

Name	Phase	Seabasin	Location	Location Name	Wind Farm type	Lead	Timeframe	Target species	Target habitat	Technological readiness level	Project description/approach	Monitoring date and methods	Results – lessons learned in project on restoration	Knowledge gaps left / recommendations	Possible negative effect	Sources	Credits
ADD; FaunaGuard	Construction	North Sea	Netherlands, Germany, France, Italy	Multiple offshore wind farm construction sites	Offshore windfarm (bottom fixed)	Van Oord and Ace Aquatec	Since 2017	Fish, Seals, Porpoises, Turtles		Implemented	FaunaGuard is a modular system that uses species-specific acoustic signals to temporarily deter marine fauna from active construction zones, minimizing harm during activities like pile driving.	Monitoring is conducted during deployment to assess effectiveness; specific dates and methods vary by project.	The system has been effective in creating temporary exclusion zones, allowing marine life to avoid harmful noise exposure during construction.	Further research is needed to optimize sound patterns for additional species and to assess long-term habituation effects.	Potential for temporary disturbance to non-target species; importance of careful calibration to avoid unnecessary stress.	Aceaquatec	OCEaN mitigation database
AdBm Noise Mitigation System	Construction	North Sea	Netherlands	Borssele Wind Farm Zone	Offshore windfarm (bottom fixed)	Van Oord & AdBm Technologies	2019-2020	Marine mammals, fish		Implemented	Used AdBm Noise Mitigation System (NMS) with acoustic resonators to reduce underwater noise, combined with a Big Bubble Curtain (BBC).	Continuous noise monitoring during construction.	Successfully reduced noise emissions below regulatory thresholds.	Further testing needed to optimize performance in variable sea conditions.	Potential localized disruption of marine life, though mitigated by noise reduction.	AdBM	OCEaN mitigation database
Noise mitigation system T-NMS-10000	Construction	North Sea	Germany	EnBW He Dreiht	Offshore windfarm (bottom fixed)	EnBW & Heerema Marine Contractors	2023-Present	Marine mammals, particularly porpoises		Implemented	Used T-NMS-10000 system with double big bubble curtain and IQIP's PULSE system to reduce noise by up to 24 dB.	Ongoing real-time acoustic monitoring.	Demonstrated significant noise reduction, reducing impact on marine mammals.	Need for long-term impact studies on porpoise behavior.	Effectiveness may vary based on environmental conditions and sound propagation.	Heerema	OCEaN mitigation database
Marine Mammal Observer (MMO) - IJmuiden Ver Gamma Offshore Grid	Construction	North Sea	Netherlands	IJmuiden Ver Gamma	Grid Infrastructure	TenneT	2021-Present	Marine mammals		Implemented	MMO stationed on installation vessels to monitor for marine mammals before noisy activities begin, ensuring no disturbance or injury.	MMO observations recorded in real-time before pile-driving.	Effective in reducing risk to marine mammals before construction.	Best practices should be generalized for all offshore projects, not just Natura 2000 sites.	Dependent on visibility; effectiveness can be limited in poor weather conditions.	OCEaN mitigation collection	OCEaN mitigation database
Marine Mammal Observer (MMO) - Triton Knoll Offshore Wind Farm	Construction	North Sea	UK	Triton Knoll	Offshore windfarm (bottom fixed)	RWE	2020-Present	Marine mammals		Implemented	MMO stationed on installation vessels to ensure compliance with JNCC noise mitigation guidelines before pile-driving activities.	MMO observations conducted per JNCC (2021) guidelines.	Effective in reducing marine mammal exposure to harmful noise.	JNCC noise mitigation guidelines (2010) need updating to reflect new technologies and best practices.	Visibility challenges and observer fatigue can affect reliability.	JNCC (2021). Marine mammals and noise mitigation	OCEaN mitigation database
Establish Mandatory Noise Threshold Values (Cumulative Consideration)	Construction	North Sea	Germany, Denmark, Netherlands	German Bight, North Sea (Denmark), Dutch North Sea	Offshore windfarm (bottom fixed)	Government Authorities	2013	Marine mammals	Underwater noise-sensitive areas	Implemented	Legally mandated noise limits in Germany, cumulative noise guidelines in Denmark; Sweden has no national regulation.	Regulatory compliance monitoring.	Ensures consistent noise reduction strategies.	Harmonization of regulations across sea basins is needed.	Differences in regulations may lead to unequal protection across countries.		OCEaN mitigation database
Assessing Pile Drilling as Alternative to Pile Hammering	Construction	North- and Baltic Sea	EU	North Sea and Baltic Sea	Offshore windfarm (bottom fixed)	Industry Standard	2021	Marine mammals	Underwater noise-sensitive areas	Implemented	Industry shift towards pile drilling where feasible, reducing impulsive noise.	Case-specific environmental impact studies.	Significant noise reduction compared to pile hammering.	Further research on efficiency and feasibility in various seabed conditions.	Higher costs and longer installation times compared to hammering.	Bennun, L., van Bochove, J., Ng, C., Fletcher, C., Wilson, D., Phair, N., Carbone, G. (2021). Mitigating biodiversity impacts associated with solar and wind energy	OCEaN mitigation database
Soft Start & Gradual Increase of Piling Energy to Reduce Impact on Noise-sensitive Species	Construction	North Sea	Germany, Denmark, Netherlands, Belgium	German Bight, Danish North Sea, Dutch North Sea, Belgian North Sea	Offshore windfarm (bottom fixed)	Government Authorities & Developers	2022	Marine mammals	Underwater noise-sensitive areas	Implemented	Soft-start piling gradually increases noise, allowing animals to leave the area. Mandatory in Germany, advised in Denmark, implemented by Vattenfall, Elia, and TenneT.	Compliance monitoring by developers & authorities.	Effective in reducing immediate impact on marine mammals.	Further studies needed on best soft-start duration and optimal noise ramp-up rates.	Potential for animals to be affected before fully leaving the area.	PHAROS4MPAs - A review of solutions to avoid and mitigate environmental	OCEaN mitigation database
Use Passive Acoustic Monitoring (PAM) for Marine Mammal Detection	Construction	North Sea	UK	Triton Knoll Offshore Wind Farm	Offshore windfarm (bottom fixed)	RWE	2021	Marine mammals	Underwater noise-sensitive areas	Implemented	Use of PAM to detect marine mammals at night or during poor visibility conditions before construction activities.	JNCC recommended monitoring methods.	Enhances ability to detect marine mammals before disturbance occurs.	Further development of automated real-time PAM systems needed.	Potential for false positives or undetected animals if system calibration is insufficient.	JNCC (2021). Marine mammals and noise mitigation	OCEaN mitigation database
Modification of Piling Hammer with Piling Cushion	Construction	Baltic Sea	Denmark	Kriegers Flak	Research Platform	Research Project	2007	Marine mammals	Underwater noise-sensitive areas	Implemented	Integration of a layer between hammer and pile to reduce noise impact.	Environmental impact assessments conducted.	Demonstrated noise reduction compared to unmodified hammers.	Further testing on effectiveness for large-scale wind farms needed.	May reduce piling efficiency or increase construction duration.	PHAROS4MPAs - A review of solutions to avoid and mitigate environmental	OCEaN mitigation database
Deploying Big Bubble Curtain (BBC) for Noise Reduction	Construction	North Sea	Germany, Netherlands	FINO3, Alpha Ventus, Borkum West II, IJmuiden Ver Gamma Offshore Grid	Offshore windfarm (bottom fixed)	Industry Standard		Marine mammals	Underwater noise-sensitive areas	Implemented	Large-scale implementation of BBC to reduce noise during monopile and jacket foundation installation.	Project-specific monitoring of noise reduction effectiveness.	Effective but variable efficiency depending on currents and seabed conditions.	Optimization of curtain formation and energy efficiency of pumps.	GHG emissions from diesel-run pumps used in bubble generation.	PHAROS4MPAs - A review of solutions to avoid and mitigate environmental	OCEaN mitigation database
Use of Cofferdams for Noise Reduction	Construction	North Sea	Denmark	Anholt Offshore Wind Farm	Offshore windfarm (bottom fixed)	Ørsted	2013	Marine mammals	Underwater noise-sensitive areas	Implemented	Cofferdams used to reduce underwater noise from pile driving.	Environmental impact monitoring reports.	Effective in reducing noise impact compared to open-sea piling.	Further research needed on cost-effectiveness and scalability.	Higher material and installation costs.	PHAROS4MPAs - A review of solutions to avoid and mitigate environmental	OCEaN mitigation database
Time Limitations on Piling Activities	Construction	Various	EU	Multiple locations	Offshore windfarm (bottom fixed)	Industry Standard		Marine mammals	Underwater noise-sensitive areas	Implemented	Limiting hours of piling per day or number of active days to reduce cumulative noise exposure.	Regulatory compliance monitoring.	Reduces long-term noise exposure risks.	Best practices on optimal timing and duration still needed.	May extend total project duration.		OCEaN mitigation database
Seasonal Timing to Avoid Sensitive Marine Life Activities	Construction	North Sea	EU	Rampion, Princess Elisabeth Energy Island	Offshore windfarm (bottom fixed)	Ørsted, TenneT, RWE, Elia		Marine mammals, fish	Breeding, nursery, and spawning areas	Implemented	Avoid construction in critical times for feeding, spawning, and nursery habitats.	Seasonal environmental assessments.	Helps protect critical life stages of marine species.	More detailed ecological impact assessments needed.	May restrict project schedules significantly.	Bennun, L., van Bochove, J., Ng, C., Fletcher, C., Wilson, D., Phair, N., Carbone, G. (2021). Mitigating biodiversity impacts associated with solar and wind energy	OCEaN mitigation database
Adjusting Speed of Maintenance Vessels	Operational	North Sea	UK	Galloper Wind Farm	Offshore windfarm (bottom fixed)	RWE	2022-2027	Marine mammals		Implemented	Maintenance vessel speed reduced to minimize noise emissions and collision risks with marine mammals	Monitoring of vessel speed and marine mammal interaction	Speed adjustments have led to reduced noise disturbance and fewer collisions with marine mammals	Continued study on optimal vessel speeds for minimal environmental impact	Noise emissions from vessels still present, although at lower levels		OCEaN mitigation database