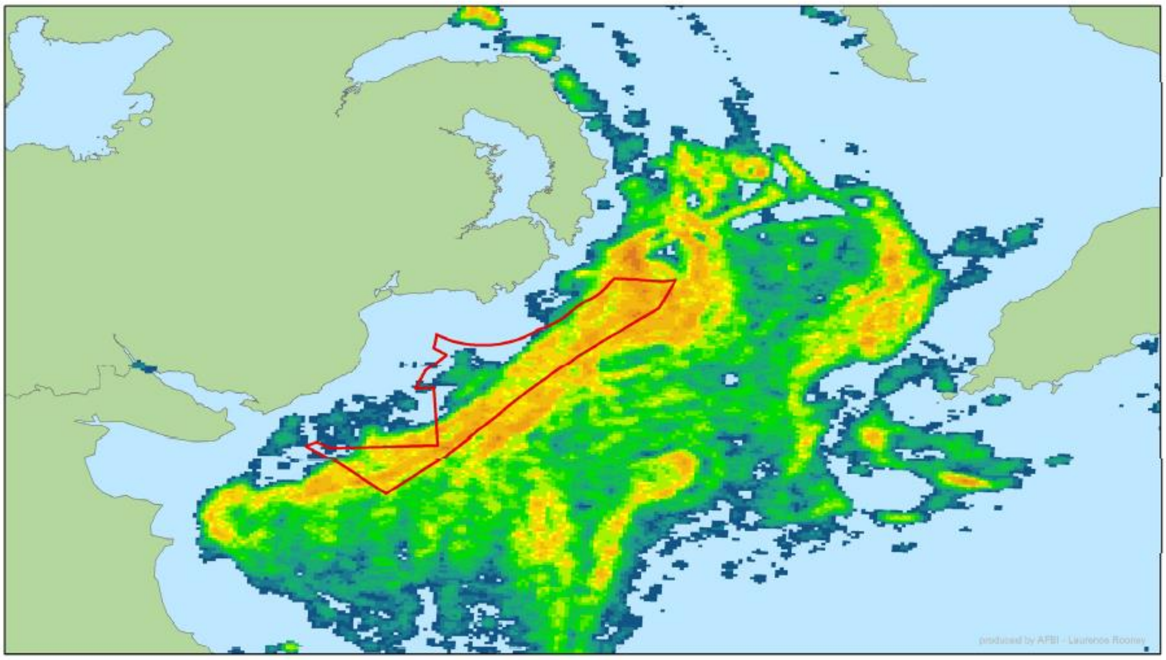
FISH RESOURCE ACCESS MAPPING PROJECT

(FISH RAMP)

ECONOMIC ANALYSIS AND LITERATURE REVIEW



Briefing Note to:

Seafish Northern Ireland Advisory Committee (SNIAC)

Funded by

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Acronyms

AFBI	Agri-Food and Biosciences Institute
CEFAS	Centre for Environment, Fisheries and Aquaculture Sciences
DARD	Department of Agriculture and Rural Development
DECC	Department for Enterprise & Climate Change
EIA	Environmental Impact Assessment
FAD	Fish Aggregating Device
FFW	First Flight Wind
FishRAMP	Fishing Resource Access Mapping Project
FLOWW	Fishing Liaison with Offshore Wind and Wet renewables group
FU	Functional Unit
ICES	International Council for Exploration of the Seas
ISCZ	Irish Sea Conservation Zone
LWE	Live Weight Equivalent
MCZ	Marine Conservation Zone
MLS	Minimum Landing Size
MMO	Marine Management Organisation
MPA	Marine Protected Area
MSY	Maximum Sustainable Yield
MW	Megawatt
OWF	Offshore Wind Farm
SNIAC	Seafish Northern Ireland Advisory Committee
SSC	Suspended Sediment Concentration
UWTV	Underwater Television
VMS	Vessel Monitoring System
WRZ	Wind Resource Zone

1 INTRODUCTION

1.1 BACKGROUND

This report contributes to the outputs of the Fishing Resource Access Mapping Project (FishRAMP) being undertaken by the Agri-Food and Biosciences Institute (AFBI) and Poseidon with input from Seafish, DARD and the NI seafood industry through the Seafish Northern Ireland Advisory Committee (SNIAC).

FishRAMP assesses the many potential spatial constraints facing the Northern Ireland fishing industry from offshore developments and proposed marine protected areas and explores the implications for the Northern Ireland fishing industry. It expands work conducted in 2012 on the impact of Irish Sea Conservation Zones (ISCZ) on the NI fishing industry. At the request of industry, a FishRAMP report focusing on the impact of the Wind Resource Zone (WRZ) off the County Down coast was produced in 2013.

Two distinct outputs are presented in this report:

1. An assessment of the economic importance to the Northern Ireland fishing industry of areas impacted by the potential spatial constraints identified in the first section by AFBI.
2. A literature review exploring the impacts of wind farm developments on fishing operations.

1.2 METHODOLOGY

1.2.1 Approach

The economic analysis involved two stages:

1. AFBI overlaid fishing intensity data for Northern Ireland (NI) fishing vessels with the boundaries for a range of current restrictions and proposed offshore developments and Marine Protected Areas (MPAs).
2. Poseidon used DARD and MMO landings data (2007-2013) to determine average landed values for relevant fleet segments and estimates the proportion attributable to those areas based on AFBI estimates of fishing intensity.

The literature review focused on the following aspects:

- Physical & management (safety zone) constraints to operations;
- Response of fishing operators to wind farms during and post construction;
- Impact on ground conditions (changes to sediment types etc.) and how this may impact each NI fleet segment (*Nephrops*, herring, scallop, potting);
- Displacement, concentration of fishing effort and resulting ‘tipping points’ for exploitation levels; and
- Research needs specific to the Northern Ireland fleet & wind farm developments.

The above review considered peer reviewed papers and grey literature sources (such as monitoring reports from wind farm developments) that are available to the consultants.

1.2.2 Data limitations

- This assessment is based on best available data and is therefore dependent on and limited by data made available to the project by DARD and industry.
- The 2007-2014 VMS data made available to the project was not broken down by gear type, which would have helped to refine the analysis. Consequently industry consultation was used to determine the spatial extent of distinct metiers such as scallopers.
- Historic VMS data are not available for vessels under 15m. 12-15m vessels are now required to have VMS onboard, but this does not include the majority of the inshore fleet.
- As the *Nephrops* fishery is confined to specific *Nephrops* grounds, it can be assumed that under 15m *Nephrops* trawlers are fishing the same grounds as the over 15m vessels.
- For the inshore potting fleet, the location of activity cannot be assumed in the same manner as the *Nephrops* fleet. The setting of strings of pots by a potting fleet prevents vessels from fishing on exactly the same areas of ground.
- Since 2013 a small number of NI potting vessels have had a Succorfish system on board that provides spatial information. Despite requests, industry did not provide Succorfish data for the Irish Sea. The usefulness of such data for this exercise is somewhat limited due to the small number of vessels in the sample and the lack of historic data.
- Available data on the potting fleet cannot accurately estimate fishing effort and therefore value per area. However a comparative indication was calculated using landed pots per port. Data was derived from an extensive industry consultation on the NI brown crab fishery conducted by Poseidon in 2010 and DARD monthly shellfish returns.
- DARD provided landings data for the years 2007-2011 by species, vessel category (under 15m and over 15m), homeport and ICES rectangle. MMO landings data was then used to update with 2012 and 2013 Northern Ireland landings data.
- Industry consultation indicates that around 60% of the catch from the Clyde fishery is landed back to Northern Ireland. To be consistent with the approach to VMS calculations of fishing intensity (where activity in the Clyde is not included in fishing intensity calculations), this landed value is removed from the total landed value.
- The value of landings for an area is calculated by applying the estimated fishing intensity as a proportion of total estimated activity to the total value of catch. This assumes that the value of catch is consistent and is a function of fishing effort, i.e. catch per unit effort is constant. In reality this is not the case, but a precise catch value per area is impossible to establish across a fleet with currently available data.
- Using data from the years 2007 to 2013 enables seven-year average and short-term trends to be established, but it should be noted that this period includes the global economic downturn, which severely impacted the seafood trade. A significant upturn in landed value occurred in 2011 and 2012, but 2013 total landed value declined with reduced volumes landed. Effort limitations (days at sea) were also in place over the entire period as part of the cod recovery plan for the Irish Sea, placing further constraint on fishing operations.

In light of the above, the following should be noted:

- The valuations presented are based on average values per area and these are assumed to be proportional to fishing intensity. As shown for the rMCZs in the Irish Sea (Poseidon, 2012), there are differences in the scale and quality of the catch from the areas concerned, e.g. different sized *Nephrops* or different catch composition such as by-catch of high value whitefish.
- While not represented in the VMS, it is assumed that *Nephrops* vessels under 15m show the same relative fishing intensities as the over 15m fleet (that are the basis for the VMS data). This may be an underestimate for the under 15m fleet as grounds close to port may be comparatively more important to the smaller vessels than the over 15m vessels, some of which fish further afield in the Eastern Irish Sea.
- The location of scallop activity was determined through consultation with skippers of scallop vessels. It is assumed that the reported scallop landings into NI represent 100% of the landings from the Irish Sea by NI vessels.

  (see AFBI section XXX for further explanation of data limitations and assumptions made).

1.2.3 Development Impacts

This document reports the estimated value of catches from certain areas, including areas potential developments may occur. It does not estimate the impact on revenue resulting from a development in these areas.

An Environmental Impact Assessment (EIA), required for any significant offshore development, should involve extensive consultation and would assess the significance of impacts, which are likely to extend beyond a potential loss of revenue. There are also potential benefits to the sector resulting from renewables developments. However additional revenue from ancillary services (guard work etc.) should be clearly distinguished from the impact on commercial fisheries.

A wind farm may have several impacts on commercial fisheries, including:

- Damage or disturbance to target resources
- Exclusion from the whole or certain areas of the development
- Displacement of fishing effort (potentially leading to reduced catches, unsustainable fishing effort in remaining areas and increased gear conflict)
- Additional gear snagging risk
- Additional steaming times (reducing profit with increased fuel costs)

The above impacts may occur over a short timescale (construction/decommissioning) or a longer timescale (operation) and they can be localised in their nature or impact further afield.

An EIA is also required to consider the cumulative effect of developments and known future constraints. It is essential that, in addition to the various planned or licensed offshore developments, the in-combination effects of further restrictions from MPA network development should be taken into account within the EIA process.

2 VALUATION OF FISHING ACTIVITY

The following results are based on the calculations of fishing intensities per area calculated by AFBI (section XX). The NI fleet is divided into the trawler fleet (targeting *Nephrops*), the potting fleet (targeting crab, lobster and velvet crab) and the scallop fleet. It is assumed that the small numbers of NI vessels that operate mid-water trawls or purse seine will not be significantly impacted by spatial restrictions.

2.1 ALL SPATIAL RESTRICTIONS

2.1.1 Trawler fleet

Table 2-1 presents estimates of landed values by NI trawlers landing into NI ports from the areas assessed. These include the *Nephrops* and whitefish landed by the fleet based on DARD & MMO landings data for 2007-2013[1].

Existing environmental designations and current restrictions (cables, wrecks and other obstructions) are estimated to overlap with just under 2% of *Nephrops* fleet activity in the Irish Sea. By contrast, proposed development areas overlap with 10.5% of *Nephrops* fleet fishing activity. This amounts to a substantial £1.6 million in landed value.

Table 2-1 Summary of % and value of *Nephrops* fleet activity potentially impacted by proposed developments

PROPOSED	% fishing (VMS)	Average value (2007-13)	Proportion of value
WRZ dev. Area*	3.84%	£549,670	37%
Other renewable dev areas	0.59%	£84,203	6%
UK MCZs	5.80%	£830,230	55%
Aggregate licences	0.27%	£39,096	3%
Total potential areas	10.50%	£1,503,200	100%

*Average of four potential development areas within the WRZ (see section 2.2)

Source: Poseidon analysis

The most significant proposed developments are the Marine Conservation Zones (MCZs), accounting for 55% of impacted area. The potential impacts of these MCZs are explored in more detail in the earlier report "The value of Irish Sea Marine Conservation Zones to the Northern Irish fishing industry" (Poseidon, 2012).

2.1.2 Potting fleet

The limited available data on potting vessel activity combined with fishing effort and landings data that is less accurate than for other fleet segments, suggests that the assessed value of the potting fleet is unreliable and should only be considered indicative of key restrictions. The nature and limited range of potting fleets can make localised impacts more significant for individual potting vessels compared to other fleet segments.

[1] To be consistent with the VMS data landed value assumed to result from fishing activity in the Clyde is excluded.

While most potting effort occurs within six miles of shore and there is some delineation between grounds that are regularly trawled and where pots are set, seasonal variations mean that some overlap between trawl and potting fisheries is possible.

A key distinction for pot fishing is the extent of overlap with current environmental designations. 45% of fishing activity occurs within areas with some form of environmental designation (Table 2-2). Potting is considered to have a relatively low environmental impact compared to other fishing methods. But as experience with Strangford Lough illustrates, pot-fishing restrictions in Natura sites are possible if management determines such measures are necessary to protect interest features.

For proposed developments, the key area of overlap is the aggregate license area. There is a concentration of potting effort associated with Kilkeel as DARD shellfish returns indicate more pots are being fished by vessels from Kilkeel compared to adjacent ports (Ardglass/Annalong) and Portavogie to the north. This results in a large proportion (26%) of fishing activity overlapping with the licensed aggregate area.

Table 2-2 Summary of % and value of potting activity potentially impacted by proposed developments

Potting			
CURRENT	**% fishing (pots)**	**Av. value (2007-13)**	**proportion of value**
cables	0	0	0%
Environmental designations	44.80%	£844,294	97%
Extraction	1.25%	£23,561	3%
wrecks & obstructions	0.05%	£948	0%
Total current areas	46%	£868,803	100%

PROPOSED	**% fishing (pots)**	**Av. value (2007-13)**	**Total value**
WRZ dev area*	0.81%	£15,334	3%
Other renewable dev areas	0.00%	£-	0%
UK MCZs	0	£-	0%
Aggregate licences	25.80%	£486,201	97%
Total potential areas	26.61%	£501,535	100%

*Average of four potential development areas within the WRZ (see section 2.2)

Source: Poseidon analysis

2.1.3 Scallop fleet

A seven-year average value (2007-2013) for NI scallop landings (totalling £2million) is used in the following calculations to be consistent with the VMS data provided.

The mapping of scallop activity with proposed developments shows overlap with around 7% of areas where scallop activity currently occurs, amounting to £128,000 based on the same five-year average as the VMS data (Table 2-3).

The MCZs proposed for the Eastern Irish Sea account for 80% of the impacted area. The aggregate licence area accounts for 20% of the potentially impacted area. Only a small area of the WRZ in the southern corner may overlap with scalloping activity.

Table 2-3 Summary of % and value of scallop activity potentially impacted by proposed developments

PROPOSED	% fishing	value	proportion of value
WRZ dev area*	0.05%	£1,037	1%
Other renewable dev areas	0.00%	£-	0%
UK MCZs	5.41%	£108,212	79%
Aggregate licences	1.35%	£26,936	20%
Total potential areas	6.81%	£136,185	100%

*Average of four potential development areas within the WRZ (see section 2.2)

Source: Poseidon analysis

2.2 THE COUNTY DOWN WIND RESOURCE ZONE

First Flight Wind (FFW) is exploring the potential to develop a 600MW wind farm within the County Down WRZ. The size and location of the area to be developed within the WRZ will be defined by the size, number and spacing of turbines proposed as well as any physical or operational constraints identified across the WRZ. For this research, an early estimate suggested by FFW of approximately 120 km^2 is used as an estimated footprint for the development area (Figure 1), which represents around 25% of the WRZ (which has a total area of 438 km^2). The <u>indicative</u> 120km^2 areas are in the (A) northern, (B) central, (C) southern and (D) a more offshore area in the north-eastern corner of the WRZ.

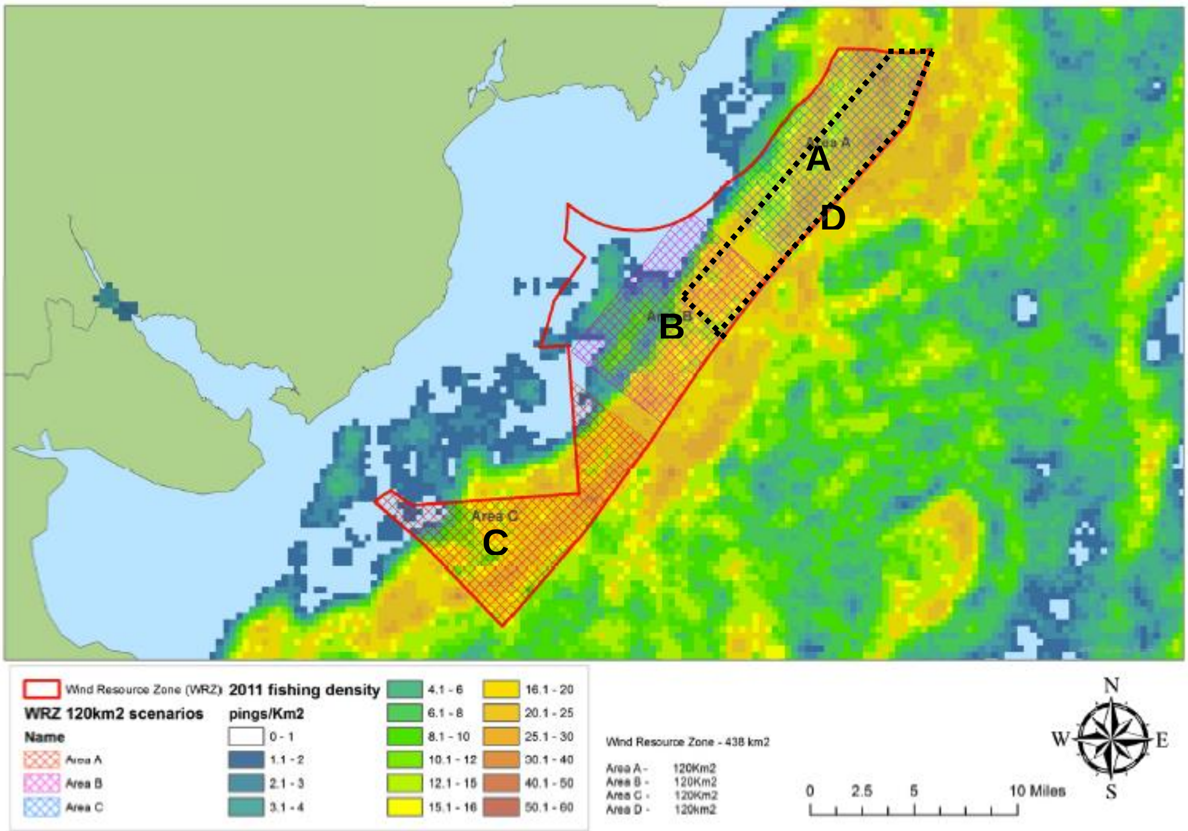

Figure 1 Wind Resource Zone (red) and potential wind farm development areas, each 120km^2 (Areas A, B & C hatched areas, Area D dashed line)

Source: AFBI, 2013

Table 2-4 presents estimates of landed values by NI *Nephrops* trawlers landing into NI ports from the indicative development areas.

Table 2-4 Estimated landed values by NI trawl fleet from WRZ areas

Year	Whole WRZ	Area A	Area B	Area C	Area D
2007	£1,383,922	£640,084	£387,445	£520,734	£696,166
2008	£1,571,645	£752,897	£416,398	£567,453	£775,946
2009	£1,195,560	£527,521	£312,259	£494,110	£522,668
2010	£1,650,226	£693,988	£379,312	£789,925	£726,443
2011	£1,682,380	£739,741	£415,970	£606,893	£759,091
2012	£2,046,845	£601,171	£312,037	£468,055	£667,014
2013	£1,209,500	£436,565	£294,860	£435,134	£450,879
7 year average	**£1,534,297**	**£627,424**	**£359,754**	**£554,615**	**£656,887**

Source: Poseidon analysis

The table above illustrates the significant landed values in the four indicative development areas considered and the variability between these. The fishing intensity (and so value of landings) attributed to Area D is 70% greater than the average for the WRZ as a whole. While the 120km^2 areas each represent 27% of the 438km^2 of the whole WRZ, the values are above this for all areas, other than the central Area B:

Area A 41%

Area B 23%

Area C 36%

Area D 43%

2.3 SOCIO-ECONOMICS

Marine Management Organisation (MMO) figures for 2013 give 675 full time NI fishermen and 814 in total (full and part-time), which is an 18% increase on the 2011 total. The NI trawl fleet represents the vast majority of jobs in the NI catching sector and the fleet's landings of prawns supports the bulk of shore-based jobs.

Around 80% of Live Weight Equivalent (LWE) prawn landings are tailed with the remaining 20% landed as whole prawns. Local scampi processors purchase nearly all (95-99%) of the tails landed by the fleet. Close to 75% of whole prawns landed by the fleet are also purchased by these processors.

These data show local marketing chains are highly dependent on the presence of local processors as buyers; there is a co-dependence between the NI fleet and NI processors. This is supported by findings from the Seafish processor survey, which found 82% of supplies were sourced from auction (Seafish, 2008), the highest dependency on local landings of all the UK regions.

Local landings do not fully support the raw material demands of Northern Ireland's scampi processors. Around 60% of processed *Nephrops* tails comes from the local fleet, with additional supplies from Ireland and elsewhere in the UK. Prawn processing capacity has built up in Kilkeel and other NI ports to tap into the direct supplies from the local fleet.

As the NI processing industry retains nearly all NI fleet landings, the impacts on the UK economy from reductions to NI landings can be expected to predominantly occur in Northern Ireland. Any significant loss of landed value would have a major impact on the NI fishing industry and the sectors and communities that depend upon it. Those impacts would be felt acutely in the three main fishing ports of Portavogie, Ardglass and Kilkeel (the largest port) respectively located west of the northern, central and southern areas of the WRZ.

There has been some consolidation of the scampi processing sector in recent years, but this appears to have stabilised. In June 2014 Kilkeel Seafoods, which employs 140 workers, announced 33 new jobs over the next two years. This investment is based on the expectation that most NI fleet landings will continue to be into Northern Ireland.

With less supply available from the local fleet, processors would have to source a greater proportion from elsewhere. The strategic benefit of being located at the Northern Ireland ports would be diminished. As the main market is on the UK mainland, companies would weigh up the pros and cons of continued operation in Northern Ireland. If more landings were to the UK mainland, relocation or (for larger companies) consolidation to mainland premises would be more likely.

If the NI processors closed, the vessels would land less of their remaining catch into Northern Ireland's ports and instead land to the remaining processors in South West Scotland and Cumbria creating a cycle of decline in Northern Ireland's fishing ports. This illustrates that developments impact vessel owners through lost revenues, but will also affect crew, processors, ancillary industries and their associated staff and local communities.

The number of full time fishermen at the three main NI fishing ports Ardglass, Kilkeel and Portavogie in 2012 and how this relates to local employment in the towns (ward level) is presented in Table 2-5. This illustrates the high level of dependency on fishing employment in these areas, which is higher still when upstream and downstream industries are taken into account, such as employment in scampi processing.

Table 2-5 Fishing employment (2012) as a proportion of local employment (2011)

Port	Full time fishermen	Total employment	Fishing as % of total
Ardglass	103	517	19.9%
Kilkeel	315	2,624	12.0%
Portavogie	215	452	47.6%

Source: MMO, NISRA

Gross Value Added (GVA)[2] for the West and South of Northern Ireland average was £12,971 per head of population in 2014. This is lower than the NI average and compares to a UK average of £21,295 (ONS, 2014). Recent figures on regional employment illustrate that Northern Ireland suffered from the economic downturn with a 1.2% decrease in the employment rate 2007-2014, while it is unchanged for the UK as a whole[3]. Despite this the number of full time fishermen and fishing's contribution to local employment has increased in each of these three ports since 2009. This illustrates the importance of these

[2] GVA is a measure of the value of goods and services produced in the economy.

[3] http://www.ons.gov.uk/ons/rel/regional-trends/regional-economic-indicators/july-2014/sst-region-economic-indicators.html

indigenous local businesses during period of recession as other employment opportunities reduce.

Seafish conducted an input-output analysis to show the value of UK fishing and fish processing to the UK economy (Seafish, 2006). Based on 2002 data it was estimated that if the value at first sale of fish landings decreased or increased by £1 million, the expected impacts for shellfish species are:

• UK Output would change by £7.16 million;

• UK Employment would change by 113 FTE jobs;

• UK GDP would change by £2.57 million.

The above figures are outdated, but these do illustrate the broad scale of impact that reduced landings would have on overall economic activity and on employment. As the NI processing industry retains nearly all NI landings, the impacts on the UK economy from reductions to NI landings can be expected to predominantly occur in Northern Ireland.

The average annual value of NI landings potentially impacted by proposed developments amounts to £2.14 million for the years 2007-2013. If this level of revenue were to be lost from Northern Ireland landings it would have a major impact on the Northern Ireland fishing industry and the sectors and communities that depend upon it.

2.4 SUMMARY & CONCLUSIONS

This section presents the estimated value of catches from certain areas based on data from the years 2007 to 2013.

Table 2-6 Summary of average value of fishing activity by NI fleets potentially impacted by proposed developments

PROPOSED	Nephrops	Potting	Scallops	Total value	% of value
WRZ*	£549,670	£15,334	£1,037	£566,041	26%
Other renewable dev areas	£84,203	£0	£0	£84,203	4%
UK MCZs	£830,230	£0	£108,212	£938,442	44%
Aggregate licences	£39,096	£486,201	£26,936	£552,233	26%
Total potential areas	£1,503,200	£501,535	£136,185	£2,140,919	

*Average of four potential development areas within the WRZ (see section 2.2)

Source: Poseidon analysis

The assessment has focused on three key segments in the Northern Ireland fishing fleet: *Nephrops* trawl, potting and scalloping. Around 10% of Northern Ireland's fishing activity amounting to £2.1m average landed value was found to overlap with proposed developments; mainly the proposed MCZs, the WRZ offshore wind development and the aggregate licensing area (Table 2-6).

The high dependence of processing companies on local landings and the high dependence of Northern Ireland's fishing ports on those landings makes this a significant risk to landed value of concern to the regional economy as a whole.

The proposed developments show different levels of significance for each fleet segment, but the MCZs alone are found to account for 44% of the value in these areas with Eastern MCZs most significant for scallopers and those in the Western Irish Sea overlapping most with *Nephrops* trawl fleet activity. For the potting fleet, where poor quality data mean that valuations may well underestimate true values, the significant activity out of Kilkeel results in the adjacent aggregate license area being highly significant. It is also significant that nearly 45% of potting activity occurs in areas where some environmental designation exists.

This valuation does not estimate the impact on revenue resulting from a development in these areas; this will depend upon the scale and extent of disturbance to resources and displacement from current fishing grounds. There is also the potential for positive impacts on non-fishing revenue for certain vessels in providing vessel services to developers.

Seasonal fishing patterns are dictated by the need to disperse effort across grounds throughout the year. Displacement from current fishing areas would result in additional pressure on remaining grounds that are already fished, which could lead to lower catch per unit effort and may be unsustainable in the longer term. These issues are explored in more detail in the following section.

3 LITERATURE REVIEW

3.1 BACKGROUND

This section presents a literature review focusing on the following aspects:

- Physical and management (safety zone) constraints to operations;
- Response of fishing operators to wind farms during construction and operation;
- Impact on ground conditions (changes to sediment types etc.) and how this may impact each NI fleet segment (*Nephrops*, herring, scallop, potting);
- Displacement, concentration of fishing effort and resulting 'tipping points' for exploitation levels; and
- Research needs specific to the Northern Ireland fleet and wind farm developments.

3.2 CONSTRAINTS TO FISHING OPERATIONS

There is much debate over the extent to which wind farm operations constrain fishing operations. The ability to fish within a wind farm may be constrained due to:

- **Physical constraints** (obstructions such as turbines, platforms or cables and associated scour protection preventing the use of fishing gear in an area);
- **Management constraints** (the definition of safety zones to prohibit fishing areas where significant risk of collision or gear snagging is identified); and
- **Fisher response** (after assessing the risk, a skipper may decide not to fish an area irrespective of physical or management constraints, resulting in a *de facto* constraint).

The sections below present research and experience in relation to these above constraints. In addition, as fishing is targeting a biological resource, any impact on that resource in an area will affect both its availability and the desire to fish it. Such effects on key biological resources targeted by the Northern Ireland fleet resulting from wind farm impacts related to noise and vibration, electro-magnetic fields and changes in ground conditions are considered in Section 3.3.

The extent to which fishing is constrained by a wind farm will depend on many variables including:

- Characteristics of the offshore development (spacing and position of turbines, platforms & cables, cable burial, cable protection such as rock armouring etc.);
- Stage of development (construction, operation, decommissioning, post-decommissioning);
- Safety Zones and the offshore developer's policy on Precautionary Areas;
- Size of fishing vessel;
- Type of gear;
- Weather, time of day (visibility) and sea conditions; and
- Skippers attitude to risk (which can vary depending on circumstance).

Many of the above are dependent on the specific location of the wind farm. Therefore experiences elsewhere may not directly translate to potential experiences for the Northern Ireland fleet in Irish Sea developments, but will give a good indication of likely constraints.

3.2.1 Physical constraints

An offshore wind farm is likely to consist of the following offshore structures, which are considered in more detail below:

- Wind turbine generators;
- Cabling within the wind farm (inter-array cables connecting turbines and platform inter-connectors) including cable protection such as rock armouring where necessary;
- Export cable from wind farm to shore including associated infrastructure (e.g. collector substation and converter or reactive compensation substations); and
- Other infrastructure such as accommodation platform(s) (dependant on location and distance of the wind farm from shore).

Wind Turbine Generators

The capacity of turbines can vary from 3.6 MW up to 15 MW per device. Often the target project capacity is fixed (i.e. the total generating capacity that is licensed). The turbine specification chosen for the project will determine the overall number of turbines, with a clear trend towards fewer, larger capacity turbines. The layout for offshore turbines is generally in uniform rows and columns running in the direction of the prevailing wind. Landscape and visual aspects are of lesser concern compared to onshore wind farms where rows/columns of turbines are actively avoided due to aesthetics.

The turbine capacity and area of the development site determines the spacing between rows and columns of turbines, which impacts the potential for resumption of fishing. Table 3-1 presents the minimum turbine spacing proposed by developers of North Sea Round 3 Zones in UK waters (construction is expected to commence over the next five years) and the corresponding assessment of exclusion of fishing assessed within the EIAs during construction and operation. After some level of exclusion during construction, all EIA assessments of these latest Offshore Wind Farms (OWF) assume a resumption of fishing.

Table 3-1: Minimum turbine spacing for North Sea Round 3 Zones

Wind farm	Minimum turbine spacing	Construction (and decommissioning)	Operation and maintenance
Hornsea Project One	924 x 1320 m	Phased exclusion	Resumption of fishing
East Anglia ONE	675 x 900 m	500m safety zones and advisory exclusion zones around construction works	Resumption of fishing
Dogger Bank Creyke Beck A & B	700 x 700 m	Complete exclusion	Resumption of fishing
Hornsea Project Two	(810) 878 x 1323 m	Complete exclusion	Resumption of fishing

As presented in Figure 2, evidence is available of demersal trawl fisheries operating within Thanet Offshore wind farm (minimum turbine spacing 500 x 800 m), Barrow Offshore Wind Farm (500 x 750 m) and Kentish Flats Offshore Wind Farm (700 x 700 m) (ScottishPower Renewables and Vattenfall, 2012).

Consultation with UK and European fisheries representatives has cited 1 km as a general minimum spacing for operating within a wind farm, although this depends on the operating requirements of different gear types. As Table 3-1 shows, the EIAs conclude that a resumption of fishing is expected during the operation of the wind farm despite the turbine spacing being below the 1km cited by industry.

The Dogger Bank EIA (Forewind, 2013) provide lengths for maximum gear spreads for a number of fishing methods (Table 3) all of which do not exceed 220 m, with the exception of seine netting which is specific to the Dogger Bank area. While gear spread for demersal trawl is cited as 220 m, this clearly depends on the gear configuration and whether pair trawling or twin rigging is being undertaken.

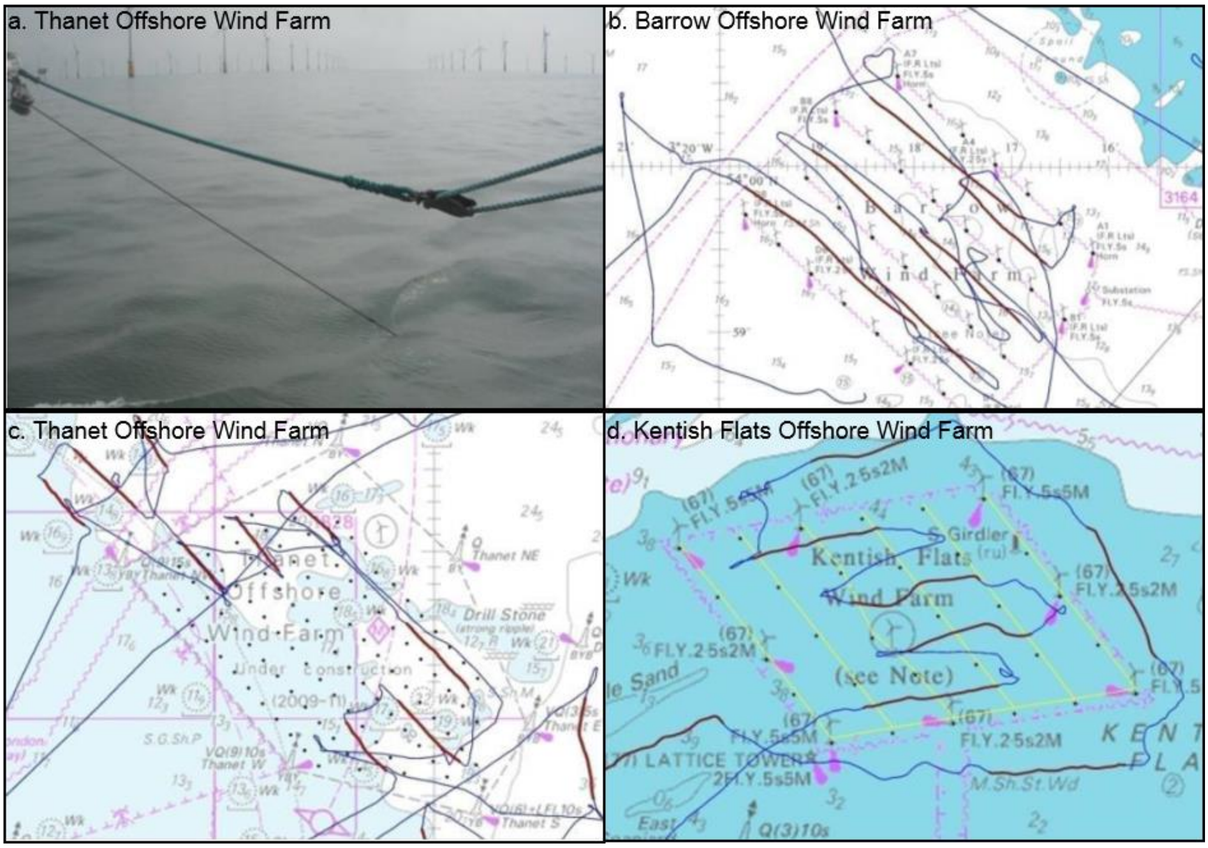

Figure 2: Evidence of trawling taking place at operational wind farms (Source: ScottishPower Renewables and Vattenfall, 2012)

Table 3: Maximum fishing gear spreads (Source: Forewind, 2013)

Gear	Maximum gear spread
Beam trawl	40 m between beam trawl outer shoes
Demersal otter trawl	220 m between otter boards
Industrial sandeel trawl	120 m between otter boards
Seine netting	2.9 km^2 per operation

A range of turbine foundations is available including monopiles, steel jackets and gravity-based foundations, which will determine the overall footprint of the project. Each will require a degree of scour protection that can include gravel, artificial fronds or seaweed, concrete mattresses, bags of gravel, rock placement, grout or other concrete. This scour protection will not extend beyond safety zones (considered below).

Cabling

Inter-array cabling connects individual turbines to collector substations before transport via the export cable to shore. Inter-connector cables will also be necessary to provide electricity to accommodation platforms etc. Cable burial is the strong preference for developers to ensure the integrity of cables and minimise maintenance. Cable installation methods include: water jetting, ploughing, trenching and rock-cutting. Where cable burial is not possible, or not to sufficient depths to avoid possible fishing gear interaction, then cable protection will be used (as described for turbine scour protection).

Mobile fishing is likely to be restricted where cable burial has not been achieved and cable protection is required. The design of inter-array cables can minimise such an impact, for example by running inter-array cables between turbines in one direction, allowing a 'fishing corridor' between columns of turbines; however in practise this may not be feasible and depends on ground conditions.

The impact of the export cable on fishing is similar to that described for inter-array cables, but is likely to have a higher magnitude of impact as it covers a larger distance and width. Other infrastructure related to the export cable and accommodation platforms (if required) will form physical obstacles and require safety zones/ safe operating distances as described for turbines and expanded upon below.

3.2.2 Management (safety zones)

The recent Fishing Liaison with Offshore Wind and Wet renewables group (FLOWW, 2014) guidance provides a useful overview of safety zones, their application to offshore renewable energy installations, the planning process for safety zones and recommendations on how developers communicate locations of approved safety zones.

Safety zones are granted by Department for Enterprise & Climate Change (DECC) or the MMO during the construction, maintenance and decommissioning phases of an Offshore Renewable Energy Installation (OREI), in order to safeguard the safety of other users of the marine environment and the OREI itself. Once the project is fully constructed and operating normally, operational safety zones are only approved if there is a clear justification for their implementation (FLOWW, 2014).

The safety zones should not be confused with 'exclusion zones'. The term exclusion zone is used within oil and gas sector legislation in reference to a permanent 500m exclusion zone around above-surface oil and gas installations i.e. it is in place for the lifetime of the installation. In contrast, as per the Energy Act 2004, safety zones are temporary in nature, except in exceptional circumstance.

Types of safety zones that are typical for different stages of an offshore wind farm are summarised in **Error! Reference source not found.** Typically, offshore wind farms safety zones have been for a 50m zone around the turbine bases and 500m around construction zones / vessels engaged in construction activities; in some cases 50m safety zones have also been granted around wind turbines or foundations where work is not actually in progress but where work has yet to be finished e.g. where a turbine is waiting to be commissioned.

It should however be noted that not all OREIs have safety zones in place or will apply for them as it is not mandatory. To date, some offshore wind farms have been constructed without safety zones.

Table 3-2 Types of safety zones at different project stages (source: FLOWW, 2014)

Project stage	Type of Safety Zone
Construction	Typically up to 500m around single installations under construction. Likely to include a mobile 500m safety zone at construction points such as cable laying.

Pre-commissioning	Typically up to 50m around installations where construction has finished but some work is on-going e.g. turbine incomplete or in the process of being commissioned.
Operation	Where justified, up to 50m around single installations in operation
Major maintenance	Typically up to 500m when major maintenance is in progress.
Decommissioning	Typically up to 500m around single installations that are being decommissioned.

In addition to safety zones, offshore wind farm developers may recommend that a further precautionary area is adhered to by sea users during construction, maintenance and decommissioning. The precautionary area is not a legal safety or exclusion zone, but constitutes an area that all sea users will be advised to avoid, or if they must enter, to use extreme caution. For example, precautionary areas may be stipulated to accommodate installation vessels with larger anchor spreads. As with safety zones, precautionary areas are temporary in nature and not implemented during normal operation of the wind farm.

3.2.3 Fisher response

The potential operational issues faced by fishermen working within a wind farm are summarized in Table 3-3 for small (<10m in length), medium (10-15m) and large (>15m) fishing vessels. Table 3-3 does not take into account the gear types or gear spread being deployed by the vessels and has assessed implications based on turbines and wind farms being commissioned in 2010 (when turbines where generally 3.6MW and spaced closer together than newer developments). As discussed in Section 2.1, there is a greater distance between turbines for larger (>5MW) devices and therefore, where inter-array cabling can be effectively buried, it should theoretically be possible to fish between turbines within ‘fishing corridors’. However, the decision to fish within a wind farm is ultimately made by skippers on an individual basis and dependent on their perception of risk on any given day.

Table 3-3 Summary of operational issues for different sized fishing vessels (Source: Blyth-Skyrme, 2010)

Fishing vessel size	Summary of operational issues
Small (vessel length: <10m)	• Greatly limited by weather; • May be very range limited, although modern, fast vessels can have considerable daily range; • Tend to be day-trip vessels only; • Never restricted by size or power regulations inshore; • Unlikely to operate over a wide area— may be very locally focused; • May be somewhat multi-purpose and so adaptable to different fishing opportunities; and • Depending on gear, may work within wind farms.
Medium (vessel length: 10-15m)	• Somewhat limited by range and weather; • Tend to be day-trip vessels, but may undertake short multi-day trips;

	• Rarely restricted by size or power regulations inshore; • Likely to be relatively locally focused, but may operate over quite a wide regional area, or undertake seasonal movement to follow fisheries; • Limited adaptability to different fishing opportunities; and • Depending on gear, may work within wind farms.
Large (vessel length: >15m)	• Rarely limited by range or weather; • Tend to be multi-day vessels; • Often prevented from fishing inshore by size or power regulations; • Likely to operate over a wide geographic area as opportunities allow; • Likely to be highly specialised for a particular mode of fishing; and • Likely to use heavy towed gears and therefore may not be permitted to fish within wind farms.

Consultation with industry as part of EIAs for Round 3 wind farms has shown skipper exhibit differing responses and attitudes to operating within wind farms. Some define a minimum safe distance between turbines (often suggesting 1km or more), while others maintain they would not fish within wind farms. This depends on both the type of gear and gear characteristics, as well as individual preferences and/or risk assessments. For example, potters operating long strings of pots have a greater risk of entanglement with infrastructure, but could shorten strings to allow safer operation. Similarly, beam trawlers may choose to operate lighter gear (ground conditions allowing) to minimise extent of ground penetration and therefore reduce any risk of gear snagging with cables; and demersal otter trawlers may seek to reduce their gear spread and avoid twin trawls or pair trawling.

3.2.4 Summary

With the move towards fewer, larger turbines that have significant distances between then, coupled with a preference for cable burial, there is an increasing assumption that vessels using mobile fishing gear will operate within wind farms.

Management constraints are likely to be minimised and safety zones limited to construction and decommissioning periods.

The choice of whether to fish in a wind farm will mostly remain with the individual skipper and be driven by a variety of factors, not least the availability of target resources (explored in the following section) and the sea conditions on any given day. A presumption that fishing is possible within an operating wind farm should not, however, be interpreted as 'no impact' as the fishable area will inevitably be smaller than pre-development.

The potential constraints to commercial fisheries within a wind farm are summarised in Table 3-4 by gear type and stage of development (not including resource impacts that are discussed in Section 3.)

Table 3-4: Summary of potential physical and management constraints of offshore wind farms for various fishing gears

Gear type	Construction (and decommissioning*)	Operation (and post-decommissioning**)
Trawler	Construction safety zones	Operational safety zones of 500 m around offshore

	of 500 m from perimeter of construction works. Potential for up to 1 km advisory precautionary area around entire wind farm boundary. Although, potential for all gears to operate within boundary of site if construction works are being phased and early communication of this is provided by the developer.	platforms. No safety zones around turbines, although 50 m safe operating distance is expected. 500 m roaming safety zone during major maintenance activities. Resumption of fishing within corridors between turbines, assuming that cabling has been sufficiently buried or is designed to allow for 'fishing corridors'. Dependant on gear spread (twin and pair trawling is unlikely to be possible).
Scalloper		Safety zones as per trawler. Resumption of fishing within corridors between turbines, assuming that cabling has been sufficiently buried to enable dredging or is designed to allow for 'fishing corridors'.
Potter		Safety zones as per trawler. Resumption of fishing dependant on length of pot strings and tidal conditions. Gear conflict may also be an issue due to concentration of activity within 'fishing corridors'.
Netter		Safety zones as per trawler. Drift netting unlikely to be possible. Potential for fixed nets to be set between turbines, dependant on tidal conditions as high risk of entanglement with infrastructure.
Seiner		Safety zones as per trawler. Based on gear spread of up to 2.9km^2, resumption of fishing within a wind farm is unlikely.

* Decommissioning assumes removal of all above sea infrastructure and possible removal of some or all sub-sea infrastructure including cables, scour protection, foundations etc. (which would be subject to a decommissioning assessment) and therefore constraints would be the same or similar to those during wind farm construction.

** Post-decommissioning assumes that some sub-sea infrastructure would remain in-situ and therefore constraints would be the same or similar to those during wind farm operation.

3.3 IMPACT ON FISHERIES RESOURCES

Throughout the lifespan of an offshore wind farm a range of impacts can affect fish and shellfish resources, including underwater noise during construction, electromagnetic fields (EMF) emitted from cables during wind farm operation and changes to ground conditions. The range of potential impacts is outlined in Table 3-5 for each stage of the development. In relation to long term effects on fisheries resources, changes in ground conditions are thought to pose the most significant effect and are therefore discussed in the greatest detail within this section. Potential noise and EMF effects are also summarised below.

Table 3-5: Impacts during lifespan of an offshore wind farm resulting in potential effects on fish and shellfish receptors (adapted from SMart Wind, 2014)

Phase	Potential impacts
Construction	Temporary habitat loss/disturbance from construction operations including

	foundation installation and cable laying operations. Underwater noise as a result of foundation installation (i.e., piling) and other construction activities (e.g., cable installation). Increased suspended sediment concentrations as a result of foundation installation, cable installation and seabed preparation. Sediment deposition as a result of foundation installation, cable installation and seabed preparation. Seabed disturbances leading to the release of sediment contaminants. Accidental pollution events.
Operation and maintenance	Underwater noise as a result of operational turbines and maintenance vessel traffic. Electromagnetic fields (EMF) emitted by inter-array and export cables during the operational phase causing behavioural responses in fish and shellfish receptors. Long term habitat loss due to presence of turbine foundations and scour/cable protection. Long term changes to habitat due to scour. Introduction of turbine foundations and scour/cable protection (hard substrates and structural complexity) leading to creation of reef habitat. Temporary habitat loss and disturbance from maintenance operations (i.e., jack up operations). Potentially reduced fishing pressure offering some protection and possible local enhancement.
Decommissioning	As per impacts listed under construction phase. Effects on fish and shellfish receptors due to removal of foundations and cable protection leading to loss of hard substrates and structural complexity.

3.3.1 Noise and vibration

The negative impact of underwater sound on fish and shellfish species ranges from physical injury/mortality to behavioural effects. In general, biological damage as a result of sound is either related to a large pressure change (barotrauma) or to the total quantity of sound energy received by a receptor. For a wind farm, the most significant noise results from turbines installed via piling. Demersal fish injury as a result of piling noise would be expected in close proximity (<500m) to piling operations; with startle response potentially occurring within 1km and avoidance of 5 to 26km from noise source (dependant on piling hammer energy) (SMart Wind, 2014). The extent of impact for hearing specialists such as herring would be expected to be greater.

Information on the impact of underwater noise on marine shellfish is scarce. Studies that looked at the effect on crustacean catch rates in response to seismic air guns observed little or no effect (Parry and Gason, 2006). There is some indication that cephalopods and crustaceans may be capable of 'hearing' low frequency noise, such as piling noise, suggesting that it may impact behaviour of local populations (Lovell *et al*., 2005; Hu *et al*., 2009). Overall, shellfish injury, startle response and avoidance is expected to be less than that for demersal fish (SMart Wind, 2014). In terms of vibration, behavioural effects on crustaceans are also unknown, although any vibration would be expected to decay more rapidly than underwater noise.

Generally demersal fish and shellfish species are considered to have a low vulnerability and high recoverability to localised noise and vibrational impacts resulting from offshore wind farms. Long-term significant effects as a result of noise and vibration emulating from an offshore wind farm would not be expected for fish and shellfish resources.

3.3.2 Electromagnetic fields

Electromagnetic (EMF) fields emitted from the transport of electricity through subsea power cables can affect the sensory mechanisms of some species of fish and shellfish, particularly electrosensitive species.

Crustacea, including lobster and crab, have been shown to demonstrate a response to magnetic fields, with the spiny lobster *Panulirus argus* known to use a magnetic map for navigation (Boles and Lohmann, 2003). However, it is uncertain if other crustaceans including commercially important Nephrops, *Nephrops norvegicus*, brown crab *Cancer pagurus* and European lobster *Homarus gammarus* are able to respond to magnetic fields in this way. Limited research undertaken with the European lobster found no neurological response to magnetic field strengths considerably higher than those expected directly over an average buried power cable (Normandeau *et al*., 2011; Ueno *et al*., 1986).

With the exception of elasmobranchs, no experiments have highlighted significant concerns as a result of EMF for fish or shellfish species (Switzer and Meggitt, 2010; Polagye, *et al.,* 2011). Evidence from post construction surveys of Round 1 wind farms (Kentish Flats, Lynn and Inner Dowsing, Burbo Bank and Barrow) show no discernable changes to fish (including elasmobranchs) or shellfish populations as a result of EMF.

3.3.3 Sediment, seabed morphology and scour

The potential impacts on sediment as a result of an offshore wind farm are summarised in Table 3-5 and include:

- During construction: Increased suspended sediment concentrations and sediment deposition as a result of foundation installation, cable installation and seabed preparation.
- During operation: Long term habitat changes including loss of existing habitat and creation of reef habitat due to turbine foundations; and changes in seabed morphology, scour and presence of post-construction debris.

A survey of sediment monitoring within Round 1 wind farms found that the main impacts on sediment are evident during the operational phase as a result of post-construction debris left in situ and scour associated with the turbines and jack-up rig positions (ABP Mer *et al*, 2010). These, together with the lesser impacts experienced during construction are discussed in detail below.

Increased Suspended Sediment Concentrations

Monitoring of operational Round 1 wind farms has found short-term localized impacts of increased Suspended Sediment Concentrations (SSC) due to cable laying and foundation installation that occur across timescales comparable to the construction process. For Round 1 wind farms, monitored changes in SSC are within natural variations and there is no evidence of permanently elevated suspended sediment concentrations within constructed wind farm arrays, nor in the area outside array footprints (ABP Mer *et al*, 2010).

However, time-series modelling undertaken to investigate SSC in Round 3 wind farms have predicted that construction activities will result in SSC considerably higher than background levels, although peaks in SSC will only persist for very short periods of time (less than two hours) (Smart Wind, 2014). Modelling showed that, not only are the peaks in SSC very short lived; dispersion of fine material is rapid with levels returning to background levels 27 hours after the start of the release. The spatial extent of dispersion was found to be up to 12-16 km from source (Smart Wind, 2014).

Sedentary shellfish species would be expected to be more vulnerable to increased SSC than most finfish as they are less mobile and many are filter feeders. Some shellfish species may suffer reduced growth or increased mortality, particularly during spatfall as a result of increased SSC (ABP Research, 2007). Brown crabs have a high tolerance to suspended sediment and are reported to be insensitive to increases in turbidity; however, they are likely to avoid areas of increased suspended sediment concentration as they rely on visual acuity during predation (Neal and Wilson, 2008). Berried crustaceans (e.g., brown crab, European lobster and *Nephrops*) are likely to be more vulnerable to increased SSC as the eggs carried by these species require regular aeration. However, as impacts are so short term in nature no lasting impacts are expected to commercial fisheries resources as a result of increased SSC.

Certain stages of a species lifecycle are particularly vulnerable to increased SSC. Herring spawning produces mats of eggs on the seabed making them vulnerable to smothering. The larvae of many commercial species (including herring, plaice and cod) use sight for prey location and so increases in SSC can reduce feeding success as larvae are less able to move to less turbid areas of water.

Creation of reef habitat

The introduction of turbines, their foundations and scour/cable protection will result in both habitat loss and the creation of new hard substrate habitat throughout the lifetime of the wind farm. This new creation of reef habitat is likely to be primarily colonised within hours or days after construction by demersal and semi-pelagic fish species (Andersson, 2011). The dominant natural substrate character of the construction area, (e.g., soft sediment or hard rocky seabed), will determine the number of new species found on the introduced vertical hard surface and associated scour protection. When placed on an area of seabed that is already characterised by rocky substrates, few species will be added to the area, but the increase in total hard substrate could sustain higher abundance (Andersson and Öhman, 2010). Conversely, when placed on a soft seabed, most of the colonising fish will be from rocky (or other hard bottom) habitats, thus the overall diversity of the area will increase (Andersson *et al*., 2009). A new baseline species assemblage will be formed via recolonisation and the original soft-bottom population will be displaced (Desprez, 2000). This was observed in studies by Leonhard *et al*. (Danish Energy Agency, 2012) at the Horns Rev offshore wind farm, and Bergström *et al.* (2013) at the Lillgrund offshore wind farm, where an increase in fish species associated with reefs, such as goldsinny wrasse *Ctenolabrus rupestris*, lumpsucker *Cycloplerus lumpus* and eelpout *Zoarces viviparous*, and a decrease in the original sandy-bottom fish population were reported.

A number of studies on the effects of vertical structures and offshore wind farm structures on fish and benthic assemblages have been undertaken in the Baltic Sea (Wilhelmsson *et al.,* 2006a; 2006b). These studies have shown evidence of increased abundances of small demersal fish species (including gobies Gobidae, and goldsinny wrasse) in the vicinity of structures, most likely due to the increase in abundance of epifaunal communities, which increase the structural complexity of the habitat (e.g., mussels and barnacles *Cirripedia* spp.). It was speculated that in true marine environments (e.g., the Irish Sea or the North Sea) offshore wind farms may enhance local species richness and diversity, with small demersal species such as gobies providing prey items for larger, commercially important species including cod (which have been recorded aggregating around vertical steel constructions in the North Sea; Wilhelmsson *et al*., 2006a). Monitoring of fish populations in the vicinity of an offshore wind farm off the coast of the Netherlands indicated that the wind farm acted as a refuge for at least part of the cod population (Lindeboom *et al*., 2011; Winter *et al*., 2010).

In contrast, post construction fisheries surveys conducted in line with the FEPA licence requirements for the Barrow and North Hoyle offshore wind farms, found no evidence of fish abundance across these site being affected, either positively or negatively, by the presence of the wind farms (Cefas, 2009; BOWind, 2008), therefore, suggesting that any effects, if seen, are likely to be highly localised.

In terms of creation of reef habitat, it is likely that the greatest potential for positive effects exists for crustacean species, such as crab and lobster, due to expansion of their natural habitats (Linley *et al*., 2007) and the creation of additional refuge areas. Where foundations and scour protection are placed within areas of sandy and coarse sediments, this will represent novel habitat and new potential sources of food in these areas and could potentially extend the habitat range of some shellfish species. Post-construction monitoring surveys at the Horns Rev offshore wind farm noted that the hard substrates were used as a hatchery or nursery grounds for several species, and was particularly successful for brown crab. They concluded that larvae and juveniles rapidly invade the hard substrates from the breeding areas (BioConsult, 2006).

Seabed Morphology

In one of the first wind farm arrays constructed at Horns Rev, the sediments in the wind farm and reference areas can generally be characterised as homogeneous and medium sorted medium-fine to coarse sand. Post-construction surveys found that the average medium grain size of the sediment in the wind farm area has significantly increased ($P<0.01$) from 345 μm in 2001 to more than 500 μm in 2003 and 2004 (Leonhard, 2005).

In 2008 the first six wind mills of the C-Power farm were installed on the Thornton Bank in the Belgian EEZ using gravity based foundations (GBF). The use of GBFs implies important dredging works to prepare the seabed, whereby sand piles were stored in the concession area. The monitoring showed that, during the installation of the GBFs, an important amount of sand was dredged at the concession area for the backfill of the foundation pits and the fair channel, and that some sand pits were created. It appeared that more material was dredged and used than was expected. During backfill, most of the sediment was lost during disposal. Monitoring of these sand pits, during several months, showed that the sand pits are relatively stable and that no natural filling of the sand pits occurs (Degraer *et al*, 2010).

The issue of morphology differs between different geographic areas. High levels of morphological change are noted from areas of sand within exposed, high current coastal areas (e.g. Scroby Sands). Impacts due to the presences of offshore structures, such as scour around turbines (see below) and bed-level changes between turbines, are evident, but the environment is naturally highly dynamic. Lower levels of morphological change, and consequently less severe impacts due to structures, characterise areas where the oceanographic conditions are less aggressive (e.g. Thornton Bank). However, the general the natural variation in bed level at many coastal sites is not known. The short time-base of observations (3.5 years) necessarily limits the ability in dynamic areas to separate large-scale and longer-term morphological change that could be attributed to natural processes (ABP Mer *et al*, 2010).

What has been shown from the Scroby Sands project is that the natural dynamics of the sandbank remain very high. CEFAS (2006) estimated that sediment transport activity for modal medium sands occurs for around 80% of the time in summer conditions increasing to 94% during winter. This level of activity leads to continual changes in the sandbank form as well as general bedform movement across the bank (e.g. sandwaves) due to natural processes (ABP Mer *et al*, 2008) i.e. no major changes in general seabed profiles are attributable to wind farms.

Scour

Scouring is where seabed morphology changes as the speed of water movement increases around objects; this occurs around natural seabed structures as well as offshore structures. The rates of seabed erosion, sediment transport and movement of bed features at any one location are controlled by natural oceanographic processes including tidal range, currents, storm surges and wave action (Stride, 1982). The current distribution of sediments on the continental shelf reflects the balance between the supply of different grades of sediment (clay-silt-sand-gravel) and prevailing hydrodynamic conditions (Whitehouse *et al*., 2010). The installation of wind turbine foundations increases local hydrodynamic fields, which produce an associated increase in sediment transport and erosion. This subsequently leads to scouring of the seabed around foundations, the extent of which is dependent on hydrological and sediment conditions. To mitigate this effect, scour protection in the form of rock is often applied around the turbine base, which prevents scouring in the immediate vicinity, but does result in secondary scour (as described in Amoudry, 2009). At Scroby Sands Offshore Wind Farm (OWF), scour tails up to 400m in length were identified (greater than the inter-turbine spacing of 375m) (Figure 3).

Monitoring at Kentish Flats OWF consistently found site scour around turbine foundations which was limited to ~5-10m in diameter from the turbine and stabilised at a maximum of circa 1.9m depth depressions. Furthermore, no scour was recorded at inter-array cables and depressions arising from the jack-up vessels used for installation were found to be infilling as a result of natural sedimentary processes. The monitoring concluded that no additional scour protection was required.

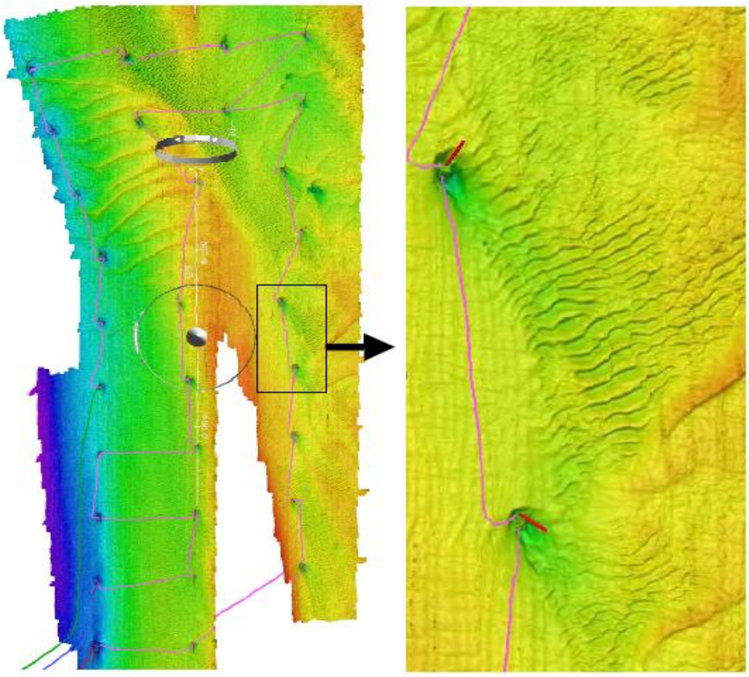

Figure 3 Example of seabed morphology at Scroby Sands OWF. (Left image = seabed morphology at array scale, Right = localised view of turbines with red lines representing turbines with scour tails in green) (source: ABP Mer *et al*, 2008)

Table 3-6 summarises the findings of scour monitoring from a number of Round 1 wind farm sites. Overall it shows most impacts (after a short monitoring timescale) were found to be as predicted in the EIAs.

Table 3-6: Site by site summary of scour monitoring (Source: ABP Mer *et al*, 2008)

Wind Farm	ES Prediction	Scour Protection Installed	Observed Impacts
North Hoyle	Minimal scour due to boulder clay	No	Results confirm predictions
Kentish Flats	Scour predicted but limited due to London Clay	No	Initial surveys found unexpected deep pits around mono-piles and location of jack-up legs, but subsequently scour found to stabilise and jack-up leg depressions to naturally infill.
Scroby Sands	Deep scour predicted	Yes (quantified after first survey)	Depth of scour generally as predicted, but extent of scour greater than predicted. Secondary scour formed.
Barrow	Scour predicted in areas of fine sand (and limited by substrata)	No	Initial results confirm predictions
Arklow Bank	Deep scour predicted	Yes (rock protection)	Minimal secondary scour recorded

One surprise from the detailed monitoring conducted at Scroby Sands was the appearance of secondary sour in certain locations over the period of available surveys. Secondary scour is defined as a measurable effect represented by a lowered seabed profile that is not immediately in contact with a turbine foundation or similar subsea infrastructure. At Scroby Sands, these features have been described as scour 'tails' or 'wakes' and appeared in the direction of the dominant flood tide and for distances of around 400 m.

Analysis found that where a scour tail extended towards an existing surface wreck there was apparent development of group scour. Scour wakes had not been anticipated in any part of the EIA or engineering design process and are considered to be a 'surprise'. It is possible that similar patterns may be revealed in the future for other projects, especially for sites with highly mobile seabeds and with active bedform features. (ABP Mer *et al*, 2008).

Callaway *et al* (2009) explored the scouring processes around the Pisces Reef complex in the Irish Sea. Three habitats were described from the data sets: 1) Fine mud dominated by burrowing megafauna, 2) Scoured mud dominated by infaunal polychaetes and 3) Mud veneer over rock dominated by infaunal sipunculids and polychaetes. The data indicates that the scouring action may be sorting the substrate, removing the finer sediment and leaving coarser sediment, hence the occurrence of taxa in both the reef top and scour hollow samples that are absent in the mud flat samples. The population data infers that if this is the case the remaining substrate is more conducive to supporting higher species diversity than the surrounding mud habitat.

Although the mud flat and scour hollow communities differed slightly there is not enough evidence to define them as separate biotopes (Callaway *et al*, 2009). The authors do, however, recognise that the implications of this may be important for both proposed renewable energy projects and the understanding of benthic ecology in other areas of the Irish Sea.

3.4 FISHERIES IMPLICATIONS

3.4.1 Nephrops

Nephrops and seabed conditions

Owing to its burrowing behaviour, the distribution of *Nephrops* is restricted to areas of a particular sediment type; mud, sandy mud and muddy sand (McIntyre *et al*, 2012). Burrow density and animal size are related to sediment characteristics and hydrography (Chapman and Bailey, 1987). Around Scotland it has been found that areas of fine sediments are characterised by large *Nephrops* occurring in low densities and areas of coarser sediments are characterised by smaller *Nephrops* at higher densities (Tully and Hillis, 1995). A survey of the Pisces Reef complex in the Irish Sea (Figure 4) found that burrow densities were highest in 'mud' substrate, reducing in shelly mud and not present where there was a mud layer on cobbles and rock. This illustrates that a sufficient depth of soft sediment is required to enable burrow formation. The particle size of soft sediment then determines the burrow density.

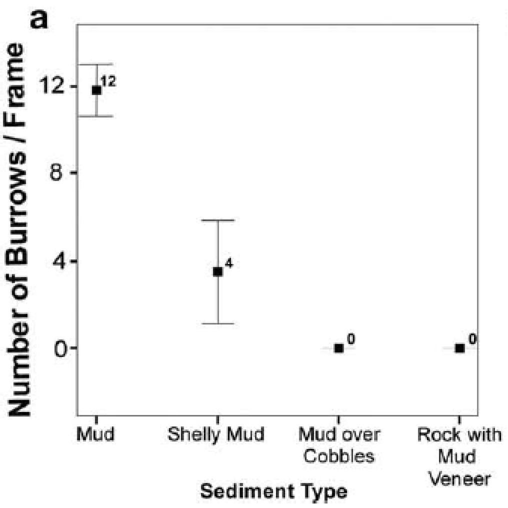

Figure 4 Density of Nephrops burrows by sediment type (Source: Callaway *et al*, 2009)

Research by Afonso-Dias (1998) and Campbell *et al*. (2009a) investigated a 'dome-shaped' relationship between burrow density and sediment composition. Sandy sediments are too fluid for *Nephrops* burrowing, so densities are low at high sand ratios. Densities are optimal at moderately high silt-clay ratios (i.e. low sand); however, extremely high silt-clay ratios become 'too much of a good thing' as they stimulate more extensive burrowing, potentially leading to increased intraspecific interactions, and therefore to lower densities in these sediments.

There are clearly variables alongside silt-clay content that may contribute to the relationship between sediment type and density. One of the additional variables may be the percentage (or quality) of organic matter (OM). Burrow density in coarser sediments may be enhanced where OM is present due to improved sediment cohesion that aid burrowing or due to higher prey availability (Johnson *et al*, 2013).

Burrow density from Underwater Television (UWTV) footage shows an inverse relationship with *Nephrops* size (mean weight in the landings) at several functional management units (FUs). At one end of the spectrum are the low-density-large *Nephrops* (e.g. at the Porcupine Bank or Fladen grounds, FU16 and 7 respectively), and at the other extreme we see high-density-small *Nephrops* e.g. at Irish Sea West (FU15). The shift in mean weight between these extremes is large, up to 28.5 g, or 175 % difference in the average weight of *Nephrops* per FU.

The burrow densities typically observed in the Irish Sea West FU15 are amongst the highest observed of all *Nephrops* stocks, but the mean sizes of individuals in the catches are relatively small. It appears that growth is suppressed due to competition and/or recruitment effects (Johnson, et. al, 2012). Burrow densities show inter-annual fluctuation. Doyle *et al* (2013) found burrow density for the Western Irish Sea (FU15) was 16% lower than in 2012, but overall the stock remains well above Maximum Sustainable Yield (MSY).

Length frequency data from catches at Irish Sea West during recent years (2002-2008) have not dramatically changed from historical levels in 1960-1962 (Cole, 1965); the only point to note is a slight decrease in the largest size categories i.e. greater than ~37 mm carapace length. Overall, we can tentatively suggest that there has not been a dramatic reduction over time in mean size caught at the Irish Sea West. We might further suggest that the differences in effort between grounds such as Irish Sea West (FU15) and Porcupine Bank are probably not enough to explain the large difference between these grounds in size/density.

The main factors that might suppress mean size are competition (which may lead to growth suppression at high densities) and recruitment. If recruitment were relatively high inside FUs such as Irish Sea West, this could reduce mean size in the landings. This is a strong possibility because it is known that there is high larval production in this area (Briggs *et al*., 2002; Dickey-Collas *et al*., 2000). Further, the ‘average’ hydrological conditions including the Irish Sea Gyre at that time of year may act to retain the peak larval production and bring about high levels of recruitment in the Irish Sea.

Research is required to explore the extent to which developments in the Irish Sea may:

- Alter sediment type and particle size composition (and so impact Nephrops burrow density)
- Change hydrological conditions (and so have the potential to impact laval retention of Nephrops)

Nephrops and wind farms

The Walney offshore wind farm was constructed in the years 2010 and 2011 and encroaches into *Nephrops* fishing grounds off the Cumbrian coast (ICES rectangle 37E6). A study was undertaken in 2012, which examined *Nephrops* landings from ICES rectangle 37E6 over the period 2006-2011 (Table 2). This study is not publically available at present although the data that the study is based on is readily available from the Marine Management Organisation (MMO). The average landings of *Nephrops* during the construction years of 2010-11 were 127t. This was higher than both the average during the six-year study period (119t) and also the average during the four-year pre-construction period (115t). The study also showed that there were no significant changes in the monthly patterns of *Nephrops* landings throughout the six-year study period (FFW, 2013). However, as Figure 5 illustrates, the extent of fishing activity (predominantly targeting *Nephrops*) within the ICES rectangle in relation to the Walney OWF boundary suggests that landings for this rectangle should not be used to infer the status of the *Nephrops* grounds within the OWF.

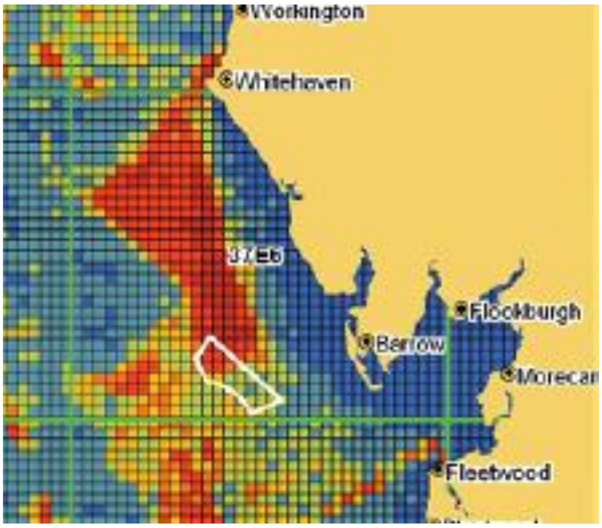

Figure 5: Fishing activity in vicinity of Walney (red indicates higher intensity) (Source: Dong Energy)

Catch rates of *Nephrops* have varied in the surveys within the Walney I area, but have shown a slight decrease post-construction. Due to the low levels recorded in all Walney I surveys it is likely that this is from natural variation, or a number of other unrelated factors.

Total catch rates for fish and shellfish species in the otter trawl survey were similar in all surveys, with the exception of the June 2009 pre-construction survey, where notably high catch rates were recorded. High catch rates were observed at the control stations and within the wind farm during this survey; this is attributable to the large numbers of *Nephrops* caught. The authors concluded that as species diversity showed a slight increase post-construction, it suggested that the operational wind farm might not have adversely affected localised fish and shellfish populations (Dong Energy, 2013). However, it is important to note that an impact on *Nephrops* productivity (the critical issue from a fisheries perspective) cannot be inferred from an increase in species diversity.

3.4.2 Herring

Herring is an important traditional seasonal fishery in the Irish Sea with plans to seek protected origin status for Mourne herring in recognition of this. While pelagic fisheries could be expected to be able to better cope with displacement than demersal fisheries that target specific grounds, there is concern that offshore developments will negatively impact critical habitat for herring.

Figure 6 shows the approximate location of herring spawning grounds and nursery areas. Herring spawning and nursery areas are sensitive and vulnerable to anthropogenic influences. Activities that have an impact on the spawning habitat of herring, such as extraction of marine aggregates (such as gravel and sand) and construction, can impact spawning. Herring abandon and repopulate spawning grounds and an absence of spawning in any particular year does not mean that the spawning ground is not required to maintain a resilient herring population (ICES HAWG, 2014).

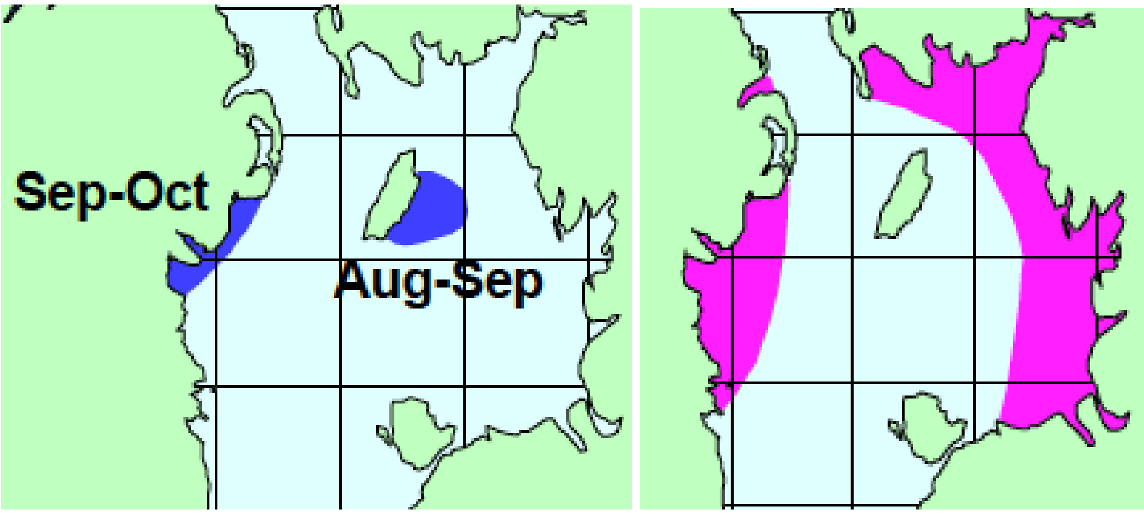

Figure 6 Herring spawning (left) and nursery areas (right) in the central Irish Sea (source: Coull *et al*, 1998)

Griffin et al (2009) suggest that the attachment of particles to herring eggs can lead to retarded development and reduced larval survival rates at SSC as low as 250mg/l. Additionally, herring are known as being relatively sensitive to underwater noise (see 3.3.1) with responses identified over several kilometers. In addition to the location of construction activities, their timing and duration will therefore be critical to the impact on herring resources.

3.4.3 Other fisheries

One of the earliest offshore wind farms to be built, the "Horns Rev 1 Offshore Wind Farm" was analysed throughout seven years post-construction. Overall the study showed that fish communities varied significantly with season, but that a distinct horizontal distribution and higher species diversity was found close to the turbines. Reef habitat species not previously recorded in the wind farm area were observed and species diversity increased. Sandeel assemblages typically found in sand bank areas like the Horns Reef were not impacted (Leonhard *et al*, 2011).

The results from the acoustic surveys indicate that there was a diurnal difference in fish distribution patterns with fish mainly being present in the impact area during the day while migrating to deeper waters north-west of the wind farm site in the night. Such diurnal shift in spatial distribution has also been observed in autumn for gadoids in a Dutch OWF (Winter *et al*. 2010), around ships wrecks (Karlsen, 2011) and for pelagic species that tend to travel between individual reefs and between a reef area and surrounding areas depending on for example their feeding capacity and differential use of habitat type (Bohnsack, 1989). This suggests that even though the impact area offers a more diverse habitat, fish are still utilising areas outside the wind farm either due to size constrains of the park area or that adjacent areas provide alternative services (prey, refuge, physics etc.) not found in the impact area.

In general, and in contrast to the hypothesis that wind farms would attract pelagic and demersal fish species to the farm area, fewer fish of the different fish species were caught in the windfarm area after deployment. However, it was also evident that abundance in the control area was similarly lower than before deployment suggesting larger-scale processes were affecting fish occurrence in that part of the North Sea.

The main fishery in the Horns Rev wind farm area is for sandeels. According to Vessel Monitoring System (VMS) data generated from the area, commercial fishing for sandeels in 2009 occurred in areas with high predicted suitability for sandeels in close proximity to the boundaries of Horns Rev I, including the control area. A notable increase in sandeel fishing density occurred between 2003 and 2009, primarily around Horns Rev I. The authors conclude, "We therefore cannot exclude the possibility that, given the wind farm is large enough and located in a suitable location, it may serve as a marine reserve." (Leonhard, 2011).

In other studies on effects of offshore constructions it has been shown that larger predatory species (e.g. saithe and cod) often aggregate around oil platforms (Løkkeborg, *et al.*, 2002) (Soldal, *et al.*, 2002) while higher residence times for cod were noted near the turbines at offshore wind farms in the southern North Sea off Holland Winter *et al.* (2010). From the same wind farm Couperus *et al.* (2010) presented acoustic qualitative results that indicated mackerel (*Scomber scombrus* and *Trachurus trachurus*) and cod concentrations around the turbines could be higher within the first 15 – 20 meters.

Gadoid (cod, whiting) species were shown to have a high affinity for vertical structures especially in deeper waters (Hille Ris Lambers and ter Hofstede, 2009; Løkkeborg *et al*., 2002). The deployment of new farms in deeper waters may thus provide a habitat for larger gadoids, in contrast to the present Horns Rev Offshore Wind Farm (in relatively shallow water compared to newer wind farms), where an increase in fish abundance was indicated with increasing depth. The cumulative effect of introducing vertical structures in deeper waters may be an aggregation of larger gadoids in this area (Leonhard, 2011).

A study investigating the impact of offshore wind farms on European Lobster and Brown Crab fisheries (Skerritt *et al,* 2012) concluded that a large population of crab, with a larger average size was observed at wind farm sites. However, it remains unclear whether spatial variations in the shellfish populations are influenced by habitat differences or other physical properties, such as distance from shore, depth of water or temperature.

It is important to note that knowledge is still limited for some commercial marine species at certain life stages. For example post-larval lobsters are thought to burrow and remain in benthic substrates until they emerge as juveniles after two years. However, information on the preferred substrates and population densities during this benthic phase is very limited.

3.5 DISPLACEMENT AND TIPPING POINT

3.5.1 Displacement of fishing effort

During consultation on proposed North Sea OWFs, fishermen frequently reported that there were no alternative grounds and that displacement amongst the smaller <10 m vessels would lead to increased competition, conflict and escalating fuel costs. It was believed that larger vessels excluded from existing grounds would be similarly impacted, and, if displaced to neighbouring inshore grounds, could displace several smaller vessels for each larger vessel. Their additional concerns of short and long-term disruption to fish behaviour patterns and abundance caused during construction and operation, suggested that the overall impacts of wind farm development were strongly negative. This view was widely held by fishermen, with few regarding wind farm development as an opportunity, other than the potential to fish within wind farms using fixed gear, and the possible conservation benefits to stocks if access was reduced. (Mackinson *et al*, 2006). These concerns are illustrated in Figure 7.

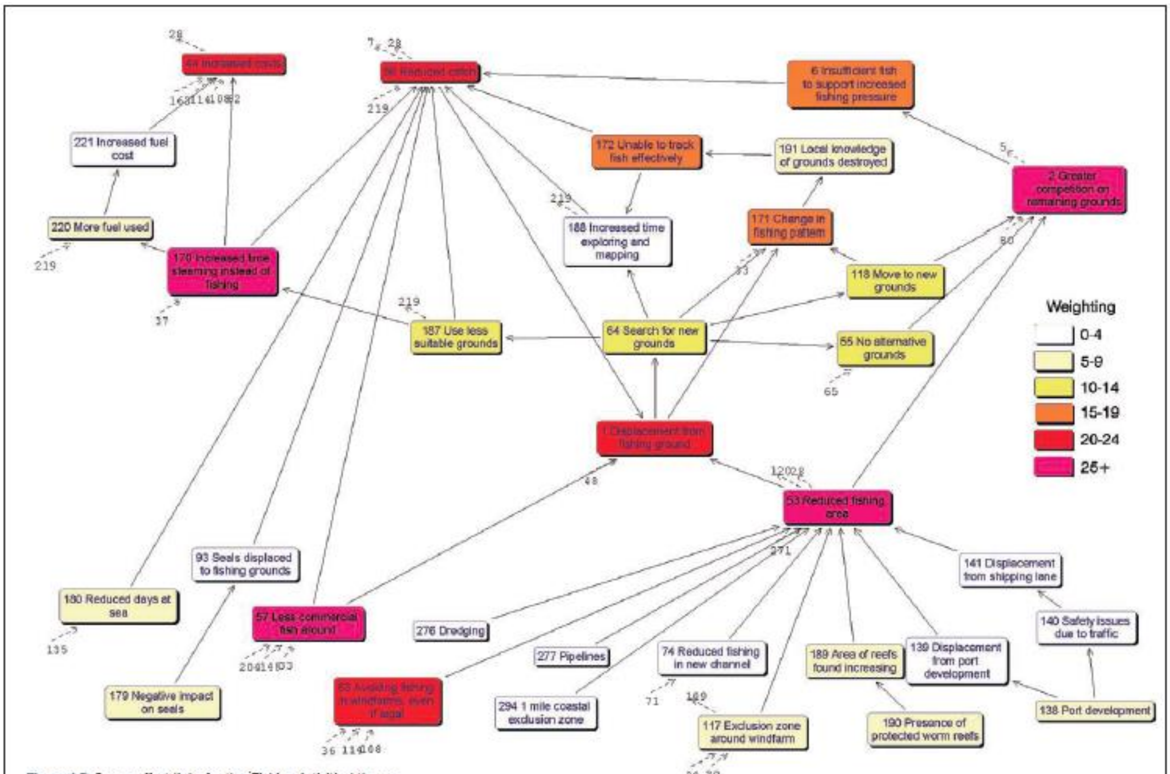

Figure 4.5. Cause-effect links for the 'Fishing Activities' theme. The numbers in the boxes refer to the ID number for each concept.

Figure 7 Cause-effect links for fishermen's perceptions of impact (Source: Mackinson *et al*, 2006)

For *Nephrops* fisheries in the Irish Sea, the AFBI analysis of fishing activity against habitat types show that 98% of shelf mud area is fished and 73% of all types of mud areas. This suggests that virtually all suitable *Nephrops* habitat is fished to some degree. Restrictions on fishing within these areas (through development or MPA establishment) will result in effort being displaced within existing fishing grounds that remain accessible. As these are already being fished to some extent, this creates a risk of over fishing an area and a tipping point being reached.

3.5.2 Tipping point in Nephrops fisheries

There are numerous examples of fish populations being overfished as fishing mortality exceeds sustainable levels of exploitation. However, it is understood that *Nephrops* fisheries are somewhat resilient to fishing pressure. This section explores whether a tipping point could be reached in *Nephrops* fisheries and other implications for stock dynamics.

When ICES examined exploitation in *Nephrops* fisheries, there was no relationship between mean landings per unit effort (kg/hr) and mean burrow density (no./m^{-2}). The productivity measured in landings at most FUs was similar. This conforms to the law of constant yield i.e. a constant biomass is available per functional unit, with density and size being regulated to achieve this limited biomass. Since other constraints including management measures will also maintain productivity below a certain level, ~40 kg hr^{-1} effort is not an absolute threshold of *Nephrops* productivity. But management constraints will tend to apply in a standard way; so common limits on productivity are nevertheless possible across *Nephrops FUs.*

Several studies illustrate that *Nephrops* fisheries are resilient to trawl pressure, more so than demersal fish fisheries for example. This is because female Nephrops remain in their burrows when they are carrying eggs and are therefore less prone to capture by trawl.

Some fished areas may be trawled more than 7 times a year and yet landings have been maintained at historically high levels for 30 years (ICES, 2012 Area VII). However, there are clearly upper limits to fishing removal and disturbance as some *Nephrops* stocks have declined (e.g., Fariña and González Herraiz, 2003). Fishing practices including trawl duration, seasonality, gear (otter or beam trawl), and net design (e.g., Drewery *et al*., 2010) are all likely to affect the resilience of *Nephrops* populations depending on the extent to which burrows are disturbed and/or un-fished individuals damaged.

Queirós *et al*. (2006) suggested that burrowing Crustacea (*Jaxea nocturna* in their example) could dominate benthic communities in trawled areas as burrowing reduces vulnerability to trawling while sediments mobilized by trawling and bioturbation may smother filter-feeding competitors. *Nephrops* may dominate the areas in part due to trawling and so without trawling (e.g. through the creation of no-trawl areas within wind farms) there is the potential for competitor and perhaps predator populations (such as cod) to increase.

Similarly fishing pressure can result in smaller average sizes (and so lower average price) as new recruits to the fishery make up the majority of a heavily exploited stock. Sarda (1998) compared the size structure of the Norway lobster population exploited off Barcelona on the Serola Bank fishing grounds in 1974 and 1994. The results clearly indicate that most catches in the 90's were of younger individuals as the mean difference of 4 mm carapace length is approximately equivalent to one-year's growth. This meant that adult females with peak spawning capacity had been fished out, with an associated decrease in reproductive potential. This type of exploitation pattern exerts a dual effect: on one hand, exploitation is directed at younger individuals closer to the size at first reproduction and on the other, it removes a substantial proportion of the spawning stock.

3.5.3 Impact of closed areas on *Nephrops* fisheries

Smith & Jensen (2008) modelled the potential impacts of closed areas on *Nephrops* fisheries. With the assumption of negligible movement of lobsters between zones, closing part of the fishing area led to a reduction in fishery yield, despite increased recruitment to the open zone and the higher fishing intensity there caused by displacement of fishing effort. Larger closed areas led to greater reductions in yield and, depending on the prior level of fishing effort, led to large oscillations in yield. The introduction of a closed area also led to reduced average size of lobsters in the population and the catch, through increased fishing intensity in the open zone, and consequently a reduced average price, which in combination with reduced yield produced lower first-sale value of landings for all modelled combinations of closed-area size and fishing effort.

The improved level of recruitment to a fished zone with a closed area did not sufficiently offset the expected reduction in yield-per-recruit (Polacheck, 1990), to prevent a reduction in yield. Moreover, the concentration of fishing effort in the fished zone after establishment of the closed area, combined with the better recruitment, meant that the simulated fishery exploited mainly recently recruited lobsters, which would command a lower price. Under the assumptions made, a closed area would reduce the weight and value of the catch in a Norway lobster fishery (Smith & Jensen, 2008).

Given the current selectivity of the fishing gear, the present model also indicated that more-intense exploitation of small lobsters resulting from a closed area would lead to greater destruction of lobster biomass through discarding, which is undesirable ecologically, economically, and ethically (Smith & Jensen, 2008). Closed areas resulting in smaller size grades being landed will have a greater impact in the future as discarding is to be phased out with the introduction of the Landing Obligation under the reformed CFP.

Concentration of fishing effort in the fished zone would also intensify the damaging impacts of trawling on the seabed there, although the seabed in the closed area would, in time, be expected to return to an undisturbed state (Jennings and Kaiser, 1998). This highlights another unknown effect of closed areas. The above simulation assumes that the area closed to trawling continues to be an unexploited *Nephrops* ground that could contribute to recruitment of *Nephrops* to the open zone. However if the density of *Nephrops* in the closed area reduces, this many not be the case.

As scavengers *Nephrops* benefit from a certain amount of ground disturbance through provision of food. Disturbance would also remove potential competitors that are more sensitive to trawl pressure such as fragile or sessile benthic species. There is evidence to indicate that *Nephrops* are part of a sub-climax ecological community, which would otherwise be less dominated by *Nephrops* and include other crustacean, molluscs and echinoderms. Ball *et al* (2000) found reduced biomass and species richness on grounds subject to trawling (see Table 3-7:). Some 62 of the species found at an un-fished mud site were not found at an offshore fished site. With the exception of *Nephrops*, the benthic macrofauna on the trawled area was sparse and dominated by small polychaetes with a few [generally juvenile] crustaceans and bivalves.

Table 3-7: Mean community metrics for fishing grounds and adjacent to a wreck site in the Irish Sea (Source: Ball *et al*, 2000)

Parameter	Fishing grounds*		"41 Fathom Fast" wreck		
	Control	Impact	Near	Middle	Far
Total species	50	37	71	71	62
Total individuals	687	513	3463	2847	2850
Biomass (gm-2)	21	19	40	189	30
Species richness	5.2	4	5.95	6.1	5.32
Shannon's Diversity	3.62	3.88	4.5	4.31	4.31
Evenness	0.64	0.75	0.73	0.7	0.72

*Control = before and Impact = 24 hours after experimental trawling

Predation of *Nephrops* is also reduced with the reduction in predators such as cod. Pinnegar and Platts (2011) found that cod consumption represented a relatively low mortality rate in *Nephrops*: predation and fishing removed 0.61 and 8.4 thousand tonnes respectively from the Irish Sea in 2007. However the ongoing recovery of Irish Sea cod stocks may make this type of mortality more significant for *Nephrops* populations in the future. With un-trawled areas favouring benthic competitors; the recovery of predator populations; and even a discard ban reducing scavenged food availability, the favourable ecological niche that *Nephrops* has occupied over recent decades may be shrinking.

In summary, the above papers indicate that closed areas (either intended such as the proposed Irish Sea MCZs or *de facto* via renewables development such as First Flight Wind's proposed development off County Down coast) may not result in benefits to the *Nephrops* fishery as:

- Concentrating fishing in a reduced area risks overexploitation. *Nephrops* fisheries have experienced reduced returns through over-exploitation (Farina & Gonzalez Herriaz, 2003; Sarda, 1998);
- Closed areas may lead to the areas that remain open showing a reduced yield and reduced sizes/prices (Smith & Jensen, 2008); and
- Closed areas may change from being *Nephrops*-dominated to a more diverse system of [mainly non-commercial] benthic species (Ball *et al*, 2000).

3.5.4 Implications for other fisheries

For nature conservation, the benefits of some marine areas being closed to trawling are evident. Many studies have identified that there is a greater abundance and diversity of benthic species in areas that are not subject to trawl pressure (e.g. Lindeboom & de Groot, 1998; Jennings & Kaiser, 1998, Lokkeborg, 2005). Several studies have also identified that demersal fish species are more varied and abundant on un-trawled grounds (e.g. see Hixton & Tissot, 2007) assumed to be a consequence of the greater biomass of benthos in un-trawled areas.

Closed areas, in which one or more forms of fishing are prohibited, are often advocated for fishery management (as opposed to nature conservation) through enhanced reproduction and emigration of larvae, juveniles, or adults (Gell and Roberts, 2003). Such benefits are most likely to be manifest in species with restricted mobility as adults and having planktonic larval dispersal (Hastings and Botsford, 1999), as found in certain marine invertebrates that are the basis of important fisheries, such as lobsters.

If the vertical structures and hard substrate of wind farm installations are also considered, it is reasonable to expect that in the long term these developments may increase species diversity in the development area compared to the existing trawl grounds. They may also be effective as *de facto* closed areas for less mobile species.

The benefits of such closed areas for demersal or pelagic species that are targeted commercially within the Irish Sea are less evident as the fish can be captured when moving outside of these refuges. The structures themselves are also more likely to act as fish aggregating devices (FADs) rather than resulting in significant additional biomass for demersal finfish fisheries.

Scallops are somewhat similar to *Nephrops* as there is some evidence that scallop grounds benefit from a degree of seabed disturbance, either natural or through fishing, as sessile competitors are prevented from becoming established on the grounds. However there are positive results for fisheries from closed areas in the Georges Bank, USA and the Isle of Man. Howarth *et al* (2011) found scallop settlement inside the Arran No Take Zone to be substantially greater than outside it and this was likely to result in spill-over benefits for the commercial fishery as juvenile scallops in the NTZ would move out of the area as they grow.

A recent review of the Scottish scallop sector (Cappell *et al*, 2013) advocated the identification of inshore fisheries refuges that were particularly important for spawning. These could operate on a rotational basis and would differ to closed areas identified for nature conservation objectives that would benefit from permanent closure to scallop dredging. Spatial or temporal restrictions, which are already informally applied in many scallop fisheries, add a 'safety valve' ensuring that all of the population is not being exploited at the same time.

However, there is no clear relationship between stock size and recruitment in scallop fisheries (Hancock, 1973). A spawning refuge in one area does not automatically result in healthy recruitment in an adjacent area, as recruitment is dependent on many environmental variables. Recruitment [is] unrelated to resident stock in any given bed, but derived from contiguous areas as a function of larval drift in relation to residual circulation (Young, 1994). Scallop refuges therefore only better ensure successful spawning events and the availability of planktonic larvae, but not necessarily larval settlement in a fishable area and so recruitment to the fishery. Consequently scallop fisheries are reliant the flexibility to fish a variety of known grounds to find areas where catch per unit effort (CPUE) levels are economically viable.

Closed or unfishable areas may create a refuge, but this also reduces the accessible grounds to allow for the inter-annual variability in recruitment and risks overexploitation with the concentration of scallop fishing effort into a smaller open area.

3.6 CONCLUSIONS

Future Offshore Wind Farms are likely to have larger, but fewer turbines with greater spacing in between the turbines compared to those currently in operation. This has led to an expectation that fishing activity will continue within wind farms rather than be excluded from within the development area. This should not be interpreted as there being no impact to commercial fishing.

Management constraints (i.e. those imposed by regulators or developers) are likely to be minimised and safety zones may be limited to construction and decommissioning periods.

Ultimately the likelihood of fishing within a wind farm will depend on a variety of factors, including the favorable alignment and burial of interconnecting cables to create trawl corridors.

As wind farms create additional hazards, fishing within wind farms would be less likely in poor visibility or sea conditions and so some restriction to fishing would still be expected.

Proposed offshore developments also have the potential to impact key target resources for the Northern Ireland fleet. Impacts on *Nephrops* resources may occur through changes in sediment particle size, affecting burrow density, and changes to hydrology, influencing larval recruitment.

Research is required to explore the extent to which developments in the Irish Sea may:

- Alter sediment type and particle size composition (and so impact *Nephrops* burrow density)
- Change hydrological conditions (and so have the potential to impact larval retention of *Nephrops*)

Significant impacts to *Nephrops* from increased suspended sediments are less likely as dynamic conditions already persist. The potential impact of increased suspended sediment concentrations on herring spawning areas are, however, of significant concern for Northern Ireland’s traditional herring fishery.

Previous research suggests that closed areas (either intended via the proposed Irish Sea MCZs or *de facto* closed areas via renewables development) may not result in benefits to *Nephrops* fisheries because:

- Concentrating fishing in a reduced area increases the risk of over-exploitation, resulting in reduced income as seen in *Nephrops* fisheries elsewhere (e.g. Farina & Gonzalez Herriaz, 2003; Sarda, 1998);
- Closed areas may lead to the areas that remain open showing a reduced yield and reduced sizes/prices (e.g. Smith & Jensen, 2008); and
- Closed areas may change from being *Nephrops*-dominated to a more diverse system of [mainly non-commercial] benthic species (e.g. Ball *et al*, 2000).

Further research would be useful to explore what may be sustainable levels of fishing intensity for Irish Sea *Nephrops* grounds (which are highly productive functional units) and to explore the potential influence of offshore structures on recruitment to the fishery via changes to larval dispersion.

This literature review has focused on the impact of offshore wind farm developments on fishing activity and key biological resources for Northern Ireland’s fishing fleet. It highlights the need to fully consider cumulative and in-combination effects of proposed developments and other spatial restrictions in the Irish Sea.

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