Cumulative Adverse Effects of Offshore Wind Energy Development on Wildlife

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Why do we care?

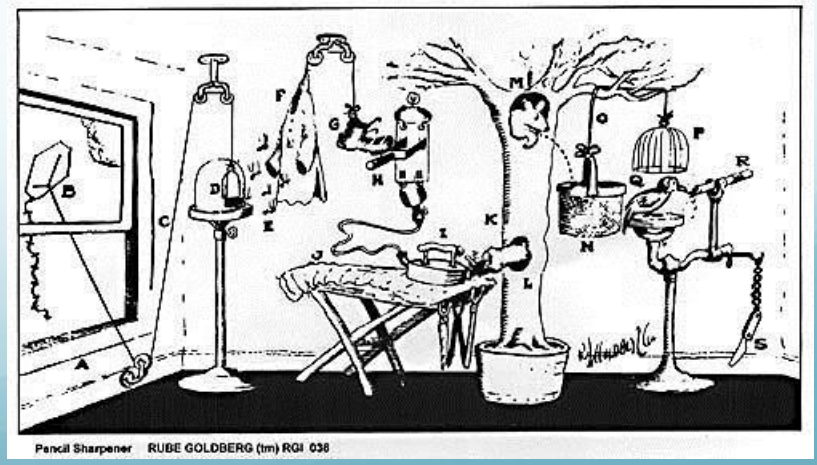
- **Legal**: Legal requirement to include cumulative effects in environmental assessments in the U.S., Canada, U.K., E.U.
- **Ecological**: Ecologically it is the accumulation of all anthropogenic actions over time and space
- **Offshore wind energy development** (OWED): Nearly every paper on OWED effects 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

NEPA Definition

- "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**

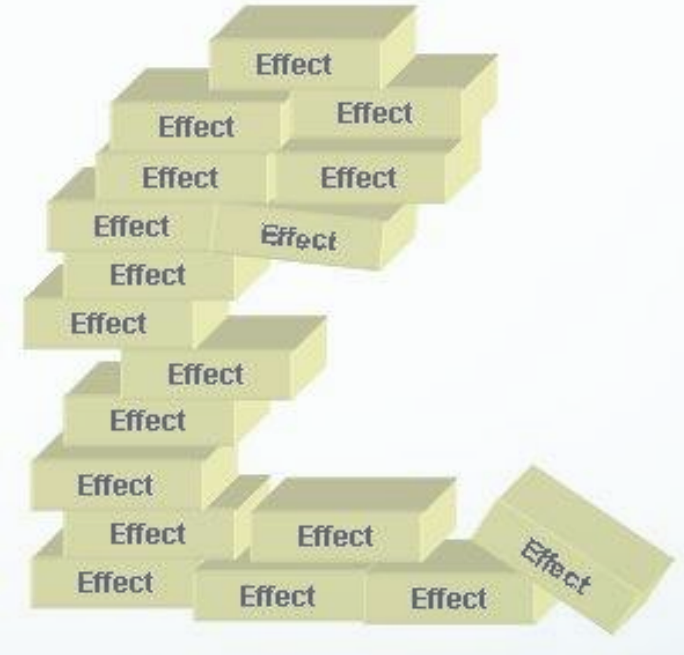
Effect vs. Impact

- 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

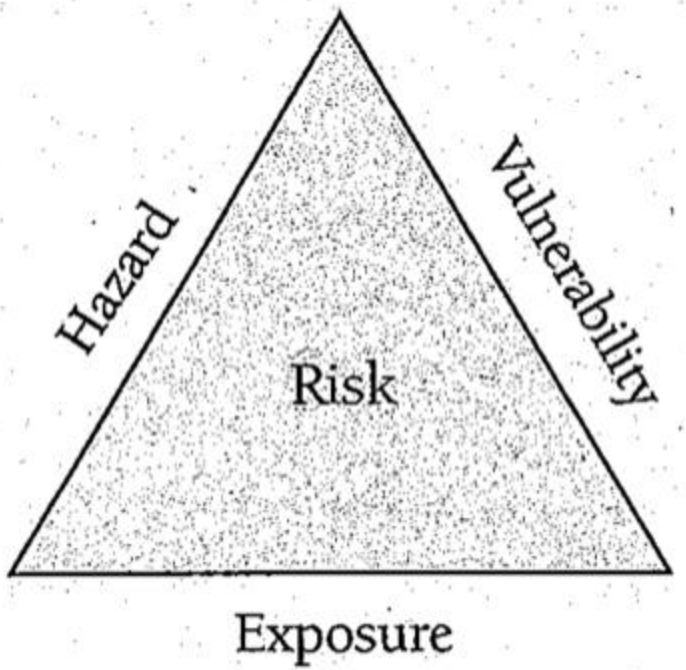


A Modeling Approach

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

- 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?



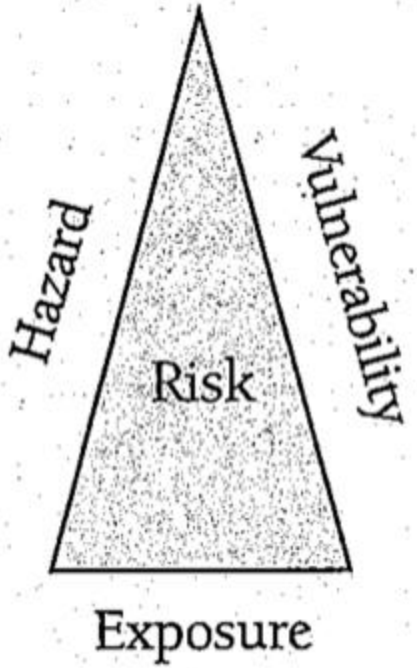


Figure 3: The Risk Triangle

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.

Adverse effects = Hazards & Vulnerability & Exposure

Pre-construction | Construction | Operation | Decommissioning

Hazards

Network connection

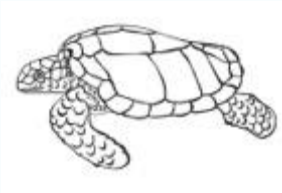
?

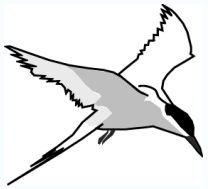
Individual Effects Pathways

Direct ⟷ ***Indirect***

Vulnerable Receptors

Fish | Sea turtle | Marine mammal | Bird | Bat





Exposure

Time

⟷

Space

Cumulative Effects Pathways

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

Population Threshold | Population Threshold

Cumulative Adverse Effects

Goodale and Milman 2014

OWED Hazards: Cause

Development phase	Development component	Hazard source	Hazard
Preconstruction	Turbines	Seismic profiling	Noise, pressure
	Network Connection	Seismic profiling	Noise, pressure
Construction	Turbines	Pile driving	Noise, pressure, turbidity, sedimentation, physical alteration of habitat
	Network Connection	Trenching	Turbidity, sedimentation, physical alteration of habitat
Operation	Turbines	Turbines, wind farm footprint	Disturbed air space, turbulence, noise, permanently altered habitat
	Network Connection	Electrical cable	EMF
Decommissioning	Turbines	Decommissioning activities	Unknown
	Network Connection	Decommissioning activities	Unknown
All phases	All components	Boat traffic, lighting	Disturbed marine habitat, noise, turbulence, light

Vulnerability:Adverse Effects

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

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

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

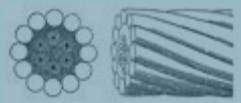
- **Pre-construction**
  - Little
- **Construction**
  - Little
- **Operation**
  - Cause: rotating turbine
  - Effect: morality/injury
- **Decommissioning**
  - Little
- **All phases**
  - Lights

Hazards

Pre-construction

Construction

Operation



Network connection

Decommissioning

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Individual Effects Pathways

Direct ⟷ *Indirect*

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Vulnerable Receptors

Fish

Sea turtle

Marine mammal

Bird

Bat

↓

Exposure

Time

⟷

Space

↓

Cumulative Effects Pathways

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

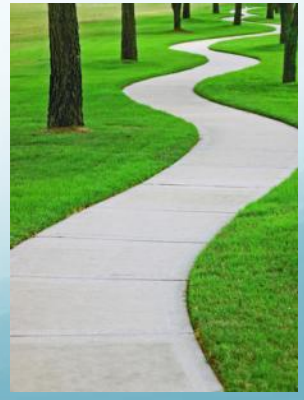
Population Threshold

Population Threshold

Cumulative Adverse Effects

Exposure

- Time
  - Past
  - Present
  - Reasonably foreseeable future actions
- Space
  - Project
  - Region
- Cumulative effects pathways
  - Additive (CAE = a + b)
  - Synergistic (CAE > a + b)
  - Antagonistic (CAE < a + B)
- Population thresholds
  - Effects to individuals pass a threshold to cause population level effects
  - Need to define your population

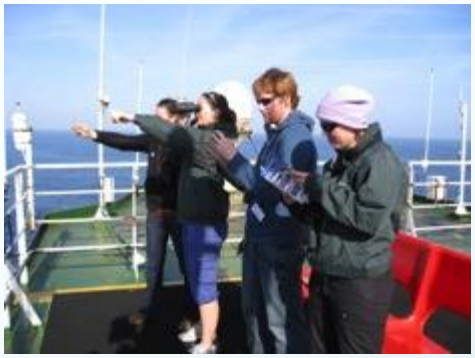


Importance of Scoping

- 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

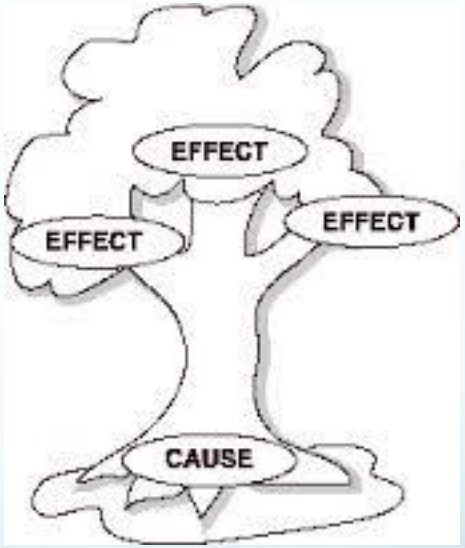
Mitigating CAE

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 effected (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?