Table 1: Impact Producing Factors, Issues and Mitigation Measures – Marine Mammals and Sea Turtles and Fish and Fish Habitat

IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
PRE-CONSTRUCTION				
1) Accidents	Marine Mammals/ Sea Turtles. Fish and Fish Habitat	Accidents at sea during site surveying and investigation work that could impact species and habitat include: • discharge of fluids/effluents or deleterious substances; and, • vessel collision and resulting fire/explosions.	• Ensure competent vessels are used and crews trained to execute the work tasks, assess the field conditions and to handle severe weather conditions. • Install observers to watch changes in sea state and weather conditions. • Ensure vessels have reliable and maintained navigation systems, propulsion systems and control systems including adequate reserve power and sufficient redundancy in these systems. In addition, technical systems may be developed to decrease the effect of human error in accident causation. • Establish emergency procedures to guarantee personnel safety. Appropriate facilities and procedures should be in place to evacuate and rescue personnel. • Establish a reporting system to record and follow-up incidents and near misses, including visiting collisions. This system must also identify trends and allow further controls to be implemented.	Bat, L., Sezgin, M., & Sahin, F. (2013). Impacts of OWF installations on fisheries: A Literature Review. Journal of Coastal Life Medicine, 1(3), 241-252. https://oaji.net/articles/2015/2154-1435735819.pdf Dai, Lijuan., Ehlers, Sören., Rausand, Marvin., Bouwer Utne,. Ingrid. (2012). Risk of collision between service vessels and offshore wind turbines. Volume 109. 18-31. https://www.sciencedirect.com/science/article/pii/S0951832012001585
2) Exclusion Zones	Marine Mammals/ Sea Turtles	• Foraging areas or migration routes, inaccessible or disrupted, during site surveying and investigation work (especially during seismic/sonar investigations).	• Avoid critical habitat and known migration routes.	Roach, M., Revill, A., & Johnson, M. J. (2022). Co-existence in practice: a collaborative study of the effects of the Westernmost Rough offshore wind development on the size distribution and catch rates of a commercially important lobster (Homarus gammarus) population.

Table 1: Impact Producing Factors, Issues and Mitigation Measures – Marine Mammals and Sea Turtles and Fish and Fish Habitat

IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
	Fisheries	• Harvest areas, inaccessible or disrupted, during site surveying and investigation work (especially during seismic/sonar investigations). • Establishment of exclusion zones during site surveying and investigation work could lead to longer steaming time (and associated costs) for fishers.	• Establish Fisheries liaison protocols early in the project design phase. • Develop communication plans outlining the extent and duration of access restrictions/or provide alternate transportation routes well ahead of time in order for fishers to plan effectively. • Develop compensation measures for loss of catch as a result of inaccessibility.	ICES Journal of Marine Science, 79(4), 1175–1186. https://doi.org/10.1093/icesjms/fsac040 Bonsu, P. O., Letschert, J., Yates, K. L., Svendsen, J. C., Berkenhagen, J., Rozemeijer, M. J. C., Kerkhove, T. R. H., Rehren, J., & Stelzenmüller, V. (2024). Co-location of fisheries and offshore wind farms: Current practices and enabling conditions in the North Sea. Marine Policy, 159, 105941-. https://doi.org/10.1016/j.marpol.2023.105941
3) Multi-beam Scan Sonar	Marine Mammals/ Sea Turtles	Technologies used to penetrate the seafloor can introduce sound into the water column, which may cause behavioural impacts in some species. • Behavioural effects of marine mammals to underwater sound include displacement and avoidance of habitats, changes in vocalizations, changes in respiration, swim speed, diving and foraging behaviour, increased stress and immune depression, and in rare cases, strandings.	• Restrict the timing, location and duration of sonar exploration to avoid sensitive areas and periods for fish and marine mammals, spawning or migratory passages. • Administer exclusion zones around vessels. • Establish an "acoustic exclusion zone" for geophysical surveys, so that the zone is clear of any marine mammals and sea turtles for a certain amount of time before acoustic sound sources can be operated.	Bat, L., Sezgin, M., & Sahin, F. (2013). Impacts of OWF installations on fisheries: A Literature Review. Journal of Coastal Life Medicine, 1(3), 241-252. https://oaji.net/articles/2015/2154-1435735819.pdf CSA Ocean Sciences Inc. (2021). Technical Report: Assessment of Impacts to Marine Mammals, Sea Turtles, and ESA-Listed Fish Species, Revolution Wind Offshore Wind Farm. Prepared for Revolution Wind, LLC. March 2021. 125 pp. Mooney, Andersson, M. H., & Stanley, J. (2020). Acoustic impacts of offshore wind energy on fishery resources: An Evolving Source and Varied Effects Across a Wind Farm's Lifetime. Oceanography (Washington, D.C.), 33(4), 82–95. https://doi.org/10.5670/oceanog.2020.408 Carroll, A.G., Przeslawski, R., Duncan, A., Gunning, M., & Bruce, B. (2017). A critical review of the potential impacts of marine seismic surveys on fish & invertebrates.
	Fish and Fish Habitat	• Potential effects to fish include physical injury (barotrauma) and hearing loss (often referred to as permanent threshold shift (PTS) and temporary threshold shift (TTS) which is a temporary reduction in hearing sensitivity caused by exposure to intense sound). • Pre-construction site surveys for OSW use multibeam and side-scan sonar, sub-bottom profiles, and other geophysical technologies to characterize the seafloor and site conditions; these techniques can impact marine fish species (CSA, 2021; Mooney et al., 2020). These lower energy, i.e., quieter,		

Table 1: Impact Producing Factors, Issues and Mitigation Measures – Marine Mammals and Sea Turtles and Fish and Fish Habitat

IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
		systems and technologies are used to penetrate the seafloor and can introduce sound into the water column, which may cause behavioural impacts in some species (CSA, 2021; Mooney et al., 2020; Bat et al., 2013).		Marine Pollution Bulletin, 114(1), 9–24. https://doi.org/10.1016/j.marpolbul.2016.11.038 Popper, A.N., Hawkins, A.D., Fay, R.R., Mann, D., Bartol, S., Carlson, T., Coombs, S., Ellison, W.T., Gentry, R., Halvorsen, M.B., Løkkeberg, S., Rogers, P., Southall, B.L., Zeddies, D. and W.N. Tavolga. (2014). Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI," ASA S3/SC1.4 TR-2014. Springer and ASA Press, Cham, Switzerland (2014) Silve, L.D., Kvadsheim, P. H., & Ainslie, M. A. (2014). Potential for population-level disturbance by active sonar in herring. ICES Journal of Marine Science, 72(2), 558–567. https://doi.org/10.1093/icesjms/fsu154

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IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
4) Seismic Surveys	Marine Mammals/ Sea Turtles	• Immediate behavioral reactions to exposure to seismic sound have been widely documented in marine mammals, e.g., avoidance behaviour, change in vocalizations, disruption in feeding behaviours. The possible longer-term consequences of short-term behavioral changes and the potential significance of these changes on a population level remain a topic of debate and research. • Behavioural effects from seismic sound on sea turtles include changes in swimming patterns, diving and overall avoidance responses. Most studies acknowledge limitations including an inadequate understanding of sea turtle behaviour at sea that make it difficult to draw firm conclusions about the effects and their significance.	• Apply mitigation measures recommended for Sonar.	Carroll, A.G., Przeslawski, R., Duncan, A., Gunning, M., & Bruce, B. (2017). A critical review of the potential impacts of marine seismic surveys on fish & invertebrates. Marine Pollution Bulletin, 114(1), 9–24. https://doi.org/10.1016/j.marpolbul.2016.11.038 Weilgart, L. (2013). "A review of the impacts of seismic airgun surveys on marine life." Submitted to the CBD Expert Workshop on Underwater Noise and its Impacts on Marine and Coastal Biodiversity, 25-27 February 2014, London, UK. Available at: http://www.cbd.int/doc/?meeting=MCBEM-2014-01

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IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
	Fish and Fish Habitat	• Seismic testing (streamer type and vertical) has been reported by some studies to effect fish including death of larvae, juveniles and adults due to underwater noise, effects on population dynamics and feeding performance, as well as loss of feeding area, migration options, and spawning grounds. The use of seismic air guns has been reported to damage fish ears. • Behavioural responses of fish to underwater sound, including seismic sound, can vary greatly among species and can include a startle response, change in swimming direction, speed or depth, change in feeding behaviour and/or temporary avoidance of the area.		Bat, L., Sezgin, M., & Sahin, F. (2013). Impacts of OWF installations on fisheries: A Literature Review. Journal of Coastal Life Medicine, 1(3), 241-252. https://oaji.net/articles/2015/2154-1435735819.pdf Popper, A.N. and M.C. Hastings. (2009). The effects of human-generated sound on fish. Integrative Zoology, 4: 43-52. DFO (Fisheries and Oceans Canada) (2004). Review of Scientific Information on Impacts of Seismic Sound on Fish, Invertebrates, Marine Turtles and Marine Mammals. Habitat Status Report 2004/002, September 2004.
	Fisheries	• Commercial fisheries are often excluded from OSW farms during the pre-construction phase due to their incompatibility with geo-physical surveys (Roach et al., 2022). • Seismic survey shooting performed during the pre-construction period of an OSW farm can negatively affect the abundances of fish and may cause catch reductions (Bat et al., 2013). Low catch rates were observed 18 nautical miles from the seismic shooting area, but the most pronounced decrease of fish abundance occurred within the shooting area (Bat et al., 2013).		Bat, L., Sezgin, M., & Sahin, F. (2013). Impacts of OWF installations on fisheries: A Literature Review. Journal of Coastal Life Medicine, 1(3), 241-252. https://oaji.net/articles/2015/2154-1435735819.pdf Roach, M., Revill, A., & Johnson, M. J. (2022). Co-existence in practice: a collaborative study of the effects of the Westermost Rough offshore wind development on the size distribution and catch rates of a commercially important lobster (Homarus gammarus) population. *ICES Journal of Marine Science*, *79*(4), 1175–1186. https://doi.org/10.1093/icesjms/fsac040

Table 1: Impact Producing Factors, Issues and Mitigation Measures – Marine Mammals and Sea Turtles and Fish and Fish Habitat

IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
5) Vessel and Equipment Activity	Marine Mammals/ Sea Turtles	Noise • Sound from vessel traffic can be a source of chronic stress for marine mammal populations and in some cases, reduce the effectiveness of marine mammal communication through masking. Some studies have shown no response to vessels, while other studies have documented cetaceans and seal species adjusting their movement behaviour around ships and/or modifying their vocal patterns. • Transmission of sound from helicopters into the marine environment is related primarily to the altitude and sea surface conditions. Behavioural responses of cetaceans to aircraft noise can include diving, reduced surfacing periods, and breaching. Reactions can depend on the animal's activity at the time of exposure. Collision • Marine mammal species that conduct surface-level activities (resting, foraging, nursing, migrating and socializing), or that conduct shallow-diving, are at higher risk of vessel collision. This can result in sharp force trauma, such as propeller injury. • Several cetacean species are susceptible to injury or mortality from direct collisions with vessels: fin, right and humpback whales being the most reported species hit. • There are few studies on sea turtle reactions to vessels although propeller and collision injuries from ships in US waters are commonly reported One study demonstrated the proportion of green sea turtles maneuvering to avoid a vessel decreased with increased vessel speed, suggesting turtles may not avoid faster moving vessels.	• Complete visual monitoring and Passive Acoustic Monitoring within proposed work areas prior to implementation to understand behaviour, distribution, and abundance of marine animals in the vicinity of proposed activities. • Establish designated traffic lanes. • Keep vessel traffic to a minimum. • Minimize vessel traffic where at-risk species are likely to occur. • Maintain a mandatory distance from species at risk. • Complete monitoring during all activities including Real-time Vessel-based Reporting to identify and share sightings. • Avoid activities in Critical Habitat.	Bat, L., Sezgin, M., & Sahin, F. (2013). Impacts of OWF installations on fisheries: A Literature Review. Journal of Coastal Life Medicine, 1(3), 241-252. https://oaji.net/articles/2015/2154-1435735819.pdf CSA Ocean Sciences Inc. (2021). Technical Report: Assessment of Impacts to Marine Mammals, Sea Turtles, and ESA-Listed Fish Species, Revolution Wind Offshore Wind Farm. Prepared for Revolution Wind, LLC. March 2021. 125 pp. Hawkins, A.D., Pembroke, A. E., & Popper, A. N. (2015). Information gaps in understanding the effects of noise on fishes and invertebrates. Reviews in Fish Biology and Fisheries, 25(1), 39–64. https://doi.org/10.1007/s11160-014-9369-3 Hawkins, A.D. and A.N. Popper. (2017). A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates. ICES Journal of Marine Science 74(3):635-651. Hildebrand, J.A. (2009). Anthropogenic and natural sources of ambient noise in the ocean. *Marine Ecology. Progress Series (Halstenbek)*, 395, 5–20. https://doi.org/10.3354/meps08353 Hudson, D.M., Krumholz, J. S., Pochtar, D. L., Dickenson, N. C., Dossot, G., Phillips, G., Baker, E. P., & Moll, T. E. (2022). Potential impacts from simulated vessel noise and sonar on commercially important invertebrates. *PeerJ (San Francisco, CA), 10, e12841–.* https://doi.org/10.7717/peerj.12841

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IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
	Fish and Fish Habitat	Noise • The number of vessels and amount of equipment used during the site surveying and investigation phases may create noise and vibration, electromagnetic fields, disturbance-maintenance activities, which may affect communication in fishes and invertebrates and can lead to permanent loss of fish and shellfish seabed habitat. • In the open water, vessel noise can influence ambient noise levels at distances of thousands of kilometers; the effects of vessel noise in shallower shelf and coastal waters are more variable due to the physical and geological properties of the seabed, sea surface and water column which influence reflection, refraction, absorption and thus propagation of noise in the water.		
CONSTRUCTION				
1) Accidents	Marine Mammals/ Sea Turtles Fish and Fish Habitat	Same as for pre-construction phase.		

Table 1: Impact Producing Factors, Issues and Mitigation Measures – Marine Mammals and Sea Turtles and Fish and Fish Habitat

2) EMF	Marine Mammals/ Sea Turtles Fish and Fish Habitat	• Subsea power cables may potentially emit EMF that can interfere with those marine animals that detect naturally occurring electric/or magnetic fields for essential life functions. Avoidance behaviours may be elicited from higher-strength EMFs while lower-strength EMFs may attract other electrosensitive species, as these could mimic the EMFs from prey. • The physical interactions between cable-induced EMF and naturally occurring EMF are poorly understood. It is possible that EMF from subsea cables may impact some species' ability to use natural EMF cues. • Benthic disturbances during construction activities result from cable burying that cause temporary, localized increases in sediment suspension within the water column; this increases turbidity and may decrease feeding efficiency for marine mammals and sea turtles causing avoidance behaviours. • There are gaps in the literature with respect to the effects of EMF on fish, specifically crustaceans. The new studies available from the UK and Eastern USA were conducted using different types and strengths of EMF and experimental methodologies; they assessed different experimental parameters which makes comparisons difficult.	• Where possible, cables should be buried to a depth of at least one metre (3.3 ft) to mitigate the impacts of the strongest magnetic and induced electrical fields by employing sediment as a physical barrier to sensitive species. • Burying transmission cables under the seafloor, or covering them with concrete mattresses, to reduce the effects of EMF of marine species.	BOEM. 2023. Environmental Studies. Electromagnetic Fields (EMF). from Offshore Wind Facilities. https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/BOEM-Electromagnetic-Fields-Offshore-Wind-Facilities_1.pdf BOEM. 2021. Electromagnetic Field Impacts on American Eel Movement and Migration from Direct Current Cables. https://espis.boem.gov/final%20reports/BOEM_2021-083.pdf U.S Offshore Wind Synthesis of Environmental Effects Research (SEER). Electromagnetic Field Effects on Marine Life. https://tethys.pnnl.gov/sites/default/files/summaries/SEER-Educational-Research-Brief-Electromagnetic-Field-Effects-on-Marine-Life.pdf Cresci, A., Durif, C.M., Paris, C.B., Shema, S.D., Skiftesvik, A.B., Browman, H.I. (2019a). Glass eels (Anguilla anguilla) imprint the magnetic direction of tidal currents from their juvenile estuaries. Commun. Biol. 2 https://doi.org/10.1038/s42003-019- 0619-8. Cresci, A., Paris, C.B., Foretich, M.A., Durif, C.M., Shema, S.D., O'Brien, C.E., Vikebø, F. B., Skiftesvik, A.B., Browman, H.I. (2019b). Atlantic haddock (Melanogrammus aeglefinus) larvae have a magnetic compass that guides their orientation. iScience 19, 1173–1178. https://doi.org/10.1016/j.isci.2019.09.001. Gill A.B. and H. Taylor. (2002). The Potential Effects of Electromagnetic Field Generated by Cabling between Offshore Wind Turbines upon Elasmobranch Fishes. Report to the

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				development. *Renewable Energy*, *177*, 72–81. https://doi.org/10.1016/j.renene.2021.05.041 Scott, K., Harsanyi, P., & Lyndon, A. R. (2018). Understanding the effects of electromagnetic field emissions from Marine Renewable Energy Devices (MREDs) on the commercially important edible crab, Cancer pagurus (L.). *Marine Pollution* Bulletin, 131(Pt A), 580–588. https://doi.org/10.1016/j.marpolbul.2018.04.062 SEER (Synthesis of Environmental Effects Research, U.S. Offshore Wind). (2022). Electromagnetic Field Effects on Marine Life. SEER Educational Research Brief: Electromagnetic Field Effects on Marine Life (pnnl.gov) Normandeau Associates Inc., Exponent Inc., Tricas, T., and Gill, A. (2011). Effects of EMFs from Undersea Power Cables on Elasmobranchs and other Marine Species (OCS Study BOEMRE 2011-09). Report by Normandeau Associates Inc. for Bureau of Ocean Energy Management Pacific OCS Region, U.S. Department of the Interior, Camarillo, CA. https://tethys.pnnl .gov/publications/effects-emfs-undersea-power-cables -elasmobranchs-other-marine-species Woodruff, D., Schultz, I., Marshall, K., Ward, J., and Cullinan, V. (2012). Effects of Electromagnetic Fields on Fish and Invertebrates Task 2.1.3: Effects on Aquatic Organisms Fiscal Year 2011 Progress Report. Report No. PNNL-20813. Report by Pacific Northwest National Laboratory for U.S. Department of Energy, Washington DC. Microsoft Word - EERE_EMF FY_11_Final_Report(May11).docx (pnnl.gov)

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IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
3) Exclusion Zones	Marine Mammals/ Sea Turtles	• Foraging areas or migration routes may be inaccessible or disrupted during site surveying and investigation work (especially during seismic/sonar investigations).	Same as for pre-construction phase.	
	Fisheries	• Harvest areas may be inaccessible or disrupted during OSW construction (including turbine installation, cable burying/connections and offshore substation). • The establishment of exclusion zones during construction could lead to longer steaming time (and associated costs) for fishers.		
4) Introduction of New/ Invasive Species	Marine Mammals/ Sea Turtles Fish and Fish Habitat`	• The introduction of marine invasive, i.e., non-native, species can occur as a result of undesirable accumulation of microorganisms, plants, algae and animals on submerged structures, e.g., boats. • Introduced species can compete with native species and result in a change to species biodiversity (loss of species and creation of new habitats).	• Ensure vessels and equipment are free from fouling (non-native accumulating) species prior to use in construction.	Hutchison, Z. L., Bartley, M. L., Degraer, S., English, P., Khan, A., Livermore, J., Rumes, B., & King, J. W. (2020). OFFSHORE WIND ENERGY AND BENTHIC HABITAT CHANGES: Lessons from Block Island Wind Farm. Oceanography, 33(4), 58–69. https://www.jstor.org/stable/26965750
5) Lighting	Fish and Fish Habitat	• Magnitude, duration and extent to exposure from construction light sources relative to baseline conditions may have a behavioural effect on fish and marine mammals. • Nighttime lighting on vessels could be a source of attraction, avoidance or other behavioural response from sea turtles. • Mote Marine Laboratory (MML) reviewed 40 references related to fish. Out of the 40 references reviewed, 11 contained information on the potential impacts of artificial light on fish. Many references describe the role that light intensity plays in diel vertical migration patterns in fish. Some of these references describe the adverse effects of nighttime lighting on fish migration behavior, foraging behavior, predator-prey relationships and	• Minimize lighting, including removal of excess lighting, using light with high directionality, and employing controls to reduce light levels around infrastructure. • The use of red lights can help to minimize impacts to fish as such lights have limited penetration though water.	Orr, T., Herz, S., and Oakley, D. (2013). Evaluation of Lighting Schemes for Offshore Wind Facilities and Impacts to Local Environments. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, Herndon, VA. OCS Study BOEM 2013-0116. [429] pp. Becker, A., Whitfield, A. K., Cowley, P. D., Järnegren, J., & Næsje, T. F. (2013). Potential effects of artificial light associated with anthropogenic infrastructure on the abundance and foraging behaviour of estuary-associated fishes. *The Journal of Applied Ecology*, *50*(1), 43–50.

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IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
		breeding cycles/reproduction. Other references describe that light and artificial light can cause an attraction or avoidance response by certain fish species. • Artificial lighting associated with anthropogenic infrastructure has effects on the abundance and foraging behaviour of fish species, including reduced mean survival, fitness, and growth rates of juvenile anemone fish compared to those exposed to natural moonlight under water. • Artificial light also increases the occurrence of large-bodied predators and the conditions created by this can benefit piscivores through concentration of prey and enhanced foraging capabilities in the case of visual predators. This can create unnatural top-down regulation of fish populations particularly within urban estuarine and coastal waters specifically.		https://doi.org/10.1111/1365-2664.12024 Schligler, J., Cortese, D., Beldade, R., Swearer, S. E., & Mills, S. C. (2021). Long-term exposure to artificial light at night in the wild decreases survival and growth of a coral reef fish. *Proceedings of the Royal Society. B, Biological Sciences*, *288*(1952), 20210454-. https://doi.org/10.1098/rspb.2021.0454 Reilly, C. E., Larson, J., Amerson, A. M., Staines, G. J., Haxel, J. H., & Pattison, P. M. (2022). Minimizing Ecological Impacts of Marine Energy Lighting. *Journal of Marine Science and Engineering*, *10*(3), 354-. https://doi.org/10.3390/jmse10030354 Keenan, S. F., Benfield, M. C., & Blackburn, J. K. (2007). Importance of the artificial light field around offshore petroleum platforms for the associated fish community. *Marine Ecology. Progress Series (Halstenbek)*, *331*, 219–231. https://doi.org/10.3354/meps331219 Nightingale, B., T. Longcore, and C.A. Simenstad. (2006). Artificial Night Lighting and Fishes.Chap. Ch. 11 In Ecological Consequences of Artificial Night Lighting., edited by C. Rich and T. Longcore. pp. 257-76. Washington, D.C: Island Press. Stenberg, C. et al. (2012). Effect of the Horns Rev 1 Offshore Wind Farm on Fish Communities. Follow-up Seven Years after Construction. edited by S.B. Leonhard, C. Stenbenberg and J. (eds.). Støttrup, 99 p. Denmark.

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				Deda, P., I. Elbertzhagen, and M. Klussmann. (2007). Light Pollution and the Impacts on Biodiversity, Species and Their Habitats. In Starlight Conference 2007. International Conference in Defense of the Quality of the Night Sky and the Right to Observe the Stars., edited by J.A. Menéndez-Pidal, Secretary General of the Conference, pp. 133-39. Teatro Chico, Santa Cruz de La Palma, April 19-20, 2007.: StarLight Foundation.
	Fisheries	• The way windfarms are lit can have an effect on fishing vessel navigation (Van Hoey et al, 2021).	• Shipping would like to see less lighting of turbines, whereas small-scale fishermen would like more lighting. A compromise between the pilotage/shipping and fishing stakeholders on lighting and buoyage is therefore essential.	Van Hoey, G., Bastardie, F., Birchenough, S., De Backer, A., Gill, A., de Koning, S., Hodgson, S., Mangi Chai, S., Steenbergen, J., Termeer, E., van den Burg, S., and Hintzen, N. (2021). Overview of the effects of offshore wind farms on fisheries and aquaculture, Publications Office of the European Union, Luxembourg, p. 99
6) Noise/ vibrations (Underwater)	Marine Mammals/ Sea Turtles Fish and Fish Habitat	<u>Increased Vessel Presence:</u> • same as for pre-construction. <u>Pile Driving</u> • Pile driving produces high intensity sound pulses at levels capable of producing acoustic injury to marine animals (CSA, 2021; Popper et al., 2014). • Current understanding of the potential effects of particle motion on fish and invertebrates is very limited; it is expected that particle motion associated with impulsive noise sources, such as impact pile driving, will have similar effects to pressure waves in fish species (CSA, 2021). • Non-auditory injury (sometimes referred to as barotrauma) results from rapid and	• To mitigate the effects of sound, several countries, including Canada, have adopted precautionary principles in their approvals process for seismic survey activities. These policies aid in mitigating the impacts of these sounds by restricting the timing, location, and duration of seismic exploration. • Using quieting technologies, such as bubble curtains, can be effective at reducing noise during pile-driving. Bubble curtains work by creating a physical bubble barrier around the pile driving platform, which reduces noise outside the curtain and helps protect marine life. Other examples include vibratory pile drivers, isolation casings, cofferdams, and hydro sound dampers. • A gradual ramp up of hammer energy for impact pile driving includes an initial set of strikes from the impact hammer at reduced energy. This initial set of strikes is followed by a waiting period and this	Bailey, B., Senior, B., Simmons, D. Rusin, J., Picken, G., Thompson, P. M. (2010). Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. Marine Pollution Bulletin, 60 (6), 888-897. https://doi.org/10.1016/j.marpolbul.2010.01.003. CSA Ocean Sciences Inc. (2021). Technical Report: Assessment of Impacts to Marine Mammals, Sea Turtles, and ESA-Listed Fish Species, Revolution Wind Offshore Wind Farm. Prepared for Revolution Wind, LLC. March 2021. 125 pp. Neo, Seitz, J., Kastelein, R. A., Winter, H. V., ten Cate, C., & Slabbekoorn, H. (2014). Temporal structure of sound affects behavioural recovery from noise impact in

Table 1: Impact Producing Factors, Issues and Mitigation Measures – Marine Mammals and Sea Turtles and Fish and Fish Habitat

IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
		instantaneous changes in the ambient pressure level in the water and subsequently within the fluids and tissue of an animal, causing physical injury to soft tissue and organs. • Temporary stressors such as impact pile driving may cause a short-term stress response in fish, but the potential for these activities to cause longer term growth and fitness consequences has not been demonstrated in a field setting (CSA, 2021). • Both intermittent, e.g., pile driving, and continuous, e.g., vessel traffic and drilling, noises elicit behavioral changes in fish, but the time it takes to return to normal baseline behavior was longer in response to intermittent noises compared to continuous noises (CSA, 2021; Neo et al., 2014).	process is repeated several times prior to the initiation of pile driving. This allows species to move away. • Use trained observers to maintain an exclusion area around pile driving activities for certain species. Pile driving activities must be shut down and delayed if a marine mammal or sea turtle is observed entering or within the relevant exclusion zones. • During construction, certain activities, e.g., pile driving, may be scheduled to avoid high animal densities or sensitive periods such as species spawning or migration periods. This may be the only option in particularly sensitive areas where an OSW project would otherwise not go ahead because of predicted negative impacts on protected species.	European seabass. *Biological Conservation*, *178*, 65–73. https://doi.org/10.1016/j.biocon.2014.07.012 Tougaard, J., Hermannsen, L. Madsen, P.T. (2020). How loud is the underwater noise from operating offshore wind turbines? J. Acoust. Soc. Am. 148 (5): 2885–2893. https://doi.org/10.1121/10.0002453 Weilgart, L (2018). The Impact of Ocean Noise Pollution on Fish and Invertebrates. Weilgart, L (2023). Best Available Technology (BAT) and Best Environmental Practice for Mitigating Three Noise Sources: Shipping, Seismic Airgun Surveys, and Pile Driving. CMS technical Series No. 46 Yang, C., Li, R., Lü, L. et al. Vibration Mechanism and Noise Characterization of Offshore Wind Turbines. Acoust Aust 52, 69–76 (2024). https://doi.org/10.1007/s40857-023-00308-6

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IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
7) Planned/ unplanned Releases	Marine Mammals/Sea Turtles Fish and Fish Habitat	• Planned and unplanned/accidental releases of chemicals and hydrocarbons could occur during installation/construction or decommissioning of offshore wind turbines, foundations and/or facilities. • Accidental releases include fuels or hazardous materials leaks, invasive species, suspended sediments, or trash. The impacts of these various materials affect resources in different ways. Similarly, accidental releases from different sources, e.g., vessels and structures, have differing pathways by which the IPF will affect resources, i.e., from a mobile source a release that could occur anywhere and could be widely distributed versus impacts from a known, fixed point such as would occur from a structure. • Refers to unanticipated release or spills of a fluid or other substance into receiving waters, which can affect water quality and associated resources. Can occur from a stationary source, e.g., oil and gas structure, a renewable energy structure, or a mobile source, e.g., vessels. Accidental releases are distinct from discharges as discharges are authorized, typically operational effluents controlled through permit systems.	• Proper waste management procedures can greatly reduce the impact of potential chemical releases on the environment. • Use of underwater cameras to monitor potential planned or unplanned/accidental release of chemicals and hydrocarbons during installation and other development phases could help mitigate negative impacts.	Bat, L., Sezgin, M., & Sahin, F. (2013). Impacts of OWF installations on fisheries: A Literature Review. Journal of Coastal Life Medicine, 1(3), 241-252. https://oaji.net/articles/2015/2154-1435735819.pdf SEER (U.S. Offshore Wind Synthesis of Environmental Effects Research). (2022). Environmental Effects of U.S. Offshore Wind Energy Development: Compilation of Educational Research Briefs [Booklet]. Report by National Renewable Energy Laboratory and Pacific Northwest National Laboratory for the U.S. Department of Energy, Wind Energy Technologies Office. BOEM. Ocean Wind 1 Offshore Wind Farm. Final EIS. Appendix G. Assessment of Resources with Minor (or Lower) Adverse Impacts in the Draft EIS. Ocean Wind 1 Offshore Wind Farm Environmental Impact Statement (boem.gov)

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IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
8) Thermal profiles, oxygen profiles, salinity and current regimes	Fish and Fish Habitat	• While the subsea power cables that are associated with OSW farms, i.e., inter-array and export cables, can transmit high levels of electric power, there is very little data in the literature on the potential temperature increase on and around either unburied or buried cables. • When reviewing hydrodynamic implications for fishes at the local scale, stressors include changes in and vertical redistribution of water temperatures, nutrient transport, turbulence, stratification, and resulting impacts on sediment resuspension or sedimentation. While the effects of each hydrodynamic parameter on fish ecology are well studied, studies of the effects specifically related to OSW farms are less comprehensive.	• Limited information available on potential mitigation measures related to thermal profile changes resulting from construction of OSW farms.	Taormina, B., Di Poi, C., Agnalt, A.-L., Carlier, A., Desroy, N., Escobar-Lux, R. H., D'eu, J.-F., Freytet, F., & Durif, C. M. F. (2020). Impact of magnetic fields generated by AC/DC submarine power cables on the behavior of juvenile European lobster (Homarus gammarus). Aquatic Toxicology, 220, 105401–105401. https://doi.org/10.1016/j.aquatox.2019.105401 van Berkel, J., Burchard, H., Christensen, A., Mortensen, L. O., Petersen, O. S., & Thomsen, F. (2020). The effects of offshore wind farms on hydrodynamics and implications for fishes. *Oceanography*, *33*(4), 108-117. Christiansen, N., Daewel, U., Djath, B., & Schrum, C. (2022). Emergence of Large-Scale Hydrodynamic Structures Due to Atmospheric Offshore Wind Farm Wakes. *Frontiers in Marine Science*, *9*. https://doi.org/10.3389/fmars.2022.818501
9) Construction of cables, pipelines, anchoring and mooring and turbine foundations (including trenching, dredging, rock cutting, pile driving, drilling).	Marine Mammals/Sea Turtles Fish and Fish Habitat	Noise • included above in Noise/Vibrations (underwater) Water Quality • Increase suspended sediment/water turbidity, scouring, and sedimentation (Bat et al, 2013). • Re-suspension of pollutants within the sediment. • Synthetic compounds, heavy metal and hydrocarbon contamination may be released accidentally as a result of offshore	• Backfill displaced material to reduce the potential for sediment remobilization. • Pre-installation seabed assessment surveys should occur to determine locations with sensitive habitat. Surveys may include detailed ground truthing of modelled habitat maps, mapping in areas where substrate and biological communities are unknown and updating biological surveys where they have been previously done (Maxwell et al. 2022). • Careful selection of cable routes and cable burial methods, including horizontal directional drilling which may avoid or reduce damage to intertidal areas. For locations used by species that are sensitive to suspended sediment, techniques may be	Bat, L., Sezgin, M., & Sahin, F. (2013). Impacts of OWF installations on fisheries: A Literature Review. Journal of Coastal Life Medicine, 1(3), 241-252. https://oaji.net/articles/2015/2154-1435735819.pdf CSA Ocean Sciences Inc. (2021). Technical Report: Assessment of Impacts to Marine Mammals, Sea Turtles, and ESA-Listed Fish Species, Revolution Wind Offshore Wind Farm. Prepared for Revolution Wind, LLC. March 2021. 125 pp. Hooper, T., Ashley, M., and M. Austen. (2015). Perceptions of fishers and

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IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
		infrastructure installation and the presence of various construction vessels. <u>Benthic/Fish Habitat Disturbance</u> • Impact to some benthic organisms, but the species are thought to return once construction ceases (Bat et al., 2013). • Temporary disturbance/loss of fish and shellfish habitat under inter-array cables and turbine base, prepared ground and construction plant movements. • Disruption of orientation, especially for migratory fish species and impediment of foraging activities. • Fish may move out of areas due to increased stress levels. • Damage to fish eggs. • Alteration of fish community composition and abundance. • Seafloor preparation, installation of the foundations, vessel anchoring, and installation of IAC and OSS-Link Cables will temporarily displace existing communities both on and in the sediment in the RWF, which is expected to alter the existing benthic habitat (CSA, 2021). • The presence of the RWF foundations and scour protection and IAC and OSS-Link Cable protection throughout the 20- to 35-year life of the Project will alter the existing sandy-bottom habitat and structural relief that may act as an artificial reef, a phenomenon known as the "reef effect" (CSA, 2021).	selected to ensure the lowest resuspension of sediment where possible. • Avoid locating near or anchoring on known sensitive seafloor habitats and using dynamic positioning vessels and jet plow embedment to minimize sediment disturbance and alteration during cable-laying. • Avoid areas with vulnerable habitat, e.g., bivalve reefs or eelgrass meadows, or areas with known contaminants in the sediment. • Site project away from sensitive habitats, e.g., eelgrass beds and high densities of corals and sponges. • Avoid periods of known significance to local marine life, e.g., spawning events or feeding migrations, when planning cable installation and maintenance activities (Svendsen et al., 218). • Use trained observers to maintain an exclusion area around pile driving activities for certain species. Pile driving activities to be shut down and delayed if a marine mammal or sea turtle is observed entering or seen within the relevant exclusion zones (SEER, 2022). This may also be relevant to fish species at risk. • Bury the subsea power cables associated with OSW development to increase the physical distance between the cables and most fish species, apart from local infauna and burrowing fish species (Svendsen et al., 2022). In the event that the substrate is rocky, and a cable cannot be buried, the cable may be installed on top of the seafloor with an additional protective layer around it (NYSERDA, 2017b). • Backfill material displaced as a result of cable burial to reduce the potential for sediment remobilization and to enable recovery of benthic organisms. Where sensitive habitats are present along a cable route, it may be necessary to remove vegetation prior to	developers on the co-location of offshore wind farms and decapod fisheries in the UK. Marine Policy, 61, 16- 22. https://doi.org/10.1016/j.marpol.2015.06.031 NYSERDA (New York State Energy Research and Development Authority). (2017a). New York State Offshore Wind Master Plan: Consideration of Potential Cumulative Effects (NYSERDA Report 17-25g). Prepared by Ecology and Environment, Inc NYSERDA (New York State Energy Research and Development Authority). (2021). Offshore Wind Submarine Cabling Overview. Fisheries Technical Working Group. Final Report (NYSERDA Report 21-14). Svendsen, J. C., Ibanez-Erquiaga, B., Savina, E., and T. Wilms. (2022). Effects of operational off-shore wind farms on fishes and fisheries. Review report. DTU Aqua. DTU Aqua-rapport No. 411-2022 NYSERDA (New York State Energy Research and Development Authority). (2017b). New York State Offshore Wind Master Plan Environmental Sensitivity Analysis. (NYSERDA Report 17-25i) Prepared by Ecology and Environment, Inc. SEER (U.S. Offshore Wind Synthesis of Environmental Effects Research). (2022). Environmental Effects of U.S. Offshore Wind Energy Development: Compilation of Educational Research Briefs [Booklet].

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IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
			installation and replant/enhance after installation (Vize et al., 2008). • Minimize cable route lengths to the extent possible. • Use horizontal directional drilling methods for burial/installation in sensitive coastal areas. • Remove and replant vegetation where sensitive habitats are present. • Place anchors and mooring cables in areas of lower ecological importance. • Establish exclusion zones. • Use tenders to lift anchors rather than dragging them across the seabed. • Use designated or directed anchoring. • Shorten mooring chain lengths to reduce scouring at floating OSW facilities.	Report by National Renewable Energy Laboratory and Pacific Northwest National Laboratory for the U.S. Department of Energy, Wind Energy Technologies Office. Maxwell, S.M., F. Kershaw, C.C. Locke, M.G. Conners, C. Dawson, S. Aylesworth, R. Loomis, and A.F. Johnson. (2022). Potential impacts of floating wind turbine technology for marine species and habitats. Journal of Environmental Management, 307,114577. https://doi.org/10.1016/j.jenvman.2022.114577m Vize, S., Adnitt, C., and R. Stanisland. (2008). Review of cabling techniques and environmental effects applicable to the offshore wind farm industry. Department for Business Enterprise and Regulatory Reform Technical Report. Available at: tethys.pnnl.gov/sites/default/files/publications/Cabling_Techniques_and_Environmental_Effects.pdf
10) Vessel and Equipment Activity	Marine Mammals/Sea Turtles Fish and Fish Habitat	Same as for pre-construction and decommissioning phases.	• Establish designated traffic lanes, keep vessel traffic to a minimum during construction and decommissioning, minimize vessel traffic where at-risk species are likely to occur, and maintain a mandatory distance from species at risk. • Use visual monitoring by trained third-party, independent Protected Species Observers, that look for marine mammals so that the possibility of vessel strikes is minimized and shut down any sound sources if marine mammals are detected within a certain distance.	Same as for pre-construction and decommissioning phases.

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IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
OPERATIONS & MAINTENANCE				
1) Accidents	Marine Mammals/Sea Turtles Fish and Fish Habitat	Same as for pre- and during construction plus: • Vessel-turbine collision and vessel-to-vessel collision. • Structural failure/ loss of turbine/cable failures due to collision or hydrodynamic forces in the water could lead to fluid discharges, anthropogenic emissions of EMFs at floating turbine sites or safety/clean up concerns.	See Pre-Construction Measures plus: • Set the approach course slightly off the installation to reduce collision with turbine. • Establish a safety zone around the turbine and maximum vessel speed. • Keep the number of visits to the turbine/s at a minimum to reduce risk.	Dai, Lijuan., Ehlers, Sören., Rausand, Marvin., Bouwer Utne,. Ingrid. (2012). Risk of collision between service vessels and offshore wind turbines. Volume 109. 18-31. https://www.sciencedirect.com/science/article/pii/S0951832012001585

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2) Thermal profiles, oxygen profiles, salinity and current regimes	Marine Mammals/Sea Turtles Fish and Fish Habitat Fisheries	• The addition of offshore wind farms to stratified regions of the continental shelf poses an anthropogenic source of turbulence, in which the foundation structures remove power from the oceanic flow that is fed into turbulent mixing in the wake downstream. • In coastal regions dominated by tidal motion, the presence of offshore wind farm (OWF) structures brings about additional turbulence and mixing of stratification. • Results of Schultz et al study suggests that the effect of OSW structures is small compared to other naturally occurring mixing mechanisms, however, large-scale OWFs could significantly affect the vertical structure of a weakly stratified water column. Stratification in certain regions of the continental shelf could be impacted by OSW farms if these are built over large areas. • Subsequent changes to surface water characteristics would likely alter the exchange across the ocean atmosphere interface, with impacts on heat storage, atmospheric CO2 uptake and benthic resupply of O2. • Changes in atmospheric wind speed, or location of stably stratified atmospheric boundary layers, due to atmospheric wakes and wind blocking, will impact air-sea exchange of heat, momentum, and trace gases. • Stronger mixing in the thermocline will drive more nutrients from the bottom water up into the subsurface chlorophyll maximum and, if the mixing is strong enough, up into the surface layer where it could support additional phytoplankton growth. • Mixing also alters the light experienced by the phytoplankton, with stronger mixing	• Hydrodynamics and wind wake effects around offshore wind turbines are driven by physical ocean processes including tides, stratification, water depth wind-driven currents and atmospheric processes such as turbulence and stability, all of which have significant natural variation. • Mitigating negative effects associated with changes to current regimes caused by OSW farms will require careful site selection and layout design. Hydrodynamic impacts are highly dependent on wind farm layout and wind turbine parameters, including turbine size (hub height and power capacity), type of foundation, turbine spacing within the wind farm, and the spacing between adjacent wind farms. • Larger, more widely spaced turbines, such as those being planned for U.S. windfarms, are likely to have less hydrodynamic influence than the smaller, more closely spaced turbines currently in operation in Europe and other parts of the world.	Rezaei, F., Contestabile, P., Vicinanza, D., & Azzellino, A. (2023). Towards understanding environmental and cumulative impacts of floating wind farms: Lessons learned from the fixed-bottom offshore wind farms. *Ocean & Coastal Management*, *243*, 106772-. https://doi.org/10.1016/j.ocecoaman.2023.106772 American Clean Power Association. (2023). Oceanographic Effects of Offshore Wind Structures and Their Potential Impacts on the North Atlantic Right Whale and Their Prey. ACP_OSW-Hydrodynamics-and-NARW_Whitepaper_2023.pdf (cleanpower.org) van Berkel, J., Burchard, H., Christensen, A., Mortensen, L. O., Petersen, O. S., & Thomsen, F. (2020). The effects of offshore wind farms on hydrodynamics and implications for fishes. *Oceanography*, *33*(4), 108-117 Nova Scotia Fisheries Alliance for Energy Engagement (NSFAEE). (2024). Briefing on the Potential Effects of Offshore Wind Energy Industry on Nova Scotia Fisheries. Nova Scotia Fisheries Alliance for Energy Engagement (aeic-iaac.gc.ca) Schultze, L. K. P., Merckelbach, L. M., Horstmann, J., Raasch, S., & Carpenter, J. R. (2020). Increased mixing and turbulence in the wake of offshore windfarm foundations. Increased Mixing and Turbulence in the Wake of Offshore Wind Farm Foundations - Schultze - 2020 - Journal of Geophysical Research: Oceans - Wiley Online Library

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		potentially disrupting light sufficiently to hinder photosynthesis. • If bacterial demand for oxygen becomes higher at depths, understanding the net effect of bottom mixing is important as many areas already experience oxygen depletion. • Hydrodynamic implications for fishes at the local scale, include stressors such as changes in temperature, nutrient transport, turbulence, stratification and resulting impacts on sediment resuspension or sedimentation. While the effects of each hydrodynamic parameter on fish ecology are well studied (Liao and Cotel, 2013; Kjelland et al., 2015; Wenger et al., 2017), studies of the effects specifically related to OSW farms are less comprehensive. • While limited, studies discuss local OSW farms (within the OSW farm footprint), impacts on fishes due to sediment resuspension or sedimentation, temperature change, nutrient transport, and substrate availability. These studies largely ignore possible effects further afield and generally conclude that any hydrodynamic impact of OWFs on fishes cannot be distinguished when compared to natural variability. • There are physical impacts to the underlying oceanography that must be considered. At its core, OSW farms seek to intercept energy from the atmosphere, preventing its translation into the ocean. This has been acknowledged to substantially impact thermal profiles, oxygen profiles, salinity and current regimes both within the development and much further afield. Depending on the scale, this may make areas within the development no longer thermally or chemically suitable for species (both commercial and non-commercial) present prior to construction. These physical changes will be magnified in the ecosystem,		Taormina, B., Di Poi, C., Agnalt, A.-L., Carlier, A., Desroy, N., Escobar-Lux, R. H., D'eu, J.-F., Freytet, F., & Durif, C. M. F. (2020). Impact of magnetic fields generated by AC/DC submarine power cables on the behavior of juvenile European lobster (Homarus gammarus). Aquatic Toxicology, 220, 105401–105401. https://doi.org/10.1016/j.aquatox.2019.105401 Christiansen N, Carpenter JR, Daewel U, Suzuki N and Schrum C (2023). The largescale impact of anthropogenic mixing by offshore wind turbine foundations in the shallow North Sea. Front. Mar. Sci. 10:1178330.doi: 10.3389/fmars.2023.1178330 Dorrell RM, Lloyd CJ, Lincoln BJ, Rippeth TP, Taylor JR, Caulfield CCP, Sharples J, Polton JA, Scannell BD, Greaves DM, Hall RA and Simpson JH (2022). Anthropogenic Mixing in Seasonally Stratified Shelf Seas by Offshore Wind Farm Infrastructure. Front. Mar. Sci. 9:830927. doi: 0.3389/fmars.2022.830927

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		creating novel local conditions that may or may not be conducive to future commercial fish production. • Any alteration of currents, productivity and chemical characteristics of the marine environment stand to impact ecosystem structure and function. For example, a minor alteration of currents in a bank ecosystem can dramatically reduce the ability for larvae to disperse, potentially impacting fisheries productivity much further afield. Similarly, reduced upper ocean cycling resulting from lost wind energy transfer stands to impact the smallest, but most important components of the marine ecosystem, cascading through the ecosystem to impact even the largest consumers, i.e., endangered marine mammals. Communities at all levels will respond to new structures, leading to ‘invasive’ species not typically found at these locations taking hold and further perturbing the system. Changes could result in behaviour, distribution, and future productivity of many aspects of the marine environment.		

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IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
3) EMF	Marine Mammals/Sea Turtles	• Subsea power cables may potentially emit EMFs that can interfere with some marine animals that detect naturally occurring electric/or magnetic fields for essential life functions. Avoidance behaviours may be elicited from higher-strength EMFs while lower-strength EMFs may attract other electrosensitive species, as these could mimic the EMFs from prey.	• Burying transmission cables under the seafloor or covering them with concrete mattresses to reduce the effects of EMF of marine species.	https://tethys.pnnl.gov/sites/default/files/summaries/SEER-Educational-Research-Brief-Electromagnetic-Field-Effects-on-Marine-Life.pdf https://espis.boem.gov/final%20reports/BOEM_2021-083.pdf https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/BOEM-Electromagnetic-Fields-Offshore-Wind-Facilities_1.pdf Harsanyi, P.; Scott, K.; Easton, B.A.A.; de la Cruz Ortiz, G.; Chapman, E.C.N.; Piper, A.J.R.; Rochas, C.M.V.; Lyndon, A.R. The Effects of Anthropogenic Electromagnetic Fields (EMF) on the Early Development of Two Commercially Important Crustaceans, European Lobster, Homarus gammarus (L.) and Edible Crab, Cancer pagurus (L.). J. Mar. Sci. Eng. 2022, 10, 564. https://doi.org/10.3390/jmse10050564
	Fish and Fish Habitat	• Electromagnetic fields (EMFs) created by cables have the potential to interact with aquatic organisms that are sensitive to electric and magnetic fields. This affects both bony fishes and elasmobranch fishes; the effect may be transient as the organism moves through the area, or alternatively, magneto-sensitive species may be attracted to, or may actively avoid, the area. • Avoidance behaviours may be elicited from higher-strength EMFs. Lower-strength EMFs may attract other electrosensitive species, as these could mimic the EMFs from prey. • Some marine animals can detect naturally occurring electric and/or magnetic fields, e.g., sharks, salmon, and sea turtles, and use these to support essential life functions such as navigating and hunting for prey. • The physical interactions between cable-induced EMF and naturally occurring EMF are poorly understood; however, it is possible that EMF from subsea cables may impact some species' ability to use natural EMF cues. • Subsea power cables can carry either AC (alternating current) or DC (direct current) power; both systems produce magnetic fields. DC power cables are capable of	• Burying cables to a depth of at least one metre (3.3 ft), where possible, may mitigate impacts of the strongest magnetic and induced electrical fields by employing sediment as a physical barrier to sensitive species.	

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		carrying higher power levels generating stronger magnetic fields than AC power cables, and research suggests that marine species may be more likely to detect and react to magnetic fields from DC cables than from AC cables. • Some studies have documented marine animals demonstrating behavioural responses, e.g., increased foraging and exploratory movements, when near subsea cables; there is no conclusive evidence to determine that EMF from an OSW farm cause impacts to individual animals or populations. • Species may exhibit different behavioural responses to EMFs. For example, American lobster (Homarus americanus) exhibits an increased likelihood of exploratory behaviours when EMFs are encountered, while the European lobster (*Homarus gammarus*) exhibits no attraction, foraging, or exploratory behaviours when exposed to static EMFs. Brown crab (*Cancer pagurus*) has been shown to exhibit attraction to EMFs. • EMFs can elicit anatomical responses during the entire life cycle of an animal. For example, when exposed to a static magnetic field, rainbow trout (*Oncorhynchus mykiss*) have been observed to hatch a day earlier.		

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4) Exclusion Zones	Marine Mammals/ Sea Turtles	• Marine mammals, such as harbor seals and harbor porpoises, are attracted to foundations to forage, and sea lions may use them as a source of shelter = potential positive effect. • Several studies suggest that sea turtles, including loggerhead sea turtles, associate with and use foreign underwater structures such as artificial reef-like structures and offshore oil rigs for foraging. • There is the potential that operators may wish to deter marine mammals and turtles from being attracted to turbine infrastructure.	• If the exclusion of marine mammals from the operating footprint of a turbine is a priority, mitigation measures that employ safeguards to the methods of deterrence would be required. More research is required.	
	Fisheries	• Loss of fishing grounds and or harvest areas which become inaccessible may be due to offshore energy regulations set by the management jurisdiction and authority (Van Hoey et al., 2021; Steins et al., 2021). • Longer steaming times from harbour/port to fishing grounds (and associated costs) for fishers (Van Hoey et al., 2021; Steins et al., 2021). • Associated effects on fishing catch volume due to changes in fish habitat and communities (Van Hoey et al., 2021; Steins et al., 2021). • In Europe, (except in UK), all OSW farms are off-limits to trawl fishing to allow disturbed benthic environment to recover after the introduction of OSW infrastructure (Gray et al., 2016). • Moving to other areas, fishing around the edge of OSW farms, or opting to use different gear types, e.g., mobile gear to crab or lobster potting, tend to be ways in which fishers compensate for the loss of fishing grounds (Gray et al., 2016). This can cause	• Directionality, grid uniformity, and spacing of OSW turbine arrays are factors which may influence fish harvesting capabilities (NYSERDA, 2022; Mackinson et al., 2006) • Size of space available for fishing under a given OSW layout may be impacted by vessel size, gear type, and whether a vessel is harvesting or transiting through an area (NYSERDA, 2022). • Early liaison with fishers using areas in which OSW development is proposed so that farm layout, incorporation of transit routes and other factors may be taken into account and may facilitate coexistence.	Bat, L., Sezgin, M., & Sahin, F. (2013). Impacts of OWF installations on fisheries: A Literature Review. Journal of Coastal Life Medicine, 1(3), 241-252. https://oaji.net/articles/2015/2154-1435735819.pdf Van Hoey, G., Bastardie, F., Birchenough, S., De Backer, A., Gill, A., de Koning, S., Hodgson, S., Mangi Chai, S., Steenbergen, J., Termeer, E., van den Burg, S., and Hintzen, N. (2021). Overview of the effects of offshore wind farms on fisheries and aquaculture, Publications Office of the European Union, Luxembourg, p. 99 Steins, N.A., Veraart, J. A., Klostermann, J. E. M., & Poelman, M. (2021). Combining offshore wind farms, nature conservation and seafood: Lessons from a Dutch community of practice. Marine Policy, 126, 104371–. https://doi.org/10.1016/j.marpol.2020.104371 NYSERDA (New York State Energy Research and Development Authority). (2022). New York Bight Offshore Wind

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		increased competition between fishers now operating in the same area. (Van Hoey et al., 2021). Secondary impacts of a loss in catch volume could affect fishing communities and/or seafood dealers, processors, and distributors (BOEM, 2022a). • When closing areas to fisheries, the total effort is re-distributed among the remaining fishing areas. This leads inevitably to an increased effort outside the closed areas, which primarily decreases the biomass of commercially targeted fish species. Within the closed areas, the reduced fishing pressure may lead to an increase in fish biomass and therefore the biomass of large piscivorous predators (Thomsen et al., 2006). • As part of an investigation of the impact of existing Eastern Irish Sea OSW developments on commercial fishing in the Irish Sea, fishermen expressed concern over the cumulative spatial encroachment of OSW farms and marine conservation requirements on fishing grounds, compounded by restrictions imposed by national and regional fisheries management. Fishermen and fisheries officers thought the financial and economic value of fisheries was probably underestimated, partly due to the difficulty of obtaining data on vessels under 10m, especially those targeting non-pressure stock species. This could limit the evidence base available to help underpin any compensation agreements (Gray et al., 2016). • Similar sentiments have been expressed to the Committee at Open House Engagement sessions during the Regional Assessment.		Farms: Collaborative Development of Strategies and Tools to Address Commercial Fishing Access (NYSERDA Report Number 22-24). Prepared by National Renewable Energy Laboratory, Responsible Offshore Development Alliance, and Global Marine Group, LLC. nyserda.ny.gov/publications Mackinson, S., Curtis, H., Brown, R., McTaggart, K., Taylor, N., Neville, S., and S. Rogers. (2006). A report on the perceptions of the fishing industry into the potential socio-economic impacts of offshore wind energy developments on their work patterns and income. Science Series Technical ReportCentre for Environment Fisheries and Aquaculture Science, 133. Available online at [A report on the perceptions of the fishing industry into the potential socio-economic impacts of offshore wind energy developments on their work patterns and income (pnnl.gov)] Roach, M., Revill, A., & Johnson, M. J. (2022). Co-existence in practice: a collaborative study of the effects of the Westermost Rough offshore wind development on the size distribution and catch rates of a commercially important lobster (Homarus gammarus) population. *ICES Journal of Marine Science*, *79*(4), 1175–1186. https://doi.org/10.1093/icesjms/fsac040 Gray, M., Stromberg, P.L., and D. Rodmell. (2016). Changes to Fishing Practices around the UK as a Result of the Development of Offshore Windfarms—Phase 1 (Revised). The Crown Estate, London, England. Available online at: thecrownestate.co.uk/media/2600/final-

Table 1: Impact Producing Factors, Issues and Mitigation Measures – Marine Mammals and Sea Turtles and Fish and Fish Habitat

IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
				published-ow-fishing-revised-aug-2016-clean.pdf BOEM (Bureau of Ocean Energy Management). (2022a). Guidelines for Mitigating Impacts to Commercial and Recreational Fisheries on the Outer Continental Shelf Pursuant to 30 CFR Part 585 Report. Available at: https://www.boem.gov/sites/default/files/documents/renewableenergy/DRAFT%20Fisheries%20Mitigation%20Guidance%2006232022_0.pdf Thomsen, F., Lüdemann, K., Kafemann, R., and W. Piper. (2006). Effects of offshore wind farm noise on marine mammals and fish, biota. Hamburg, Germany on behalf of COWRIE Ltd.
5) Introduction of New/ Invasive Species	Marine Mammals/Sea Turtles Fish and Fish Habitat	• Newly introduced structures may create hospitable conditions for invasive species to colonize and spread.	• Lessons learned from offshore oil and gas. • Implement mechanical removal of accumulated species from turbine structures.	Hutchison, Z. L., Bartley, M. L., Degraer, S., English, P., Khan, A., Livermore, J., Rumes, B., & King, J. W. (2020). OFFSHORE WIND ENERGY AND BENTHIC HABITAT CHANGES: Lessons from Block Island Wind Farm. Oceanography, 33(4), 58–69. https://www.jstor.org/stable/26965750 VanderMolen, J., Nordman, E. (2014). Offshore Wind Development and the Environment: Potential Impacts for Birds, Fish and the Coastal Environment. https://repository.library.noaa.gov/view/noaa/45978

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6) Lighting	Marine Mammals/Sea Turtles	• Artificial lighting necessary during the operational phase of OSW projects is considered low risk for marine mammals. Artificial lighting has not been shown to disturb sea turtle behaviour regardless of light colour or intermittent flashing lights with a very short on-pulse and a long off-interval. • Some marine and sea turtle species may be attracted to structures for foraging opportunities if fish or plankton are attracted to light sources.	• Use spatial planning tools to avoid critical habitat used by marine mammals (Alter et al. 2010, Murphy et al. 2012). • Develop OSW facilities in habitats that are not known to be important to marine mammals (Koschinski et al. 2003, Byrne Ó Cléirigh Ltd. 2000). If wind facilities are developed in areas used by marine mammals, conduct construction activities at times that will minimize disturbance of critical biological activities of marine mammals, such as calving or breeding (Koschinski et al. 2003, Murphy et al. 2012). • Regulate lighting to minimize the amount of light released (Depledge et al. 2010). Install unobtrusive turbine lighting (Farrugia et al. 2010). The latter was the only reference that was specific to marine mammals and offshore lighting. • Direct lights to where they are needed (Longcore and Rich 2010). • Keep light intensity low to increase overall visibility (Longcore and Rich 2010). • Use automatic timers or motion sensors if applicable to minimize light pollution (Longcore and Rich 2010). • Review spectrum choices and choose a light spectrum that is less damaging to area wildlife (Longcore and Rich 2010). • Mitigatie at the level of behavioral disturbance so that potential behavioral impacts and more serious physical injury impacts would be mitigated (Murphy et al. 2012).	Orr, T., Herz, S., and Oakley, D. 2013. Evaluation of Lighting Schemes for Offshore Wind Facilities and Impacts to Local Environments. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, Herndon, VA. OCS Study BOEM 2013-0116. [429] pp. Van Hoey, G., Bastardie, F., Birchenough, S., De Backer, A., Gill, A., de Koning, S., Hodgson, S., Mangi Chai, S., Steenbergen, J., Termeer, E., van den Burg, S., Hintzen, N., Overview of the effects of offshore wind farms on fisheries and aquaculture, Publications Office of the European Union, Luxembourg, 2021, p. 99.

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	Fish and Fish Habitat	• Nineteen out of the 40 fish references reviewed by MML describe wind facility or offshore structure impacts to fish or other marine organisms, but do not discuss lighting impacts or consider effects of lighting on fish. Even the literature that investigated lighting impacts to fish indicated that the effects of artificial light on fish and other marine organisms need to be studied in greater detail. Perkin et al. (2011) indicate that carefully designed experiments are needed to determine the exact effects of artificial light on ecosystems and over what spatial and temporal scales they may act. • De Wachter and Volckaert (2005) evaluated the impacts of human uses of the North Sea on the environment and ranked light pollution as having no impact in every category of fisheries. Likewise, Jensen et al. (2006) estimated impacts from the Horns Rev 2 Offshore Wind Facility in an Environmental Impact Assessment and recognized the disturbance of the natural light regime due to reflections caused by the turbine blades but concluded that no significant impacts to fish and fauna would be expected. These conclusions, however, may be based on the lack of available literature on the topic of artificial lighting impacts to fish.	• None of the reviewed literature specifically mentioned measures to mitigate potential adverse impacts to fish from offshore lighting; however, many of the mitigation measures mentioned above in the marine mammal and sea turtle sections could be applied to fish and are listed below. • Regulate lighting with the intent of minimizing the amount of light released (Depledge et al. 2010). • Install unobtrusive turbine lighting (Farrugia et al. 2010). • Direct lights to where they are needed (Longcore and Rich 2010). • Keep light intensity low to increase overall visibility (Longcore and Rich 2010). • Use automatic timers or motion sensors if applicable to minimize light pollution and have lights turned on only when required (Longcore and Rich 2010, EPA Australia 2006, Witherington and Martin 2003). • Review spectrum choices and choose a light spectrum that is less damaging to area wildlife (Longcore and Rich 2010). • Keep lights shielded to reduce glare and light visible to animals (FFWCC 2007; Salmon 2003, Witherington and Martin 2003) • Use long wavelengths (ambers and reds) when possible, to make the lights seem dimmer (FFWCC 2007, Salmon 2003). • Reduce luminaire wattage to the minimum required for function (Salmon 2003, Witherington and Martin 2003). • Reduce light intensity and light spillage by using long wavelength lighting, shaded lights, motion detector switching and maximizing daylight hours where “lighting” is essential (Limpus 2006). • Shield bright deck lights on vessels. Use of navigation/anchor lights on top of vessel masts is acceptable (Limpus 2006, EPA Australia 2006).	

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IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
7) Noise/ vibrations (Underwater)	Marine Mammals/Sea Turtles Fish and Fish Habitat	• During their operation OSW farms can produce nearly continuous underwater noise at relatively low amplitudes that vary with the wind speed and turbine size; operational noise from turbines, however, does not significantly exceed natural noise levels. • Depending on size and wind speed such noise may mask communication among certain species and result in permanent avoidance of the affected area. • Sea turtles detect sounds underwater and in air with auditory sensitivity overlapping with frequencies and source levels produced by low-frequency anthropogenic sources such as drilling, pile driving, and operating wind turbines and vessels. • Operational sound has the potential to cause chronic effects to marine animals over much longer periods. The principal source of sound from an operational wind farm is turbine noise that propagates into the tower and foundations, coupling the sound into the water and seabed. Most of the noise appears to be generated below 700 Hz and is dominated by narrowband tones. However, sound levels within wind farms are not significantly higher than the background noise. • There is also a particle motion component to sounds generated by wind farms, the sound component detected by all fishes, including sharks, and many invertebrates. • While the noise levels generated during the operational phase are not high enough to cause direct physical injury, there may be behavioural impacts to marine life near turbines. Studies have suggested that the low intensity turbine noise is unlikely to	• Visual monitoring by trained third-party, independent Protected Species Observers, that look for marine mammals so that the possibility of service vessel strikes is minimized and to shut down any sound sources if marine mammals are detected within a certain distance.	Bailey, B., Senior, B., Simmons, D. Rusin, J., Picken, G., Thompson, P. M. (2010). Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. Marine Pollution Bulletin, 60 (6), 888-897. https://doi.org/10.1016/j.marpolbul.2010.01.003. Mooney, T.A., M.H. Andersson, and J. Stanley. 2020. Acoustic impacts of offshore wind energy on fishery resources: An evolving source and varied effects across a wind farm's lifetime. Oceanography 33(4):82–95, https://doi.org/10.5670/oceanog.2020.408. Tougaard, J., Hermannsen, L. Madsen, P.T. (2020). How loud is the underwater noise from operating offshore wind turbines?. J. Acoust. Soc. Am. 148 (5): 2885–2893. https://doi.org/10.1121/10.0002453 Weilgart, L (2018). The Impact of Ocean Noise Pollution on Fish and Invertebrates. Weilgart, L (2023). Best Available Technology (BAT) and Best Environmental Practice for Mitigating Three Noise Sources: Shipping, Seismic Airgun Surveys, and Pile Driving. CMS techincal Series No. 46 Yang, C., Li, R., Lü, L. et al. Vibration Mechanism and Noise Characterization of Offshore Wind Turbines. Acoust Aust 52, 69–76 (2024). https://doi.org/10.1007/s40857-023-00308-6

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IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
		cause hearing impairment in fish, and that fish might adapt to these noises.		
8) Planned/ unplanned Releases/ Contamination	Marine Mammals/Sea Turtles Fish and Fish Habitat	Same as for pre-construction and construction phases.		
9) Reef Effect	Marine Mammals/Sea Turtles	• The presence of subsea infrastructure (including foundations and cables) can create additional hard substrate that may provide artificial reef habitat suitable for benthic communities.	N/A	Baulaz, Y., Mouchet, M., Niquil, N., Lasram, F. (2023). An integrated conceptual model to characterize the effects of offshore wind farms on ecosystem services. Ecosystem Services. 60 (2023). https://doi.org/10.1016/j.ecoser.2023.101513 Gates AR, Horton T, Serpell-Stevens A, Chandler C, Grange LJ, Robert K, Bevan A and Jones DOB. (2019). Ecological Role of an Offshore Industry Artificial Structure. Front. Mar. Sci. 6:675. doi: 10.3389/fmars.2019.00675
	Fish and Fish Habitat		N/A	Baulaz, Y., Mouchet, M., Niquil, N., Lasram, F. (2023). An integrated conceptual model to characterize the effects of offshore wind farms on ecosystem services. Ecosystem Services. 60 (2023). https://doi.org/10.1016/j.ecoser.2023.101513 . Gates AR, Horton T, Serpell-Stevens A, Chandler C, Grange LJ, Robert K, Bevan A and Jones DOB. (2019). Ecological Role of an Offshore Industry Artificial Structure. Front. Mar. Sci. 6:675. doi: 10.3389/fmars.2019.00675

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IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
10) Vessel and Equipment Activity	Marine Mammals/Sea Turtles Fish and Fish Habitat	Same as for pre-construction phase.		
DECOMMISSIONING				
1) Accidents	Marine Mammals/ Sea Turtles Fish and Fish Habitat	• Vessel-turbine collision and vessel-vessel collision. • Structural failure/ loss of turbine/cable failures due to collision or hydrodynamic forces in the water. This could lead to fluid discharges, anthropogenic emissions of EMFs at floating turbine sites or safety/clean up concerns.	• Proper waste management procedures using underwater cameras to monitor mooring lines etc.	Same as construction phase.
2) Exclusion Zones	Marine Mammals/Sea Turtles Fisheries	Same as construction phase.		
3) Lighting	Fish and Fish Habitat	Same as construction and operations/maintenance phases.		
4) Planned/ unplanned Releases	Marine Mammals/Sea Turtles Fish and Fish Habitat	Same as construction and operations/maintenance phases.		

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IPF	VCs Effected	Understanding of the Issue	Mitigation Measures	Literature
5) Reef Effect	Marine Mammals/Sea Turtles Fish and Fish Habitat	• Currently, partial removal is the most common method for decommissioning. This process means monopiles are removed by cutting them off several metres below the seabed, leaving behind tonnes of steel buried in the seabed. • At the end of their operational life offshore wind farms need to be decommissioned. How and to what extent the removal of the underwater structures impairs the ecosystem that developed during the operational phase of the wind farm is not known. Decision makers face a knowledge gap, making the consideration of such ecological impacts challenging when planning decommissioning.	• Partial decommissioning of offshore structures, such as leaving the scour protection layer in situ is beneficial for the conservation of local hard-bottom dwelling species and overall benthic biodiversity. This has repercussions on all aspects of the marine environment and communities. • During operation, researchers have found that marine mammals' frequent anthropogenic structures, taking advantage of aggregations of prey species. The relative importance of these foraging locations and the result of removing them during decommissioning is unknown for marine mammals, sea turtles and fish species.	Spielmann, V., Dannheim, J., Brey, T., & Coolen, J. W. P. (2023). Decommissioning of offshore wind farms and its impact on benthic ecology. *Journal of Environmental Management*, *347*, 119022–119022. https://doi.org/10.1016/j.jenvman.2023.119022 R, Hall., E, Topham., & E, João. (2022). Environmental Impact Assessment for the decommissioning of offshore wind farms. *Renewable & Sustainable Energy Reviews*, *165*, 112580-. https://doi.org/10.1016/j.rser.2022.112580
6) Noise/ vibrations (Underwater)	Marine Mammals/Sea Turtles	Same as pre-construction and construction plus: • The sound pressure levels of water jets used to cut a steel pile could be quite high (198–199 dB re 1 μPa) at distances of 10–50 m from the source. The majority of this acoustic energy was between 250 Hz and 1,000 Hz. It is difficult to predict whether disturbances occurred, yet there is certainly the potential for masking, displacement, physiological stress, and other factors, especially if they are aggregated in habitats around a wind farm pile or foundation.	Same as construction and operations/maintenance phases.	Same as construction and operations/maintenance phases.
	Fish and Fish Habitat	Same as construction and operations/maintenance phases.		

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7) Thermal profiles, oxygen profiles, salinity and current regimes	Fish and Fish Habitat	Same as construction and operations/maintenance phases unless monopile foundations are removed completely.		
8) Vessel and Equipment Activity	Marine Mammals/Sea Turtles Fish and Fish Habitat	Same as pre-construction and construction phases.	• Establishing designated traffic lanes, keeping vessel traffic to a minimum during construction and decommissioning, minimizing changes in vessel traffic where at-risk species are likely to occur, and maintaining a mandatory distance from species at risk. • Visual monitoring by trained third-party, independent Protected Species Observers, that look for marine mammals so that the possibility of vessel strikes is minimized and to shut down any sound sources if marine mammals are detected within a certain distance.	Same as pre-construction and construction phases.