Fishing within offshore wind farms in the North Sea

Schupp, Maximilian Felix; Kafas, Andronikos; Buck, Bela H.; Krause, Gesche; Onyango, Vincent; Stelzenmüller, Vanessa

Published in:
Journal of Environmental Management

DOI:
10.1016/j.jenvman.2020.111762

Publication date:
2021

Fishing within offshore wind farms in the North Sea: Multi-use perspectives from Scotland and Germany

Abstract

Offshore wind power generation requires large areas of sea to accommodate its activities, with increasing claims for exclusive access. As a result, pressure is placed on other established maritime uses, such as commercial fisheries. The latter sector has often been taking a back seat in the thrust to move energy production offshore, thus leading to disagreements and conflicts among the different stakeholder groups. In recognition of the latter, there has been a growing international interest in exploring the combination of multiple maritime activities in the same area (multi-use; MU), including the re-instatement of fishing activities within, or in close proximity to, offshore wind farms (OWFs). We summarise local stakeholder perspectives from two sub-national case studies (East coast of Scotland and Germany's North Sea EEZ) to scope the feasibility of combining multiple uses of the sea, such as offshore wind farms and commercial capture fisheries. We compiled a desk-based review with 15 semi-structured qualitative interviews with key knowledge holders from both industries, regulators, and academia to aggregate key results. Drivers, barriers and resulting effects (positive and negative) for potential multi-use of fisheries and OWFs are listed and ranked (57 factors in total). Factors are of economic, social, policy, legal, and technical nature. To date, in both case study areas, the offshore wind industry has shown little interest in multi-use solutions, unless clear added-value is demonstrated and no risks to their operations are involved. In contrast, the commercial fishing sector is proactive towards multi-use projects and acts as a driving force for MU developments. We provide a range of management recommendations, based on stakeholder input, to support progress towards robust decision making in relation to multi-use solutions, including required policy and regulatory framework improvements, good practice guidance, empirical studies, capacity building of stakeholders and improvements of the consultation process. Our findings represent a comprehensive depiction of the current state and key stakeholder aspirations for multi-use solutions combining fisheries and OWFs. We believe that the pathways towards robust decision making in relation to multi-use solutions suggested here are transferable to other international locations.

1. Introduction

Global energy demand has been rising and, although the biggest proportion of this demand has been met by conventional energy sources (oil, gas and coal), the share of renewable power generation has been growing steadily. Renewables saw a growth rate of 4% in 2018, accelerating to their fastest growth rate this decade and providing 45% of the world's electricity generation growth (IEA, 2019). Wind energy (onshore & offshore) is currently the most competitive source of renewable power and already meets 10.4% of Europe's power demand (WindEurope, 2018). Offshore wind is now a mainstream energy source and has been steadily growing since the early 2000s with a cumulative total installed capacity of 15.8 GW in Europe. Most European offshore wind installations (71%) are situated in the North Sea (Figure 1). Future growth of the European offshore wind market is predicted to concentrate mainly in UK and German waters. Combined, they are predicted to host over half of Europe's 70 GW offshore wind power cumulative capacity by 2030 (WindEurope, 2018).

Offshore wind energy generation requires large surface areas to accommodate the sector's activities at sea. It already occupies considerable areas of both the UK's and Germany’s Exclusive Economic Zones (EEZ), specifically 6,504 km² and 1,129 km² respectively (4Coffshore, 2020). The North Sea is notable for its dense coastal populations, heavy industrialisation, and intense use of the sea (Emeis et al., 2014). Thus, the current and future predicted expansion of offshore wind energy in UK and German waters creates an interesting dynamic with other established maritime users. Similar required space characteristics (e.g. shallow water, specific depth ranges, sediment types, proximity to coast, etc.) often lead users to compete for access to the same locations (Holm et al., 2017). Increased claims for exclusive use of marine space from OWFs results in significant competition among stakeholders (Buck et al., 2004; Douvere and Ehler, 2009; Jentoft and Knol, 2014; Pomeroy and Douvere, 2008; Smith and Brennan, 2012). Other established and traditional maritime users, such as capture fisheries, often find themselves primarily concerned about exclusion from historically open fishing grounds and the resultant damage to their interests and livelihoods (Krause and Stead, 2017).

The dynamic and wide-ranging distribution of commercial fisheries makes them ideal candidates for studying user interactions and the potential of multi-use solutions to mitigate spatial use conflicts. OWFs impede the movement of fishing vessels, constrain crossing or circumnavigation of fishing vessels, as well as excluding any fishing operations during their construction and (in many cases) operational phase, effectively acting as area closures (FLOWW, 2015; Gray et al., 2016; Kafas et al., 2017; SeaPlan, 2015; Vries et al., 2015).

Excluding fisheries from OWFs has a range of negative direct and indirect economic, social and environmental effects on individual fishers, the fishing industry, fishery-dependant coastal communities and wider society (Kafas et al., 2017). There is growing international pressure by the fisheries sector to change the *status quo* and encourage the re-instatement of fishing activities within offshore wind farms (Burdon et al., 2018; Christie et al., 2014; Fayram and de Risi, 2007; Hall and Lazarus, 2015; Hoagland et al., 2015; Jongbloed et al., 2014; Reilly et al., 2015; White et al., 2012; Yates et al., 2015; Zhang et al., 2017). More specifically, the argument has reached the public and academic discourse in several occasions in the UK (Ashley et al., 2014; Blyth-Skyrme, 2011, 2010; FLOWW, 2015; Gray et al., 2005; Groot et al., 2014; Hooper et al., 2017; Hooper and Austen, 2014; James and Slaski, 2006) and Germany (Berkenhagen et al., 2010; Griffin et al., 2015; Michler-Cieluch and Krause, 2008; Nicolai and Wetzel, 2017; Stelzenmüller et al., 2016, 2013; Wever et al., 2015). These initiatives are in line with Europe-wide efforts on scoping for potential combinations of multiple maritime activities in the same area, promoting a fundamental change to current thinking away from exclusive use of ocean space. More specifically, the concept of Multi-Use (MU) or the “the joint use of resources in close geographic proximity by either a single user or multiple users” (Schupp et al., 2019), has received a lot of attention over the past few years (Brennan and Kolios, 2014; Buck and Langan, 2017; European Commission, 2018a, 2018b; Krause et al., 2011; MARIBE, 2016; Quevedo et al., 2013; van den Burg et al., 2016; Wageningen, 2018) and is forecast to play an integral role in future OWF development (Wind Guard, 2019).

Comparing experiences from the two leading countries in the field of offshore wind energy (UK and Germany) can help to put scenarios for multi-use development into perspective. In this study, we take a stakeholder-focused mixed-method case study (CS) approach in two sub-national cases, one focused on the East coast of Scotland and the other on Germany’s North Sea EEZ (Figure 1). Using this approach we aim to:

(i) Identify the current barriers to establishing this MU combination,

(ii) Capture the opportunities and drivers for MU combination,

(iii) Evaluate the resulting economic, environmental, and social effects, and ultimately

(iv) Present management recommendations to support progress in developing the decision-making process based on stakeholder perspectives from the two countries.

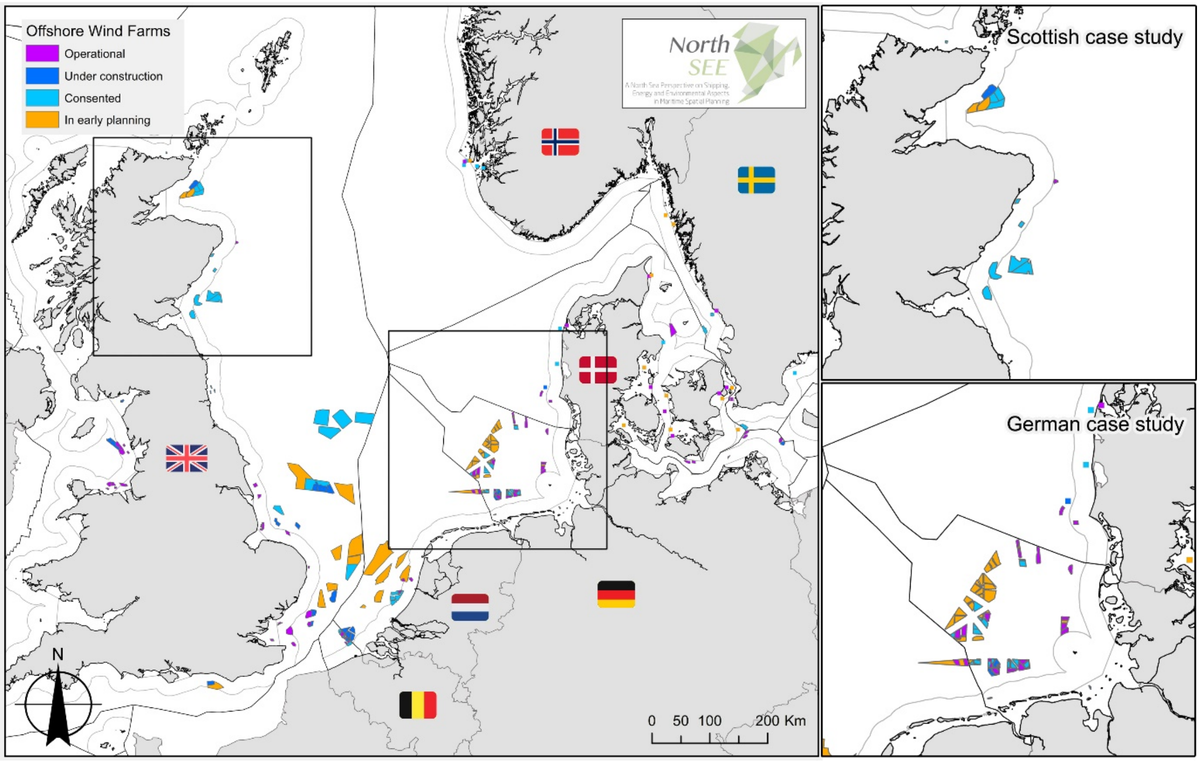

Figure 1: Map of offshore wind farms in the North Sea and the two case studies (adapted from Kafas et al., 2018).

2. Case Study Description

The two case study areas chosen in this study are the German North Sea EEZ and the Scottish part of the North Sea on the east coast of Scotland as depicted in Figure 1. Fishing has a significant, millennia-long presence in the North Sea and is deeply rooted in society, especially in the coastal regions of the UK and Germany (Engelhard et al., 2014; Fock et al., 2014).

The UK fishing sector landed 698 thousand tonnes of sea fish (including shellfish) into the UK and abroad in 2018 using a fleet of 6,036 vessels (MMO, 2019), with roughly 60% of the total catch being landed by Scottish vessels (Scottish Government, 2017). The German fishing sector is smaller than the UKs, following a drastic decline in the second half of the 20th century when states declared EEZs and limited access to international fishing vessels. German fisheries now land 261 thousand tonnes annually with a fleet comprised of 1,330 vessels in 2018 (BLE, 2019).

The UK and Germany lead the European offshore wind market with 43.3% and 33.9%, respectively, of all installed offshore wind capacity in Europe in 2018. Both CS areas contain many OWFs at various stages, which occupy large areas of ocean space (30-400 km^2 per OWF), as well as future offshore wind planning areas (called Plan Options in Scotland and Offshore Wind Clusters in Germany). Utility-scale offshore wind developments are predominantly bottom-fixed and situated in relatively shallow waters (27.5 m on average), and comparatively close to shore (41 km on average; Wind Europe, 2018). However, the offshore energy industry is constantly evolving with new advancements in technology, such as floating wind farms (Scottish Government, 2015a), allowing larger developments of bigger and more powerful wind turbines to be built further offshore.

The Scottish CS hosts both fixed-foundation and prototype floating offshore wind farms, which made it an ideal UK candidate to explore perceptions of OWF developers. The German North Sea EEZ contains most of the country’s installed OWFs and was thus chosen as the second focal point of this study to contrast Scotland.

MU policies within the CS areas are distinctly divergent. The UK and Scottish policy regimes (UK Parliament, 2011; Scottish Government, 2015b, Marine (Scotland) Act 2010, UK Electricity Act 2004) support commercial fishing activities within Scottish offshore wind farms (both offshore development areas and along the offshore export cable corridor). During the construction phase, a safety zone of 500 m around major construction vessels excluding fishing is put in place on a ‘rolling’ basis (covering only those areas of the total site in which such activities are physically taking place at a given time). During operation, installed infrastructure can be protected by safety zones of 50 m around fixed structures (or an appropriate size to incorporate its full size). Under these conditions, it is often assumed that fishing activities can resume to some degree. However, the ultimate decision to fish within an operational wind farm is down to the individual vessel skippers, who have been reported to avoid resuming fishing operations within constructed UK OWFs (Gray et al., 2016).

In Germany, different uses (or users) are assigned “priority areas” under the German Marine Spatial Plan (MSP) (BMVBS, 2009a, 2009b, 1997). “Priority areas” assign a maritime user priority over other user groups. Uses that are not compatible with the priority use are not permitted within this area. In the case of offshore wind, priority areas for OWFs adhere to strict safety regulations and, for the most part, constitute exclusion zones to any other users, including commercial fisheries. Fisheries do not have assigned priority areas due to the high spatial variability of their fishing grounds and a management system controlled primarily by the EU Common Fisheries Policy (European Commission, 2013). Instead, they are awarded special considerations in the priority areas of other uses, but no legal rights (BMVBS, 2009a). These special considerations must be considered by users and permitting authorities alike during the permitting process of offshore wind farms according to the ordinance on offshore installations (BMVBS, 2009a, 1997). However, this provision, although legally binding, does not yet result in MU combinations. Current opinion considers fisheries capable of hindering or endangering construction, operation or maintenance of the OWF (BMVBS, 2009a). This has led to a state where fishing operations, whether mobile or static, are *de facto* not permitted inside the security zone of OWFs (500 m; BMVBS, 2009b). The approach adopted is contradictory to a series of German studies since 2000 (see Buck *et al.*, 2017) which offer solutions for multi-use concepts with respect to technologies and designs for the MU of OWF areas with aquaculture and fisheries.

3. Materials and Methods

3.1 Stakeholder mapping and interviewees

A stakeholder mapping exercise identified key stakeholders on the meta-level for each CS. These comprised industry stakeholders from offshore wind and commercial fisheries sectors (both companies and cognate cluster associations), with active business interests within the locality of the two case studies, National regulators, marine planners, and academics of relevance to the case studies were also included as candidate stakeholders and approached where available (see Supplementary Material 1, Table 1 for Scotland and 2 for Germany). Available interviewer resources were targeted at representatives of wide cluster associations or industry leaders rather than individual companies, where possible. We assumed that industry associations, having close ties to and personal experiences in the industry, would represent their respective sector accurately and objectively. In cases where associations could not be reached, a random selection of remaining stakeholders was interviewed while keeping the balance between offshore wind and fisheries interests.

Energy interests included both the national renewable energy industry bodies, and individual energy companies who had submitted a consent application to the respective marine licencing authority (BSH, 2017; Marine Scotland, 2017). Commercial fisheries interests included national federations, and individual local associations who had responded to the respective statutory consultations. Additional candidates, comprising domestic and international experts, were included to share their relevant experiences. Eventually, 26 candidate stakeholders were identified for the Scottish CS and 19 for the German CS. Not all candidate stakeholders were responsive or available for an interview. As a result, a total of 10 semi-structured stakeholder interviews (n) were undertaken for the Scottish CS and 5 for the German CS. Interviews took place between July 2017 and October 2017. Where possible, face-to-face interviews were conducted in a personal setting. In some cases, interviews were undertaken via videoconferencing facilities. Interviews lasted 2 hours on average. All interviewees agreed for their information to be included in the study. Some Scottish stakeholders wished to remain anonymous at an individual or organisational level.

3.2 Desk-based review and interviews

A mixed-method approach was used comprising a desk-based review and semi-structured qualitative interviews. The review established the national policy and legal *status quo* contexts with respect to MU combination in Scotland (with links to UK policy where relevant) and Germany. Interviews with key stakeholders from the two sub-national case studies, East coast of Scotland and German North Sea EEZ, documented industry perceptions at a local level. The study followed the methodology described in Zaucha et al. (2017) and Bocci et al. (2019).

The review assessed the state-of-the-art literature regarding the opportunities and obstacles of multi-use solutions in Scotland and Germany, prior to engaging any stakeholders. *Grey* literature included national marine plans, sectoral plans, marine management legislation, as well as other associated strategic policy documents and sectoral reports. Scientific literature targeted references to the MU combination, based on a combination of key words, including: “offshore wind AND fisheries”, “co-location”, “co-existence”, “co-management”, “co-production”, “multi-use”, “multi-resource use”, “secondary use”, “symbiotic use”, and “multiple ocean uses”. The aim was to collect evidence of factors that (i) support the MU combination (drivers), (ii) hinder the MU combination (barriers), as well as (iii) result in positive effects and (iv) negative effects. Here, positive effects relate to the benefits received by a stakeholder group or society when implementing multi-use concepts. Negative effects comprise detriments i.e. damage to stakeholders’ or society’s interests by the MU combination coming into being. A catalogue of all four components (drivers, barriers, positive and negative effects) was compiled and became available for review and scoring by stakeholders during the semi-structured interviews.

The semi-structured interviews followed two steps. Firstly, stakeholders were asked to read and sign a consent form, which committed authors to high ethical standards (Supplementary Material 2). Afterwards, stakeholders were invited to share their local experiences by identifying policy, industry, and other drivers that, in their opinion, facilitate or encourage the MU combination. Similarly, they were asked to identify any barriers to MU with regard to their current status of information. Their views on the stated positive and negative effects of the MU combination were also collected. Stakeholders were invited to comment on the potential for MU extensions (innovative ways to enhance MU extending beyond the two named sectors, resulting in further benefits), and to identify any management interventions needed to overcome barriers or enhance MU. Discussion was aided by a range of open-ended questions regarding MU development (Supplementary Material 3, Table 3). Secondly, individual stakeholders were invited to review and score the initial catalogue compiled from the literature review. Any new issues identified during interviews were included in the revision of the catalogue. A semi-quantitative scoring system for factors was applied with 4 levels based on their perceived influence on the MU combination (0 – no strength, 1 – low, 2 – medium, 3 – high; as per Bocci et al. (2019). The scoring system allowed arithmetic averages to be calculated. Drivers and positive effects were scored positively (between 0 and +3), while barriers and negative effects were scored negatively (between 0 and -3). When a stakeholder did not agree with a factor or had no knowledge about it, the factor received no score (NA). Scoring allowed the calculation of the 'MU Potential' and 'MU Net Effect'. 'MU Potential' was calculated from the relative balance between the average score of drivers and average score for barriers in the catalogue. The 'MU Potential', by definition, ranges from positive to negative values. It describes the degree of opportunity in the study area to strengthen the MU combination. In other words, a score of +3 demonstrates the greatest degree of perceived opportunity by stakeholders, where market forces would suffice for the MU combination to be developed. On the other hand, a score of -3 indicates no real perceived opportunity for the MU combination. A zero value demonstrates a net counterbalance of drivers and barriers. Proactive management may remove barriers and enhance drivers which will ultimately lead the MU combination to come to fruition (subject to externalities beyond the immediate reach of management). Similarly, 'MU Net Effect' was calculated from the relative balance between the average scores of positive and negative effects. It describes the net result (positive or negative) of implementing MU in the area according to stakeholders. The 'MU Net Effect' is expected to vary between stakeholder groups, as some will benefit more than others.

Finally, after completion of the interviews, factors included in the final catalogue (collected via desk research and validated, refined and complemented by interviews) were grouped into four categories: economic, social, policy and legal, and technological. Structuring the various factors under such categories assisted in the identification of overarching themes that could be targeted collectively with management recommendations. Results from both CS were combined into a single integrated catalogue for analysis. Average scores for the integrated factors and categories were calculated by averaging the scores of all factors in each category from all interviews. In addition, summary tables listing sector-specific factors include separate average scores for Scottish and German stakeholders to allow for initial comparison of country differences. The results of the interviews were collated and central management recommendations for the MU combination were identified. All analysis and production of figures was undertaken in the R statistical environment (R Development Core Team, 2008).

4. Results

All factors collected via desk research and their verification via the semi-structured interviews in both countries were merged in a single integrated catalogue for analysis. A summary of all factors in the catalogue and respective average scores from all stakeholders is provided in Figure 2. A total of 57 unique factors (f) were identified and scored by stakeholders, including 16 Drivers, 16 Barriers, 18 positive effects and 7 negative effects. There was a large diversity in scoring applied by interviewees. Not all stakeholders scored all available factors. No factor was unanimously scored by all stakeholders. In all cases, factors were scored by a subset of stakeholders (approx. 58% of stakeholders on average). Overview tables explaining the factors along with scores and brief description of relevant interviewee comments/examples are provided separately (Supplementary Material 4) for the offshore wind sector (Table 4), commercial fishing sector (Table 5), and government (Table 6). Average factor scores are shown for Scottish (SCOT; n=10), German (DE; n=5), and all stakeholders together (ALL, n=15). Figure 3 presents average scores for all categories of factors. The category of drivers which received the highest average stakeholder score were economic drivers. Stakeholders scored the categories of barriers roughly equal with the policy and legal category ranking last. Category scores for added value had very small score differences. The categories of impacts were scored, in descending order of strength, as social, economic, and environmental. The MU combination scored very low (near-zero) on MU Potential and MU net effect metrics on average, by stakeholder group, and by case study. There were small differences by stakeholder groups and by case studies as shown in Figure 4. Finally, stakeholders proposed management measures based on their experience. Recommendations addressed the removal of barriers or enhancement of drivers for the MU combination. Stakeholders' recommendations jointly resulting from all interviews were collated and edited by authors and summarised in Table 7.

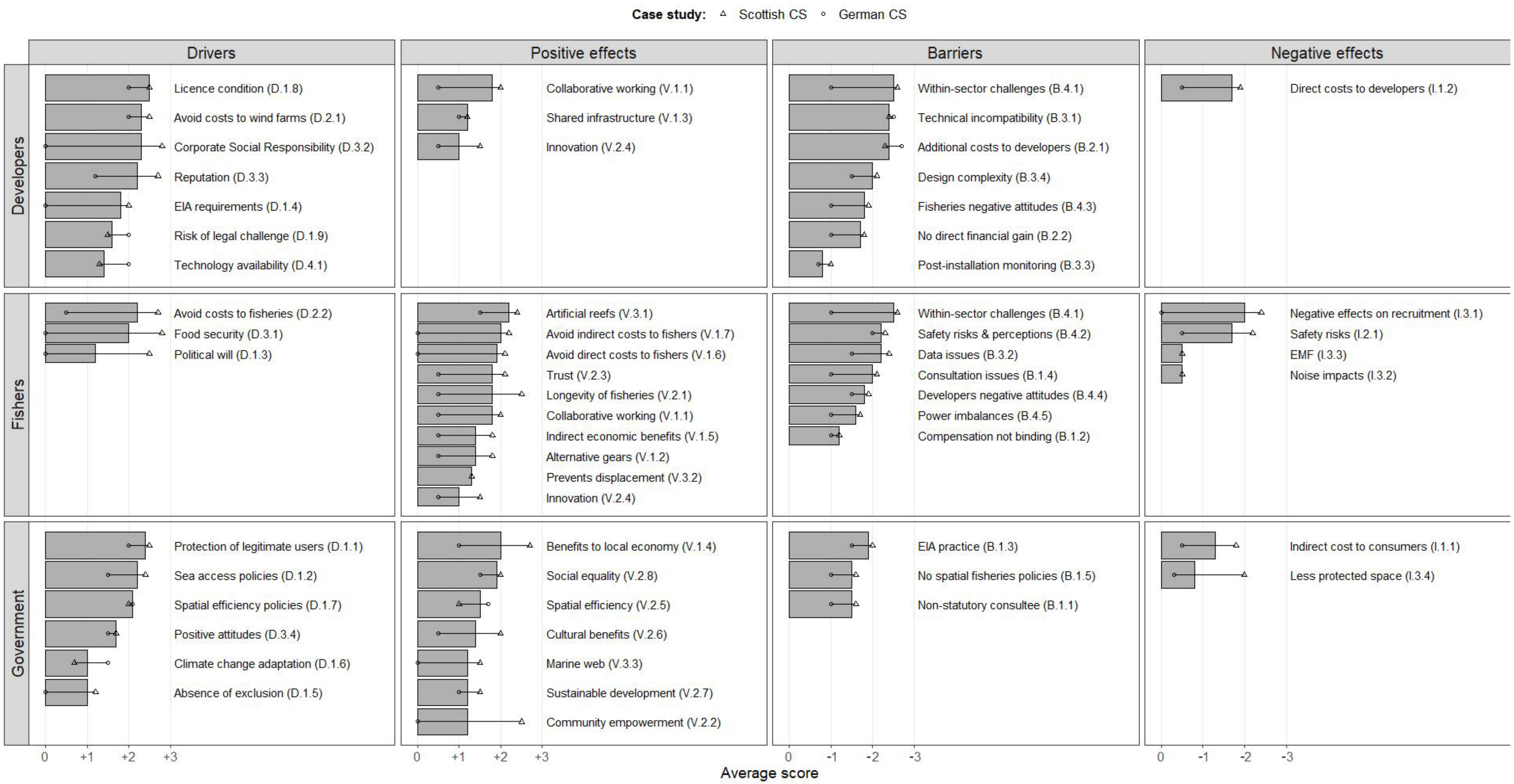

Figure 2: Integrated catalogue including all factors by stakeholder group. Factors are ranked in each panel based on stated importance (average score). Bars show average factor scores for all stakeholders, while points show scores separately for each case study.

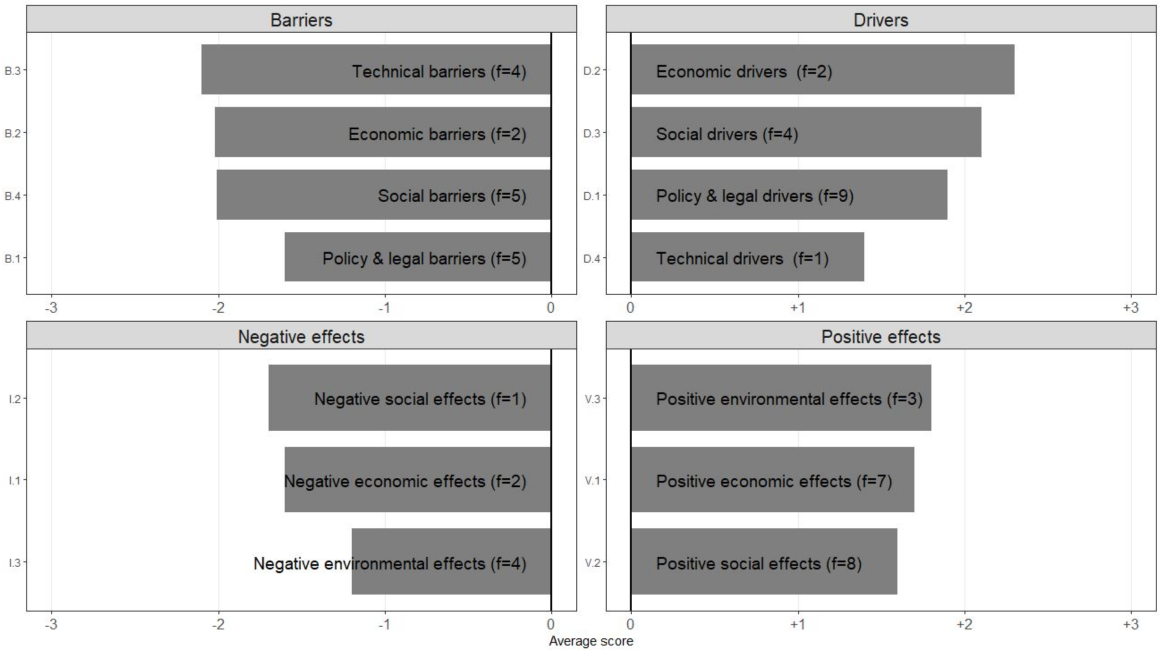

Figure 3: Categories of factors in the integrated catalogue ranked by average score.

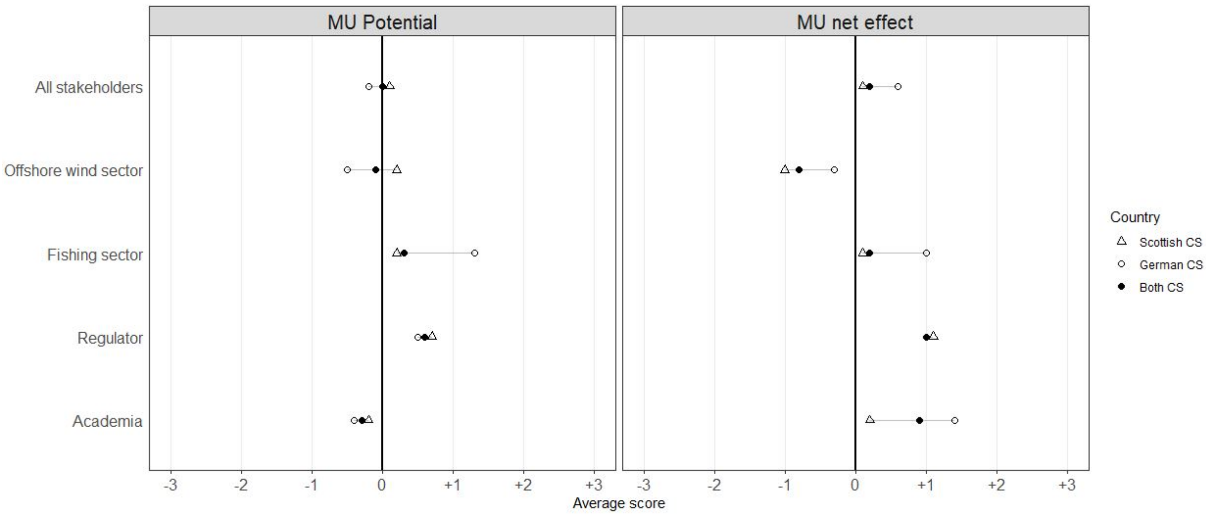

Figure 4: Degree of opportunity (MU Potential) and net result (MU net effect) for the MU combination collectively and by stakeholder groups. Calculated scores also shown separately for each case study.

Table 7: Management recommendations to remove barriers or enhance drivers for the MU combination.

	Management recommendations	Most relevant factors addressed
	Policy framework improvements	
1	Undertake "MU opportunity" mapping - encourage overlap between the two industries and demonstrate the potential benefits of coexistence.	D.1.1, D.1.7
2	Provide financial incentives for the MU combination (e.g. via state subsidy contracts).	D.2.2, D.3.4, B.2.1, B.2.2
3	Encourage innovation by reducing the scope of full-scale assessments for small-scale MU pilots.	D.2.1, B.2.1, B.3.1, B.3.4
	Regulatory framework improvements	
4	Further improvements in assessment methodologies as part of the EIA and CIA processes.	D.1.8, D.1.9, B.1.3, B.3.2
5	Establish mutually-agreed co-existence plan between the two industries as part of the marine licencing process.	D.1.4, D.1.8, D.1.9, D.3.2, D.3.3, B.1.1, B.1.4, B.4.4, B.4.5
	Good practice guidance	
6	Develop good practice technical guidance on co-design of OWFs to accommodate multiple uses, including commercial fisheries	D.1.2, B.2.1, B.3.4, B.4.4
	Empirical studies	
7	Fund and/or encourage in situ gear trials and Research and Development projects (R&D)	D.1.1, D.1.4, D.1.8, D.3.2, B.4.2
	Consultation and capacity building	
8	Reinforce and formalise direct stakeholder dialogue to exchange best available information and technology on all aspects of the MU combination	D.1.4, D.3.3, D.4.1, B.1.4, B.3.2, B.4.2, B.4.3, B.4.4, B.4.5
9	Increase stakeholder's knowledge and financial capacity via educational resources and community funding, respectively.	B.4.3, B.4.4

5. Discussion

Building on international stakeholder consultation processes in relation to multi-use of space by offshore wind farms and fisheries, we identify industry-wide factors and derive management recommendations to progress the decision process of the MU combination. Integrated results encourage mutual learning between the case studies and allow for wider applicability of the management recommendations outside the case study areas. We found that the offshore wind industry shows a low interest in multi-use of any kind, unless clear added value is demonstrated, and no risks are involved. Fulfilling legal requirements, avoiding potential costs from delays and maintaining a good company reputation are the strongest drivers for the wind sector.

In contrast, the commercial fishing sector is proactive towards multi-use projects and acts as a positive driving force for MU developments, since it, along with structurally weaker coastal regions, stands to be impacted most if MU is not implemented. Perceptions around safety of operations, and issues with data and consultations are the strongest barriers faced by the fishing sector. An interesting dichotomy appears in the impacts perceived or feared by representatives of the fisheries sector. Figure 2 shows a perceived negative impact of the MU combination on recruitment of target fin fish species. This factor was only raised by representatives in the Scottish CS and potentially shows an awareness of fishermen of positive environmental spill over effects of OWFs.

There are big differences in average factor scores between the two case studies (see Figure 2). It is likely that this, in part, reflects the policy framework in regards to the MU combination in each country. Despite the limited geographic scope of the study on the global scale, the two countries represent the extremes of the range of current European policy attitudes towards this MU combination, one allowing (Scotland/UK) and the other “in essence” prohibiting (Germany) fishing activities within domestic operational offshore wind farms. Our approach allows the lessons learned to be easily transferred to other multi-use locations around the North Sea, where management styles within the same spectrum are adopted (e.g. Belgium, Denmark, and the Netherlands; Stelzenmüller *et al.*, 2013).

However, it should also be noted that the factor scores presented here only provide a baseline of stakeholders’ subjective perceptions of the MU combination. Readers should treat individual scoring, overall ranking of factors (f=57), and score differences between CS as qualitative indicators of the knowledge and perceptions of the involved stakeholder groups.

A larger sample of stakeholders is needed in order to provide a quantitative assessment of all perceptions surrounding the MU combination. Due to this, no statistical comparison between countries was undertaken. Instead, CS scores are presented separately along with narrative text, where relevant.

5.1 Management recommendations

The results presented here demonstrate that stakeholders have high expectations for the range of benefits and positive effects from the MU of OWFs and commercial fisheries. However, the MU combination also faces several barriers and has been associated with negative effects. This is reflected in the analysis of the degree of opportunity (MU Potential) and net result (MU net effect) which both scored near zero (Figure 4). Drivers can only have an effect in the absence of barriers, which require proactive management for their removal. Stakeholders were therefore invited to offer management recommendations to overcome those barriers and enhance the MU combination (Table 7).

5.1.1 Policy framework

It was noteworthy that stakeholders in both countries advocated for more explicit references to MU within the policy framework. This calls for policy transformations, as it requires governments to adapt their management-style from reactive to proactive in relation to the MU combination. More specifically, some stakeholders stated that there are certain fleet segments that will be less compatible (e.g. mobile gears) within offshore wind farms than others. They assumed that this may present an opportunity for alternative fleet segments operating more compatible gears (e.g. pots) to benefit. In cases where new segments have a smaller environmental footprint than the previous ones, establishing OWFs in carefully selected areas can contribute to fisheries management initiatives (e.g. reduction of a fleet segment in certain areas; promotion of sustainable fishing practices) and to wider marine conservation efforts (links to *de facto* Marine Protected Areas; Inger *et al.*, 2009; Tien and van der Hammen, 2015; Vries *et al.*, 2015; Rouse *et al.*, 2017). They referred to this concept as “MU opportunity mapping”, where overlap between the two industries in a certain area is targeted rather than avoided. This is converse to traditional “constraints mapping” approaches often adopted in sectoral planning initiatives (e.g. Scottish Government, 2013; Scottish Government, 2018) and is expected to be of particular relevance to floating wind developments which bring additional challenges to the fishing industry due to the presences of cables throughout the water column (NERC, 2016).

Furthermore, most stakeholders suggested the provision of clear incentives for the MU combination. One form of incentives (financial) target existing state mechanisms for renewable energy supply contracts (e.g. UK Contracts for Difference). Assessment criteria can favour developments that maximise the sea use potential and enhance MU with other sea users, such as commercial fisheries. Evidence for co-location opportunities with fisheries can be provided via a supply chain plan (e.g. by listing employment opportunities for local fishing vessels), and commitment to fund gear trials to test the safety of available equipment and develop new gear adapted to operating inside OWFs. Another form of incentive (cost savings) targeted innovation. Innovation can be encouraged by reducing the scope of full-scale assessments for small-scale pilots demonstrating the MU combination (similar to the Scottish Survey, Deploy, and Monitor Policy applied primarily to small-scale ocean energy developments; Scottish Government, 2016).

5.1.2 Regulatory framework

Recommendations by stakeholders also extended to overcoming pitfalls of the current regulatory framework and associated assessments, including Environmental Impact Assessment (EIA) and Cumulative Impact Assessment (CIA) processes as echoed by Stelzenmüller et al. (2020). For example, definitions of the level of significant effects on fisheries are not harmonised across EIAs, and assessment of some effects, such as fisheries displacement, have previously been discounted due to a lack of relevant assessment tools or not easy-to-use decision-support tools (Pınarbaşı et al., 2017). Collectively these oversights may undermine the true cumulative impact on fishers (Berkenhagen et al., 2010; Campbell, 2015). Additional focus should be given to assessment frameworks, including the cumulative impacts or benefits of MU scenarios, and quantifying the resulting socio-economic effects, in order help support decision making.

In the German CS, it was suggested that the relevant German licensing authorities on the federal level could develop the MU decision making process by requesting a mutually-agreed co-existence plan between the two industries, prior to the submission of a licence application. The plan would detail OWF design variables, and installation methods adopted. This is similar to the Commercial Fisheries Mitigation Strategy (CFMS) for proposed OWFs adopted in Scotland (e.g. BOWL, 2015). An alternative recommendation included use of a “Statement of Common Ground” (SCG) between developers and impacted fishermen (mostly an English practice e.g. SMartWind, 2018), which can be a good starting point towards a full CFMS. No direct equivalent of CFMS or SCG exists in Germany. The implementation of CFMS in Scotland would benefit from an earlier adoption, prior to the submission of a marine licence application. Earlier agreement on the mitigation strategy (prior to securing a marine licence) will aid with stakeholder power imbalances. Currently, most of the mitigation options are examined, and agreed post-consent, by which point the perception is that developers already have the upper hand.

5.1.3 Good practice guidance

Stakeholders from both countries encouraged the idea of developing a good practice technical guidance on co-design of OWFs to accommodate multiple uses. In relation to commercial fisheries, the guidance could propose a protocol for better integration and interpretation of fisheries distribution data layers within EIAs, set gear specification for safe operation within OWFs, suggest design adjustments (e.g. turbine spacing, cable burial depths, specifications of cable protection measures, scour protection etc.), propose business models for data sharing agreements and protocols between industries (e.g. for sharing ROV footage and bathymetric survey data by developers to demonstrate to fishers that fishing can take place safely within the wind farms), offer information about alternative employment opportunities (e.g. Gwynt y Mor OWF; Hattam *et al.*, 2015) and, very importantly, make a business case for the benefits to developers when adopting such recommendations. Demonstrating benefits towards corporate social responsibility, company reputation, faster and smoother licensing are all expected to be favourable to developers.

5.1.4 Empirical studies

It was suggested by many stakeholders that empirical studies exploring the compatibility between OWFs and commercial fisheries can drive insurance costs down, boost fishing industry confidence to return to fishing grounds (if communicated effectively) and can have financial benefits to both parties. Both industries will need to be directly involved to ensure scientific results propagate fully into practice. Hence, a new mode of knowledge production is called for that centres around co-production, allowing potential direct uptake by practitioners. Funding for trials and R&D modifications in gear technology can be sourced, depending on the size the necessary investment, from local community funds, governtment funds, or directly from developers. Large utility-scale, self-insured developers should be able to absorb the risks introduced by the novel nature of trials. Hence, they can be targeted in the first instance to facilitate initial trials, and then findings will spread within the industry and funding is expected to be easier. Recommendations took the form of *in situ* gear trials and Research and Development projects (R&D).

In situ gear trials can alleviate safety concerns by fishers (e.g. in relation to dropped objects, mud berms residue from construction vessels, and rock protection profiles). It can also alleviate concerns by OWF operators and build a larger knowledge base for insurers and drive down premiums. A similar practice has been adopted by the UK Oil & Gas sector where over-trawlability surveys were undertaken by fishing bodies who then issued an unobstructed seabed certificate (SFF, 2017). Such surveys within development areas will reinforce fishers' confidence to operate within OWFs and overcome safety objections.

R&D studies should focus on better mapping of navigational hazards (e.g. dropped objects during construction), gear technology and modifications (e.g. minimising seabed penetration of scallop dredge gears; Catherall and Kaiser, 2014), fishing-friendly mooring types (e.g. tension legs), cable installation and protection methods (with guaranteed burial depths, minimal sediment suspension and post-installation obstructions), and real-time monitoring of installed cables for detection of exposed sections (e.g. distributed fibre-optic temperature sensing systems; Selker *et al.*, 2006). Stakeholders also mentioned R&D studies to further enhance the artificial reef effects of OWF by engineering turbine foundations or cable rock armouring to provide cryptic spaces that would benefit crustacean fisheries (primarily lobster; e.g. Stenberg *et al.*, 2010; Lengkeek *et al.*, 2017) and establishing alternative fishing practices (e.g. targeting a new species) within offshore wind farms (e.g. Stelzenmüller *et al.*, 2016).

5.1.5 Consultation and capacity building

The most frequently mentioned recommendation related to the need for further strengthening of dialogue opportunities between relevant stakeholders. *Ad hoc* opportunities are currently channelled through informal professional networks and research projects. Most stakeholders highlighted the need for reinforcing these opportunities through a formal government-led forum (e.g. FLOWW, 2015). There is a clear need to establish an open and direct dialogue between key stakeholders (i.e. users, regulators, and certifying companies) to exchange the best available information and technology on all aspects of the MU combination. This will serve to alleviate safety concerns and showcase added value for all stakeholders involved. Cross-border exchanges between German regulators and other countries, where this combination exists already (e.g. UK or Denmark), to find commonalities and streamline management approaches will also benefit the MU combination.

Lastly, many of the consultation issues mentioned relate to the fishers' capacity to get involved and developers' understanding of the nature of fishing. Fishers' capacity limitations relate to available resources (time, financial, and human) and understanding of the planning and licensing processes. Developer's limited understanding relates to knowledge of fishing practices, seasonality, and gear specifications. Further educational resources to increase the capacity of stakeholders will help mitigate the issues currently faced. The format could be similar to current industry-run courses on commercial fishing facilitation (e.g. fishing awareness seminars; SFF, 2018). Limitations related to financial capacity of the fishing industry, could be addressed via fishing community funds. These can cover industry-wide costs e.g. certification/labelling of sustainable fishing practices in the vicinity of OWFs, new safety equipment for interacting fleets, electrifying energy-intensive processing plants (also referred to as corporate renewable power purchase agreement; Richter, 2012), and providing electricity to fishing vessels (linked to a long term vision of electric or hydrogen-fuelled transportation).

6. Conclusions

As the demand for ocean space increases, a fundamental change to current thinking away from exclusive use of ocean space is critical. Therefore, in the North Sea, fishing within or around offshore wind farms is increasingly and will continue to be a major topic in stakeholder debates.

Satisfying legal requirements, avoiding costs, and having a positive effect on reputation are the strongest drivers for the offshore wind sector. Avoiding interferences and minimising threats to livelihoods drive the fishing sector. Both sectors face sector-specific challenges that inhibit the general uptake of the MU concept as well as barriers related to additional costs, technical issues, perceptions and negative outlooks.

Based on the findings of this study, the offshore wind industry in either country has demonstrated a low interest in multi-use, unless clear added value could be demonstrated, and no risks for the respective businesses were involved. On the other hand, the commercial fishing sector is proactive towards multi-use projects and is a positive driving force for MU developments.

The comparative CS approach taken in this study has highlighted several important differences as well as similarities between the situation of the offshore wind energy and fisheries MU combination in the UK and Germany. Providing an integrated cross-country catalogue of drivers, barriers, positive and negative effects from both countries showcases the *status quo* on a trans-boundary level. It allows both preliminary comparisons and the formulation of industry-wide management recommendations to promote the development of the MU combination.

Lastly, and maybe most importantly, if multi-use of ocean space is to become a potential sustainable solution for reducing conflict in MSP, a clear commitment is needed from policy makers towards this end. We argue that this requires a regulatory framework that guides the process of weighing multi-use options by considering both environmental and socio-economic impacts. Ultimately, MSP objectives and respective regulations are driving the implementation of spatial management measures.

Declaration of interest

None.

Acknowledgments

Financial support for the conduct of the research, collection and analysis of data, as well as preparation of the article has been received by the European Union's Horizon 2020 research and innovation programme, under the MUSES project grant agreement No 727451. The authors would like to thank all stakeholder participants involved in the research and all project partners involved in the MUSES project.

7. References

4Coffshore, 2020. Windfarm Market Intelligence Database [WWW Document]. Wind. Intell. Database. URL https://www.4coffshore.com/subscriptions/offshore-wind-farms/ (accessed 3.3.20).
Ashley, M.C., Mangi, S.C., Rodwell, L.D., 2014. The potential of offshore windfarms to act as marine protected areas - A systematic review of current evidence. Mar. Policy 45, 301–309. https://doi.org/10.1016/j.marpol.2013.09.002
Berkenhagen, J., Döring, R., Fock, H.O., Kloppmann, M.H.F., Pedersen, S.A., Schulze, T., 2010. Decision bias in marine spatial planning of offshore wind farms: Problems of singular versus cumulative assessments of economic impacts on fisheries. Mar. Policy 34, 733–736. https://doi.org/10.1016/j.marpol.2009.12.004
BLE, 2019. Die Hochsee- und Küstenfischerei in der Bundesrepublik Deutschland im Jahre 2018 - Bericht über die Anlandungen von Fischereierzeugnissen durch deutsche Fischereifahrzeuge. Bundesanstalt für Landwirtschaft und Ernährung Referat 523 - Fischwirtschaft.
Blyth-Skyrme, R., 2011. Benefits and disadvantages of co-locating windfarms and marine conservation zones, with a focus on commercial fishing, Collaborative Offshore Wind Research Into the Environment (COWRIE).
Blyth-Skyrme, R.E., 2010. Options and opportunities for marine fisheries mitigation associated with windfarms.
BMVBS, 2009a. Anlage zur Verordnung über die Raumordnung in der deutschen ausschließlichen Wirtschaftszone in der Nordsee (AWZ Nordsee-ROV), Bundesanzeiger G 5702. Berlin.
BMVBS, 2009b. Verordnung über die Raumordnung in der deutschen ausschließlichen Wirtschaftszone in der Nordsee (AWZ Nordsee-ROV), Bundesanzeiger 3107. Berlin.
BMVBS, 1997. Verordnung über Anlagen seewärts der Begrenzung des deutschen Küstenmeeres (Seeanlagenverordnung - SeeAnlV), Bundesminister für Verkehr. Berlin.
Bocci, M., Sangiuliano, S.J., Sarretta, A., Ansong, J.O., Buchanan, B., Kafas, A., Cana-Varona, M., Onyango, V., Papaioannou, E., Ramieri, E., Schultz-Zehden, A., Schupp, M.F., Vassilopoulou, V., Vergilio, M., 2019. Multi-use of the sea: A wide array of opportunities from site-specific cases across Europe. PLoS One 14, e0215010. https://doi.org/10.1371/journal.pone.0215010
BOWL, 2015. Beatrice Offshore Wind Farm Consent Plan - Commercial Fisheries Mitigation Strategy. Edinburgh, Scotland, UK.
Brennan, F., Kolios, A., 2014. Structural Integrity Considerations for the H2Ocean Multi Modal Wind-Wave Platform. Ewea 2014 112–115.
BSH, 2017. CONTIS information system [WWW Document]. GeoSeaPortal Spat. data Infrastruct.
Buck, B.H., Krause, G., Pogoda, B., Grote, B., Wever, L., Goseberg, N., Schupp, M.F., Mochtak, A., Czybulka, D., 2017. The german case study: Pioneer projects of aquaculture-wind farm multi-uses, in: Aquaculture Perspective of Multi-Use Sites in the Open Ocean: The Untapped Potential for Marine Resources in the Anthropocene. Springer International Publishing, Cham, pp. 253–354. https://doi.org/10.1007/978-3-319-51159-7_11
Buck, B.H., Krause, G., Rosenthal, H., 2004. Extensive open ocean aquaculture development within wind farms in Germany: The prospect of offshore co-management and legal constraints. Ocean Coast. Manag. 47, 95–122. https://doi.org/10.1016/j.ocecoaman.2004.04.002
Buck, B.H., Langan, R., 2017. Aquaculture perspective of multi-use sites in the open ocean: The untapped potential for marine resources in the anthropocene, Aquaculture Perspective of Multi-Use Sites in the Open Ocean: The Untapped Potential for Marine Resources in the Anthropocene. Springer International Publishing. https://doi.org/10.1007/978-3-319-51159-7
Burdon, D., Boyes, S.J., Elliott, M., Smyth, K., Atkins, J.P., Barnes, R.A., Wurzel, R.K., 2018. Integrating natural and social sciences to manage sustainably vectors of change in the marine environment: Dogger Bank transnational case study. Estuar. Coast. Shelf Sci. 201, 234–247. https://doi.org/10.1016/j.ecss.2015.09.012
Campbell, M.S., 2015. Fisheries, Marine Conservation, Marine Renewable Energy and Displacement: A Fresh Approach. University of Plymouth.
Catherall, C.L., Kaiser, M.J., 2014. Review of king scallop dredge designs and impacts , legislation and potential conflicts with offshore wind farms Report to Moray Offshore Renewables Limited. Fish. Conserv. Report, Bangor Univ.
Christie, N., Smyth, K., Barnes, R., Elliott, M., 2014. Co-location of activities and designations: A means of solving or creating problems in marine spatial planning? Mar. Policy 43, 254–261. https://doi.org/10.1016/j.marpol.2013.06.002
Douvere, F., Ehler, C.N., 2009. New perspectives on sea use management: initial findings from European experience with marine spatial planning. J. Environ. Manage. 90, 77–88.

https://doi.org/10.1016/j.jenvman.2008.07.004
Emeis, K.C., van Beusekom, J., Callies, U., Ebinghaus, R., Kannen, A., Kraus, G., Kr??ncke, I., Lenhart, H., Lorkowski, I., Matthias, V., M??llmann, C., P??tsch, J., Scharfe, M., Thomas, H., Weisse, R., Zorita, E., 2014. The North Sea - A shelf sea in the Anthropocene. J. Mar. Syst. 141, 18–33. https://doi.org/10.1016/j.jmarsys.2014.03.012
Engelhard, G.H., Righton, D.A., Pinnegar, J.K., 2014. Climate change and fishing: A century of shifting distribution in North Sea cod. Glob. Chang. Biol. 20, 2473–2483. https://doi.org/10.1111/gcb.12513
European Commission, 2018a. Multi-use affordable standardised floating Space@Sea [WWW Document]. Community Res. Dev. Inf. Serv.
European Commission, 2018b. Enabling Technologies and Roadmaps for Offshore Platform Innovation (ENTROPI) [WWW Document]. Exec. Agency SMEs website.
European Commission, 2013. Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC. Off. J. Eur. Union L354, 40. https://doi.org/10.1093/icesjms/fss153
Fayram, A.H., de Risi, A., 2007. The potential compatibility of offshore wind power and fisheries: An example using bluefin tuna in the Adriatic Sea. Ocean Coast. Manag. 50, 597–605. https://doi.org/10.1016/j.ocecoaman.2007.05.004
FLOWW, 2015. FLOWW Best Practice Guidance for Offshore Renewables Developments: Recommendations for Fisheries Disruption Settlements and Community Funds. London, UK.
Fock, H.O., Kloppmann, M.H.F., Probst, W.N., 2014. An early footprint of fisheries: Changes for a demersal fish assemblage in the German Bight from 1902-1932 to 1991-2009. J. Sea Res. 85, 325–335. https://doi.org/10.1016/j.seares.2013.06.004
Gray, M., Stromberg, P., Rodmell, D., 2016. Changes to fishing practices around the UK as a result of the development of offshore windfarms – Phase 1.
Gray, T., Haggett, C., Bell, D., 2005. Offshore wind farms and commercial fisheries in the UK: A study in stakeholder consultation. Ethics, Place Environ. 8, 127–140. https://doi.org/10.1080/13668790500237013
Griffin, R., Buck, B., Krause, G., 2015. Private incentives for the emergence of co-production of offshore wind energy and mussel aquaculture. Aquaculture 436, 80–89. https://doi.org/10.1016/j.aquaculture.2014.10.035
Groot, J. De, Campbell, M., Ashley, M., Rodwell, L., De Groot, J., Campbell, M., Ashley, M., Rodwell, L., 2014. Investigating the co-existence of fisheries and offshore renewable energy in the UK : Identification of a mitigation agenda for fi shing effort displacement. Ocean Coast. Manag. 102, 7–18. https://doi.org/10.1016/j.ocecoaman.2014.08.013
Hall, D.M., Lazarus, E.D., 2015. Deep waters: Lessons from community meetings about offshore wind resource development in the U.S. Mar. Policy 57, 9–17. https://doi.org/10.1016/j.marpol.2015.03.004
Hattam, C., Hooper, T., Papathanasopoulou, E., 2015. Understanding the Impacts of Offshore Wind Farms on Well-Being, The Crown Estate.
Hoagland, P., Dalton, T.M., Jin, D., Dwyer, J.B., 2015. An approach for analyzing the spatial welfare and distributional effects of ocean wind power siting: The Rhode Island/Massachusetts area of mutual interest. Mar. Policy 58, 51–59. https://doi.org/10.1016/j.marpol.2015.04.010
Holm, P., Buck, B.H., Langan, R., 2017. Introduction: New approaches to sustainable offshore food production and the development of offshore platforms, in: Buck, Bela H, Langan, Richard (Eds.), Aquaculture Perspective of Multi-Use Sites in the Open Ocean: The Untapped Potential for Marine Resources in the Anthropocene. Springer International Publishing, Cham, pp. 1–20. https://doi.org/10.1007/978-3-319-51159-7_1
Hooper, T., Ashley, M., Austen, M., 2017. Capturing benefits: Opportunities for the co-location of offshore energy and fisheries, in: Offshore Energy and Marine Spatial Planning. Routledge, pp. 189–213. https://doi.org/10.4324/9781315666877
Hooper, T., Austen, M., 2014. The co-location of offshore windfarms and decapod fisheries in the UK: Constraints and opportunities. Mar. Policy 43, 295–300. https://doi.org/10.1016/j.marpol.2013.06.011
IEA, 2019. Global Energy & CO2 Status Report 2019, International Energy Law. Paris. https://doi.org/10.4324/9781315252056
Inger, R., Attrill, M.J., Bearhop, S., Broderick, A.C., James Grecian, W., Hodgson, D.J., Mills, C., Sheehan, E., Votier, S.C., Witt, M.J., Godley, B.J., 2009. Marine renewable energy: potential benefits to biodiversity? An urgent call for research. J. Appl. Ecol. 46, 1145–1153.

https://doi.org/10.1111/j.1365-2664.2009.01697.x
James, M.., Slaski, R., 2006. Appraisal of the opportunity for offshore aquaculture in UK waters. Defra and Seafish Reports FC0934 119pp. https://doi.org/10.1007/s00586-006-1086-8
Jentoft, S., Knol, M., 2014. Marine spatial planning: risk or opportunity for fisheries in the North Sea? Marit. Stud. 12, 1–16.
Jongbloed, R.H., Van der Wal, J.T., Lindeboom, H.J., 2014. Identifying space for offshore wind energy in the North Sea. Consequences of scenario calculations for interactions with other marine uses. Energy Policy 68, 320–333. https://doi.org/10.1016/j.enpol.2014.01.042
Kafas, A., Donohue, P., Davies, I., Murphy, E., Scott, B., 2017. Chapter 10: Displacement of existing activities. In Press., in: Yates, K. (Ed.), Offshore Energy and Marine Planning. Earthscan, Routledge, Taylor & Francis, London, United Kingdom.
Kafas, A., Ripken, M., Wright, K., Billet, M., Sangiuliano, S., Ooms, E., Scheffler, U., 2018. Status quo report on offshore energy planning provisions in the North Sea Region Interim Report, NorthSEE project. Aberdeen, Scotland.
Krause, G., Griffin, R.M., Buck, B.H., 2011. Perceived Concerns and Advocated Organisational Structures of Ownership Supporting "Offshore Wind Farm – Mariculture Integration." From Turbine to Wind Farms - Tech. Requir. Spin-Off Prod. 218. https://doi.org/10.5772/15825
Krause, G., Stead, S.M., 2017. Governance and offshore aquaculture in multi-resource use settings, in: Buck, B.H., Langan, R. (Eds.), Aquaculture Perspective of Multi-Use Sites in the Open Ocean: The Untapped Potential for Marine Resources in the Anthropocene. Springer International Publishing, Cham, pp. 149–162. https://doi.org/10.1007/978-3-319-51159-7_7
Lengkeek, W., Didderen, K., Driessen, F., Coolen, J.W.P., Bos, O.G., Vergouwen, S., Raaijmakers, T., 2017. Eco-friendly design of scour protection: Potential enhancement of ecological functioning in designs for scour protection in offshore wind farms.
MARIBE, 2016. Unlocking the potential of multi-use of space and multi-use platforms.
Marine Scotland, 2017. Current Marine Renewable Energy Projects [WWW Document].
Michler-Cieluch, T., Krause, G., 2008. Perceived concerns and possible management strategies for governing "wind farm-mariculture integration." Mar. Policy 32, 1013–1022. https://doi.org/10.1016/j.marpol.2008.02.008
MMO, 2019. UK SEA FISHERIES STATISTICS 2018. London.
NERC, 2016. Environmental and Consenting Barriers to Developing Floating Wind Farms Including Innovative Solutions. Edinburgh, Scotland, UK.
Nicolai, B., Wetzel, D., 2017. Fischer wollen in Offshore-Windparks auf Fang gehen [WWW Document]. Welt.
Pınarbaşı, K., Galparsoro, I., Borja, Á., Stelzenmüller, V., Ehler, C.N., Gimpel, A., 2017. Decision support tools in marine spatial planning: Present applications, gaps and future perspectives. Mar. Policy. https://doi.org/10.1016/j.marpol.2017.05.031
Pomeroy, R., Douvere, F., 2008. The engagement of stakeholders in the marine spatial planning process. Mar. Policy 32, 816–822. https://doi.org/10.1016/j.marpol.2008.03.017
Quevedo, E., Carton, M., Delory, E., Castro, A., Hernandez, J., Llinas, O., De Lara, J., Papandroulakis, N., Anastasiadis, P., Bard, J., Jeffrey, H., Ingram, D., Wesnigk, J., 2013. Multi-use offshore platform configurations in the scope of the FP7 TROPOS Project, in: OCEANS 2013 MTS/IEEE Bergen: The Challenges of the Northern Dimension. IEEE, pp. 1–7. https://doi.org/10.1109/OCEANS-Bergen.2013.6608061
R Development Core Team, 2008. R: A language and environment for statistical computing.
Reilly, K., O'Hagan, A.M., Dalton, G., 2015. Attitudes and perceptions of fishermen on the island of Ireland towards the development of marine renewable energy projects. Mar. Policy 58, 88–97. https://doi.org/10.1016/j.marpol.2015.04.001
Richter, M., 2012. Utilities' business models for renewable energy: A review. Renew. Sustain. Energy Rev. https://doi.org/10.1016/j.rser.2012.01.072
Rouse, S., Kafas, A., Hayes, P., Wilding, T.A., 2017. Development of data layers to show the fishing intensity associated with individual pipeline sections as an aid for decommissioning decision-making. Underw. Technol. 34. https://doi.org/10.3723/ut.34.171
Schupp, M.F., Bocci, M., Depellegrin, D., Kafas, A., Kyriazi, Z., Lukic, I., Schultz-Zehden, A., Krause, G., Onyango, V., Buck, B.H., 2019. Toward a Common Understanding of Ocean Multi-Use. Front. Mar. Sci. 6. https://doi.org/UNSP 165 10.3389/fmars.2019.00165
Scottish Government, 2018. Sectoral Marine Plan for Offshore Wind Energy (encompassing Deep Water Plan Options) Sectoral Marine Plan for Offshore Wind Energy (encompassing Deep Water Plan Options Context Report. Scottish Gov. Rep. 18.
Scottish Government, 2017. Scottish Sea Fisheries Statistics 2017, Statistics. Edinburgh.

Scottish Government, 2016. Survey, Deploy and Monitor licensing policy guidance (Version 2), Marine Scotland Report. Edinburgh, Scotland, UK.
Scottish Government, 2015a. Hywind Scotland Pilot Park Project: Decision Letter and Conditions.
Scottish Government, 2015b. Scotland' s National Marine Plan. Edinburgh.
Scottish Government, 2013. Sectoral Marine Plans for Offshore Wind, Wave and Tidal Energy in Scottish Watters Consultation Draft.
SeaPlan, 2015. Options for Cooperation between Commercial Fishing and Offshore Wind Energy Industries. A Review of Relevant Tools and Best Practices.
Selker, J.S., Thévenaz, L., Huwald, H., Mallet, A., Luxemburg, W., Van De Giesen, N., Stejskal, M., Zeman, J., Westhoff, M., Parlange, M.B., 2006. Distributed fiber-optic temperature sensing for hydrologic systems. Water Resour. Res. 42. https://doi.org/10.1029/2006WR005326
SFF, 2018. Fisheries Awareness Seminars - SFF Consultancy Services [WWW Document]. SFF Serv. Ltd. Website.
SFF, 2017. Trawl Sweep Vessels for Overtrawlability trials, SFF Services Limited Brochure. Aberdeen, Scotland.
SMartWind, 2018. Hornsea Offshore Wind Farm, Project Two - Statement of Common Ground with the NFFO, HFIG and VisNed. London, UK.
Smith, G., Brennan, R.E., 2012. Losing our way with mapping: Thinking critically about marine spatial planning in Scotland. Ocean Coast. Manag. 69, 210–216. https://doi.org/10.1016/j.ocecoaman.2012.08.016
Stelzenmüller, V., Coll, M., Cormier, R., Mazaris, A.D., Pascual, M., Loiseau, C., Claudet, J., Katsanevakis, S., Gissi, E., Evagelopoulos, A., Rumes, B., Degraer, S., Ojaveer, H., Moller, T., Giménez, J., Piroddi, C., Markantonatou, V., Dimitriadis, C., 2020. Operationalizing risk-based cumulative effect assessments in the marine environment. Sci. Total Environ. 724. https://doi.org/10.1016/j.scitotenv.2020.138118
Stelzenmüller, V., Diekmann, R., Bastardie, F., Schulze, T., Berkenhagen, J., Kloppmann, M., Krause, G., Pogoda, B., Buck, B.H., Kraus, G., 2016. Co-location of passive gear fisheries in offshore wind farms in the German EEZ of the North Sea: A first socio-economic scoping. J. Environ. Manage. 183, 794–805. https://doi.org/10.1016/j.jenvman.2016.08.027
Stelzenmüller, V., Schulze, T., Gimpel, A., Bartelings, H., Bello, E., Bergh, O., Bolman, B., Caetano, M., Davaasuren, N., Fabi, G., Ferreira, J.G., Gault, J., Gramolini, R., Grati, F., Hamon, K., Jak, R., Kopke, K., Laurans, M., Mäkinen, T., O'Donnell, V., O'Hagan, A.M., O'Mahony, C., Oostenbrugge, H., Ramos, J., Saurel, C., Sell, A., Silvo, K., Sinschek, K., SOMA, K., Stenberg, C., Taylor, N., Vale, C., Vasquez, F., Verner-Jeffreys, D., 2013. Guidance on a Better Integration of Aquaculture, Fisheries, and other Activities in the Coastal Zone: Froom tools to practical examples, COEXIST project. https://doi.org/ISBN: 978-0-9926602-0-8
Stenberg, C., Christoffersen, M., Mariani, P., Krog, C., Maar, M., Tørring, D., 2010. Offshore wind farms and their potential for shellfish aquaculture and restocking, in: ICES CM-2010/O1210. p. 8520.
Tien, N.S.H., van der Hammen, T., 2015. Fisheries displacement effects related to closed areas: a literature review of relevant aspects. IMARES report; C170/15, 52.
UK Parliament, 2011. The UK Marine Policy Statement. Station. Off. 1–51.
van den Burg, S., Stuiver, M., Norrman, J., Garção, R., Söderqvist, T., Röckmann, C., Schouten, J.-J., Petersen, O., García, R., Diaz-Simal, P., de Bel, M., Meneses Aja, L., Zagonari, F., Zanuttigh, B., Sarmiento, J., Giannouli, A., Koundouri, P., 2016. Participatory Design of Multi-Use Platforms at Sea. Sustainability 8, 127. https://doi.org/10.3390/su8020127
Vries, R. de, Hintzen, N., Slijkerman, D., 2015. Fisheries displacement effects of managed areas: A case study of De Voordelta.
Wageningen, 2018. SOMOS: Technical Standards for Safe Production of Food and Feed from marine plants and Safe Use of Ocean Space [WWW Document]. Wageningen Mar. Res. website.
Wever, L., Krause, G., Buck, B.H., 2015. Lessons from stakeholder dialogues on marine aquaculture in offshore wind farms: Perceived potentials, constraints and research gaps. Mar. Policy 51, 251–259. https://doi.org/10.1016/j.marpol.2014.08.015
White, C., Halpern, B.S., Kappel, C. V, 2012. Ecosystem service tradeoff analysis reveals the value of marine spatial planning for multiple ocean uses. Proc. Natl. Acad. Sci. U. S. A. https://doi.org/10.1073/pnas.1114215109/-/DCSupplemental.www.pnas.org/cgi/doi/10.1073/pnas.1114215109
Wind Guard, 2019. Our Energy Our Future - How offshore wind will help Europe go carbon-neutral.
WindEurope, 2018. Offshore wind in Europe - Key trends and statistics, WindEurope Business Intelligence. https://doi.org/10.1016/S1471-0846(02)80021-X
Yates, K.L., Schoeman, D.S., Klein, C.J., 2015. Ocean zoning for conservation, fisheries and marine

renewable energy: Assessing trade-offs and co-location opportunities. J. Environ. Manage. 152, 201–209. https://doi.org/10.1016/j.jenvman.2015.01.045

Zaucha, J., Bocci, M., Depellegrin, D., Lukic, I., Buck, B., Schupp, M., Caña Varona, M., Buchanan, B., Kovacheva, A., Karachle, P.K., 2017. Analytical Framework (AF) – Analysing Multi-Use (MU) in the European Sea Basins. Edinburgh, Scotland, UK.

Zhang, Ying, Zhang, C., Chang, Y.C., Liu, W.H., Zhang, Yong, 2017. Offshore wind farm in marine spatial planning and the stakeholders engagement: Opportunities and challenges for Taiwan. Ocean Coast. Manag. 149, 69–80. https://doi.org/10.1016/j.ocecoaman.2017.09.014

8. Supplementary Material 1 – Case study information

8.1 Scottish case study

Table 1: Table of candidate stakeholders considered for the East coast of Scotland case study. A total of 10 interviews was undertaken out of the candidates.

Scottish case study	
Offshore wind interests	
1.	Scottish and Southern Energy (SSE) Renewables, on behalf of BOWL and SeaGreen offshore wind farms
2.	Energias de Portugal (EDP) Renovavels and Repsol, on behalf of Moray Offshore Wind farms
3.	Repsol Nuevas Energías UK, on behalf of ICOL
4.	Mainstream Renewable Power, on behalf of NNG
5.	2-B Energy UK, on behalf of Forthwind
6.	Atkins Ltd. and MacAskill Associates, on behalf of KOWL
7.	Statoil Wind Limited, on behalf of Hywind
8.	Floating Power Plant on behalf of Katanes
9.	Highlands and Islands Enterprise, on behalf of Dounreay Tri
10.	Vattenfall, on behalf of EOWDC
11.	Scottish Renewables (representative body of the Scottish renewable energy industry)
Commercial fisheries interests	
12.	Scottish Fishermen's Federation (SFF)
13.	Scottish Inshore Fisheries Groups (IFGs), specifically the East Coast Inshore Fisheries Group
14.	The Scallop Association (SA)
15.	Fife Fishermen's Mutual Association
16.	Firth of Forth 10 Metre and Under Association (10MUA)
17.	The Inshore Fishermen's Alliance (IFA)
18.	Arbroath and Montrose Static Gear Association (AMSGA)
19.	Firth of Forth Lobster Hatchery (FoFLH)
Regulator	
20.	Marine Scotland – Licence Operations Team (MS-LOT)
Other experts	
21.	UK National Federation of Fishermen's Organisations (NFFO)
22.	The Crown Estate's Fishing Liaison with Offshore Wind and Wet Renewables Group (FLOWW)
23.	Holderness Fishing Industry Group, UK
24.	University of Hull, UK
25.	Kelley Drye Law firm, New York, NY, USA
26.	Johann Heinrich von Thunen Institute, Germany

8.2 German case study

Table 2: Table of candidate stakeholders considered for the German North Sea EEZ case study. A total of 5 interviews was undertaken out of the candidates.

German case study	
Offshore wind interests	
1.	AREVA Wind GmbH
2.	Ørsted
3.	Stiftung Offshore Wind
4.	WindMW
5.	EnBW
6.	Siemens Wind Power GmbH
7.	RWE Innogy GmbH
Commercial fisheries interests	
8.	Kutterfisch GmbH
9.	Niedersächsische Muschelfischer GbR
10.	Royal Frysk Muscheln GmbH
11.	Deutscher Fischereiverband e.V.
12.	Erzeugerorganisation schleswig-holsteinischer Muschelzüchter e.V.

13.	Verband der Kleinen Hochsee- und Küstenfischerei im Landesfischereiverband Weser-Ems e.V.
14.	Landesfischereiverband Schleswig-Holstein e.V.
Regulator	
15.	Federal Maritime and Hydrographic Agency (BSH)
16.	Federal Waterways and Shipping Authority (WSV)
Other experts	
17.	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research
18.	vThuenen Institute for Sea Fisheries
19.	Frauenhofer IWES

9. Supplementary Material 2 – Interviewee consent forms

PARTICIPANT INFORMATION SHEET – VERSION 1.0
Multi-Use in European Seas (MUSES) Project

Study Title:
The Multi-Use in European Seas (MUSES) project.

Funding:
The project has been awarded €1.98 million of funding by the European Union's Horizon 2020 research and Innovation programme under grant agreement No. 727451.

Invitation:
I would like to invite you to take part in the MUSES research study. We have invited you today as we believe that your contribution to the MUSES Project will be extremely valuable and bring significant added value to our research. Before you decide, you may find it helpful to have some information on why the research is being done and what it would involve for you. Please take time to read the following information carefully. Ask questions if anything you read is not clear or would like more information. Take time to decide whether or not to take part.

Purpose of study:
The Multi-Use in European Seas (MUSES) project will look at how European seas are currently being used and what could be the real multi-uses opportunities. The Multi-Use in European Seas (MUSES) project will review existing processes, used across the EU, for marine and coastal development to ensure they are sufficient for the sustainable, multi-use of the marine environment.

The two year Project will be undertaken by 10 European partners: Marine Scotland (Scotland), The Maritime Institute Gdansk (Poland), THETIS SPA (Italy), The SUBMARINER Network for Blue Growth EEIG (Baltic Sea Region), The Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (Germany), Ecorys (Netherlands), Fundação Gaspar Frutuoso (Portugal / Azores), The Hellenic Centre for Marine Research (Greece), The Institute of Marine Sciences - National Research Council (Italy), and The University of Dundee (Scotland).

The project will provide Regional overviews of the EU sea basins, including: Baltic Sea, North Sea, Mediterranean Sea, Black Sea and Eastern Atlantic. A comprehensive set of case-studies will also be conducted and analysed and an action plan will be put forward to look at how to: build on and reduce gaps in existing knowledge, identify impacts and risks and maximise local benefits while overcoming existing barriers.

Why have I been invited?
You have been identified by one of the partners in the MUSES project as someone that has knowledge and expertise in a sector and/or geographical sea basin that will assist us meeting the aims of our study which are briefly set out above.

Do I have to take part?
It is up to you to decide, the research is completely voluntary. We have provided information on this sheet on the study and the researcher will be happy to answer any questions that you may have. We will then ask you to sign a consent form to show you agreed to take part. You are free to withdraw at any time, without giving a reason and without prejudice or negative consequences.

What will happen to me if I take part?
The researcher will provide you with information on the following:

- how long you will be involved in the interview
- If there will be any follow up work after the interview
- The format of the interview and how information will be captured and recorded.
- How your information be used in the project

Risks and Benefits of Participating:
Relevant policy and procedures have been put in place to address risks.

The benefit of participating in this project is the knowledge and expertise you have will be used to help achieve a sustainable, multi-use of the marine environment, including reducing gaps in existing knowledge, identifying impacts and risks and maximising local benefits while overcoming existing barriers. One of the most relevant benefits for the project will be capturing contributions from real stakeholders, like you, that can strengthen the desk analysis.

Will my taking part in the study be kept confidential?
All the information we receive from you, including your name and any other identifying information (if applicable), will be strictly confidential. The information will be stored on a password protected, document storage and management system which is only accessible by Project Partners. Any information about you which is published will have your name and contact details removed so that you cannot be recognised, unless you have given permission to be identified on the consent form.

What will happen if I don't carry on with the study?
If you withdraw from the study all the information and data collected from you, to date, will be destroyed and your name removed from all the study files.

What will happen to the results of the research study?
The information will be used by the project consortium to support the successful completion of the project. Any information or data generated by MUSES will only be made publicly available in an anonymised form, such that it will not be possible to disaggregate or identify any individual to which it relates (unless the owner of the data has given express permission for non-anonymised data to be made publically available).

Data Retention & Destruction
Once the final data sets have been evaluated, personal data will be dissociated from the rest of the dataset and stored separately for the duration of the MUSES project. At the end of the project, personal data will be erased.

For Further information and contact details:

1. General information about the MUSES Project (https://muses-project.eu/)
2. Specific information about this research project (Andronikos.Kafas@gov.scot)
3. Who you should approach if unhappy with the study:
   (Researcher: Andronikos.Kafas@gov.scot or Project Co-ordinator: bruce.buchanan@gov.scot)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 727451

Consent Form for Multi-Use in European Seas (MUSES) Project

Name Participant:	
Name Researcher:	

Tick

1. I can confirm that I have read the 'Participant information sheet – Version 1.0' for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I am content to participate and understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without penalty. ☐
3. I understand that my personal details will not be revealed to people outside the project, unless I provide authority to do so. ☐
4. I understand that personal data will be subject to the 1998 Data protection Act and will be stored securely. ☐

Please indicate whether you are willing for the information you provide to be made available to others. Once final data sets have been evaluated, personal data will be dissociated from the rest of the dataset and stored separately for the duration of the MUSES project. At the end of the project, personal data will be erased:

	Yes	No
I may be identified in research data which is shared publically		
I may be identified as a contributor in reports, publications, written web material, photographs and images		
My words may be quoted and attributed to me		
My words may be quoted without attribution to me		
I would like to receive information on the MUSES Project *please provide email below		
Comments:		

	Participant	Researcher
Print name:		
Signature:		
Date:		
Email:*		

10. Supplementary Material 3 – Open questions

Table 3: List of open-ended questions regarding the MU combination used as a guide during interviews with stakeholders.

1.	Is it possible to establish / widen / strengthen MU in the case study area? (Y/N) For which MU combination in particular? What needs would MU satisfy?
2.	Is space availability an issue for MU development / strengthening in the case study area at present? (Y/N) Will space availability become an issue for your area in the future? (Y/N) For what elements is / could space availability become an issue?
3.	Are there MUs combinations that will share the same resources but in different times (e. g. reuse of an infrastructure after the end of its first life and original scope)? (Y/N) What are they?
4.	What would be the most important resources to be shared between uses (infrastructures, services, personnel, etc.)?
5.	Are existing and/or potential MUs taken into account within the existing or under development Maritime Spatial Plans? (Y/N)
6.	How are MUs connected or related to land-based activities?
7.	Is the needed knowledge and technology for MU development/strengthening in the case study area already available? (Y/N) What is the level of maturity of available knowledge? What is the level of readiness of available technology? Are there still research needs? (Y/N)
8.	What action(s) would you recommend to develop / widen / strengthen MU in the case study area? What actor(s) do you see particularly important to develop / widen / strengthen MU in the case study area?
9.	Do you see Added Value for society and economy at large and/or for local communities of developing / widening / strengthening MU in the case study area? (Y/N). What are the most important ones?
10.	Is it possible to quantify the socio-economic benefits related to MUs and how they (could) contribute to the sea economy at local and regional/national scale? (Y/N) What tools, knowledge, experiences are available?
11.	Would MU development / strengthening be an opportunity for job creation and / or job requalification in your area? (Y/N)
12.	Do you see possible elements of attractiveness for investors in developing / widening / strengthening MU in the case study area? (Y/N) What are these elements?
13.	What are possible investors interested in developing / widening / strengthening MU in the case study area?
14.	Is there sufficient dialogue between the stakeholder sectors for developing / widening / strengthening MU? (Y/N) Would dialogue facilitation be an asset? (Y/N)
15.	In order to promote MU development / strengthening in the case study area:
	– Would the availability of a vision/strategy (e. g. at national or sub-regional level) be helpful? (Y/N) – Would a feasibility study including evaluation of alternative scenarios be helpful? (Y/N) – Would detailed projects on already identified simulations be useful? (Y/N) – Do you see other enablers?
16.	What are / would be the environmental Added Value (= positive environmental impacts) of developing / widening / strengthening MU in the case study area?
17.	Which tools (conceptual, operational) are used or should be further developed and used to better estimate environmental impacts and benefits of MU?
18.	Is saving free sea space for nature conservation a driver for MU in the case study area? (Y/N) Is there evidences about the present and future benefits of reserving free sea space? (Y/N) What are they?
19.	What practical actions would you undertake to link MU development / widening / strengthening to improved environmental compatibility of maritime activities?
20.	Are there win-win solutions triggering both socio-economic development and environmental protection already available for the case study area that MU should take up? (Y/N) What are they?
21.	Is the environmentally friendly knowledge / technology for MU development/strengthening in the case study area available? (Y/N) Which is the level of readiness of available solutions? Are there still research needs on blue/green technologies for MU? (Y/N)

22.	Would it be possible to promote MU through SEA/EIA procedures? (Y/N) What modifications would you suggest at your national / local level to promote MU through SEA/EIA procedures?
23.	Does current legislation encourage multi-use? (Y/N) How is this being handled in practice?
24.	Can multi-use enhance the acceptance or ease the achievements of the societal license to operate (SLO)?
25.	Where do you see the biggest problems in regard to insurance of multi-use operations? How could these be addressed?
26.	Do you believe current licensing frameworks and authorities are well equipped to handle multi-use applications? Where do you see room for improvement?

11. Supplementary Material 4 – Catalogue of factors

Table 4: Catalogue of factors for the offshore wind sector.

Code		Factor description	SCO	DE	All
Drivers					
1	D.1.8	Discharge consent condition related to fisheries (i.e. meet legal requirements) by accommodating reasonable concerns raised by the fishing industry during construction and operation (e.g. through agreed installation timing and methods).	2.5	2	2.5
2	D.2.1	Avoid costs resulting mainly from delays with additional surveys (e.g. need for removal of gears) and delays during the marine licensing process.	2.5	2	2.3
3	D.3.2	Contribute towards local community and wider societal acceptance of offshore wind farm (a.k.a. Corporate Social Responsibility or Societal Licence to Operate).	2.8	0	2.3
4	D.3.3	Contribute to a positive company reputation for developers, which may contribute favourably to timescale for obtaining a licence.	2.7	1.2	2.2
5	D.1.4	Satisfy general EIA requirements for identifying, consulting, and mitigating all affected stakeholders.	2	0	1.8
6	D.1.9	Mitigate risks for legal challenge to consent decisions by dissatisfied stakeholders.	1.5	2	1.6
7	D.4.1	Suitable installation technologies are available to facilitate the cross-sector coexistence (e.g. specialised vessels, navigational precision, etc.).	1.3	2	1.4
Positive effects					
8	V.1.1	Stimulate collaborative working relationships between the two industries (e.g. in-kind contributions with information sharing, avoidance of survey disruptions).	2	0.5	1.8
9	V.1.3	Reduce costs from sharing support infrastructure (e.g. vessels, harbours) during operations and maintenance.	1.2	1	1.2
10	V.2.4	Benefit from innovation advances to facilitate fishing operations (e.g. installation methods, foundation types etc.).	1.5	0.5	1
Barriers					
11	B.4.1	Within-sector challenges, including issues with other receptors (e.g. ornithology), and strong competition within the energy sector to secure government subsidies	-3	-1	-3
12	B.2.1	Additional costs to developers from (i) insurance premiums and additional protection measures to cover cable asset risks, (ii) alternative but more expensive foundation types, installation methods friendlier to fishing, as well as (iii) a longer planning and design process to allow for discussions about turbine micro-siting, cable routing, and to design any additional surveys.	-2	-3	-2
13	B.3.1	Offshore wind farm components not always technically compatible with fishing operations (e.g. not all vessel sizes compatible with turbine spacing). Fishing operations may challenge the integrity of offshore assets (e.g. not all gear specifications could be deployed over export or inter-array cables).	-2	-3	-2
14	B.3.4	Offshore wind farm design process is complex and non-flexible discouraging any MU consideration.	-2	-2	-2
15	B.4.3	Negative attitudes exhibited by the fishing industry hinder relationships (e.g. claims of sole ownership of the sea space, limited engagement during consultation exercises, and past instances of exploitation behaviour with compensation claims).	-2	-1	-2
16	B.2.2	No direct financial gain to developers by allowing fishing to take place within OWFs	-2	-1	-2
17	B.3.3	Stringent post-installation monitoring requirements to determine liability in case of accidents and damage to offshore wind turbines. Need for specialised, high-resolution, monitoring equipment (e.g. distributed temperature sensing systems for exposure of cable sections).	-1	-1	-1
Negative effects					
18	I.1.2	Bear direct costs resulting from more demanding post-installation surveys, insurance premiums due to increased risk to asset integrity, and burial (or additional protection measures) of power cables.	-2	-1	-2

Table 5: Catalogue of factors for the commercial fishing sector.

Code		Factor description	SCO	DE	All
Drivers					
1	D.2.2	Avoid any interference with fishing operations and any unnecessary additional cost to the sector (e.g. loss of income, increased insurance premiums, loss of gears).	2.7	0.5	2.2
2	D.3.1	Avoid threats to the livelihoods of fisheries and enable fisheries to contribute to the national and European food security.	2.8	0	2
3	D.1.3	Political will and support to sustain fishing opportunities.	2.5	0	1.2
Positive effects					
4	V.3.1	Offer protected habitats for marine species, which may increase the available biomass in the immediate surroundings with positive knock-on effect for fishing.	2.4	1.5	2.2
5	V.1.7	Avoid indirect costs to fishers from e.g. displacement, overcrowding (in alternative grounds or port infrastructure), reduction in quality of catches, knock-on effects on the supply chain.	2.2	0	2
6	V.1.6	Avoid direct costs to fishers from e.g. loss of income due to area exclusions, increased fuel costs due to longer steaming distances, capital costs for diversifying to alternative locations, and any costs for new fishing equipment.	2.1	0	1.9
7	V.2.1	Promote the continued survival of the domestic fishing industry	2.5	0.5	1.8
8	V.1.1	Stimulate collaborative working via alternative employment opportunities (e.g. guard vessel duties).	2	0.5	1.8
9	V.2.3	Help build trust with local fishermen and local communities.	2.1	0.5	1.8
10	V.1.2	Offer opportunity for alternative gears such as creels to proliferate due to spatial restrictions to competing fleet segments (e.g. mobile gears).	1.8	0.5	1.4
11	V.1.5	Other indirect economic benefits (e.g. employment opportunities in the future)	1.8	0.5	1.4
12	V.3.2	Prevent fisheries displacement and avoid any potential implications on fish and shellfish stocks in cases of localised overfishing to adjacent areas.	1.3	NA	1.3
13	V.2.4	Promote innovation advances (e.g. gear modifications).	1.5	0.5	1
Barriers					
14	B.4.1	Within-sector challenges e.g. current fisheries policy landscape and increasing space demand for ocean conservation.	-3	-1	-3
15	B.3.2	Data reliability and availability. Issues related to access, coverage, deficiency, and misrepresentation.	-2	-2	-2
16	B.4.2	Maritime safety risk perceptions related both to navigation and fishing operations. Low confidence to cope with extraordinary conditions (e.g. engine failure, snagging incidents, extreme weather conditions, health issues, *force majeure,* and others).	-2	-2	-2
17	B.1.4	Issues with consultation related to timing, frequency, insincere support, governance structure, representation, power imbalances, and conflicts of interests.	-2	-1	-2
18	B.4.4	Developers' negative attitudes such as deferring mitigation discussion for later stages, insincere support to consultation exercises, and declining compensation to legitimately affected fishers.	-2	-2	-2
19	B.4.5	Perceived weak position to oppose multinational developers and government agendas. Small-scale fishing companies unable to afford potentially increased insurance premiums to operate within offshore wind farms.	-2	-1	-2
20	B.1.2	No formal legal requirements for developers to offer compensation.	-1	-1	-1
Negative effects					
21	I.3.1	Negative effects on shellfish stock recruitment due to sediment suspension during construction.	-2	0	-2
22	I.2.1	Increase in safety risk from unburied/exposed sections of power cables, with the potential for loss of life	-2	0.5	-2
23	I.3.2	Noise impacts on sensitive life stages of commercial stocks	-1	NA	-1
24	I.3.3	Electro-magnetic field (EMF) effects on electro sensitive fish species	-1	NA	-1

Table 6: Catalogue of factors for government.

	Code	Factor description	SCO	DE	All
Drivers					
1	D.1.1	Fulfil policies related to the protection of legitimate users.	2.5	2	2.4
2	D.1.2	Fulfil policies related to sea access.	2.4	1.5	2.2
3	D.1.7	Fulfil policies related to spatial efficiency.	2	2.1	2.1
4	D.3.4	Accord to political and social positive views towards the MU combination.	1.7	1.5	1.7
5	D.1.5	No legal basis for excluding fisheries from certain sea areas.	1.2	0	1
6	D.1.6	Adapt commercial fisheries to climate change.	0.7	1.5	1
Positive effects					
7	V.1.4	Facilitation between the two industries can have a positive knock-on effect for the local economy e.g. harbours that their commercial viability was uncertain without the presence of the offshore wind industry.	2.7	1	2
8	V.2.8	Promote social justice and equality to all stakeholders.	2	1.5	1.9
9	V.2.5	Decrease overall human footprint and promote efficiency in ocean space.	1	1.7	1.5
10	V.2.6	Reduce external negative stressors to the fishing industry which prevents the loss of cultural traditions and local knowledge.	2	0.5	1.4
11	V.2.2	Contribute to community empowerment e.g. local community funding offered by offshore wind developments has catalysed the fishing sector to benefit from better governance, supported fisheries management, and engaged the industry in stock assessment activities via industry-run surveys.	2.5	0	1.2
12	V.2.7	Achieve sustainable development targets, such as tackling climate change while maximising domestic energy and food security supply.	1.5	1	1.2
13	V.3.3	Maintain *status quo*. Perceptions that due to fishermen' long presence in the marine environment, any drastic removal may have unpredictable effects on commercial stocks and food web interactions.	1.5	0	1.2
Barriers					
14	B.1.3	Current EIA practice does not explicitly consider MU.	-2	-2	-2
15	B.1.1	No single representation body for the commercial fishing industry. Fisheries are not a 'statutory consultation body' in the Scottish marine licensing process.	-2	-1	-2
16	B.1.5	Limited spatial policies protecting fisheries interests.	-2	-1	-2
Negative effects					
17	I.1.1	Higher energy cost to consumers while developers recover additional expenditure to make an offshore wind farm fishing-proof.	-2	-1	-1
18	I.3.4	By realising the MU combination, there will be less protected space from fishing.	-2	-0	-1