).

3. In water depths between 200 metres – 1,500 metres cables buried by a plough with an overall disturbance footprint of 2 metres width – the minimum width reported (Carter et al., 2009). In water depths greater than 1,500 metres non-buried cables, 20 mm diameter.

4. In waters depths between 200 metres – 1,500 metres cables buried by a plough with an overall disturbance footprint of 8 metres width - the maximum width reported (Carter et al., 2009). In water depths greater than 1,500 metres non-buried cable, 20 mm diameter.

The data were input into ArcGIS. Cables whose entire length was in water < 200 metres depth were removed from the dataset. The lines depicting the cables were segmented to account for the different depth zones (200 – 1,500 metres and >1,500 metres). The relevant depth zones were extracted from the GEBCO dataset. The linear features were intersected with the depth zones, splitting the line at the boundaries of the zones and the sections were attributed with the required width values (50 mm, 20 mm, 2 metres and 8 metres). This allowed variable buffers to be created for different sections of each line. The depth contours were simplified in areas of complex geomorphology to avoid adding spurious detail to the calculations. Cables crossing areas of Mid-Atlantic Ridge at depths < 1,500 metres were assumed to be 20 mm diameter as there is no cable burial or armouring in this area.

2.2.3 Waste disposal

This study focused on chemical and conventional munitions and low level radioactive waste dumped prior to the 1996 London Protocol (IMO, 1996). This protocol, which came into force on 24 March 2006, prohibits ocean dumping of any waste or other matter other than those specifically allowed to be considered for dumping at sea (the “reverse list”). The list recognises seven categories of waste: i) dredged material; ii) sewage sludge; iii) fish waste (or material resulting from industrial fish processing operations); iv) vessels and platforms or other man-made structures at sea; v) inert, inorganic geological material; vi) organic material of natural origin. The seventh category includes “bulky items primarily comprising iron, steel, concrete and similar unharmful materials for which the concern is physical impact and limited to those circumstances, where such wastes are generated at locations, such as small islands with isolated communities, having no practicable access to disposal options other than dumping” (IMO, 1996).

Radioactive waste

Between 1949 and 1982 radioactive waste was dumped routinely at sites in the North East Atlantic. It included i) "low level" wastes from nuclear power plant operations; ii) other nuclear fuel cycle operations, including fuel fabrication and reprocessing; iii) radionuclide use in medicine, research and industry and iv) decontamination and dismantling of redundant plant and equipment (NEA, 1985).

In 1983 increasing concern over the continued sea disposal of radioactive waste led the Contracting Parties to the London Convention (IMO, 1972) to adopt a voluntary moratorium on the sea dumping of all types of radioactive waste. Amendments to the Convention, adopted in 1993, which came into force on 20 February 1994, eventually banned sea dumping of all types of radioactive waste (IMO, 1996). Twenty five years from this date, contracting parties are required to "complete a scientific study relating to all radioactive wastes and other radioactive matter other than high level wastes ", followed by further studies at 25 year intervals (IMO, 1972). However, the methods for such studies and the reporting process are not specified.

Information relating to dumping sites for radioactive waste was obtained from a single source (NEA, 1985) (Table 2.1). This appears to be the only openly available source of such information. An estimate of the total area designated for dumping of radioactive waste in water deeper than 200 metres was 26,323 km^2, based on the aggregated areas with overlapping boundaries dissolved for each of the four designated sites (Table 2.6). However, this does not represent the area of seafloor covered by drums of waste, so a second estimate of the extent of this activity was based on the tonnage and estimated number of drums (Table 2.6). Thiel (2003) estimated that, in total, between 1949 and 1982, 222,732 drums containing 114,726 tonnes (t) of radioactive waste were dumped at sites in the deep North East Atlantic. This is a mean of ~0.5 t of waste per drum. Of the 42 dumping events listed in NEA, (1985), 24 events totalling 112,793 t (Table 2.6) of waste were deposited in the OSPAR area in waters deeper than 200 metres. A second estimate was calculated based on a mean of 0.5 t of waste per drum. It was estimated that there were 225,586 drums within the OSPAR area in waters deeper than 200 metres with an approximate footprint area of 1 metre^2 per drum (NEA, 1985).

Munitions and chemical weapons

Both conventional and chemical munitions have been dumped at sea since World War I (Beddington and Kinloch, 2005). The locations of dumpsites for conventional and chemical munitions were identified by reference to OSPAR, (2005) (Table 2.1). Of the 148 dumpsites recorded, 24 are in waters deeper than 200 metres (Table 2.7). While the locations of dumpsites were reported, there was no indication of the area of each. However, twelve sites are described as "scuttled ship". Based upon this information a nominal square 100 metres x 100 metres was assigned for each site.

2.2.4 Military activities

It was not possible to estimate the spatial extent of this activity. Requests for information relating to military activities on the seafloor during 2005 were made to sources listed in Table 2.2. Only the Irish Defence Forces responded, reporting no activities on the seafloor deeper than 200 metres during 2005. The UK Ministry of Defence redirected the request to the UK Hydrographic Office for locations of practice and exercise areas, but these contained no specific details of activities. The request to NATO was directed to the NATO Science Department which was unable to help as the request did not fall within the remit of the department.

2.2.5 Oil and gas industry

Geospatial data for oil and gas industry subsurface installations, pipelines and exploration and development wells were obtained from the UK Digital Energy Atlas & Library (UKDEAL) (UKDEAL, 2006) and the Norwegian Petroleum Directorate (NPD) (NPD, 2009) (Table 2.1).

The locations of pipelines were reported in the UK and Norwegian datasets but the diameter was recorded only in the UKDEAL data. Diameters for Norwegian pipelines were extracted individually from *NPD Facts* (NPD, 2005). These data were imported into ArcGIS. Sections of pipeline in waters 200 metres or deeper were identified and buffered to represent their respective diameters.

Neither the UKDEAL nor NPD datasets contained dimensions of other types of installations. Eastwood et al. (2007) proposed two categories of installations, 'platform' and 'well' and assigned nominal areas of ~180 metres^2 and a diameter of 50 metres respectively. The UKDEAL datasets listed one platform and eleven wellheads in waters deeper than 200 metres. Circular buffers of 180 metres^2 and 50 metres diameter respectively were applied to estimate the spatial extent of these features.

Most Norwegian deep water installations are floating platforms with wells drilled through templates on the seafloor. The original downloaded NPD dataset did not include the type of installation but, on request, a dataset was provided which included date installed and type of installation. In waters deeper than 200 metres three platforms sited on the seafloor and 230 templates were listed. Four legs sit on the seabed supporting the template which typically covers 416 metres^2 of seafloor (Tore

Indreiten, Statoil, personal communication). A square buffer of 416 metres^2 was applied to estimate the spatial extent of these installations and circular buffers of 180 metres^2 were applied to estimate the spatial extent of platforms.

In addition to structures on the seafloor, piles of drill cuttings are a part of the footprint of oil and gas operations. A variety of oil-based, synthetic and water-based drilling fluids have been used, each with different technical and environmental properties (OLF, 2006). Typically, cuttings piles are a mixture of man-made and natural substances containing higher concentrations of metals and hydrocarbons than background sediments. They consist of fragments of rock, mixed with drilling muds (Breuer et al., 2004). Discharge to the seafloor of oil-based drilling muds and associated cuttings ceased in 1993 and 1996 in Norway and the UK respectively. While water based drilling fluids and cuttings can, with permission, be discharged, used oil-based drilling fluids and cuttings are now either transported to land for processing or injected into the seafloor (OLF, 2009). Recent photographic surveys carried out by the SERPENT Project[27] at exploration drilling sites in the Faroe-Shetland Channel and the Norwegian Sea indicate a mean area of 21,744 metres^2 at each site is covered by drill cuttings in the deep sea (Jones and Gates, 2010). To estimate the spatial extent of oil and gas industry activities, including the presence of cuttings piles, a circular buffer of 21,744 m^2 (radius of ~83 metres) was applied to wells, platforms and templates. This area represents the physical presence of cuttings rather than the extent of biological impacts.

A further component of oil and gas industry activities is the drilling of exploration, development and appraisal wells. In the period up to and including 2005 the UKDEAL and NPD datasets report a total of 1,608 of these in waters deeper than 200 metres. Buffers of 21,744 metres^2 (radius ~83 metres) with overlapping boundaries merged and dissolved were also applied to these wells to estimate the spatial extent of drill cuttings. Of the wells listed, coordinates for 114 UK wells were not readily available. The buffered area for these was estimated from the mean area of the other UK wells.

2.2.6 Bottom trawling

From 1 January 2005 all vessels i) exceeding 15 metres overall length operating in European waters and ii) belonging to contracting parties to the NEAFC Vessel Monitoring System (VMS) Programme over 24 metres overall length operating within the NEAFC Regulatory Area (Figure 2.1), were required to install and operate satellite-based tracking devices (EC, 2003b; NEAFC, 2010d). Vessels were required to transmit data at intervals of 2 hours or less to Fishing Monitoring Centres (FMCs) located in the

[27] SERPENT Project: www.serpentproject.com

States in which they were registered. In November 2009 an amendment to the NEAFC convention required data to be transmitted at least once every hour in the NEAFC Regulatory Area (NEAFC, 2010c). Data relating to vessels operating beyond EEZs in the NEAFC Regulatory Area are transmitted from the flag State to NEAFC.

There was no definitive source identifying i) bottom trawling vessels, ii) where trawls started and ended and iii) the size of the gear deployed. Therefore the spatial extent of bottom trawling had to be estimated from VMS datasets only. VMS data for 2005 were requested from the sources listed in Table 2.3. Only France, the UK and NEAFC provided data. These data comprised a reporting code, position, time and date. The NEAFC dataset occasionally included details of the catch. No dataset gave any indication of whether the vessel was engaged in fishing at the time the position was reported. Data supplied by the UK, covering UK waters, included information about the type of vessel (for example demersal trawler, purse seiner) but this was not reported for all vessels. The French dataset, covering French waters, did not include speed. This had to be calculated by reference to time and distance covered between successive reported positions.

Bottom trawling activity was inferred by examining the course of each vessel in relation to seabed contours and speed. Unlike pelagic trawlers, bottom trawlers, while fishing, are likely to follow the contours of the seafloor (ICES, 2007). Additionally, deep water bottom trawlers can fish only within a limited range of speeds: 1.5-5.0 knots (Davies et al., 2007; ICES, 2007) (Tables 2.8 and 2.9). The size of the fishing gear was not reported. The possible distance between trawl doors, 22 metres, 80 metres and 125 metres was identified by reference to published literature (Hall-Spencer et al., 2002) and personal communication (Dick Ferro, Fisheries Research Services, Aberdeen, UK, personal communication).

The NEAFC data allowed a detailed study of just one fishery in the OSPAR area in the vicinity of Hatton and Rockall. These data were used to estimate the spatial extent of bottom trawling because it was possible to determine the relationship between vessel movements and seafloor contours. This is a conservative approach to the interpretation of these data in terms of whether vessels are fishing. This relationship was less clear for other areas within the NEAFC Regulatory Area and within French and UK waters, consequently these areas were not included in this study.

Speed frequency profiles, produced for each vessel in the NEAFC dataset using GeoCrust2.0 software (Afonso-Dias et al., 2004), were provided by ICES. These profiles identified vessels with peaks of activity within the 1.5-5.0 knot range. As a further check the entire 2005 NEAFC dataset comprising 797 vessels was imported into ArcGIS and patterns of vessel activity, following seafloor contours were studied. Twenty eight vessels were identified as engaged in bottom trawling in the Hatton - Rockall area. All vessels not considered to be bottom trawling were removed from the dataset. Data for the remaining 28 vessels were filtered to remove points with speeds outside the 1.5-5.0 knots range. Data points, within the speed range but lying outside the fishing grounds, in waters too deep to bottom trawl, were also removed. Sequences of consecutive data points were considered to indicate trawling periods. It was decided that each sequence was considered to have ended when the time difference between data points exceeded 2.5 hours. This time difference was chosen because occasionally the time between consecutive signals was greater than 2 hours. The resulting dataset encompassed the full range of speeds identified for bottom trawling (1.5-5.0 knots). Three further datasets were produced for the speed ranges: 3.5-5.0 knots (Davies et al., 2007), 1.5-4.5 knots (Davies et al., 2007) and 2.0-3.0 knots (ICES, 2007). Each spreadsheet was imported into ArcGIS and a point to polyline conversion used to map vessel tracks.

A limitation of this method is that although vessel activity relates to seafloor contours and speeds fall within the range of bottom trawling speeds, is it not certain when fishing gear is in contact with the seafloor. Further limitations are i) the two-hourly signal frequency gives a limited indication of the true speed and activity of vessels, ii) the distances between data points are represented by straight lines so represent the minimum distance covered, iii) the absence of information about gear type and size makes further assumptions necessary.

The estimates of spatial extent of bottom trawling represent only a proportion of the true extent of this activity in the OSPAR area as they are based on an analysis of vessels operating only within the Hatton - Rockall area from the NEAFC dataset. Deep water bottom trawling also takes place on the Reykjanes Ridge, the Mid-Atlantic Ridge and the continental slope (Gianni, 2004) but these areas were not included in this study.

2.3 Results

2.3.1 Marine scientific research

There was no single source for marine scientific research cruise data. The quality of station lists and cruise reports ranged from purely narrative, lacking description of equipment and latitude and longitude of sampling sites, to comprehensive, including station number, cast number, type of gear, event, date and time, decimal latitude and longitude, depth, remarks, core length where applicable and institute responsible for sample.

Table 2.4 shows that approximately 22 km^2 of marine research comprised activities carried out by fisheries research vessels and approximately 4 km^2 were attributable to non-fisheries marine research. This includes the tracks of trawls, dredges and sleds and the footprint of individual pieces of static equipment on the seafloor such as corers and grabs, which are removed immediately, and the anchor weights of moorings (~ 1metre^2), which remain on the seafloor.

The cruises mapped in this study, based on data derived from station lists and cruise reports, were estimated to represent approximately 45 per cent of all the scientific cruises reported on the ROSCOP website which carried out sampling on the seafloor during 2005 in water depths greater than 200 metres in the OSPAR area. Data from the remaining cruises were not available. Table 2.5 shows figures extrapolated to include the cruises for which no data were available. Extrapolating these figures gives a total spatial extent of approximately 49 km^2 and 9 km^2 respectively for fisheries and non-fisheries research.

For those data that were available confidence ratings of 2 and 3 denote that the location of activities were, in most instances, available but the extent of individual activities (for example the size of equipment deployed, length of trawls) were occasionally unreported.

Table 2.4 Estimates of the spatial extent and confidence ratings for six major human activities on the seafloor within the OSPAR area of the North East Atlantic in waters > 200 metres during 2005. Includes structures and artefacts resulting from past activities. Estimates for bottom trawling and marine scientific research are based on 2005 data only.

Activity (> 200m water depth)	**Estimated spatial extent (km^2)**	**Confidence rating†**
Scientific research: (estimated 45% of all cruises impacting on seafloor during 2005)		
Non-fisheries research cruises	4	2 - 3
Fisheries research cruises	22	2 - 3
Submarine communications cables: (estimated 41% of all submarine cables)		
No burial: between 200-1500 m wd, 50 mm cable diameter >1500 m wd, 20 mm cable dia.	2	1 - 2
No burial: between 200 - > 1500 m wd, 50 mm cable dia.	4	1 - 2
Cable burial: between 200 -1500 m wd with 2 m wide disturbance strip*; no burial >1500 m wd, 20 mm cable dia.	15	1 - 2
Cable burial: between 200 -1500 m wd with 8 m wide disturbance strip*; no burial >1500 m wd, 20 mm cable dia.	61	1 - 2
Waste disposal:		
Radioactive waste	0.2	2
Munitions and chemical weapons	1.4	1
Military:	No data made available	
Oil and gas:		
Pipelines	4	3
[1,2]Structures: platforms, templates and wellheads	0.2	2
[2]Structures with associated cuttings piles ([3]~83 m radius)	3	2
[2]Wells drilled during 2005 with associated cuttings piles ([3]~83 m radius)	1	2
[2]Wells drilled between 1960 and December 2005 and associated cuttings piles ([3]~83 m radius)	15	2
Total pipelines, structures, wells and cuttings piles	23	2-3
Bottom trawling: (2005, Hatton and Rockall area)		
- Speed range 2.0-3.0 knots, gear width 22 m:		1-2
Tracks not merged	741	
Tracks merged	548	
- Speed range 1.5-5.0 knots, gear width 125 m:		1-2
Tracks not merged	37,160	
Tracks merged	13,920	

wd: water depth

† Confidence ratings: (Eastwood et al., 2007):1= estimated location and estimated extent; 2 = known location, estimated extent; 3= known location and known extent

* Carter et al., 2009

[1]Information from NPD and Statoil datasets and Eastwood et al., 2007

[2] Overlapping boundaries merged

[3]Jones and Gates, 2010

Table 2.5 Comparison between estimated spatial extent of human activities during 2005 based on available data and the spatial extent extrapolated to the whole OSPAR deep seafloor.

Activity (> 200m water depth)	Estimated	Extrapolated
	km²	km²
Scientific research: (45% of cruises with activities on the seafloor reported to ROSCOP during 2005)		
Non-fisheries research cruises	4	9
Fisheries research cruises	22	49
Submarine communications cables: Cables mapped represent an estimated ~41% of cables		
No burial: between 200-1500 m wd, 50 mm dia cable; >1500 m wd, 20 mm dia cable	2	5
No burial: between 200 - > 1500 m wd, 50 mm* diameter cable	4	10
Burial: between 200 -1500 m wd with 2 metre wide disturbance strip*; no burial >1500 m wd, 20 mm diameter cable	15	**
Burial: between 200 -1500 m wd with 8 metre wide disturbance strip*; no burial >1500 m wd, 20 mm diameter cable	61	**
Waste disposal: Includes all recorded data		
Munitions and chemical weapons	1.4	1.4
Radioactive waste	0.2	0.2
Military	No data made available	
Oil and gas: Includes all recorded data and extrapolations (see text for method)		
Pipelines	4	4
[1,2]Structures: platforms, templates and wellheads	0.2	0.2
[2]Structures and associated cuttings piles ([3]~83 m radius)	3	3
[2]Wells drilled during 2005 and associated cuttings piles (~83 m radius[3])	1	1
[2]Wells drilled between 1960 and December 2005 and associated cuttings piles ([3]~83 m radius)	15	15
Total pipelines, structures, wells and cuttings piles	23.2	23.2
Bottom trawling in Hatton and Rockall during 2005 ~50% of all OSPAR deep-sea bottom trawling areas		
- Speed range 2.0-3.0 knots, gear width 22 m:		
Tracks not merged	741	1482
Tracks merged	548	1096
- Speed range 1.5-5.0 knots, gear width 125 m:		
Tracks not merged	37,160	74,320
Tracks merged	13,920	27,840

wd: water depth; *Carter et al., 2009; **Extrapolation inappropriate – see text.

[1]Information from NPD and Statoil datasets and Eastwood et al., 2007;

[2] Overlapping boundaries merged and dissolved;

[3] Jones and Gates, 2010

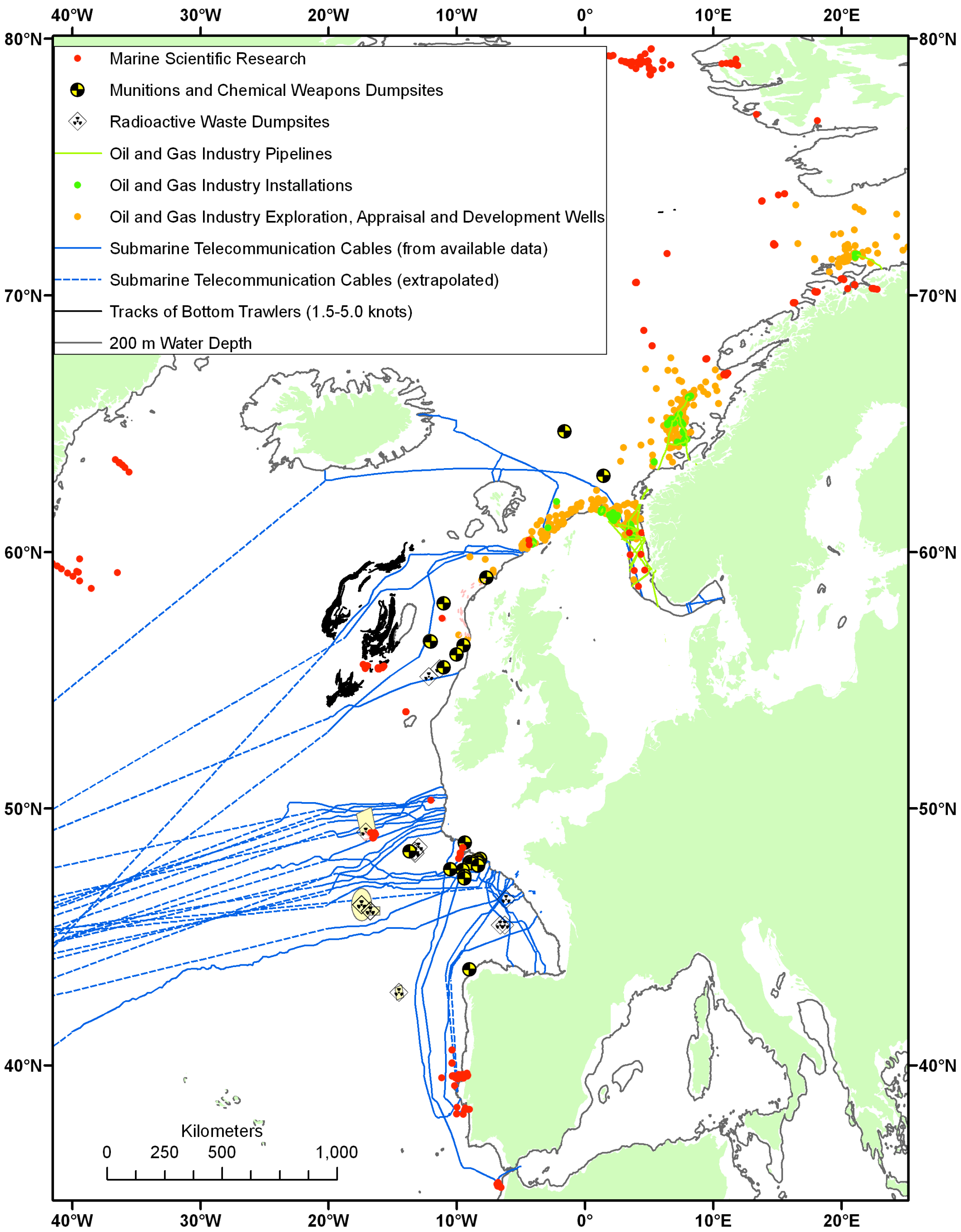

Figure 2.2 The spatial distribution of human activities on the seafloor, from available data, including structures and artefacts present on the seafloor resulting from past activities, within the OSPAR Maritime Area, > 200 metre water depth, during 2005.

2.3.2 Submarine communication cables

The data for this activity were from the two sources listed in Table 2.1. However, these data do not include all cables present on the seafloor. The complete dataset is only available commercially.

The results for the four scenarios considered for submarine communication cables (Table 2.4) demonstrate that this activity covers a relatively small spatial extent in all cases. The first scenario, giving an estimated 2 km^2, represents the spatial extent of the physical presence of submarine cables for the study area. The second scenario, giving an estimated area of 4 km^2, is independent of cable type and burial and uses a single value for cable width. The third scenario, giving an estimated area of 15 km^2 introduces the concept of plough burial and is based on the most conservative estimate of the width of the disturbance strip, 2 metres, reported in Carter et al., (2009). The fourth scenario, giving an estimated area of 61 km^2, is based on the maximum estimated width of disturbance strip of 8 metres (ibid.).

The values for scenarios 1 and 2, representing a calculated 41 per cent of all submarine communications cables, can be extrapolated to give an estimate of the total extent of this activity because they represent the physical presence of cables on or in the seabed (Table 2.5). The extrapolated values are 5 km^2 and 10 km^2 respectively. It is not appropriate to extrapolate scenarios 3 and 4 because plough burial was not introduced until the 1980s, all cables laid before that date were laid on the seabed surface.

The confidence rating of 1 and 2 denotes that while data relating to the location of submarine cables for areas to ~ 25º West were available there was no specific indication of the cable diameter or whether it was buried. There was no freely available information for areas beyond 25º West.

2.3.3 Waste disposal

Radioactive waste

Information relating to dumping sites for radioactive waste was obtained from a single source (NEA, 1985) (Table 2.1). While the total area designated for dumping of radioactive waste was estimated to be 26,323 km^2, based on the aggregated areas with overlapping boundaries dissolved for each of the four designated dumping sites (Table 2.6) this does not represent the area of seafloor covered by drums of waste. A second estimate of ~0.2 km^2 was calculated based on the tonnage, estimated number of drums (Table 2.6) and the area of each.

The confidence rating of 2 relating to the spatial extent of this activity denotes that while the location is reported[28] the spatial extent is based on an estimated number of drums and drum size.

Table 2.6 Radioactive waste dumpsites in water deeper than 200 m in the OSPAR region of the North East Atlantic between 1949 and 1984. Location of dumping area, quantities and sources of radioactive waste (based on NEA, 1985).

Longitude	Latitude	Year	Tonnes	Country of	Description of
-16.75	46.00	1977	5 605	NL-CH-UK	a rectangle 45.8333 to 46.1666 and -16.00 to -17.50
		1978	8 046	B-NL-CH-UK	
		1979	5 416	B-NL-CH-UK	
		1980	8 391	B-NL-CH-UK	
		1981	9 434	B-NL-CH-UK	
		1982	11 693	B-NL-CH-UK	
-17.42	46.25	1971	3 968	B-NL-CH-UK	a circle of radius 35 nautical miles centred on 46.25, -17.41666
		1972	4 131	B-NL-CH-UK	
		1973	4 350	B-NL-UK	
		1974	2 265	NL-CH-UK	
		1975	4 454	B-NL-CH-UK	
		1976	6 772	B-NL-CH-UK	
-13.25	48.25	1965	1 760	UK	not described
		1966	1 044	UK	
-13.27	48.33	1970	1 674	UK	not described
		1968	3 164	UK	
-13.00	48.50	1949	9	UK	not described
-11.33	55.43	1951	33	UK	not described
-12.17	55.13	1953	57	UK	not described
-6.17	46.45	1962	253	UK	not described
-6.27	45.45	1963	5 809	B-UK	not described
-6.60	45.45	1964	4 392	UK	not described
-14.50	42.83	1967	10 895	B-F-D-NL-UK	a square of side 50 km centred on 42.83333, -14.5
-17.08	49.08	1969	9 178	B-F-I-NL-S-CH-UK	a square of side 50 nautical miles centred on 48.5, -17.08333
		Total	112 793		

B = Belgium; CH = Switzerland; D = Germany; F = France; I = Italy; NL = Netherlands; S = Sweden; UK = United Kingdom.

[28] Although this activity has been assigned a confidence rating of 2, anecdotal evidence suggests that drums of radioactive waste were not always dumped within the areas designated for this activity.

Munitions and chemical weapons

Table 2.7 Location and known details of conventional and chemical munitions dumpsites in waters > 200 m in the OSPAR region (OSPAR, 2005).

Site number	Longitude	Latitude	Type of munitions	Details
42	-13.66	48.33	Conventional	Only remaining UK dumpsite by 1993
43	-9.02	43.73	Conventional	
45	1.46	62.97	Chemical	4,500 tons scuttled vessels
46	-7.67	59	Chemical	
49	-11	58	Chemical	
51	-12.08	56.52	Chemical	
52	-12	56.5	Chemical	
53	-9.45	56.37	Chemical	
54	-10	56	Chemical	
55	-11	55.5	Chemical	
56	-9.37	48.67	Chemical	Scuttled ship, Dora Oldendorf - Feb 1947.
57	-8.15	48.05	Chemical	Scuttled ship, Empire Nutfield - September 1946.
58	-8.35	48	Chemical	Scuttled ship, Lanark - November 1946.
59	-8.56	47.95	Chemical	Scuttled ship, Empire Peacock - August 1946.
60	-8.97	47.92	Chemical	Scuttled ship, Harm Freitzen - March 1948.
61	-8.26	47.92	Chemical	Scuttled ship, Empire Lark - July 1947.
62	-8.35	47.9	Chemical	Scuttled ship, Kindersley - October 1946.
63	-8.85	47.87	Chemical	Scuttled ship, Empire Connyngham - June 1949.
64	-8.31	47.79	Chemical	Scuttled ship, Thorpe Bay - September 1947.
65	-10.5	47.63	Chemical	CW (Approx 70 Tonnes) encased in concrete. Dumped in 1980.
66	-9.52	47.6	Chemical	Scuttled ship, Margo - November 1947.
67	-9.4	47.38	Chemical	Scuttled ship, Miervaldis - September 1948.
68	-9.4	47.28	Chemical	Scuttled ship, Empire Success - August 1948.
70	-1.6	64.7	Chemical - Tabun	462 shells recovered in Wolgast Harbour dumped, set in concrete.

Inadequate documentation at the time of dumping of chemical weapons and munitions and the subsequent loss or destruction of documentation means that the full extent of this activity is unknown (OSPAR, 2005). Accurate information on the quantities, present condition and current location of these materials is lacking (Thiel, 2003; OSPAR, 2005; 2009a). While the location and type of some conventional and chemical munitions are recorded (Table 2.7), other material is reported to have been dumped outside official dumping areas (Beddington and Kinloch, 2005). Furthermore, movement across the seabed, burial through natural processes and anthropogenic activity have complicated establishing the locations of dumped munitions (Beddington and Kinloch, 2005). The disposal of redundant munitions has continued intermittently (OSPAR, 2000). The most recent known event occurred during 1994 when Portugal, under Sovereign Immunity[29], scuttled a redundant vessel loaded with > 2,000 t of surplus munitions 346 km from the Portuguese coast at the edge of their EEZ in > 4,000 metres of water (OSPAR, 1995).

The total spatial extent for this activity was estimated to be 1.4 km^2.

While information relating to munitions dumpsites was available openly online (OSPAR, 2005) (Table 2.7), lack of knowledge about the precise initial and current locations and extent of dumped material is reflected in a low confidence rating of 1.

2.3.4 Oil and gas industry

The datasets and GIS shapefiles for this activity were downloaded free of charge in February 2008. However UKDEAL shapefiles are now available only on payment of a subscription (£360 for an individual subscription and £3,000 for a corporate subscription). Norwegian data remain available without charge.

The estimated spatial extent of oil and gas industry pipelines in water deeper than 200 metres was 4 km^2, while the footprint for structures on the seafloor (platforms, templates and wellheads) totalled 0.2 km^2. This figure is likely to be an underestimate as it includes only templates, wellheads and platforms. Other equipment and activities such as anchors and rock dumps were not included. The addition of the associated cuttings piles to the latter estimate resulted in a total estimated spatial extent of 3 km^2. The estimated spatial extent of exploration, development and appraisal wells drilled between 1960 and December 2005 together with the associated cuttings piles totalled approximately 15 km^2 while that for the single year, 2005, totalled 1 km^2. The total spatial extent of pipelines, structures and associated cuttings piles together with all exploration, appraisal and development wells drilled between 1960 and December 2005 and their associated cuttings piles in water deeper than 200 metres was 23.2 km^2.

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[29] Sovereign immunity provides that governments and government entities are generally immune from suit by private parties.

Oil and gas industry installations are complex. A wide variety of equipment is used each with its own type of disturbance (for example rock dumps and anchors). It has not been possible to evaluate these impacts in this study because data are not readily available. Confidence ratings of 2 and 3 reflect the variations in the quality of data. The UKDEAL dataset reported both location and diameter of pipelines resulting in a confidence rating of 3. Although diameters of Norwegian pipelines were not recorded in the NPD dataset, this information was available by searching for each pipeline individually in *NPD Facts* (NPD, 2005) also giving a confidence rating of 3. Neither dataset indicated the size of individual installations on the seafloor, although the location of each is reported, giving a confidence rating of 2. Similarly, the location of development, appraisal and exploration wells are reported but no indication of the extent of these activities was recorded. It was unclear what type of installation was being referred to in the NPD dataset without following a hyperlink for each individual facility. Although a description of the individual installations was given in the UKDEAL dataset (for example clump weight, pipe crossing, wellhead) no indication of dimensions was included.

2.3.5 Bottom trawling

As there was no definitive source identifying i) bottom trawling vessels, ii) where trawls started and ended and iii) the size of the gear deployed, the spatial extent of bottom trawling had to be estimated from analysis of VMS datasets. Willingness to provide VMS datasets varied between States. Only two States out of the nine to which requests for data were made provided VMS datasets.

Figure 2.3 shows the distribution of bottom trawling in the Hatton - Rockall area during 2005 based on analysis of the NEAFC VMS dataset. This comprises VMS data from Contracting Parties to NEAFC fishing in the NEAFC regulatory area.

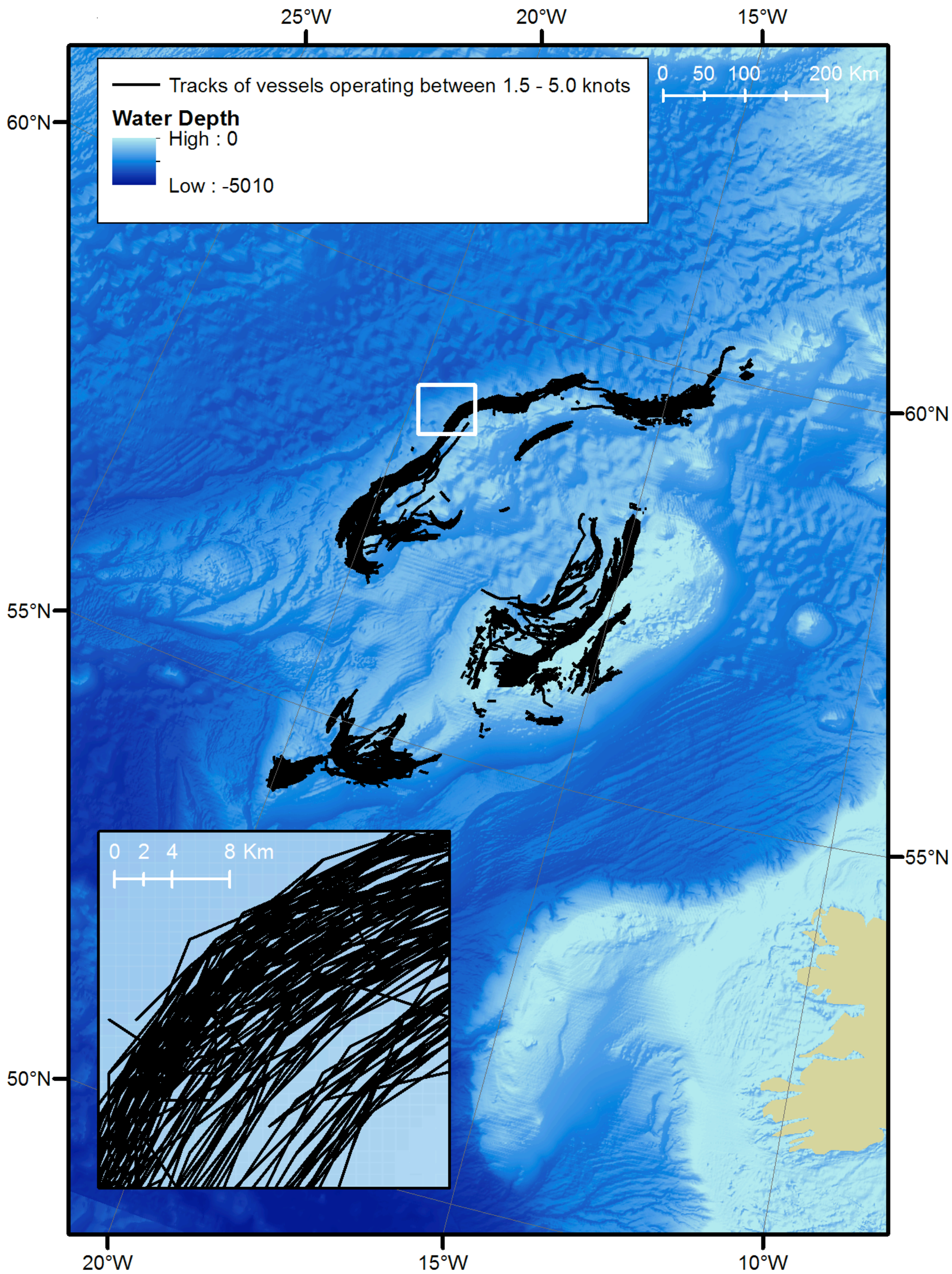

Figure 2.3 Bottom trawling. Tracks of vessels operating between 1.5 and 5.0 knots in the Hatton - Rockall area during 2005.

Table 2.8 shows the total area of seafloor trawled for each speed range, calculated by applying buffering to the vessel tracks of 22 metres (Hall-Spencer et al., 2002), 80 metres and 125 metres, the possible spreads of the trawl doors. The least possible area trawled, 741 km^2, relates to the narrowest speed range of 2.0-3.0 knots and gear width of 22 metres (Tables 2.4 and 2.8). The greatest possible area trawled, 37,160

km^2 relates to the widest speed range of 1.5-5.0 knots and gear width of 125 metres (Tables 2.4 and 2.8).

Table 2.8 Spatial extent of seafloor trawled on Hatton and Rockall Banks during 2005: overlapping tracks not merged or dissolved. Estimates based on 28 vessels engaged in bottom trawling, identified from speed profiles and pattern of activity. All overlapping tracks included in estimate.

Speeds (knots)	Area trawled based on *125 m gear width (km^2)	Area trawled based on *80 m gear width (km^2)	Area trawled based on **22 m gear width (km^2)
[1]3.0-5.0	21346	13631	3738
[1]1.5-4.5	27487	17619	4855
[2]2.0 – 3.0	4255	2711	741
[3]1.5 – 5.0	37160	23855	6585

* R. Ferro, Fisheries Research Services, Aberdeen, personal communication

** Hall-Spencer et al., 2002

[1] Davies et al., 2007

[2] ICES, 2007

[3] 1.5-5.0 knots encompasses the range of bottom trawling speeds referred to by Davies et al. (2007) and ICES (2007)

Table 2.9 shows the spatial extent of bottom trawling when overlapping tracks were merged. Even if multiple trawls pass over a section of seafloor during the year only a single area is calculated. The least possible area trawled, 548 km^2, relates to the narrowest speed range of 2.0-3.0 knots and gear width of 22 metres (Tables 2.4 and 2.9). The greatest possible area trawled, 13,920 km^2 relates to the widest speed range of 1.5-5.0 knots and gear width of 125 metres (Tables 2.4 and 2.9).

Table 2.9 Spatial extent of seafloor trawled on Hatton and Rockall Banks during 2005: overlapping tracks merged. Estimates based on 28 vessels engaged in bottom trawling, identified from speed profiles and pattern of activity. Overlapping tracks merged to give single area.

Speeds (knots)	Area trawled based on *125 m gear width (km^2)	Area trawled based on *80 m gear width (km^2)	Area trawled based on **22 m gear width (km^2)
[1]3.0 - 5.0	8051	6067	2227
[1]1.5 - 4.5	12041	8983	3192
[2]2.0 - 3.0	2710	1837	548
[3]1.5 - 5.0	13920	10624	3994

* R. Ferro, Fisheries Research Services, Aberdeen, personal communication

** Hall-Spencer et al., 2002

[1] Davies et al., 2007

[2] ICES, 2007

[3] 1.5-5.0 knots encompasses the range of bottom trawling speeds referred to by Davies et al. (2007) and ICES (2007)

The spatial extent of bottom trawling during 2005 in the Hatton - Rockall area is greater than that of any other activity in the OSPAR region. The most conservative estimate of 548 km^2 is one order of magnitude greater than the largest estimate for impacts by the oil and gas industry, while the estimate of 13,920 km^2, based on the widest gear (125 metres) and widest speed range (1.5-5.0 knots) with overlapping tracks merged is three orders of magnitude greater. The spatial extent for the two scenarios above without merging overlapping tracks is 741 km^2 and 37,160 km^2 respectively. This suggests that trawlers trawled the same area of seafloor more than once during the year.

Calculations for the spatial extent of bottom trawling were based on data from only one part of the OSPAR area, Hatton – Rockall. Extrapolations have been made based on the estimate that the Hatton - Rockall area comprises ~ 50 per cent of the deep sea trawling grounds in the OSPAR area (Table 2.5). The estimate for the most conservative speed range and gear width (2.0-3.0 knots, 22 metre) with overlapping tracks not merged is an extrapolated value of 1,482 km^2. The widest speed range and gear width (1.5-5.0 knots, 125 metre) with overlapping tracks not merged gives an extrapolated value of 74,320 km^2.

The extrapolated estimate for the most conservative speed range and gear width (2.0-3.0 knots, 22 m) with overlapping tracks merged is an extrapolated value of 1,096 km^2. The widest speed range and gear width (1.5-5.0 knots, 125 metre) with overlapping tracks merged gives an extrapolated value of 27,840 km^2.

The confidence rating of 1-2 (Table 2.4) reflects that while VMS data indicate the position of vessels and fishing can be inferred from speed and course, neither the location nor extent of the bottom impact i.e. actual trawling were reported.

2.4 Discussion

The results in Tables 2.4 and 2.5 are a first attempt to quantify the physical extent of human activities in the deep North East Atlantic together with an evaluation of confidence in the data. It is not practicable to present one definitive, unequivocal value for each activity as each encompasses a range of alternatives. Variables include the size of fishing gear, speed ranges within which vessels can operate, width of submarine cables, buried or non-buried cables, the size of individual oil and gas industry installations and extent of cuttings piles. Nevertheless, the figures presented represent the best estimates available and the estimates provided are based, where applicable, on both high and low extremes for example for the fishing data.

Although the principal scope of this study is to establish the physical spatial extent of each activity it is worth noting that while some activities have an immediate impact, after which seafloor communities may be re-established (albeit on perhaps long timescales) (Bluhm, 2001; Althaus et al., 2009). Other activities, such as waste disposal, may have an effect for many years and the impact is likely to extend far beyond the physical disturbance (Charmasson, 1998).

This study has highlighted how complex it is to determine the physical spatial extent of human activities in the deep sea from existing data and how difficult it is to establish a comprehensive baseline for management. To assess the extent of chemical and biological impacts, for example the effects of drilling muds from the hydrocarbon industry or the effects of micro-plastics on the deep-sea benthos presents even greater difficulties. Cumulative and interactive impacts of human activities may have direct or indirect effects on ecosystem components making detection and assessment more complex than simple cause and effect mechanisms (Halpern et al., 2007b). The interaction of activities with natural temporal or spatial variability in environmental conditions makes impacts even more difficult to identify (ibid.).

As knowledge of the deep-sea has expanded the impacts of some human activities on deep-sea ecosystems have been taken into account and monitoring has been put in place, at least partially, leading to management and conservation actions (Ramirez-Llodra et al., 2010). Examples include establishing areas closed to fishing such as the Darwin Mounds (Hall-Spencer et al., 2002; De Santo and Jones, 2007) and 'move-on rules' to protect vulnerable marine ecosystems from destructive fishing practices (UNGA, 2007b)[30]. However, the impacts on deep-sea habitats of other direct and indirect human activities such as litter accumulation, chemical pollution and climate change remain unknown. A major limitation to the development of robust conservation and management options is the relatively small amount of information available on deep-sea habitat distribution, faunal composition, biodiversity and ecosystem functioning (van den Hove and Moreau, 2007). High uncertainty and the lack of knowledge about the deep-sea environment make impact assessments essential prior to the commencement of human activities and once activities have started, there is a continuing need for monitoring (ibid.). This may require the adaptation of existing methodologies or the development and testing of new techniques suitable for the deep-sea conditions and environment (ibid.). Appropriate timescales for monitoring will have to be determined and adopted.

The results of this study demonstrate that the extent of human activities on the deep-sea floor in the OSPAR area of the North East Atlantic varies widely. Of the activities assessed, dumping of waste was found to have the lowest spatial extent. The combined total of radioactive waste, munitions and chemical weapons dumpsites was found to be 1.6 km^2. The strategy of sea disposal of low level radioactive waste was one of dispersal and dilution rather than containment (Calmet, 1989). The lifetime of the iron drums containing the waste was estimated to be between 15-150 years while bitumen or concrete blocks encasing waste were estimated to last 1,000 years (NEA, 1985). So, although the dumping has ceased, such material will still leak from containers into the environment (NEA, 1985). The main source of artificial radionuclides in the deep North East Atlantic is from atomic weapons testing carried out during 1960s. However, $^{233}Pu/^{239+240}Pu$ isotopic ratios in some samples of the fish *Coryphaenoides armatus* suggest an influence from the dumped material (Charmasson, 1998). Similarly, while the spatial extent of munitions and chemical weapons dumpsites, estimated to be 1.4 km^2, is a relatively small area, the presence of this material poses a significant risk, particularly when disturbed (OSPAR, 2005). As the reach of human activities is now extending into deeper waters this risk is not likely to diminish.

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[30] The current effectiveness of the 'move-on rule' in the NEAFC Regulatory Area is disputed by (Rogers and Gianni, 2010)

Non-fisheries marine scientific research has a relatively small footprint. It is usually carried out by academic institutions using a range of equipment on the seafloor to sample the marine environment including moorings, grabs, corers, dredges and trawls. Much of this equipment has only a single impact of a few square metres. Considerably more research is carried out by academic institutions or fisheries research laboratories to determine fish population size and distribution. The spatial extent of fisheries marine scientific research is moderate. Because fisheries research also involves the deployment of sampling equipment, such as grabs and moorings, it involves a higher proportion of bottom impact trawling.

The spatial extent of telecommunication cables is low to moderate depending on whether cable burial is included in the calculation. The maximum extent of this activity (61 km^2), based on an 8 metre wide disturbance strip in water depths between 200 – 1,500 metres is likely to be an overestimate. This is because about 20 per cent of cables in 200 – 1,500 metres water depth are not buried and an 8 metre wide disturbance strip may be an overestimate in many cases.

The spatial extent of oil and gas industry activities is moderate. While structures such as templates, wellheads, platforms and cuttings piles have been included in the estimates it is likely that this is an underestimate as other equipment and activities, for example, weights, anchors, rock dumps are not included.

A major finding of this study is that the spatial extent of bottom trawling is orders of magnitude greater than that for the other activities assessed. Despite the spatial extent of this activity, it is interesting to note that the total global catch from high seas bottom fisheries (longliners, gillnetters and bottom trawlers) of 252,000 tonnes contributed only 0.31 per cent to the total marine capture during 2006 (Bensch et al., 2008). In the NEAFC regulatory area of the North East Atlantic the total high seas bottom catch during 2005 was 80,617 tonnes (ibid*.)* out of the total catch for the year of 3,595,223 tonnes for all 77 species listed in the NEAFC Catch Information 2005[31], representing approximately two per cent. These figures are an underestimate of the actual total tonnage as they do not include by-catch or illegal, unregulated and unreported (IUU) fishing. Gianni (2004) estimates that the overall value of high seas bottom trawl fisheries is not likely to exceed US $300-400 million annually at first sale, approximately 0.5 per cent of the estimated value of the global marine fish catch in 2001. Furthermore, high seas bottom-trawl fisheries do not support tens of millions of jobs and the fish caught do not contribute to global food security but are destined for

[31] NEAFC catch information: http://www.neafc.org/system/files/%252Fhome/neafc/drupal2_files/final-catch-2005.pdf

high value markets (Gianni, 2004).The limited contribution of deep-water bottom trawl fisheries to total global fisheries' production and employment is in stark contrast to the results of this study which show that, even on the lowest possible estimates, the spatial extent of bottom trawling in the North East Atlantic is an order of magnitude greater than the sum of all the other activities.

The maximum total area impacted by the various activities discussed here is 27,932 km^2 (Table 2.5, based on the merged trawler tracks and 50 mm cable diameter data). This is a very small percentage of the total OSPAR area (11,032,175 km^2), but such a calculation does not provide useful information. An analogy would be the area of annual destruction of Amazon rainforest as a percentage of the landmass of South America, which would mean far less than destruction as a percentage of the total area of the rainforest. Human activities are concentrated in certain areas and particularly in shallower depths. The OSPAR area also comprises many different habitats each with different and diverse ecosystems. The percentage impact in each of these habitats would provide important information but unfortunately there is virtually no detailed seabed and habitat mapping in the deep sea to provide this information.

This study has demonstrated the relative physical extent of the six activities. Non-fisheries scientific research, submarine communication cables and waste disposal were found to have the lowest spatial extents while oil and gas activities and fisheries scientific research have moderate extents. However, the spatial extent of bottom trawling is at least an order of magnitude greater than all the other activities combined.

This study has also shown that the quality and availability of data on human activities in 2005 were inadequate to meet the requirements of an ecosystem approach to deep-sea governance and management. Reporting regimes varied, some data were withheld and, for some activities, basic information had to be extracted by extensive processing. These limitations are discussed further in chapters 4 and 5.

3 Human Activities Data for the North West Atlantic: Availability, Access and Comparison with North East Atlantic Data

3.1 Introduction

The original aim of this chapter was to map the location and estimate the extent of human activities on the seafloor in the North West Atlantic. It was also anticipated that examples of 'good practice' in data access and availability would be identified. However, because of problems identifying data sources, access to and availability of human activities data the focus of this chapter has changed. It now seeks to establish whether the limitations in data availability, access and quality encountered during the study of human activities in the North East Atlantic (Chapter 2) are also applicable to data for the same activities in the North West Atlantic. This chapter describes this study, identifies, where possible, data sources and concludes by discussing the limitations of both North East and North West Atlantic human activities data.

'Where?' and 'How much?' are two of the basic questions to ask about an activity. Knowledge of the location and extent of human activities is fundamental to understanding their impacts – both individual and cumulative. Data on human activities are currently collected and held by public institutions and private companies to fulfill regulatory requirements, for commercial and operational purposes and for scientific research. Data are seldom collected for the purpose of ecosystem-based management (Lester et al., 2010) and the organizations holding data are often disparate.

The work carried out to estimate the relative spatial extent of human activities in the deep North East Atlantic (Chapter 2) exposed limitations regarding the supply, access to, unwillingness to share, arrangement and content of data. The problems exposed included identifying reliable data sources, a lack of compatibility between datasets, charges for access to data, partial coverage of datasets, fragmentation of data relating to the same activity between different data sources, lack of detail and commercial confidentiality. Other studies requiring access to data on human activities in the North East Atlantic and European seas have also reported problems of access to data and limitations in the quality of the data available (Lumb et al., 2004; Eastwood et al., 2007; Gerritsen and Lordan, 2010).

How is it that such problems have occurred?

In the past, policies have been determined industry by industry and State by State. Governance objectives were sectoral. However, ecosystems are not constrained by national and administrative boundaries. The natural boundaries of marine ecosystems can be subtle and are defined, for example, by temperature, currents, depth, stratification and salinity and over a range of scales from ocean to regional to estuarine (Laffoley et al., 2004).

Governance objectives now also include the health of ecosystems. Marine ecosystems provide a wide range of goods and services of benefit to mankind (Costanza et al., 1997; Armstrong et al., 2010; Foley et al., 2010). However, the provision of such goods and services by ecosystems depends on their continuing health. Human activities are now known to disrupt energy flows (Choi et al., 2004), alter biological communities (Hinz et al., 2009) and reduce biodiversity (Worm et al., 2006). The health of ecosystems and their ability to supply goods and services is undermined. Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, is a core goal of the ecosystem approach (UNEP, 2000).

In order to achieve ecosystem-based management, an infrastructure and mechanisms able to support multiple sources of diverse information and data on human activities is essential. Halpern et al., (2008) suggest that "the management and conservation of the world's oceans require synthesis of spatial data on the distribution and intensity of human activities and the overlap of their impacts on marine ecosystems". Application of the ecosystem approach requires "management actions at multiple scales, and inter-sectoral cooperation" (Douvere, 2008). The need for mechanisms that allow for multiple sources of information to inform policy and management decisions is evident. In 2006 the UN Secretary General, recognized that "Appropriate mechanisms for horizontal integration among different levels of Government and vertical integration among agencies with different mandates are essential for the application of an ecosystem approach" (UNGA, 2006a).

The consequence of previous governance and management decisions has been that the data required for operational purposes has mainly focused on, for example, catch reports and licence blocks. However, this has not included data on the spatial and temporal distribution of human activities which are fundamental for ecosystem-based governance and management (Eastwood et al., 2007; Halpern et al., 2008; Lester et al., 2010).

In summary it can be said that conservation of marine ecosystems and sustainable human use of marine resources requires an integrated approach to management based on knowledge of the spatial and temporal distribution of multiple human activities in a specific area together with the spatial distribution of important ecosystems, the intensity and location of impacts as well as the responses of the human and non-human components to the combined effects of these impacts (Eastwood et al., 2007; Foden et al., 2010; Lester et al., 2010).

Currently a variety of marine information is gathered for different purposes. This includes oceanographic (physics, biology, chemistry, mapping), governmental (jurisdictions and administrative areas) and industrial (licensed areas, usage and resources). This is held by intergovernmental organisations, governments, regional administrations, industries, scientific databases and academic institutions. Broadly there are two kinds of data, metadata and the data themselves.

The following section describes the scoping study to assess availability and access to human activities data for the North West Atlantic.

3.2 Methods

3.2.1 North West Atlantic scoping study

The area selected for the North West Atlantic study lies between 25º North and 61º North and extends from the 200 m depth contour, the shelf break, on the eastern coast of USA and Canada to 42º West, the western boundary of the OSPAR Maritime Area. It encompasses both United States and Canadian waters as well as waters beyond their EEZs (Figure 3.1).

To avoid over complicating the study, data availability was assessed only within the jurisdictions of Canada, the USA and in areas beyond national jurisdiction. Two areas (St. Pierre and Miquelon and Bermuda) which lie inside the study area are within the sovereignty of France and the UK respectively and a small section in the south of the study area lies within the sovereignty of the Bahamas. These were not included in the study.

The study focused on the five activities researched in the earlier work for the North East Atlantic: marine scientific research, submarine telecommunication cables, the historical dumping of waste (radioactive waste and chemical weapons and munitions), oil and gas industry and bottom trawl fisheries. The year selected for this study was 2008. Like 2005 - the year selected for the study in the North East Atlantic, this was two years prior to the date of the study to allow for data to have been processed.

Basic data necessary to estimate the spatial extent of human activities are the location of the activity as well as the area of seafloor covered by its physical footprint, for example the diameter of pipelines or the width of fishing gear. Temporal information is required to identify trends. Consequential impacts such as sediment plumes and chemical effects were not included within the scope of this study (see Chapter 2).

No central source of information was apparent. After making a search of the literature and extensive internet research to determine what might be the appropriate agencies, requests for data were sent by email to government departments, regional administrations and organisations in the USA and Canada. An email request for satellite based vessel monitoring (VMS) data was also made to the Northwest Atlantic Fisheries Organisation (NAFO).

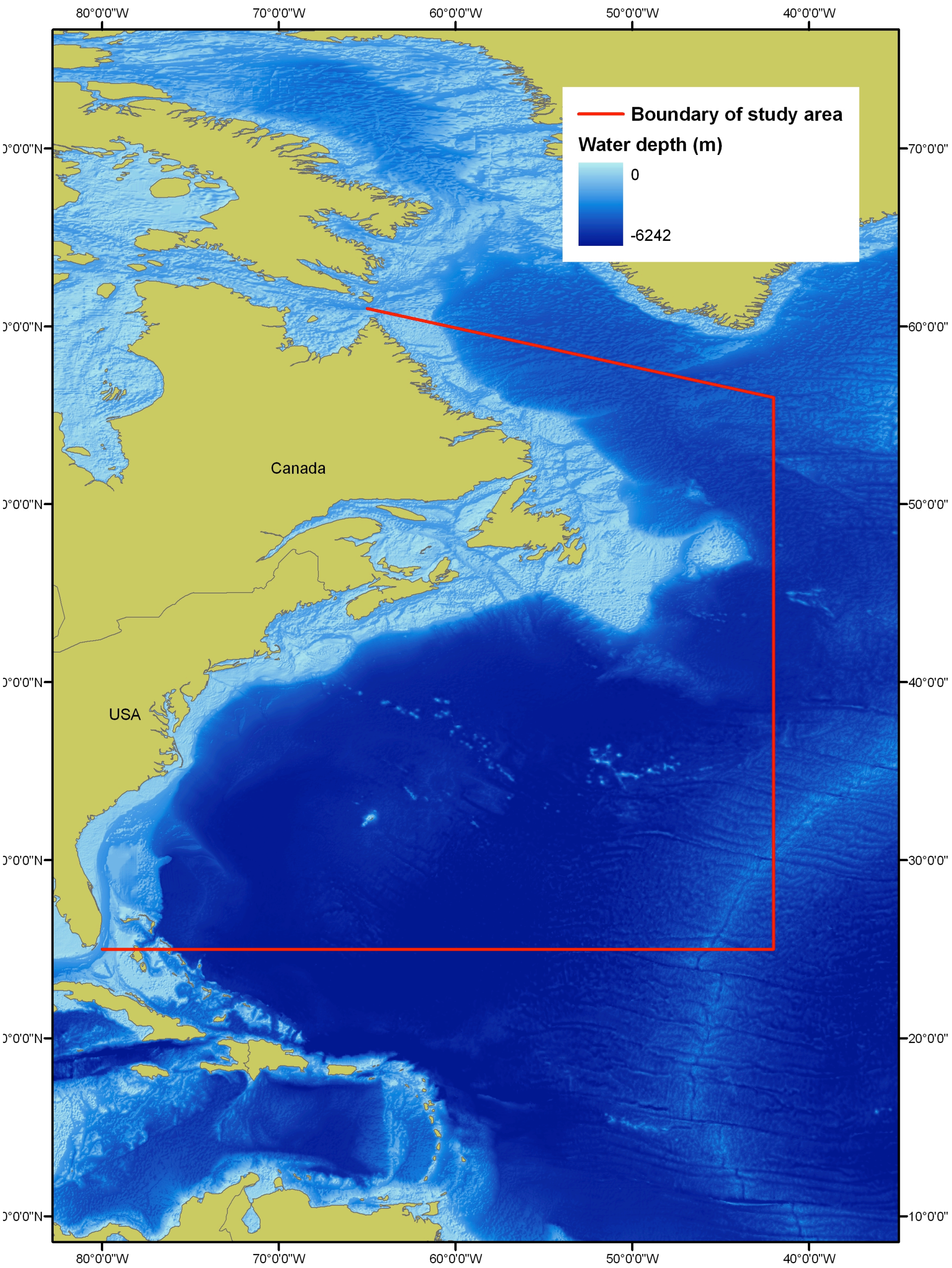

Figure 3.1 The study area in the North West Atlantic

3.3 Results

Neither the governance structures for the North West Atlantic nor the infrastructure mechanisms appear to be arranged in such a way as to provide an overarching view to support the implementation of the ecosystem-based approach. Canadian and US data-sources on human activities in the North West Atlantic were found to be fragmented. There is no one single source for such data in either country, or metadata to indicate where such data were held. It was not straightforward to determine which organizations might be responsible for data, where these data were held and by whom. A request was made to the Canadian Hydrographic Service (CHS) for suitable sources of data. CHS identified a number of possible sources and these are amongst those detailed in the following sections. Several different sources were approached in the USA.

In both countries, data appear to be held on a sector by sector basis and some by individual states. Each activity is now considered in turn.

3.3.1 Marine scientific research

A number of databases hold information on research cruises. These include the Pan European Infrastructure for Ocean and Marine Data Management website SeaDataNet Cruise Summary Report Inventory (CSR)[32], the Partnership for Observation of the Global Oceans (POGO) website[33], Ocean-going research vessels International Cruise Summary Report, the British Oceanographic Data Centre (BODC)[34] and the ICES online ROSCOP database (Report of Observations/Samples collected by Oceanographic Programmes)[35]. All of these databases contain information on cruises in the North West Atlantic. The Woods Hole Oceanographic Institute (WHOI)[36] and the University-National Oceanographic Laboratory System (UNOLS)[37] databases hold only US research vessel cruise data. The National Oceanic and Atmospheric Administration (NOAA) Marine Operations website[38] carries a list of US research vessels. However, no cruise details or station lists were publicly available. The University of Delaware, Research Ship Schedules and Information webpage[39] contains details of 196 research vessels from around the world, but again this site can only be searched vessel by vessel and no cruise reports or station lists were available.

To maintain consistency throughout searches, only the search terms '1 January 2008 to 31st December 2008' and 'North West Atlantic' were used. Searches were broad to achieve maximum coverage of the possible data and not restricted by discipline, data type, vessel, institute or country of origin. However, neither the WHOI nor the UNOLS databases could be searched using these search terms. The UNOLS database was searched vessel by vessel. The WHOI database contained primarily data from 1931-

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[32] SeaDataNet: http://seadata.bsh.de/csr/retrieve/V1_index.html

[33] POGO: http://www.pogo-oceancruises.org/

[34] BODC: https://www.bodc.ac.uk/data/information_and_inventories/cruise_inventory/search/

[35] ROSCOP: http://www.ices.dk/Ocean/roscop/index.asp).

[36] WHOI: http://dlaweb.whoi.edu/DIG_RES/cruises.html

[37] UNOLS: http://www.unols.org/info/vessels.htm

[38] NOAA Marine Operations: http://www.moc.noaa.gov/

[39] University of Delaware, Research Ships: http://www.researchvessels.org/

1998. Only three vessels with cruises occurring later than this date were listed. These cruises were also listed, in greater detail, on the UNOLS database.

The search of SeaDataNet CSR produced seven cruises which took place in the North West Atlantic during 2008. However none fell within the study area. The results of the same search on the POGO site listed three cruises. Again, none fell within the area of the study. These cruises were also included in the SeaDataNet website. The search of the BODC cruise inventory data identified three cruises in the North West Atlantic during 2008 – none of which appeared in the previous searches. A search on the ROSCOP database, using the same search terms, produced a further three cruises which were not identified by searches on the other databases but which fell within the study area. The UNOLS database contained a list of 206 cruises carried out by ten vessels during 2008 which took place wholly or partially within the North West Atlantic. However, the information available on this database was not of sufficient detail to identify the precise location of the cruises nor the activities carried out. Two of these cruises were also included in the BODC database.

It was not clear how many cruises took place within the study area during 2008. Despite some of the cruises listed not falling within the area of the study, each database was inspected to see what information was available. This varied from i) reporting of the type of measurement, description of equipment, position, depth and date either on the website or in a cruise report linked to the site, to ii) a brief description of the cruise (project, chief scientist, cruise dates, area of cruise, institute, ship and objectives). The former would be suitable for mapping and the footprint could be estimated using the generic method detailed in Chapter 2. However the latter would require contacting the individual institutions or scientists for more complete data.

To map and estimate the spatial extent of marine scientific research on the seafloor in the study area during 2008 would require considerable resources. While the mapping of activities reported in station lists would be relatively straightforward, tracking down cruise reports and station lists from individual institutions was found to be very time consuming and, when carrying out this work for the North East Atlantic, was sometimes found to be unproductive.

3.3.2 Submarine communication cables

The department of Fisheries and Oceans Canada (DFO) hosts the Atlantic Submarine Cable and Pipeline viewer[40]. This site, created by the Canadian Hydrographic Service and International Telecom, was still under construction in 2010. It displays, in a searchable map format, cables and some pipelines in the North West Atlantic (covering US and Canadian waters as well as beyond the EEZs). The site provides a link to an ftp server[41] where submarine cable and pipeline coordinates are available to download in the form of a table. While the data would need to be re-formatted, this site could be used as a source of data for mapping.

A request for USA data was made to the North American Submarine Cable Association (NASCA) enquiring whether cable-awareness websites exist for the study area similar to those for UK and French cables in the North East Atlantic. Those sites allow cable routes to be downloaded either as ESRI shapefiles or MS Excel tables, which can be imported into ArcGIS for mapping. NASCA provided a CD of Mid-Atlantic Cable Charts (*Catch Fish not Cables*) and a downloadable data-viewer for use by fishermen to prevent cable damage. These are versions of paper-based charts and while they could be used to estimate the spatial extent of submarine cables in waters up to ~2,000 m depth, coverage does not extend into deeper waters. Extensive work would be required to convert the charts into a suitable digital format for mapping in ArcGIS.

3.3.3 Waste disposal

Radioactive waste

Data for radioactive waste dumpsites were sourced in the International Atomic Energy Agency report, *Inventory of radioactive waste disposals at sea*, Annex A.13 (IAEA, 1999). These data can be entered manually into an MS Excel spreadsheet from which they can be imported into ArcGIS for mapping. The coordinates of each dumpsite are reported from which the location can be mapped. The extent of each site is not recorded. However, as the number of containers of waste dumped at each site is reported, the method used to calculate the extent of the dumpsites in the North East Atlantic (Chapter 2) can be applied here, based on an estimated footprint area 1 metre x 1 metre (NEA, 1985) for each container.

Munitions and chemical weapons

Data relating to the location and extent of munitions and chemical weapons dumpsites was difficult to find as there appear to be very few sources. A Report to US Congress of past disposal of chemical weapons between World War II and 1970 lists approximate

[40] DFO Cable and Pipeline viewer: http://bluefin.mar.dfo-mpo.gc.ca/imf-ows/imf.jsp?site=cables

[41] Link to ftp server: ftp://starfish.mar.dfo-mpo.gc.ca/pub/chs/cables/coordinates.txt

disposal areas, for example “Atlantic Ocean, off Charleston, South Carolina” (Bearden, 2006), as does an article in *The Bulletin of the Atomic Scientists* (Schollmeyer, 2006). A more detailed list, containing coordinates, descriptions and tonnages of dumping sites was identified in a report by Mitretek Systems (now Noblis) (MitretekSystems, 2006). However, the coordinates for some sites are not known. Whilst an MS Excel table of the extant data could be produced manually and imported into ArcGIS for mapping, the data are insufficient for estimating the spatial extent of each dumpsite because the disposal method is not reported.

3.3.4 Oil and gas

Data on oil and gas activities were very fragmented and suitable data sources were difficult to identify. Unlike the UK and Norwegian sectors there appears to be no publicly available downloadable GIS shapefiles or MS Excel sheets containing the locations of wells, pipelines and other subsurface installations off the eastern coasts of the USA and Canada.

Natural Resources Canada is the government department responsible for oil and gas activities. The areas of activity are off Nova Scotia, Newfoundland and Labrador and are regulated by the Canada-Nova Scotia Offshore Petroleum Board and the Canada-Newfoundland and Labrador Offshore Petroleum Board. An interactive map showing location of wells is available on the Natural Resources Canada website[42], although the locations of pipelines and other installations are not shown. Areas on the map can be selected and a table generated containing details of the selected wells. This can be copied and pasted into MS Excel from where it can be imported into ArcGIS for mapping. The spatial extent of these wells could be estimated based on the methodology used in Chapter 2.

In the USA the National Energy Information Administration (EIA), in response to a request for information on the sources of data relating to offshore US oil and gas activities, replied that it was a “neutral agency” and, as such, did not hold data. A further request to the Department of Energy was unsuccessful as the inquiry did “not fall within the purview of the Department”. The reply suggested the Department of the Interior as a possible source of information. A subsequent email to the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) (a bureau within the Department of the Interior) requesting data, has received no reply. However, although predominantly dealing with the Gulf of Mexico, within the BOEMRE website[43] an MS Excel sheet containing a list of 51 wells completed between 1976 and 1984, of

[42] Natural Resources Canada: http://gdr.ess.nrcan.gc.ca/basin/e/viewer.htm

[43] BOEMRE: http://www.gomr.boemre.gov/homepg/offshore/atlocs/atlocs.html

which 43 are in water deeper than 200 metres, in the North West Atlantic could be used as a basis for mapping locations. An estimate of the footprint could then be calculated using the algorithms developed in the study of the North East Atlantic (Chapter 2). It is not clear whether this list is exhaustive. Sources of suitable data for pipelines and other seafloor installations were not identified.

3.3.5 Bottom trawling

Data relating to fisheries in the North West Atlantic are held by several agencies. DFO has responsibility for Canadian Fisheries. On the east coast this is divided into four administrative regions: Quebec, Maritimes, Gulf and Newfoundland / Labrador. In the USA the responsibility for fisheries falls to the NOAA Fisheries Service, an agency of the U.S. Department of Commerce. Fisheries on the east coast of the USA are divided into two regions – the Northeast and Southeast. NAFO is responsible for the management and conservation of fishery resources in the area beyond the EEZs.

To estimate the spatial extent of bottom trawling in the study area it would be necessary to access VMS data to identify where bottom trawls were carried out during the year. In the study of the North East Atlantic individual trawls were identified from extensive and time-consuming analysis of VMS data based on the relationship between seafloor contours and vessel speed. The footprint of the activity was then estimated based on a range of possible gear sizes.

To research the area beyond national jurisdiction, a request to NAFO for 2008 VMS data produced the response that although the data for 2008 exist, the NAFO Secretariat simply houses the data and is not entitled to disseminate it to the public. It is only available to NAFO Scientific Council in summary form and specifically to answer requests made by the Fisheries Commission (NCEM, 2010 Article 26.8)[44]. The twelve individual NAFO contracting parties have ownership of their own data and would have to be contacted individually.

A preliminary request was made to NOAA for US VMS data and, based on the advice received, a Freedom of Information (FOI) request was then submitted to NOAA Fisheries Service. The FOI request was however declined by NOAA, citing that VMS data fall within an exemption under the Magnuson-Stevens Fishery Conservation and Management Act. Data in an ‘aggregated format’ were available but as these data simply indicate the number of vessels in a 10 degree square during a given time period they are not suitable for estimating the location or spatial extent of bottom trawling. Researching Canadian fisheries, an initial request was made to the DFO

[44] NCEM: http://nafo.int/fisheries/frames/regs-cem.html

specifically for VMS data but received no reply. A further, more general request made to DFO Canada for information on all the activities in the study included a request for access to Canadian VMS data. This general request was forwarded to the CHS. The CHS searched for VMS data but were unable to find a source and suggested that NAFO may be able to supply the data.

Fisheries data that were available for both Canada and USA focused either on individual species or fishing intensity. No VMS datasets were available. NAFO does not have authority to share the VMS data from its Regulatory Area, the USA turned down the FOI request for VMS data and no VMS data were available from Canada. Based on these findings neither the accessibility of data nor its quality would allow estimates to be made of the spatial extent of bottom trawling in the North West Atlantic in 2008 nor to establish a temporal baseline from which to identify trends.

3.3.6 In summary:

- The available information about human activities in the deep North West Atlantic from USA and Canadian sources was mainly administrative, focusing on regulatory and licensing areas or was oceanographic data.

- Data that were available were collected primarily for commercial and operational purposes and for scientific research. Such data were not gathered for the purpose of ecosystem-based management

- Data on human activities, where they exist, are collected and held disparately by multiple public and private institutions and organisations (Table 3.1).

- Basic data indicating the spatial and/or temporal distribution of activities was rare. Even where available, for example, submarine cables and oil wells, the data would require further work to clean and format.

- As shown in Table 3.1, there was no single point of contact within either the USA or Canada through which to access data on human activities and neither the USA nor Canada hold a metadata set identifying sources of such data.

- Some government departments and organizations were not aware of the location of datasets or of the procedures required to access them, nor where to direct requests.

Table 3.1 Summary table showing organisations and institutions from which data were sought and search results.

Activity	Organisations/Institutions from which data sought*	Data
Scientific research	SeaDataNet	No cruises listed within study area.
	POGO	No cruises listed within study area.
	BODC	3 cruises listed within study area. 2 cruise reports contained sufficient detail to map.
	ROSCOP	3 cruises listed in study area. Insufficient detail to map.
	WHOI	No cruises listed within study area
	UNOLS	206 cruises listed in 2008 either wholly or partially within NW Atlantic. Insufficient detail to map.
	NOAA, Marine Operations	List of vessels but no cruise details.
	University of Delaware, Research Ships	Details of research vessels but no cruise reports or station lists.
Submarine telecommunication cables	DFO	Atlantic Submarine Cable and Pipeline Viewer. Data could be manually exported to ArcGIS for mapping.
	NASCA	Catch Fish not Cables data-viewer. Not suitable for mapping.
Waste disposal: Radioactive waste	*Inventory of radioactive waste disposals at sea.* Annex 13 (IAEA, 1999)	Table of dumpsites locations in published report. Data could be manually exported to ArcGIS for mapping.
Munitions/chemical weapons	Bearden, 2006; Schollmeyer, 2006	List approximate location of some but not all disposal areas. Insufficient detail to map.
	Mitretek Systems, 2006	List of locations and tonnages for some but not all sites.
Oil and gas	Canada Natural Resources website	Table giving location of wells can be generated and exported to ArcGIS.
	BOEMRE	MS Excel sheet giving location of wells. Could be exported to ArcGIS for mapping.
Bottom trawling	NAFO NOAA DFO CHS	No VMS data available.

*See text and footnotes for full titles of organisations and institutions.

- There was no evidence of cross-border coordination in either data-gathering or data-sharing. There appears to be no mechanism in place for exchange, sharing, access and use of interoperable spatial data within either the United States or Canada - or trans-boundary.

- Where information was available it was gathered by a variety of agencies (Table 3.1). Organizations holding data were diverse and included industry organizations, publicly accessible databases, government departments (both regional and national) and a regional fisheries management organization.

- Legal barriers and commercial confidentiality prevented open access to some data.

3.4 Discussion

Other studies requiring data on human activities in the North West Atlantic have identified problems of access to or limitations in the quality of the data available (Horsman and Breeze, 2006; Lester et al., 2010). The findings of an NOAA workshop on mapping human activities in the marine environment also reported that lack of data on some activities presented a challenge (NOAA/DOI, 2005). The current study finds that there are issues with data content, availability and infrastructure. This would inhibit the effective implementation of ecosystem-based governance and management.

3.4.1 Governance and management

The complexity of governance structures in both Canada and the USA is evident.
In Canada 27 federal departments and agencies are responsible for managing marine-related activities, incorporating 25 principal pieces of federal legislation and an additional 35 pieces of related federal legislation. Eight of the ten provinces and all three territories have some authority for managing Canada's oceans and coasts. In the USA, at least 20 federal agencies implement over 140 federal ocean-related statutes. A number of consequences follow from this complexity. One of the consequences is that decision making is *ad hoc* (Crowder et al., 2006). It is harder to gain agreement for the overarching objectives required for ecosystem-based governance. Cumulative effects and conflicts across sectors are difficult to resolve without clear authority (ibid.).
Within this administrative labyrinth, in both countries, it is unclear which departments and agencies are responsible for holding data on human activities. Further compounding this complexity, individual industries, industry sectors and companies

also gather and hold data on human activities. Such complex governance and management structures tend to perpetuate a sectoral approach (ibid.).

In the USA it is too early to tell whether an Executive Order signed by President Obama on 19th July 2010 will address this fragmentation. The Order establishes a National Policy for the Stewardship of the Ocean, Coasts and Great Lakes[45] and provides for "the development of coastal and marine spatial plans that build upon and improve existing Federal, State, tribal, local, and regional decision making and planning processes. These regional plans will enable a more integrated, comprehensive, ecosystem-based, flexible, and proactive approach to planning and managing sustainable multiple uses across sectors and improve the conservation of the ocean, our coasts, and the Great Lakes".

In Europe an example of good practice is offered by the MSFD providing overarching ecosystem governance objectives (EC, 2008b).

The simultaneous implementation of the Ocean Stewardship Order in the USA and the ongoing implementation of the European MSFD could provide an opportunity to broaden the interoperability and comparability between data from the North East and North West Atlantic, although neither the Ocean Stewardship Order nor the MSFD specifically addresses the sharing of data beyond their administrative boundaries. However, interoperability and integration of data are being addressed in other forums. The IODE of the Intergovernmental Oceanographic Commission (IOC)[46] recommends international standards for the exchange of data, for example the use of standardised country codes (UNESCO, 2010) and a standardised format for dates and times (UNESCO, 2011) for use in the exchange of oceanographic data. It is worth noting that in the past IODE has made a number of unsuccessful attempts to agree on data management standards. They attribute the lack of success to insufficient coordination with other similar initiatives[47]. The emerging science of geoinformatics is bringing together international scientists and data providers to advance international data interoperability[48]. Technological advances are now making the sharing of data, especially internationally across web-systems, more practicable.

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[45] Executive Order: http://www.whitehouse.gov/the-press-office/executive-order-stewardship-ocean-our-coasts-and-great-lakes

[46] IOC: http://www.iode.org/

[47] IODE, Data Standards: http://www.iode.org/index.php?option=com_content&view=article&id=101&Itemid=125

[48] European Geosciences Union General Assembly 2011

Within the US (although the project works in collaboration with organisations and institutions within Europe) the Marine Data Interoperability Project[49] promotes integration and interoperability of marine metadata. Within Europe an example of an attempt to achieve such large scale integration is the INSPIRE Directive (EC, 2007b). This requires the adoption, by Member States, of measures for the exchange, sharing, access and use of interoperable spatial data and spatial data services across different levels of public authority and across different sectors. This does not, however, necessarily apply to bodies not exercising public authority such as scientific and academic institutions and industry and it does not override intellectual property rights or cover near-real time observations or historic archives of data (EC, 2010a). Industry data also fall outside the Directive.

3.4.2 Data

Such complex and fragmented governance and management make the integration of data problematic. This has a number of consequences:

- All relevant data holders are difficult to identify.
- Multiple data sources and no metadata set means that data may not be comprehensive.
- Information is fragmented.
- Multiple permissions may be required before data can be accessed.
- Different data holders, using different systems, store data in different formats.
- Different spatial resolutions mean data are not comparable.
- Integrated assessments and assessing cumulative impacts is made problematic.
- The complexity of data holdings inhibits communication and creates barriers between public and private interests and between sectoral interests.

The consequences of such fragmentation can be mitigated by vertical and horizontal agreements across industry sector administrations as well as within and between governments to achieve interoperability and sharing. Diffuse responsibilities and fragmentation of data may themselves create a self-reinforcing cycle. Fragmented data may impede holistic governance and management while the lack of holistic governance and management may lead to fragmentation of data. Within sector-based governance and management each sector develops its own rules and practices for data collection, management, access and use. The fisheries sector is an example of such an approach where there is no incentive to integrate across sectors. Such strictly sector-based data make wider, holistic problems difficult to identify and integrated assessments of such problems difficult to achieve. Furthermore, Murawski (2007) suggests that entrenched

[49] Marine Metadata Interoperability Project: http://www.marinemetadata.org

sectoral interests and their governance institutions may, in fact, perpetuate this fragmentation, perceiving an ecosystem-based approach as a threat to their control.

3.4.3 Data quality

Oceanographic and environmental data collected by marine scientific research and, in some cases collected by industries, were available and the sources well documented. The IODE[50] provides links to three oceanographic databases. The US-based World Ocean Database[51], the European SeaDataNet[52] and within the UK, the MEDIN[53] network all provide access to oceanographic data. Much effort is being expended to construct these databases. However, there is currently no comprehensive dataset covering human activities, for either the North East or North West Atlantic. One consequence of this is that the data are not standardized. Data collected for different purposes may be measured in different spatial resolutions. A consequence is that, for example, mismatches may occur which make it difficult to quantify pressures of a similar type across multiple human activities (Eastwood et al., 2007).

There is currently no metadata set. It is suggested here that such metadata should list the data source, data controller, a link to the relevant data providers, a description of the content, the format in which the data are held, the confidence limits and any uncertainties associated with the data, the area covered and any conditions which apply to data use. Suitable repositories of such meta-datasets might be the DFO Canada, NOAA's National Ocean Service in the USA, the European DG MARE and for the wider North East Atlantic, OSPAR.

3.4.4 Data control

A key problem identified in both the North East and North West Atlantic studies was the difficulty identifying holders of data. Data ownership is distributed. The complex array of government bodies, industry organisations and institutions which may gather and hold such data has consequences. Identifying data sources is problematic and time-consuming. The control of data and its release is inconsistent. Restrictive usage compounded by commerciality makes the balancing of interests more difficult.

No payment was required for access to the datasets identified in the USA and Canada and even the submarine cables data supplied on a CD by NASCA, an industry body, was provided free of charge. In Europe, legislation allows for charges to be made for

[50] IODE: http://www.iode.org/

[51] World Ocean Database: http://www.nodc.noaa.gov/OC5/WOD/pr_wod.html

[52] SeaDataNet: http://www.seadatanet.org/

[53] MEDIN: http://www.oceannet.org/

extracting and processing data, for example EC Regulation 199/2008 permits Member States to charge the actual costs of extracting and, if necessary, aggregating the data (EC, 2008c) and European Commission Directive 2003/4/EC establishes that "public authorities should be able to make a charge for supplying environmental information but such a charge should be reasonable" (EC, 2003c). However, there is no requirement for charges to be reasonable for data supplied by the private sector. Data on human activities, such as the comprehensive dataset of all cable routes in North East Atlantic, are a commodity and, as such, have a price. The price quoted for access to this data set was £50,000. Such commercial charges act as a barrier to the sharing and use of these data. This is an issue which needs to be addressed if human activities are to be fully incorporated into ecosystem-based management and into the wider stakeholder participation. A solution might be that such commercial charges should be waived for scientific use and ecosystem management.

A further consequence of such fragmentation of data, in both the North West and North East Atlantic, is that there is little accountability in some sectors. There is no obligation on industry to make their data available. A major block to access within Europe is that while legislation covers information held by public authorities there are no obligations on individual industries to make data available. This point is discussed further in Chapter 4. This lack of transparency fuels the silo mentality with the further consequence that co-operative mechanisms for ecosystem management are restricted.

3.4.5 Rights and responsibilities

Data on human activities is held primarily by industries and there is a tendency to hold data in confidentiality. Some industry data are commercially sensitive and are held in a restrictive way barring access by other users.

Extensive European legislation and measures promoting access to and sharing of environmental information already exist and might be thought to offer a suitable model for application on a broader scale, for example, the whole of the North Atlantic. These laws and measures include the United Nations Economic Commission for Europe Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (the Aarhus Convention) (UNECE, 1998)[54]. This convention grants rights to the public regarding access to information, public

[54] The Aarhus Convention defines environmental information as "… any information in written, visual, aural, electronic or any other material form on…..factors, such as … activities affecting or likely to affect the elements of the environment … water, soil, land, landscape and natural sites, biological diversity and its components … and the interaction among these elements" and, as such, encompasses information on human activities.

participation and access to justice in governmental decision-making processes on environmental matters at local, national and trans-boundary levels. Another directive, the Environmental Information Directive, requires Member States to release environmental data when requested (EC, 2003c). The Directive on the Re-use of Public Sector Information facilitates the re-use of public data by establishing a common legislative framework regulating how public sector bodies should make their information available for re-use in order to remove barriers such as discriminatory practices, monopoly markets and a lack of transparency (EC, 2003e). The latest measure, the European Marine Observation and Data Network (EMODNET)[55] was proposed by the Commission in its Green Paper on maritime policy (EC, 2006a) as a data infrastructure delivering improved access to data, coherence across borders and known confidence limits which will enable Member States to meet their obligations under the Marine Strategy Framework Directive (EC, 2008b).

These instruments and measures enhancing public rights to access imply that data would be readily available, accessible and compatible. While the objectives are laudable, in practice, and within the context of the study on human activities in the North East Atlantic, access to data remained a problem.

In particular, the lack of appropriate and available data for the fisheries sector has important consequences. The earlier study found that the spatial extent of bottom trawling in the North East Atlantic was an order of magnitude greater than that of all the other activities combined. Of all fishing activities bottom trawling has the most disruptive effect on the deep seafloor (UNGA, 2006b) and is arguably the most destructive human activity taking place in the deep sea and has been compared to clear-cutting forests (Watling and Norse, 1998) or mining where depletion is rapid and recovery unlikely (Roberts, 2002). Despite the significance of this activity in the marine environment, data on bottom trawling was difficult to access. Legislation and its interpretation allow the fishing sector to avoid its responsibilities for data sharing. Although VMS data were provided by two European Member States and NEAFC for the North East Atlantic study, such access is rare. No data were available from the remaining States in the North East Atlantic study and none from the USA, Canada or NAFO.

The confidentiality of VMS data, particularly concerning location of fishing grounds (fishing positions) and catch data, is a particularly sensitive issue for the fishing industry. Such data are considered by the industry to be highly valuable commercial information the disclosure of which may put a vessel's owner at a commercial

[55] EMODNET: http://ec.europa.eu/maritimeaffairs/eu-marine-observation-data-network-mission_en.html

disadvantage. It can be argued that such types of information, by reason of their commercial nature, may require a higher level of protection (Cacaud, 1998). It can also be argued that if all VMS data were anonymized and made openly available then this would provide an equal basis for all participants in the market. While the concerns of the fishing industry are real there also needs to be a balance of interests.

Fishing vessels operating in both the North East and North West Atlantic were originally legally required to install VMS units for monitoring, control and surveillance of fishing activities by fisheries management authorities. However, information that can be derived from VMS data on the location, extent and frequency of bottom fishing is also essential for a broader understanding of the impacts of this activity on the ecosystem. Knowledge of where particular fishing activities are taking place can be used in a number of important ways. It allows studies of the spatial extent of a specific fishing activity - such as bottom trawling (Eastwood et al., 2007; Benn et al., 2010), it allows identification of potential sites for fisheries closures (Hall-Spencer et al., 2009) and it also enables the study of impacts of bottom trawling on benthic ecosystems (Hiddink et al., 2006). The level of compliance with regulations, limitations in existing data and recommendations for improvement are discussed in Chapters 4 and 5.

The inclusion of human activities as an essential component of ecosystem-based governance and management is well established. However, this study has found that while structures and mechanisms for the collection and sharing of oceanographic data exist on both sides of the North Atlantic there are no such structures and mechanisms for human activities data. Where data on human activities do exist they are not currently collected for the purposes of ecosystem-based management. The study also found that, within Europe, while rights are being extended to the public for wider access to data and information which would allow debate on ecosystem-based governance, the responsibilities of some interests are not being discharged in a way that would support ecosystem-based management.

4 Human Activities in the Deep North East Atlantic: Legal and Policy Framework, Reporting Requirements and Recommendations

4.1 Introduction

No area of the world's oceans remains unaffected by human influence whether directly or indirectly (Halpern et al., 2008). In the deep sea, the extent, intensity and range of human activities are increasing. The same developments in technology which have enabled advances in our understanding of the deep sea also allow access to resources of economic value. Two drivers - increasing demand and diminishing or exhausted terrestrial and shallow water resources, are pushing existing human activities ever deeper into the world's oceans (van den Hove and Moreau, 2007). New opportunities are also emerging which include the prospecting and exploration of polymetallic nodules in the Area (ISA, 2000) and exploitation of marine genetic resources (UNGA, 2007a).

Fundamental to the ecosystem-based approach to governance and management is knowledge of the location and extent of human activities (Eastwood et al., 2007; Halpern et al., 2007; Lester et al., 2010). However, during the work to map and quantify human activities on the deep seafloor in the OSPAR Maritime Area of the North East Atlantic (Figure 1.1), problems of data quality and availability were identified as major barriers to mapping the location and estimating extent of activities.

To identify why such basic data are not readily available, this chapter identifies the legal and policy regimes as well as organisations under whose aegis human activities lie. It describes, where possible, for each of the activities the current reporting requirements and their limitations and concludes by proposing recommendations to enable the location and extent of human activities to be monitored.

The extent of marine zones and the rights and duties of States under the UNCLOS[56] regime are outlined in Chapter 1, Section 1.1 and Figure 1.2.

[56] UNCLOS text: http://www.un.org/Depts/los/convention_agreements/texts/unclos/unclos_e.pdf

4.2 Legal instruments, non-binding agreements and organisations concerned with regulating the human activities included within this study in the deep North East Atlantic

Governance of the deep sea is complex. The rights and responsibilities of States are contained in a wide range of international, regional and national binding and non-binding conventions, agreements and instruments. An array of organisations, mechanisms and processes provide the means to further develop and implement the legislation.

It is useful to describe this complexity in terms of global, regional and national perspectives.

4.2.1 Global

Table 4.1 provides a summary of the key global legal instruments, non-binding agreements and organisations and their main objectives and principles concerned with regulating human activities in the deep sea.

The 1982 United Nations Convention on the Law of the Sea (UNCLOS)

UNCLOS provides the legal framework that applies to all activities in the seas and oceans. UNCLOS establishes the rights of States to exercise traditional freedoms of the high seas such as navigation, fishing, laying of submarine cables and pipelines, marine scientific research and the construction of artificial islands and other installations (Article 87.1). It further states that “these freedoms shall be exercised by all States with due regard for the interests of other States in their exercise of the freedom of the high seas, and also with due regard for the rights under this Convention with respect to activities in the Area” (Article 87.2). UNCLOS also establishes obligations to protect and preserve the marine environment (Articles 145 and 192) calling for international and regional cooperation for the protection and preservation of the marine environment (Article 197).

Two further UN agreements to implement UNCLOS are:

i) ***The Agreement relating to the implementation of Part XI of the Convention***

Also known as the Part XI Implementing Agreement, this is an amendment of the deep seabed mining regime.

ii) ***The Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks***

This is generally referred to as the UN Fish Stocks Agreement (UNFSA).
The emerging evidence of overfishing during the early 1990s prompted the UN to impose more stringent obligations on both fishing nations and coastal nations. The agreement sets out principles for the conservation and management of straddling and highly migratory fish stocks and establishes that such management must be based on the precautionary approach and the best available scientific information. It also requires transparency in decision making and cooperation between States to ensure conservation and promotes "the objective of the optimum utilization of fisheries resources both within and beyond the exclusive economic zone".

Additionally, the FAO developed a Code and an Agreement (now integrated) to guide fisheries' practises:

Food and Agriculture Organization of the United Nations (FAO) Code of Conduct for Responsible Fisheries (1995)

The Code of Conduct for Responsible Fisheries (FAO, 1995) is a global, voluntary, non-binding code providing principles and standards applicable to the conservation, management and development of all fisheries.

The Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas (FAO Compliance Agreement)

The FAO Compliance Agreement (FAO, 1993) was formally integrated into the FAO Code of Conduct when that instrument was adopted in 1995. However, unlike the other parts of the Code the Compliance Agreement is a legally binding treaty. It entered into force on 24 April 2003, after acceptance by 25 Parties. The Agreement contains two main elements i) the concept of flag State responsibility and ii) promotion of the free flow of information on high seas fishing activities.

Other intergovernmental instruments and organisations have a bearing on human activities in the deep sea:

The 1979 Convention on Migratory Species (CMS or Bonn Convention)

The Bonn Convention (UNEP, 1979) is an intergovernmental treaty concluded under the aegis of the United Nations Environment Programme, which aims to conserve terrestrial, marine and avian migratory species. States which fall within the range ('Range States') of a listed migratory species are required to protect the species as well as their habitat. Also included within Range States are those whose vessels are engaged in taking a migratory species outside national jurisdictional limits (CMS, Article 1.1.h).

The 1992 Convention on Biological Diversity (CBD)

The CBD (UNEP, 1992) has three main objectives:

1. conservation of biological diversity;
2. sustainable use of its components;
3. fair and equitable sharing of the benefits derived from utilization of genetic resources.

Parties to the Convention must ensure that activities within their jurisdiction or control do not damage the environment of other States or areas beyond national jurisdiction and parties must cooperate in the conservation and sustainable use of biological diversity in areas of national jurisdiction. Concerning the marine environment, the UN General Assembly and other relevant international and regional organizations were called upon at the 2004 Conference of the Parties to the CBD to take measures to protect seamounts, hydrothermal vents, cold water corals and other vulnerable ecosystems. A further goal of the CBD is the establishment by 2012 of comprehensive, representative and effectively managed national and regional systems of marine protected areas.

The Convention on Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (The London Convention) and the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (The London Protocol)

The London Convention is the primary global convention for controlling waste disposal at sea. This was extended in 1996 by the London Protocol which entered into force on 24th March 2006 prohibiting all dumping except for wastes on the 'reverse list'.

1958 Geneva Conventions

The 1958 Geneva Conventions were the basis for much of UNCLOS. These Conventions are now generally seen as obsolete by the majority of States. UNCLOS 1982, Article 311, paragraph 1 states that the 1982 Convention "shall prevail, as between States Parties, over the Geneva Conventions on the Law of the Sea of 29 April 1958". The 155 parties to the 1982 Convention include most States bound by the Geneva Conventions. The Geneva Conventions are now binding only between, or in relationships with, those

States that are party to the relevant Geneva Convention but not party to the 1982 UNCLOS Convention – these include the USA, Colombia, Israel and Venezuela. This diminishes the global reach of UNCLOS.

International Seabed Authority (ISA)

The ISA is an autonomous international organisation established under UNCLOS through which States that are parties to the 1982 UNCLOS Convention organise and control activities on and within the seabed in areas beyond national jurisdiction (the Area). ISA has established rules, recommendations and procedures to regulate prospecting, exploration and exploitation of marine minerals in the Area (ISA, 2010b).

Table 4.1 Summary of the **key global** legal instruments, non-binding agreements and organisations and their main objectives and principles concerned with regulating human activities in the deep sea.

Instrument/Organisation	**Main objectives and principles**	**Activities**
UNCLOS	Objectives: To provide a legal framework applicable to all activities in the oceans Establishes: • marine zones and legal jurisdictions • freedoms of the high seas • obligations to protect and preserve the marine environment Calls for an integrated approach to ocean use and conservation	All activities
UN Fish Stocks Agreement	Objectives: • To ensure long-term sustainability of fish stocks • To minimise impacts of fishing • To protect biodiversity and habitats of special concern Principles: • The precautionary approach • The ecosystem approach • Transparency and public participation in decision-making	Fishing
FAO Code of Conduct for Responsible Fisheries	Objectives: • To conserve living aquatic resources and ecosystems • To ensure that fisheries' management decisions are based upon best scientific evidence available • To ensure that decision making processes are transparent and achieve timely solutions Promotes the application of the precautionary principle	Fishing
FAO Compliance Agreement	Objective: To promote compliance with international conservation and management measures by fishing vessels • Establishes the concept of flag State responsibility • Requires that States ensure vessels flying their flag do not undermine the effectiveness of international conservation and management measures • Promotes the free flow of information on high seas fishing activities	Fishing
Convention on Biological Diversity	Objectives: • To conserve biological diversity and the sustainable use of its resources • Fair and equitable sharing of benefits derived from genetic resources Promotes application of: • the ecosystem based approach • the precautionary principle	All activities
London Convention and London Protocol	Objectives: • To effectively control all sources of pollution of the marine environment • To prevent pollution caused by dumping of waste liable to create hazards to human health, to living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea	Waste dumping
ISA	Objectives: • To establish rules, recommendations and procedures to regulate mining of marine minerals in the Area • To develop environmental regulations to protect the marine environment including application of the precautionary approach	Seabed mining

4.2.2 Regional

Table 4.2 provides a summary of the key regional legal instruments, non-binding agreements and organisations and their main objectives and principles concerned with regulating human activities in the deep sea.

The Convention for the Protection of the Marine Environment of the North East Atlantic (1992) (The OSPAR Convention)

The Oslo Convention preventing the dumping of hazardous substances at sea was adopted in 1972 and was followed in 1974 by the Paris Convention which dealt with land-based sources of pollution. These legal instruments were later merged into the present day OSPAR Convention which entered into force in 1998. The Convention's implementing body is the OSPAR Commission, comprising 15 countries, the European Union and observers from 27 non-governmental organisations representing environmental groups and industry. The main principles of the OSPAR Convention are: the ‘precautionary principle', the ‘polluter pays principle', the Best Available Techniques (BAT), and the Best Environmental Practice (BEP).

The current decisions (which are legally binding on Contracting Parties), recommendations and other agreements applicable within the framework of the OSPAR Convention cover, *inter alia*, carbon dioxide storage, pollution, discharges, disposal at sea and marine research.

Convention on Future Multilateral Cooperation in North East Atlantic Fisheries

The Convention promotes multilateral cooperation between parties. NEAFC, the Regional Fisheries Management Organisation (RFMO) for the North East Atlantic, was formed to recommend measures to maintain the rational exploitation of fish stocks in the Convention Area. Advice is provided to NEAFC by ICES[57]. NEAFC is the competent organisation for recommending measures to Contracting Parties to promote the rational exploitation of fisheries in the NEAFC regulatory area - beyond areas under national fisheries jurisdiction of Contracting Parties. However, if requested by Contracting Parties, NEAFC will recommend measures for areas under the fisheries jurisdiction of Contracting Parties.

[57] The role of ICES is to coordinate and promote marine research on oceanography, the marine environment, the marine ecosystem, and on living marine resources in the North Atlantic. ICES is a scientific and research organization for the provision of information and advice to member countries and international bodies. The main objectives are i) to promote and encourage research and investigations for the study of the sea, in particular related to living resources; ii) to instigate and organise programmes required for this purpose; iii) to disseminate the results of research and investigations carried out under its auspices.

NEAFC is made up of delegations from Contracting Parties (the EU, Denmark on behalf of the Faroe Islands and of Greenland, Iceland, Norway and the Russian Federation) who have agreed to abide by the rules of the Convention which entered into force in its current form in November 1982. Other flag States which have an interest in fisheries in the North East Atlantic can be accorded Co-operating Non-Contracting Party status (CNCP), allowing them to authorise vessels flying their flag to operate in the NEAFC area and requiring that they enforce NEAFC's measures. There are currently five CNCPs: Belize, Canada, Cook Islands, Japan and New Zealand.

The European Commission

The European legislative framework is complex and is evolving continuously. The European Commission is the legislative arm of the European Union. A range of legislation covers human activities on the seafloor. These include regulations and directives relating to fishing activities as well as environmental legislation concerning, for example, emissions from oil and gas activities. The main departments concerned with developing and drafting this legislation are the Directorate-General of Maritime Affairs and Fisheries and the Directorate–General of the Environment.

a*) Directorate-General of Maritime Affairs and Fisheries (DG MARE)*

DG MARE is the Commission department responsible for the implementation of the Common Fisheries Policy (CFP) and the Integrated Maritime Policy.

- Common Fisheries Policy (CFP):
  The CFP is the European Union's instrument for the management of fisheries and aquaculture. It has four components:

  1. Sustainable conservation and management of fishery resources;
  2. Structural adaptation and modernisation measures;
  3. Common organisation of markets;
  4. Relations with third countries.

- Integrated Maritime Policy:
  The aims of the Integrated Maritime Policy are i) to realise the economic potential of the oceans and seas while remaining “in harmony with the marine environment and the needs of coastal communities” and ii) the effective and cost-efficient development of cross-cutting policy tools.

b) *Directorate-General Environment (DG Environment)*

The remit of DG Environment is to protect, preserve and improve the environment for present and future generations. It proposes policies to ensure a high level of environmental protection in the European Union and to preserve the quality of life of EU citizens. It ensures the correct application of EU environmental law in Member States, investigates complaints made by citizens and non-governmental organisations and can take legal action if it is deems there has been an infringement. In certain cases DG Environment represents the European Union in environmental matters at international meetings such as the United Nations CBD.

The Marine Strategy Framework Directive (MSFD)

The MSFD, adopted in 2008, is the environmental pillar of the European Union's Integrated Marine Policy and establishes a framework within which Member States will take measures to maintain or achieve good environmental status in the marine environment by 2020. It requires that marine strategies be implemented that protect and preserve the marine environment, prevent its deterioration and, where practicable, restore marine ecosystems and also prevent and reduce inputs that have a significant impact.

The Directive established European Marine Regions on the basis of geographical and environmental criteria. Each Member State, cooperating with each other as well as non-EU countries within a marine region, is required to develop strategies for their marine waters. These strategies must contain a detailed assessment of the state of the environment, a definition of good environmental status at regional level and the establishment of clear environmental targets and monitoring programmes.

The Birds and Habitats Directives

The Birds and Habitats Directives require Member States to protect natural habitats and species of wild plants and animals within waters of national jurisdiction through the designation of Special Areas of Conservation (SAC) for habitats and Special Protection Areas (SPAs) for birds, forming the Natura 2000 network.

Table 4.2 Summary of the **key regional** legal instruments, non-binding agreements and organisations and their main objectives and principles concerned with regulating human activities in the deep North East Atlantic.

Convention/ organisations	**Main objectives and principles**	**Activities**
OSPAR Convention	Objectives: Protection of the marine environment of the North East Atlantic Promotes: • The precautionary principle • The polluter pays principle • Best available techniques • Best environmental practice • The ecosystem-based approach	Carbon dioxide storage Pollution Discharges Disposal at sea Marine research Oil and gas industry
Convention on Future Multilateral Cooperation in North East Atlantic Fisheries	Objectives: To ensure the long term conservation and optimal utilization of fishery resources in the Regulatory Area based on the best scientific evidence available • Promotes the precautionary approach	Fishing
European Union: Common Fisheries' Policy	Objectives: • Sustainable biological, environmental and economic exploitation of living aquatic resources • Guaranteed income for fishers • Regular supply at reasonable prices for consumers and the processing industry Promotes[1]: • The ecosystem-based approach • The precautionary principle • Commitment to transparency • Improved access to information	Fishing
European Union Integrated Maritime Policy/ Marine Strategy Framework Directive	Objectives: To provide a holistic and integrated approach to economic and sustainable development across European Union seas and oceans Promotes: • The ecosystem-based approach • The precautionary principal • A transparent legislative framework • Public access to environmental information	All activities

[1]Lutchman et al. (2009) point out that how the balance between economic, environmental and social aspects are to be achieved is not specified

4.2.3 National

National laws, regulations and requirements vary between individual States. States interpret and apply regional and international legislations idiosyncratically. National instruments include regulations, licensing, permissions and reporting requirements. These are discussed in relation to specific activities below using the UK as an example.

4.3 Requirements for the permissions and conduct of human activities on the seafloor

It was noted in Chapter 1 that jurisdiction in the deep sea includes areas both within and beyond national jurisdiction. Consequentially there is an array of legislation covering an individual activity depending on where it takes place within UNCLOS maritime zones (Figure 1.2). As reporting requirements often have their basis within laws or regulations governing an activity, a brief overview of these is given at the start of the following sections. Where national reporting requirements are described, the UK has been used as the case study.

4.3.1 Marine scientific research

Marine scientific research is carried out for a variety of different purposes. These include military, exploratory (for example in the search for natural resources such as hydrocarbons and minerals for commercial exploitation) and research by scientific institutions, including fisheries research.

Scientific research, including fisheries research is the focus of this section.

The main legal instrument governing marine scientific research is UNCLOS. Marine research is a freedom of the high seas (Article 87). All States have the right to carry out research there (Article 257). The Area (the seabed and subsoil of the high seas beyond the continental shelf) (Figure 1.2) and its resources are the common heritage of mankind (Article 136). All States have the right to carry out research in the Area (Article 256) provided it is carried out "exclusively for peaceful purposes and for the benefit of mankind as a whole" (Article 143.1). States are also required to promote international cooperation in marine scientific research in the Area (Article 143.3) by:

"(a) participating in international programmes and encouraging cooperation in marine scientific research by personnel of different countries and of the Authority[58];
(b) ensuring that programmes are developed through the Authority or other international organizations as appropriate for the benefit of developing States and technologically less developed States with a view to:
(i) strengthening their research capabilities;
(ii) training their personnel and the personnel of the Authority in the techniques and applications of research;
(iii) fostering the employment of their qualified personnel in research in the Area;

[58] The International Seabed Authority

(c) effectively disseminating the results of research and analysis when available, through the Authority or other international channels when appropriate".

The consent of the coastal State is required to carry out marine research in territorial seas (Figure 1.2) and this may be subject to additional conditions laid down by the coastal State (Article 245). UNCLOS provisions relating to marine research in the EEZ and on the continental shelf are contained in Articles 246 to 255. Consent of the coastal State is required (Article 246.2). Coastal States shall "establish rules and procedures ensuring that … consent will not be delayed or denied unreasonably" (Article 246.3) provided that research is "exclusively for peaceful purposes and in order to increase scientific knowledge of the marine environment for the benefit of all mankind". However coastal States may withhold their consent to the conduct of marine scientific research if, for example, the project is "of direct significance for the exploration and exploitation of natural resources, whether living or non-living" (Article 246.5(a)) or "involves drilling into the continental shelf, the use of explosives or the introduction of harmful substances into the marine Environment" (Article 246.5(d)).

Under UNCLOS various obligations attach to permissions to carry out marine research within an EEZ and on the continental shelf of another State. The coastal State must be provided with specified information about the proposed project a minimum of six months in advance of the expected starting date using Form A - Application for consent to conduct Marine Scientific Research (Article 248). This requires details of the institutions involved, a description of the project, the geographical area in which the project is to be conducted, details of the platform (vessel, aircraft, AUV, etc), instruments and methods to be used, installations and equipment, dates of entry(ies) and departure(s), intended port calls, details of the participation of a representative from the coastal State and access to data, samples and results.

Requests from non-UK institutions to operate in UK waters are sent via the State Department or equivalent in the State requesting permission to the Foreign and Commonwealth Office (FCO) in the UK. Diplomatic clearance is granted in a *nota verbal* sent from the FCO via the same route to the research institution. Vessels from UK establishments are not required to submit Form A to carry out marine scientific research in UK waters.

In the UK the deposition "of any scientific instrument or associated equipment (other than for the purpose of disposal) in connection with scientific experiment or survey" is exempt from the Food and Environment Protection Act 1985 (FEPA) (UK Government, 1985). However, the addition of tracers and particulates to the marine environment require licensing under the FEPA.

UNCLOS requires that the coastal State is provided with the results of research and that such results are made available internationally. It also imposes an obligation to assist the coastal State if requested to interpret and assess the data and results (Article 249.1(b) to (e)). If these obligations are not met the coastal State may suspend or require cessation of research (Article 253).

Other reporting requirements may be imposed by funding bodies. ROSCOP cruise summary reports may be required to be submitted to, for example, BODC[59] or data may be required to be deposited in national or international databases such as PANGAEA[60] within a stipulated period of time. BODC Cruise Summary Reports require, *inter alia*, the location of moorings and bottom-mounted gear to be recorded on the form as well providing an option to include the location of fixed sites which are returned to routinely in order to construct long time series.

Fisheries research

In the UK, fisheries research, for example trawl surveys for fish stock assessments and testing of gear types, falls within the Marine Managements Organisation's (MMO) 'Dispensation' category. Licensing related to fisheries research is controlled by the EU Marketing and Days at Sea Manager who is part of the MMO Fisheries Management and Control team (FMCT), responsible for issuing dispensations from national domestic and European marine fisheries legislation for the purposes of genuine scientific research. A Dispensation request form[61] must be submitted at least four weeks prior to the start of a research programme. For research in Scottish and Welsh waters, dispensations are issued by the relevant devolved administration. Local by-laws are the responsibility of the local sea fisheries committees[62].

4.3.2 Submarine telecommunications cables

International law relating to submarine telecommunications cables is contained in:

1. The International Convention for Protection of Submarine Cables (1884) (The Cables Convention), Articles 1-16.

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[59] BODC: http://www.bodc.ac.uk

[60] PANGAEA: http://www.pangaea.de

[61] MMO Dispensation Form: www.marinemanagement.org.uk/fisheries/management/forms/dispensation.pdf

[62] Association of Sea Fisheries Committees: www.asfc.org.uk

2. The Geneva Conventions on the High Seas (1958), Articles 26–30 and Continental Shelf 1958, Article 4. Within the cable industry The Cable Convention continues to be widely used. Although UNCLOS establishes cable laying as a freedom of the high seas and outlines the rights and duties of States in relation to cables, the Cable Convention is the only treaty that details the procedures required to implement them (Carter et al., 2009).

3. The United Nations Convention on the Law of the Sea (1982) (UNCLOS), Articles 21, 58, 71, 79, 87, 112-115 and 297.1(a) relating to areas beyond the territorial sea.

Carter et al., (2009) summarise the main legal principles contained in UNCLOS applying to international submarine cables:

- The freedoms to lay, maintain and repair cables outside territorial seas.
- The requirements that parties apply domestic laws to prosecute persons who endanger or damage cables wilfully or through culpable negligence.
- The requirement that vessels, unless saving lives or ships, avoid actions likely to injure cables.
- The requirement that vessels must sacrifice their anchors or fishing gear to avoid injury to cables.
- The requirement that cable owners must indemnify vessel owners for lawful sacrifices of their anchors or fishing gear.
- The requirement that the owner of a cable or pipeline, who in laying or repairing that cable or pipeline causes injury to a prior laid cable or pipeline, indemnify the owner of the first laid cable or pipeline for the repair costs.
- The requirement that coastal states, along with pipeline and cable owners, shall not take actions which prejudice the repair and maintenance of existing cables.

Beyond territorial seas, no permits or licences are required under international law. However, a submarine cable landing in a coastal State or entering its territorial seas normally requires licences. These licences are based on domestic law requirements of the coastal State involved. The licensing authority responsibility varies between countries. Some counties require Environmental Impact Reports but others may not. The specific requirements also vary depending upon whether the cable passes through any designated protection zones or fishing areas (John Reynolds, International Cable Protection Committee, personal communication).

There are no legal reporting requirements on cable routes in international waters. However cable routes within the EEZ are usually reported to charting authorities so that mariners will have notice of cable locations (Douglas Burnett, Squire Sanders & Dempsey L.L.P., USA, personal communication).

In UK waters cable laying requires consent from the MMO under the Coast Protection Act 1949 (UK Government, 1949). Information is usually reported to charting authorities so that mariners will have notice of cable locations. Global Marine Systems Limited holds data on all cable routes, including the high seas, in GIS format. This information is provided, under licence, to the UK Hydrographic Office and to other, paying, clients.

Cables routes are included in charts covering shallow waters but not in the open ocean. Routes of cables currently in-service are available from cable-awareness websites aimed at demersal trawlers and other users of the sea, to avoid cable damage (for example, Kingfisher Information Service – Cable Awareness and FranceTelecom's SigCable sites listed in Chapter 2, Table 2.1).

4.3.3 Dumping of waste

Radioactive waste

Between 1949 and 1982 low level radioactive waste was dumped routinely at sites in the North East Atlantic. In 1983, following increasing concern over the continued sea disposal of radioactive waste, the Contracting Parties to the London Convention (IMO, 1997) adopted a voluntary moratorium on the sea-dumping of all types of radioactive waste. Amendments to the Convention, adopted in 1993, which came into force on 20 February 1994, eventually banned sea-dumping of all types of radioactive waste (IMO, 1993). Within twenty five years from this date, contracting parties are required to complete a scientific study relating to all radioactive wastes and other radioactive matter other than high level wastes, followed by further studies at twenty five year intervals and shall review the prohibition of dumping such substances. However, as noted in Chapter 2, details of the methods and reporting processes for these studies are not specified.

Munitions and chemical weapons

Dumping of munitions at sea is now prohibited. Under the 1996 London Protocol all dumping is prohibited, except for 'reverse list' wastes. These comprise:

- dredged material;
- sewage sludge;
- fish wastes;
- vessels and platforms;
- inert, inorganic geological material (for example mining wastes);

- organic material of natural origin;
- bulky items primarily comprising iron, steel and concrete; and
- carbon dioxide streams from carbon dioxide capture processes for sequestration.

Although the dumping of munitions is no longer permitted, OSPAR holds a centralised database (OSPAR, 2009c) listing encounters with dumped munitions. This is currently updated on a three-yearly basis from reports supplied to OSPAR by Contracting Parties. An exception to the three-yearly reporting cycle is encounters with clusters of munitions which must be reported to OSPAR immediately.

4.3.4 Oil and gas industry

While UNCLOS does not refer to oil and gas specifically, Article 77 provides that coastal States exercise sovereign rights over the continental shelf “for the purpose of exploring it and exploiting its natural resources”. Natural resources are defined as “mineral and other non-living resources of the seabed and subsoil together with living organisms belonging to sedentary species, that is to say, organisms which, at the harvestable stage, either are immobile on or under the seabed or are unable to move except in constant physical contact with the seabed or the subsoil” (Article 77.4). It further provides that “if the coastal State does not explore the continental shelf or exploit its natural resources, no one may undertake these activities without the express consent of the coastal State” (Article 77.2). UNCLOS also gives coastal States the exclusive right to authorize and regulate drilling and oil exploration in the EEZ and on the continental shelf (Articles 56, 60 and 81). It imposes a duty to protect the marine environment (Article 192) including in relation to pollution from oil rigs and the operation and maintenance of installations (Articles 194 and 208). It also imposes duties of international cooperation (Article 197) and of monitoring and environmental assessment (Article 204) and publication of the results (Article 205).

Within Europe the Directive 94/22/EC (EC, 1994) of the European Parliament and of the Council of 30 May 1994, on the conditions for granting and using authorizations for the prospection, exploration and production of hydrocarbons, provides the legal basis for issuing licences for prospecting, drilling and producing oil within EU Member States. The aim of the Directive is to prevent a single entity from having exclusive rights for an area whose prospection, exploration and production can be carried out more effectively by several entities. The procedures for granting authorizations must be introduced in a transparent manner and based on non-discriminatory criteria. They must be open to all interested entities. The selection from among the applicants must be based on criteria relating to their technical and financial capabilities as well as the price which the entity is prepared to pay in order to obtain the authorization if it is for sale. All information relating to the authorisation (for example the type of authorisation, the geographical area which may be applied for – either as a whole or a part, the likely deadline for granting the authorization and the selection criteria) has to be published in the *Official Journal of the European Union* at least 90 days before the deadline for the submission of applications.

Member States have the right to grant access and to carry out the activities subject to various considerations including national security, public safety, public health, security of transport, protection of the environment, protection of biological resources and the payment of a financial contribution or a contribution in hydrocarbons. Member States are required to provide annual reports on the geographical areas which have been opened, any authorizations which have been granted, which entities hold those authorizations and the reserves available within their territory.

In the UK the Petroleum Act 1998 (UK Government, 1998) legislates for offshore oil and gas activities. The Department of Energy and Climate Change (DECC) is responsible for issuing licences for exploration and for regulating oil and gas developments on the UK continental shelf. Each element of a proposed development undergoes technical and environmental scrutiny in the form of consents and environmental applications or approvals. For example, for the drilling of wells, an operator is required to have a Well Consent underpinned by environmental approvals under the Environmental Impact Assessment (EIA) Regulations, the Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 (as amended) (UK Government, 2001) and the Offshore Chemical Regulations 2002 (as amended) (UK Government, 2002). A similar procedure is required for pipelines, the commencement of production operations and other operations. All offshore structures whether temporary or permanent require a Consent to Locate. It is through this process that the location of wells, pipelines, installations and rigs are recorded. It is also through this process that the Admiralty, Marine Coastguard Agency, fisheries authorities and the lighthouse authorities are notified of when and where a structure will be placed on the seabed and, ultimately, other users of the sea made aware of its presence. From the Consent to Locate the Admiralty updates marine charts. Each Consent will have location data fed into this process and this information is logged. Operators, as part of their licence/consent conditions are required to provide this information and data. These data are contained in returns forms, sent by the operator and can be accessed through the UK DEAL website[63] (Dr. Sarah Dacre, DECC, UK, personal communication).

[63] UK DEAL: www.ukdeal.co.uk

The information on the UK DEAL site includes pipeline positions and descriptive attributes; platforms and subsea infrastructure (manifolds, anchors, wellheads). Pipelines, surface and subsea infrastructure details are collected at six-monthly intervals from infrastructure owners. Up until early 2008 these data were available to download in GIS format free of charge. After this date downloads were only available upon payment of a subscription – although the data can be viewed free of charge on the UK DEAL website after registering for a password. (Downloadable GIS shapefiles and other information relating to oil and gas activities in Norwegian waters are available free of charge on the Norwegian Petroleum Directorate web pages.)

4.3.5 Bottom trawling

High Seas

UNCLOS Article 87.1(e) establishes fishing as a freedom of the high seas, subject to the conditions laid down in Article 87.2, and as such, is open to all States. Section 2, Article 116 provides that all States have the right for their nationals to engage in fishing on the high seas subject to obligations and duties relating to specific species and straddling stocks. These are managed by the Regional Fisheries Management Organisations (RFMOs).

In the North East Atlantic NEAFC is the RFMO responsible for managing high seas fisheries. NEAFC decides upon conservation and management measures for the regulatory area (Figure 1.1) (NEAFC, 2007). Such measures can be stock, species, area or time specific. In order to fish within the regulations in the NEAFC Area, vessels are required to abide by both the NEAFC Scheme of Control and Enforcement (NEAFC, 2010d) and the management measures in force at that time[64]. NEAFC does not issue fishing licences. Vessels are licenced by Flag States' ministries or agencies responsible for fisheries. The NEAFC Secretariat keeps a central list of vessels licenced by its Contracting Parties. The requirements to fish in the NEAFC Regulatory Area include the operation of a Vessel Monitoring System (VMS) for all fishing vessels over 24 metres overall length. This is a satellite-based system that provides data to the fisheries authorities at regular intervals on the location, course and speed of vessels. From 6th February 2010 hourly transmissions are required for vessels fishing in the NEAFC Regulatory Area. Prior to this date, transmissions were required two-hourly. The information required in each transmission includes (NEAFC, 2010d):

- vessel identification,
- the most recent geographical position of the vessel (longitude, latitude) with a position error less than 500 metres, with a confidence interval of 99 per cent;

[64] NEAFC Current Measures List: http://www.neafc.org/current-measures-list

- the date and time of the fixing of the position;
- 'where applicable', data relating to the catch on board;
- 'where applicable', data relating to transhipment.

Vessels operating within the NEAFC Regulatory Area are also required to record their catch either in a paper-based or electronic logbook (NEAFC, 2010d). The logbook should record: a) each entry into and exit from the Regulatory Area and the cumulative catches retained on board; b) on a daily basis and/or for each haul, by species in live weight kilograms:

- catches retained on board;
- the estimated cumulative catch since the entry into the Regulatory Area;
- the type of gear (number of hooks, length of gill nets, etc);
- the number of fishing operations per day (where appropriate);
- the statistical rectangle or fishing location (longitude and latitude);
- the amount of fish discarded;
- the fishing depth (where appropriate).

This information is sent to the Fisheries Ministry or government agency of the flag State of the vessel which communicates it to the NEAFC Secretary. Completed Port State Control forms 1 or 2 are required for vessels which caught the fish or vessels to which the fish have been transferred.

UNCLOS Article 56.1(a) establishes that within an EEZ each coastal State has "sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living". Various duties are, however, attached to these rights. These include the duty to "ensure through proper conservation and management measures that the maintenance of the living resources in the exclusive economic zone are not endangered by over-exploitation" and "to maintain or restore populations of harvested species at levels which can produce the maximum sustainable yield, as qualified by relevant environmental and economic factors, including the economic needs of coastal fishing communities and the special requirements of developing States ..." (Article 61.3). The allowable catch is to be set by each coastal State within its EEZ (Article 61). Additionally, Article 62 allows, *inter alia*, that coastal States lacking the capacity to harvest the entire allowable catch should give other States access to the surplus; that other States fishing within the EEZ comply with conservation measures and other conditions and regulations relating to, for example, licencing of fishermen, vessels and equipment, payment of fees, determining species which may be caught and quotas, regulating gear and specifying what information is required of fishing vessels – including catch and effort statistics and vessel position reports.

European Community Waters

The European Community has competence to conclude fisheries agreements (Community Fishing Agreements) on behalf of the Member States (Treaty Articles 32-37 and 300). Legislation relating to fisheries is extensive and complex[65]. However, the purpose of this study is to identify reporting requirements for activities on the deep sea floor and, as such, specific legislation relating directly or indirectly to the reporting requirements for vessels engaged in fishing for deep-sea species have been selected.

From 1 January 2005 all European Union (EU) vessels and non-EU vessels operating within Community waters exceeding 15 metres overall length are required to operate VMS. From 1 January 2012 this will apply to all vessels exceeding 12 metres overall length. Commission Regulation 2244/2003 (EC, 2003f) details the reporting requirements. These include the transmission of the following data at least once every 2 hours:

- the fishing vessel identification;
- the most recent geographical position of the fishing vessel, with a position error which shall be less than 500 metres, with a confidence interval of 99 per cent;
- the date and time (expressed in Universal Time Coordinated (UTC)) of the fixing of the said position of the fishing vessel;
- with effect from 1 January 2006 at the latest, the speed and course of the fishing vessel.

This information is essentially the same as that required under the NEAFC Scheme of Control and Enforcement described earlier for items i, ii and iii. However, NEAFC requires that data on the catch and any transhipment also be included in VMS transmissions while the EU requires the inclusion of speed and vessel course. Additionally, the transmission interval is two-hourly in Community waters, rather than one-hourly as in the NEAFC Regulatory Area. Further, the Commission regulation applies to vessels with an overall length exceeding 15 metres whereas the NEAFC regulation applies to vessels exceeding 24 metres overall length.

European Commission Council Regulation 1077/2008 (EC, 2008d) lays downs the rules for the electronic recording and reporting of fishing activities. The electronic reporting system (ERS) is now used to record activity including catches, landings and sales and to report them to fisheries authorities in the Member States. This replaces paper

[65] Current fisheries legislation: http://eur-lex.europa.eu/en/legis/latest/chap04.htm

logbooks. The system is compulsory for vessels exceeding 24 metres overall length from 1 January 2010 (as from 1 July 2011 for vessels exceeding 15 metres). In addition to the reporting requirements detailed in Regulation 1077/2008, Council Regulation 2347/2002 of 16 December 2002 (EC, 2002b) establishes specific access requirements and associated conditions applicable to fishing for deep-sea stocks. Annex III requires that vessels fishing for deep-sea species using towed gear must report the size of the mesh used in the nets, the total time the nets have been in the sea in a twenty four-hour period and the total number of hauls in this time and fishing depths.

Table 4.3 summarises the reporting requirements for each activity.

Table 4.3 Summary of reporting requirements for each activity

Activity	Required by	Content
Marine scientific research and fisheries research	UNCLOS Funding bodies and voluntary	Coastal State to be provided with results of research ROSCOP/ cruise summary reports recording general details of cruises together with the location of moorings, bottom mounted gear and an option to include the location of fixed sites which are returned to routinely
Specific to fisheries research	National law	In the UK 'Dispensation forms' are required to be submitted to the MMO. These list the fishing activity to be undertaken and dates – but not the location
Submarine cables	National law	Charting bodies to be informed of cable routes within EEZs
Dumping of waste: • Radioactive waste • Munitions and chemical weapons	London Convention OSPAR	'Scientific study' to be completed 25-yearly Encounters with material to be reported
Oil and gas industry	National law	In the UK 'Consent to Locate' forms indicating the location of offshore structures to be submitted to the DECC
Bottom trawling	NEAFC	Vessels > 24 m length required to transmit hourly VMS signals reporting: • vessel identification • longitude and latitude • date and time • data relating to the catch on board • data relating to transhipment Vessels are also required to report in logbooks: • Entry into and exit from RA[1] • catches retained on board; • the estimated cumulative catch since the entry into the Regulatory Area • the type of gear • the number of fishing operations per day • fishing location • amount of fish discarded • fishing depth (where appropriate)
	EU law	Vessels >15m length are required to transmit 2-hourly VMS signals reporting: • vessel identification • the most recent geographical position date and time • speed and course Vessels are also required to electronically[*] report details of: • Catch, landings and sales Vessels fishing for deep sea species: • Size of mesh • Total immersion time in 24 hour period • Number of hauls in same period • Fishing depth

[*]Compulsory for vessels: > 24 m from 1 January 2010 and for vessels >15 m from 1 July 2011

4.4 Discussion

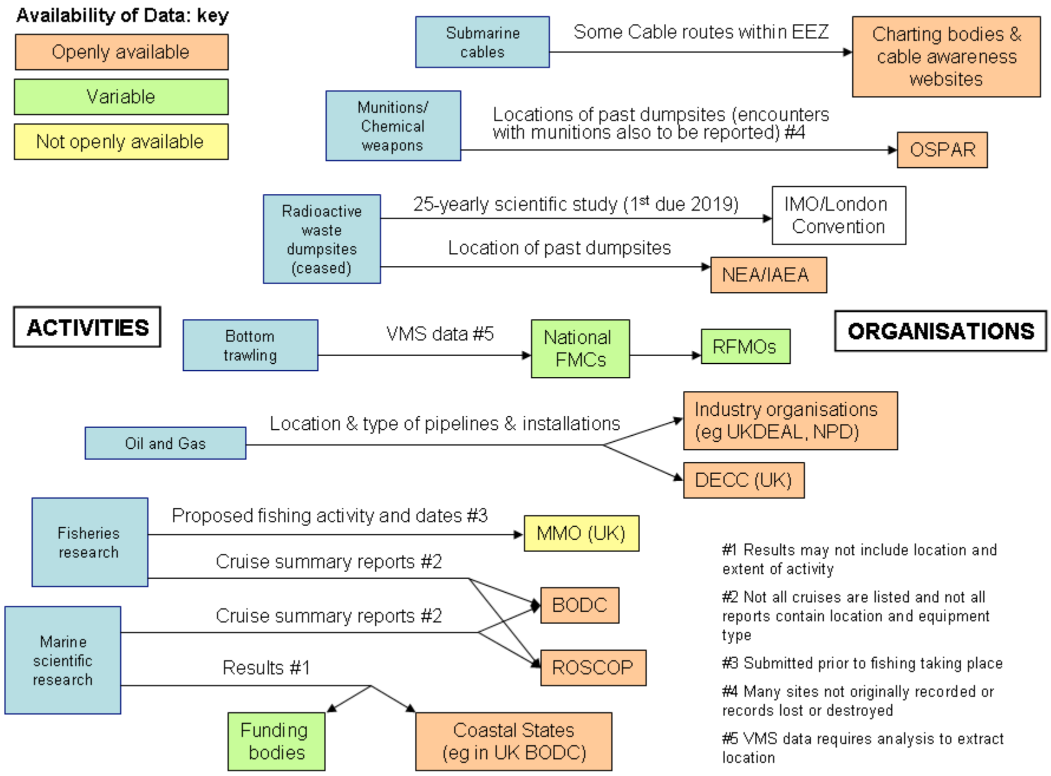

Figure 4.1 Organisations to which data on the location of human activities have been, are or will be reported at a future specified date and data availability. (See text for explanation of acronyms).

Knowledge of the location and extent of human activities in the marine environment is fundamental to the ecosystem approach to management (Eastwood, et al., 2007; Halpern et al., 2008; Lester et al., 2010). This study has found that the legal and regulatory frameworks set up internationally, regionally and nationally require some element of reporting for all of the human activities included in this study (Table 4.3 and Figure 4.1). The details of these requirements are determined either by the custom and practice of each industry or to fulfil requirements laid down by current laws and regulations. However, these relate mainly to resource allocation and management or to the separation of interests. None of the reporting regimes have been established primarily to inform assessments of human activities as part of an ecosystem-based management regime. None of the reporting regimes include the details necessary to estimate the spatial extent of the activities – and consequently of their actual and potential physical impacts. It is currently only possible to derive these essential parameters through additional research and further analysis of the data. Without an understanding of the extent of human activities is it not possible to fulfil obligations requiring integrated and comprehensive assessments of ecosystems. These include assessments required by the Marine Strategy Framework Directive (EC, 2008b) and the UN Regular Process (UNGA, 2002).

The reporting regimes for each activity are now discussed. Where applicable, changes to the current reporting regimes are proposed which would allow the specific location of activities, and not simply the area designated for activities, to be mapped and the spatial extent of each activity to be estimated based on the information provided.

4.4.1 Marine scientific research including fisheries research

UNCLOS requires information from foreign cruises within a State's waters to be reported to that State. Other than requirements that may be imposed by funding bodies, no other compulsory reporting requirements appear to exist for this activity.

Within the UK, MEDIN[66] and, more broadly within Europe, SeaDataNet[67] and EMODNET[68,69] are beginning to address the problems of fragmented and incompatible biogeochemical marine data. However, while these cover scientific data they do not specifically include the location and spatial extent of the research activities.
The location of marine scientific research activities on the seafloor can be derived from station lists (held in online databases or in hyperlinked cruise reports). This study found data recorded in a variety of formats ranging from:

i) station number, the type of measurement, description of equipment, position (latitude and longitude), water depth, time/date and institution responsible, to
ii) a brief description of the cruise (project, chief scientist, cruise dates, area of cruise, institute, ship and objectives).

The detail in the latter example is insufficient for either mapping or estimating the spatial extent of the activity. The former would be adequate for mapping the location of each sampling event. The spatial extent of the activity could be estimated based on the method described in Chapter 2. Alternatively, it is recommended here that the footprint of gear, for example width of trawls and dredges, the area of seafloor covered by corers and grabs should be included in station lists.

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[66] MEDIN: http://www.oceannet.org/

[67] SeaDataNet: http://www.seadatanet.org/

[68] EMODNET pilot portal for chemistry: http://www.emodnet-chemistry.eu/portal/portal/

[69] EMODNET pilot portal for hydrography: http://www.emodnet-hydrography.eu/

A requirement by funders for the use of a standardised format for station lists has the potential to improve accountability, usefulness and efficiency.

Although data were publically accessible, the station lists were held in a number of different databases (see Figures 2.1 and 4.1), impeding a comprehensive search. A further issue was that, even though some cruises were listed in the databases, no data were available two years after the cruise took place. To ensure that data are made available, funding should be dependent upon data from cruises being made available in a standard format within a set time limit.

4.4.2 Submarine cables

For navigation purposes the routes of submarine cables are currently included on charts of waters on the continental shelf (Figure 4.1). However, charts covering the deep sea do not include cable routes. Information on all submarine cables, including those currently in service as well historical cables is held by commercial organisations which charge for access to these data.

Historically, with the exception of ship wrecks and dumping of waste, there were no human activities which could impact on cables in the deep sea. However, the expansion of scientific research, oil and gas exploration and exploitation and bottom fisheries and mining for minerals mean this is no longer true.

Submarine cable route data should be made available free of charge for ecosystem management and scientific research. Information about the cable type (armoured or non-armoured) and the method of cable-laying (cable buried in the seafloor or unburied) should also be included.

4.4.3 Dumping of waste

Dumping of radioactive waste and munitions is no longer permitted in the deep sea. While OSPAR holds a centralized dataset listing encounters with munitions (OSPAR, 2009c) there is no equivalent dataset for reporting encounters with containers of radioactive waste. The locations of designated dumping areas have been documented and occasionally the coordinates of individual dumping events have been reported (NEA, 1985), however the precise location of much of this material is unknown.

Previously there has been little likelihood of encounters with radioactive waste as most dumpsites were in water depths beyond the reach of human activities other than cable-laying. Now, with increasingly sophisticated equipment extending the depth range of marine scientific research, such encounters are more likely. Most encounters with this material are likely to be in areas beyond national jurisdiction. It is recommended here that locations of encounters or observations of radioactive waste containers should be reported to OSPAR via a similar process to that in use for encounters with munitions and held on an accessible database.

4.4.4 Oil and gas industry

There are, as yet, no oil and gas activities in areas beyond national jurisdiction in the North East Atlantic. Detailed information on the oil and gas industry, including the location of wells, installations and pipelines, in UK waters is recorded and is readily accessible via an industry website[70]. In Norway detailed oil and gas industry information is held on a publicly accessible government website[71]. The footprint areas of installations or cuttings piles on the seafloor in the UK or Norway are not recorded in the UKDEAL or NPD datasets. However, in the UK, Environmental Statements require the design and size of the activity to be reported. Environmental Impact Regulations require that public notices are placed in The Independent newspaper and relevant named, local newspapers stating where these reports can be obtained or viewed. Estimates of the spatial extent of this activity are problematic as the footprint of each installation and associated cuttings pile varies. A generic footprint for cuttings piles and for each type of installation has been applied in assessments of spatial extent (Benn et al., 2010 and Eastwood et al., 2007). While the true spatial extent on the seafloor of individual installations and cuttings piles would allow a more accurate estimate of the spatial extent of this activity, in the absence of the actual footprints, these standard generic footprint areas should be adopted.
The UK Deal data format includes the diameter of each pipeline within the pipeline dataset. However, the diameters of Norwegian pipelines are not included within the datasets but are reported individually in the annually published *NPD Facts*[72]. It is recommended here that this information should be included in the pipeline dataset so that the spatial extent of pipelines can be estimated.

Cuttings piles, installations and pipelines represent only part of the footprint of the oil and gas industry on the seafloor. For example, rock placements, not currently included in datasets, are built to protect and support pipelines and can comprise thousands of tonnes of rock transported from onshore[73] and may extend tens of metres on either side of sections of a pipeline (BP, 2001).To enable a more comprehensive estimate of

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[70] United Kingdom Digital Energy Atlas and Library: www.ukdeal.co.uk

[71] Norwegian Petroleum Directorate: www.npd.no

[72] http://www.npd.no/en/Publications/Facts/Facts-2010/

[73] http://www.pennenergy.com/index/petroleum/display/118467/articles/offshore/volume-61/issue-8/news/netherlands-iceberg-scours-intensify-scope-of-sgard-rock-dump-program.html

the spatial extent of oil and gas activities, the location and extent of rock placements and other ancillary features and equipment should be included in datasets.

4.4.5 Bottom trawling

Information to identify which type of gear is being used by a fishing vessel and the locations at which the gear is being deployed is currently not available from Member States or NEAFC. Gear type is legally required to be recorded in vessel log books but not in VMS datasets. Vessels licenced to fish for deep-sea species are also legally required to record in their electronic logbooks the number of fishing operations in twenty four hours and the number of hours the gear was deployed for. However only vessels fishing with static or fixed gear are legally required to record in their electronic log books the location and time of shooting and hauling of their gear. Electronic log books contain a wide range of information which could inform the planning of marine protected areas, enable more accurate estimates of the extent of fishing activities and allow the impacts of bottom trawling to be assessed. However, access to log books is restricted by commercial confidentiality.

In the absence of complete information, the only method to estimate the location and spatial extent of bottom trawling is analysis of VMS data, although the current transmission frequency and content limit interpretation. The activity of vessels in relation to the seafloor contours and the vessel speed are the most important parameters.

In 2009, in response to a request from NEAFC to evaluate the use and quality of VMS data and records of catch and effort for providing information on the spatial and temporal extent of current deepwater fisheries in the NE Atlantic, ICES reported that the quality of the data was not yet sufficient to provide information on the spatial and temporal extent of current deepwater fisheries in the NE Atlantic (ICES, 2009).The current two hourly (in European waters) and hourly (in the NEAFC Regulatory Area) transmission periods for VMS signals are not sufficient to identify the detailed vessel activity. The length of time between consecutive transmissions allows for a wide range of activity between signals which would not be picked up in the data. Half-hourly transmissions would provide a more detailed resolution for identifying a vessel's movements. More frequent signals, for example every 10 minutes, would provide greater detail of a vessel's route, although this would (anecdotally) "swamp" the existing system. This suggests that improvements to the existing system or a new system should be installed and able to handle increased data.

If log books, which report gear type, are not made available for analysis, then VMS data should indicate the type of gear deployed. Log books, if available, or VMS data, should include the size of gear being deployed. In the case of trawlers, this would be the distance between trawl doors. This information would end the need to infer the gear type from speed profiles and the relationship between vessel activity and seafloor contours.

Log books, if available for analysis, or VMS data, should record the locations at which gear is deployed. In the case of bottom trawling this would indicate locations of shooting and hauling the net. This would allow a more accurate estimate of the spatial extent of this activity.

A system to record the shooting and hauling of gear integrating RFID (Radio Frequency Identification) technology with VMS datasets is currently (2011) being developed and tested on five inshore vessels in the West of England. The VMS system uses mobile phone technology as a means of reporting vessel positions and was instigated by inshore fishermen concerned that the introduction of special areas of conservation (SACs) could limit access to their fishing areas. The inshore VMS system would give assurance that vessels were not fishing in sensitive areas. The system can transmit vessel positions as frequently as every four seconds. While this allows a detailed picture of fishing activity the cost of such frequent transmissions using satellite technology would be prohibitive. A current limitation of the present RFID system is that vessels operating more than 15 miles offshore are out of GPRS range. However, a second hybrid version of the system will become available in April 2011 which combines mobile phone and satellite technology and will be viable for monitoring high seas fisheries (Richard Caslake, Seafish, personal communication). It is recommended here that the hybrid system be considered as a requirement for use in the high seas.

As described in Chapter 3, VMS data are considered by the fishing industry to be commercially sensitive. However it is recommended here that anonymized VMS data should be made routinely available for ecosystem management and scientific research.

It is apparent from the above discussion that the collection and dissemination of data is a significant barrier to ecosystem-based management of human activities. Identification of comprehensive and valid data sources was a major barrier for the North West and North East Atlantic studies.

4.4.6 The need for a meta-dataset

Since the original study of human activities in the North East Atlantic was undertaken MEDIN, EMODNET and SeaDataNet have been established and are addressing problems of the fragmentation and incompatibility of marine data within the UK and Europe. These websites act as focus for marine data and provide portals and links to oceanographic, atmospheric and geological data as well as marine scientific research cruise reports and station lists. This enables extensive access to marine biogeochemical data. However, access to data relating to human activities on the seafloor is less well documented and more fragmented. A single meta-dataset containing links to public authorities, institutions, organisations and private companies holding valid and current data on the location and, where possible, the extent of human activities is essential. Knowledge of the location and extent of human activities is fundamental to fulfilling international and regional obligations to implement an ecosystem-based approach to management. There should be a requirement for industries to report not only the location but also the extent of their activities. The requirement for such basic data appears to have been overlooked. For data relating to the North East Atlantic, OSPAR would be a suitable organisation for housing such a meta-dataset, particularly as OSPAR Contracting Parties already monitor and assess the state of the environment and the impacts of human activities in the North East Atlantic. Such metadata should list the data source, data controller, a link to the relevant data providers, a description of the content, the format in which the data are held, the confidence limits and any uncertainties associated with the data, the area covered and any conditions which apply to data use.

4.4.7 Marine spatial planning

Ecosystems, natural resources and the human activities affecting them are place-based. Consequently, all policies and management strategies for human use of ecosystems and their resources will inherently have a spatial and temporal dimension and need to be looked at from a spatial and temporal perspective (Douvere, 2008). While a number of MSP projects within individual Member States have been undertaken (for example the Irish Sea Project (JNCC, 2004), within the Netherlands (IMPNS, 2005) and Belgium (Maes, 2005) there is currently no attempt to undertake marine spatial planning beyond national jurisdictions, in the high seas and the deep sea of the North East Atlantic.

Human activities in the deep sea are not static. The extent of each activity will fluctuate over time and the locations will alter depending on the depletion or availability of resources and developments in technology. It is recommended here that a comprehensive map of human activities in the North East Atlantic should be developed as an on-going process. Such spatial planning should be combined with an estimate of the spatial extent of each activity. This is an important underpinning of governance, enabling policy review and development. Mapping and estimates over time would enable trends in the spatial extent of activities to be identified as well as any changes in the locations in which activities are taking place. Ideally the addition of data would be done in real-time with information being updated as, for example, submarine cables were laid, oil and gas pipelines and seafloor installations were completed and marine scientific research cruise data were filed. However, there is currently no quick and simple way to add bottom fishing activities to such a map or to estimate the extent of this activity as current VMS data, if available, require lengthy filtering and analysis to extract this basic information. The recommendations made earlier in this chapter regarding VMS data would improve this process. Where real-time reporting is impracticable, it is recommended here that VMS data should be made available for mapping within one month of the activity occurring.

Ardron et al., (2008) point out that in the high seas obligations to protect and conserve the marine environment are not being met – despite the ongoing depletion of resources. They suggest that this is brought about by a range of factors including fragmented governance regimes, lack of a common mandate - even within individual industry sectors, a lack of legal capacity and, in some cases, a lack of political will. Marine spatial planning is proposed as a possible solution, particularly for the high seas, where data gaps obstruct conventional management approaches (ibid.). Such spatial planning for the deep sea would not be without its difficulties. It would have to accommodate a multiplicity of jurisdictions and interests including in the high seas in areas beyond national jurisdictions. Ardron et al., (2008) suggest that conventional management options in the high seas are difficult to enforce but, with some institutional reforms, marine spatial planning is a practical way forward.

4.4.8 Implementing the key principles

The key principles listed in Tables 4.1 and 4.2 which are of particular relevance to this thesis are i) the ecosystem-based approach, ii) the precautionary principle, iii) improved access to environmental information and iv) a commitment to transparency. These principles raise fundamental questions about the need for data and their management.

The ecosystem-based approach requires information on the social, economic and environmental sectors (Laffoley et al., 2004) and this should be timely. Implementation of the precautionary principle demands the location, extent and timing of activities to be known - even if there is inconclusive evidence of a causal link between an activity and environmental damage.

Improved access to information and a commitment to transparency, defined by Mol (2010) as "the disclosure of information" both raise questions of exactly who should be allowed access to information and for what purposes? Also, what information and which aspects of activities are covered by the legislation? And, should provision of information be free of charge? A further question raised is, if information is required to be made available to a wider community beyond the industry-sector then what is such information likely to be needed for? Also, would the current data-collection and formatting support these external requirements? If not, should additional data be collected or the format changed to allow a wider use?

Table 4.4 summarises the recommendations suggested by this study for each activity.

Table 4.4 Summary of recommendations for each activity

Activity	Recommendations
All activities	• Development of a metadata set listing the sources of data on human activities, a link to the relevant data providers, a description of the content and format in which the data are held, the confidence limits and any uncertainties associated with the data, the area covered and any conditions which apply to data use • Development of a map showing the location of human activities in the deep North East Atlantic • The right to carry out an activity should be dependent on complying with the associated obligations
Marine scientific research	• Standardised format for station lists • Requirement to make data available within a specified period • A comprehensive database for North East Atlantic cruises
Submarine cables	• Routes of all submarine cables should be available free of charge for ecosystem management and scientific researchers • Details of the type of cable and whether buried or non-buried should be included
Radioactive waste	• Locations of encounters or observations of radioactive waste containers should be reported to OSPAR via a similar process to that in use for encounters with munitions and held on an publically accessible database
Munitions and chemical weapons	• Continuation of OSPAR database of encounters
Oil and gas industry	• Inclusion of footprint area of installations in datasets • Inclusion of diameter of pipelines in NPD dataset • Inclusion of rock placements and other ancillary features and equipment together with their footprint areas should be included in datasets
Bottom trawling (and other Methods of bottom-fishing)	• More frequent transmission of VMS data – ideally every 10 minutes • VMS data to be made available within 1 month of transmission • The type and size of gear being used should be included in VMS data • The location of shooting and hauling of gear should be recorded in VMS data • Development of the hybrid VMS system for all vessels fishing on the high seas • Anonymized VMS data should be available for scientific research and ecosystem management

For the ecosystem-based approach to be effectively translated from a guiding theory into practice these questions need to be answered. Despite becoming the dominant approach to management of natural resources and the environment (Olsen et al., 2006), there is a danger that, in practice, commercial interests will still be allowed to outweigh environmental ones. Currently, only public authorities are bound by European environmental information disclosure legislation. This issue is addressed further in Chapter 5.

While the instruments and agreements in Tables 4.1 and 4.2 promote, at least in theory, the concept of improved data access and transparency and the application of the precautionary principle and the ecosystem approach, in practice little or no guidance is given is about how this is to be achieved. Gjerde, (2008) describes the absence of international and regional mechanisms and instruments to ensure the consistent application of these principles and the lack of detailed international rules and standards to implement modern conservation principles for existing activities. A finding of this study is that what guidance is given is open to interpretation. This finding is supported by Mason (2010) who finds that disclosure of information is limited by the discretion and interpretation accorded to the parties holding information.

Attitudes to data collection and data access vary between sectors as do the underlying reasons for holding data on the locations of activities. This study found that no data were collected specifically for ecosystem-based management. Figure 4.1 shows that some data are collected and held as a record of where an activity has taken place albeit with varying accuracy and completeness – for example marine scientific research and past dumping at sea of munitions and radioactive waste. Other datasets, for example submarine cable route data, indicate the current location of at least part of the activity[74].

The oil industry and fisheries are both extractive activities. Their data, which indicate the location of sites of potential commercial interest are valuable. However, there is a difference in the degree of transparency between the industries. The commercial sensitivity of the hydrocarbon industry is well regulated by a series of steps in the licencing process. The licencing process for hydrocarbon exploration and exploitation is open to scrutiny. Permissions are dependent upon environmental impact assessments. Data showing the location of installations are in the public domain. In contrast, the location of fishing activities has been determined through custom and practice. The actual location of fishing activity is considered traditionally to be commercially sensitive and not specifically covered in licences – which are allocated according to fish-stock management requirements.

[74] Not all cable routes are included on the publicly available datasets.

Fishing is generally 'open access' which results in a race to fish. As a consequence, access to fisheries data and in particular data about fishing location, for example VMS data, is restricted. This is an important issue which underlies VMS data availability. Legal and confidentiality constraints often make access to these data problematic (Gerritsen and Lordan, 2010). Cacaud (1998) suggests that, because of their commercial value, it could be argued that VMS data should be afforded a higher level of protection.

A further important consideration is the balance between short-term commercial interests and gains of an industry against the wider, long-term collective interests of society in general. Gjerde in UNEP (2006) points out that the lack of consideration for the effects of economic activity on habitats and ecosystem services may create long-term costs greatly exceeding the short-term economic benefits of unsustainable exploitation and use. She proposes the need for policies that achieve a balance by protecting ecosystem services while pursuing economic development.

The effects of marine scientific research, with a few exceptions for example at the most visited hydrothermal vents (Glowka, 2003) and ocean fertilization (Güssow et al., 2010), are not generally perceived as a serious long-term threat to the environment. Similarly, laying submarine cables on the deep-sea floor is considered to have only negligible, short-term effects (Carter et al., 2009). The potential for serious, extensive, long term impacts arising from the oil and gas sector are evident (Jernelov, 2010). The Deepwater Horizon spill in the Gulf of Mexico highlighted questions about the environmental and financial accountability of the offshore industry within Europe. In October 2010 The European Commission issued a Communication (EC, 2010b) resolving to address the fragmented environmental and safety management regimes, and the licencing process, to review the current financial security and accountability arrangements and to improve public engagement and the responsibility of the offshore industry in Europe.

In contrast to the very obvious risks to the environment associated with the hydrocarbon industry, the long-term damage and the full extent of fishing activities and their impacts are only now emerging (Hall-Spencer et al., 2002; Freiwald et al., 2004; Althaus et al., 2009; Bailey et al., 2009; Benn et al., 2010; Priede et al., 2011). Management of the fisheries sector has evolved through custom and practice over many years and still carries with it baggage from the past. Images of fishermen battling against the elements persist. However, while this is true in some instances, the image does not fit with large-scale industrial deep-water trawlers equipped with the most modern fish-finding devices and advanced sonar equipment capable of remaining at sea for months at a time.

Pauly, (2009) proposes that to continue the ‘business as usual’ scenario for fisheries will lead to the transformation of marine ecosystems into dead zones. His alternative is to implement a more balanced ecosystem-based management approach taking into consideration a wider range of stakeholders than the fishing industry alone. However, incentives, other than legal obligations, for the industrial deep-water fishing industry to comply with such a proposal are difficult to identify. In the absence of compliance, “the tragedy of the commons” described by Hardin, (1968) seems likely to prevail. One solution proposed here is that in future the ‘right’ to fish should be directly linked with an obligation to transparency allowing an integrated ecosystem-based approach to management.

Olsen et al. (2006) identifies a paradigm shift in management towards ecosystem-based management of natural resources. However, it is suggested here that this would also require a paradigm shift in industry attitudes away from short-term sectoral interests to a broader more open approach. Transparency is an essential component of such a shift. Strengthening the linkages between the right to carry out an activity and the corresponding obligations may be a way to ensure that compliance with the key principles identified in this chapter is achieved.

5 Availability of VMS and Environmental Data

5.1 Introduction

It has been shown in earlier chapters that the uses of fisheries data should no longer be restricted to the fishing industry. Chapters 2, 3 and 4 have highlighted the importance of fishing vessel VMS data in broader, ecosystem-based management and its significance to wider marine scientific research, in the planning of protected areas and for identifying areas for effective fisheries closures (Hiddink et al., 2006; Davies et al., 2007; Eastwood et al., 2007; Hall-Spencer et al., 2009; Benn et al., 2010). Chapter 2 has described the process for analysing VMS data while Chapters 3 and 4 explained the limitations in the quality, completeness and availability of the data. This chapter defines ‘environmental information’ and argues that VMS data fall within this description. It goes on to describe existing European regulations relating to environmental information and limitations. It concludes by describing the responses to requests for VMS data made to twenty one Member States citing European Council Regulation (EC) No. 199/2008 which covers, *inter alia*, the collection, management and use of data in the fisheries sector.

The spatial distribution of important ecosystems, the intensity and location of impacts as well as the responses of the human and non-human components to the combined effects of these impacts are essential for effective ecosystem-based management (Lester et al., 2010). As has been shown in earlier chapters, bottom trawling is the most extensive of the human activities included in this thesis, covering an area of seafloor in the North East Atlantic at least an order of magnitude greater than all the other activities combined. Restrictions placed on access to VMS data, analysis of which can indicate the location of fishing activities, present a major barrier to the effective implementation of ecosystem-based management as well as the planning of closed areas and MPAs. The knock-on effect of such a lack of VMS data is illustrated by ICES’ (2010b) comment in relation to vulnerable deep-water habitats in the NEAFC Regulatory Area, that as no new (post 2006) VMS data on fishing activity of vessels operating within the NEAFC regulatory area were made available to ICES, then no new advice could be provided. This has serious consequences for governance and management, delaying and possibly preventing timely decision-making.

Lack of access to VMS data also presents a significant and widely experienced barrier to a range of marine science research activities (Jeff Ardron, Marine Conservation Biology Institute, personal communication; Kerry Howell, University of Plymouth, personal communication). Where the detailed location of fishing activities is necessary for research, for example to identify potential conflicts between vulnerable marine ecosystems and bottom fishing or mapping and estimating the extent of deep-water bottom fishing, work has been delayed by the lack of access to VMS data.

It has already been established in previous chapters that information on human activities is an essential prerequisite of the ecosystem approach (Eastwood et al., 2007; Halpern et al., 2007a; Lester et al., 2010). In the following sections it is shown that human activities, and in particular, VMS data fall clearly within the definition of 'environmental information'. Within the European Union access to environmental information and fisheries data is controlled by a variety of instruments, including the Aarhus Convention and its associated Regulation and Directives and EC Regulation 199/2008. These are now discussed.

5.1.1 The Aarhus Convention

On 25 June 1998 the European Community adopted the United Nations Economic Commission for Europe (UNECE) Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (Aarhus Convention) (UNECE, 1998)[75]. The Convention came into force on 30 October 2001. The objective of the Convention (Article 1) is "to contribute to the protection of the right of every person of present and future generations to live in an environment adequate to his or her health and well-being, each Party shall guarantee the rights of access to information, public participation in decision-making, and access to justice in environmental matters in accordance with the provisions of this Convention".

Regulation (EC) No. 1367/2006 (Aarhus Regulation), which applies the Aarhus Convention to Community institutions and bodies, was adopted in September 2006 (EC, 2006b). Institutions and bodies are required to adapt their internal procedures and practices to the provisions of the Regulation which requires them to provide for public participation in the preparation, modification or review of "plans and programmes relating to the environment". The Commission published two Directives designed to align Community legislation. Directive 2003/35/EC (EC, 2003d) and Directive 2003/4/EC (EC, 2003c), adopted in 2003, address two of the key themes of the Convention i) public participation in environmental decision-making and ii) public access to environmental information respectively. This thesis addresses the latter, public access to environmental information.

The definition of environmental information given in the EU Regulation is the same as that in the Convention itself apart from the additional reference in the Regulation to 'coastal and marine areas'. The definition in the Regulation (Article 2(d)) includes "any

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[75] As of 19 August 2010, there were 44 Parties to the Convention.

information in written, visual, aural, electronic or any other material form" on*, inter alia*:

"(i) the state of the elements of the environment, such as air and atmosphere, water, soil, land, landscape and natural sites including wetlands, coastal and marine areas, biological diversity and its components, including genetically modified organisms, and the interaction among these elements;

(ii) factors, such as substances, energy, noise, radiation or waste, including radioactive waste, emissions, discharges and other releases into the environment, affecting or likely to affect the elements of the environment referred to in point (i);

(iii) measures (including administrative measures), such as policies, legislation, plans, programmes, environmental agreements, and activities affecting or likely to affect the elements and factors referred to in points (i) and (ii) as well as measures or activities designed to protect those elements."

It is argued here that point iii) covers VMS data which is "information in … electronic form" on an activity, namely fishing, "affecting or likely to affect the elements … referred to in points (i) and (ii)", namely marine areas, biological diversity and its components (EC, 2008e).

While the Aarhus Convention is laudable for increasing rights of access to environmental information and establishing more transparent and accountable regulatory processes there are limitations to its effectiveness (Mason, 2010). One limitation created by the interpretive discretion accorded to Parties is the dilution of the information rights granted by the Convention. Parties may exercise discretion in disclosing information – including the conditions under which disclosure can be refused. These include reasons of national defence and security, commercial confidentiality and personal data protection (Mason, 2010). A further limitation of the Convention is that, as the Convention applies to public authorities, private entities are excluded from the mandatory duty to disclose information (ibid.). Additionally, Article 4.2(d) of Directive 2003/4/EC sets out various exceptions to implementing the Regulation which include confidentiality of commercial or industrial information. Research during the preparation of this thesis and also that of other researchers has shown that confidentiality of data is frequently cited as the reason for withholding VMS data (Gerritsen and Lordan, 2010).

5.1.2 Fisheries data

While the Aarhus Convention and its associated Regulation and Directives address environmental information in general, a more focused instrument specifically addressing fisheries data is Council Regulation (EC) No 199/2008 (EC, 2008c). This was subsequently implemented by Commission Regulation (EC) No 665/2008 (EC, 2008f).

Regulation (EC) No 199/2008 establishes a framework of multiannual Community programmes together with rules on the collection and management of biological, technical, environmental and socio-economic data relating to the fisheries sector (Article 1(a)). Member States must adopt national programmes on the collection and management of such data and, when doing so, must comply with the provisions laid down in this Regulation. The Regulation establishes rules covering the transmission and use of data concerning the fisheries sector in the framework of the Common Fisheries Policy (CFP) for the purpose of scientific analysis (Article 20). The Regulation aims in particular at the improvement of the scientific advice needed for the implementation of the CFP. However provision for sharing data with the scientific community is also indicated (Preamble, 13) and it was considered that this Regulation would offer improved access to data for the scientific community (Poul Degnbol, DG MARE, personal communication).

Regulation 199/2008 covers the provision of VMS data for the following reasons:

Article 2 provides definitions of terms used within the text of the Regulation. Those of particular relevance to this chapter are summarised below together with an explanation of how they may be applied to VMS data:

- "'Primary data' means data associated with individual vessels, natural or legal persons or individual samples" (Article 2(e)). The VMS data transmitted by each vessel is data associated with an individual vessel.

- "'Detailed data' means data based on primary data in a form which does not allow natural persons or legal entities to be identified directly or indirectly" (Article 2(g)). This relates to VMS data from which information allowing the identification of individual vessels has been removed, for example a vessel's Community fleet register (CFR) number or international radio call sign (RC). Following further analysis of speeds and activities in relation to the seafloor contour, these are the data that can be used for mapping the location of fishing activities.

- "'Aggregated data' means the output resulting from summarising the primary or detailed data for specific analytic purposes" (Article 2(h)). Aggregated VMS data were available in response to the FOI request submitted as part of this project to the United States. This comprised the number of vessels in a 10º square in a given time period and individual vessels were not identifiable. In the UK a request for VMS data made to the MMO produced similar data. This was described as 'anonymized' rather than 'aggregated' but also related to rectangles from which the activity of individual vessels could not be identified. However, in neither case would the data be suitable for identifying the location of fishing activity nor the type of fishing.

- "'End-users' means bodies with a research or management interest in the scientific analysis of data in the fisheries sector" (Article 2(i)). In the context of this chapter this would include marine scientific research institutions with an interest in analysis of VMS data to identify the location of bottom trawling.

The Preamble to the Regulation contains two paragraphs which relate directly to broader data access:

Preamble, Paragraph 6 introduces the concept of the ecosystem approach to the Regulation and also establishes "... the need for improved quality, completeness and broader access to fisheries data ..." While expressly widening access to fisheries data this paragraph does not, however, specifically address the terms under which data will be available or to whom.

Preamble, Paragraph 13 specifies that "It is in the interest of the scientific community that data which does not allow for personal identification is available to any party who has an interest in its analysis." Again this paragraph is vague but, by implication, any party that is part of the scientific community would seem to be included. However, there is no definition of what constitutes the scientific community. Despite this lack of clarity, the paragraph implies that data that 'do not allow for personal identification' should be available 'to any party who has an interest in its analysis'. The replacement of any means of vessel identification from VMS data, for example, the radio call sign, with an anonymized identifier would prevent the identity of the vessels being disclosed.

Regulation 199/2008 is far-reaching, addressing a wide array of issues relating to fisheries data including national programmes, cooperation, sampling programmes and financial assistance. However two articles, Article 18 and Article 20, are of particular relevance to the sharing of VMS data. These are now discussed together with their limitations.

Article 18.1 states that "Member States shall make detailed and aggregated data available to end-users to support scientific analysis:

(a) as a basis for advice to fisheries management, including to Regional Advisory Councils;
(b) in the interest of public debate and stakeholder participation in policy development;
(c) for scientific publication."

The provisions detailed in parts (a) and (b) are not directly relevant for access to VMS data in the context of this chapter, although it could be argued that scientists are also stakeholders and, as such, need information to participate in policy development. However, it is suggested here that VMS data which will contribute to research to be published in peer reviewed journals would be covered by part (c) of this Article.

Article 18.2 asserts that "where necessary, to ensure anonymity Member States may refuse to provide data on vessel activity based on information from vessel satellite monitoring to end-users for the purposes referred to in paragraph 1(b)". It is argued that, by implication, while specifically asserting that VMS data can be withheld for the purposes of "public debate and stakeholder participation in policy development" it will be available for the other purposes. It is unclear why VMS data should be withheld, to ensure anonymity, solely for the purposes of public debate and stakeholder participation in policy development – and not for scientific publication. Later, Article 20.2(b) appears to contradict Article 18.1(b), by defining the time limit for transmitting detailed and aggregated data for the purposes of public debate and stakeholder participation in policy development. Presumably, these data do not break the rules of anonymity.

Article 20.3 requires that where detailed and aggregated data are requested for scientific publication referred to in Article 18.1(c), Member States:
(a) may, in order to protect the professional interests of the data collectors, withhold data transmission to the end-users for a period of three years following the date of collection of the data. Member States shall inform the end-users and the Commission of any such decisions. In duly justified cases the Commission may authorise that period to be extended;

(b) shall in case that three years period has already expired, ensure that the data is provided to end-users within two months from the receipt of the request for these data.
Article 20.3(a) provides for the protection of the intellectual property interests of the parties collecting the data allowing the opportunity to publish before other researchers. It is arguable whether this should apply to VMS data as the data are automatically generated by VMS units on each vessel and transmitted to Fishing Monitoring Centres for monitoring fishing activity rather than comprising data collected by individual researchers for a specific purpose. While the term "in duly justified cases" in the final sentence of sub-part (a) permits an extension to the period during which data may be withheld, it fails to specify what constitutes such cases and is, consequently, open to a range of interpretations by individual Member States. Additionally, while the provisions allow for i) a three-year period or, in certain cases, an even greater period to transpire (Article 20.3(a)) and for ii) a period of three years to have already transpired (Article 20.3(b)), no time limit is set for transmission of data for which no three-year withholding period is necessary.

Article 20.4 lists the only conditions under which Member States can refuse to transmit the relevant detailed and aggregated data:

(a) "If there is a risk of natural persons and/or legal entities being identified." In this case the Member State may propose alternative means that would meet the needs of the end-user while still preserving anonymity. In the context of VMS data the provision of aggregated or anonymized data would constitute alternative means. However, during the course of this thesis research showed that aggregated data were unsuitable for detailed analysis and it is suggested that anonymized data would be preferable.

(b) Where an end-user has failed to comply with obligations set out in Article 22.1. These obligations comprise:

- that data should only be used for the purpose stated in the request;
- that data sources be acknowledged;
- the responsible and scientifically ethical use of the data;
- that any problems with the data be reported to the Commission;
- member States and the Commission should be provided with references to the results;
- data should not be shared with third parties without consent of the Member State;
- data should not be sold by end-users to a third party.

(c) "If the same data are already available in another form or format which is easily accessible by end-users."

Paragraphs (b) and (c) initially seem to be reasonable obligations. However, as the process by which Member States and the Commission are to be provided with references are not specified there is a possibility that end-users may fail to meet their obligations and jeopardise future access to data.

Article 20.5 makes provision for Member States to charge end-users the actual costs of extraction and, if required, aggregation of the data before their transmission. This provision applies "where the data requested by end-users other than appropriate regional fisheries management organisations to which the Community is contracting party or observer and relevant international scientific bodies are different from those already provided to appropriate regional fisheries management organisations to which the Community is contracting party or observer and relevant international scientific bodies ..." Lack of punctuation makes the meaning of this paragraph very unclear.

5.2 Methods

Requests for VMS data for analysis to assess the extent of bottom trawling within European Community waters were made to twenty one Member States. The request also offered the opportunity to analyse the range of responses received. This allowed an overview of how Regulation 199/2008 was being applied. As regulations relating to data-access have changed over recent years the request accommodated a range of dates. It is the analysis of responses that is the focus of the following section.

During March 2010 applications for VMS data were sent by email to the twenty one Community Fishing Monitoring Centres (FMCs) listed in the European Commission Directorate-General for Maritime Affairs and Fisheries FMC contact list[76] (Table 1). FMCs were chosen as the initial point of contact for the applications for data as the Regulation did not specify where requests for information should be addressed. The reasons for selecting FMCs were: i) the email addresses for every FMC in the Community were contained in the contact list, ii) part of the remit of FMCs is to collect VMS data and iii) the FMC within each State represented a common starting point for the initial application for data. As the Regulation does not specify the language in which requests should be made, all requests were made in English, again, to provide a common starting point.

[76] FMC list: http://ec.europa.eu/fisheries/cfp/control/fmc_contact_list_en.pdf

The emails, sent from the National Oceanography Centre, Southampton, requested "detailed" VMS data to be used for "scientific publication" in accordance with Council Regulation No 199/2008.

In order to establish the availability and access to data over time, the application requested:

- Data from 2009, the first year covered by the Regulation.
- Data from 2006, to establish whether the provisions for access to data under Regulation 199/2008 would also apply to data collected prior to the Regulation coming into force. Additionally, as these data were collected more than 3 years prior to the date of the request it would test the Article 20.3(b) which provides that data collected more than three years prior to a request should be provided to end users within two months from the receipt of the request.
- Data from January to March 2010, the most current data at the time of the application.
- The application also requested that the data be provided within the "appropriate time limits" specified in the Regulation.

Table 5.1 The States to which requests to FMCs for VMS data were made.

Belgium	Bulgaria	Cyprus	[†]Denmark
Estonia	[*]Finland	[†]France	Germany
Greece	Ireland	Italy	[*]Latvia
Lithuania	Malta	[*]Netherlands	Poland
Portugal	Slovenia	[†]Spain	[*]Sweden
[†]UK			

[*]States which provided the VMS datasets requested.

[†]States that responded to the request for VMS data.

The remaining 14 States failed to respond to the request.

5.3 Results

Of the twenty one States to which applications for data were made, only four, Netherlands, Sweden, Latvia, and Finland provided the VMS datasets requested (Table 5.1). These datasets were all provided within two months of the date of the application. The formats varied between detailed and aggregated. However, the data-format was not the subject of this analysis. The only additional information required was to identify a suitable format (MS Excel, MS Notepad) and method of transmission (email attachment or CD ROM).

Responses were received from a further four States: Denmark, France, the UK and Spain. These responses revealed a range of interpretations of the Regulation which are now described.

5.3.1 Denmark

The Danish response was sent from the Technical University of Denmark, National Institute of Aquatic Resources, National Correspondent for Data Collection. It stated that Council Regulation 199/2008 related only to data for the period 2009-2013 consequently only data from that period could be requested. Data for 2010 would be available at the beginning of 2011. A further condition for the release of the data was a detailed description of the scientific project to be carried out or an extended abstract should be provided in order to "evaluate" the data required and the cost of extracting it. In addition, the names of other Member States to which applications for data had been made were requested and, subsequently, where the work might be published.

It was considered that the requirements that had to be met in order for data to be released by Denmark had been established therefore no further applications for data were made.

5.3.2 United Kingdom

The initial response from the UK, sent by the MMO, stated that, in accordance with the EU Confidentiality Obligation, Article 113 of EC Regulation 1224/2009, establishing a Community control system for ensuring compliance with the rules of the common fisheries policy (EC, 2009c), it was no longer possible to supply data from satellite monitoring systems although manually recorded data and data from air and sea patrol sightings were still available.

An examination of Article 113, EC Regulation 1224/2009 established that "applicable rules on professional and commercial secrecy" must be applied to data collected within the framework of the Regulation. Four of the seven sub-sections could apply to sharing VMS data[77]. However, in this instance the provision most likely to prevent access to

[77] Other provisions within EC Regulation 1224/2009 Article 113 which are relevant to requests for VMS data are contained Article 113.1, 2, 3 and 4 which, *inter alia*, establish that:

- data should be treated in accordance with "applicable rules" on professional and commercial secrecy of data";
- when data is exchanged between Member States permission must be granted by the Member State and authority providing the data before data can be shared with any party other than those "whose functions require them to have such access ..."

VMS data is Article 113.4(b). This provides that if disclosure of data would undermine "the commercial interests of a natural or legal person, including intellectual property" data "shall be subject to applicable rules[78] on confidentiality".

Article 20.4(a) of Regulation 199/2008 provides that "if there is a risk of natural persons and/or legal entities being identified … alternative means to meet the needs of the end-user which ensure anonymity" can be proposed. The alternative offer of surveillance data would meet this requirement.

A subsequent telephone conversation during November 2010 with the MMO indicated that VMS data would be available in an anonymized format.

5.3.3 France

The FMC acknowledged receipt of the application for data and reported that it had been passed to the "Direction des pêches maritimes et de l'aquaculture" (DCF). No further communication was received. However, following a further email to the DFC in October 2010 an email response was received in November from the national correspondent for DCF. This requested that, in order to provide the data, the application should be made by official letter stating which data were required, for which regions, the purpose of the request and what the data would eventually be used for. It was again decided that to disclose the purpose of the application could influence the decision to provide data and the application for data was therefore discontinued.

5.3.4 Spain

The first response from the Ministerio de Medio Ambient y Medio Rural y Marino was a letter, in Spanish, stating that as the language used for administration of the State was Spanish (Castilian) that unless the request was made in Spanish it would not be possible to answer the questions. As requested, the application for data was resubmitted in Spanish.

The response to this request was also by letter and in Spanish. The letter challenged the wording of the application and the authenticity of the requesting body and argued that the requirements (under Article 2(i)) of being a body "with a research or

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- data will not be used for any purpose other than that for which was provided without the consent of the authority providing the data.

[78] The rules cited within the Regulation are:

- Directive 95/46/EC, of 24 October 1995, on the protection of individuals with regard to the processing of personal data and on the free movement of such data;
- Regulation (EC) No 45/2001 of 18 December 2000 , on the protection of individuals with regard to the processing of personal data by the Community institutions and bodies and on the free movement of such data

management interest in the scientific analysis of data in the fisheries sector" were not fulfilled in the application. It further argued that the application did not specify what data were being requested and questioned the time-frame within which data should be supplied. However, while containing observations and criticisms of the wording of the application it failed to explain what information was required in order to provide the requested VMS data.

It is unclear why the remaining fourteen States failed to respond.

5.4 Discussion

EU Regulations are legally binding on all Member States. However, the findings suggest that individual Member States' interpretation and application of Regulation 199/2008 vary widely.

Regulation 199/2008, Article 20 stipulates time-limits for the transmission of data under particular circumstances. These establish that where detailed and aggregated data are requested for scientific publication Member States *may* withhold transmission for three years following the date of collection in order to protect the professional interests of the data collectors. If three years has expired, the data should be provided to end-users within two months from receipt of the request. However, no time limit is set for transmission if there is no requirement to withhold data to protect professional interests, although it would be reasonable to assume that the limit of two months would apply. The Netherlands, Latvia, Finland and Sweden supplied the data requested upon the first application and within two months of the application date.

All four States provided all the data requested: 2009 to March 2010 data (less than 3 years prior to the date of the application) and 2006 (more than 3 years prior to the application). These data were provided without charging for data extraction and aggregation – although Article 20.5 permits Member States to charge end-users for such processing.

States' interpretations of the time period to which the Regulation applies varied. The first response from Denmark stipulated that as the Regulation "only concerns data from 2009 to 2013" only data from that period could be requested. Nevertheless, data from 2006 were provided by the four States which provided their datasets. The interpretation by Denmark is questionable as Chapter IV, Article 15, Data Covered, provides that "this Chapter shall apply to all data collected: (a) under Regulations … (EC) 244/2003 …" This Regulation lays down detailed provisions regarding satellite-based Vessel Monitoring Systems. If *all* data are included, arguably this extends to data collected prior to Regulation 199/2008 entering into force. However, Article 15(b) specifically refers to data collected under the framework for Regulation 199/2008 and sub-part (i) establishes that this includes "data on vessels' activity based on information from satellite monitoring and other monitoring systems with the required format". In this case it could be argued that only data collected within the framework set up by this Regulation would be included.

While the original application for detailed data for scientific publication was sufficient for four States to provide the data requested, Denmark and later France both required more detailed information to support the application. There is no provision in the Regulation regarding the format for applications for data or how much detail is required to be given about what the data will be used for. Although EU Regulations are directly enforceable in Member States without the need to transpose them into national law the ambiguity and lack of clarity of some articles allows a range of possible approaches to implementation. There is a danger that such a lack of clarity about the criteria which must be met before data can be transmitted will result in 'value-judgements' and if a Member State finds the purpose for which the data will be used unacceptable the transmission of data could presumably be withheld.

Refusal by a Member State to transmit data is covered in Article 21. Article 21.1 refers to Article 20.3(a) which relates to data for scientific publication and refers specifically to data withheld "to protect the professional interests of the data collectors". Article 21.1 provides that if data are withheld for this reason the end-user may request the Commission to review the refusal - although the procedure for such a request is not specified. In the case that the Commission deems a refusal unjustified the Member State must supply the data within one month or risk a reduction in Community financial assistance.

Different attitudes of Members States to the implementation of Regulation 199/2008 were evident. A standardized format for data applications including the criteria to be met before data are released would go some way towards preventing such idiosyncratic interpretations.

The UK response to the application, stating that VMS data were not available due to confidentiality issues, did however offer possible alternatives. This was in compliance with the latter section of Regulation 199/2008 Article 20.4(a) "... the Member State may propose alternative means to meet the needs of the end-user which ensure anonymity". However, the alternative which was proposed would not "meet the needs of the end-user" as surveillance data are unsuitable for identifying detailed vessel activity. The question of anonymity of data is also crucial. An ongoing dialogue with MMO has resulted in agreement, in theory at least, that VMS datasets in which just the vessel reporting code is replaced with a random identifier would be acceptable for transmission.

MMO are currently (March 2011) reviewing their position re access to VMS data (Darren Sanders, MMO, personal communication).

At the time of the application for data (March 2010) the structure of marine management in the UK was undergoing changes. Since 1 April 2010 the MMO has been operational. The MMO website contains a Satellite Monitoring page[79] detailing the costs of extracting anonymous VMS data. Charges for extraction and aggregation are permissible under Article 20.5 of Regulation 199/2008. This allows that "In cases where the data requested by end-users other than appropriate regional fisheries management organisations to which the Community is contracting party or observer and relevant international scientific bodies are different from those already provided to appropriate regional fisheries management organisations to which the Community is contracting party or observer and relevant international scientific bodies, Member States may charge those end-users the actual costs of extraction and, if required, aggregation of the data before their transmission".

The fourteen remaining States on the FMC contact list failed to respond to the application for data. There are a number of possible reasons for this. One possibility is that as the request was made in English, it may not have been understood by the recipients. However, it was anticipated that, if this were the case, the FMC would reply asking for correspondence to be in their native language. One of the States which did respond specified that correspondence would only be conducted in their official language while the other seven States replied in English. Further possibilities are that i) the institution requesting the data was either not recognised or not considered as an appropriate institution to which data should be released and ii) the purpose for which the data were requested was not described in sufficient detail. However, evidence of the authenticity and status of the institution and a more detailed description of the proposed research could have been requested. Two States which did respond requested further information on the purpose of the research and one requested this information be in an official letter. If the failure to respond to a request for data can be interpreted as a refusal to supply data then it would be possible to pursue this via Article 21 - review of refusal to provide data. This allows that, following an opportunity

[79] MMO Satellite Monitoring: http://marinemanagement.org.uk/fisheries/monitoring/satellite.htm

to provide reasons to the Commission for failure to comply with a request, Community financial assistance may be reduced if data are not supplied.

It can be seen from the responses that although the applications for data were made to the FMCs in each Member State some of the applications were forwarded to other government departments. At the start of this study it was not clear to where in each Member State applications for VMS data should be addressed. A clearly defined contact point and clearly defined responsibility within each Member State for processing applications for VMS data together with a formalised format for applications would improve accountability and may improve the provision of these data from, for example, the Members States who failed to respond. The existing random and piecemeal approach to data access is inadequate to meet the requirements of Regulation 199/2008 and the provision of fisheries data "to any party who has an interest in its analysis".

Within the text of Regulation 199/2008 there are some terms which are not clearly defined and so open to interpretation. There is, for example, no definition of the term 'scientific publication'. One, more specific, definition of this could be 'peer-reviewed journal'. There is no indication of what constitutes "any party who has an interest in its analysis" and the wording of the definition of 'end-users' is open to interpretation. It is unclear whether "bodies with a research or management interest in the scientific analysis of data in the fisheries sector" means data are only available to end-users if they are from within the fisheries sector. This seems to be in contradiction to the one of the principal aims of the Regulation which is to make fisheries data available to the wider scientific community (Preamble, paragraphs 6 and 13). An alternative, less ambiguous, wording would be "bodies with a research or management interest in the analysis of data *from* the fisheries sector". Additionally, the inclusion of a phrase stating that data should be made available for whole ecosystem management would clarify that non-fisheries bodies may also have access to such data. Further clarification is also needed to more clearly define the types of end-user to which data can be released. Does this include academic institutions, research institutions, other industry sectors?

There is a danger that without improved clarification selective interpretation of this Regulation will prevent these data being available to the wider scientific community and in a timely way.

There is detailed and extensive guidance for States on the implementation of the Aarhus Convention and the associated secondary legislation[80] as well as guidance, for the general public, on the Aarhus Regulation[81]. However, there is no guidance for the implementation of Regulation 199/2008 and no process by which good practice can be shared. A process to identify which Member States are implementing both the spirit and the letter of this Regulation and guidance on how this should be achieved is required. This could be similar to the Aarhus process and guidance. While deterrents for failure to provide data under the terms of Regulation 199/2008 are set out in the text it is not possible to judge how effective these are. It is difficult to see what incentives could encourage administrations to comply.

5.5 Conclusions

While the underlying ethos of both Regulation 199/2008 and the Aarhus Convention is the sharing of information, this study found that barriers to VMS data-access remain. Member States' interpretations of the Regulation and its implementation varied. A standardised format for environmental data requests and an indication of what constitutes an acceptable end-user and an acceptable use of such data would limit the individual interpretations of this legislation. It is questionable whether some Member States recognise the spirit of the Regulation which is to broaden access to fisheries data.

Barriers to data access are further compounded by the limitations to the implementation of the Aarhus Convention, described by Mason (2010). He proposes that the exclusion of the private sector from mandatory duties to disclose information and the discretionary authority granted to Parties has resulted in a narrower implementation of the legislation than the letter or spirit of the Convention. Further, he suggests that the right to commercial confidentiality as a justified basis for withholding information has diluted the force of obligations under the Convention.

Currently the traditional sector-based approach to management still appears to prevail and there is a marked unwillingness to disseminate data beyond the fisheries sector. There appears to be no incentive for administrations to comply with requirements set out in the legislation. Despite the European Commission's stated commitment to disclosure of information (EC, 2006b; 2008c) and the implementation of the ecosystem approach (EC, 2007a), the effectiveness of legislation to promote data access will continue to remain limited unless there is a radical shift in thinking which moves away

[80] UNECE Aarhus Convention: http://www.unece.org/env/pp/

[81] Guidance for the general public on the Aarhus Regulation : http://ec.europa.eu/environment/aarhus/pdf/guide/AR%20Practical%20Guide%20EN.pdf

from the prioritisation of commercial secrecy over the wider needs of ecosystem-based management.

5.5.1 Update

In May 2010, ICES (2010c) reported the results of a questionnaire sent to EU Member Sates by the Working Group of Data and Information Management (WGDIM). The questions, framed in terms of the obligations of the EU data collection framework EC Regulation 199/2008), related to the provision of VMS data to ICES and included i) whether policy for provision of VMS data to end-users existed in each State, ii) whether standardized formats for data exchange existed, iii) whether the requirement to provide anonymized VMS data under the Regulation was considered to override or to be subordinate to data protection, freedom of information, human rights (for example regarding intrusive surveillance) and commercial confidentiality legislation. Interestingly, out of fifteen Member States contacted, only six replied.

A summary of results indicated i) that, with only a couple of exceptions, there appeared to be no formal policies governing provision to VMS data to ICES, ii) States referred to the need to follow “the legal requirements” and iii) access would be negotiated on a case-by-case basis. It was suggested that the different responses indicated that data protection principles and regulations will create “shades of grey” about access to VMS data. A selection from the Member States’ responses included that i) data should only be requested by the EC, ii) that it only applied to data collected within 3 years of the request, iii) that access had to be negotiated with the fisheries department and iv) that a fully-reasoned formal enquiry would be responded to.

These questions were framed in the context of the provision of VMS data specifically to ICES. Nevertheless, their responses support the findings of the current study, namely, that this Regulation is open to a wide range of interpretations between States and implementation is inconsistent and piecemeal. It also appears from the low response rate both to the ICES questionnaire and the current study that this Regulation is not accorded much importance.

ICES is currently in the process of developing databases for VMS data. While still only in the discussion stage it is hoped that this initiative will help research groups who are having difficulty accessing these data.

6 Key Findings and Recommendations

6.1 Overview

This thesis has addressed the questions: "What is the extent of human activities on the seabed of the North East Atlantic?" and "Do we have sufficient data on human activities for effective governance and sustainable management of deep-sea ecosystems?"

The hypothesis tested is that "We have sufficient information on human activities to enable the effective implementation of ecosystem-based management in the deep sea".

In answer to the first question the research found that human activities on the deep-sea floor of the OSPAR area of the North Atlantic are extensive but there is a wide variation in the spatial extent of each. It was noted that while some activities have an immediate impact, after which seafloor communities could re-establish (Kogan et al., 2006), other activities can continue to make an impact for many years (Althaus et al., 2009) and the impact may extend far beyond the physical disturbance (Charmasson, 1998). Additionally, while some impacts may be reversible over a relatively short time period, for example the removal of submarine cables (Carter et al., 2009), others, such as bottom trawling on seamounts and other hard-bottom communities, are likely to be irreversible (Rogers, 2004). The irreversibility of an impact is an important consideration in the application of the precautionary principle.

The results showed that in the deep North East Atlantic the relative spatial extent[82] of non-fisheries scientific research (9 km^2), submarine communication cables (61 km^2) and waste disposal (1.6 km^2) was low while the spatial extent of oil and gas activities (23.2 km^2) and fisheries scientific research (49 km^2) was moderate. However, the spatial extent of bottom trawling, with the overlapping vessel tracks merged, even based on the minimum gear size and the narrowest speed range (1,096 km^2), is an order of magnitude greater than all the other activities combined. When based on the more likely gear size and speed range (27,840 km^2) it is two orders of magnitude greater than all the other activities combined.

This study was the first time that a quantification of the relative extent of human activities in the deep sea had been undertaken and the results are an important finding. Bottom trawling is arguably currently the most destructive human activity

[82] The spatial extents in this paragraph are the maximum estimated extent of each activity, where applicable, extrapolated to the entire OSPAR maritime area.

taking place in the deep sea and has been compared to clear-cutting forests (Watling and Norse, 1998) or mining where depletion is rapid and recovery unlikely (Roberts, 2002). The results of this study put the scale of this activity into context in relation to other activities in the deep sea. This has important implications for governance and management decisions.

In response to the second question and the main hypothesis of this study, it was found that we do *not* have sufficient data on human activities for effective governance and the sustainable management of deep-sea ecosystems. The following is a summary of these findings and their implications.

6.2 Sources and availability of data on human activities

This work has shown that identifying and, in some cases, accessing reliable sources of information on human activities can be problematic. This finding is a cause for concern. The shift over the past three decades in the approach to the governance and management of natural resources has resulted in the emergence of a more integrated, ecosystem-based approach (Olsen et al., 2006) replacing traditional management approaches which were based on an individual activity, species or component of an ecosystem. The shift towards ecosystem-based management is evident at the level of discourse if not in practice and it is now incorporated as an objective into a range of global, regional and national instruments. For example, the 1982 Law of the Sea Convention (UN, 1982), the 1992 Rio Declaration (UN, 1992b) and Agenda 21 (UN, 1992a), the FAO Code of Conduct for Responsible Fisheries (FAO, 1995), the 1995 UN Fish Stocks Agreement (UN, 1995) and within Europe, the Integrated Maritime Policy (EC, 2007a) and the Common Fisheries Policy (EC, 2002a).

Implementation of the ecosystem-based approach demands knowledge of the spatial and temporal distribution of multiple human activities in a specific area together with the spatial distribution of important ecosystems, the intensity and location of impacts as well as the responses of the human and non-human components to the combined effects of these impacts (Lester et al., 2010).

As data on the location and extent of human activities is fundamental to the effective implementation of ecosystem-based governance and management, it was presumed by this study that these data would be comprehensive and available – particularly as the marine ecosystems in the North East Atlantic were identified by Halpern et al., (2007a) as heavily impacted. Nevertheless, a number of serious problems were identified here relating to availability, access and quality of data on human activities in both the North East and North West Atlantic. These included the lack of clearly identifiable definitive sources of current data, fragmented and incomplete data, misreported data, limited access, and for some activities, no access to data. It was found that considerable effort has gone into setting up databases and mechanisms for collecting and disseminating marine scientific data for both the North East and North West Atlantic. However, despite their seminal role in the application of a more integrated and holistic approach to governance and management of the deep sea, data on the human activities that are taking place there have not received the same attention.

A recommendation of this study is the development of an openly available meta-dataset of holders of data on human activities. The dataset should list the data source, data controller, a link to the relevant data providers, a description of the content, the format in which the data are held, the confidence limits and any uncertainties associated with the data, the area covered and any conditions which apply to data use. The OSPAR Commission may be a suitable organization to hold such a dataset.

One conclusion of this study was that such fragmentation of data may produce a self-perpetuating cycle. Fragmented data may impede holistic governance and management while the lack of holistic governance and management may lead to fragmentation of data. Within sector-based governance and management each sector develops its own rules and practices for data collection, management, access and use. The fisheries sector was found by this study to be an example of such an approach where there was no incentive to integrate across sectors and an apparent unwillingness to do so despite legislation designed to encourage data sharing across a wider community. Such strictly sector-based data make wider, holistic problems, for example damage to benthic habitats from bottom trawling, difficult to identify and integrated assessments of such problems difficult to achieve. To break this cycle will involve a fundamental shift in attitudes by the actors involved.

6.3 Suitability of data on human activities for ecosystem-based governance and management

For all the activities included in this study an element of reporting was required either by external authorities as part of a permissions and licencing process, for example in the hydrocarbon and submarine cables industries, as an obligation imposed by funding bodies, for example marine scientific research, or as a legal obligation, for example fisheries VMS data. Nevertheless, data were not being collected for the primary purpose of ecosystem governance and management by any of these activities. This wider purpose was not considered when reporting requirements were established. The limitations of the data currently collected for each activity are detailed in Chapter

4 together with recommendations to improve their suitability for use in ecosystem management (Table 4.4).

This finding highlights an important problem. The shift away from sector-based governance and management towards an ecosystem-based approach is an ongoing process which has evolved over the past three decades and continues to evolve as tools for its implementation are developed. Current industry management regimes and reporting requirements have also evolved over time, specifically to fulfil the needs and obligations of each individual sector. Most sectoral policies address diverse uses, impacts and major ecosystem components like fish, seabirds, water quality, and habitat features separately (ICES, 2005a). Implementation of the ecosystem approach will require that management should be better integrated across agencies, economic sectors, and levels of government, to ensure both policies and practices are mutually compatible (ibid.). A conclusion of this study is that the fulfilment of this requirement demands that industry reporting regimes must now consider the wider needs of ecosystem-based management.

6.4 Marine spatial planning for the deep North East Atlantic

It is alarming that this study has been the first to map and estimate the spatial extent of human activities in the deep North East Atlantic. Given the number and extent of activities and their impacts, the study highlights a significant gap in informed governance and management. Marine spatial planning is now recognized as a key tool in implementing ecosystem-based management. Progress is being made towards establishing marine spatial planning within Europe (Douvere, 2008). A recommendation of this study is that efforts should be made to develop marine spatial planning for the deep North East Atlantic in areas beyond national jurisdictions. It is suggested that the OSPAR Commission may be a suitable coordinator of this work.

6.5 Fisheries VMS data

Access to and the quality of fisheries VMS data were found to be a major problem. There is an urgent need for this problem to be addressed because of the damage caused by bottom trawling, particularly as this study has now shown the extent of the activity.

Most States failed to reply to requests for VMS data. For those that did reply commercial confidentiality was given as a primary reason for restricting access to these data. This study found that recent EU legislation, EC 199/2008 (EC, 2008c), one of the objectives of which was to facilitate easier access to fisheries data for the wider scientific community, was weak in practice. The lack of a coherent approach and the varying interpretation of the details of the Regulation by Member States resulted in a patchy implementation and, in some cases, no implementation.

The quality of the VMS data that was available was inadequate to accurately identify the location and type of fishing activities. The data are collected for fisheries management purposes and not to fulfil the wider role of ecosystem based management. As a consequence, extensive analysis is required for the data to be used to identify fishing activity and the confidence levels associated with the results are, accordingly, low. A range of recommendations for improvements to these data are detailed in Chapter 4. The most important and urgent changes are that the type and size of gear and the geographical location of shooting and hauling the gear should be mandatory in VMS transmissions.

The findings of this study suggest that despite "progressive implementation of an ecosystem approach to fisheries management" being a stated objective of the Common Fisheries Policy (EC, 2002a), in reality the will within the industry and States to change traditional attitudes to information-sharing lags behind this vision. Gaps and loopholes in the current legislation further compound the problem. Currently the traditional sector-based approach still appears to prevail and there is a marked unwillingness to disseminate data beyond the fisheries sector. Additionally, there appears to be little incentive for administrations to comply with requirements set out in legislation. Short-term commercial objectives still appear to prevail over the longer-term ecosystem requirements. It maybe that growing awareness of corporate social responsibility and its role in sustainability and environmental protection (EC, 2006c), together with liability regimes, will trigger shifts in industry attitudes and practices.

6.6 Conclusions

This work has presented a snap-shot of human activities in the deep sea and the associated problems of data-access over a relatively short period of time. While recommendations have been suggested it is appreciated that, where they involve changes to industry culture, these are not necessarily easy to implement. The challenges for industries of data collection, management and dissemination are not easily overcome and the day-to-day challenges of business often take priority over bigger fundamental changes. However, the findings have highlighted a number of important issues which bear closer examination such as the underlying reasons why data are difficult to access.

Continuation of the work to map the location of human activities in the deep sea is necessary for the identification of sites for marine protected areas and would also help to identify areas of current and potential conflict between vulnerable marine ecosystems and human activities. A map incorporating human activities with, where available, seafloor habitats would provide an invaluable tool for policy-makers. The methodology used to estimate the spatial extent of activities in Chapter 2 could be applied to other regions, for example, the North West Atlantic and the Mediterranean.

If the stated objective to implement ecosystem-based management is to be achieved a shift in attitude towards a more holistic approach will be required.

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8 Appendix

Benn et al., 2010 *Human Activities on the Deep Seafloor in the North East Atlantic: An Assessment of Spatial Extent*. PLOS One 5(9)

PLoS one

Human Activities on the Deep Seafloor in the North East Atlantic: An Assessment of Spatial Extent

Angela R. Benn[1]*, Philip P. Weaver[2], David S. M. Billet[1], Sybille van den Hove[3,4], Andrew P. Murdock[5], Gemma B. Doneghan[5], Tim Le Bas[2]

1 Ocean Biogeochemistry and Ecosystems Group, National Oceanography Centre Southampton, Southampton, United Kingdom, **2** Geology and Geophysics Group, National Oceanography Centre Southampton, Southampton, United Kingdom, **3** Median, Valldoreix, Spain, **4** Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, Barcelona, Spain, **5** GeoData Institute, University of Southampton, Southampton, United Kingdom

Abstract

Background: Environmental impacts of human activities on the deep seafloor are of increasing concern. While activities within waters shallower than 200 m have been the focus of previous assessments of anthropogenic impacts, no study has quantified the extent of individual activities or determined the relative severity of each type of impact in the deep sea.

Methodology: The OSPAR maritime area of the North East Atlantic was chosen for the study because it is considered to be one of the most heavily impacted by human activities. In addition, it was assumed data would be accessible and comprehensive. Using the available data we map and estimate the spatial extent of five major human activities in the North East Atlantic that impact the deep seafloor: submarine communication cables, marine scientific research, oil and gas industry, bottom trawling and the historical dumping of radioactive waste, munitions and chemical weapons. It was not possible to map military activities. The extent of each activity has been quantified for a single year, 2005.

Principal Findings: Human activities on the deep seafloor of the OSPAR area of the North Atlantic are significant but their footprints vary. Some activities have an immediate impact after which seafloor communities could re-establish, while others can continue to make an impact for many years and the impact could extend far beyond the physical disturbance. The spatial extent of waste disposal, telecommunication cables, the hydrocarbon industry and marine research activities is relatively small. The extent of bottom trawling is very significant and, even on the lowest possible estimates, is an order of magnitude greater than the total extent of all the other activities.

Conclusions/Significance: To meet future ecosystem-based management and governance objectives for the deep sea significant improvements are required in data collection and availability as well as a greater awareness of the relative impact of each human activity.

Citation: Benn AR, Weaver PP, Billet DSM, van den Hove S, Murdock AP, et al. (2010) Human Activities on the Deep Seafloor in the North East Atlantic: An Assessment of Spatial Extent. PLoS ONE 5(9): e12730. doi:10.1371/journal.pone.0012730

Editor: Peter Roopnarine, California Academy of Sciences, United States of America

Received May 20, 2010; **Accepted** August 18, 2010; **Published** September 13, 2010

Funding: AB was supported by the Continental Margin Ecosystems (COMARGE) project of the Census of Marine Life initiated by the Alfred P. Sloan Foundation. This research was also supported by the HERMES project, EC contract no GOCE-CT-2005-511234, funded by the European Commission's Sixth Framework Programme under the priority ''Sustainable Development, Global Change and Ecosystems''; the HERMIONE project (EU contract 226354 funded by the European Commission's Seventh Framework Programme under the priority 'Deep-Sea Ecosystems'). The publication reflects only the views of the authors and the EC is not liable for any use that may be made of the information contained therein. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing Interests: The authors have declared that no competing interests exist.

* E-mail: arb103@noc.soton.ac.uk

Introduction

Environmentally sustainable governance and management requires the availability of reliable and comprehensive information on the natural environment as well as information on the social, economic, legal and political systems. However, even though the deep seafloor covers approximately 60% of Earth's surface [1] only about 0.0001% of it has been the focus of biological scientific investigation [2]. Whilst remoteness and inaccessibility restrict research, they have not protected these depths from human impacts. Increasing demand for living and non-living resources and diminishing or exhausted reserves on land and in shallow water are pushing human activities ever deeper into the world's oceans. At the same time advances in technology now allow access to resources of economic value that were previously inaccessible. This has resulted in an increasing number of direct and indirect anthropogenic pressures on deep-sea ecosystems [1–6].

Governance and management of the deep sea is of increasing international concern. The United Nations, the Regional Seas conventions and organisations, including the European Union, are developing marine environment policies as well as monitoring and reporting procedures. Rules and codes of conduct are being established to regulate activities impacting on the deep ocean. For example, the OSPAR Commission has recognised the scientific case for establishing Marine Protected Areas in areas beyond national jurisdiction in the deep North East Atlantic e.g. [7]. It has developed a code of conduct for Responsible Marine Research in the Deep Seas and High Seas of the OSPAR Maritime Area [8] (Figure 1). The North East Atlantic Fisheries Commission (NEAFC) (Figure 1) has adopted procedures and rules for existing and new bottom-fishing areas aimed at the protection of vulnerable marine habitats [9–12]. NEAFC and the OSPAR Commission have initiated the first efforts towards multi-sectoral management in the High Seas in the North East Atlantic. Under a new memorandum of understanding, adopted by the two organisations in 2008, an attempt is being made to combine fisheries and conservation management [7].

The requirement for environmental and socio-economic data is recognised in many political forums. The 1995 United Nations (UN) Fish Stocks Agreement calls for the sharing of "complete and accurate data concerning fishing activities" [13]. The Convention on Biological Diversity [14] promotes the ecosystem approach as its primary framework for action. The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way, recognizing that humans and their activities are integral to ecosystems. At the European level, the Marine Strategy Framework Directive (MSFD) [15] and the OSPAR Biological Diversity and Ecosystems Strategy [16] both require assessments of human activities within the marine environment, some of which will be in the deep sea and beyond national jurisdictions. To fulfill these assessments and to implement the ecosystem approach, comprehensive and consistent information on human activities is necessary.

Data on human activities are collected and held i) by public institutions and private companies to fulfill regulatory requirements, ii) for commercial and operational purposes and iii) or for scientific research. In addition, the European Union Directive on Public Access to Environmental Information [17] defines environmental information to include "measures (including administrative measures), such as

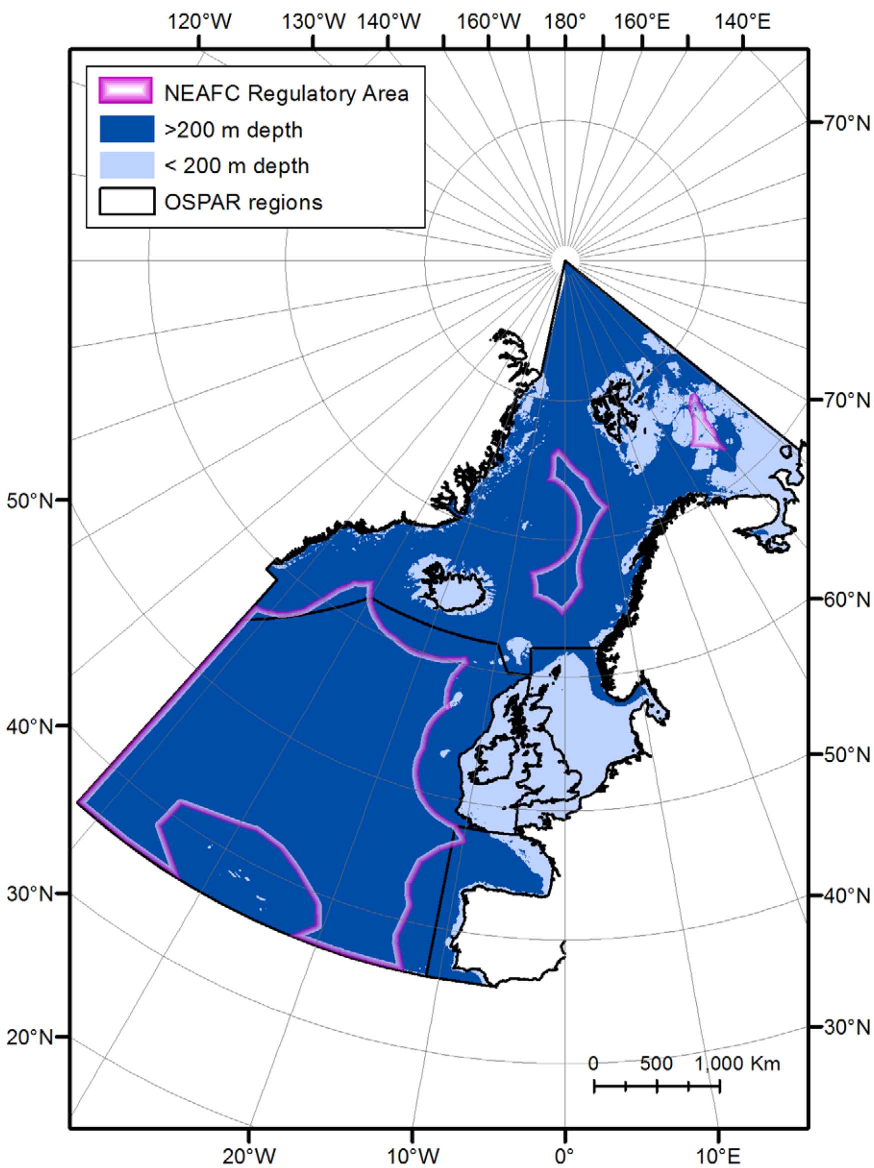

Figure 1. North East Atlantic Fisheries Commission Regulatory Area and OSPAR Maritime Area. OSPAR Regions I: Arctic Waters, II: Greater North Sea, III: Celtic Seas, IV: Bay of Biscay and Iberian Coast, V: Wider Atlantic.
doi:10.1371/journal.pone.0012730.g001

policies, legislation, plans, programmes, environmental agreements, and activities affecting or likely to affect the elements and factors …". These include "… water, soil, land, landscape and natural sites, … marine areas, biological diversity and its components, … and the interaction among these elements".

This study assesses, for the first time, the relative spatial extent of major human activities in the deep North East Atlantic, within and beyond Exclusive Economic Zones (EEZs) in the OSPAR maritime area of the North Atlantic (Figure 1), of which 8,517,010 km^2 is deeper than 200 m, during the single year, 2005. The marine ecosystems here are some of the most heavily impacted by human activities [18]. The availability and suitability of data relating to these activities are assessed and the spatial extent of the direct physical impact on the seafloor is quantified. However, the extent of collateral physical impacts, for example smothering caused by sediment plumes and chemical effects on the benthos, for example those related to oil industry cuttings piles, are not assessed. In addition, we do not estimate the wider chemical and biological impacts caused by pollution. In the current study, "human activities", identified by reference to literature [1–5], are defined as intentional human activities occurring directly on the sea floor as well as structures and artefacts present on the seafloor resulting from past activities. Previous studies in shallower waters have examined much smaller areas in detail [19,20] , or have looked at single activity impacts [21], whilst some studies such as Halpern et al. [18] have taken a broad global view.

Methods

Data for activities were requested from sources listed in Tables 1, 2 and 3. They were rarely in a format immediately suitable for assessing the spatial extent of each activity. Typically, data were provided as text files or MS Excel sheets with XY point locations of features; for example marine scientific research sample sites or radioactive dumpsites. In the case of vessel tracks or pipelines data were either strings of coordinate points (in text files or MS Excel) or actual GIS datasets (polyline features). As such, these have no areal definition but merely describe the route a vessel took based on its GPS track or location of a point on the seabed.

To define a realistic areal footprint for features, the data were processed in ArcGIS v. 9.3 (Environmental Systems Research Institute) for processing. This industry standard GIS package has tools for 'buffering' spatial features by a specified width (or range of widths). The output of this processing is a polygon shape which is a proxy for the actual spatial location and extent of the features on the seabed (the footprint). The tools operate on point or polyline features and can be used in a variety of coordinate systems.

Table 1. Data sources.

Source	Contact information
Marine Scientific Research	
Report of Observations/Samples collected by Oceanographic Programmes (ROSCOP) Cruise Summary Reports	http://www.ices.dk/Ocean/roscop/index.asp
British Oceanographic Data Centre (BODC)	http://www.bodc.ac.uk
Hotspot Ecosystem Research on the Margins of European Seas (HERMES)	http://www.eu-hermes.net/members/cruises.html
Intergovernmental Oceanographic Commission of UNESCO, International Oceanographic Data and Information Exchange	http://www.oceandataportal.org
National Marine Facilities, National Oceanography Centre, Southampton	http://www.noc.soton.ac.uk/nmf
Ocean Information Centre, Research Ship Schedules and Information	http://www.researchvessels.org
Pangaea Publishing Network for Geoscientific & Environmental Data	http://www.pangaea.de
Various individual scientific institutions	
Submarine Cables	
Kingfisher Information Service – Cable Awareness	www.kisca.org.uk/charts.htm#option4
France Telecom SigCables	www.sigcables.com/cgi-bin/index.pl
Waste disposal: Radioactive Waste	
NEA.1985. Review of the Continued Suitability of the Dumping Site for Radioactive Waste in the North-East Atlantic. Nuclear Energy Agency, Organisation for Economic Cooperation and Development, Paris. 448pp.	
Waste Disposal: Munitions and chemical weapons	
OSPAR. 2005. (Revised). Overview of Past Dumping at Sea of Chemical Weapons and Munitions in the OSPAR Maritime Area. Biodiversity Series. OSPAR, London. 13 pp.	http://www.ospar.org/documents%5Cdbase%5Cpublications%5Cp00222_2005%20Revised%20Dumping%20at%20Sea%20of%20chemical%20weapons.pdf
Oil and Gas Industry	
UK Digital Energy Atlas and Library	http://www.ukdeal.co.uk
Norwegian Petroleum Directorate	http://www.npd.no/en/

Sources from which data were acquired.
doi:10.1371/journal.pone.0012730.t001

Table 2. Military activities.

Source	Contact Information
NATO	mailbox.natodoc@hq.nato.intscience@hq.nato.int
French Ministry of Defence	http://www.defense.gouv.fr/formulaire_de_contact
Norwegian Ministry of Defence	postmottak@fd.dep.no
Portuguese Ministry of Defence	gcrp@defesa.pt
Spanish Ministry of Defence	comunicacion@fn.mde.es
Irish Defence Forces (Freedom of Information request)	foi@defenceforces.ie
UK Ministry of Defence (Freedom of Information request)	http://www.mod.uk/DefenceInternet/ContactUs/ FreedomOfInformationInformationRequest.htm
Government of Greenland	info@gh.gl
Government of Iceland	external@utn.stjr.is

Sources to which requests for information on military activities during 2005 in the North East Atlantic were addressed.
doi:10.1371/journal.pone.0012730.t002

ArcGIS's implementation of the *North Pole Lambert Azimuthal Equal Area Conic projection* was chosen as appropriate for use within the OSPAR regional extent and is designed to minimise area distortions.

Some of the datasets contained the necessary information to create the areal footprint, for example, known diameters of oil industry pipelines. Where this information was unavailable, values were sought from owners of the assets, industry experts or from published literature values.

Depth zones were identified by reference to the GEBCO dataset (General Bathymetric Chart of the Oceans) [22]. GEBCO is a world bathymetry dataset on a 1 arc minute grid and is the most extensive freely available bathymetric dataset.

Buffer polygons were created for each feature and the area values (automatically created by the GIS) were extracted and totalled to estimate the spatial extent of each activity (Table 4). A confidence rating relating to the quality of data was applied, based on the method described by Eastwood et al. [19]. A score of 1 denotes an estimated location and extent; 2 denotes a known location but estimated extent and 3, a known location and extent. Figure 2 shows the geographical distribution of activities. Where the data used to calculate the estimates did not represent the total extent of an activity in the OSPAR deep water area, (marine research, submarine cables and bottom trawling) a further estimate, extrapolated to represent the total of each activity, was calculated (Table 5).

The datasets were drawn from a variety of sources. They were collected for a variety of purposes. Some data were only indicative. Some were derived from GPS tracking. Others were surveyed precisely. Therefore, positional accuracies varied. This is a broad scale strategic study and while it is important to obtain as accurate information as possible, the study is considering the *relative* spatial extent of these activities in the context of the OSPAR region, and small errors are not likely to be significant to the final values. The study quantifies the physical footprint but does not quantify how significant (detrimental or beneficial) these impacts might be on the surrounding ecosystems. This study does not tackle contamination that may be spread away from the specific impact e.g. leakage of radioactivity.

Marine Scientific Research

Marine scientific research is carried out by academic institutions or fisheries research laboratories. Research by academic institutions involves a range of equipment on the seafloor to sample the marine environment including moorings, grabs, corers, dredges and trawls. Much of this equipment has only a single impact of a few square meters. While fisheries research also involves the

Table 3. Sources to which requests for VMS data were addressed.

State	Source	Contact
†Denmark	Fiskeridirektoratet	sat@fd.dk
†France	Cross Atlantique	Csp-France.CROSS-Etel@developpement-durable.gouv.fr
Greenland	Fisheries Authority	APNA@gh.gl
Iceland	Ministry of Fisheries and Agriculture	postur@slr.stjr.is
†Ireland	Fisheries Monitoring Centre	nscstaff@eircom.net
Norway	Ministry of Fisheries and Coastal Affairs	postmottak@fkd.dep.no
†Portugal	Direcção Geral das Pescas e Aquicultura, Departamento de Inspecção das Pescas	ccc@ip.dgpa.min-agricultura.pt
†Spain	Secretaría General de Pesca Maritíma	csp@mapya.es
†UK	Marine Fisheries Agency Data and Communications	sat.ops@mfa.gsi.gov.uk

†EC Fishing Monitoring Centres Contact List: http://ec.europa.eu/fisheries/cfp/control/fmc_contact_list_en.pdf.
doi:10.1371/journal.pone.0012730.t003

Table 4. Spatial extent and confidence rating of activities.

Activity (>200m water depth)	**Estimated spatial extent (km²)**	**Confidence rating**†
Scientific research: (estimated 45% of all cruises impacting on seafloor during 2005)		
Non-fisheries research cruises	4	2–3
Fisheries research cruises	22	2–3
Submarine communications cables: (estimated 41% of all submarine cables)		
No burial: between 200–1500 m wd, 50 mm diameter cable ; >1500 m wd, 20 mm diameter cable	2	1–2
No burial: between 200–>1500 m wd, 50 mm** diameter cable	4	1–2
Cable burial: between 200–1500 m wd with 2 m wide disturbance strip*; no burial >1500 m wd, 20 mm diameter cable	15	1–2
Cable burial: between 200–1500 m wd with 8 m wide disturbance strip*; no burial >1500 m wd, 20 mm diameter cable	61	1–2
Waste disposal:		
Radioactive waste	0.2	2
Munitions and chemical weapons	1.4	1
Military	No data made available	
Oil and gas:		
Pipelines	4.0	3
[1,2]Structures: platforms, templates and wellheads	0.2	2
[2]Structures with associated cuttings piles (~83 m radius[3])	3	2
[2]Wells drilled during 2005 with associated cuttings piles (~83 m radius[3])	1	2
[2]Wells drilled between 1960 and December 2005 and associated cuttings piles (~83 m radius[3])	15	2
Total pipelines, structures, wells and cuttings piles	23.2	2–3
Bottom trawling: (2005, Hatton and Rockall area)		
- Speed range 2.0–3.0 knots, gear width 22 m:		1–2
Tracks not merged	741	
Tracks merged	548	
- Speed range 1.5–5.0 knots, gear width 125 m:		1–2
Tracks not merged	37,160	
Tracks merged	13,920	

Estimates of the spatial extent of six major human activities occurring directly on the sea floor, including structures and artefacts present on the seafloor resulting from past activities, within the OSPAR maritime area of the North East Atlantic in waters >200 m during 2005. Estimates for bottom trawling and marine scientific research are based on 2005 data only.
wd: water depth;
†Confidence ratings indicate whether the spatial extent of each activity is based on data or estimates of location and extent (Eastwood et al., 2007) [19]: 1, estimated location and estimated extent; 2 known location, estimated extent; 3, known location and extent.
*Carter et al., 2009 [23].
[1]Information from NPD and Statoil datasets and Eastwood et al., 2007 [19].
[2]Overlapping boundaries merged.
[3]SERPENT Project, unpublished data.
doi:10.1371/journal.pone.0012730.t004

deployment of sampling equipment, such as grabs and moorings, it involves a higher proportion of bottom impact trawling.

Data were obtained from the seven online sources listed in Table 1 and individual scientists. Twenty four cruises, which took place in water deeper than 200 m and carried out activities on the seafloor, were identified from cruise reports and station lists. A further 29 cruises which may have impacted on the seafloor in water deeper than 200 m were accessed on the ROSCOP website but searches in PANGAEA, BODC and European project databases (e.g. HERMES) did not locate station lists or cruise reports. Cruises for which data were available represent approximately 45% of the total number of cruises identified during 2005 which may have impacted on the seafloor within the OSPAR area listed on the ROSCOP cruise summary. Where cruise reports and station lists were available activities on the seafloor were mapped. According to the footprint size of each piece of equipment buffers were applied to estimate the spatial extent on the seafloor. Where the footprint area of each activity was not included in the cruise report (size of equipment deployed, length and width of trawl) it was estimated based on published literature and advice from individual institutions.

Submarine Communication Cables

Greater than 95% of international communications are routed via submarine fibre-optic cables. In areas where cables are vulnerable to damage from fishing or anchoring (200–1,500 m water depth) they often have one or more layers of armour and

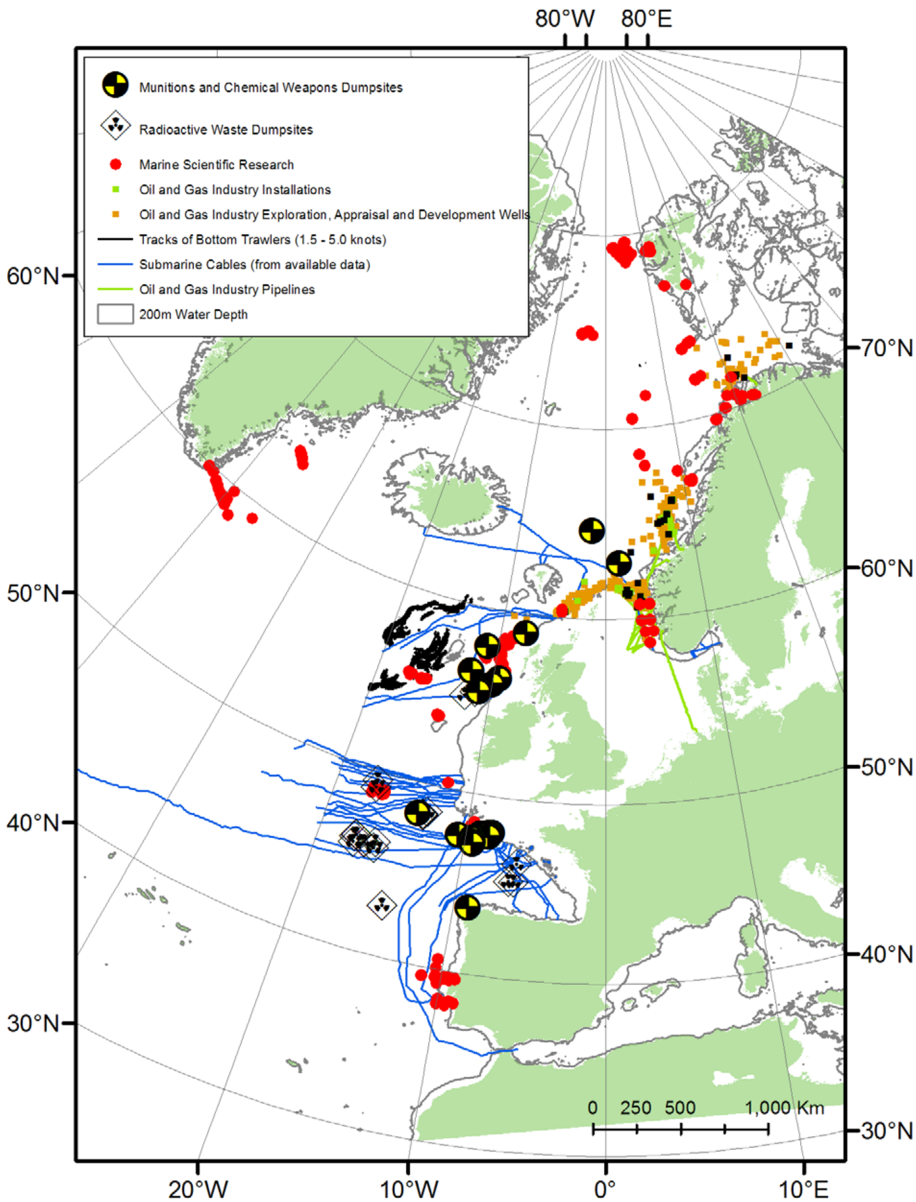

Figure 2. Human activities on the seafloor, including structures and artefacts present on the seafloor resulting from past activities, within the OSPAR Maritime Area, >200 m water depth, during 2005.
doi:10.1371/journal.pone.0012730.g002

can be up to 50 mm in diameter. In waters deeper than 1,500 m, currently beyond the reach of fishing, cables are non-armoured and are between 17 mm and 20 mm in diameter [23]. An alternative protective measure is the burial of cables in water depths shallower than 1,500 m [23]. During the burial operation a plough opens a furrow in the seafloor into which the cable is laid and the sediment replaced. Skids supporting the plough can leave a footprint on the seabed, particularly in zones of soft sediment, potentially increasing sediment compaction and leading to the disturbance of the marine fauna. The overall width of the disturbance strip produced by the plough-share and skids in direct contact with the seabed ranges from 2 to 8 m width [23]. The spatial extent calculated here represents the width of either the unburied cables on the seafloor or, for buried cables, the footprint of the plough based on the minimum and maximum width of disturbance strips (2 m and 8 m) [23], although it is unlikely that the disturbance strip is 8 m everywhere.

Geospatial data for submarine cables were obtained from the two sources listed in Table 1. Kingfisher Information Service – Cable Awareness data were available in Microsoft Excel format to an accuracy of 10 m and France Telecom's SigCables, available as ESRI shape files. These websites, for users of the seabed and, in particular, for skippers of fishing vessels, give cable locations to approximately 25°W, beyond which the water is too deep for the cables to be in danger. As no data were available beyond ~25°W, the cable lines were extrapolated from the final data point provided for each cable to a landfall in the United States or Canada, identified from ICPC, 2008 [24]. The distance to the western boundary of the OSPAR maritime area, 42°W was calculated. Forty five cables were identified with an approximate total length of 75,055 km, which included all of the current in-

Table 5. Comparison of extrapolated spatial extent of human activities in the OSPAR area in 2005.

Activity	Estimated spatial extent	Extrapolated to 100% of activity
(>200m water depth)	**(km^2)**	**(km^2)**
Scientific research: 45% of cruises with activities on the seafloor reported to ROSCOP during 2005		
Non-fisheries research cruises	4	9
Fisheries research cruises	22	49
Submarine communications cables: Estimate based on 41% of cables		
No burial: between 200–1500 m wd, 50 mm diameter cable ; >1500 m wd, 20 mm diameter cable	2	5
No burial: between 200–>1500 m wd, 50 mm** diameter cable	4	10
Cable burial: between 200–1500 m wd with 2 m wide disturbance strip*; no burial >1500 m wd, 20 mm diameter cable	15	Extrapolation inappropriate – see text.
Cable burial: between 200–1500 m wd with 8 m wide disturbance strip*; no burial >1500 m wd, 20 mm diameter cable	61	Extrapolation inappropriate – see text.
Waste disposal: Includes all recorded data		
Radioactive waste	0.2	0.2
Munitions and chemical weapons	1.4	1.4
Military	No data made available	No data made available
Oil and gas: Includes all recorded data and extrapolations		
Pipelines	4	4
[1,2]Structures: platforms, templates and wellheads	0.2	0.2
[2]Structures and associated cuttings piles (~83 m radius[3])	3	3
[2]Wells drilled during 2005 and associated cuttings piles (~83 m radius[3])	1	1
[2]Wells drilled between 1960 and December 2005 and associated cuttings piles (~83 m radius[3])	15	15
Total pipelines, structures, wells and cuttings piles	23.2	23.2
Bottom trawling in Hatton and Rockall during 2005 estimated as ~50% of all deep sea bottom trawling area in the OSPAR area		
- Speed range 2.0–3.0 knots, gear width 22 m:		
Tracks not merged	741	1,482
Tracks merged	548	1,096
- Speed range 1.5–5.0 knots, gear width 125 m:		
Tracks not merged	37,160	74,320
Tracks merged	13,920	27,840

Estimates and extrapolations of the spatial extent of six major human activities occurring directly on the sea floor, including structures and artefacts present on the seafloor resulting from past activities, within the OSPAR maritime area of the North East Atlantic in waters >200 m during 2005. Estimates for bottom trawling and marine scientific research are based on 2005 data only.
wd: water depth;
*Carter et al., 2009] [23].
[1]Information from NPD and Statoil datasets and Eastwood et al., 2007 [19].
[2]Boundaries merged and dissolved.
[3]SERPENT Project, unpublished data.
doi:10.1371/journal.pone.0012730.t005

service systems as at 2005. However, this does not take into account all systems dating back to the start of telegraphic communications. The total approximate length of all cables (including coaxial, fibre optic and telegraph cables but not including military) on the seafloor within the OSPAR area during 2010 is estimated at 184,200 km (Steve Bennett, Global Marine Systems Limited, personal communication). This is the nearest total value obtainable by the study. The spatial extent of cables calculated within this study is estimated to represent approximately 41% of the total area of cables.

Neither dataset reported whether the cables were buried, armoured or non-armoured. Therefore, 4 scenarios have been considered based on the following assumptions:

1. No cable burial at any water depth. Cable diameter 50 mm in water depths 200 m–1,500 m and 20 mm diameter in water depths greater than 1,500 m.
2. No cable burial at any water depth. Cable diameter of 50 mm at all water depths (the maximum diameter of modern, double armoured fibre optic cables [23]).
3. In water depths between 200 m–1,500 m cables buried by a plough with an overall disturbance footprint of 2 m width – the minimum width reported [23]. In water depths greater than 1,500 non-buried cable, 20 mm diameter.
4. In waters depths between 200 m–1,500 m cables buried by a plough with an overall disturbance footprint of 8 m width - the

Table 6. Radioactive waste dumpsites in water deeper than 200 m in the OSPAR region of the North East Atlantic between 1949 and 1984.

Longitude	Latitude	Year	Tonnes	Country of Origin	Description of Dumpsite
−16.75	46.00	1977	5 605	NL-CH-UK	a rectangle 45.8333 to 46.1666 and −16.00 to −17.50
		1978	8 046	B-NL-CH-UK	
		1979	5 416	B-NL-CH-UK	
		1980	8 391	B-NL-CH-UK	
		1981	9 434	B-NL-CH-UK	
		1982	11 693	B-NL-CH-UK	
−17.42	46.25	1971	3 968	B-NL-CH-UK	a circle of radius 35 nautical miles centred on 46.25, −17.41666
		1972	4 131	B-NL-CH-UK	
		1973	4 350	B-NL-UK	
		1974	2 265	NL-CH-UK	
		1975	4 454	B-NL-CH-UK	
		1976	6 772	B-NL-CH-UK	
−13.25	48.25	1965	1 760	UK	not described
		1966	1 044	UK	
−13.27	48.33	1970	1 674	UK	not described
		1968	3 164	UK	
−13.00	48.50	1949	9	UK	not described
−11.33	55.43	1951	33	UK	not described
−12.17	55.13	1953	57	UK	not described
−6.17	46.45	1962	253	UK	not described
−6.27	45.45	1963	5 809	B-UK	not described
−6.60	45.45	1964	4 392	UK	not described
−14.50	42.83	1967	10 895	B-F-D-NL-UK	a square of side 50 km centred on 42.83333, −14.5
−17.08	49.08	1969	9 178	B-F-I-NL-S-CH-UK	a square of side 50 nautical miles centred on 48.5, −17.08333
		Total	**112 793**		

Location of dumping area, quantities and sources of radioactive waste (based on NEA, 1985) [26].
B = Belgium; CH = Switzerland; D = Germany; F = France; I = Italy; NL = Netherlands; S = Sweden; UK = United Kingdom.
doi:10.1371/journal.pone.0012730.t006

maximum width reported [23]. In water depths greater than 1,500 non-buried cable, 20 mm diameter.

The data were input into ArcGIS. Cables whose entire length was in water <200 m depth were removed from the dataset. The lines depicting the cables were segmented to account for the different depth zones (200–1,500 m and >1,500 m). The relevant depth zones were extracted from the GEBCO dataset. The linear features were intersected with the depth zones, splitting the line at the boundaries of the zones and the sections were attributed with the required width values (50 mm, 20 mm, 2 m and 8 m). This allowed variable buffers to be created for different sections of each line. The depth contours were simplified in areas of complex geomorphology to avoid adding spurious detail to the calculations. Cables crossing areas of Mid-Atlantic Ridge at depths <1,500 m were assumed to be 20 mm diameter as there is no cable burial or armouring in this area.

Waste Disposal

This study focused on chemical and conventional munitions and low level radioactive waste dumped prior to the 1996 London Protocol [25]. This protocol came into force on 24 March 2006 and recognised seven categories of waste; i) dredged material; ii) sewage sludge; iii) fish waste (or material resulting from industrial fish processing operations); iv) vessels and platforms or other man-made structures at sea; v) inert, inorganic geological material; vi) organic material of natural origin. The seventh category includes "bulky items primarily comprising iron, steel, concrete and similar unharmful materials for which the concern is physical impact and limited to those circumstances, where such wastes are generated at locations, such as small islands with isolated communities, having no practicable access to disposal options other than dumping" [25].

Radioactive waste. Between 1949 and1982 radioactive waste was dumped routinely at sites in the North East Atlantic. It included i)'low level' wastes from nuclear power plant operations; ii) other nuclear fuel cycle operations, including fuel fabrication and reprocessing; iii) radionuclide use in medicine, research and industry and iv) decontamination and dismantling of redundant plant and equipment [26].

In 1983 increasing concern over the continued sea disposal of radioactive waste led the Contracting Parties to the London Convention [27] to adopt a voluntary moratorium on the sea dumping of all types of radioactive waste. Amendments to the Convention, adopted in 1993 , which came into force on 20 February 1994, eventually banned sea dumping of all types of radioactive waste [25]. Twenty five years from this date, contracting parties are required to complete a scientific study relating to all radioactive wastes and other radioactive matter

Table 7. Conventional and chemical munitions dumpsites in waters >200 m in the OSPAR region (OSPAR, 2005) [28].

Site number	Longitude	Latitude	Type of munitions	Details
42	−13.66	48.33	Conventional	Only remaining UK dumpsite by 1993
43	−9.02	43.73	Conventional	
45	1.46	62.97	Chemical	4,500 tons scuttled vessels
46	−7.67	59	Chemical	
49	−11	58	Chemical	
51	−12.08	56.52	Chemical	
52	−12	56.5	Chemical	
53	−9.45	56.37	Chemical	
54	−10	56	Chemical	
55	−11	55.5	Chemical	
56	−9.37	48.67	Chemical	Scuttled ship, Dora Oldendorf - February 1947.
57	−8.15	48.05	Chemical	Scuttled ship, Empire Nutfield - September 1946.
58	−8.35	48	Chemical	Scuttled ship, Lanark - November 1946.
59	−8.56	47.95	Chemical	Scuttled ship, Empire Peacock - August 1946.
60	−8.97	47.92	Chemical	Scuttled ship, Harm Freitzen - March 1948.
61	−8.26	47.92	Chemical	Scuttled ship, Empire Lark - July 1947.
62	−8.35	47.9	Chemical	Scuttled ship, Kindersley - October 1946.
63	−8.85	47.87	Chemical	Scuttled ship, Empire Connyngham - June 1949.
64	−8.31	47.79	Chemical	Scuttled ship, Thorpe Bay - September 1947.
65	−10.5	47.63	Chemical	CW (Approx 70 Tonnes) encased in concrete. Dumped in 1980.
66	−9.52	47.6	Chemical	Scuttled ship, Margo - November 1947.
67	−9.4	47.38	Chemical	Scuttled ship, Miervaldis - September 1948.
68	−9.4	47.28	Chemical	Scuttled ship, Empire Success - August 1948.
70	−1.6	64.7	Chem. - Tabun	462 shells recovered in Wolgast Harbour dumped, set in concrete.

doi:10.1371/journal.pone.0012730.t007

other than high level wastes, followed by further studies at 25 year intervals [27].

Information relating to dumping sites for radioactive waste was obtained from a single source [26], (Table 1). An estimate of the total area designated for dumping of radioactive waste was 26,323 km^2, based on the aggregated areas with overlapping boundaries dissolved for each of the four designated sites (Table 6). However, this does not represent the area of seafloor covered by drums of waste so a second estimate of the extent of this activity was based on the tonnage and estimated number of drums (Table 6). Thiel [5] estimates that, in total, between 1949 and 1982, 222,732 drums containing 114,726 tonnes (t) of radioactive waste were dumped at sites in the deep North East Atlantic. This is a mean of ~0.5 t of waste per drum. Of the 42 dumping events listed in [26], 24 events totalling 112,793 t (Table 6) of waste were deposited in the OSPAR area in waters deeper than 200 m. A second estimate was calculated based on a mean of 0.5 t of waste per drum. It was estimated that there were 225,586 drums within the OSPAR area in waters deeper than 200 m with an approximate area of 1 m^2 per drum [26].

Munitions and chemical weapons. The locations of dumpsites for conventional and chemical munitions were identified by reference to [28] (Table 1). Of the 148 dumpsites recorded, 24 are in waters deeper than 200 m (Table 7). While the locations of dumpsites were reported, there was no indication of the area of each. However, twelve sites are described as a ‘‘scuttled ship’’. Based upon this information a nominal square 100 m×100 m was assigned for each site.

Military Activities

It was not possible to estimate the spatial extent of this activity. Requests for information relating to military activities on the seafloor during 2005 were made to sources listed in Table 2. Only the Irish Defence Forces responded, reporting no activities on the seafloor deeper than 200 m during 2005. The UK Ministry of Defence redirected the request to the UK Hydrographic Office for locations of practice and exercise areas, but these provided no specific details of activities. The request to NATO was directed to the NATO Science Department which was unable to help.

Oil and Gas Industry

Geospatial data for oil and gas industry subsurface installations, pipelines and exploration and development wells were obtained from the UK Digital Energy & Atlas Library (UKDEAL) [29] and the Norwegian Petroleum Directorate (NPD) [30] (Table 1).

The locations of pipelines were reported in the UK and Norwegian datasets but the diameter was recorded only in the UKDEAL data. Diameters for Norwegian pipelines were extracted individually from NPD Facts [31]. These data were imported into ArcGIS. Sections of pipeline in waters 200 m or deeper were identified and buffered to represent their respective diameters.

Neither the UKDEAL nor NPD datasets contained dimensions of other types of installations. Eastwood et al. [19] proposed two categories of installation, ‘platform’ and ‘well’ and assigned nominal areas of ~180 m^2 and a diameter of 50 m respectively. The UKDEAL datasets listed one platform and eleven wellheads

Table 8. Spatial extent of seafloor trawled in the Hatton - Rockall area during 2005: overlapping tracks not merged.

Speeds (knots)	Area trawled based on *125 m gear width (km^2)	Area trawled based on *80 m gear width (km^2)	Area trawled based on **22 m gear width (km^2)
[1]3.0–5.0	21,346	13,631	3,738
[1]1.5–4.5	27,487	17,619	4,855
[2]2.0–3.0	4,255	2,711	741
[3]1.5–5.0	37,160	23,855	6,585

Estimates based on 28 vessels engaged in bottom trawling, identified from speed profiles and pattern of activity. All overlapping tracks included in estimate.
*Dick Ferro, Fisheries Research Services, Aberdeen, personal communication.
**Hall-Spencer et al., 2002 [39].
[1]Davies et al., 2007 [3].
[2]ICES, 2007 [38].
[3]1.5–5.0 knots encompasses the range of bottom trawling speeds referred to by Davies et al., 2007 [3] and ICES, 2007 [38].
doi:10.1371/journal.pone.0012730.t008

in waters deeper than 200 m. Circular buffers of 180 m^2 and 50 m diameter were applied to estimate the spatial extent of these features.

Most Norwegian deep water installations are floating platforms with wells drilled through templates on the seafloor. The original downloaded NPD dataset did not include the type of installation but, on request, a dataset was provided which included date installed and type of installation. In waters deeper than 200 m three platforms sited on the seafloor and 230 templates were listed. Four legs sit on the seabed supporting the template which typically covers 416 m^2 of seafloor (Tore Indreiten, Statoil, personal communication). A square buffer of 416 m^2 was applied to estimate the spatial extent of these installations and circular buffers of 180 m^2 were applied to estimate the spatial extent of platforms.

In addition to structures on the seafloor, drill cuttings piles are a part of the footprint of oil and gas operations. A variety of oil-based, synthetic and water-based drilling fluids have been used, each with different technical and environmental properties [32]. Typically, cuttings piles are a mixture of man-made and natural substances containing higher concentrations of metals and hydrocarbons than background sediments. They consist of fragments of rock, mixed with drilling muds [33]. Discharge to the seafloor of oil-based drilling muds and associated cuttings ceased in 1993 and 1996 in Norway and the UK respectively. While water based drilling fluids and cuttings can, with permission, be discharged, used oil-based drilling fluids and cuttings are now either transported to land for processing or injected into the seafloor [34]. Recent photographic surveys carried out by the SERPENT Project (www.serpentproject.com) at exploration drilling sites in the Faroe-Shetland Channel and the Norwegian Sea indicate a mean area of 21,744 m^2 is covered by drill cuttings in the deep sea (SERPENT Project, unpublished data). To estimate the spatial extent of oil and gas industry activities, including the presence of cuttings piles, a circular buffer of 21,744 m^2 (radius of ~83 m) was applied to wells, platforms and templates. This area represents the physical presence of cuttings rather than the extent of biological impacts.

A further component of oil and gas industry activities is the drilling of exploration, development and appraisal wells. In the period up to and including 2005 the UKDEAL and NPD datasets report a total of 1,608 of these in waters deeper than 200 m. Buffers of 21,744 m^2 (radius ~83 m) with overlapping boundaries merged and dissolved were also applied to these wells to estimate the spatial extent of drill cuttings. Of the wells listed, coordinates for 114 UK wells were not readily available. The buffered area for these was estimated from the mean area of the other UK wells.

Bottom Trawling

From 1 January 2005 all vessels i) exceeding 15 m overall length operating in European waters and ii) belonging to contracting parties to the North East Atlantic Fisheries Commission (NEAFC) Vessel Monitoring System Programme over 24 m overall length operating within the NEAFC Regulatory Area (Figure 1), were required to install and operate satellite-based tracking devices [35,36]. Vessels were required to transmit data at intervals of 2 hours or less to Fishing Monitoring Centres (FMCs) located in the States in which they were registered. (In November 2009 an amendment to the NEAFC convention required data to be transmitted at least once every hour in the NEAFC Regulatory Area [37]). Data relating to vessels operating beyond EEZs (in the NEAFC Regulatory Area) are transmitted from the flag State to NEAFC.

There was no definitive source identifying i) bottom trawling vessels, ii) where trawls started and ended and iii) the size of the gear deployed. Therefore the spatial extent of bottom trawling had to be estimated from VMS datasets. VMS data for 2005 were requested from the sources listed in Table 3. Only France, the UK and NEAFC provided data. These data comprised a reporting code, position, time, date and occasionally details of the catch. No dataset gave any indication of whether the vessel was engaged in fishing at the time the position was reported. Data supplied by the UK, covering UK waters, included information about the type of vessel (e.g. demersal trawler, purse seiner) but this was not reported for all vessels. The French dataset, covering French waters, did not include speed. This had to be calculated by reference to time and distance covered between successive reported positions.

Bottom trawling activity was inferred by examining the course of each vessel in relation to seabed contours and speed. Unlike pelagic trawlers, bottom trawlers, while fishing, are likely to follow the contours of the seafloor [38]. Additionally, deep water bottom trawlers can fish only within a limited range of speeds: 1.5–5.0 knots [3,38] (Tables 8 and 9). The size of the fishing gear was not reported. The possible distance between trawl doors, 22 m, 80 m and 125 m was identified by reference to published literature [39] and personal communication (Dick Ferro, Fisheries Research Services, Aberdeen, UK).

The NEAFC data allowed a detailed study of just one fishery in the OSPAR area in the vicinity of Hatton and Rockall. These data were used to estimate the spatial extent of bottom trawling because it was possible to determine the relationship between vessel movements and seafloor contours. This relationship was less clear for other areas within the NEAFC Regulatory Area and within French and UK waters, consequently these areas were not included in this study.

Table 9. Spatial extent of seafloor trawled in the Hatton - Rockall area during 2005: overlapping tracks merged.

Speeds (knots)	Area trawled based on *125 m gear width (km^2)	Area trawled based on *80 m gear width (km^2)	Area trawled based on **22 m gear width (km^2)
[1]3.0–5.0	8,051	6,067	2,227
[1]1.5–4.5	12,041	8,983	3,192
[2]2.0–3.0	2,710	1,837	548
[3]1.5–5.0	13,920	10,624	3,994

Estimates based on 28 vessels engaged in bottom trawling, identified from speed profiles and pattern of activity. Overlapping tracks merged to give single area.
*Dick Ferro, Fisheries Research Services, Aberdeen, personal communication.
**Hall-Spencer et al., 2002 [39].
[1]Davies et al., 2007 [3].
[2]ICES, 2007 [38].
[3]1.5–5.0 knots encompasses the range of bottom trawling speeds referred to by Davies et al., 2007 [3] and ICES, 2007 [38].
doi:10.1371/journal.pone.0012730.t009

Speed frequency profiles, produced for each vessel in the NEAFC dataset using GeoCrust2.0 software [40], were provided by ICES. These profiles identified vessels with peaks of activity the 1.5–5.0 knot range. As a further check the entire 2005 NEAFC dataset comprising 797 vessels was imported into ArcGIS and patterns of vessel activity, following seafloor contours were studied. Twenty eight vessels were identified as engaged in bottom trawling in the Hatton - Rockall area. All vessels not considered to be bottom trawling were removed from the dataset. Data for the remaining 28 vessels were filtered to remove points with speeds outside the 1.5–5.0 knots range. Data points, within the speed range but lying outside the fishing grounds, in waters too deep to bottom trawl, were also removed. Sequences of consecutive data points were considered to indicate trawling periods. It was decided that each sequence was considered to have ended when the time difference between data points exceeded 2.5 hours. This time difference was chosen because occasionally the time between consecutive signals was greater than 2 hours. The resulting dataset encompassed the full range of speeds identified for bottom trawling (1.5–5.0 knots). Three further datasets were produced for the speed ranges: 3.5–5.0 knots [3], 1.5–4.5 knots [3] and 2.0–3.0 knots [38]. Each spreadsheet was imported into ArcGIS and a point to polyline conversion used to map vessel tracks.

A limitation of this method is that although vessel activity relates to seafloor contours and speeds fall within the range of bottom trawling speeds, is it not certain when fishing gear is in contact with the seafloor. Further limitations are i) the two-hourly signal frequency gives a limited indication of the true speed and activity of vessels, ii) the distances between data points are represented by straight lines so represent the minimum distance covered, iii) the absence of information about gear type and size makes further assumptions necessary.

The estimates of spatial extent of bottom trawling represent a proportion of the true extent of this activity in the OSPAR area as they are based on an analysis of vessels operating only within the Hatton - Rockall area from the NEAFC dataset. Deep water bottom trawling also takes place on the Reykjanes Ridge, the Mid-Atlantic Ridge and the continental slope [41] but these areas were not included in this study.

Results

Marine Scientific Research

There was no single source for marine scientific research cruise data. The quality of station lists and cruise reports ranged from purely narrative, lacking description of equipment and latitude and longitude of sampling sites, to comprehensive, including station number, cast number, type of gear, event, date and time, decimal latitude and longitude, depth, remarks, core length where applicable and institute responsible for sample.

Table 4 shows that approximately 22 km^2 of marine research comprised activities carried out by fisheries research vessels and approximately 4 km^2 were attributable to non-fisheries marine research. This includes the tracks of trawls, dredges and sleds and the 'footprint' of individual pieces of static equipment on the seafloor such as corers and grabs, which are removed immediately and the anchor weights of moorings ($\sim$1 m^2) which remain on the seafloor.

The cruises mapped in this study were estimated to represent approximately 45% of all scientific cruises reported on the ROSCOP website which carried out sampling on the seafloor during 2005 in water depths greater than 200 m in the OSPAR area. Table 5 shows figures extrapolated to include the cruises for which no data were available. Extrapolating these figures gives a total spatial extent of approximately 49 km^2 and 9 km^2 respectively for fisheries and non-fisheries research.

For those data that were available confidence ratings of 2 and 3 denote that the location of activities were, in most instances, available but the extent of individual activities (e.g. size of equipment deployed, length of trawls) were occasionally unreported.

Submarine Communication Cables

The data for this activity were from the two sources listed in Table 1. However, these data do not include all cables present on the seafloor. The complete dataset is only available commercially.

The results for the 4 scenarios (Table 4) considered for submarine communication cables demonstrate that this activity covers a relatively small spatial extent in all cases. The first scenario, giving an estimated 2 km^2, represents the spatial extent of the physical presence of submarine cables for the study area. The second scenario, giving an estimated area of 4 km^2, is independent of cable type and burial and uses a single value for cable width. The third scenario, giving an estimated area of 15 km^2 introduces the concept of plough burial and is based on the most conservative estimate of the width of the disturbance strip, 2 m, reported in [23]. The fourth scenario, giving an estimated area of 61 km^2, is based on the maximum estimated width of disturbance strip of 8 m [23].

The values for scenarios 1 and 2, representing an estimated 41% of all submarine communications cables, can be extrapolated to give an estimate of the total extent of this activity because they represent the physical presence of cables on or in the seabed (Table 5). The extrapolated values are 5 km^2 and 10 km^2 respectively. It is not appropriate to extrapolate scenarios 3 and 4 because plough burial was not introduced until the 1980s, all cables laid before that date were laid on the seabed surface.

The confidence rating of 1 and 2 denotes that while data relating to the location of submarine cables for areas to ~25°W were available there was no specific indication of the cable diameter or whether it was buried. There was no freely available information for areas beyond 25°W.

Waste Disposal

Radioactive waste. Information relating to dumping sites for radioactive waste was obtained from a single source [26], (Table 1). While the total area designated for dumping of radioactive waste was estimated to be 26,323 km^2, based on the aggregated areas with overlapping boundaries dissolved for each of the four designated sites (Table 6) this does not represent the area of seafloor covered by drums of waste. A second estimate of ~0.2 km^2 was calculated based on the tonnage, estimated number of drums (Table 6) and the area of each.

The confidence rating of 2 relating to the spatial extent of this activity denotes that while the location is reported the spatial extent is based on an estimated number of drums and drum size.

Munitions and chemical weapons. Inadequate documentation at the time of dumping of chemical weapons and munitions and the subsequent loss or destruction of documentation means that the full extent of this activity is unknown [28]. Accurate information on the quantities, present condition and current location of these materials is lacking [5,28,42]. While the location and type of some conventional and chemical munitions are known, other material is reported to have been dumped outside official dumping areas [43]. Furthermore, movement across the seabed or burial through natural processes or anthropogenic activity, have complicated establishing the locations of dumped munitions [43]. The disposal of redundant munitions has continued intermittently [4]. The most recent known event occurred during 1994 when Portugal, under Sovereign Immunity, scuttled a redundant vessel loaded with >2000 t of surplus munitions 346 km from the Portuguese coast at the edge of their EEZ in >4000 m of water [44].

The total spatial extent for this activity was estimated to be 1.4 km^2.

While information relating to munitions dumpsites was available openly online [28], lack of knowledge about the precise current location and extent of dumped material is reflected in a confidence rating of 1.

Oil and Gas Industry

The datasets and GIS shapefiles for this activity were downloaded free of charge in February 2008. However UKDEAL shapefiles are now available only on payment of a subscription. Norwegian data remain available without charge.

The estimated spatial extent of oil and gas industry pipelines in water deeper than 200 m was 4 km^2, while the footprint for structures on the seafloor (platforms, templates and wellheads) totalled 0.2 km^2. This figure is likely to be an underestimate as it includes only templates, wellheads and platforms. Other equipment and activities such as anchors and rock dumps were not included. The addition of the associated cuttings piles to the latter estimate resulted in a total estimated spatial extent of 3 km^2. The estimated spatial extent of exploration, development and appraisal wells drilled between 1960 and December 2005 together with the associated cuttings piles totalled approximately 15 km^2 while that for the single year, 2005, totalled 1 km^2. The total spatial extent of pipelines, structures and associated cuttings piles together with all exploration, appraisal and development wells drilled between 1960 and December 2005 and their associated cuttings piles in water deeper than 200 m was 23.2 km^2.

Oil and gas industry installations are complex. A wide variety of equipment is used each with its own type of disturbance (e.g. rock dumps, anchors). It has not been possible to evaluate these impacts in this study because data are not readily available. Confidence ratings of 2 and 3 reflect the variations in the quality of data. The UKDEAL dataset reported both location and diameter of pipelines resulting in a confidence rating of 3. Although diameters of Norwegian pipelines were not recorded in the NPD dataset this information was available by searching for each pipeline individually in NPD Facts [31] also giving a confidence rating of 3. Neither dataset indicated the size of individual installations on the seafloor, although the location of each is reported, giving a confidence rating of 2. Similarly, the location of development, appraisal and exploration wells are reported but no indication of the extent of these activities was recorded. It was unclear what type of installation was being referred to in the NPD dataset without following a hyperlink for each individual facility. Although a description of the individual installations was given in the UKDEAL dataset (e.g. clump weight, pipe crossing, wellhead) no indication of dimensions was included.

Bottom Trawling

As there was no definitive source identifying i) bottom trawling vessels, ii) where trawls started and ended and iii) the size of the gear deployed the spatial extent of bottom trawling had to be estimated from analysis of VMS datasets. Willingness to provide VMS datasets varied between States. Only two States out of the nine to which requests for data were made provided VMS datasets.

Table 8 shows the total area of seafloor trawled for each speed range, calculated by applying buffering to the vessel tracks of 22 m [39] , 80 m and 125 m, the possible spreads of the trawl doors. The least possible area trawled, 741 km^2, relates to the narrowest speed range of 2.0–3.0 knots and gear width of 22 m (Tables 4 and 8). The greatest possible area trawled, 37,160 km^2 relates to the widest speed range of 1.5–5.0 knots and gear width of 125 m (Tables 4 and 8).

Table 9 shows the spatial extent of bottom trawling when overlapping tracks were merged. Even if multiple trawls pass over a section of seafloor during the year only a single area is recorded. The least possible area trawled, 548 km^2, relates to the narrowest speed range of 2.0–3.0 knots and gear width of 22 m (Tables 4 and 9). The greatest possible area trawled, 13,920 km^2 relates to the widest speed range of 1.5–5.0 knots and gear width of 125 m (Tables 4 and 9).

Figure 3 shows the distribution of this activity in the Hatton - Rockall area.

The spatial extent of bottom trawling during 2005 in the Hatton - Rockall area is greater than that of any other activity in the OSPAR region. The most conservative estimate of 548 km^2 is one order of magnitude greater than the largest estimate for impacts by the oil and gas industry, while the estimate of 13,920 km^2, based on the widest gear (125 m) and widest speed range (1.5–5.0 knots) with overlapping tracks merged is three orders of magnitude greater. The spatial extent for the two scenarios above without merging overlapping tracks is 741 km^2 and 37,160 km^2 respectively. This suggests that much of the seafloor was trawled more than once during the year.

Calculations for the spatial extent of bottom trawling were based on data from only one part of the OSPAR area - Hatton -

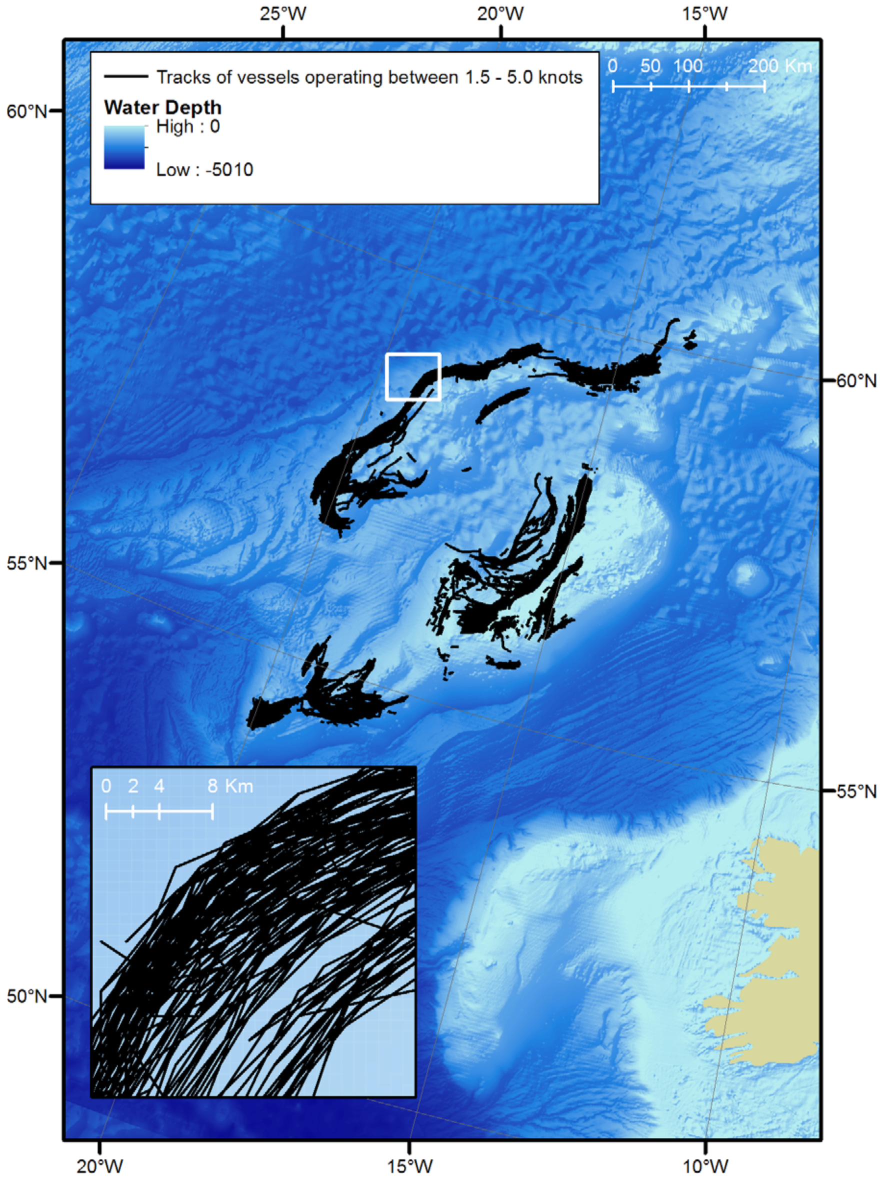

Figure 3. Bottom trawling. Tracks of vessels operating between 1.5 and 5.0 knots in the Hatton - Rockall area during 2005.
doi:10.1371/journal.pone.0012730.g003

Rockall. Extrapolations have been made based on the estimate that the Hatton - Rockall area comprises ~50% of the deep sea trawling grounds in the OSPAR area (Table 5). The estimate for the most conservative speed range and gear width (2.0–3.0 knots, 22 m) with overlapping tracks not merged is an extrapolated value of 1,482 km^2. The widest speed range and gear width (1.5–5.0 knots, 125 m) with overlapping tracks not merged gives an extrapolated value of 74,320 km^2.

The extrapolated estimate for the most conservative speed range and gear width (2.0–3.0 knots, 22 m) with overlapping tracks merged is an extrapolated value of 1,096 km^2. The widest speed range and gear width (1.5–5.0 knots, 125 m) with overlapping tracks merged gives an extrapolated value of 27,840 km^2.

The confidence rating of 1–2 (Table 4) reflects that while VMS data indicate the position of vessels and fishing can be inferred from speed and course, neither the location nor extent of the bottom impact i.e. actual trawling were reported.

Discussion

The results in Tables 4 and 5 are a first attempt to quantify the extent of human activities in the deep North East Atlantic together with an evaluation of confidence in the data. It is not practicable to present a definitive, unequivocal value for each activity as each encompasses a range of alternatives. Variables include the size of fishing gear, speed ranges within which vessels can operate, width of submarine cables, buried or non-buried cables, the size of individual oil and gas industry installations and extent of cuttings piles. Nevertheless, the figures presented represent the best estimates available and we have provided estimates based on both high and low extremes e.g. for the fishing data. This study has highlighted how complex it is to determine impacts in the deep-sea and how difficult it is to establish a comprehensive baseline for management.

Although the principal scope of this study is to establish the spatial extent of each activity it is worth noting that while some activities have an immediate impact after which seafloor communities may be re-established (albeit on perhaps long timescales), other activities, such as waste disposal, may have an effect for many years and the impact is likely to extend far beyond the physical disturbance.

The results demonstrate that the extent of human activities on the deep-sea floor in the OSPAR area of the North East Atlantic varies widely. Of the activities assessed dumping of waste was found to have the lowest spatial extent. The combined total of radioactive waste, munitions and chemical weapons dumpsites was found to be 1.6 km^2. The strategy of sea disposal of low level radioactive waste was one of dispersal and dilution rather than containment [45]. The lifetime of the iron drums containing the waste was estimated to be between 15–150 years while bitumen or concrete blocks encasing waste were estimated to last 1000 years [26]. So, although the dumping has ceased, such material may still leak from containers into the environment [26]. The main source of artificial radionuclides in the deep North East Atlantic is from atomic weapons testing carried out during 1960s. However, $^{233}Pu/^{239+240}Pu$ isotopic ratios in some samples of the fish *Coryphaenoides armatus* suggest an influence from the dumped material [46]. Similarly, while the spatial extent of munitions and chemical weapons dumpsites, estimated to be 1.4 km^2, is a relatively small area, the presence of this material poses a significant risk, particularly when disturbed [28].

Non-fisheries marine scientific research has a relatively small footprint. It is usually carried out by academic institutions using a range of equipment on the seafloor to sample the marine environment including moorings, grabs, corers, dredges and trawls. Much of this equipment has only a single impact of a few square meters. Considerably more research is carried out by academic institutions or fisheries research laboratories to determine fish population size and distribution. The spatial extent of fisheries marine scientific research is moderate. While fisheries research also involves the deployment of sampling equipment, such as grabs and moorings, it involves a higher proportion of bottom impact trawling.

The spatial extent of telecommunication cables is low to moderate depending on the whether cable burial is included in the calculation. The maximum extent of this activity (61 km^2), based on an 8 m wide disturbance strip in water depths between 200–1,500 m is likely to be an overestimate. This is because about 20% of cables in 200–1,500 m water depth are not buried and an 8 m wide disturbance strip may be an overestimate in many cases.

The spatial extent of oil and gas industry activities is moderate. While structures such as templates, wellheads, platforms and cuttings piles have been included in the estimates it is likely that this is an underestimate as other equipment and activities, for example, weights, anchors, rock dumps are not included.

A major finding of this study is that the spatial extent of bottom trawling is orders of magnitude greater than that for the other activities assessed. Even on the lowest possible estimates it is an order of magnitude greater than the sum of all the other activities. Despite the extent of this activity the total global catch from bottom fisheries - longliners, gillnetters and bottom trawlers - contributed only 0.31% to the total marine capture during 2006 [47].

The maximum total area impacted by the various activities discussed here is 27,932 km^2 (Table 5, based on the merged trawler tracks and 50 mm cable diameter data). This is a very small percentage of the total OSPAR area (11,032,175 km^2), but such a calculation does not provide useful information. An analogy would be the area of annual destruction of Amazon rainforest as a percentage of the landmass of South America, which would mean far less than destruction as a percentage of the total area of the rainforest. Human activities are concentrated in certain areas and particularly in shallower depths. The OSPAR area also comprises many different habitats each with different and diverse ecosystems. The percentage impact in each of these habitats would provide important information but unfortunately there is virtually no detailed seabed mapping to provide this information.

Conclusions

To meet future ecosystem-based management and governance objectives for the deep sea significant improvements are required in data collection and availability as well as a greater awareness of the relative impact of each human activity. In this paper we have shown the relative physical impacts of different activities with non-fisheries scientific research, submarine communication cables and waste disposal having low physical impacts whilst oil and gas activities and fisheries scientific research have moderate impacts. The impact of bottom trawling is at least an order of magnitude greater than all the other activities combined.

Acknowledgments

We are grateful to Professor Robert Carney of Louisiana State University for his support and interest; Carlos Pinto of ICES for advice on the analysis of the NEAFC VMS dataset; Tore Indreiten of Statoil and Jan-Allan Ede of the Norwegian Petroleum Directorate for additional oil industry data and assistance in its interpretation; Andrew Gates, SERPENT Project, for advice on recent research into cuttings piles; Richard Hill, Chairman of the United Kingdom Cable Protection and Steven Bennett of Global Marine Systems Limited for advice on submarine cables; Dick Ferro, Fisheries Research Services, Aberdeen, UK for advice on deep sea trawling and Brian Bett and Ben Boorman, National Oceanography Centre, Southampton, UK for advice on marine research equipment.

Author Contributions

Conceived and designed the experiments: AB PW DB SvdH. Performed the experiments: AB. Analyzed the data: AB AM GD TLB. Contributed reagents/materials/analysis tools: AM GD TLB. Wrote the paper: AB. Commented on manuscript: PW DB SvdH AM GD.

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