European Offshore Wind Deployment Centre

Environmental Statement

Appendix 22.2: Salmon and Sea Trout EIA Technical Report

A project part-funded by the European Union under the European Economic Plan for Recovery in the field of Energy

European Offshore Wind Deployment Centre (EOWDC)

Salmon and Sea Trout Impact Assessment

Undertaken by
Brown & May Marine Ltd

Reference	Date of Issue	Issue Type	Checked	Approved
EOWDC-SSTIA01	09/05/2011	FINAL	SJA/PJM/SX	SJA

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1.0 Introduction

The following document details the Salmon and Sea Trout Impact Assessment for the European Offshore Wind Deployment Centre (EOWDC).

The primary focus of this report is the assessment of the potential for salmon and sea trout, especially during migration, to be affected by the EOWDC. Given the socio-economic importance of the salmon and sea trout fishery in Scotland, both in rivers and in coastal waters, the potential for the fishery to be directly or indirectly affected has also been evaluated (Section 3.5).

2.0 Methodology

2.1 Key Guidance Documents

In the absence of guidelines specific to the assessment of impacts on salmon and sea trout and in relation to offshore wind farm developments, the following documents have provided guidance:

- Strategic Environmental Assessment (SEA) of Draft Plan for Offshore Wind Energy in Scottish Territorial Waters: Volume 1: Environmental Report. Marine Scotland. 2010
- Habitats Regulations Appraisal Draft Plan for Offshore Wind Energy in Scottish Territorial Waters: Appropriate Assessment Information Review. Marine Scotland .2011
- Offshore Wind Farms guidance note for Environmental Impact Assessment in respect of FEPA and CPA requirements. Version 2- 2004
- EOWDC Marine Scotland Scoping Response (December 2010 and January 2011 update)

2.2 Information and Data Sources

The principal sources of information used for the undertaking of this assessment are as follows:

- Marine Scotland Review of Migratory routes and behaviour of Atlantic salmon, sea trout and European eel in Scotland's coastal environment: Implications for the development of marine renewables (Malcolm *et al*., 2010)
- Scottish Natural Heritage Literature review on the potential effect of electromagnetic fields and subsea noise from marine renewable energy developments on Atlantic salmon, sea trout and European eel (Gill and Barlett, 2010)
- Consultation with District Salmon Fishery Boards and other relevant stakeholders
- Collaborative Offshore Wind Research Into the Environment (COWRIE) Publications
- Monitoring Surveys undertaken in Operational Wind Farms
- Other publically available research literature

2.3 Consultation

Consultation meetings were held with all the salmon fishery boards located within the North East region and with representatives of the netting fishery in the North East.

These were as follows:

- Ugie District Salmon Fishery Board (26/10/2010)
- Ythan District Salmon Fishery Board (26/10/2010)
- Don District Salmon Fishery Board (27/10/2010)
- Dee District Salmon Fishery Board (17/01/2011)
- Esk District Salmon Fishery Board (27/10/2010)
- Usan Fisheries (Montrose) (17/02/2011)

In addition to the above meetings, questionnaires were circulated to all the salmon district fishery boards in Scotland, through the Association of Salmon Fishery Boards (ASFB), and to netsmen, through the Salmon Net Fishing Association of Scotland.

2.4 Data and Information Limitations and Data Gaps

Extensive studies and research concerning the behaviour of salmon, and to a lesser extent sea trout, have been, and are being, undertaken. Despite this, however, the behavioural patterns of the species in the marine environment, particularly on the Scottish east coast, are not fully known and a degree of uncertainty exists regarding salmon and sea trout migratory routes, behaviour in coastal waters, navigation mechanisms and the implication of responses to factors such as noise and EMFs during migration. In light of this, and in order to provide a robust assessment of impacts, a number of assumptions have been made that are further discussed in Section 2.5.7 below.

2.5 Impact Assessment Methodology

The assessment aims to describe the magnitude of effect for each potential impact (i.e. the change created by an activity in terms of its spatial extent, duration and scale) and the sensitivity of each receptor (i.e. the environmental resources that would be affected) based on its importance and recoverability. The effect and sensitivity of the receptor are then used to derive the significance of each potential impact.

2.5.1 Potential Impacts

The potential impacts to be considered are summarised in Table 2.1 below for the construction, operational and decommissioning phases. For the purposes of this assessment and given the uncertainties relating to decommissioning methods at this stage, it has been assumed that the impacts derived from the decommissioning phase will, at worst, be of the same significance as those derived from construction.

Table 2.1 Summary of Key Potential impacts on Salmon and Sea Trout

Development Phase	Source of Impact	Potential Effect
Construction/ Decommissioning	Noise	Direct Impact: Lethal Effects and Hearing Damage
		Disturbance/Delay /Barrier to Migration
		Indirect Impacts: Loss of Key Prey Species
	Increased Sediment Concentrations	Direct Effects
		Disturbance/Delay/Barrier/ to migration
Operation	Noise	Disturbance/Delay /Barrier to Migration
		Indirect Impact: Loss of Key Prey Species
	Physical Presence of Turbines	Disturbance/ Delay/Barrier to Migration
	EMFs	Disturbance /Delay/Barrier to Migration

Given the migratory nature of salmon and sea trout and the potential for the proposed EOWDC to have different impacts on these species depending on the life stage under consideration, for the purposes of this assessment, the receptors have been sub-divided as follows:

- Juvenile salmon (smolts/post-smolts)
- Juvenile sea trout (smolts/post smolts)
- Adult salmon (grilse and Multi-Sea Winter (MSW) salmon)
- Adult sea trout

2.5.2 Assessment Criteria

The criteria used in the assessment are given below:

Spatial Extent of Effect

- A national/international effect
- A regional effect
- A local, site specific effect including within 5km of the site

Duration of Effect

- A long term/permanent effect (more than 10 years)
- A medium effect (existing for 5 to 10 years)
- A short term effect (existing for 1 to 5 years)
- A temporary effect (existing for less than 1 year)

Scale of Effect

- Above accepted standards/guidelines
- Within accepted standards/guidelines
- Where there are no standards/guidelines available, the impact relative to background conditions

Recoverability of the Receptor

- High
- Medium
- Low or None

Importance of the receptor (taking into account international, national and regional legislation, and function within the ecosystem)

- High
- Medium
- Low or None

The impact significance is then given as *MAJOR, MODERATE, MINOR* or *NEGLIGIBLE* guided by the matrix is given in Table 2.2.

Table 2.2 Matrix Used to Guide Significance Ratings of Impacts

		Sensitivity of Receptor			
		VERY HIGH	HIGH	MEDIUM	LOW
Magnitude of Effect (based on spatial, duration and scale)	VERY HIGH	Major	Major	Major	Moderate
	HIGH	Major	Major	Moderate	Minor
	MEDIUM	Major	Moderate	Minor	Minor
	LOW	Moderate	Minor	Minor	Negligible
	NEGLIGIBLE	Minor	Negligible	Negligible	Negligible

2.5.3 Implications of Significance

Where the significance for a potential impact is classified as ***MODERATE** to **MAJOR*** or ***MAJOR**,* it is considered to be a potentially significant effect. It should be noted however that significant effects may not be unacceptable as their effect may be reversible. A ***NEGLIGIBLE*** significance is assigned to a potential impact if it produces no discernible effect on the environmental resource in question.

2.5.4 Cumulative and In-combination Impact Assessment Methodology

The cumulative and in-combination impact assessments have applied the same methodology and potential impacts outlined above.

In-combination impacts relate to European protected sites that could be affected by the proposed development. These assessments have been addressed within the Habitats Regulations Assessment.

Cumulative impact assessments have been undertaken on those developments and activities which could be reasonably be expected to have an effect.

Other Offshore Wind Farms

The wind farm developments which could contribute to the cumulative impacts are those proposed in the Firth of Forth to the south and the Moray Firth to the north.

Offshore Oil & Gas Developments

Current available information suggests that there is not anticipated to be offshore oil and gas exploration or production activities within the general area of the proposed EOWDC site which could contribute to cumulative effects. This activity has therefore been scoped out of the cumulative assessment process.

Introduction of Marine Protected Areas (MPAs)

The Marine (Scotland) Act has established powers for the development of Marine Protected Areas (MPAs) in the seas around Scotland. These areas, however, have yet to be defined. The introduction of MPA's is not however expected to have any adverse impact on salmon and sea trout and have therefore been scoped out of the cumulative assessment process.

Aggregate Dredging

The Middle Bank licensed dredging area in the Firth of Forth, approximately 150 km from the EOWDC, is the closest licensed dredging area. It should be noted that at present it is not active. This activity has therefore been scoped out of the cumulative assessment process.

Other Offshore Works

Currently there is no information on other offshore works that would contribute to cumulative impacts on salmon and sea trout.

Ocean Laboratory

It is proposed that an Ocean Laboratory may be installed within the site. This will be subject to a separate application and EIA. As such, at this stage, it will only be assessed in terms of its cumulative effect.

2.5.5 Assessment of Impacts against a Changing Baseline

A number of factors unrelated to the proposed EOWDC development may cause changes to salmon and sea trout populations over the life of the project. For instance, increased marine mortality, a trend that has been observed in recent years and thought to be related to environmental factors, could result in a further decline in the numbers of salmon and sea trout in rivers. Furthermore, changes in fishing practices in the coastal and marine environment, and the introduction of further legislation and conservation measures could also impact the state of salmon and sea trout stocks.

2.5.6 Worst Realistic Case

The worst realistic case is assumed to be the installation of 11 turbines, all of which have 8.5 m diameter monopile foundations. The theoretical worst case in terms of cumulative assessment would be the simultaneous construction of the proposed offshore wind developments in the Firth of Forth and in the Moray Firth, coinciding with the proposed EOWDC.

2.5.7 Assumptions

As stated above data gaps exist with respect to the salmon and sea trout baseline and therefore for the purposes of the impact assessment certain assumptions have been made.

Figure 2.1 below shows the location of the EOWDC relative to the principal salmon rivers in the regional area. It can be seen that the Dee, Don and Ythan are closest to the development and the assumption has been made that fish from these rivers are more likely to transit the site. It is also recognised however that fish from other rivers, both within the region (e.g North Esk, South Esk, Ugie) and from other Scottish areas (e.g Moray Firth, North, etc) may on occasions also be present in the vicinity of the development.

Taking a precautionary approach the following assumptions, based on the behavioural patterns of salmon and sea trout, have been made for fish originating in the Dee, Don and Ythan Districts:

- Juvenile salmon and sea trout transit through, or in close proximity to, the site on their seaward migration
- Adult salmon (grilse and MSW) and sea trout transit through, or in close proximity to, the site on their return migration
- Sea trout are present in the vicinity of EOWDC and transit the site as part of their foraging activity

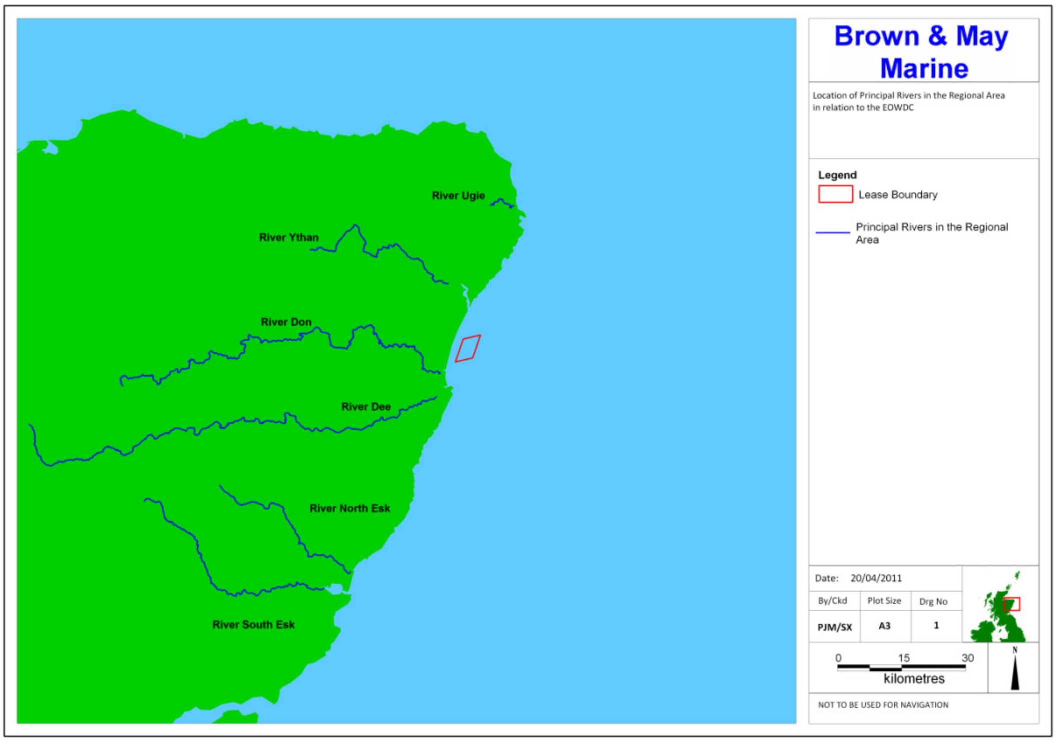

Figure 2.1 Location of the Principal Rivers in the Region in relation to the EOWDC

3.0 Impact Assessment

3.1 Noise and Vibration

3.1.1 Construction and Decommissioning

The principal source of noise during the construction phase will be the possible piling of foundations (monopiles and to a lesser extent jacket structures). Although cable laying and burial, rock placement for scour protection (should it be required) and vessel movements will also result in some levels of noise, these activities will be temporary and localised.

The theoretical maximum number of piling events will be limited to eleven and piling will not be continuous. Under normal conditions, the durations of piling individual foundations for wind farms constructed to date, have typically varied between 20 minutes and thirteen hours. For the purposes of this project, five days is taken as the theoretical maximum duration for the installation of a single foundation within which 24 hours continuous piling is assumed as worst case (further details in Chapter 3, Description of the Proposed Development).

Predicted noise levels from piling activity at the proposed EOWDC were modelled based on piling of 8.5 m diameter piles (worst case) at four different locations (turbines 1, 3, 7 and 11) and taking account of the hearing ability of salmon using the dB_{ht} *(Species)* metric. The model predicts that noise levels which would result in traumatic hearing damage in salmon ($130dB_{ht}$ *(Salmo salar))* could occur at distances of within 20 m of piling (Nedwell *et al.*, 2011). Contour plots of estimated $90dB_{ht}$ *(Salmo salar)* impact ranges, at which strong behavioural reactions would be expected, were also produced. The results suggest that, at turbine 7 where the $90dB_{ht}$ impact range was greatest, the average impact range would be 4.2 km (value range 3.6 km- 4.7 km).

An indication of the spatial ranges at which behavioural reactions in salmon may occur for two of the four locations modelled is given in Figure 3.1. This illustrates the estimated 90dB$_{ht}$ *(Salmo salar)* and the 75bB$_{ht}$ *(Salmo salar)* impact ranges contours. It is considered that at 75dB$_{ht}$ levels, 85% of individuals would react to noise although effects will probably be limited due to habituation.

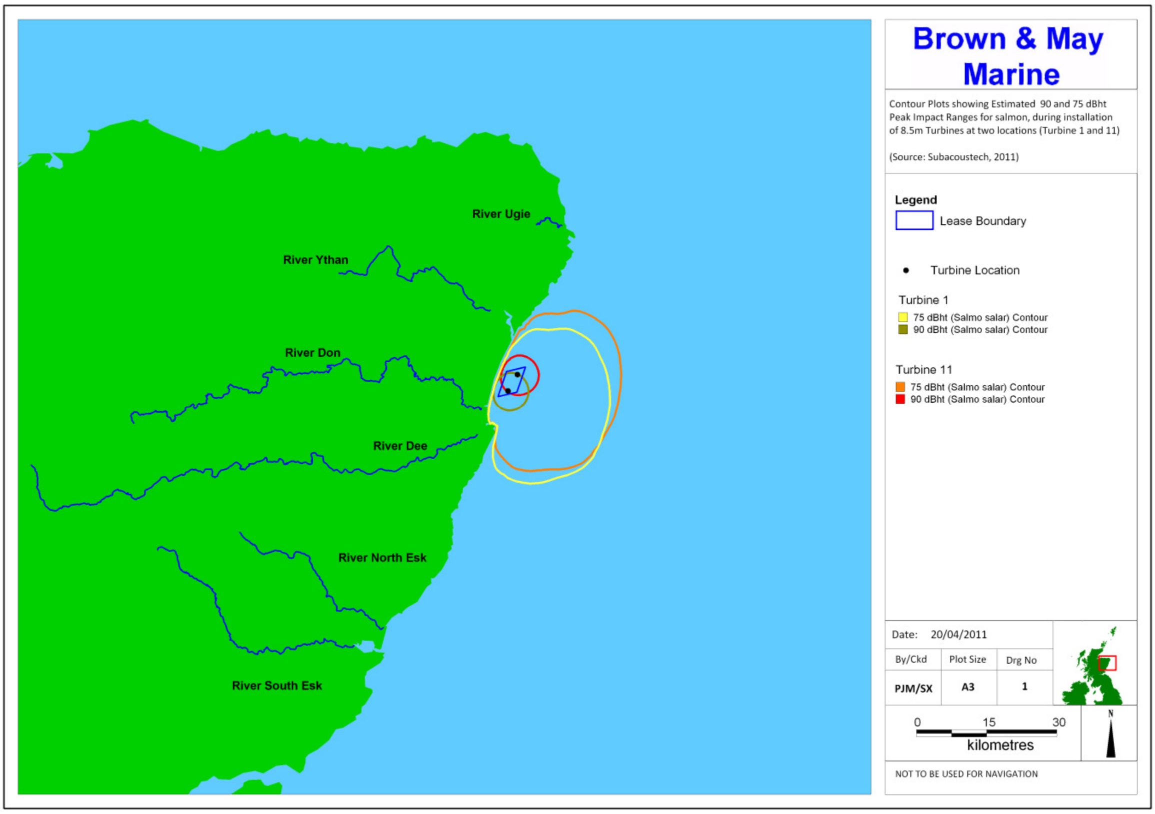

Figure 3.1 Contour Plots showing Estimated 90 and 75dB$_{ht}$ *(Salmo salar)* peak impact ranges during installation of 8.5m diameter Turbines at two locations (Turbine 1 and 11) (Source: Nedwell *et al.*, 2011)

It should be noted that the assessment given below is based on a theoretical worst case scenario, involving piling of 11 monopiles of 8.5 m diameter. As the EOWDC is an experimental development to trial various foundations types, in reality it is expected that less than eleven monopiles will be installed.

Unlike hearing specialists such as herring, salmonids have no direct connection between the swim bladder and the ear and are therefore considered to be hearing generalists.

Salmon have been shown to respond to low frequency sounds (below 380 Hz), with best hearing (threshold 95 dB re 1 μ Pa) at 160 Hz (Hawkins and Johnstone, 1978). The ability of salmonids to respond to sound pressure is regarded as relatively poor with a narrow frequency span, a limited ability to discriminate between sounds, and a low overall sensitivity (Gill and Bartlett, 2010). Based on sound measurements undertaken in the River Dee, Hawkins and Johnstone (1978) concluded that salmon are unlikely to detect sounds originating in air, but may be sensitive to substrate borne sounds.

Research carried out on the effects of piling noise on caged brown trout (*Salmo trutta)* at the Red Funnell's Southampton Terminal (Nedwell *et al*., 2003a) found no behavioural reactions to vibro-piling and no responses to hammer pile operations for fish as close as 50 and 417 m from the source, respectively. Further studies carried out on brown trout (*Salmo trutta*) suggest that the hearing of brown trout is less sensitive than that of salmon. Analysis using the dB_{ht} metric indicated that the noise at the nearest locations during impact piling reached levels at which salmon were expected to react strongly, however, brown trout showed little reaction (Nedwell *et al*., 2006).

For the purposes of this assessment, salmon has been used as a surrogate for sea trout, whilst it is appreciated that the sensitivities of the two species may be different. In addition, it is recognised that juveniles, such as smolts, and small grilse, may also have different sensitivities than adults, being generally considered to be more vulnerable to noise impacts (Hastings and Popper, 2005; MS, 2011). In experimental and river settings they have been found to avoid localised high intensity sounds less than 10 Hz (Sand *et al*., 2001; Knudsen *et al.,* 1992; Knudsen, 1997).

3.1.1.1 Direct Impacts: Lethal Effects and Hearing Damage

Potential Impact

Based on the results of the noise modelling undertaken for salmon (Nedwell *et al.*, 2011), it is expected that lethal noise levels during construction would only occur in the immediate vicinity of areas where piling is being undertaken (< 3 m from the pile).

Similarly the potential for traumatic hearing damage in salmon and sea trout would only take place in localised areas. Using the $130dB_{ht}$ criteria from Nedwell *et al*. (2007), and assuming fish are not deterred from the area, salmon would be expected to suffer traumatic hearing damage within 20-30 m of the piling activity. This distance has been further refined using the fleeing animal model which assumes that animal swim away from the noise source. Using a swim speed of 1 m/s and taking into account the accumulated noise dose near a typical piling operation, the model calculates that fish within 1 m of the piling activity, at the onset of piling, are unlikely to be able to flee before suffering hearing damage.

As lethal/traumatic hearing damage effects are only predicted to occur very close to the pile, and given that soft start piling will deter animals from this area, the magnitude of this impact is considered to be *NEGLIGIBLE*. The receptors, taking the small number of fish potentially present at a given time within the small spatial area where impacts could occur and given their importance as conservation species are considered of *HIGH* sensitivity. The potential direct impacts derived from construction noise on salmon and sea trout are therefore considered of *NEGLIGIBLE* significance.

Mitigation

None other than the use of soft start piling.

Residual Impact

NEGLIGIBLE

Cumulative Impact

None

3.1.1.2 Disturbance/Delay/Barrier to Migration

As illustrated in Figure 3.1 there is potential for behavioural responses to occur in a wider area than just the immediate turbine locations ($95dB_{ht}$ and $75dB_{ht}$ contours). The implications of behavioural responses will depend on the life stage under consideration and the ecology of the species, and on assumptions (Section 2.5.7), rather than definitive research evidence of salmon and sea trout migration routes.

Potential Impact

Salmon and Sea Trout Juveniles (Smolts/Post-smolts)

Information on the behaviour of salmon and sea trout smolts and post-smolts in Scottish waters once they leave the freshwater habitat is limited. Smolts usually leave rivers from April to June and are thought to make limited use of estuarine habitats moving rapidly to the open sea. Research based on salmon suggests post-smolts normally swim in the upper few metres of the water column (1-3m) and do not closely follow nearby shores, having being recorded swimming at distances up to 2-5km from the shore.

Given the close proximity of the Don, Dee and Ythan to the proposed EOWDC, juvenile salmon and sea trout (smolts and post-smolts) originating from these rivers may transit close to or through the proposed EOWDC during their early marine phase. It is also possible that post-smolts originating in other rivers, especially those in the regional study area (Ugie, North Esk and South Esk), may transit close to or through the proposed EOWDC where noise levels could result in strong ($90dB_{ht}$) or mild ($75dB_{ht}$) behavioural reactions.

In the case of sea trout, which do not generally venture to distant offshore feeding grounds, there is potential for post-smolts to transit the proposed EOWDC site during their early marine phase as part of their foraging activity.

It is considered that any delay in smolt/post-smolt migration would be extremely short term, given the durations of the worst case piling events (24 hours per pile) and the localised area where strong behavioural reactions are expected to occur (approx. 4 km radius). The magnitude of the impact is therefore considered to be *LOW.* The number of juvenile salmon and sea trout originating from most rivers potentially transiting areas where strong behavioural reactions could occur at any given time is also expected to be low.

The sensitivity of the receptors, particularly those smolts/post-smolts originating in the Dee, Don and Ythan, given the close proximity of the rivers to the proposed EOWDC site is however considered to be *HIGH/VERY HIGH*.

The potential impact of construction noise on juvenile salmon and sea trout (smolts/post-smolts) migration is therefore considered of *MINOR/MODERATE* significance in the case of fish originating in the Dee, Don and Ythan.

Adult Salmon and Sea Trout

On the east coast of Scotland, as far north as the Aberdeenshire coast, the migration of adult salmon in coastal waters is believed to predominantly occur in a northerly direction, potentially starting as far south as the north east coast of England. On this basis, it is likely that adult salmon from the Dee, Don, Ythan and Ugie may migrate through the proposed EOWDC and its vicinity. Fish from other rivers could also transit the site and adjacent areas, principally fish returning to the Esk rivers, and to a lesser extent rivers flowing into the Moray Firth and other Scottish regions, although this would be expected to occur to a lesser extent.

In the case of sea trout, it is expected that adult fish transiting the site both as part of their migration or foraging activity will principally originate from the Dee, Don and Ythan and to a lesser extent other rivers in the regional area (Ugie, North Esk and South Esk). As for salmon, it is possible that sea trout originating in other Scottish regions could also transit the area of EOWDC, as long distance migrations have also been observed.

Adult salmon and sea trout returning to the Dee, Don and Ythan have been reported to remain in estuaries waiting for appropriate conditions to enter the river. Noise levels around the Dee, Don and Ythan estuarine areas are not expected to be above $75dB_{ht}$ *(Salmo salar)* (Figure 3.1), and therefore may, at worst, only cause mild behavioural reactions in salmon and sea trout.

In the absence of specific information on the implications of behavioural responses triggered by noise in pre-spawning adult salmon and sea trout in the marine environment prior to river entry, it is considered that the fish may react in one of the following ways:

- Avoid the area and return to the estuary once construction noise has ceased. Assuming the worst case scenario of 24 hour continuous piling per pile, this would result in a short term delay in upstream migration, similar to that caused by natural factors (e.g waiting for adequate flow conditions).

- Reproductive instinct may overrule behavioural reactions potentially triggered by noise (e.g avoidance reactions) and salmon and sea trout may remain in the estuary and enter the river at the time they would normally do, despite of the noise. For example, research undertaken on herring, a hearing specialist, at a spawning site, concluded that the high priority given to reproductive activities may in some instances overrule avoidance responses (Skaret *et al.,* 2004).

For salmon and sea trout originating in other rivers in the region, if transiting areas where noise levels could cause significant avoidance reactions, it is likely that the implications on their migration will be limited to slight changes in their migratory patterns and potentially, slight delays in river entry.

Taking the worst case scenario, that adult fish migrating into the Dee, Don and Ythan will avoid the area due to noise levels, it is considered that the magnitude of the impact will be *LOW*, on the basis of the relatively short duration of a piling event and the relatively short nature of any delays in migration. Given their importance as species of conservation, especially in the case of salmon in the Dee SAC, and taking account of the relatively small number of fish potentially affected by a piling event, on the basis of the diversity of salmon runs and river entry timing in the case of salmon to take place in some rivers throughout the year, the receptors are considered of *HIGH* sensitivity. The impact due to construction noise on adult salmon and sea trout returning to the Dee, the Don and the Ythan is therefore considered of *MINOR* significance.

Mitigation

Juvenile Salmon and Sea Trout

It is proposed that piling activities be scheduled in consultation with Marine Scotland Science, Scottish Natural Heritage and the Dee, Don and Ythan District Salmon Fishery Boards to ensure minimal disturbance to smolt runs.

The timing of the principal smolt runs in the Ythan, Dee and Don Salmon Fishery Districts as given by the Boards during consultation is given in Table 3.1 below.

Table 3.1 Principal Smolt Runs in the Ythan Dee and Don

District Salmon Fishery Board	Timing of Smolt Runs
Ythan	mid May- end of June
Dee	March-June
Don	May-early June
	September

Adult Salmon and Sea Trout

In light of the different time of river entry in salmon and sea trout originating in different rivers and the diversity and relative importance of salmon and sea trout runs on a river specific basis, the scheduling of piling activities to minimise potential impacts may not be possible for all adult salmon and sea trout migrations. The final piling schedule will however be agreed and defined in consultation with Marine Scotland, Scottish Natural Heritage and the Ythan, Dee and Don District Salmon Fishery Boards.

The timing of the principal salmon and sea trout runs in the rivers located in the proximity of the proposed EOWDC as specified by the Ythan, Don and Dee District Salmon Fishery Boards during consultation are given in Table 3.2 below.

Table 3.2 Principal Salmon and Sea Trout Runs in

District Salmon Fishery Board	Principal Grilse Run	Principal Salmon Run	Principal Sea Trout Runs
Ythan	Autumn	Autumn	May-August
Dee	late May-September	Feb-May (Spring salmon)	May-June
		Summer and Autumn (2SW salmon)	
Don	July-Mid October	mid Dec-April (Spring Salmon)	June- early August
		May-June (2SW salmon)	

Residual Impact

Juvenile Salmon and Sea Trout

Provided that piling operations are scheduled to minimise potential impacts on salmon and sea trout juveniles, it is considered that the residual impact of construction noise on juvenile salmon and sea trout migration will be of *NEGLIGIBLE-MINOR* significance.

Adult Salmon and Sea Trout

The residual impact is expected to be the same as the potential impact (*MINOR)* and possibly *NEGLIGIBLE* depending on final piling schedules, foundation types and installation methods used.

Cumulative Impact

Juvenile Salmon and Sea Trout

The installation of the proposed Ocean Laboratory will involve the piling of a 8.5 m diameter pile, assuming the worst case scenario. This would result in further 24h piling in the area of the EOWDC being undertaken. Given the small area to be affected and the short duration of the noise disturbance, it is not considered that the installation of the proposed Ocean Laboratory will result in a significant cumulative impact in relation to construction noise. In addition, the installation of the Ocean Laboratory, as proposed for the installation of the turbines, would also be scheduled to minimise potential impacts on juvenile salmon and sea trout.

Adult Salmon and Sea Trout

In the case of adult salmon, noise derived from construction activities in the Firth of Forth proposed developments, could result in further impacts on fish migrating towards rivers in the regional area. Taking the worst case scenario, that piling activities in the proposed offshore wind farm developments in the Firth of Forth area are undertaken coinciding with piling operations at the proposed EOWDC, potential direct impacts and avoidance reactions in the Firth of Forth area could result in disturbance to adult salmon migration, further contributing to potential delays in migration/river entry.

Given the limited number of turbines to be installed in the proposed EOWDC in comparison to the offshore wind developments proposed in the Firth of Forth, the contribution of EOWDC to any cumulative impact is likely to be of *NEGLIGIBLE* significance.

3.1.1.3 Key Prey Species

Potential Impact

Noise and vibration during construction could result in a displacement of the food resource if avoidance reactions are triggered in species of importance as prey items to salmon and sea trout. This is relevant in the case of clupeids, such as herring and sprats, as they are hearing specialists and are among the preferred prey species of salmon and sea trout.

Potential impacts derived from prey displacement, if any, are likely to be of greater significance for sea trout than for salmon as they generally remain in coastal areas during their marine phase.

The magnitude of the impact on sea trout through displacement of food resource is considered to be *LOW* on the basis of the spatial scale of the impact and its relatively short duration (theoretical worst case of 11 piling events and 24 hours continuous piling per pile). The sensitivity of the receptor is considered to be *LOW* on the basis of the relatively small number of sea trout potentially feeding in the area from which the food resource could be displaced at a given time, the mobility of sea trout and the availability of other key prey species which are not likely to be disturbed by noise in the wider area (e.g sandeels). The significance of the impact is therefore considered to be *NEGLIGIBLE.*

Mitigation

None required

Residual Impact

Same as the potential impact

Cumulative Impact

There is potential for salmon, in some cases, and more importantly sea trout, to use the Moray Firth and Firth of Forth areas as a feeding ground, principally in relation to the presence of herring and sandeels in these areas.

In view of the limited number of turbines and piling events to be undertaken in the EOWDC in comparison to the developments proposed in the Firth of Forth and the Moray Firth, the contribution by the EOWDC to the any cumulative impact on key prey species due to construction noise would be *NEGLIGIBLE*.

3.1.2 Operation

Noise may arise from a variety of sources during the operational phase of a wind farm, including aerodynamic blade noise, gearbox noise and noise from other machinery (Nedwell *et al.*, 2003b).

Potential Impact

Studies carried out in Denmark on the effect of offshore wind farms on the distribution of fish in areas relevant to the Horns Rev Offshore Wind Farm (Hoffman *et al.,* 2000) found that significant noise levels in the frequency range at which fish typically exhibit a strong response would be expected to be confined to the immediate vicinity of the turbines, within a radius of no more than several hundred of metres. Hoffman *et al.*, 2000 suggested that because of the spatial extent of the low-frequency fields from the turbines, fish would perceive them to be very different compared to the low-frequency fields of other animals. It was therefore concluded that fish species were not expected to be impaired in their ability to detect predators and prey. It was also suggested that the continuous character of the turbine noise was likely to promote habituation in fish species.

In line with this, post-construction monitoring work undertaken in Horns Rev did not find evidence to confirm that fish densities in the general vicinity of the turbines were different from within the ar ray with species such as sandeel, sprat, mackerel and schools of cod recorded in-between the turbines (Hvdt *et al.,* 2006; Hvdt *et al*., 2005). Furthermore, research on species attracted to hard bottom substrates at Horns Rev found that noise and vibration from the turbine generator did not have an impact on the fish communities within the wind farm site (Leonhard *et al*., 2005). Similarly the results of post-construction monitoring fish surveys carried out in the Barrow Offshore Wind Farm and in the North Hoyle Wind Farm did not find significant differences in catch rates during operation in relation to pre-construction catches (BOWind, 2009; RWE npower renewables, 2008), further suggesting that operational noise does not prevent fish from transiting the area of the wind farms.

Walhberg and Westerberg (2005) estimated that Atlantic salmon detect operational turbines at a distance of 0.4 km and 0.5 km at wind speeds of 8 and 13m/s respectively and found that fish are consistently scared away from turbines only at ranges shorter than 4 m, and only at high wind speeds (above 30m/s). The same study concluded that the acoustic impact of wind turbines on fish is restricted to masking communication and orientation signals rather than physiological damage or consistent avoidance reactions.

It should be noted that given the proximity of the proposed EOWDC to major shipping routes into Aberdeen harbour, it is likely that salmon and sea trout transiting the area are habituated to relatively high background noise levels (ANATEC, 2011).

In light of this it is expected that noise generated during operation will not result in a significant impact on the migration of salmon and sea trout juveniles and adult migration neither have an effect on salmon and sea trout feeding and prey availability. The magnitude of the impact and the sensitivity of the receptors are considered to be *LOW*, hence the potential impact of operational noise is considered to be of *NEGLIGIBLE* significance.

Mitigation

None proposed.

Residual Impact

NEGLIGIBLE

Cumulative Impact

None expected.

3.2 Increased Sediment Concentrations

3.2.1 Construction and Decommissioning

Construction activities such as cable laying, piling and rock placement have potential to result in temporary sediment re-suspension increasing turbidity (OSPAR, 2004).

As indicated in the coastal processes section, after installation of the first three turbines, the resulting sediment plume is expected to record a maximum concentration of 35mg/l which extends from Aberdeen harbour to approximately 3 km south of the river Ythan. After installation of 11 foundations, higher concentrations will also remain levelled with Aberdeen Harbour to approximately 3 km of the River Ythan (ABPMER, 2011,). It should be noted that during project specific surveys suspended sediment concentrations found in the area ranged from 0.1 to 43.1 mg/l, with an average value of 20.7 mg/l (ABPMER, 2011a).

Potential Impacts

A wide range of studies have assessed the effect of turbidity levels above natural background on the physiology and behaviour of salmonids. The majority of these are, however, based on freshwater and experimental settings rather than the marine environment. The research indicates that high levels of suspended sediment may be fatal to salmonids while lower levels of suspended sediment and turbidity may cause chronic sub-lethal effects such as loss or reduction of foraging capability, reduced growth, resistance to disease, increased stress and interference with cues necessary for orientation in homing and migration (Bash *et al.,* 2001). Lethal levels of sediment in fish typically range from hundreds to thousands mg/l whilst sub-lethal effects may manifest at significantly lower levels, ranging from tens to hundreds mg/l depending on species specific tolerance (Birtwell, 1999).

A summary of the principal physiological and behavioural effects of turbidity on salmonids is given in Table 3.3.

Table 3.3 Principal Physiological and Behavioural Effect of Turbidity on Salmonids (Bash *et al.,* 2001)

Physiological	Behavioural
Gill trauma	Avoidance
Osmoregulation	Territoriality
Blood Chemistry	Foraging and Predation
Reproduction and Growth	Homing and Migration

Research on the behaviour of juvenile Atlantic salmon has found that initial introduction of sediment (20mg/l) increases foraging activity (Robertson *et al.,* 2007). The same study found a decline in territorial behaviour and avoidance reactions at sediment levels ranging from 60 to 180mg/l. Short term pulses of suspended sediment have also been shown to disrupt feeding behaviour and elicit alarm reactions that may cause fish to relocate downstream to undisturbed areas (Berg and Northcote, 1985)

Whilst physiological and behavioural responses have been observed in a number of studies, salmonids are considered to have the ability to cope with some level of turbidity at certain life stages. Juvenile salmonids are present in turbid estuaries prior migration, as well as in streams with high natural levels of glacial silt, and therefore high turbidity and low visibility (Gregory and Northcote, 1993). In addition salmonids may also encounter naturally turbid conditions during flood events and other natural circumstances (Bash *et al.,* 2001). Measurements undertaken in the River Don (Hillier, 2001), found that concentrations of suspended solids typically ranged from 1 to 10mg/l during base flows, however reached levels up to 150mg/l during high flows.

It should be noted that the potential disturbance through increased sediment concentrations will be short term as once construction works cease, the sediment source for the suspended sediment plume is removed and the tidal regime acts to further reduce the sediment concentrations back to background levels by continual dispersion (ABPMER, 2011).

Based on the relatively short term scale of any potential impact caused by the plume, its relative small spatial extent, and the fact that the expected sediment concentrations within the plume are in line with background levels observed in the area, the magnitude of the impact is considered to be *LOW*. The receptors (adult and juvenile salmon and seat trout), given their tolerance to the expected levels of suspended sediment and their swimming capability, are considered to have a *LOW-MEDIUM* sensitivity in the case of fish originating in the Dee, Don and Ythan, as they are more likely to transit the EOWDC site. The impact of suspended sediments during construction is therefore considered of *NEGLIGIBLE-MINOR* significance.

Mitigation
No mitigation required.

Residual Impact
Same as the potential impact.

Cumulative Impact
In the absence of other offshore activities that could potentially contribute to increased sediment concentrations (e.g. dredging) expected to take place in the vicinity of the proposed EOWDC, no cumulative impacts are expected to take place.

3.3 Electromagnetic Fields (EMFs)
3.3.1 Operation
The magnetic fields anticipated to be produced by the AC cables associated with the proposed EOWDC are small (1.5 µT) in comparison to the Earth's magnetic field (approximately 50 µT). Atlantic salmon are expected to perceive these magnetic fields as new localised additions to the heterogeneous pattern of geomagnetic anomalies already occurring naturally and anthropogenically in the sea (MS, 2011).

Potential Impact
The potential impacts on salmon and sea trout migration derived from the magnetic fields generated by the export and inter array cables could theoretically range from small or large scale disorientation to a barrier to migration.

The Collaborative Offshore Wind Research into the Environment (COWRIE) group has published a number of reviews of current knowledge on the potential impacts of EMFs derived from offshore wind farm developments on electrically and magnetically sensitive species (Gill *et al*., 2009; Gill *et al.,* 2005; CMACS, 2003). The focus of these reports has however been on elasmobranch species, as they are the main group known to be electroreceptive and magnetosensitive (Gill *et al.*, 2009; Gill *et al.*, 2005).

The OSPAR Commission (2008) review of impacts associated with power cables considered that whilst the presence of magnetite in migratory species, including salmonids, suggests that they may use the earth's geomagnetic field for navigation, there is no experimental evidence to determine whether migrating salmon can detect and/or could be affected by anthropogenic magnetic fields of a magnitude comparable to the earth's geomagnetic field. For example, research undertaken on the effect of modified magnetic fields on ocean migration using maturing chum salmon (*Oncorhynchus* *keta*), found no observable effect on the horizontal and vertical movements when the magnetic field was modified (Yano *et al.,* 1997).

In line with the above, Ohman *et al*. (2007) point out that detection of stimuli may not necessarily lead to behavioural responses in fish and that senses that detect magnetic fields are not the only means of spatial orientation, as vision, hearing and olfaction as well as hydrographic and geoelectric information could all be used for spatial orientation. The use of olfaction cues in the final freshwater stage of the homing migration is well documented and it is generally accepted that as salmon approach their natal rivers there is a transition from oceanic orientation mechanisms to mechanisms more appropriate for river migration (Dittman and Quinn, 1996). Ueda *et al.,(*1998) carried out research on the homing mechanisms of sockeye salmon (*Oncorhynchus nerka*) and found that interference of magnetic cues by the attachment of a magnetic ring did not affect the direct return of the fish to the home river and it was concluded that fish returned straight to the vicinity of the natal area using visual cues and finally reach the exact homing point using olfactory cues.

The Environmental report of the Scottish Marine Renewables SEA 2, Environmental Report, 2007 (Section C: Chapter 18- Electromagnetic Fields) states, based on current research and existing cables, that fish species sensitive to magnetic fields such as salmon and eels are not expected to be impacted by the magnetic fields likely to be produced during the operation of device arrays and export cables of tidal and wave energy marine installations proposed in the north coast of Scotland. Similarly, the *Habitats Regulations Appraisal of Draft Plan for Offshore wind Energy in Scottish Territorial Waters: Appropriate Assessment Information Review* (MS, 2011) considers the maximum level of risk in relation to impacts of EMFs on Atlantic salmon to be low.

Gill and Barlett (2010), in a review of the potential impacts of noise and electromagnetic fields from marine renewable installations on salmon, sea trout and European eels, state that there is unclear evidence to assess the overall effect of EMFs from subsea cables on migration and movement behaviour of salmon and sea trout. In addition, it is also stated that whilst physiological responses to EMFs have been demonstrated on laboratory based studies in both salmon and sea trout, there is no evidence on which to determine the effect of a small, local change in magnetic field in the context of their large scale migration or how this may impact their migratory routes.

The magnitude and intensity of the potential movement and behavioural effects on salmonids would be closely linked to the proximity of the fish to the source of the EMF. If there is going to be any effect on their migration, this will be most likely dependent on the depth of water and the proximity of the rivers to the development site (Gill and Barlett, 2010).

The key receptors of potential impacts derived from EMFs would primarily be adult salmon and sea trout returning to the Dee, Don and Ythan, and potentially the Ugie, assuming they transit the site and or the area of the export cable during migration. It should be noted, however, that given the proximity of the EOWDC to the rivers, it is likely that salmon and sea trout may be using olfactory and potentially other types of cues for spatial orientation, in addition to or instead of, magnetic mechanisms, at the time that they will encounter the magnetic fields generated by the EOWDC.

Given the small area of the wind farm and the total cabling involved, a maximum of 13 km for inter array cables and 26 km for the four export cables (1 x 5 km, 1 x 6 km, 1 x 7 km, 1 x 8 km) (further details in Chapter 3, Description of the Proposed Development), the fact that magnetic fields will only be encountered in close proximity to the cables (within tens of metres) and the potential for fish to be using spatial orientation mechanisms other than magnetic navigation, the magnitude of the impact is considered to be *NEGLIGIBLE* to *LOW*. Taking a precautionary approach based on the conservation importance of the species and the lack of definitive evidence in respect of impacts on the migration of salmonids, the receptors, salmon and sea trout originating in rivers within the regional study area, are considered of *HIGH* sensitivity. The impact of EMFs on salmon and sea trout migration is therefore considered to be of *NEGLIGIBLE* to *MINOR* significance.

Mitigation

The cables will be buried. Burial to depth realistically achievable offshore (0.6 m – 3 m) will not make significant difference to the resultant fields or the distance over which they propagate. Cable burial to a depth of at least 1 metre is only likely to provide some mitigation for the possible impacts of the strongest B-fields and induced E-fields that exist within millimetres of the cable (CMACS, 2003).

Residual Impact

Same as the potential impact.

Cumulative Impact

EMF emissions from the proposed offshore wind farm developments in the Firth of Forth and in the Moray Firth could potentially further affect migrating salmon. Assuming the prevalent travelling direction of coastal migration is northerly, there is potential for salmon heading to the rivers in the regional area to be present in the vicinity of the proposed developments in the Firth of Forth at an early stage of their migration. Similarly, there is potential for sea trout to transit both the Moray Firth and the Firth of Forth development areas either during migration or as a result of foraging activity.

Given the relatively small area of the proposed EOWDC and the total cabling used in comparison to the proposed offshore wind developments in the Moray Firth and the Firth of Forth, it is considered that for salmon and sea trout originating in rivers in the regional area the contribution of the EOWDC to any potential cumulative impact would be of *NEGLIGIBLE* significance.

3.4 Physical Presence of the Turbines

3.4.1 Operation

Potential Impact

The physical presence of the turbines could potentially result in disturbance, delays or a barrier to migration. The minimum spacing between turbines assuming installation of 11 turbines would be of 750 m. On the basis of the small total area of the proposed EOWDC, the spacing between turbines, and the ability of salmon and sea trout to overcome obstacles during migration such as dams and other man made obstructions, it is not considered that the physical presence of the turbines will significantly affect salmon and sea trout migration. The impact is considered to be of *LOW* magnitude. The sensitivity of the receptors on the basis of their importance is considered to be *LOW*. The potential impact of the physical presence of the turbine is therefore considered of *NEGLIGIBLE* significance.

Mitigation

None required.

Residual Impact

Same as potential impact.

Cumulative Impact

None expected.

3.5 Impacts on the Salmon and Sea Trout Fisheries

3.5.1 Potential Impacts

The potential impacts that fisheries could theoretically sustain from the EOWDC development are:

- Loss of or restricted access to fishing areas
- Interference to fishing activities
- Loss of or reduction of catch

Loss of or Restricted Access to Fishing Areas

In the case of the local coastal fisheries, given the limited range of netting operations (1300 metres from the shore Low Water), There will be no loss of area or restricted access impacts associated with the construction and operation of the EOWDC and therefore the significance of the impact will be *NEGLIGIBLE.*

Whilst the export cable route has yet to be finalised, taking the worst case scenario that the cable route would pass through a coastal netting station, there could be a small, localised temporary loss of fishing area. As given in the Salmon and Sea Trout Baseline Assessment for the proposed EOWDC, there has been a progressive decline in coastal netting by fixed engines in the local area since 2000 with no reported catches being recorded in the Don District in 2008 and 2009.

Taking the short duration of export cable laying and therefore the short period of exclusion, if the export cable route should pass through a fishing area which was being actively fished, the unmitigated impact is considered to be localised and of *MODERATE* significance.

In the case of rod and line fisheries, due to the distance of both the wind farm site and the export cable route from salmon and sea trout rivers, there will not be any loss of fishing area or restricted access, therefore the impact will be of *NEGLIGIBLE* significance.

Mitigation

Mitigation may well naturally occur whereby the final export cable route will avoid any areas where coastal netting occurs. Similarly, as occurred in 2008 and 2009 in the Don District, fixed engine activity may not occur. The appropriate liaison and consultation will be undertaken with the relevant stakeholders with the objective of minimising potential impacts to *NEGLIGIBLE* significance.

Interference to Fishing Activities

As with loss of, or restricted access to fishing areas, the installation of turbines and intra-field cables will not have any direct impact in terms of interfering with fixed engine, net and coble or rod and line fishing activities. Similarly, apart from a possible temporary loss of access associated with the export cable installation, discussed above, it not expected that any other activity associated with the development will directly affect salmon and sea trout fishing. The impact is therefore predicted to be of *NEGLIGIBLE* significance.

Mitigation

Same as for loss of or restricted access to fishing areas

Loss or Reduction of Catches

The impact of loss or reduction of salmon and sea trout catches, will in effect, be directly related to the effects on the ecology of the two species as assessed above. As given in Table 4.1 below, the significance of the residual impacts is predicted to range from *NEGLIGIBLE* to *MINOR*.

In the case of coastal fisheries, and particularly those which currently appear to not be actively fished, it is expected that the residual impacts will be for the most part *NEGLIGIBLE.* There is however the possibility of *MINOR* impacts, if piling coincides with the migration times of returning adult fish following migration routes along which fishing occurs. An impact would only occur however if construction activities caused the fish to alter their migration routes away from fishing locations as opposed to them only causing a short term delay in migration.

The significance of the impacts on rod and line fisheries, which have a substantially greater overall socio-economic value than the coastal fisheries in the relevant districts, will similarly be dependent upon the short and longer term impacts of the development on salmon and sea trout. As given above, it is considered that the impacts of the construction, operational and decommissioning phases of the EOWDC will range in significance from *NEGLIGIBLE* to *MINOR*. It is however recognised that the scale and magnitude of the potential impacts will vary between districts and will also be related to the relative values of the rod and line fisheries within individual districts and the timing and importance of runs within specific rivers.

With completion of construction activities it is envisaged that the fully operational phase of the development will, with the exception of possible limited EMF related effects, not have any significant effects on salmon and sea trout fisheries. Therefore the potential impacts are, for the most part, considered to be of *NEGLIGIBLE* significance.

3.6 Monitoring

As emphasized above, the assessment of the effects of the construction/decommissioning and operation of EOWDC upon salmonids is constrained by gaps in available baseline information, particularly that describing the behaviour of salmon and sea trout not only in the vicinity of the proposed development but also in the wider marine environment. In addition, there is insufficient direct evidence relating to the potential impacts of offshore wind farms on salmon and sea trout. As a consequence, the precautionary principle has been adopted by taking the 'worst case scenario'.

In practice, however, it is possible that salmon and sea trout may not be adversely affected by the construction and operation of EOWDC, particularly in light of the known obstacles the species overcome during their respective life cycles and the limited number of turbines to be installed. EOWDC will consult with Marine Scotland, Scottish Natural Heritage and the Dee, Don and Ythan Salmon District Fishery Boards in order to identify feasible and relevant monitoring options.

4.0 Summary

The significance level of the impacts derived of the construction, decommissioning and operational phase of the proposed EOWDC, on salmon and sea trout, including cumulative effects, are summarised in Table 4.1 below. A summary of the impacts on salmon and sea trout fisheries is given in Table 4.2.

Table 4.1 Impact Assessment Summary

<table>
<tr><th colspan="8">Salmon and Sea Trout Impact Assessment</th></tr>
<tr><th colspan="8">Construction and Decommissioning</th></tr>
<tr><th>Source of Potential Impact</th><th>Potential Impact</th><th>Receptor</th><th>Significance Level</th><th>Mitigation</th><th>Residual Significance</th><th>Cumulative Impact</th><th>Monitoring</th></tr>
<tr><td rowspan="4">Noise</td><td>Direct Impact</td><td>Adult and juvenile salmon and sea trout</td><td>Negligible</td><td>Soft-start piling</td><td>Negligible</td><td>None Expected</td><td rowspan="4">Appropriate and relevant monitoring will be assessed through discussion with relevant stakeholders and regulators</td></tr>
<tr><td rowspan="2">Disturbance/ Delay/Barrier to Migration</td><td>Salmon and sea trout juveniles</td><td>Minor to Moderate</td><td>Installation schedule to be discussed with relevant stakeholders and regulators</td><td>Negligible to Minor</td><td>Negligible</td></tr>
<tr><td>Salmon and sea trout adults</td><td>Minor</td><td>Installation schedule to be discussed with relevant stakeholders and regulators</td><td>Negligible to Minor</td><td>Negligible</td></tr>
<tr><td>Key prey species</td><td>Adult sea trout</td><td>Negligible</td><td>None required</td><td>Negligible</td><td>None expected</td></tr>
<tr><td>Increased sediment concentration</td><td>Direct effects/ Disturbance/ Delay/Barrier to Migration</td><td>Juvenile and adult salmon and sea trout</td><td>Negligible to Minor</td><td>None required</td><td>Negligible to Minor</td><td>None expected</td><td>None planned</td></tr>
<tr><th colspan="8">Operational</th></tr>
<tr><th>Source of Potential Impact</th><th>Potential Impact</th><th>Receptor</th><th>Significance Level</th><th>Mitigation</th><th>Residual Significance</th><th>Cumulative Impact</th><th>Monitoring</th></tr>
<tr><td rowspan="2">Noise</td><td>Disturbance/ Delay/Barrier to Migration</td><td rowspan="2">Adult and juvenile salmon and sea trout</td><td rowspan="2">Negligible</td><td rowspan="2">None required</td><td rowspan="2">Negligible</td><td rowspan="2">None expected</td><td rowspan="2">None planned</td></tr>
<tr><td>Feeding</td></tr>
<tr><td>EMFs</td><td>Disturbance/Delay/Barrier to Migration</td><td>Adult and juvenile salmon and sea trout</td><td>Negligible to minor</td><td>None other than cable burial</td><td>Negligible to minor</td><td>Negligible</td><td>None planned</td></tr>
<tr><td>Presence of Turbines</td><td>Disturbance/ Delay/Barrier to Migration</td><td>Adult and juvenile salmon and sea trout</td><td>Negligible</td><td>None required</td><td>Negligible</td><td>None expected</td><td>None planned</td></tr>
</table>

Table 4.2 Salmon and Sea Trout Fishery Impact Assessment

<table>
<tr><th colspan="5">Salmon and Sea Trout Fisheries Impact Assessment</th></tr>
<tr><th colspan="5">Construction and Decommissioning</th></tr>
<tr><th>Potential Impact</th><th>Receptor</th><th>Potential Impact</th><th>Mitigation</th><th>Residual Impact</th></tr>
<tr><td rowspan="3">Loss of or Restricted Access to Fishing Areas</td><td>Coastal netting during cable installation</td><td>Moderate</td><td rowspan="7">Liaison and consultation with relevant stakeholders</td><td rowspan="3">Negligible</td></tr>
<tr><td>Coastal netting during other construction activities</td><td rowspan="2">Negligible</td></tr>
<tr><td>Rod and line fisheries</td></tr>
<tr><td rowspan="3">Interference with fishing activities</td><td>Coastal netting during cable installation</td><td rowspan="3">Negligible</td><td rowspan="3">Negligible</td></tr>
<tr><td>Coastal netting during other construction activities</td></tr>
<tr><td>Rod-and-line fisheries</td></tr>
<tr><td>Loss or reduction of catch</td><td>Netting and rod-and-line fisheries</td><td>Negligible to minor</td><td>Negligible to minor</td></tr>
<tr><th colspan="5">Operation</th></tr>
<tr><th>Potential Impact</th><th>Receptor</th><th>Potential Impact</th><th>Mitigation</th><th>Residual Impact</th></tr>
<tr><td>Loss or reduction of catch</td><td>Netting and rod-and-line fisheries</td><td>Negligible</td><td>Liaison and consultation with relevant stakeholders</td><td>Negligible</td></tr>
</table>

5.0 References

ABPMER. 2011. European Offshore Wind Deployment Centre: Coastal Processes Assessment Report. Report R. 1789

ABPMER, 2011a. European Offshore Wind Deployment Centre: Coastal Process Baseline Report. Report R. 1741

ANATEC Ltd. 2011.Navigational Risk Assessment, European Offshore Wind Deployment Centre Technical Note.

Bash, J., Berman, C. and Bolton, S. Effects of Turbidity and Suspended Solids on Salmonids. Centre for Streamside Studies. University of Washington. November, 2011.

Berg, l. and Northcote, T.G. 1985. Changes in Territorial, Gill-flaring, and Feeding Behaviour in Juvenile Coho Salmon (*Oncorhynchus kisutch*) following Short-term Pulses of Suspended Sediment. Canadian Journal of Fisheries and Aquatic Sciences. 42: 1410-1417.

Birtwell, I.K. 1999. The Effects of Sediment on Fish and their Habitat. Fisheries and Oceans Canada. Canadian Stock Assessment Secretariat. Research Document 99/139.

BoWind. 2009. Post Construction Monitoring Report (2007-2008).Barrow Offshore Wind Ltd.
Available online at:
http://bowind.co.uk/pdf/post%20cmr%202009/Construction_Monitoring_Report-_Full_012009.pdf
Accessed: 13/04/2011

CMACS. 2003. A baseline assessment of electromagnetic fields generated by offshore windfarm cables. COWRIE Report EMF- 01-2002. 66.

Dittman, A. and Queen, T. 1996 Homing in Pacific salmon: mechanisms and ecological basis. The Journal of Experimental Biology. 199. 83-91.

Gill, A.B. and Bartlett, M. 2010. Literature review of the potential effects of electromagnetic fields and subsea noise from marine renewable energy developments on Atlantic salmon, sea trout and European eel. Scottish Natural Heritage Commissioned Report No. 401.

Gill., A.B., Huang, Y., Gloyne-Philips, I., Metcalfe, J., Quayle, V., Spencer, J. and Wearmouth, V. 2009. COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2.0: EMF-sensitive fish response to EM emissions from sub-sea electricity cables of the type used by the offshore renewable energy industry. Commissioned by COWRIE Ltd (project reference COWRIE –EMF-1-06).

Gill, A.B., Gloyne-Philips, I., Neal, K.J and Kimber, J.A. 2005. COWRIE 1.5 Electromagnetic Fields Review. The potential effects of electromagnetic fields generated by sub-sea power cables associated with offshore wind farm developments on electrically and magnetically sensitive marine organisms- a review. COWRIE Commissioned Report.

Gregory, R.S and Northcote, T.G. 1993. Surface, planktonic, and benthic foraging by juvenile Chinook salmon (*Oncorhynchus tshawytscha*) in turbid laboratory conditions. Canadian Journal of Fisheries and Aquatic Sciences 50: 233-240. *In*- Bash, J., Berman, C. and Bolton, S. Effects of Turbidity and Suspended Solids on Salmonids. Centre for Streamside Studies. University of Washington. November, 2011.

Hastings, M.C. and Popper, A.N. 2005. Effects of Sound on Fish. Report produced for the California Department of Transportation Contract No. 43A0139.

Hawkins, A.D. and Johnstone, A.D.F. 1978. The hearing of Atlantic Salmon, Salmo salar. Journal of Fish Biology. 13 (6): 655-673.

Hillier, S. 2001. Particulate composition and origin of suspended sediment in the R. Don, Aberdeenshire, UK. The Science of the total Environment. 265 (1-3):281-293.

Hoffman, E., Astrup, J., Larsen, F. and Much-Petersen, S. 2000. Effects of marine windfarms on the distribution of fish, shellfish and marine mammals in the Horns Rev area. Report to ELSAMPROJEKT A/S. Baggrundsrapport nr. 24.

Hvdt, C.B., Leonhard, S.B., Kaustrup, M. and Pedersen, J. 2006. Hydroacoustic Monitoring of Fish Communities at Offshore Wind Farms. Horns Rev Offshore Wind Farm Annual Report. 2005.

Hvdt, C.B., Brunner, L., Knudsen, F.R. 2005. Hydroacoustic Monitoring of Fish Communities in Offshore Wind Farms. Horns rev Offshore Wind Farm Annual Report. 2004.

Knudsen, F.R., Schreck, C.B., Knapp, S.M., Enger, P.S and Sand., O. 1997. Infrasound produces flight and avoidance responses in Pacific juvenile salmonids. Journal of Fish Biology. 51(4):824-829.

Knudsen, F.R., Enger, P.S. and Sand, O. 1992. Awareness reactions and avoidance responses to sound in juvenile Atlantic salmon, Salmo salar, L. Journal of Fish Biology. 40 (4): 523-534.

Leonhard S.B., and Pedersen, J. 2005 Hard Bottom Substrate Monitoring at Horns Rev Offshore Wind Farm. Annual Status Report. 2004.

Malcolm, I.A., Godfrey, J. and Youngson, A.F. 2010. Review of migratory routes and behaviour of Atlantic salmon, sea trout and European eel in Scotland's coastal environment: Implications for the development of marine renewable. Environmental Research Institute, Thurso. Published by Marine Scotland Science. ISSN:2043-7722.

MS. 2011. Habitats Regulations Appraisal of Draft Plan for Offshore Wind Energy in Scottish Territorial Waters: Appropriate Assessment Information Review. Published by the Scottish Government, March 2011.

Nedwell J.R., Brooker A.G., Barham R.J., 2011. *Subsea noise modelling in support of the European Offshore Wind Deployment Centre Development.* Subacoustech Environmental Report No. E278R0215Nedwell, J.R., Turnpenny, A.W.H, Lovell, J., Parvin, S.J., Workman, R., Spinks, J.A.L and Howell, D. 2007. A validation of the dBht as a measure of the behavioural and auditory effects of underwater noise. Subacoustech Report No. 534R1231. Report prepared for the U.K Department of Business, Enterprise and Regulatory reform under Project No. RDCZ/011/0004.

Nedwell, J.R., Turnpenny, A.W., Lovell, J.M and Edwards, B. 2006. An investigation into the effects of underwater piling noise on salmonids. Journal of Acoustical Society of America. 120: 2550-4.

Nedwell, J.R., Edwards, B and Bourke, P.J. 2005. Underwater Noise generated by Piling Operation in the River Hamble, Hampshire. Report for The Crown Estate Funded through The Crown Estate Marine Stewardship Programme. November 2005.

Nedwell, J., Turnpenny, A., Langworthy, J. Edwards, B. 2003a. Measurements of underwater noise during piling at the Red Funnel Terminal, Southampton, and observations of its effect on caged fish. Subacoustech Ltd. Report Reference: 558 R 0207.

Nedwell, J., Langworthy, J. and Howell, D. 2003b. Assessment of sub-sea acoustic noise and vibration from offshore wind turbines and its impact on marine wildlife; initial measurements of underwater noise during construction of offshore windfarms, and comparison with background noise. COWRIE Report. No. 544 R 0424.

Ohman, M.C., Sigray, P. And Westerberg, H. 2007. Offshore Windmills and the Effects of Electromagnetic Fields on Fish. Royal Swedish Academy of Science. Dec 2007. Vol. 36. No.8.
OSPAR. 2008. Background Document on potential problems associated with power cables other than those for oil and gas activities. OSPAR Commission, Biodiversity Series.

OSPAR. 2004. Problems and benefits associated with the Development of Offshore Wind-Farms. OSPAR Commission, Biodiversity Series.

RWE npower renewables. 2008. Marine Fish. Post-Construction Monitoring undertaken between 2006-2007 in the North Hoyle Wind Farm. RWE npower renewables. Available online: http://www.rwe.com/web/cms/mediablob/en/311888/data/311620/2/rwe-npower-renewables/sites/projects-in-operation/wind/north-hoyle-offshore-wind-farm/environment/7.-Marine-Fish. Accessed: 12/04/2011.

Robertson, M.J., Scruton, A.D. and Clarke, K.D. 2007. Seasonal Effects of Suspended Sediment on the Behaviour of Juvenile Atlantic Salmon. Transactions of the American Fisheries Society. 136(3):822-828.

Sand, O., Enger, S., Karlsen, H.E. and Knudsen, F.R. 2001. Detection of infrasound in fish and behavioural responses to Intense Infrasound in Juvenile Salmonids and European Silver Eels. A Minireview. American Fisheries Society Symposium 26: 183-193.2001

Skaret, G., Axelsen, B.E., Nottestad, L., Ferno, A. and Johannessen, A. 2004. The behaviour of spawning herring in relation to a survey vessel. ICES Journal of Marine Science. 62 (6): 1061-1064.
Ueda, H.K.M., Musaka, K., Urano, A., Kudo, H., Shoji, T. And Tokumitsu, Y. 1998. Lacustrice sockeye salmon return straight to their natal area from open water using both visual and olfactory cues. Chemical Senses 23 (2):207-212.

Walhberg, M. and Westerberg, H. 2005. Hearing in fish and their reactions to sounds from offshore wind farms. Marine Ecology Press Series. 288: 295-309.

Yano, A., Ogura, M., Sato, A., Sakaki, Y., Shimizu, Y., Baba, N. and Nagasawa, K. 1997. Effect of modified magnetic field on the ocean migration of maturing chum salmon, *Onchorhynchus keta.* Marine Biology. 129 (3): 523-530.