
Technical Literature Review

Reference: The Impact of Above-Ground Noise and Vibration Near Waterbodies on Aquatic Receptors

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Abstract

This technical literature review examines the current understanding of the effects of above-ground noise and vibration from construction and operational activities on aquatic receptors, particularly fish and invertebrates, in proximity to UK waterbodies. Recent research demonstrates that noise and vibration from terrestrial sources such as piling, heavy machinery, and vehicle traffic can propagate into aquatic habitats, causing acute and chronic effects on resident species (Roberts et al., 2016; Popper et al., 2021; Marine Scotland, 2024). The review analyses how noise and vibration propagate at varying distances (adjacent, 10m, 50m, and 100m from the waterbody) and summarizes the sensitivity of aquatic species to these disturbances. Acute impacts, such as stress, startle responses, and avoidance behaviour, are most pronounced within 10 meters, while chronic exposure at greater distances may alter habitat use, community structure, and reproductive success (Hawkins et al., 2014; Radford et al., 2016). Invertebrates are generally less affected by airborne noise but can be sensitive to substrate-borne vibration, which may disrupt settlement, foraging, and predator avoidance (Roberts et al., 2016; Branscomb and Rittschof, 1984). The review highlights recent laboratory and field studies, recommends mitigation strategies such as noise barriers, activity scheduling, and real-time monitoring, and underscores the importance of site-specific assessment and proactive management to protect aquatic ecosystems during nearby terrestrial works.

Introduction

Construction and operational activities near waterbodies, such as piling, earthworks, and heavy vehicle movements, can generate significant levels of airborne noise and ground-borne vibration. These disturbances have the potential to impact aquatic receptors, including fish and invertebrates, depending on proximity, intensity, and duration of exposure (Marine Scotland, 2024; Fab Link, 2016; Mona ES, 2024). Propagation of noise over water is influenced by factors such as geometric spreading, atmospheric absorption, and ground reflections, which can amplify or attenuate sound levels at the water's edge (Mona ES, 2024). Substrate-borne vibrations can travel considerable distances through the ground and into the aquatic environment, where they are detected as particle motion by both fish and invertebrates (Roberts et al., 2016; Popper et al., 2021).

Recent advances in understanding fish hearing mechanisms demonstrate that most fish species primarily respond to particle motion rather than sound pressure, making substrate-borne vibration particularly relevant to their sensory ecology (Popper and Hawkins, 2018; Hawkins et al., 2021). New research has also revealed that fish utilise both direct particle motion detection and indirect pressure sensing pathways, with the

relative importance varying between species and frequency ranges (Nedelec et al., 2016; Popper et al., 2019).

Impact Zones

Adjacent (0–10m):

Aquatic receptors within 10 meters of high-intensity noise or vibration sources are at greatest risk of acute effects. Fish may exhibit stress responses, startle reactions, avoidance behaviour, and reduced feeding or spawning activity (Marine Scotland, 2024; OceanCare, 2018; Roberts et al., 2016). Recent studies show that fish exposed to construction noise levels exceeding 150 dB re 1µPa demonstrate immediate behavioral changes including increased swimming speed, altered depth distribution, and elevated stress indicators (Andersson et al., 2023; Popper et al., 2021).

Vibration can destabilise sediments, affecting invertebrate habitats and potentially disrupting benthic communities (Roberts et al., 2016; Brims Tidal, 2015). André et al. (2011) demonstrated that short-term exposure to high-intensity low-frequency sound can cause severe physiological damage to cephalopods, and similar mechanisms may affect sensitive invertebrate taxa in freshwater and estuarine systems. New research indicates that macroinvertebrates show behavioral responses to substrate vibration across frequencies of 5-410 Hz, with highest sensitivity around 170 Hz for crustaceans (Roberts et al., 2015; Heinisch and Wiese, 1987).

10–50m:

At intermediate distances, intermittent disturbance and masking of communication signals become more relevant. Chronic stress can result from repeated exposure, potentially leading to altered movement patterns, reduced foraging efficiency, or displacement from preferred habitats (Fab Link, 2016; Radford et al., 2016; River Thames Scheme, 2024). Fish may habituate to repeated noise, but chronic exposure can still result in changes to hearing thresholds and long-term population effects (Radford et al., 2016; Popper et al., 2021).

Recent field studies demonstrate that fish schools lose cohesion and coordination when exposed to pile-driving noise, potentially increasing predation vulnerability (Ioannou et al., 2017). Laboratory experiments show that even relatively low-intensity noise (120 dB re 1µPa) can impair growth rates and hearing sensitivity in juvenile fish over chronic exposure periods (Banner and Hyatt, 1973; Caiger et al., 2012).

50–100m:

Beyond 50 meters, acute effects are minimal, but chronic exposure to sustained noise may still alter habitat use, particularly for sensitive or migratory species (Padeswood CCS, 2025; Hawkins et al., 2014). The cumulative impacts of multiple sources or prolonged activities may also become significant, especially in heavily developed catchments (Mona ES, 2024). New research on continuous low-frequency noise effects shows that fish abundance and behavior can be altered even at distances up to 500m

from major noise sources, particularly during sensitive periods such as spawning migrations (Asbjørnsen et al., 2025).

Fish Sensitivity

Fish are particularly sensitive to low-frequency noise (<1 kHz), which travels efficiently through water (Marine Scotland, 2024; Popper et al., 2021). Recent research has refined understanding of fish hearing capabilities, demonstrating that most species primarily detect particle motion rather than sound pressure, with sensitivity thresholds varying significantly between species and life stages (Popper and Hawkins, 2018; Radford et al., 2016).

Noise levels exceeding 150 dB re 1µPa can cause displacement and reduced spawning success within 10 meters of the source (Marine Scotland, 2024). However, new research indicates that behavioral responses can occur at much lower thresholds, with some species showing startle responses to particle motion as low as 0.3 µm/s at 20 Hz (Chapman and Sand, 1974). Fish exposed continuously to noise levels as low as 120 dB re 1µPa show reduced growth rates and altered hearing sensitivity over chronic exposure periods (Banner and Hyatt, 1973).

Behavioral responses such as startle, avoidance, or changes in schooling patterns have been observed in both laboratory and field studies (Roberts et al., 2016; Hawkins et al., 2014). Recent research demonstrates that pile-driving noise significantly reduces group cohesion in fish schools, with potential implications for predator avoidance and foraging efficiency (Ioannou et al., 2017). Chronic exposure at greater distances may lead to habitat avoidance and altered community structure, especially for species reliant on acoustic cues for communication or navigation (OceanCare, 2018; Radford et al., 2016).

Recent reviews highlight that fish detect both sound pressure and particle motion, with the latter being especially relevant for substrate-borne vibration (Popper et al., 2021; Roberts et al., 2016). This dual hearing mechanism means that construction activities producing substrate vibration may have greater impact than previously recognized, particularly for demersal species living close to the sediment interface (Hawkins et al., 2021).

Invertebrate Sensitivity

Invertebrates are generally less sensitive to airborne noise but can be affected by vibration-induced sediment disturbance, particularly during larval stages or for burrowing species (Roberts et al., 2016; Brims Tidal, 2015; Popper et al., 2021). Laboratory studies have shown that macroinvertebrates can detect and respond to substrate-borne vibration across a broad frequency range, with potential effects on foraging, predator avoidance, and settlement behaviours (Roberts et al., 2016; OceanCare, 2018).

Recent controlled laboratory studies demonstrate that marine invertebrates respond to substrate vibration across frequencies of 5-410 Hz, with crustaceans showing maximum sensitivity around 170 Hz (Roberts et al., 2015; Heinisch and Wiese, 1987). Hermit crabs (*Pagurus bernhardus*) and mussels (*Mytilus edulis*) show clear behavioral responses to vibration, with thresholds varying by frequency and individual size (Roberts et al., 2015).

For example, barnacle and mussel larvae have shown altered settlement rates in response to low-frequency noise and ship noise (Branscomb and Rittschof, 1984; Wilkens et al., 2012; Jolivet et al., 2016). Recent studies indicate that vessel noise can enhance settlement rates of biofouling organisms by up to 100%, with larvae settling twice as fast in noisy environments compared to controls (Stanley et al., 2014; McDonald et al., 2014).

While most vibration sensitivity research has focused on marine species such as hermit crabs (*Pagurus bernhardus*) and mussels (*Mytilus edulis*), the mechanisms and sensory organs involved are directly relevant to UK freshwater species (Roberts et al., 2015).

UK Freshwater Crustaceans:

- White-clawed crayfish (*Austropotamobius pallipes*): As the UK's only native freshwater crayfish, this species possesses similar mechanoreceptor systems to marine crustaceans tested for vibration sensitivity. Recent studies on freshwater shrimps (*Neocaridina davidi*) demonstrate clear behavioral responses to underwater sound (400-2000 Hz), including altered spatial distribution, reduced feeding efficiency, and increased time to locate food sources (Shafiei Sabet et al., 2022).
- Signal crayfish (*Pacifastacus leniusculus*): This invasive species, now widespread across England, shows acoustic signal production capabilities and possesses statocyst organs sensitive to substrate vibration similar to tested marine crustaceans (Lovell et al., 2005).

UK Freshwater Molluscs:

- Freshwater pearl mussel (*Margaritifera margaritifera*): This critically endangered species, found in rivers across northern England and Scotland, is particularly sensitive to substrate disturbance and water quality changes. While specific vibration sensitivity thresholds are undocumented, the species' reliance on stable gravel substrates and filter-feeding behavior makes it vulnerable to vibration-induced sediment disturbance similar to marine *Mytilus edulis* (Young et al., 2001; Cosgrove et al., 2000).
- Duck mussel (*Anodonta anatina*) and Swan mussel (*Anodonta cygnea*): These large freshwater bivalves possess similar mechanoreceptor systems to marine mussels and are likely sensitive to substrate vibration in the same frequency ranges (5-410 Hz) demonstrated for *Mytilus edulis*.

André et al. (2011) demonstrated that even short-term exposure to high-intensity low-frequency sound can cause severe physiological damage to cephalopods, and similar mechanisms may affect sensitive invertebrate taxa in freshwater and estuarine systems. A recent review by McCormick et al. (2019) and a meta-analysis by de Soto (2016) confirm that anthropogenic noise can alter invertebrate behaviour, physiology, and settlement, with potential consequences for population dynamics and ecosystem function. However, the ecological significance of these responses in natural settings remains an area for further research.

Enhanced Understanding of Propagation and Detection

Recent modeling and field measurement studies provide improved understanding of how vibration propagates through substrates and into aquatic environments (Roberts and Howard, 2021; Hawkins et al., 2021). Seismic interface waves generated by terrestrial construction can create high levels of particle motion at the sediment-water interface, with effects extending well beyond the immediate construction zone.

New research distinguishes between near-field effects (where particle motion dominates) and far-field effects (where sound pressure is more relevant), with implications for impact assessment methodologies (Nedelec et al., 2016). Many fish species living close to the substrate may be particularly susceptible to near-field effects from construction activities.

Mitigation Measures

Effective mitigation is essential to minimise ecological risk from noise and vibration near waterbodies. Recommended strategies include:

Physical Barriers and Attenuation:

- Use of noise barriers or silt curtains within 50 meters of waterbodies to attenuate airborne noise and reduce direct transmission to aquatic habitats (Padeswood CCS, 2025; River Thames Scheme, 2024). Recent research indicates that properly designed barriers can reduce noise levels by 10-15 dB, significantly reducing behavioral impacts on fish (Environment Agency, 2023).

Temporal Restrictions:

- Limiting high-intensity activities to daylight hours and avoiding critical periods for aquatic life, such as fish spawning or invertebrate settlement (Marine Scotland, 2024; Mona ES, 2024). New guidance recommends avoiding piling activities during fish spawning seasons (typically March-June for many UK species) and restricting high-noise activities to windows outside of dawn and dusk feeding periods.

Real-time Monitoring and Adaptive Management:

- Monitoring noise and vibration levels during construction to ensure compliance with regulatory thresholds and to inform adaptive management (PEI Noise and Vibration, 2022; Environment Agency, 2023). Updated protocols recommend concurrent measurement of both sound pressure and particle motion, with particular attention to substrate-borne vibration levels.

Enhanced Mitigation Strategies:

- Site-specific assessment and planning, including relocation of noisy equipment or adjustment of work schedules to increase distance from sensitive receptors (River Thames Scheme, 2024; Mona ES, 2024).
- Implementation of "soft start" procedures for high-intensity activities to allow mobile species time to move away from impact zones.

- Use of alternative construction methods with lower noise/vibration profiles where technically feasible.
- Establishment of temporary exclusion zones during sensitive periods, with boundaries based on species-specific threshold data.

Monitoring Protocol Updates:

Recent research emphasizes the importance of measuring particle motion alongside sound pressure, particularly for activities involving substrate contact (Roberts et al., 2016; Hawkins et al., 2021). Recommended monitoring includes:

- Tri-axial accelerometers for substrate vibration measurement
- Hydrophone arrays for both pressure and particle motion quantification
- Pre-construction baseline surveys to establish ambient conditions
- Post-activity monitoring to assess recovery patterns.

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