Electro-magnetic fields from floating offshore wind & potential impacts to marine fauna

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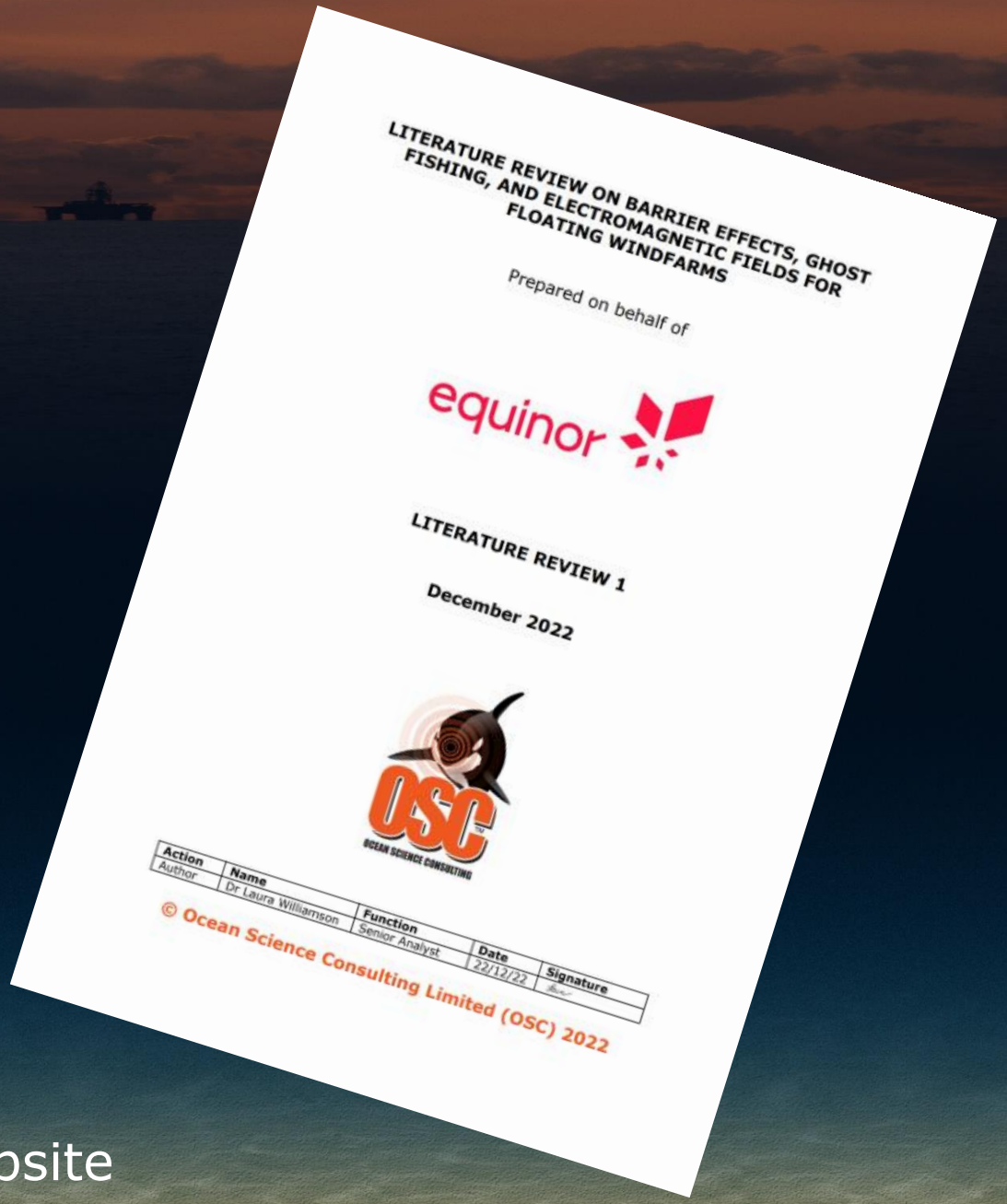
Literature review

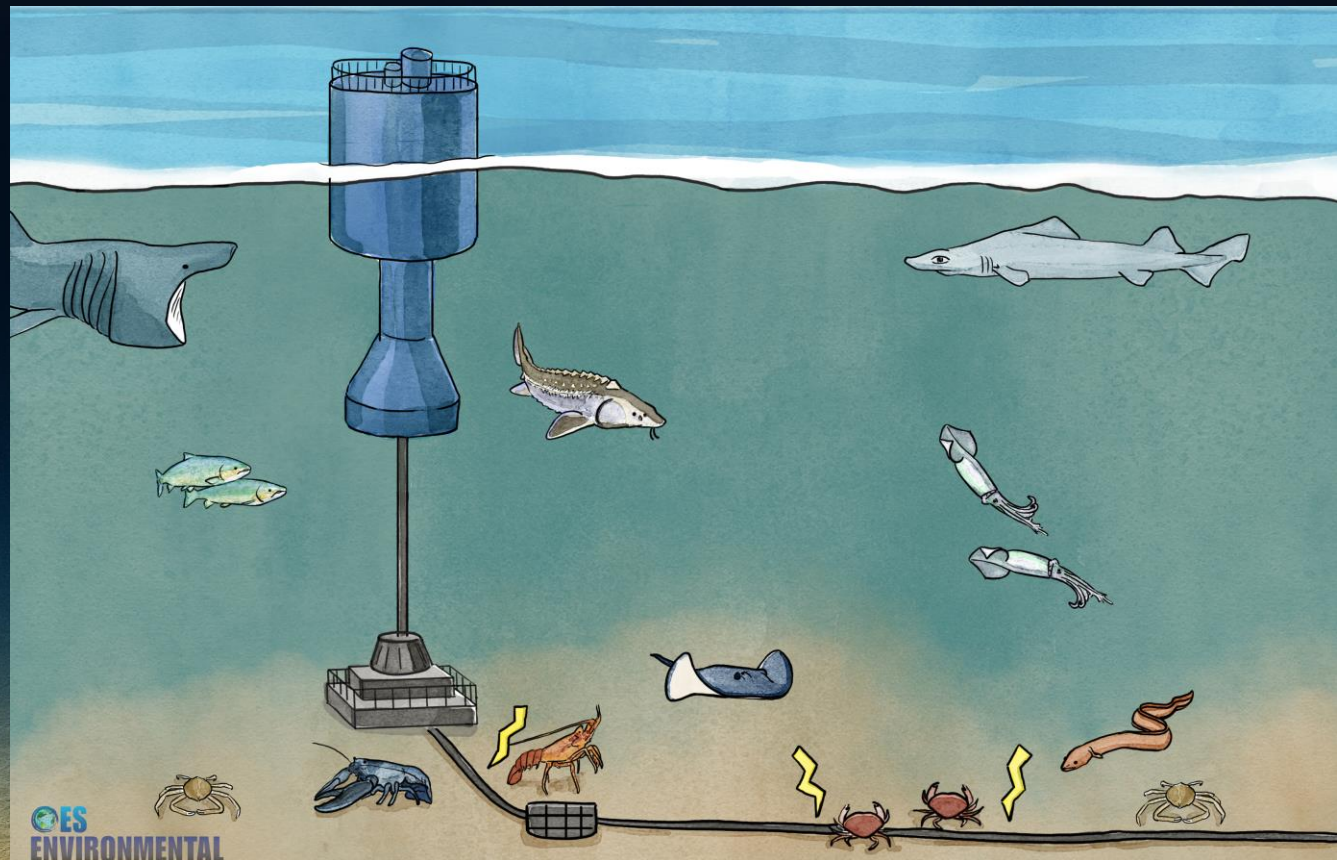
- Barrier effects
- Ghost fishing
- Electro-Magnetic Fields (EMF)



- Report available on Equinor website

Outline

- What are EMFs?
- What causes EMFs?
- How do animals sense EMFs?
- What are potential impacts to:
  - Marine mammals
  - Diving seabirds
  - Turtles
  - Sharks
  - Bony fish
  - Invertebrates
- Knowledge gaps



What are EMFs

- Electric fields = e-fields
  - Produced by difference in electric potential (voltage)
  - Can often be shielded to reduce impacts
- Magnetic fields = b-fields
  - Magnetic materials & electric currents surrounded by b-fields
  - Not contained by shielding

- Vectors = directional (unlike °C, pressure, etc.)
  - Can add to / subtract from other fields

Sources of EMFs

Natural sources

- Earth's geomagnetic field (GMF)
- Magnetic rocks
- Lighting
- Solar wind
- Geological movement
- Movement of water/organisms through GMF

- Living organisms
  - Heartbeat, nerves, ion exchange
  - Stun prey

Anthropogenic sources

- Power cables (AC or DC)
- Renewable energy devices
- Telecommunication cables
- Cathodic protection systems
- Heating of O&G pipelines

Sensing EMFs

Electroreception

- Detect e-fields

- Foraging & prey detection
- Predator avoidance
- Social/reproductive behaviour

Magnetoreception

- Detect b-fields

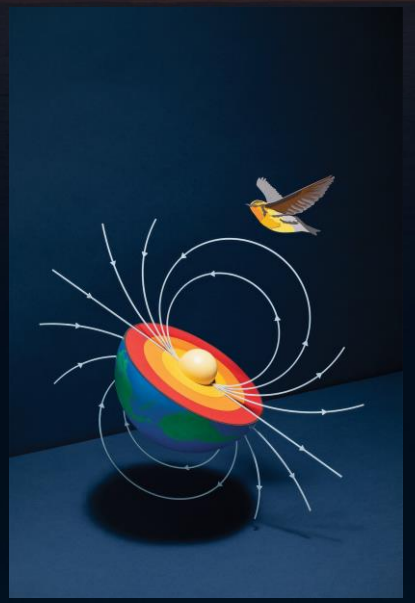
- Navigation
- Homing behaviour
- Orientation

- Biogenic magnetite
- Electromagnetic induction
- Optical pumping

Marine mammals

- Guiana dolphin = evidence of electroreception
  - Previously, platypus was the only known electroreceptive mammal
  - Hairless vibrissal crypts on the dolphin's rostrum serve as electroreceptors
- Many marine mammals likely to detect low-level b-fields
  - Likely through biogenic magnetite
  - Some strandings correlated
    - Due to local magnetic distortio
- Pinniped sensitivity to E
  - Some species undergo long
- Unlikely to be under inf
- Multiple cables along m

Diving seabirds



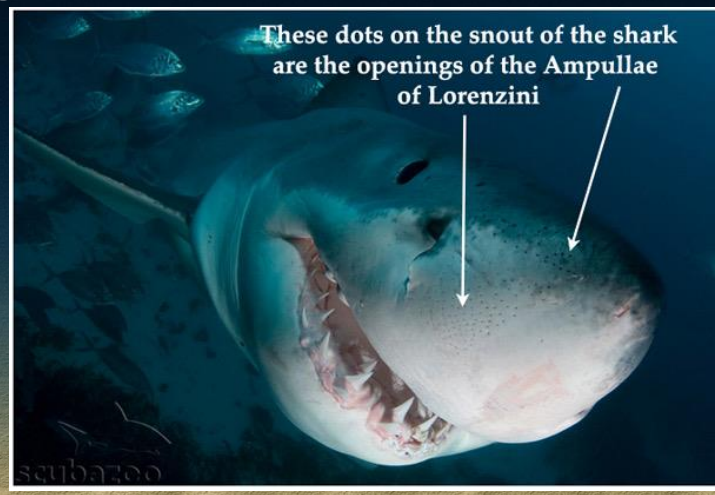
- Electroreception not confirmed
- Magnetoreception established
- Directional information about B-fields
  - Likely detected through photochemical reactions in the eyes
- Orientation using b-fields requires prolonged exposure
  - > 1 hr for chickens
- Impacts of EMF on birds through prolonged exposure
  - Reduced breeding success, changes in egg size & development
  - Hindered song development, stress, etc.
  - Highly unlikely to spend enough time in proximity to EMFs underwater
- Diving birds likely using vision for orientation
- No studies on underwater EMFs on diving birds

Turtles

- Electroreception not confirmed
- Magnetoreception established
- Thought to sense GMF at all life stages
  - Used for navigation, migration and orientation
- Geomagnetic sensitivity of 0.00469–4,000 μT
- Hatchlings imprint on natal beach – magnetic signature
  - EMFs could disrupt this if near nesting sites

Elasmobranchs

- Strong evidence for both e-field & b-field detection
- e-fields detected through ampullae of Lorenzini
  - Some species sensitive to < 1 nV cm^{-1}
- May be able to detect even shielded cables
- Unclear if b-fields detected directly or through electrosense or electromagnetic induction
- Impacts to behaviour which could interrupt foraging, increase energy expenditure, detection of prey/conspecifics
- Directional/navigational miscues



Bony fish

- Evidence for electroreception and/or magnetoreception
  - More for pelagic than demersal
- Electroreceptors sensitive to as low as 0.1 μV cm^{-1}
- Some species generate e-fields
  - Detect distortions from prey swimming through
  - Actively stun prey or deter predators
- Magnetoreception used for orientation & navigation
- Most studies are lab-based & on freshwater species
  - EMFs may impact development/growth or cause physiological effects
  - Considerable uncertainty regarding field & cumulative impacts
- No impacts to salmon/sturgeon migrations

Invertebrates

- Evidence for electroreception and/or magnetoreception
  - Arthropods, molluscs & echinoderms
- Decapods may be sensitive to b-fields a 5 μT & use GMF
- Potential for impacts to navigation, orientation & homing
- Some avoidance/burrowing behaviour from polychaetes & lobsters

Knowledge gaps

- Most research to date is lab-based
  - Field studies lacking – difficult or only a few species/individuals
- Characterisation of EMFs in real-world conditions
  - How these change with environmental variables & power (e.g. wind speed)
- Cumulative effects
- What species are receptive
  - What is their sensitivity to EMF levels

Acknowledgements

- Equinor
- Zoe Hodgson, Laura Park & Alex Turvill