Offshore wind farm impacts and regulations: Should Nova Scotia learn from Europe?

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Research Purpose: to summarize the major effects of Offshore Wind Farms (OWFs) on marine ecosystems, using harbour porpoises as a case study. I researched the intersection between scientific research and policy within the EU to identify if legislation aligned with scientific findings and recommendations to mitigate OWF ecosystem impacts. These findings were used to recommend future guidelines for Nova Scotia's impending 2025 OWF framework.

Methods: I carried out a literature review identifying OWF impacts on marine ecosystems. OWF impacts were identified in site selection, construction, and operation stages of an OWF. I compared OWF related policies from Germany, the Netherlands and Belgium. These were selected as representative countries as Europe has the most OWFs in the world (WindEurope, 2022), and these countries have adequate scientific research regarding OWF impacts on harbour porpoises. Legislation was then compared to its respective country's scientific research to identify if legislation followed scientific recommendations. Scientific research that was shown to be integrated into legislation was utilized to provide recommendations for Nova Scotia's impending 2025 OWF framework.

OWF Components & Broad Impacts:

- Project stages of an offshore wind farm include site selection, construction (2-4 years), operations, and decommissioning.
- The most common foundations used in OWF construction are monopiles, hollow, circular, steel piles with a diameter of ~5m (Gapta & Basu, 2020). These are driven into the seabed through the process of pile driving, in which steel piles are forced into the sediment via a hydraulic hammer. Submarine cables are then laid out and linked to the varying turbines, as well as the substation (the main structural unit for energy capture). This station collects turbine energy, transforms the power to a higher voltage, and sends it to shore through an export cable (Orsted, n.d.)

Site Selection Considerations	Construction Impacts	Operational Impacts
- Ecosystem services (i.e. fisheries reduction due to OWF implementation) - Stakeholder involvement: impact on material (fisheries) and non-material (aesthetic appeal)	- Physical alterations: seafloor substrate removal or alteration - Chemical alterations: reduced photosynthesis due to suspended particulate matter - Biological alterations: reduction of biological diversity	- Creation of artificial reefs - Increased biological diversity - Introduction of invasive species

Harbour Porpoise Overview & OWF Impacts:

Harbour porpoises (*Phocoena phocoena*) are small marine mammals living in cold to temperate waters. They do not follow clear migrations, forage almost continuously (550 small fish/hour) (Wisniewski et al., 2016) and rely heavily on sound for orientation and foraging (Gilles et al., 2009). They are also considered an indicator species for impulsive noise (Koschinski et al., 2020).

Site Selection Considerations	Construction Impacts	Operational Impacts

- Locating OWFs away from areas of significance such as harbour porpoise breeding and foraging grounds	- Pile driving noise (impulsive noise) has the largest impact on harbour porpoises. This noise can induce temporary threshold shifts (TSS) and permanent threshold shifts (PTS) in harbour porpoises, causing physiological disfunction or permanent physical injury .
	  - Reduce foraging ability (impacts echolocation)
	  - Increase avoidance reactions, impacting foraging and natural distribution
	  - Impact reproduction (reduced foraging ability - energy requirements unmet)
		- Expansion of artificial reef production improves harbour porpoise habitat quality (+)
		- Minimal noise disturbance ~8-63m

Intersection of Scientific Research & Legislation

The intersection of research and legislation was identified across three EU countries. All legislation below aligns with, or falls conservatively beneath, research thresholds for appropriate acoustic noise. This is useful information for Nova Scotia to utilize as they formulate their own legislation regarding OWFs.

LEGEND
SEL: Sound Exposure Level (re 1 µPa2s)
BC: Bubble Curtain
SBC: Single Bubble Curtain
DBBC: Double Big Bubble Curtain
Lz-p: Sound Pressure Level measure (zero to peak)(re 1µPa)

PILE DRIVING RESEARCH & LEGISLATION	NOISE RESTRICTION	NOISE MITIGATION	NOISE MONITORING	SEASONAL PILING RESTRICTION	ACOUSTIC DETERRENT DEVICE	SOFT START PILING
RESEARCH	SEL @750m: varied in SEL from 154 to 175 dB re 1 µPa2s at 750 m - **No BC**: 164 to 170 dB re 1 µPa2 - **With SBC**: 157 dB re 1 µPa2	Applied a BC	yes, C Pod logging device	N/A	Two types of acoustic harassment devices (pingers and seal scarers) were used prior to piling	Not mentioned
LEGISLATION	SEL @750m: - unweighted broadband single event level (SEL) von 160 dB re 1µPa2s - peak level (Lp,pk) of 190 dB re 1µPa	Construction projects in water depths > 25 m and with pile diameters ≥ 6 m must apply a combination of near-to-pile and far-from-pile Noise Abatement Systems	Continuous, by permit holder	During May 1st to August 31st no more than 1% of the subregion I of the nature conservation area: „Sylter Außenriff – Östliche Deutsche Bucht“	Yes, standardized deterrence procedure before the start of pile driving	Yes * - project specific
RESEARCH	SEL @ 57m: - **No BC:** 178 dB re 1 uPa^2s - **With DBBC:** No value given, *indicated below appropriate threshold	N/A	N/A	N/A	N/A	N/A
LEGISLATION	SEL @ 750m: - 160-172 dB re ppa2s (1)	Yes, if limit is exceeded, It will be left to the builders to determine how they will meet this standard	Continuous, by permit holder	No piling from January 1st till and including May 31st (2)	Yes, starts 30 min before piling	Yes
RESEARCH	- **No BC:** Lz-p : 198 and 200 dB re 1µPa. - **With SBC**: Lz-p at 750m : 188 to 190 dB re 1µPa - **With DBBC**: 183 to 185 dB re 1µPa	Applied a BC	Yes, conducted	August 6 - November 12	ADD was often switched on much earlier (average 150 minutes) before the start of pile driving	No
LEGISLATION	Lz-p @ 750m: 185 dB re 1 µPa	Yes, if limit is exceeded	Ad hoc inspections, by government	No piling from January 1st to April 30th	Yes, starts 30 min prior to piling	Yes

Nova Scotia - Future Recommendations

Site Selection	Construction	Operations
Formal processes of stakeholder input, prior to permits being granted to identify material and nonmaterial stakeholder impacts	**Deterrent:** Acoustic Porpoise Deterrent prior to piling **Sound Threshold**: dB threshold limit: dual criterion of 160 dB re 1µPa^2s (SEL) and 190 dB re 1µPa^2 (peak to peak sound pressure level) **Mitigation:** DBBCs during piling, prior assessment of tidal currents to ensure DBBC effectiveness	Re-occurring monitoring program to identify invasive species, including the collection of pre-development baseline monitoring data

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