NnG OFFSHORE WIND

Appendix 7.2

Atlantic salmon – Appraisal of Original EIA

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1 Introduction

1. Neart na Gaoithe Offshore Wind Ltd (hereafter referred to as 'NnGOWL'), is developing the Neart na Gaoithe Offshore Wind Farm (hereafter referred to as 'the Project'). The Project is a proposed offshore wind farm located in the Firth of Forth, with a maximum output of 450 megawatts (MW).
2. The Project will comprise the Offshore Wind Farm (54 wind turbines, their foundations and associated inter-array cabling); and the Offshore Transmission Works (OfTW) (comprising of up to two Offshore Substation Platform(s) (OSP(s)), their foundations and the Offshore Export Cables).
3. NnGOWL has prepared an Environmental Impact Assessment Report (EIA Report) to accompany an application to the Scottish Ministers for a Section 36 Consent under the Electricity Act 1989 and Marine Licences under the Marine (Scotland) Act 2010. The EIA Report provides a full description of the Project and its likely significant effects on the environment seaward of mean high water springs (MHWS) in accordance with the Scoping Opinion received from Marine Scotland Licensing Operations Team (MS-LOT) on 8 September 2017.
4. This appendix has been prepared to address comments received from consultees in relation to Atlantic salmon (*Salmo salar*).

1.1 Aims and Objectives of this Report

5. This report appraises the impact determinations for Atlantic salmon presented in the Original ES against the refined worst case design envelope for the Project, taking into account more recent publications and findings in relation to Atlantic salmon. The report aims to address comments received from consultees in response to the Scoping Report as detailed within the Scoping Opinion (NnGOWL, 2017). Key comments relevant to Atlantic salmon are presented in Section 2.1.
6. The report will address the following objectives:

- Summarise the baseline and impact determinations reported in the Application and ES for the Originally Consented Project;
- Review recent publications and findings in relation to Atlantic salmon migration patterns and sensitivities and update / validate the baseline as required; and
- Review the impact determinations reported in the Original ES and validate / update, as required, in light of the updated baseline and refined design parameters.

2 Scoping

7. The Project proposed by NnGOWL is broadly analogous in terms of location and most aspects of its design to the Originally Consented Project. It should, however, be noted that the Original EIA (reported in the Original ES submitted in support of the consent applications lodged with the Scottish Ministers by NnGOWL in 2012) was undertaken on a scheme design comprising of up to 125 offshore wind turbines (and associated foundations and other infrastructure). An Addendum submitted in June 2013 reassessed the effects on some (but not all) receptors based on a reduced Project design envelope comprising of up to 90 turbines. The conclusions set out in the Original ES and referred to in the Scoping Report submitted to MS-LOT on 15 May 2017 (NnGOWL, 2017) were therefore made on that basis (although the consent was subsequently granted for a scheme comprising of up to 75 wind turbines).

8. Significant existing data and knowledge regarding the environmental characteristics of the Development Area are already available, acquired through site specific surveys, technical studies and data gathering to inform the Original EIA and Addendum. In addition, the potential effects of the Originally Consented Project on the environment have been thoroughly assessed, and the outcomes of that assessment considered by the Scottish Ministers in their determination of the Original Application. On this basis, NnGOWL maximised, where appropriate, the use of existing data and the previous impact assessments in order to inform the Scoping Report.

9. In maximising the use of existing data and previous impact assessments, receptors were scoped out of the Project EIA where the following principles were met:

- The residual impacts from the Original Application were not significant;
- There is no increase in the relevant worst case design parameters;
- The baseline data and technical studies used to inform the Original ES remain valid and sufficient; and
- There has not been a change to relevant policy guidance or legislation that may invalidate the approach to the assessment.

2.1 Scoping Opinion

10. As part of the EIA process, NnGOWL has consulted with various statutory and non-statutory stakeholders. A formal scoping opinion was requested from MS-LOT alongside submission of the Scoping Report on 15 May 2017.

11. Following submission of the Scoping Report MS-LOT hosted a consultation meeting to discuss any issues relating to fish and shellfish with NnGOWL and key stakeholders on 13 June 2017. Key items raised in relation to Atlantic Salmon are summarised in Table 2-1

12. In response to NnGOWL's request, MS-LOT issued a Scoping Opinion which requested a review of the findings of the Original ES in light of more recent publications, detailing the current understanding of Atlantic salmon migratory behaviour and sensitivity to offshore renewable infrastructure. The comments addressed in this report in respect of Atlantic salmon are summarised in Table 2-1.

Table 2-1: Consultation responses in relation to potential impacts on Atlantic salmon

Date and consultation phase / type	Consultation and key issues raised	Section where comment addressed
13/06/2017 – MS-LOT Pre-application scoping meeting	Marine Scotland Science (MSS) requested that the EIA Report should include consideration of recent publications on the distribution and migratory patterns of Atlantic Salmon based on recent Atlantic Salmon tagging studies. MSS also advised that recent publications on the role of electromagnetic fields on Atlantic Salmon navigation should be considered.	See Section 5
	Scottish Natural Heritage (SNH) advised that it would be acceptable to SNH to scope the assessment of potential impacts on diadromous fish out of the EIA and Habitats Regulations Appraisal (HRA) from their perspective.	Noted
08/09/2017, Scoping Opinion – Scottish Ministers	The 2017 EIA Regulations require that the Scottish Ministers come to a reasoned conclusion, based on up to date information, on the significant effects of the Revised Development. As the information noted above [references relating to diadromous fish ecology provided by MSS] has been published since the previous assessment the Scottish Ministers advise NnGOWL to consider whether it changes the outcome of the Original Development ES and, if so, carry out a further assessment. If NnGOWL consider no further assessment is required they must provide justification of their reasons.	See Section 5 for consideration of updated information on salmon distribution and sensitivity
	The Scottish Ministers are satisfied with the embedded mitigation but note that further mitigation may be required if any concerns are raised following the outcome of the assessment on diadromous fish and particle motion. The Scottish Ministers note the comments of the River Tweed Commission (RTC) and the Forth District Salmon Fishery Board (FDSFB) and advise NnGOWL to take account of the new information available and include it in the EIA as noted above.	See Section 5 regarding updated baseline and also Section 4.1.1 regarding embedded mitigation. Consideration is given to the suitability of mitigation measures in Table 6-1.
	The Scottish Ministers advise NnGOWL to review the cumulative impact assessment for the Original Development to take account of the points raised in relation to particle motion and diadromous fish.	See EIA Report Chapter 7: Fish and Shellfish for assessment of particle motion See Section 5 for consideration of updated information on

Date and consultation phase / type	Consultation and key issues raised	Section where comment addressed
	If, after this review, NnGOWL consider that there is no need to update the cumulative impact assessment they should provide justification for this decision.	salmon distribution and sensitivity.
08/09/2017, Scoping – SNH	SNH confirmed that the scoping report provides full consideration and justification for scoping out diadromous fish species (and other qualifying interests of Special Areas of Conservation (SAC) rivers) from further assessment.	See Section 5 for consideration of updated information on salmon distribution and sensitivity.
08/09/2017, Scoping – MSS	MSS provided a list of references in relation to diadromous fish and effects of particle motion on fish species to inform the assessment for the Project.	See Section 5 for consideration of updated information on salmon distribution and sensitivity in relation to diadromous fish. Studies relating to particle motion have been referenced within the EIA Report Chapter 7: Fish and Shellfish Ecology.
08/09/2017, Scoping – FDSFB	FDSFB consider the information presented in the Scoping Report to be insufficient to scope out diadromous fish species. FDSFB suggested use of the Harding *et al*. (2015); Knudsen *et al*. (1996) and Malcom *et al*. (2010).	See Section 5 for consideration of updated information on salmon distribution and sensitivity.
	FDSFB also proposed that a piling strategy informed by further assessment be considered to mitigate the risk to effects on salmonids.	See Section 4.1.2 for anticipated consents condition commitments.
08/09/2017, Scoping – RTC	Expressed concern over use of wind farms by seals and effects on salmon of increased seal predation.	The Scottish Ministers concluded in the Scoping Opinion, based on advice from MSS, that Atlantic salmon present within the Offshore Wind Farm area are likely to be actively migrating through the site and less at risk of being predated.
	The RTC highlighted information relating to salmon tagging studies in Norway and records of fish returning to the east	These historical publications were not available. However, a literature review was undertaken looking at the most

Date and consultation phase / type	Consultation and key issues raised	Section where comment addressed
	coast of Scotland indicating migrating salmon may pass through the project area.	recent peer reviewed publications to update the baseline and sensitivity assumptions of Atlantic salmon (See Section 5)
	The RTC concluded that diadromous fish should be scoped into the EIA.	See Section 6: review of diadromous fish ecology baseline and confirmation of the scoping.

3 Review of Original ES

3.1 Baseline Conditions considered in the Original ES

13. Atlantic salmon spawn in their natal rivers between mid-October and late February. After a number of years in the river (most commonly two or three in Scotland) juvenile salmon (or parr) undergo a transformation both externally and internally, which allows them to adapt to salt water. They are then referred to as 'smolts'. Smolts move down rivers from April to June to start their marine migrations (Thorpe, J. E., 1988). Once they enter the sea they are known as post-smolts, until the spring of the following year. After one or more years feeding at sea, salmon return to their home rivers to spawn. Fish that have spent one winter feeding at sea are called grilse (one-sea-winter salmon), whilst salmon which have spent more than one winter at sea are known as multi-sea-winter salmon (MSW).

14. Malcolm et al. (2010) undertook a review of the migratory routes and behaviour of salmon, sea trout (*Salmo trutta*) and European eel (*Anguilla anguilla*) in Scottish coastal waters. The study noted that there is a paucity of information regarding the dispersion and migration routes of salmon to their distant feeding grounds, and on return to their natal rivers in Scotland. This is particularly the case for salmon emerging into the North Sea from rivers on the east coasts of Scotland, where they have the potential to interact with the Project. Malcolm et al. (2010) reported a pattern of general post-smolt migration to areas to the north and west of Scotland although there was no information around the exact migration route. In addition, Malcolm et al. (2010) reported that there is limited information for the east coast of Scotland, where there are no surface trawl data to corroborate this direction of travel for fish originating within the Forth and Tay region.

15. On leaving natal rivers, it has been reported that salmon undertake a rapid and active migration away from their river of origin, as reported by Martin and Mitchell (1985) who caught post-smolts tagged in Scottish rivers in the Faroese fishery within 6 months of leaving freshwater. This was also observed during studies in Canada and Norway, where smolts were reported to undergo rapid and active migration towards open marine areas within the uppermost surface waters (Thorstad et al., 2004 & 2007; Finstad et al. 2005). These studies also showed that in general, the fish did not follow nearby shores.

16. Adult salmon return to natal rivers generally from a northerly direction into the North Sea, which suggests they utilise dominant feeding grounds around the Faroe Islands and Greenland during their marine phase. However, on the east coast of Scotland, analysis of extant tagging data provides evidence that once at the coast, salmon appear to move northwards from the Northumbria coast to the Forth and Tay area (Malcolm et al., 2010). This is in line with the model of adult salmon migration proposed by Shearer (1992), where it was suggested that from Aberdeenshire southwards, fish travel in a northerly direction, having migrated south past their home rivers through the North Sea, and approach the coast around Northumberland (Potter & Swain, 1982).

17. Assuming this is the case, there is potential for not only salmon originating in rivers within the regional study area (as assigned in the Original ES), but also in rivers further north (Dee, Don, Ythan), to transit through or in close proximity to the Wind Farm Area and Offshore Export Cable Corridor.

18. Salmon of different sea-ages tend to return at different times of year, and often spawn in different parts of the rivers (Potter and Ó Maoiléidigh, 2006). In most countries, salmon runs tend to only take place at specific times, normally during late summer and autumn. In Scotland, however, salmon enter the rivers throughout the year, resulting in the existence of a range of salmon runs (Youngson et al., 2002). MSW fish tend to return in greatest numbers during the Spring whilst grilse tend to migrate to natal rivers return later in the year in late summer and early autumn (Hawkins and Smith, 1986).

3.1.1 Atlantic Salmon Vulnerabilities and Sensitivities

19. Salmon do not have nursery or breeding areas directly within the Firth of Forth (these are restricted to the freshwater environment) although they are known to travel through the area as adults and post-smolts. The Original ES noted that the migratory behaviour of diadromous species (including Atlantic salmon) means that there is potential for them to interact with the Project, potentially being impacted upon by noise generated during construction (both sound pressure and / or particle motion) and operation (EMF generated by subsea cables). Noise generated by pile driving is reported to be lethal for those species with a swim bladder, which includes Atlantic salmon, although it is recognised that mortality or Permanent Threshold Shift (PTS) is only likely to occur at close range to the source of the noise (Gill and Bartlett, 2010).

20. Atlantic salmon are likely to utilise EMF for navigation purposes during long distance migrations (Gill et al., 2005). In addition, diadromous species are known to be sensitive to pollution. Therefore, raised sediment levels may cause population fragmentation through individual avoidance behaviour (Thorstad et al., 2005; Wilber and Clarke, 2001).

3.2 Original EIA Determinations

3.2.1 Construction Impacts – Offshore Wind Farm

3.2.1.1 Physical Habitat Disturbance

21. Direct habitat disturbance from the Originally Consented Project was concluded to have potential impact on fish populations, particularly if it encompassed spawning and nursery areas. This assessment took into account the low magnitude of the effect due to temporal (during construction) and spatial (local to the source) limitation, together with medium severity, as sediment disturbance, across the whole site, was estimated to encompass 2.11 km^2 of the Development Area. This scenario assumed, installation of gravity base structures, use of jack-up vessels with a maximum size of spud can to install the maximum number of turbines and OSPs, and disturbance of a 10 metres (m) wide corridor for the inter-array cables, whereas in practice, trench widths usually range from 0.3 to 0.7 m and are up to 1.5 m deep (NnGOWL, 2012).

22. Atlantic salmon were not considered specifically in relation to physical habitat disturbance. The assessment concluded that highly mobile species such as salmon are able to avoid disturbance and survive (EMU, 2004). It was concluded that in general, the fish assemblage had a low sensitivity to physical disturbance.

23. Considering the low magnitude and low vulnerability, the overall significance of impact was considered to be of minor significance. The assessment was reported to carry a low level of uncertainty.

3.2.1.2 Increased Suspended Sediment Concentration and Turbidity

24. The Original ES stated that an increase in suspended sediment concentration (SSC) and turbidity had the potential to have an effect on activities such as filter feeding, migration and movement of fish, survival of pelagic eggs and fish larvae, and forage opportunities of visual predators (Birkuland and Wijsman, 2005). Increases in SSC associated with the Originally Consented Project was likely to occur following preparation of the seabed for gravity base foundations, which require levelling of the seabed by dredging. Results of the model analysis (NnGOWL, 2012) show that the discharge of dredged material during this process would lead to elevated SSC with peaks of up to 300 milligrams per litre (mg/l) (depth averaged) very close to the release location. However, the modelling confirmed that the resulting plumes would be comparable to background levels at around 1 kilometre (km) from the

source. The suspended sediment plume (>1 mg/l) was predicted to extend up to 4 km from the release location and settle out of the water column within one day if released near the surface.

25. The duration over which the activity will take place was described as being short and limited to the proximity of the release location. Overall, the magnitude of the effect was assessed to be low due to its limited spatial and temporal extent and intermittent frequency during the construction works.

26. Adult fish would normally be able to detect significantly elevated levels of SSC and avoid the affected area (EMU, 2004), although juvenile fish may be more susceptible than adult fish to plumes. Since winter storm events occur within the area, it is likely that many of the fish and shellfish species found in the area will be adapted to temporary increases in SSC. The SSC generated during such a storm was determined to be of greater magnitude than will be produced by the construction works, so sensitivity will be low for most species. Further, highly mobile species were concluded to be more tolerant of increases in SSC (ABP Research, 1997). Atlantic salmon were assessed as part of the wider fish and shellfish assemblage, and the vulnerability was adjudged to be negligible.

27. Considering the low magnitude and negligible vulnerability, the overall significance of the impact of increased SSC and turbidity on Atlantic salmon was considered to be of minor significance. The assessment was reported to carry a low level of uncertainty.

3.2.1.3 Increased Sediment Settlement and Smothering

28. Results of the modelling studies completed to inform the Original EIA indicated that if the dredged material was released at the surface of the water, the deposition footprint would be up to 0.1 m thick directly around the indicative turbine locations and up to 0.003 m within the boundary of the Wind Farm Area (NnGOWL, 2012). This footprint would be elliptical and aligned with the tidal ellipse, extending up to about 1 km away from the turbine location, to a thickness of 1 mm or more. The deposition footprints around each gravity base would overlap neighbouring footprints to form a more or less continuous layer of deposited dredged material of varying thickness across the Wind Farm Area.

29. However, if the dredged material were released close to the seabed, the magnitude of the depth averaged concentrations in the resulting plume would be similar, but its extent would be smaller. As with the sea surface release, the sediment deposition footprints would overlap but would not extend as far beyond the Wind Farm boundary. This assessment assumed that all the dredged material was released into the water column.

30. Due to the relatively limited spatial and temporal extent and intermittent frequency, the magnitude of the smothering effect of sediment dredging and release for the construction of the gravity base foundations was assessed as being low.

31. Atlantic salmon were considered as part of the wider fish and shellfish assemblage. However, in reality, Atlantic salmon are likely to be unaffected by sedimentation due to their mobility and limited interaction with the seabed during offshore migrations to and from natal rivers. The overall vulnerability of fish and shellfish species within the Study Area was assessed to be negligible, this was also applied to Atlantic salmon.

32. Considering the low magnitude and low vulnerability, the overall significance of the impact of increased sediment settlement and smothering was predicted to be of minor significance. The assessment was reported to carry a low level of uncertainty.

3.2.1.4 Pile Driving Noise

33. The Original ES reported that the potential impact of underwater noise and vibration on fish and shellfish populations was associated with pile driving, which could increase the noise level significantly above natural background levels. The assessment noted the varying hearing capabilities of different fish species in detecting noise based on certain physiological adaptions.

34. The impact assessment was carried out with consideration given to four distinct areas where different impacts or injuries could occur. These are briefly summarised below:

- **Zone of hearing loss, injury or discomfort** - When anthropogenic noise in the sea reaches certain levels, fish may sustain lethal or physical injury (Nedwell et al., 2007) or sustain temporal or permanent hearing loss, referred to as Temporal Threshold Shift (TTS) and Permanent Threshold Shift (PTS) respectively (Thomsen et al., 2006). If the hearing loss is only temporal, the fish will recover within hours or days, depending on the duration and frequency of the noise; however, during the recovery time fish may be more vulnerable to predation or inhibited to perform biologically important activities (Andersson, 2011).
- **Zone of masking** - Fish produce sounds in a 'social' context for antagonistic interactions (aggression, defence, territorial) as well as for courtship and mating (Thomsen et al., 2006). Anthropogenic noise raises the ambient level of sound making the detection of sound more difficult as the signal-to-noise ratio decreases leading to a reduction in signal detection distance; this occurs only if there is an overlap in frequencies between the induced noise and the sound of interest (Andersson, 2011).
- **Zone of audibility** - The zone of audibility is linked to the hearing threshold and sensitivity of the individual species (Andersson, 2011). Masking is overcome when the signal-to-noise ratio is high enough for a fish to sense the sound, while even if the natural ambient sounds (e.g. from wind, waves, rain and biological activities) are higher than the induced anthropogenic noise, the fish will not hear it. This is because fish can detect a narrow band signal in a broad band noise, which is the normal acoustic state of the sea (Andersson, 2011).
- **Zone of responsiveness** - The zone of responsiveness is the region within which fish react behaviourally to a given noise (Thomsen et al., 2006). Behavioural responses can range from startle and avoidance, to more subtle reactions such as changes in swimming activity, vertical distribution and schooling behaviour (Andersson, 2011). Fish will most likely respond in different ways to noise, as the tolerance thresholds are linked to age, sex, condition, season and habitat preferences (Andersson, 2011). If fish remain in an area exposed to noise levels above the hearing threshold, but not at a level that triggers behavioural response, other indirect effects may occur such as 'physiological stress' (e.g. increased levels of the stress hormone cortisol which could disrupt growth, maturation and reproductive success) (Thomsen et al., 2006).

3.2.1.4.1 Underwater Noise Modelling Approach and Magnitude

35. The potential impact for noise impacts related to pile driving operations associated with the construction of the Project was investigated by means of subsea noise modelling using the modelling software package INSPIRE (Original ES Appendix 13.1: Noise Model Technical Report of the). This considered the likely range at which injury and behavioural response might be expected for selected fish species of which Atlantic salmon was one.

36. The dB_{ht}(species) perception unit, corresponding to the sound level above a species' hearing threshold (Nedwell *et al*., 2007), was used for modelling the assessment, which considered the following impact ranges for the 3.5 m diameter pile (Original ES worst (realistic) case scenario) and the 2.5 m (Original ES most likely scenario):

- 130 dB_{ht}: traumatic hearing loss;
- 90 dB_{ht}: strong avoidance behaviour; and
- 75 dB_{ht}: significant avoidance behaviour.

37. The criteria assumed to assess behavioural responses described above are based on observations by Nedwell et al. (2007) during experimental trials in large circular tanks. The study concluded that that at levels of 90 dB_{ht} and above virtually all individuals of each species tested will avoid the sound. These behavioural responses served as precautionary estimates, and were used in the absence of more widely agreed and independently evaluated figures.

38. The use of a 130dB_{ht} level provides a suitable criterion for predicting the onset of traumatic hearing damage, taking into account the hearing sensitivity of the species (Nedwell et al., 2007). Based on a large body of measurements of fish avoidance of noise, a level of 90 dB_{ht} was used as the level at which a strong likelihood of disturbance, to the majority of individuals of a species, would be expected (Nedwell *et al*., 2007). A lower level of 75 dB_{ht} was used to indicate that a significant behavioural impact, in approximately 85% of individuals, is likely to occur, although the response from individuals within a species will vary, i.e. one individual may react, whereas another individual may not. In addition, there is some evidence indicating that fish become habituated to lower level noise (Nedwell *et al*., 2007).

3.2.1.4.2 Atlantic Salmon Vulnerabilities to Underwater Noise

39. When the Original ES was prepared, the available information on the migratory routes of salmon was limited. As a result of this uncertainty, a precautionary approach was applied, and it was assumed that salmon were present offshore.

40. Based on the available information at the time, the Original ES reported that post-smolt salmon migrate rapidly and actively towards open sea from their river sources (Thorstad *et al.*, 2007, Finstad *et al.*, 2005; Lacroix *et al.*, 2005), and do not follow nearby shores, except in areas subject to strong coastal currents (Lacroix *et al.,* 2005). Once at sea, migration is predominately in a northward direction, likely following dominant ocean currents (Malcolm *et al.,* 2010). Spent or spawned salmon, known as kelts, migrate to sea rapidly in shallow waters (Malcolm *et al.*, 2010). Adults return to Scottish waters from areas to the north and west of the British Isles (Malcolm *et al.*, 2010).

41. The hearing sensitivity of salmon was considered to be relatively low, reflecting the fact that Atlantic salmon do not have close connectivity between the swim bladder and the ear anatomy, and taking account of published species-specific research studies (Hawkins and Johnstone, 1978; Nedwell et al., 2003).

3.2.1.4.3 Underwater Noise Modelling Results and Assessment of Impacts: Mortality and Traumatic Hearing Loss

42. The site-specific modelling study, undertaken to inform the Original EIA, indicated that the range of lethal effect on fish populations is restricted to less than 10 m from the noise source, whereas physical injury will occur within a radius of less than 60 m from the noise source when considering the worst case piling scenario (Subacoustech, 2012). The area of lethality was calculated to be 78.54 m^2 per pile and the area over which physical injury may occur was 2,827.4 m^2 per pile.

43. Based on the results of the modelling study, the extent of the radius of traumatic hearing loss was predicted to be localised (<1 km from noise source) from each piling operation, and restricted to the duration of pile driving activities. The overall magnitude of the effect was presented in the Original ES as medium within the text and low within the final impact assessment tables. Given the temporary and intermittent nature of piling, and the small spatial extent of mortality, trauma and hearing loss, it is considered that the most appropriate magnitude score should have been low based on the magnitude descriptors in the Original EIA methodology. The vulnerability of the species to mortality or severe traumatic hearing loss was considered to be moderate for all fish species without specialised hearing adaptions. Atlantic salmon were attributed to this category.

44. It is recognised that most fish species will swim away from the noise source as indicated by experimental studies (Mueller-Blenkle et al., 2010). As a highly mobile species that is likely to pass through the Development Area during long distance migrations, this is likely to be the case for Atlantic salmon. Based on the results of the modelling study, and the information currently that was reviewed to inform the Original ES, the impact of traumatic hearing loss from construction noise on fish and shellfish communities was concluded to be of minor significance. The Original ES did acknowledge the uncertainty in the assessment, on the basis that there remain many gaps in the literature with regards to hearing thresholds / range estimations, since they are based on the assumption that all fish within a species have the same hearing threshold. In reality, there are individual differences in sound detection, and in an area with different acoustic properties, the detection distance can be either shorter or further (Andersson, 2011).

3.2.1.4.4 Underwater Noise Modelling Results and Assessment of Impacts: Behavioural Responses

45. The impact of noise from pile driving may also result in behavioural avoidance. Modelling to determine the potential ranges of behavioural impact (dB_{ht} (Species)) estimated that for 3.5 m (1635 kJ) and 2.5 m (1200 kJ) piles, salmon would strongly avoid an area out to a maximum of 2.6 km and 1.5 km respectively; the radius of significant avoidance behaviour for salmon was predicted to extend up to 14 and 9.2 km for 3.5 m diameter and 2.5 m diameter piles respectively.

46. The behavioural avoidance as a consequence of increased underwater noise on migratory species, e.g. salmon and sea trout, is not fully documented. At the time of production of the Original ES, the available literature indicated a mild reaction by the salmon at distances of 60 to 80 m (Nedwell, 2003). Salmon and trout are highly mobile species that undergo large seasonal movements and migrations to forage and breed. They are reported to be vulnerable to structures which could act as a barrier, preventing movement to their foraging or nursery grounds. The degree of impact of barrier effects on these species will depend on their ability to move and avoid barrier structures, thus, for example, structures placed in a highly confined estuary are likely to be more of an issue than in the open coast.

47. The magnitude of the effect on salmon was considered to be negligible for the strong avoidance behaviour and medium for the significant avoidance behaviour, based on the spatial extent of the radius, and the temporary and intermittent nature of the impact during construction.

48. The vulnerability of salmon and trout was considered to be low in the Original ES and the overall significance of effect on salmon populations was predicted to be of minor significance. The assessment was reported to carry a medium level of uncertainty.

3.2.2 Construction Impacts – Export Cable

3.2.2.1 Physical Habitat Disturbance

49. The corridor for cable installation activities is relatively long (33 km[1], landfall to Offshore Wind Farm Area), sediment disturbance from the installation of the cables is restricted to 5 m either side of the two Offshore Export Cables, and therefore the footprint of temporary habitat disturbance has a limited spatial extent.

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[1] NB. This distance has increased to 43 km in the Project EIA to account for the distanced between the Project boundary and the OSP locations.

50. The Original ES reported that the level to which the seabed is disturbed, is primarily related to the nature of the ground, and the type of tool selected to bury the cable, the latter likely to have a secondary influence (BERR, 2008). Given the nature of the seabed sediment (i.e. muddy sand) along the Offshore Export Cable route, ploughing is the most likely method to be employed for cable installation activities. This method ensures that soil disturbance is kept to a minimum. It also allows the sediment to infill rapidly following disturbance, enabling habitat recovery to occur. The cable will be installed using a plough which will travel along the seabed on runners or skis. The transit of the cable plough along the Offshore Export Cable route will result in a low severity of disturbance to a 10 m corridor. Within this 10 m corridor, 2 m in the centre will be subject to a high severity of disturbance as the sediments are turned and removed by the plough blade.

51. Results of the modelling study carried out to inform the Original ES indicated that the maximum volume of sediment displaced is likely to be 800 m^3 per hour, based on a trench width of 1 m, dug to a depth of 2 m, and assuming a typical rate of trenching of 400 m per hour.

52. Due to the temporally and spatially restricted nature of the cable installation activities, the impacts are likely to be highly localised and short term. As a result, the magnitude of effect was considered to be low. Atlantic salmon were assessed as part of the wider fish and shellfish community; the sensitivity to physical habitat disturbance was concluded to be negligible, as mobile species will be able to avoid the disturbance. The overall impact of the installation of the Offshore Export Cables on fish and shellfish communities was assessed to be of minor significance in the Original ES and carried a low level of uncertainty.

3.2.2.2 Increased Suspended Sediment Concentration and Turbidity

53. Cable burial by ploughing minimises the amount of sediment likely to be brought into suspension due to the controlled operation by which cable ploughs work, followed by the backfilling of the trench (BERR, 2008). However, the fine sediment (mud) is still likely to mix with water and to be dispersed by tidal currents. Coarser sediments are also likely to be brought into suspension, but are expected to quickly settle back to the seabed and are unlikely to be dispersed over long distances by tidal currents.

54. Results of the modelling studies conducted to inform the Original ES indicated that, regardless of the location along the Offshore Export Cable route, the elevated SSC was predicted to be between 3 and 10 mg/l, with some localised peaks in small areas reaching 30 mg/l. The associated suspended sediment plumes were predicted to be less than 5 km in extent and settle out within a maximum of four hours, with resulting deposition footprints being localised.

55. The magnitude of the effect was assessed to be negligible as it is limited in time (installation) and space (along the Export Cable Corridor). Atlantic salmon were assessed as part of the wider fish and shellfish assemblage, and it was concluded that the sensitivity to increased SSC and turbidity was likely to be negligible.

56. The overall impact of increased SSC and smothering associated with the installation of the Offshore Export Cables was assessed to be of minor significance and carried a low level of uncertainty.

3.2.2.3 Sediment Settlement and Smothering

57. The Original ES reported that the maximum predicted deposition thickness would be 3 mm, and the extent of the deposition footprint, with thickness greater than 0.1 mm is likely to extend up to about 2 km either side of the cable trench. In reality, the amount of sediment that will be re-suspended into the water column is likely to be less, as the modelling study carried out to inform the Original ES assumed that the entire volume of the trench would be suspended into the water column with no backfilling.

58. The magnitude of the effect was assessed to be negligible as it is limited in time (installation) and space (along the Offshore Export Cable Corridor). Atlantic salmon was considered as part of the wider

fish and shellfish assemblage and was concluded to have negligible sensitivity to sediment settlement and smothering.

59. The overall impact of increased SSC and smothering associated with the installation of the Offshore Export Cables was assessed to be not significant and carried a low level of uncertainty.

3.2.3 Operational Impacts – Wind Farm Area

3.2.3.1 Permanent Habitat Loss

60. The loss of seabed to turbine foundations and associated scour protection has the potential to impact on fish and shellfish in a number of ways: through changes in the predator-prey dynamics as a result of a potential shift in the species composition of benthic fauna; through removal of key habitats crucial to their survival (e.g. spawning and nursery habitats) and through direct uptake.

61. The Original ES acknowledged that impacts on species that are highly mobile, and do not rely on key habitats or prey resources within the Development Area, will be less sensitive to impacts from habitat loss. In addition, the Original ES reported that adult stocks of fish are considered to not be vulnerable to habitat loss in terms of their adaptability and tolerance by way of their mobile nature and generalist feeding behaviour. The vulnerability of Atlantic salmon was considered as part of the wider fish assemblage and was considered to be negligible in relation to permanent habitat loss.

62. The permanent habitat loss due to turbine installation and scour protection was estimated to be 0.25 km^2 (0.05 %) of the Wind Farm Area, based on the presence of 75 x gravity base foundations and inter-array cables protected to a degree with scour protection; therefore, the magnitude of the effect was assessed as being low.

63. The overall significance of impact of habitat loss on fish and shellfish communities was considered to be of minor significance. The Original ES considered that this determination carried a low level of uncertainty.

3.2.3.2 Changes in Hydrodynamic Regimes

64. The assessment of the impacts on the metocean environment due to the Project was modelled and discussed within Chapter 9: Physical Processes of the Original ES.

65. The modelling predicted changes to water levels, tidal currents, wave climate and sediment transport. The modelling outputs confirmed that these changes would be minor, fluctuating within 6% of baseline conditions in all cases, and limited to the local vicinity of the structures.

66. The physical process modelling also assessed impacts of scour. The results illustrated that under the worst (realistic) case scenario, under the design envelope, the resulting elevated SSC would be small and localised with sedimentation only occurring in the immediate vicinity of the turbine bases.

67. The magnitude of effect from the changes in hydrodynamic regime around the structures was, therefore, considered to be negligible due to the limited spatial extent, low frequency and duration. The fish and shellfish assemblage was considered to be of negligible vulnerability to changes in hydrodynamic regime. Therefore, the overall significance of effect was concluded as minor significance and carried a low level of uncertainty.

3.2.3.3 Introduction of New Substrates

68. Wind farms add new hard substrate to the marine environment; however, these man-made structures cannot be regarded as surrogates for natural substrate, since epibenthic assemblages on artificial

surfaces have been shown to differ compared to assemblages on natural hard substrate (Wilhelmsson and Malm, 2008).

69. The hard substrate habitat created by the introduction of wind turbine foundations, associated scour protection and inter-array cable protection will likely result in aggregations of fish and shellfish species within hours or days after the construction by bottom-living and semi-pelagic fish species (Andersson, 2011).

70. The substrate character of the Wind Farm Area encompasses soft and to a lesser extent hard seabed sediment, therefore, the addition of turbines and scour protection is not likely to change the habitat dramatically. The new surface available for colonisation, on 125 x gravity bases and their associated scour protection (and scour protection on inter-array cables) was estimated at 0.39 km^2, which was considered to be negligible within the Wind Farm Area, and even more so within the wider geographical context. This is a very broad estimate as habitat enhancement is difficult to quantify due to different surface texture, gaps, and crevices, which are all potentially relevant in providing additional micro habitats (Linley et al., 2007).

71. The fish and shellfish assemblage (including Atlantic salmon) were considered to have low vulnerability to the introduction of hard substrata. Overall, the significance of impact of the introduction of new substrate reported in the Original ES on fish populations was considered to be of minor significance, but this assessment carried medium uncertainty, particularly in view of the fact that proving the link between offshore wind farms and changes in fish populations requires years of monitoring in order to distinguish the effects of the wind farm from natural annual variation.

3.2.3.4 Operational Noise

72. The noise from the operation of wind turbines is generated by the gearbox and generator and transferred into the water and sediment through the tower and foundations. Wind farms noise source levels are influenced by size and shape of the foundation, age and model of the turbines, and the number of turbines. In addition, transmission loss is site specific, hence any estimate of the amount of noise likely to be generated during the operational phase of a wind farm are highly site specific (Andersson, 2011), with the highest noise levels likely to be recorded in close proximity (1 m) from the foundation during moderate wind speeds (Sigray and Andersson, 2011).

73. The Original ES considered both the impact of the sound pressure component, and the particle motion component of operational noise. The Original EIA focused on species with greater hearing sensitivity, however, it did note that salmon can detect offshore wind turbines at a maximum distance of about 0.4 km at wind speeds of 8 and 13 m/s (Wahlberg and Westerberg, 2005). The research found no evidence that wind farms cause temporal or permanent hearing loss in fish, even at a distance of a few metres. The wind turbines produce sound intensities that may cause permanent avoidance by fish within ranges of around 4 m, but only at high wind speeds (13 m/s).

74. Although Atlantic salmon have a swim bladder they do not have any enhanced hearing adaptations, therefore, the Original ES reported that salmon will possibly detect the noise up to 1 km distance, and therefore the vulnerability was assessed as low. Data on background noise within and around the Wind Farm Area, and model studies for the predicted source level and transmission loss for the areas were not available, all of which are important in estimating the zone of audibility of different species based on their known audiograms. The assessment was, therefore, qualitative, based on the available literature. The magnitude of the impact of operational noise on fish was considered to be low, due to the relatively low number of turbines and predicted high background noise levels (based on known commercial and industrial activities in the areas). The overall significance of effect was concluded to be of minor significance. However, this assessment carried a medium uncertainty due to lack of site specific background noise data and limited knowledge of fish sound detection.

3.2.4 Operational Impacts – Export Cable

3.2.4.1 Heating Effects

75. The heat dissipation due to transmission losses for Alternating Current (AC) cables may result in a temperature rise of the surrounding sediment (OSPAR, 2009a,b). The literature used to inform the Original ES reports one set of field measurements of seabed temperature near power cables at Nysted offshore wind farm, however, the results are not considered to be robust enough to draw conclusions applicable to other cases (OSPAR, 2009a,b).

76. Published theoretical calculations of the temperature effects of operational buried cables are consistent in their predictions of significant temperature rise of the surrounding sediment (OSPAR, 2009a,b). This may be of importance here as there is evidence that various marine organisms react sensitively to even very small increases in ambient temperature (OSPAR, 2009a,b). Preliminary laboratory experiments showed that species responded differently to seabed temperature increase; however, in the absence of robust field data, there remains some uncertainty in the assessment of effects of artificially increased temperature on marine animals. The magnitude of the impact associated with heating effects of seabed sediments was reported to be negligible in the Original ES. The vulnerability of the wider fish and shellfish assemblage was reported to be low, although this is conservative for salmon who do not interact with the seabed during their marine life phase. The significance of effect along the Offshore Export Cable Corridor from potential heating effects of operational power cables was assessed as being not significant in view of the low number and small spatial extent of the cables, however the Original ES stated that this assessment carried a high uncertainty, due to lack of robust data from field studies.

3.2.4.2 Electromagnetic Fields (EMF) generated by subsea cables

77. The term EMF covers both the electric (E) field, measured in volts per metre ($V\ m^{-1}$) and the magnetic (B) field measured in tesla (T). Background measurements of the B field are approximately 50 µT in the North Sea, and the naturally occurring electric field in the North Sea is about 25 $\mu V\ m^{-1}$ (Tasker et al., 2010). Wind farms transmit the energy produced along a network of cables. As energy is transmitted, the cables emit low-energy EMF (Boehlert and Gill, 2010). The E and B fields generated increase proportionally to the amount of electricity transmitted. These fields are known to be in the range of detection of electromagnetic sensitive species (CMACS, 2003). The flow of electricity in an AC cable changes direction (as per the frequency (Hz) of the AC transmission) and creates a constantly varying E field in the surrounding marine environment (Huang, 2005).

78. The Original ES reported that EMF have the potential to interfere with the navigation of migratory species by affecting the speed and / or the course of their migration, causing subsequent potential problems if they do not reach essential feeding, spawning and nursery grounds. Specifically, interaction may occur if the fish migration route coincides with the cables, particularly in shallow waters (<20 m), where there is greater probability of encountering the high voltage cables coming to shore.

79. The assessment presented in the Original ES was qualitative and relied on the literature published prior to 2010 to support the assessment. The Original ES reported that changes in fish behaviour due to effects from subsea cable will be greater when in close proximity to the source of the EMF (Gill and Bartlett, 2010). Gill and Bartlett (2010) also noted that B fields are strongly attenuated and decrease as an inverse square distance from the cable.

80. The magnitude of impact resulting from EMFs was assessed to be of minor significance based on the relatively small footprint of the cables within the Development Area. The vulnerability of the fish assemblage present within the study area was considered to be low, on the basis that although most

fish species are reported to be capable of EMF detection, the current view within the scientific community is that there is no evidence that this capability will translate into any significant effect (Gill and Bartlett, 2010; Gill et al., 2009; Öhman et al., 2007).

81. The Originally ES also noted that the use of conductive sheathing, armouring and burial would be used to mitigate the effects of EMF on fish species. While sheathing and armouring is only effecting in blocking the E field from the marine environment, burial also has the effect of increasing the distance between the cable and electro-sensitive species (Gill et al., 2005), and therefore reducing the radius of effect and exposure of sensitive species to the strongest EMF that exist at the surface of the cable.

82. The residual significance of effect reported in the Original ES was concluded to be of minor significance. The Original ES did acknowledge the paucity of information available and noted that there was a high level of uncertainty associated with the final significance of effect determinations.

3.2.5 Decommissioning Impacts

83. By applying the precautionary principle, the potential impacts from decommissioning activities on fish and shellfish, including Atlantic salmon, were anticipated to be similar to the construction phase (albeit they will realistically be less due to cables and other structures below the seabed being left in situ and due to no piling activity being required). Therefore, the impacts of decommissioning were considered to be analogous to those described for the construction phase, but in reverse.

3.2.6 Cumulative Impact Assessment

84. The cumulative impact assessment in the Original ES considered the following projects cumulatively with the Originally Consented Project:

- Inch Cape Offshore Wind Farm;
- Seagreen Alpha and Bravo Offshore Wind Farms.

85. The original assessment considered impacts which had either overlapping areas of effect, or had the potential to additively effect a single receptor.

3.2.6.1 Cumulative Construction Impacts

3.2.6.1.1 Physical Habitat Disturbance

86. The overall area of physical habitat disturbance associated with the three projects in the Firth of Forth and Tay remain a small percentage of the overall area of similar habitat type in the wider North Sea. The Original ES therefore concluded that the impacts on the wider fish and shellfish assemblage from physical habitat disturbance would be of minor significance with low uncertainty.

3.2.6.1.2 Increased Suspended Sediment Concentration, Sediment Settlement and Smothering

87. Regional modelling, incorporating details of the three Forth and Tay projects, was undertaken of increased suspended sediment to assess the impacts of increased SSC, settlement and smothering, incorporating details of the three Projects. The result indicated that the proposed offshore wind farm developments would not cause net changes to the regional sediment transport regime or sediment dynamics along the nearby coastline, even when the three sites are considered cumulatively. The potential cumulative effect of increased SSC was assessed as minor significance with low uncertainty.

3.2.6.1.3 Pile driving noise

88. Regional noise modelling work was undertaken incorporating the worst case pile driving scenarios associated with the three Forth and Tay projects. The magnitude of the impact from pile driving noise

was considered to be low, with respect to the strong avoidance behaviour, and moderate for significant avoidance behaviour, based on the outputs of the modelling. The vulnerability of Atlantic salmon was considered to be low for the strong avoidance behaviour, and moderate for the significant avoidance behaviour, and the overall impact was therefore concluded to be of minor to moderate significance with medium uncertainty.

3.2.6.2 Cumulative Operational Impacts

3.2.6.2.1 Permanent Habitat Loss

89. Habitat loss beneath the turbine and met masts, and associated scour protection and supporting infrastructures, was estimated to be up to 9.7 km^2 across all three sites based on the worst case scenario for each development, which assumes the largest gravity base foundations in most cases. Therefore, the overall impact was assessed as minor significance with low uncertainty.

3.2.6.2.2 Changes in Hydrodynamic Regimes

90. The cumulative effects of the Originally Consented Project, Inch Cape and Seagreen offshore wind farms on the sediment regime were modelled cumulatively with analysis of the seabed sediment characteristic. Results of the modelling study indicate that the predicted cumulative changes to sediment transport processes due to the three projects are likely to be small, within natural variability, and restricted to the immediate vicinity of the development sites. Based on this information, the likely impact on Atlantic salmon was assessed to be minor significance with low uncertainty.

3.2.6.2.3 Introduction of New Substrates

91. The introduction of artificial structures was considered to be of low magnitude when considered in the wider geographical context. The impact of artificial reefs on fish and shellfish populations as a whole was assessed as being of minor significance, and this assessment carried medium uncertainty. This is considered to be overly conservative for Atlantic salmon who will likely use the Development Area for transiting between remote feeding grounds and natal rivers for spawning.

3.2.6.2.4 Operational Noise

92. Evidence from published literature at the time of submission of the Original ES indicated that fish such as Atlantic salmon may detect operational noise of a wind turbine at relatively short distances (e.g. 1 km) (Thomsen et al., 2006). There was also evidence that fish may be able to distinguish between the nature of similar sounds and habituate to the continuous operational sound of wind turbines (Thomsen et al., 2006). In view of this, the cumulative impact from operational noise on fish and shellfish populations, including Atlantic salmon, was assessed to be of minor significance but with medium uncertainty.

3.2.6.2.5 Electromagnetic Fields (EMF) generated by subsea cables

93. Cumulative effects were considered from export and inter-array cables from the three Forth and Tay projects. The potential cumulative impact from EMF of subsea cables on fish and shellfish communities, including Atlantic salmon, was assessed to be of minor significance with a medium uncertainty.

4 Design Envelope

94. Table 4-1 sets out the worst-case design scenario defined by the Original ES, that was used to assess the effects on Atlantic salmon as summarised in Section 3.2 above, compared to the proposed worst case scenario for the Project. This is provided at a level of detail that is sufficient to draw conclusions in relation to the magnitude of impacts and likely significance of effect on salmon taking account of the revised design envelope.

Table 4-1: Worst case design scenario definition

Potential Impact	Original Project Design Envelope (NnGOWL, 2012)	Project Design Envelope	Difference
Construction and Decommissioning			
Physical habitat disturbance	125 x Wind turbines on 4 leg jacket foundations and installation (including scour protection) = 0.52 km^2; 2 x Substation foundations = 0.048 km^2; 3 x met mast foundations = 0.125 km^2; Inter-array cable plough based on 140km of array cabling and installation vessel anchors = 1.4 km^2; Offshore Export Cable plough based on 2 x 33 km Offshore Export Cables and installation vessel anchors = 0.66 km^2	54 x wind turbines on 4 leg jacket foundations[2] (including scour protection) = 0.0648 km^2 2 x Substation foundations on 8 leg jacket = 0.048 km^2; 1 x met mast foundation on a 4 leg jacket = 0.0012 km^2 Inter-array cable plough based on 140km of array cabling and installation vessel anchors = 1.4 km^2; Offshore Export Cable plough based on 2 x 43 km Offshore Export Cables and installation vessel anchors = 0.86 km^2	Reduction in number of installed wind turbine foundations. No change to OSPs or inter-array cable infrastructure. Increase in the length of the two Offshore Export Cables to account for distance between the Wind Farm boundary and the OSPs. The overall area of direct seabed habitat disturbance has reduced by 0.38 km^2.
Increased suspended sediments	125 turbine and 3 met mast GBS with pre-installation dredging to	54 turbines on 6 leg jackets, 1 met mast on 4 leg jackets and 2 OSPs on	No pre-installation dredging required at turbine locations. Increased length of Offshore Export Cable. No change

[2] Note it is anticipated that the 4 leg jacket option would require more scour protection and so is considered the worst case scenario.

Potential Impact	Original Project Design Envelope (NnGOWL, 2012)	Project Design Envelope	Difference
concentration and turbidity **Increased sediment settlement and smothering**	2m depth across a 50 m x 50 m area of seabed; 140 km of inter-array cabling trenched to a depth of 2m; 2 x 33 km export cabling trenched to a depth of 2m.	8 leg jackets (no pre-installation dredging required). 140 km of inter-array cabling trenched to a depth of up to 3m; 2 x 43 km export cabling trenched to a depth of up to 3m.	to OSP or Inter-Array Cable infrastructure. The increased SSC associated with installation of the Offshore Export Cable is offset by the reduction in SSC due to the fact the GBS are no longer being considered. Therefore, any potential effects associated with Increased SSC would fall within the worst case design envelope previously considered in the Original EIA.
Pile driving noise and vibration	Number of structures: 125 turbines (500 piles), 2 OSPs (up to 16 piles) and 3 met masts (up to 18 piles). Assessment based on four legged jackets using 3.5 m piles per turbine and 8 legged jackets at each OSP location using a 3.5m pile.	Number of structures: 54 turbines (324 piles), 2 OSPs (up to 16 piles) and 1 met mast (up to 4 piles). Assessment based on 6 leg jackets using 3.5 m piles at turbine locations, 4 leg jacket at met mast location and 8 leg jackets using 3.5 m piles at the OSP locations.	Reduction in total number of piles required from 534 to 344 (186 less). It is anticipated that the six-leg jacket foundation will reduce the required penetration depth per pile resulting in further reductions in piling time.
Operation and Maintenance			
Permanent habitat loss	75 x GBS wind turbine foundations[3] plus scour protection around each structure = 0.17 km^2; Substation foundations based on 4 leg jacket foundation = 0.001 km^2; Inter-array cable scour protection = 0.14 km^2 and	54 x wind turbines on 4 leg jacket foundations (including scour protection) = 0.0648 km^2 2 x Substation foundations on 8 leg jacket = 0.048 km^2; 1 x met mast foundation = 0.0012 km^2	Reduction in number of turbines and reduction in footprint at each foundation location due to use of jackets. No change to OSPs or cable infrastructure. It is anticipated that the lengths of Offshore Export Cable within the Wind Farm Area will be buried and therefore no additional scour protection is required.

[3] The worst case scenario of loss of habitat was considered to be 75 foundations with a 1,600 m^2 footprint rather than the 125 foundation scenario with a 700 m^2 footprint.

Potential Impact	Original Project Design Envelope (NnGOWL, 2012)	Project Design Envelope	Difference
	Offshore Export Cable scour protection = 0.05 km^2.	Inter-array cable scour protection estimated to be 20% of the total length = 0.28 km^2; Offshore Export Cable scour protection estimated to be 15% of the total length = 0.13 km^2	
Change in hydrodynamic regimes	Effects on hydrodynamics were modelled using the FTMS based on the following input parameters: GBS with a base diameter of 35 m and conical height of 34 m; Turbine spacing of 1,008 m along the line and 630 m between the line; The model considered a worst case layout using the minimum possible turbine spacing, therefore the worst case scenario comprised of 126 turbines.	Number of structures = 54 turbines plus 1 met mast on 6 leg jacket structures with a 35 m x 35 m footprint at the seabed plus 2 OSP foundations on a 8 leg jacket with a 60 m x 60 m footprint at the seabed.	Reduction in number of structures and reduction in impedance associated with 6 leg jackets as opposed to GBS.
Introduction of new substrata	128 GBS wind turbine foundations[4] (30 m diameter and 34 m cone height) plus scour protection = 0.23 km^2; Substation foundations = unknown;	54 x wind turbines on 4 leg jacket foundations (including scour protection) = 0.0648 km^2; 2 x Substation foundations on 8 leg jacket = 0.048 km^2;	Reduction in number of turbine foundations. No change in OSPs or cable infrastructure.

[4] 128 locations were identified although the ES confirmed only 125 turbines would be installed. The assessment took into consideration every location identified.

Potential Impact	Original Project Design Envelope (NnGOWL, 2012)	Project Design Envelope	Difference
	Inter-array cable scour protection = 0.14 km^2; and Offshore Export Cable scour protection = 0.09 km^2	1 x met mast foundation = 0.0012 km^2; Inter-array cable scour protection estimated to be 20% of the total length = 0.28 km^2; Offshore Export Cable scour protection estimated to be 15% of the total length = 0.13 km^2	
Operational noise	Qualitative assessment based on the operation of 125 turbines.	Based on the operation of 54 turbines.	Reduction in noise due to fewer turbines and less operational requirements
Heating effects	15 circuits, 140km of cabling. Two inter-array cables buried between 1 – 3m in depth. Where this cannot be achieved (up to 20%) cable will be laid on seabed and cable protection will be used. Direct width impact of 2m. 33km of Offshore Export Cable, two cables.	14 circuits, 140km of inter-array cables and interconnector cables buried up to 3 m deep. It is estimated up to 20% or inter-array cables may require cable protection where adequate burial depths cannot be achieved. Two 43km of Offshore Export Cables buried up to 3 m deep. It is estimated that up to 15% of the export cable may require cable protection where adequate burial depths cannot be achieved.	No change in inter- array cables or Offshore Export Cable lengths.
EMF	15 circuits, 140km of cabling. Two inter-array cables buried between 1 – 3m in depth. Where this cannot be achieved (up to 20%) cable will be laid on seabed and cable	14 circuits, 140km of inter-array cables and interconnector cables buried up to 3 m deep. It is estimated up to 20% or inter-array cables may require cable protection	No change in inter- array cables or Offshore Export Cable lengths.

Potential Impact	Original Project Design Envelope (NnGOWL, 2012)	Project Design Envelope	Difference
	protection will be used. Direct width impact of 2m. 33km of Offshore Export Cable, two cables.	where adequate burial depths cannot be achieved. Two 43km of Offshore Export Cables buried up to 3 m deep. It is estimated that up to 15% of the export cable may require cable protection where adequate burial depths cannot be achieved.	

4.1.1 Embedded Mitigation

95. A number of mitigation options, both embedded, and further, were identified within the design envelope for the Originally Consented Project, during the consultation phase of the Original Application and during the on-going liaison with stakeholders and with MS-LOT. As set out in the Scoping Report (and as summarised in Chapter 5: Scoping and Consultation and Chapter 7: Fish and Shellfish Ecology of the Project EIA Report), these have been adopted into the Project design as the design envelope has evolved.

96. Those embedded mitigation measures that are relevant to the potential impacts on Fish and Shellfish that have been captured within the design envelope for the Project are:

- Soft start procedure is incorporated into the start of piling in order to reduce the potential for noise related fatality and injury. This has been built into the design and noise modelling calculations;
- Inter-array, interconnector and Offshore Export Cables will be suitably buried (to a maximum of 3m) or will be protected by other means when burial is not practicable. This will reduce the potential for effect and exposure of electromagnetically sensitive species to the strongest EMF;
- To minimise the extent of any unnecessary habitat disturbance, material displaced as a result of cable burial activities will be back filled, where possible, in order to promote recovery; and
- Cable specifications will be used that reduce EMF emissions as per industry standards and best practice such as the relevant IEC (International Electrotechnical Commission) specifications.

4.1.2 Anticipated Consent Conditions Commitments

A number of consent conditions were attached to The Consents to manage the environmental risk associated with the Originally Consented Project. NnGOWL anticipate that any future consents issued to the Project may incorporate similar conditions to manage the risk to Atlantic salmon and other diadromous fish receptors, commensurate with the Project design envelope, where it remains necessary to do so.

Table 4.2 sets out the conditions attached to The Consents which have some relevance to the management of effects on Atlantic salmon.

Table 4.2: Original Consent Requirements relating to Fish and Shellfish

Mitigation Measure	Deliverable
Piling Strategy	Setting out, for approval, the pile driving methods, in accordance with the Application and detailing associated mitigation incorporating data collected as part of pre-construction survey work to demonstrate how the risk to Atlantic salmon, cod and herring will be managed.
Cable Plan	Setting out, for approval, in accordance with the application and detailing routing considerations, including environmental sensitivities based on pre-construction survey data, and any relevant mitigation ensure all relevant environmental risks associated with cable installation and operation are managed in respect of fish receptors.
Environmental Management Plan	Setting out, for approval, the over-arching environmental management procedures that will be implemented across the Project to minimise the risk to environmental receptors from, for example, potential pollution, introduction of non-natives, and dropped objects.
Project Environmental Monitoring Programme	Setting out, for approval, the proposed environmental monitoring programme, to include as relevant and necessary the monitoring of sandeels, marine fish and diadromous fish.
Participation in the Forth and Tay Regional Advisory Group (FTRAG)	Participate in the monitoring requirements as laid out in the 'National Research and Monitoring Strategy for Diadromous Fish' so far as they apply at a local level (the Forth and Tay).
Participation in the Scottish Marine Environment Group (SSMEG)	Participation in the SSMEG with respect to monitoring and mitigation of diadromous and commercial fish.
Participation in the 'National Research and Monitoring Strategy' for Diadromous Fish	Engage with and participate in the delivery of the strategic salmon and trout monitoring strategy at a local level (the Forth and Tay).

5 Review of Literature

97. In considering the adequacy of the Original EIA in respect of potential impacts on Atlantic salmon, a review of studies published since the submission of the Original Application has been undertaken. This information has been used to confirm or update the impact determinations reported in the Original Application documents.

98. A recent study undertaken by the Scottish Centre for Ecology and the Natural Environment (SCENE), in the River Deveron in Scotland, found that the trajectory of smolts leaving the river was north-easterly, which is the direction needed for fish to exit to the North Sea. On this swimming trajectory, smolts remained closer to the centre of the bay than to the coast, indicating that they may not follow geographical features, but have a mechanism for navigation that does not include contouring coastal land features (Lothian, et al., 2017). Lothian et al.'s (2017) study concurs with the literature used to inform the Original ES which suggested post-smolts actively and rapidly migrate away from their natal rivers.

99. Malcolm et al. (2015) investigated the timing of post-smolt migration to characterise periods of potential sensitivity. Analysis of pre-existing data around Scotland indicated that the majority of post-smolts will migrate between day of the year 103 – 145 (13 April – 24 May) from their natal rivers across Scotland. This may indicate periods of greater sensitivity when large numbers of smolts may be in coastal waters, however, no information on the amount of time that fish will spend in the coastal zone is available. In considering, the potential impacts of the Originally Consented Project, post-smolt migration was reported to occur between April and June. Although more recent publications suggest a narrower window of peak migrations, the general period of post-smolt migration aligns with the longer migration period, from late spring to early summer, considered in the Original EIA.

100. Recent tagging studies corroborated historical findings that migrating Atlantic salmon appear to show a preference for surface waters during return migrations, although fish do regularly use the full water column (Godfrey et al., 2015; Holm et al., 2005; Starlaugsson, 1995). Godfrey et al.'s (2015) recent observations, based on telemetry data from salmon tagged off the north coast of Scotland, noted that homing salmon may typically follow coastal swimming routes, but are by no means restricted to this zone. The Original ES relied on Malcolm et al.'s (2010) review of Atlantic salmon migratory patterns to inform the Original EIA, which also noted that migrating salmon often follow coastal swimming routes.

101. Godfrey et al. (2015) reported minimum daily travel rates of 23.4 km per day. Findings reflected historical findings of homing salmon migration estimated by mark-recapture in the Norwegian sea and fjords and the open sea off Scotland's east coast (Hansen, et al., 1993 and Pyefinch and Woodward, 1955, respectively), and by acoustic tracking off Scotland's east coast (Hawkins et al., 1979; Smith, et al., 1981). This confirms the understanding that migrating salmon within the Development Area are likely only transiting through the area on route to distant feeding grounds, or back to natal rivers. However, Godfrey et al. (2014) does acknowledge that interpretation of minimum daily travel rates should be interpreted with caution, since swimming behaviour may not necessarily reflect actual distance travelled.

102. Recent studies into the mechanism for navigation of Atlantic salmon when returning to natal rivers was conducted using historical datasets for sockeye salmon on the west coast of Canada. Putman et al. (2013) concluded that homing to natal rivers is achieved at least partially by geomagnetic navigation, and then by olfactory senses once in close proximity. Further study concluded that smolts inherit a 'magentic map' which allows smolts to navigate to remote feeding grounds and return to natal rivers (Putman et al., 2014). Putman (2015) noted that salmon species likely respond to spatial gradients in components of the geomagnetic field, such as the inclination angle of field lines, and the total field intensity, to navigate to and from natal rivers. Therefore, it may not be as simple as identifying magnetic field strength in the context of background magnetic field strength in identifying potential

effects in salmon species. This supports the assumption that EMF from cabling have the potential to impact on Atlantic salmon migratory behaviour considered in the Original ES, however, there remain gaps in scientific understanding that limit the confidence in predicting effects from subsea cabling.

103. Recent research has tried to further characterise the response behaviour of salmon to fishing using carefully controlled laboratory conditions. Harding et al. (2015) exposed Atlantic salmon to pile driving noise in aquaria using playback facilities, and did not observe any significant behavioural or physiological changes. This concurs with the Original EIA which considered salmon to be a hearing generalist, and not highly sensitive to noise related piling effects.

6 Appraisal of Original EIA Determinations

104. Published research since the submission of the Original ES has contributed to narrowing the gaps in knowledge of Atlantic salmon migratory behaviour across Scotland, although there remains a limited understanding of migration pathways to and from Scottish east coast rivers. Studies published since the Original EIA was undertaken largely support the assumptions underpinning the Original ES, and no new evidence has come to light to suggest otherwise. An appraisal of the original EIA determinations against the current design envelope for the Project, and in light of more recent scientific publications, is summarised in Table 6-1.

105. It is considered that recent publications in Atlantic salmon migratory behaviour align with the assumptions used to inform the Original EIA, and therefore validate the Original ES baseline. Further publications on Atlantic salmon's capability for detecting EMF provides further evidence that there is potential for Atlantic salmon to be affected by EMF associated with subsea cabling. This was assumed to be the case in conducting the Original EIA, and therefore does not invalidate the assessment methodology. Given the reduced project design parameters, and the application of embedded mitigation as detailed within the Scoping Report (NnGOWL, 2017) and section 4.1.1 above, it is considered that the determinations of the Original ES are still adequate and valid. As a result, effects on Atlantic salmon have been scoped out of the Project EIA, and are not considered further within Chapter 7: Fish and Shellfish Ecology of the Project EIA Report, except where they relate to pile driving associated effects of particle motion.

Table 6-1: Summary of the appraisal of the Original EIA in light of the revised design envelope and recent scientific publications and information on Atlantic salmon

Table Header	Original EIA significance of effect	Project design envelope change	Appraisal of recent research and information	Updated significance of effect
Construction – Offshore Wind Farm				
Physical habitat disturbance	Minor significance	Reduction in installed number of turbines from 125 to 54. Reduction in area of disturbance as gravity base foundations are no longer being considered.	Lothian et al., (2017) confirms that post-smolts are likely to migrate actively and directly away from natal rivers to remote feeding grounds. For returning grilse and MSW fish Godfrey et al. (2015) noted a preference for migrating along coastal swimming routes, although noted that fish are not restricted to these areas.	Recent information supports the initial assessment that migrating salmon are likely to pass through the site transiting to distant feeding grounds or natal rivers and are unlikely to utilise the Development Area for significant periods of time (e.g. extensive feeding). The significance of effect is still considered to be minor.
Increased suspended sediment	Minor significance	Reduction in installed number of turbines from 125 to 54. No pre-installation dredging as considered in the Originally Consented Project.	In addition to the findings of Godfrey et al. (2015) and Lothian et al. (2017), Godfrey et al. (2015) also found that salmon show a preference for surface waters although they do regularly use the entire water column.	As Atlantic salmon are likely to transit the site showing a preference for surface waters the potential impact of increased suspended sediment is not predicted to vary from the Original ES.

Table Header	Original EIA significance of effect	Project design envelope change	Appraisal of recent research and information	Updated significance of effect
				The significance of effect is still considered to be minor.
Increased sediment settlement and smothering	Minor significance	Reduction in installed number of turbines from 125 to 54. No pre-installation dredging as considered in the Originally Consented Project.	As detailed above for increased suspended sediment.	The significance of effect is still considered to be minor.
Pile driving noise	Minor significance	Reduction in total number of piles from 532 to 336 although only up to 10% will be piled, the rest will likely be installed using a drill-drive-drill method.	As above, Atlantic salmon are likely to transit through the site and are not likely to be excluded from important habitats as a result of pile driving noise. Harding et al's (2015) investigation into salmon sensitivity to pile driving noise corroborated the assumption that Atlantic salmon was a hearing generalist with low sensitivity to pile driving noise.	The evidence from Harding et al. (2015) supports the findings of the Original EIA. The significance of effect is still considered to be minor.

Table Header	Original EIA significance of effect	Project design envelope change	Appraisal of recent research and information	Updated significance of effect
Construction – Export Cable				
Physical habitat disturbance	Minor significance	The length of the Offshore Export Cable for the Project has increased from 33 km to 43 km to account for the distance between the Wind Farm Area boundary and the OSP locations in the centre of the Wind Farm Area. However, the overall area of disturbance for the Project remains within the overall disturbed area associated with the Originally Consented Project due to the reduction in turbine numbers and consideration of jacket foundations only.	As above for physical habitat disturbance.	The significance of effect is still considered to be minor.
Increased suspended sediment	Minor significance	The length of the Offshore Export Cable for the Project has increased from 33 km to 43 km to account for the distance between the Wind Farm Area boundary and the OSP locations in the centre of the Wind Farm Area. However, the overall area	As detailed above for increased suspended sediment (Construction – Offshore Wind Farm).	The significance of effect is still considered to be minor.

Table Header	Original EIA significance of effect	Project design envelope change	Appraisal of recent research and information	Updated significance of effect
		of disturbance for the Project remains within the overall disturbed area associated with the Originally Consented Project due to the reduction in turbine numbers and consideration of jacket foundations only.		
Increased sediment settlement and smothering	Not significant	The length of the Offshore Export Cable for the Project has increased from 33 km to 43 km to account for the distance between the Wind Farm Area boundary and the OSP locations in the centre of the Wind Farm Area. However, the overall area of disturbance for the Project remains within the overall disturbed area associated with the Originally Consented Project due to the reduction in turbine numbers and consideration of jacket foundations only.	As detailed above for increased suspended sediment (Construction – Offshore Wind Farm).	The significance of effect is still considered to be not significant.

Table Header	Original EIA significance of effect	Project design envelope change	Appraisal of recent research and information	Updated significance of effect
Operation – Offshore Wind Farm				
Permanent habitat loss	Minor	Reduction in number of turbines from 75[5] to 54, and a reduction in overall footprint of the jackets from 1,600 m^2 to 1,200 m^2. OSPs and cable infrastructure remains the same.	Historical and more recent evidence suggests salmon predominately follow coastal swimming pathways and may pass through the Wind Farm Area in transit to feeding grounds and / or natal rivers (Godfrey et al., 2015; Lothian et al. 2017).	The significance of effect is still considered to be minor.
Changes in hydrodynamic regimes	Minor	Reduction in number of turbines from 125 to 54 and change in foundation type (gravity bases to jackets).	The modelling of the hydrodynamic regime considered 126 gravity base structures. The Original ES concluded that changes in the hydrodynamic regime would be highly localised and within natural fluctuations. Given the reduction in the number of	The significance of effect is still considered to be minor.

[5] 75 gravity base foundations with a footprint of 1,600 m^2 was considered the worst case with regards to loss of habitat as it was greater than the area of habitat lost due to the 125 turbine option.

Table Header	Original EIA significance of effect	Project design envelope change	Appraisal of recent research and information	Updated significance of effect
			turbines, and the change in design to a jacket foundation, the Original ES assessment remains valid for the Project.	
Introduction of new substrata	Minor	Reduction in number of turbines and associated scour protection from 125 to 54.	As above for permanent habitat loss.	The significance of effect is still considered to be minor.
Operational noise	Minor	Reduction in number of operating turbines from 125 to 54.	There has been no further research into the potential impacts on salmon resulting from operational turbine noise since the submission of the Original ES. Given the reduction in turbine numbers, it is anticipated that there will be an overall smaller footprint of noise exposure. In addition, Harding et al.'s findings that salmon are considered a hearing generalist further support the Original ES determinations.	The significance of effect is still considered to be minor.

Table Header	Original EIA significance of effect	Project design envelope change	Appraisal of recent research and information	Updated significance of effect
Operation – Export Cable				
Heating effects	Not significant	Increase in cable length from 33 km per Offshore Export Cable to 43 km per Offshore Export Cable to account for distance from the Wind Farm Area boundary to the OSP locations.	There has been no further findings on the potential effects of heating on Atlantic salmon. However, the proposed mitigation (see Section 244.1.1) remains effective in reducing the likelihood of any effects.	The significance of effect is still considered to be not significant.
Electromagnetic fields generated by subsea cables	Minor significance	Increase in cable length from 33 km per Offshore Export Cable to 43 km per Offshore Export Cable to account for distance from the Wind Farm Area boundary to the OSP locations.	Recent research by Putman et al., (2013, 2014) and Putman (2015) confirms the assumption that salmon may be sensitive to EMF from subsea cabling. However, given the proposed embedded mitigation (see Section 244.1.1) and the limited spatial footprint of the Offshore Export Cable, it is considered that the Original EIA remains valid.	The significance of effect is still considered to be minor.

Table Header	Original EIA significance of effect	Project design envelope change	Appraisal of recent research and information	Updated significance of effect
Cumulative Construction Impacts				
Physical Habitat disturbance	Minor significance	The Project design parameters have been refined as detailed above. It is likely that the design envelopes for the Inch Cape and Seagreen projects that are likely to be built out on the existing consents, or based on the most recent refined project design envelopes that are outlined in their respective project scoping reports (ICOL, 2017; Seagreen, 2017), will have the same or lesser effect on Atlantic salmon than those assessed in the Original EIA.	As detailed above in relation to the Project alone.	The significance of effect is still considered to be minor.
Increased Suspended Sediment Concentration, Sediment Settlement and Smothering	Minor significance	The Project design parameters have been refined as detailed above. It is likely that the design envelopes for the Inch Cape and Seagreen projects that are likely to be built out on the existing consents, or based on the refined down project design envelopes outlined in their respective project scoping	As detailed above in relation to the Project alone.	The significance of effect is still considered to be minor.

Table Header	Original EIA significance of effect	Project design envelope change	Appraisal of recent research and information	Updated significance of effect
		reports (ICOL, 2017; Seagreen, 2017), will have the same or lesser effect on Atlantic salmon than those assessed in the Original EIA.		
Piling noise	Minor to moderate significance	The proposed scoping reports for Inch Cape and Seagreen were both scoped based on increased hammer energy and the use of monopiles respectively. Therefore, the impact associated with pile driving noise may be greater.	As detailed above in relation to the Project alone. In addition, following consent, the Scottish Ministers attached a consent condition requiring a Piling Strategy to be submitted, for approval, outlining any mitigation required in respect of a number of fish species. It is anticipated that this condition will be attached to future consents to manage and mitigate the risk to fish receptors including Atlantic salmon.	The significance of effect is still considered to be minor to moderate.

Table Header	Original EIA significance of effect	Project design envelope change	Appraisal of recent research and information	Updated significance of effect
Cumulative Operational Impacts				
Permanent habitat loss	Minor significance	As above in relation to permanent habitat loss for the Project alone.	As above in relation to permanent habitat loss for the Project alone.	The significance of effect is still considered to be minor.
Changes in hydrodynamic regime	Minor significance	As above in relation to changes in hydrodynamics for the Project alone.	As above in relation to changes in hydrodynamics for the Project alone.	The significance of effect is still considered to be minor.
Introduction of new substrates	Minor significance	As above in relation to introduction of new substrate for the Project alone.	As above in relation to introduction of new substrate for the Project alone.	The significance of effect is still considered to be minor.
Operational noise	Minor significance	As above for in relation to operational noise for the Project alone.	As above for in relation to operational noise for the Project alone.	The significance of effect is still considered to be minor.
Electromagnetic fields generated by subsea cables	Minor significance	As above in relation to EMF for the Project alone.	As above in relation to EMF for the Project alone.	The significance of effect is still considered to be minor.

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