The Keadby 3 Low Carbon Gas Power Station Project

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The Keadby 3 (Carbon Capture Equipped Gas Fired Generating Station) Order

Land at and in the vicinity of the Keadby Power Station site, Trentside, Keadby, North Lincolnshire

Environmental Statement
Volume II - Appendix 11H: Underwater Sound Effects on Fish

The Planning Act 2008

The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017

Applicant: Keadby Generation Limited

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GLOSSARY

Abbreviation	Description
ANSI	American National Standards Institute
dB	Decibel
MLWS	Mean Low Water Springs
NSR	Noise Sensitive Receptor
PTS	Permanent Threshold Shift
SEL	Sound Exposure Level
SPL	Sound Pressure Level
SSL	Sound Source Level
TTS	Temporary Threshold Shift

CONTENTS

TABLES

1.0 INTRODUCTION

1.1 Overview

1.1.1 This Technical Appendix provides additional detail in relation to the potential effects of underwater sound on relevant fish species (species of conservation importance) to supplement and inform the ecological impact assessment of the proposed construction works within either (depending on the final choice on the cooling water supply for the Proposed Development) the River Trent or the Stainforth and Keadby Canal. The ecological impact assessment is provided in **Chapter 11**: Biodiversity (ES Volume I – **Application Document Ref. 6.2**). The construction activity most relevant to fish and therefore the related ecological impact assessment is construction of a cofferdam, due to the associated requirements for piling (as described below in Section 1.2) which can generate underwater sound and vibration.

1.1.2 The relevant fish species likely to be present in the River Trent are river and sea lamprey (*Lampetra fluviatilis* and *Petromyzon marinus* respectively), European eel (*Anguilla anguilla*) and Atlantic salmon (*Salmo salar*).

1.1.3 Only European eel is likely to be found in association with the Stainforth and Keadby Canal given this watercourse is not favourable habitat for the other species and due to the presence of physical barriers to access (canal locks). Given that similar construction works have relatively recently been consented and completed within the Stainforth and Keadby Canal for the Keadby 2 Power Station cooling water intake, it is considered that it is reasonable to assume that European eel was considered for that consent and that no impact on conservation status was considered likely. Given this, it is considered that this presumption can be re-applied for the Proposed Development. Accordingly, no further assessment of the works in the canal is required within this appendix, and the focus of the assessment is on relevant fish species associated with the River Trent.

1.1.4 As a designating feature of the Humber Estuary SAC and Ramsar site, the effect of underwater sound in relation to river and sea lamprey are also considered in the Habitat Regulations Assessment Screening Report (**Application Document Ref. 5.12**).

1.2 Cofferdam Construction

1.2.1 The activities required for the construction of a cofferdam for the Proposed Development cooling water intake are described in **Chapter 5**: Construction Programme and Management (ES Volume I – **Application Document Ref. 6.2**) and are anticipated to produce impulsive sounds (where hammer pile-driving is required) and continuous sounds (where vibratory pile-driving is undertaken, and from the movement of project vessels). These activities will be sources of underwater sound and vibration within the river, which in turn has the potential to affect fish. However, the proposed cofferdam is relatively small in scale and the construction period and associated duration of the sound and vibration impact is expected to be of relatively limited duration (refer to paragraph 1.2.2).

1.2.2 The exact materials to be used for the construction of the cofferdam are not known and so the assessment is informed by typical cofferdam construction methods within marine and tidal conditions and is based on previous AECOM project experience and information available in literature. The cofferdam construction assumptions used as the basis for this assessment are therefore as follows:

- vibratory or press piling will be used where this is reasonably practicable, but it is often necessary to drive the final stages of a pile with a hammer and thus the impacts of (hammer driven) piling and vibratory piling have both been assessed;
- sheet piles, such as an AZ-36 700N (100 x 600 mm) would be used for the construction of the cofferdam;
- the cofferdam would require approximately 100m of sheet piles which equates to approximately 200 individual piles;
- based on the relatively shallow depth of water in which the cofferdam is proposed, it is assumed that the cofferdam will comprise a single wall, but the structure will require bracing and pile ties to secure the cofferdam wall before dewatering. Thus, periods of piling activity will be regularly interspersed with other construction activities that will not generate underwater sound;
- it is estimated that each pile will take 1-2 hours to install, depending on conditions, and that 4-5 piles can be installed per day based on the core construction working hours from 07:00 to 19:00 (**Chapter 5**: Construction Programme and Management (ES Volume I - **Application Document Ref. 6.2**));
- on this basis, the estimated piling installation time (vibratory and impact) for the cofferdam will be 25 days. This will be spread throughout the construction period which is expected to also involve bracing and addition of pile ties as the construction progresses. Piling will therefore be intermittent throughout the cofferdam construction programme, with gaps between piling even when no underwater sound is produced; and
- a jack-up barge will be required for installation of the piles below Mean Low Water Springs (MLWS).

1.2.3 The above approach is supported by wider requirements for responsible construction given the proximity of the proposed cofferdam residential noise sensitive receptors (NSR) along Trentside, Keadby village. This is further described in **Chapter 9**: Noise and Vibration (ES Volume I – **Application Document Ref. 6.2**).

1.3 Underwater Sound Background

1.3.1 Sound travels about four-and-a-half times faster in water than in air. The absorption of sound at frequencies where man-made sound generally has the most energy is much smaller in water than in air. As a result, sound is typically audible underwater over much greater distances.

1.3.2 Sound is usually categorised according to whether it is impulsive or continuous in nature. Impulsive sounds are of short duration and can occur singularly, irregularly, or as part of a repeating pattern. Activities generating impulsive sound includes impact piling and explosions, as well as geophysical and seismic survey works. In contrast, continuous sounds occur without pauses or pulses and arise from activities that include vessel movements, drilling and vibratory piling.

1.3.3 The impact of underwater sound on fish ranges from behavioural responses to auditory injury, with the magnitude of impact dependent on the intensity and duration of the sound. In the most extreme cases, such as explosions from the detonation of unexploded ordnance, underwater sound results in tissue injury or mortality.

1.3.4 Not all fish species are equally sensitive/ vulnerable. The impact of underwater sound on fish is, to a large extent, determined by the physiology of fish, particularly the presence or absence of a swim bladder and the potential use of the swim bladder to improve the hearing sensitivity and range of hearing. These morphological features have been used to define three categories of fish, related to their sensitivity (how they might be affected by) to underwater sounds (Popper *et al*., 2014), as described below:

- **high hearing sensitivity fish** – species in which hearing involves a swim bladder or other gas volume (e.g. herring and other Clupidae species). These species are susceptible to barotrauma (e.g. rupture of swim bladder) and detect sound pressure as well as particle motion.
- **medium hearing sensitivity fish** – species with swim bladders in which hearing does not involve the swim bladder or other gas volume (including priority species such as Atlantic salmon and European eel). These species are susceptible to barotrauma although hearing only involves particle motion, not sound pressure.
- **low hearing sensitivity fish** – species with no swim bladder or other gas chamber (e.g. all lamprey species and elasmobranchs) are less susceptible to barotrauma. Hearing in these species involves detecting particle motion rather than sound pressure.

1.3.5 Where more sensitive fish species (i.e. those with swim bladders, so excluding lamprey species) are in very close proximity to a sound source of very high sound pressure level, such as impact pile driving of very large steel piles, physical injury (e.g. swim bladder rupture) and subsequent mortality could occur. The extent of injury is related to sound intensity (the sound pressure level) and the number of pile-driving strikes (Halvorsen *et al*., 2012). A range of other physiological effects (e.g. barotrauma[1] induced effects such as haemorrhaging, embolism and bulging eyes) and physical damage to the auditory system structures (i.e. inner ear/sensory hair cells and otoliths) may also occur (Nedwell *et al*., 2006).

1.3.6 Behavioural responses can also occur (and this can also have a bearing on the likelihood of injury occurring, as explained later) and include startle reactions, changes in swimming patterns and orientation, disrupted schooling patterns, altered horizontal or vertical distributions, disrupted feeding, and displacement. The behavioural response to adverse underwater sound levels are of most concern when works are being undertaken during periods of high seasonal sensitivity. In particular, underwater sound can lead to abandonment of fish spawning sites and diversion or delay of fish migration. In most situations this is only a potential concern when the affected species are of conservation concern (threatened or specifically protected).

[1] Barotrauma is physical damage to body tissues caused by a difference in pressure between a gas space inside, or in contact with, the body, and the surrounding gas or fluid.

2.0 TECHNICAL ASSESSMENT

2.1 Impact Piling – European Eel and Atlantic salmon

2.1.1 The most up-to-date underwater sound thresholds for fish are the 2014 guidelines published by the American National Standards Institute (ANSI) (Popper *et al*., 2014). Table 1 below summarises the thresholds defined for impulsive sound, such as impact piling, for each of the three fish hearing sensitivity categories for impact criteria ranging from injury to behavioural responses.

2.1.2 For impulsive sound, the injury thresholds are expressed as dual criteria including a single strike peak sound pressure level (SPL) and the cumulative energy over a period of impulses, called the sound exposure level (SEL_{cum}). The thresholds cover physical injury (mortality/ mortal injury and recoverable injury), and auditory injury which is called temporary threshold shift (TTS) and is an elevation in hearing threshold resulting in a temporary reduction in hearing sensitivity.

2.1.3 There are no generally accepted quantitative thresholds available for behavioural responses, largely due to a lack of experimental evidence and high levels of context specific variation in behaviour depending on factors such as sex, age, size and motivation (e.g. foraging) of individual fish. Instead behavioural impact criteria are provided in terms of a relative risk (high, moderate, low) at a distance from the impulsive sound source defined in relative terms as 'near' (N), 'intermediate' (I), and 'far' (F) (Table 1). Whilst absolute values cannot be ascribed to these categories, near can be defined to be in the range of tens of metres from the source, intermediate in the hundreds of metres, and far in the thousands of metres.

Table 1: Underwater sound impact thresholds for fish in relation to impulsive sound sources

Fish Hearing Sensitivity	Mortality/mortal injury	Recoverable injury	Temporary Threshold Shift (TTS)	Behaviour
Low e.g. lamprey	$213dB_{peak}$ $219dB\ SEL_{cum}$	$213dB_{peak}$ $216dB\ SEL_{cum}$	$186dB\ SEL_{cum}$	(N) High (I) Moderate (F) Low
Medium e.g. Atlantic salmon	$207dB_{peak}$ $210dB\ SEL_{cum}$	$207dB_{peak}$ $203dB\ SEL_{cum}$	$186dB\ SEL_{cum}$	(N) High (I) Moderate (F) Low
High e.g. Herring	$207dB_{peak}$ $207dB\ SEL_{cum}$	$207dB_{peak}$ $203\ dB\ SEL_{cum}$	$186dB\ SEL_{cum}$	(N) High (I) High

Fish Hearing Sensitivity	Mortality/mortal injury	Recoverable injury	Temporary Threshold Shift (TTS)	Behaviour
				(F) Moderate
Eggs and larvae	207 dB_{peak} 210 dB SEL_{cum}	-	-	(N) Moderate (I) Low (F) Low

2.1.4 The SPL is a measure of the amplitude or intensity of a sound. For impulsive sound sources this is typically measured as a peak value (i.e. the highest amplitude of the pulse). In contrast, the SEL is a time-integrated measurement of the sound energy, which takes account of the level of sound as well as the duration over which the sound is present in the acoustic environment. The assessment of effects to fish and other marine species is based on dual criteria, with a threshold for both the SPL and the SEL metric, and the impact zone is determined by whichever results in the largest estimated distance.

2.1.5 To determine whether impact piling activities are likely to generate sound levels which may exceed the sound thresholds of fish, literature values of the zone of influence, based on geometric spreading calculations for impact piling of a very wide range of pile types have been used (as agreed with by AECOM with regulators previously for the Uig Harbour Redevelopment EIA, see AECOM, 2019). These literature values, provided below in Table 2, include predicted impact zones for large tubular piles, known to generate high sound levels, and so this represents a worst-case that covers sound levels produced during the installation of the sheet piles used to construct a cofferdam.

2.1.6 For the determination of the distance at which the thresholds are met based on SEL, the calculations have assumed an impact piling strike every 15 seconds over a 15-minute accumulation period for a single pile. In practice, as explained previously in Section 1.2, hammer driven piling is generally short term, with its use limited to driving the final section of the pile into the ground. In addition, construction is intermittent with regular breaks to allow for tolerance checks and the addition of bracing and pile ties required for the stability and strength of the cofferdam. Thus, underwater sound from impact piling will be short-term and intermittent, occurring for a period of around 15 minutes, 3-4 times per day. However, the TTS zone of influence is also provided for an uninterrupted piling period of one hour, although it is not likely that it would continue for this long.

2.1.7 The predictions are based on a stationary receiver and a stationary source assumption, and do not take into account any movement of the source or receiver, the frequency spectrum of the sound source or the hearing sensitivity weightings of the receptor species. In addition, geometric spreading calculations over-estimate the effect at distance.

Table 2: Estimated worst case impact distances (m) for fish in relation to underwater sound from impact piling (based on geometric spreading calculations)

Fish Hearing Sensitivity	Metric	Mortality/ mortal injury (m)	Recoverable injury (m)	TTS (m)
Low e.g. Lamprey	SPL SEL_{cum}	<10 <10	<10 <10	40 (15 mins) 101 (60 mins)
Medium e.g. Atlantic salmon	SPL SEL_{cum}	<10 <10	<10 <10	
High e.g. Herring	SPL SEL_{cum}	<10 <10	<10 <10	
Eggs and larvae	SPL SEL_{cum}	<10 <10	<10	

2.1.8 Sound propagation calculations indicate that physical injury to fish, even species with the most sensitive hearing, based on both the SPL and the SEL thresholds, is highly unlikely to occur unless fish are in very close proximity i.e. within 10m of the sound source from impact piling.

2.1.9 A temporary impairment in the hearing of all fish species (TTS) is predicted up to a maximum distance of 40m from the sound source for a 15-minute exposure. This increases to 101m for a continuous 60-minute exposure. It is anticipated that impact piling is only likely to occur without interruption for a period of between 15 and 30 minutes, after which there will be a break in the underwater sound produced. So, the zone of influence for potential hearing impairment will be somewhere between these two distances.

2.1.10 While acknowledging these potential pathways for impact, it is required that standard mitigation for impact piling in marine waters be adopted (JNCC, 2010). Thus, a soft-start or slow ramp-up of piling hammer power will be employed at the commencement of any impact piling activity or after a break of more than 10 minutes. This will assist in allowing sound levels to increase gradually, and any fish in the immediate vicinity of piling has an opportunity to make a behavioural response to the sound and move away before any permanent or temporary injury is likely to occur.

2.1.11 Thus, no injury or impairment to hearing, either permanent or temporary, is likely to occur in any fish species, including species of conservation concern.

2.1.12 Some disturbance of fish is still likely to occur in response to impact piling, particularly in areas closest to the sound source. Behavioural responses can range from startle reactions and sudden fleeing to a slight alteration in swimming orientation or position in the water column.

2.1.13 Given the relative thresholds shown in Table 2, there is considered to be a moderate risk that behavioural disturbance in low and medium sensitivity fish (including migratory Atlantic salmon and European eel) will occur at intermediate distance, i.e. within the order of hundreds of metres from the sound source. The risk of behavioural disturbance is only high for fish in close proximity, in the order of tens of metres distance from the impact piling activity. As the River Trent at this location is approximately 150m wide, the behavioural impact from piling could therefore potentially extend across the full width of the river and pose a barrier to fish movements, including the identified species of conservation concern.

2.1.14 While this potential behavioural response is beneficial for reducing likelihood of fish injury or mortality within 10m of the sound source, it could also be adverse if it affected the ability of fish to access key habitats within the wider river. While a behavioural response is likely, the ecological/ fitness consequences of this response for the fish species concerned is likely to be limited, due to the mitigation described above, the timing and intermittent nature of the sound, and the reasonable expectation that there will be gradual habituation of the affected fish species.

2.1.15 Any such behavioural disturbance would be intermittent only, due to the restricting of piling works to core daytime working hours. In combination with soft start, this will provide a significant period of time each day when there is no construction activity and associated underwater sound.

2.1.16 There is no evidence to suggest that there are fish species or life stages exhibiting strong site fidelity within the potential zone of influence of the piling (see **Appendix 11G**: Aquatic Ecology Survey Report (ES Volume II - **Document Reference 6.3**)). The exception to this may be where the behavioural response meaningfully impedes the movement of migratory species.

2.1.17 There are migratory species of conservation concern known to be present, transiting through the study area and that can use areas of the river beyond the impact zone. The proposed restrictions on when piling operations take place have direct relevance to assessment of potential for behavioural impacts on key migratory fish species, as certain life stages (juveniles/smolts of Atlantic salmon and adult European eel) migrate predominately at night (Environment Agency, 2017). Thus, there is limited potential for downstream migration of juvenile Atlantic salmon or adult European eel to be disrupted by the piling works. However, there remains potential for impedance of the upstream migration of adult Atlantic salmon and juvenile European eel as this could occur during daylight hours when piling is ongoing.

2.1.18 To address the risk to adult Atlantic salmon, piling would be subject to a precautionary seasonal restriction, with no piling activity in the period

September to November (while the River Trent is not a major Atlantic salmon river the species is present, and recent projects to remove physical barriers to migration are anticipated to benefit the population over time).

2.1.19 In the case of European eel, upstream migration of juveniles (glass eels) is less seasonal in nature meaning that activity is not concentrated within a limited timeframe, and consequently survival or fitness of juveniles is less likely to be affected (relative to adult Atlantic salmon). The time that juvenile eels spend in estuaries before moving into freshwater can last from a few weeks to years and the tendency for migration is correlated with body condition (Cresci, 2020) therefore there is no clear period in which the overall population is likely be affected. Juveniles also tend to utilise the tidal flood current to assist movement, given the limited period over which such tidal movements occur, this also serves to limit the potential for movements of juvenile European eels to coincide with piling (Cresci, 2020). Given this, European eel is inherently less sensitive to potential disturbance from piling given the restricted timeframe required for these works (estimated as 25 days, see Section 1.2). Therefore, no specific mitigation is considered necessary.

2.1.20 Considering all of the above, including adherence to JNCC guidance and seasonal restrictions on piling, the potential for adverse underwater sound impacts and effects on fish from impact piling is **very limited** and is not likely to affect the conservation status of any fish species.

2.2 Impact Piling – Lamprey Species

2.2.1 While the parameters for assessment are the same as defined above in Section 2.1, given the specific importance of the two lamprey species it is considered appropriate to address these species separately.

2.2.2 Lamprey species are categorised as low hearing sensitivity fish species (Popper *et al.*, 2014) because they lack specialist hearing structures and consequently their ear is relatively simple (they have no swim bladder or anatomical structure tuned to amplify sound signals). Instead, lamprey species are generally considered to be sensitive only to sound particle motion within a narrow band of frequencies. Indeed, some research indicates that they may only be sensitive to particle motion (Popper & Hawkins, 2019).

2.2.3 Because of this physiology they are inherently resilient to the kinds of physical injury (e.g. barotrauma) that other fish species can experience as result of adverse levels of underwater sound and vibration and therefore physical injury is highly unlikely to occur.

2.2.4 Regardless of this conclusion, in order to protect other fish species that are not qualifying features of the Humber Estuary SAC, the Proposed Development will adopt the standard mitigation for protection of marine receptors from the effect of underwater sound (JNCC, 2010), specifically a soft-start for all hammer driven piling activity. Whilst these measures are designed for the protection of marine mammals, they also provide protection for fish. These measures ensure that sound intensity from piling, and any associated particle motion, will increase only gradually before reaching full power. This soft start will allow opportunity for individual lampreys located within the potential zone of influence for an adverse noise or vibration impact (i.e. within 10m of the noise/vibration source) opportunity to move away from the construction area before there is potential for an impact to be realised.

2.2.5 For the reasons given above and in Section 2.1, it is usually considered that adverse changes in behaviour (e.g. behavioural changes that affect migration) as a result of underwater noise and vibration on lamprey are also not likely to occur. Lampreys would need to be very close to a powerful noise source for a behavioural response to occur (Popper, 2005; Popper and Hastings, 2009). Lenhardt and Sismour (1995) carried out experiments on sea lamprey and detected a startle response to frequencies between 20 and 100Hz. However, the response was considered likely to be more due to vibration than waterborne noise. Startles while swimming were rare, suggesting that direct contact with the vibrating surface was needed to trigger the reaction. As further indirect evidence of this, the river lamprey was included in a study on the effect of a playback system (with emission frequencies between 20 and 600Hz) in reducing estuarine fish intake rates at a power plant cooling water inlet (Maes *et al*., 1999 and 2004). No significant reductions in river lamprey catches were observed confirming a lack of behavioural response to the noise deterrent.

2.2.6 The absence of a significant sensitivity or response of lamprey within the above studies combined with the adopted good practice construction methods indicates that it is not likely that the conservation status of lamprey species would be adversely affected by underwater sound and vibration.

2.3 Continuous Sound

2.3.1 Vibratory piling and the movement of vessels (primarily on the River Trent) during construction also has the potential to produce underwater sound. These sound sources are continuous in nature, for which a mixture of qualitative and quantitative thresholds are defined (Popper *et al*., 2014), as set out in Table 3. Thus, whilst vibratory piling is much quieter than impact piling, it does occur for longer and thus any particle motion effects will be of a longer duration.

2.3.2 In relation to vessel movements, the River Trent is an existing well-used navigable river with existing port facilities at various points, including at Keadby, adjacent to the Proposed Development Site (Waterborne Transport Offloading Area). Any vessels deployed are likely to be relatively small due to the depth of the river at the cofferdam location. In addition, the jack-up barge used for piling activities will be stationary for much of the time, with its legs jacked down onto the riverbed. Thus, the limited vessel movements during construction are not anticipated to materially alter the baseline underwater sound conditions or affect fish species. Consequently, the impact assessment is concerned only with additional noise sources from vibratory piling.

2.3.3 Very little information has been found to be available on the impact of particle motion from vibratory piling. Even the most recent studies of the impact of sound on fish (e.g. see Hawkins and Popper, 2017; Popper and Hawkins, 2019) concentrate mainly on the effect of sound pressure. Quantitative thresholds are only available for recoverable injury and TTS in high sensitivity fish. Thus, for the fish species in the river of conservation importance (Atlantic salmon, European eel and lamprey) the only available thresholds are qualitative, using relative risk ratings such as those applicable for behavioural responses to impulsive sound as described in above in Section 2.1.

Table 3: Underwater sound impact thresholds for fish for continuous sound sources

Fish Hearing Sensitivity	Mortality/ mortal injury	Recoverable injury	Temporary Threshold Shift (TTS)	Behaviour*
Low e.g. Lamprey	(N) Low (I) Low (F) Low	N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low
Medium e.g. Atlantic salmon	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low
High e.g. Herring	(N) Low (I) Low (F) Low	170 dB SPL_{rms} (unweighted) re. 1µPa, for 48 hours	158 dB SPL_{rms} (unweighted) re. 1µPa, for 12 hours	(N) High (I) Moderate (F) Low
Eggs and larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low

2.3.4 The thresholds indicate that the risk of mortality from vibratory piling and vessel movements, for all hearing categories of fish at all distances, even in very close proximity from the activity, is low (Table 3). The potential for recoverable injury is also considered to be of low risk for low hearing sensitivity (lamprey species) and medium hearing sensitivity (Atlantic salmon and European eel) fish species. No species of high hearing sensitivity have been identified as being functionally reliant on the river. Thus, the risk of significant harm to fish of conservation importance from vibratory piling is considered to be negligible.

2.3.5 Table 3 indicates that the most important impact on all fish receptors from continuous sound sources anticipated during construction relates to the potential for behavioural responses (e.g. displacement and disturbance) rather than physical or physiological effects. There is a moderate risk for low and medium sensitivity fish in the near and intermediate distance (probably between 10s to 100s of metres from the sound source). Migratory species such as Atlantic salmon and lamprey species are known to be sensitive to particle motion as well as sound pressure (with lamprey needing to make contact with a vibrating surface for a response to be likely, see Section 2.2).

2.3.6 Behavioural responses are likely to include swimming away and a change of swimming direction, orientation or position in the water column. However, the risk of the more significant responses such as startle reactions from vibratory piling and vessel movements is low.

2.3.7 It is anticipated that most of the piling activity will be vibratory in nature, with each pile expected to take circa 1-2 hours (including impact piling for the last stage of piling) with an average of 4-5 piles installed per day. However, as several construction activities need to take place between piles, vibratory piling will also be highly intermittent. Thus, as soon as the vibratory piling stops, fish may return to areas around the cofferdam construction. Fish are also known to habituate to sound over time, particularly when there is high motivation to do so (Popper *et al*., 2014) e.g. migration or access to feeding habitats.

2.3.8 The commitment to avoid any piling activity in the period September to November is sufficient to manage the potential impact on adult Atlantic salmon (it having already been established that juveniles migrate primarily at night when piling would not take place). The rationale presented for European eel in Section 2.1 also remains relevant, given the relatively limited duration for piling (up to 25 days) are not likely coincide with the majority of movements by this species. Lamprey species are also not a relevant consideration given their inherent lack of sensitivity to underwater sound means that adverse impacts are unlikely (Section 2.2).

2.3.9 Considering the committed mitigation for impact piling, and the seasonal restriction for the protection of migratory Atlantic salmon, and the relatively low magnitude of any potential behavioural responses over the limited period of piling (which includes breaks in activity), any potential impact is considered **negligible** and is <u>not likely to be adverse for the conservation status of any fish species.</u>

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