Cumulative Adverse Effects of Offshore Wind Energy Development on Wildlife

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Why do we care?

- **Legal:** Legal requirement to include cumulative effects in environmental assessments in the U.S., Canada, U.K., E.U.

- **Ecological:** Ecologically it is the accumulation of all anthropogenic actions over time and space.

- **Offshore wind energy development (OWED):** Nearly every paper on OWED effects on wildlife finds that while the effects of one project may not be significant, those cumulatively from multiple projects will be.

- If U.S. OWED goals are met, there would be ~9,000 turbines in the water.
“Cumulative impact” is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. 40 CFR §1508.7
Effect vs. Impact

- Impact
  - action of one object coming forcibly into contact with another
  - influence of one person, thing, or action, on another

- Effect
  - a change that is a result or consequence of an action

- “Adverse effects”
  - Used in environmental legislation
  - NOAEL “no observed adverse effect level”
Cumulative Adverse Effects (CAE)

- What is this?
  - People, place, or thing??

- CAE is a **process** with levels of severity
  - Low
  - Medium
  - High

- The process through which adverse effects accumulate

- Effect on **individuals** accumulate to cause **population** declines
A Modeling Approach

\[ CI = \sum_{i \in A} \sum_{j \in R} \int_{x \in \Omega} \left( \int_{t_0}^{t_c} I(A_i, R_j, x, t) \, dt + \int_{t_c}^{t_1} I(A_i, R_j, x, t) \, dt \right) \, dx \]

- Actions (Ai) and receptors (Rj) are discrete values taken from sets, A and R, respectively.

- Space (x) is represented as x-y locations in a 2-dimentional plane within a bounded area (Ω), however space could instead be represented as a set of areas.

- Time (t) is divided into two periods, past (t0) to present (tc) and present to some defined point in the future (t1).

- Masden et al. 2010
What are adverse effects?

Figure 3: The Risk Triangle

Chrichton 2009: The Risk Triangle
Adverse effects of OWED on Wildlife

- **Hazards**: physical changes to the environment from OWED (i.e., “impact-producing factors”)
- **Vulnerability**: species that are vulnerable to the hazards of OWED
- **Exposure**: vulnerable species must be exposed to OWED to have adverse effects. If they are not there they cannot be adversely affected.

\[
\text{Adverse effects} = \text{Hazards} \& \text{Vulnerability} \& \text{Exposure}
\]
Vulnerable
Receptors

Hazards

Individual
Effects Pathways

Vulnerable
Receptors

Exposure

Cumulative
Effects Pathways

Direct

Indirect

Fish
Sea turtle
Marine mammal
Bird
Bat

Time

Space

Additive (CAE = a + b)
Synergistic (CAE > a + b)
Antagonistic (CAE < a + b)

Population Threshold

Population Threshold

Cumulative Adverse Effects

Pre-construction
Construction
Operation
Decommissioning

Network connection

Goodale and Milman 2014
## OWED Hazards: Cause

<table>
<thead>
<tr>
<th>Development phase</th>
<th>Development component</th>
<th>Hazard source</th>
<th>Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preconstruction</strong></td>
<td>Turbines</td>
<td>Seismic profiling</td>
<td>Noise, pressure</td>
</tr>
<tr>
<td></td>
<td>Network Connection</td>
<td>Seismic profiling</td>
<td>Noise, pressure</td>
</tr>
<tr>
<td><strong>Construction</strong></td>
<td>Turbines</td>
<td>Pile driving</td>
<td>Noise, pressure, turbidity, sedimentation, physical alteration of habitat</td>
</tr>
<tr>
<td></td>
<td>Network Connection</td>
<td>Trenching</td>
<td>Turbidity, sedimentation, physical alteration of habitat</td>
</tr>
<tr>
<td><strong>Operation</strong></td>
<td>Turbines</td>
<td>Turbines, wind farm footprint</td>
<td>Disturbed air space, turbulence, noise, permanently altered habitat</td>
</tr>
<tr>
<td></td>
<td>Network Connection</td>
<td>Electrical cable</td>
<td>EMF</td>
</tr>
<tr>
<td><strong>Decommissioning</strong></td>
<td>Turbines</td>
<td>Decommissioning activities</td>
<td>Unknown</td>
</tr>
<tr>
<td></td>
<td>Network Connection</td>
<td>Decommissioning activities</td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>All phases</strong></td>
<td>All components</td>
<td>Boat traffic, lighting</td>
<td>Disturbed marine habitat, noise, turbulence, light</td>
</tr>
</tbody>
</table>
Vulnerability: Adverse Effects

- **Direct effects**: injury or death
- **Indirect effects**: habitat modification and behavioral modification (avoidance/attraction)

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Vulnerable characteristic</th>
<th>Vulnerable life stage</th>
<th>Primary exposure</th>
<th>Adverse effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish</td>
<td>Sensitive to habitat alterations, EMF, and noise; present at all OWEDs</td>
<td>All</td>
<td>All</td>
<td>Mortality, injury, displacement, habitat alteration, reef effect</td>
</tr>
<tr>
<td>Sea turtle</td>
<td>Sensitive to EMF and noise; inability to escape boat hazards; widespread abundance.</td>
<td>All but nesting</td>
<td>All</td>
<td>Mortality, injury, behavioral alteration</td>
</tr>
<tr>
<td>Marine mammal</td>
<td>Long-lived/high adult survival/low annual reproductive rate; widespread abundance; sensitive to sound; inability to escape boat hazards</td>
<td>Migrating</td>
<td>Construction</td>
<td>Mortality, injury, hearing damage from noise, behavioral alteration</td>
</tr>
<tr>
<td>Bird</td>
<td>Long-lived/high adult survival/low annual reproductive rate; fly at rotor height; attraction to and avoidance of turbines</td>
<td>Breeding, migrating, wintering</td>
<td>Operation</td>
<td>Mortality, injury, displacement</td>
</tr>
<tr>
<td>Bat</td>
<td>Long-lived/high adult survival/low annual reproductive rate; attraction to turbines</td>
<td>Migrating</td>
<td>Operation</td>
<td>Mortality</td>
</tr>
</tbody>
</table>
OWED Effects on Fish

- **Pre-construction**
  - **Cause:** Seismic surveys (noise and pressure)
  - **Effect:** Mortality (fish and eggs), displacement

- **Construction**
  - **Cause:** Pile-driving (noise and pressure), trenching
  - **Effect:** Mortality (fish and eggs), displacement, hearing loss, habitat modification

- **Operation**
  - **Cause:** New hard substrate in the water (scour protection) & EMF
  - **Effect:** Habitat modification changing local biodiversity, avoidance

- **Decommissioning**
  - **Cause:** To be determined activities
  - **Effects:** local disturbance of marine habitat

- **All phases**
  - Lights, boat traffic, pollution
OWED Effects on Sea Turtles

- **Pre-construction**
  - *Cause*: Seismic surveys (noise and pressure)
  - *Effect*: Hearing damage, behavioral change

- **Construction**
  - *Cause*: Pile-driving (noise and pressure), trenching
  - *Effect*: Mortality (hatchlings), displacement, hearing loss,

- **Operation**
  - *Unknown*

- **Decommissioning**
  - *Cause*: To be determined activities
  - *Effects*: local disturbance of marine habitat

- **All phases**
  - *Lights*, boat traffic, pollution
OWED Effects on Cetaceans

- **Pre-construction**
  - **Cause**: Seismic surveys (noise and pressure)
  - **Effect**: Hearing damage, behavioral change

- **Construction**
  - **Cause**: Pile-driving (noise and pressure)
  - **Effect**: Hearing damage, behavioral change

- **Operation**
  - **Cause**: new hard substrate in the water (scour protection) & EMF
  - **Effect**: habitat modification changing local biodiversity, avoidance

- ** Decommissioning**
  - **Cause**: To be determined activities
  - **Effects**: local disturbance of marine habitat

- **All phases**
  - Lights, *boat traffic*, pollution
OWED Effects on Birds

- **Pre-construction**
  - Little

- **Construction**
  - Little

- **Operation**
  - **Cause:** rotating turbines, project footprint
  - **Effect:** morality/injury and displacement

- **Decommissioning**
  - Little

- **All phases**
  - **Lights**
OWED Effects on Bats

- **Pre-construction**
  - Little

- **Construction**
  - Little

- **Operation**
  - **Cause:** rotating turbine
  - **Effect:** morality/injury

- **Decommissioning**
  - Little

- **All phases**
  - **Lights**
Vulnerable Receptors

Hazards

\[ \text{Pre-construction} \quad \rightarrow \quad \text{Construction} \quad \rightarrow \quad \text{Operation} \quad \rightarrow \quad \text{Decommissioning} \]

Individual Effects Pathways

\[ \text{Direct} \quad \leftrightarrow \quad \text{Indirect} \]

\[ \text{Fish} \quad \rightarrow \quad \text{Sea turtle} \quad \rightarrow \quad \text{Marine mammal} \quad \rightarrow \quad \text{Bird} \quad \rightarrow \quad \text{Bat} \]

Exposure

Time

\[ \text{Additive (CAE} = a + b) \quad \rightarrow \quad \text{Synergistic (CAE} > a + b) \quad \rightarrow \quad \text{Antagonistic (CAE} < a + b) \]

Cumulative Effects Pathways

Space

Population Threshold

Cumulative Adverse Effects
Exposure

- **Time**
  - Past
  - Present
  - Reasonably foreseeable future actions

- **Space**
  - Project
  - Region

- **Cumulative effects pathways**
  - Additive ($\text{CAE} = a + b$)
  - Synergistic ($\text{CAE} > a + b$)
  - Antagonistic ($\text{CAE} < a + b$)

- **Population thresholds**
  - Effects to individuals pass a threshold to cause population level effects
  - Need to define your population
Importance of Scoping

- Defining the *hazards* (impact-producing factors)
  - Understanding the source
    - Homotypic
    - Heterotypic
  - Understanding effects pathways
- Defining *vulnerable* species
  - Refining the receptors
  - Having a clear baseline
  - Stating a threshold
- Defining *exposure*
  - Determine spatial boundaries
  - Determine temporal boundaries
Mitigating CAE

1. Avoid
   - Site projects away from biological hot spots

2. Minimize
   - Use best practices to reduce hazards during all operational phases

3. Compensate
   - Increase reproductive success by protecting breeding sites
   - Increase adult survivorship by reducing other anthropogenic stressors (e.g., fisheries bycatch)
Challenges

- How do we make decisions on something that may theoretically occur but we cannot detect in the field?

- Lack of cause/effect evidence
  - OWED hazards = or ≠ population decline
  - We don’t know our populations!

- Analysis boundaries
  - Temporal/spatial/source

- Responsibility
  - Developer/government/third party
  - Financial, research, data management

- Data sharing
  - Project based analysis can be proprietary
Solutions

- **Field research**
  - **Exposure**: What species are where, when (i.e., surveys)
  - **Vulnerability**: What species will be adversely affected (i.e., cause/effect studies)
  - **Hazards**: What are the impact producing factors and how far do they propagate into the environment (e.g., distance of pile-driving noise)

- **Guidelines**: BOEM CAE scoping guidelines to provide certainty to developers and regulators on what to include in an analysis

- **Collaborative governance**
  - Actions/decisions need to be taken PRIOR to CAE being detected (if it can be detected)
  - Private-public partnerships
    - COWRIE/SOSS/We@Sea/NWCC

- **Mitigation** on assumed/predicted adverse effects
  - Best practices
  - Avoid/minimize/compensate
My Research

- **Step 1: Literature Synthesis**
  - Effects of OWED on wildlife
  - CAE literature
  - Framework for understanding CAE
  - Scoping CAE assessment

- **Step 2: Interviews with regulators**
  - 12 complete

- **Step 3: Analysis of EIS of OWEDs in U.S. and Europe**
  - How has CAE been approached
Thank you!

Questions?