Influence of Emissions from Subsea Power Transmission Cables on Animal Behaviour

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Together we are working for
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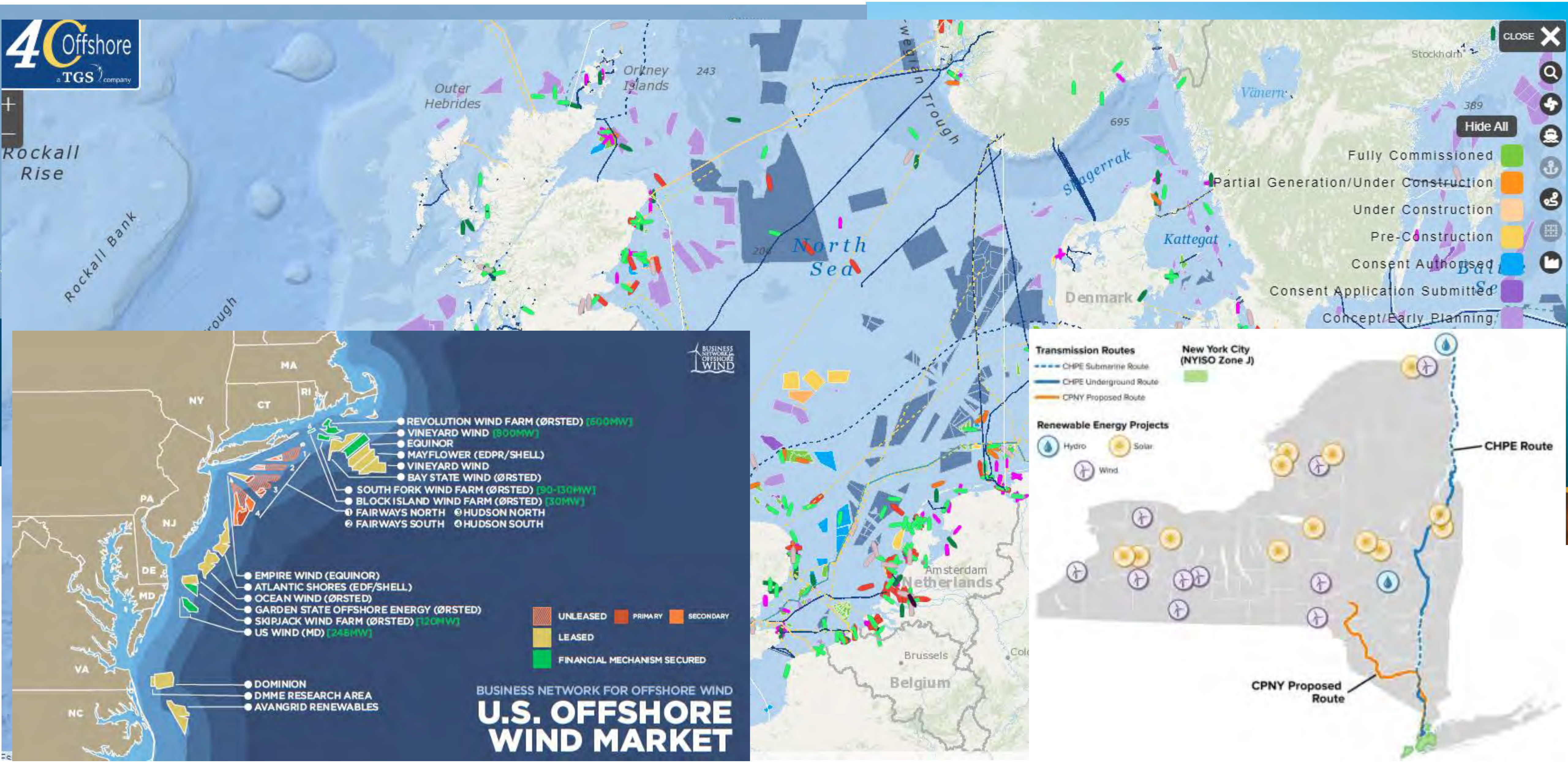
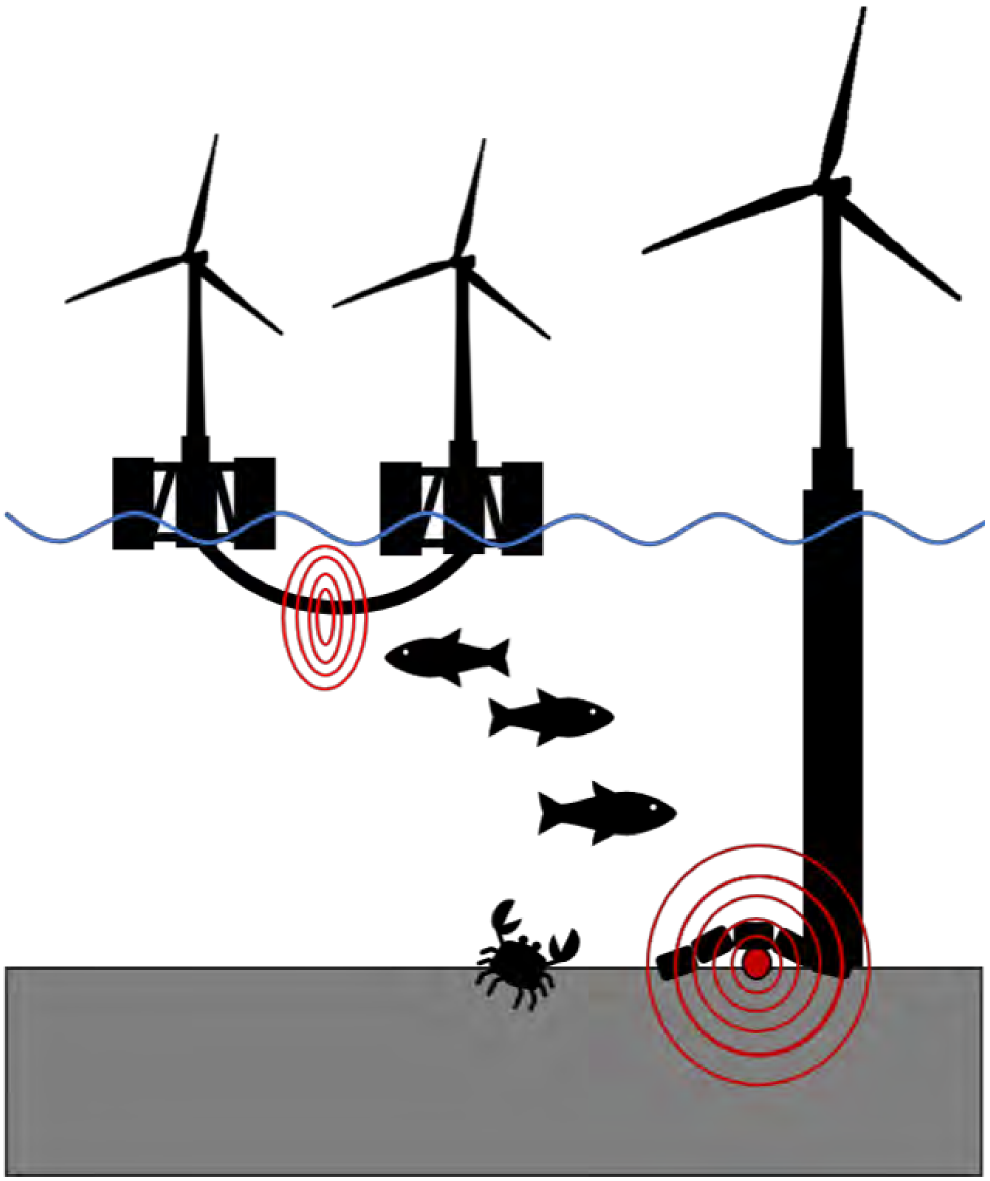
Why are we interested in the topic

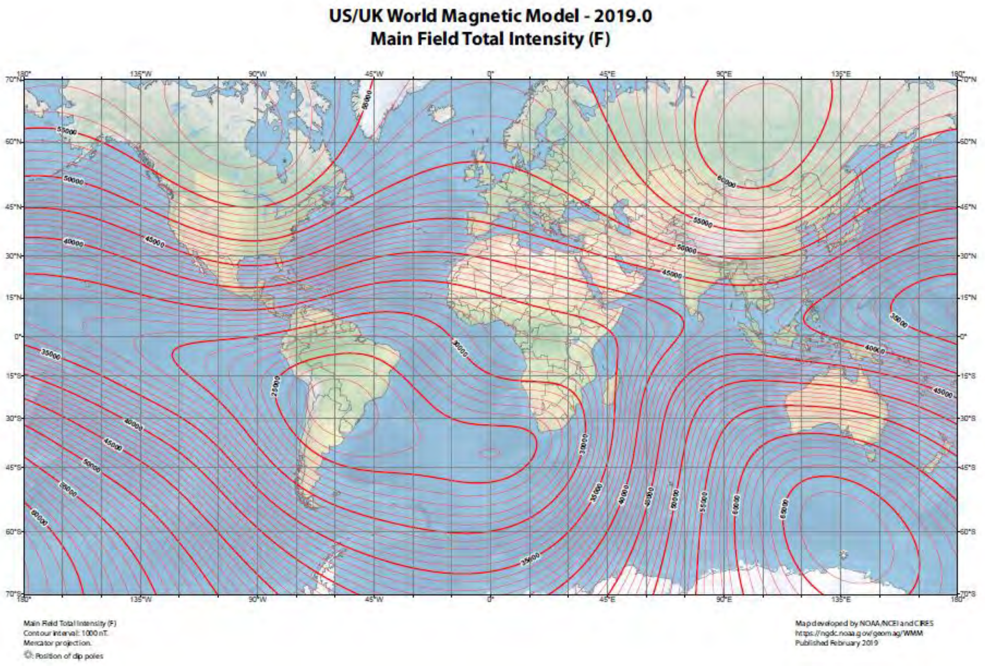


Overview

- Natural electromagnetic fields
- Why are they important to species and why should we care?
- Determining ‘impact’ from ‘effects’
- Intro to cable EMFs
- Advancing our understanding
- What’s needed
    - road map



Natural electromagnetic fields



NOAA, NCEI, 2019

Magneto-reception

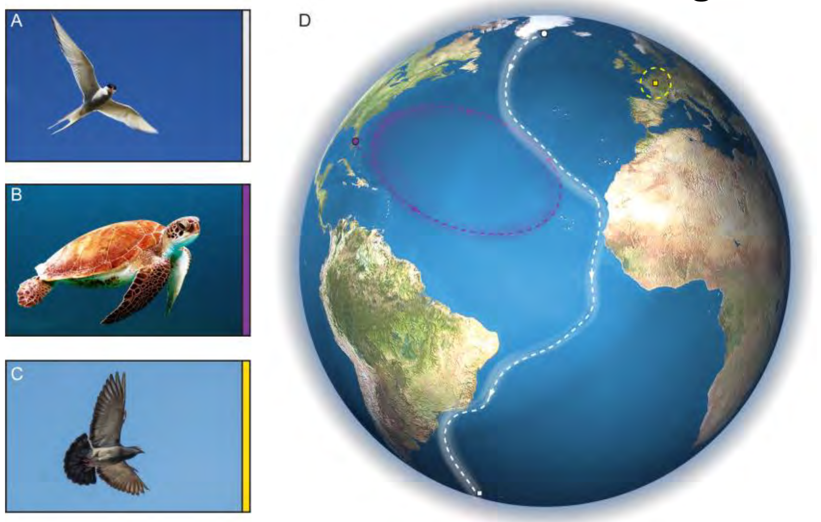
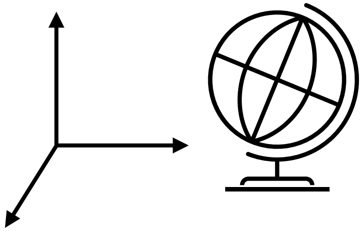


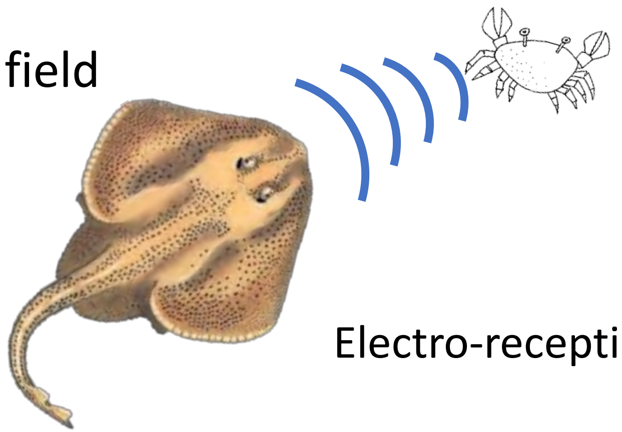
Image Source: Nordmann et al., 2017

- Geomagnetic field
- c.a. 25 – 65 µT



Also in the sea:

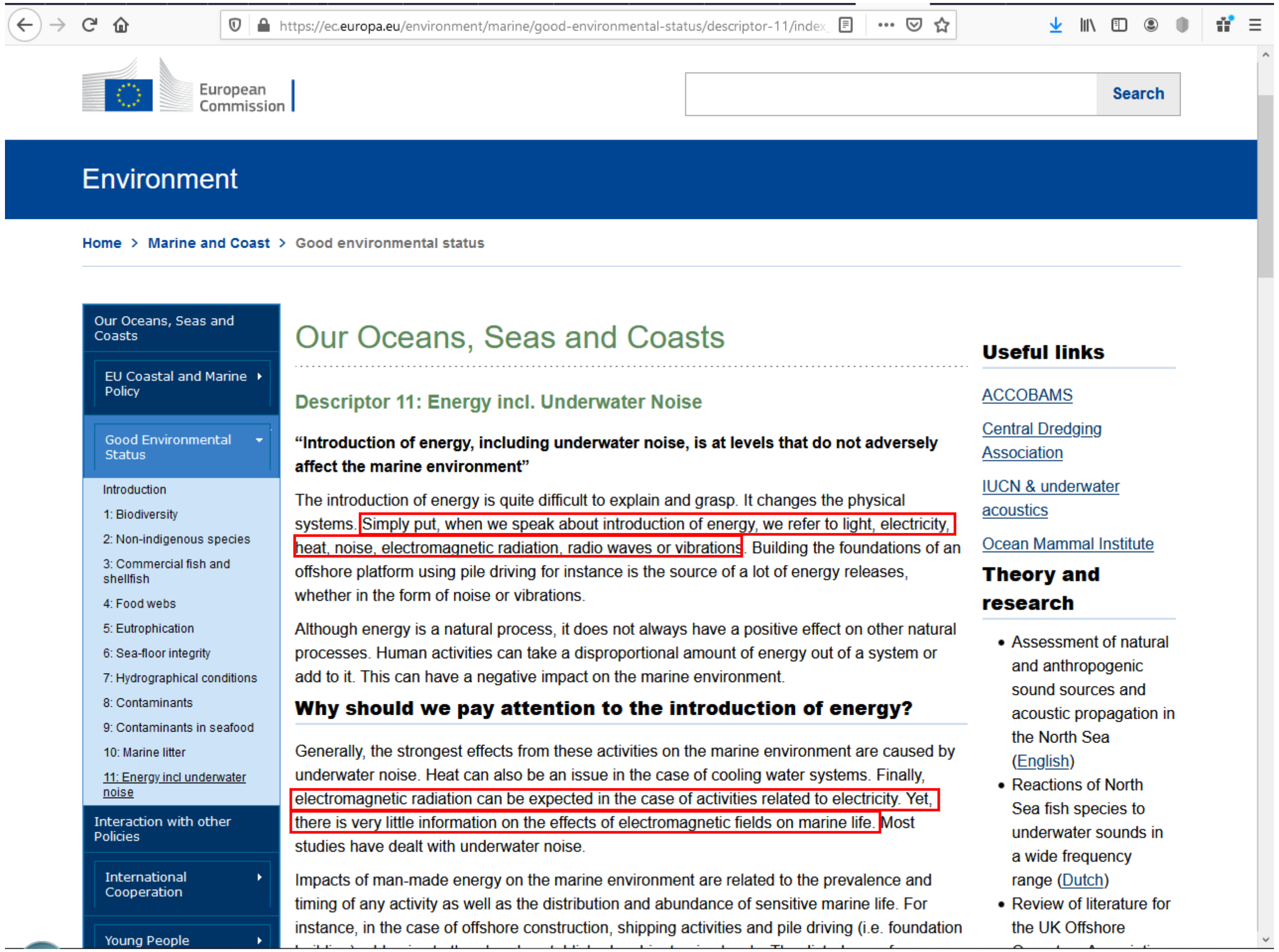
- Motionally induced electric field
- Weak bioelectric fields



Electro-reception

So what . . . Why should we care?

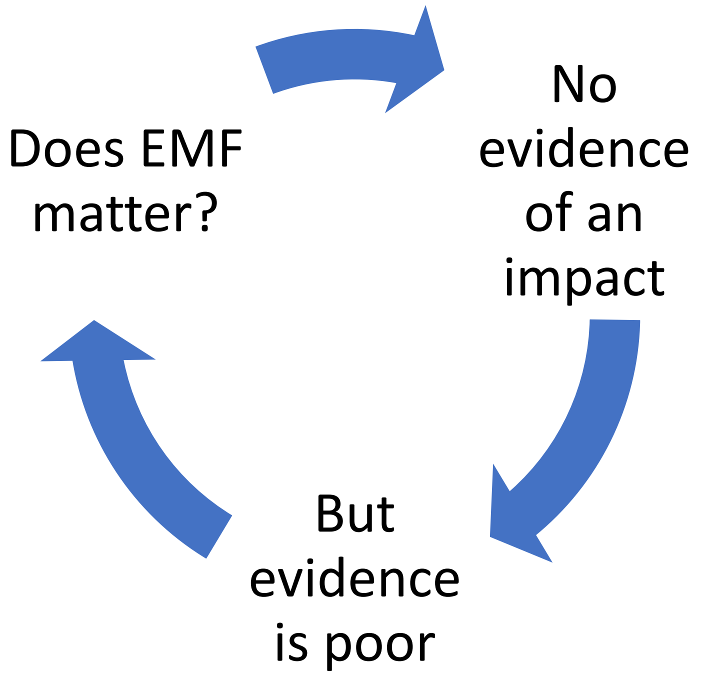
- Legislation
  - EU Marine Strategy Framework Directive
    - Descriptor 11
- Biodiversity crisis & related policies
- Stakeholder concerns
  - Commercial fisheries
  - Recreational fisheries
- Precautionary Principle
  - High degree of uncertainty
- Reviews of EIAs highlights strong uncertainty



There are no standards for EMF in marine environment

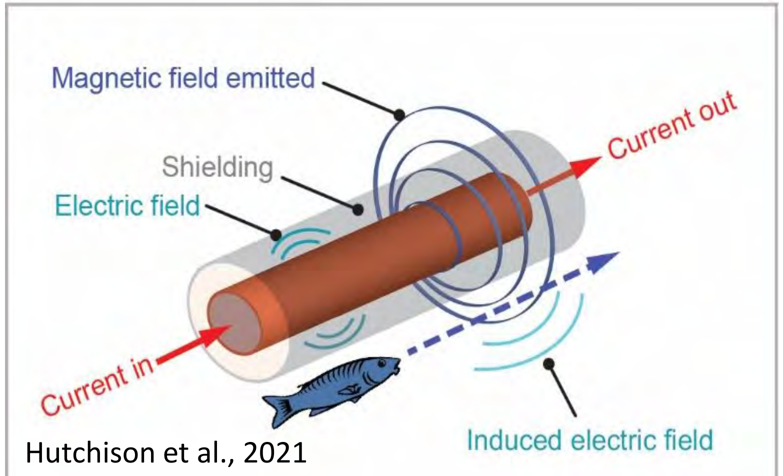
Determining 'Impact'

- Many studies used in EIAs are not suitable to determining if there is an impact
  - Where impact = biologically meaningful effect on a species (e.g. consequences for the species population)
- Uncertainty is frustrating for all
  - Developers and operators – why do we need to do this?
  - Regulators – how are we meant to assess this?
- Topic keeps getting shelved due to lack of knowledge
- Lots of interest at present
  - Stakeholder concerns
  - Developers and operators are keen to address it



Introduction to Cable EMFs

Two interacting components, electric and magnetic fields = electromagnetic fields

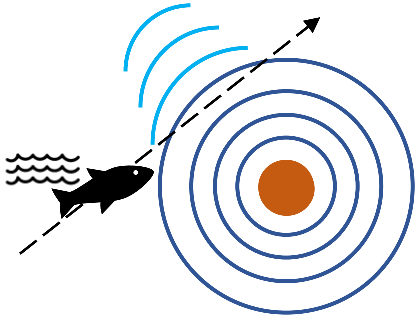


Hutchison et al., 2021

Motionally induced electric field

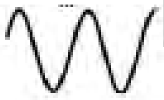
Interacts with the geomagnetic field

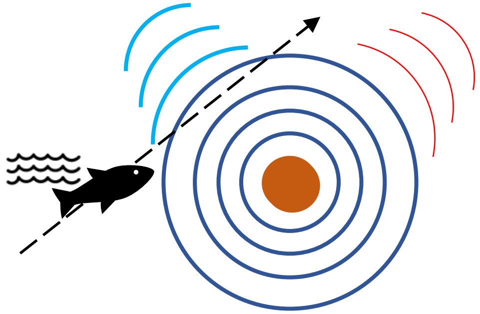
DC
(Static)



Electric field is contained within the cable sheathing

AC
(Alternating)





Magnetic field (direct)

Motionally induced electric field

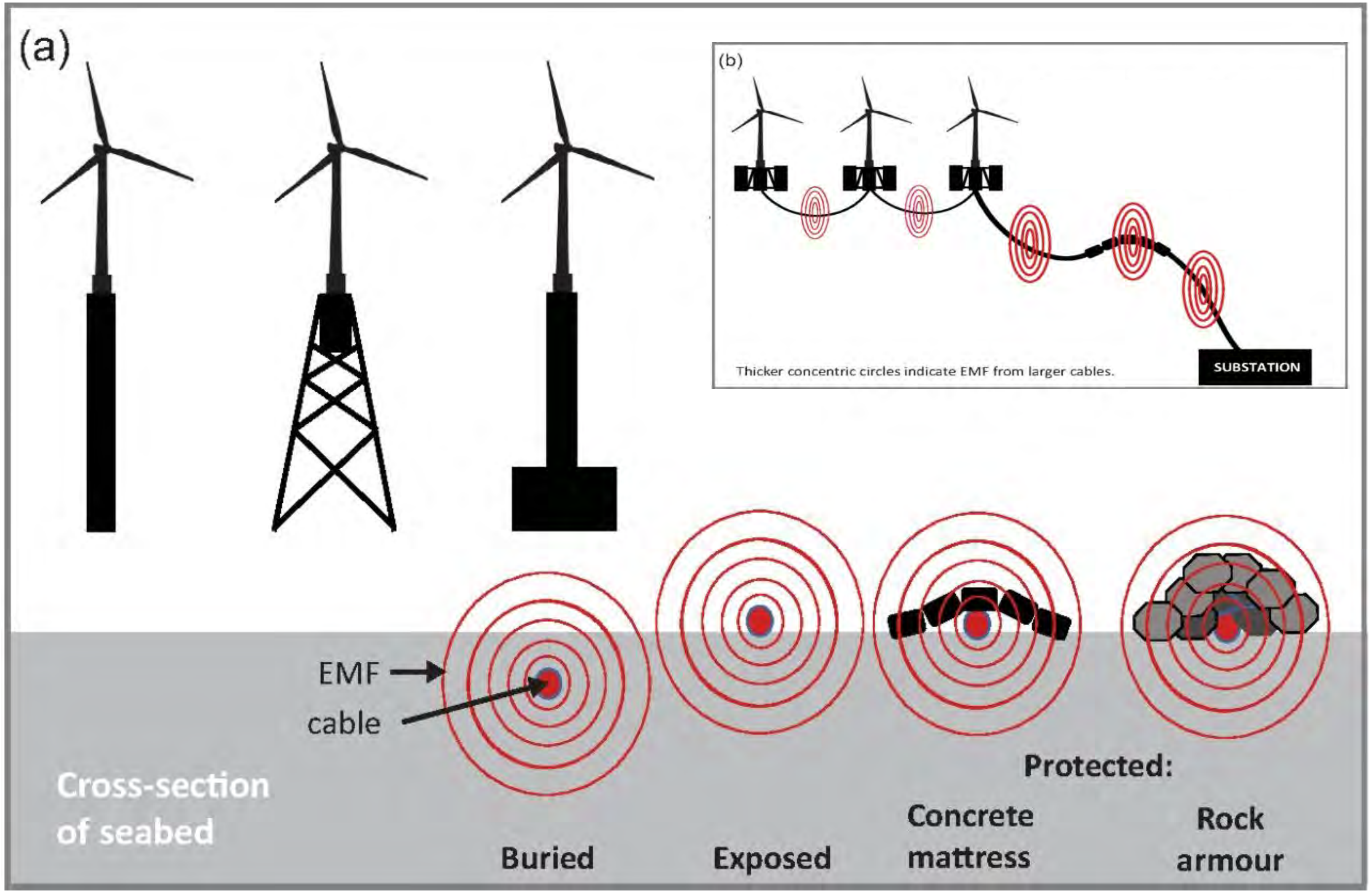
Magnetic field (direct)

Induced electric field

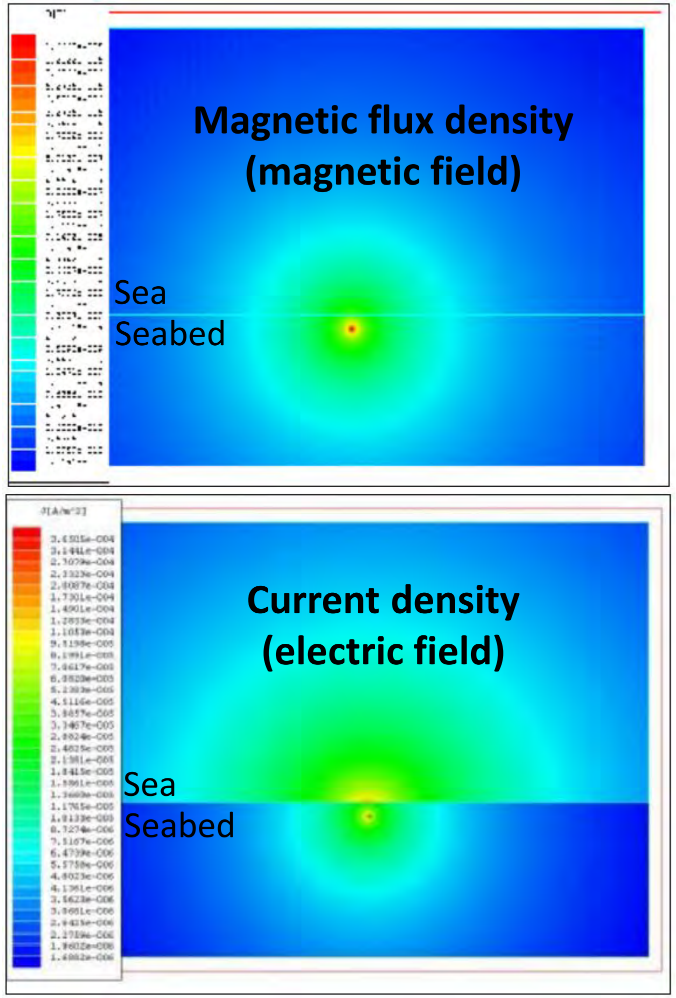
Motionally induced electric field

Introduction to Electromagnetic Fields . . .

. . . in the marine environment

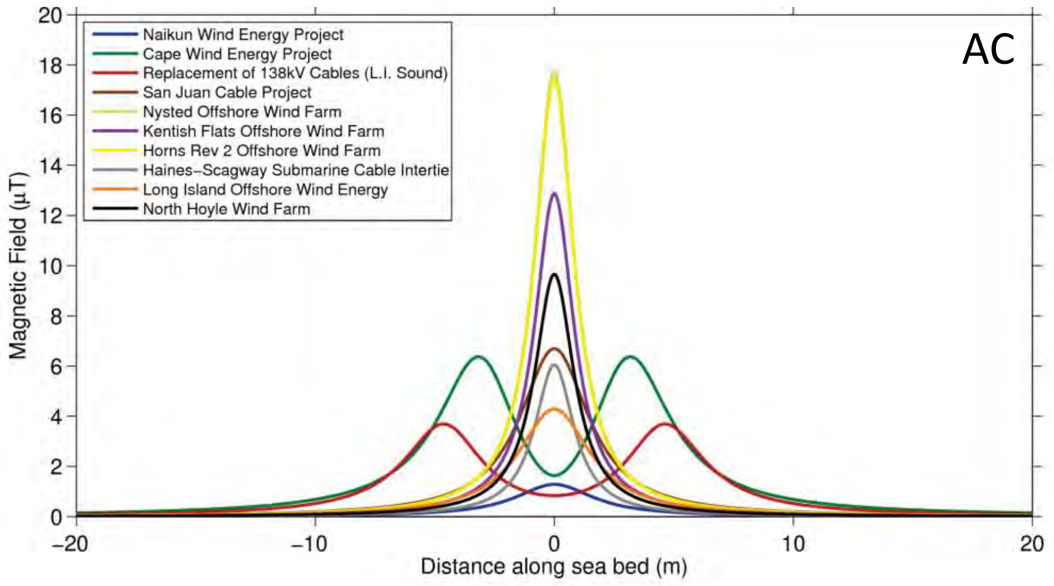


Adapted from Hutchison et al., 2020, *Oceanography*



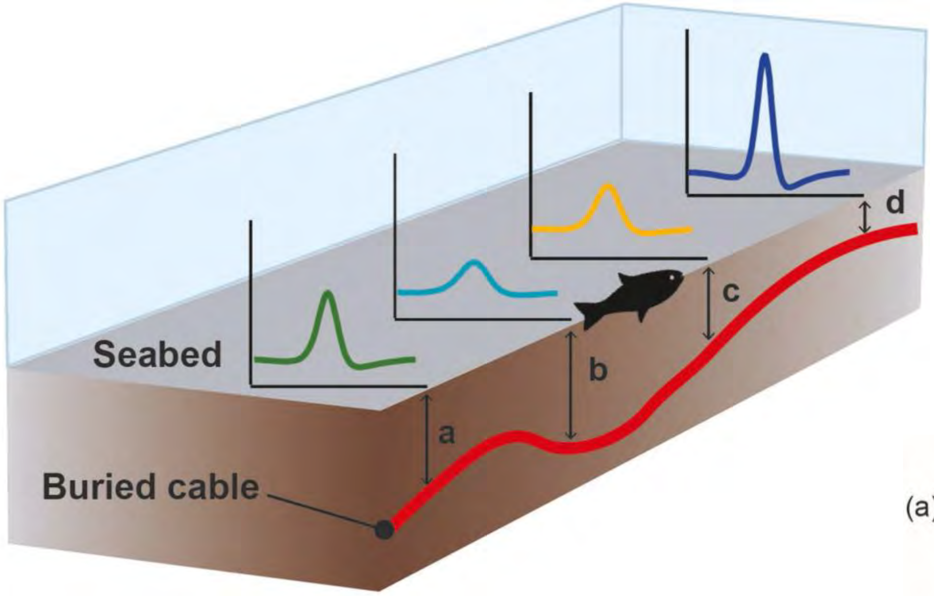
Adapted from CMACS, 2003; Gill et al., 2012, *IEEE*

Typical Modelling



- Models are applied at maximum operating capacity
  - Not fully representative of the operational range
  - Sometimes variable power levels are used but inconsistent
- Model EMF at 1 m distance from the cable
  - Doesn't account for the full spatial extent of the emission?
- Only models the magnetic component
  - Doesn't include the induced electric field or motionally induced electric field?
- Only models the cable emission
  - There is a need to consider the interaction with the local geomagnetic field for HVDC?
  - 'Total field' would consider the interaction and would vary with geography and cable orientation along the route
- Models are not validated
  - Therefore, there remain unknowns?

Sources of EMF variability

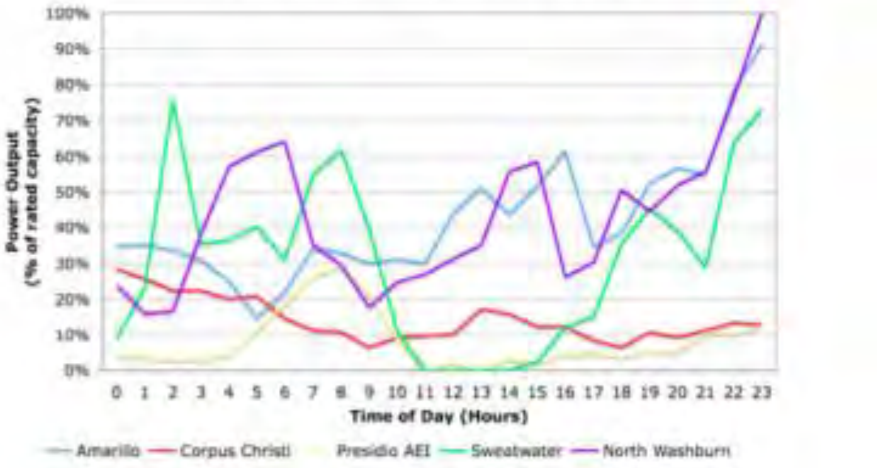


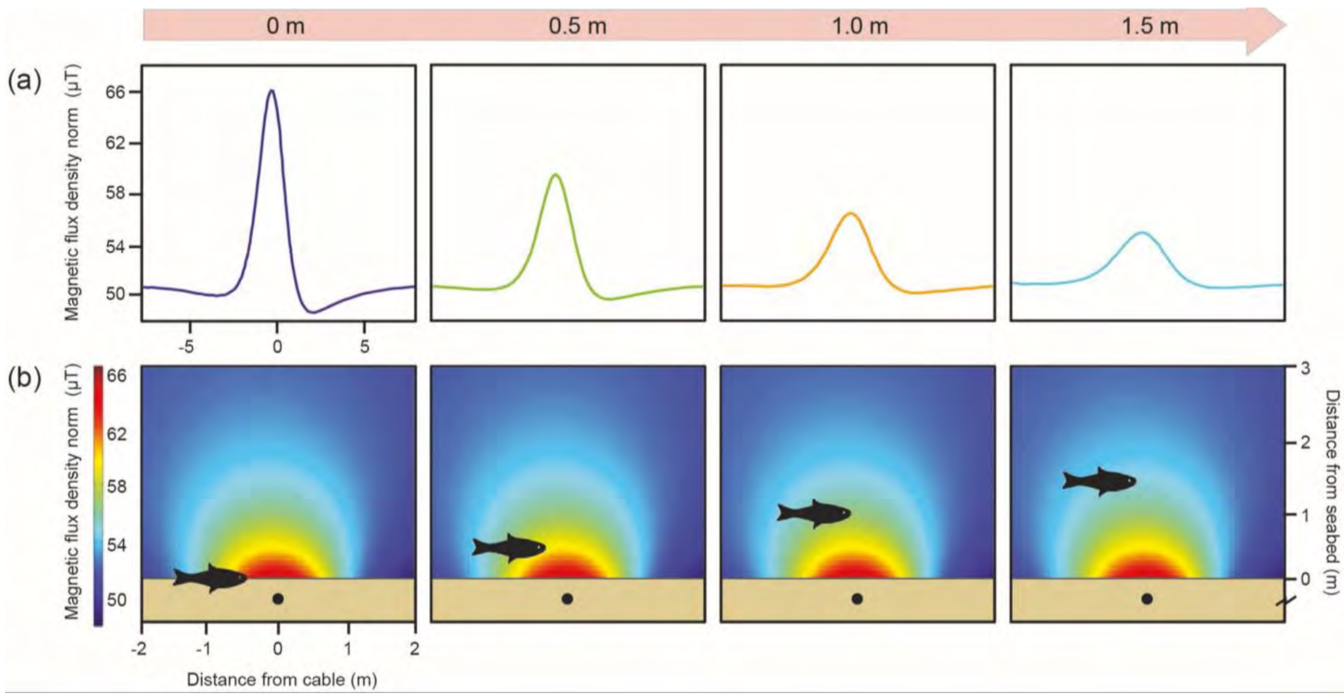
Physical cable route will not have a consistent burial depth

- Targeted burial depths
- Actual burial depths (variable)

Hutchison et al., 2021, *Renewable Energy*

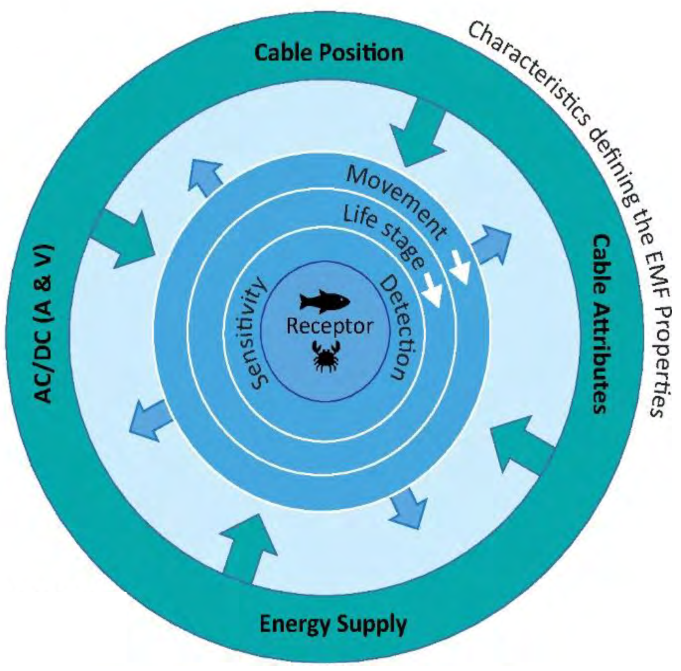
Figure 3. Daily Variation in Power Output (5 sites in Texas, January 1, 2004)





'Fish' movement will influence the EMF encountered by varying the distance from source

How best to advance our understanding



Adapted from Hutchison et al., 2020, Oceanography

Take the vantage point of the receptive species

- Take their position in space and time
- Consider how they perceive their sensory environment
- Which cues are important at that time
- More informed by OSW cable characteristics

Life Stage

- How does the perception of EMF change through a species life history?
  - Sensory ability
  - Biological function
  - Ecological context

Ball et al., 2016, Dev. Neur.
Sisneros et al., 1998, J. Comp. Phys. A

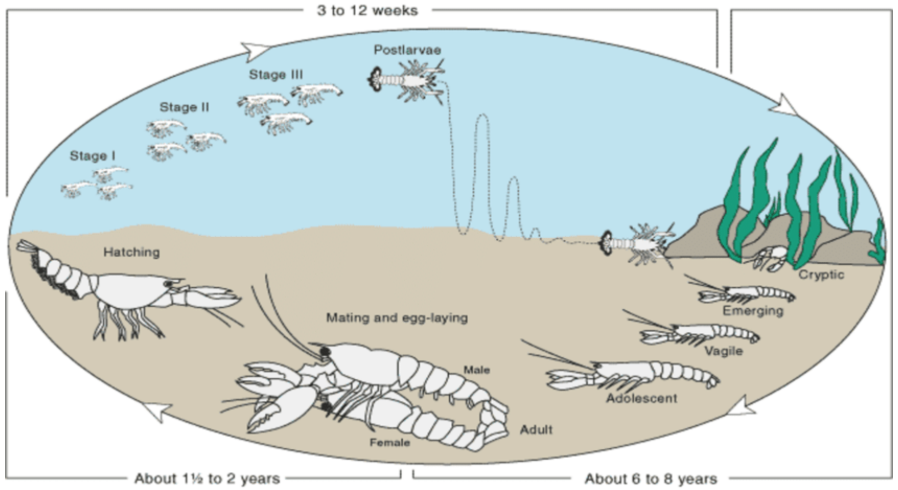


Image Source: St-Lawrence-Global-Observatory-SLGO

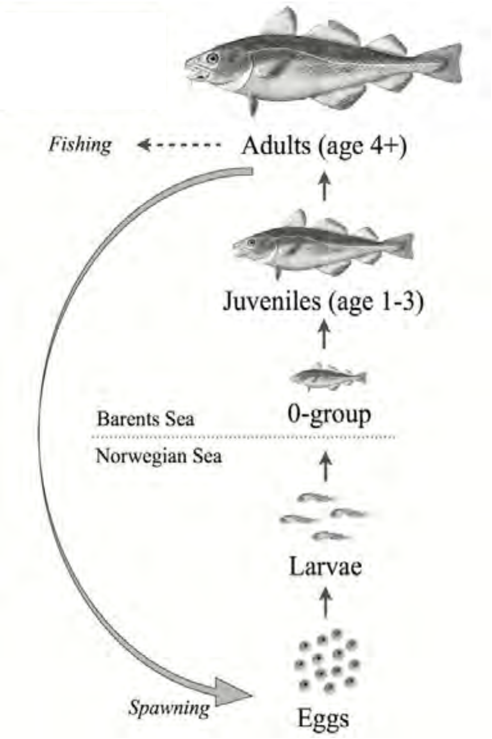


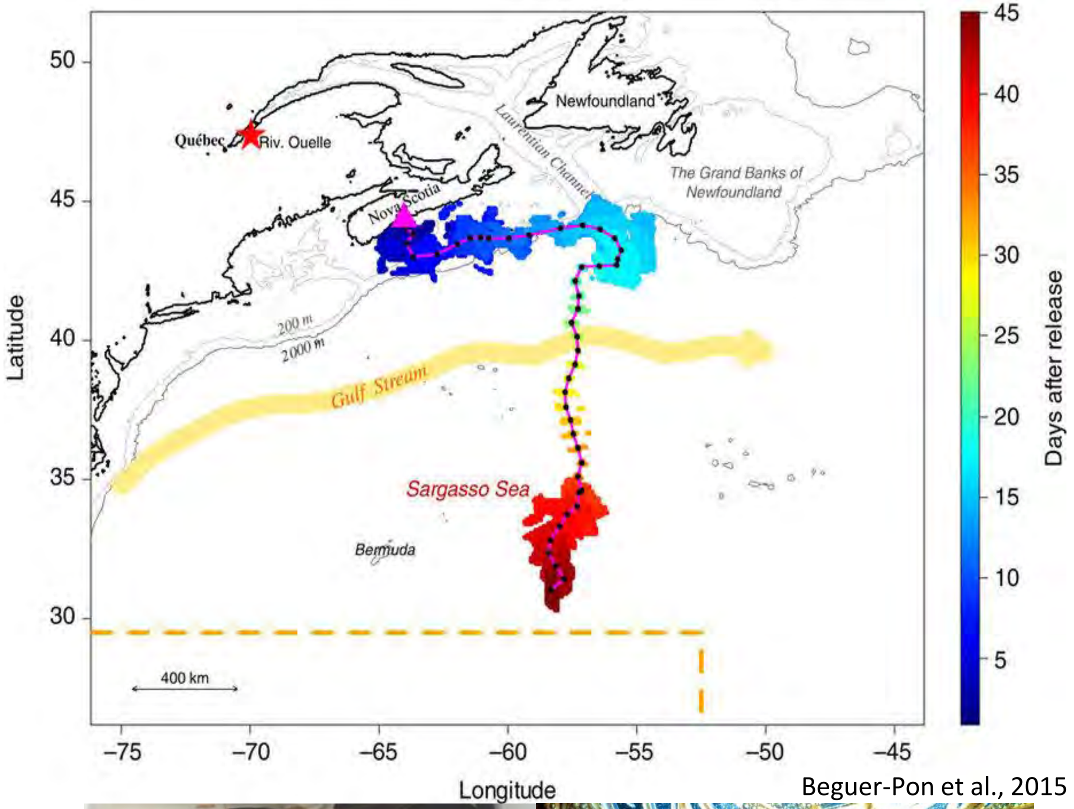
Image Source: adapted from Ohlberger et al., 2014

Movement

- How does movement ecology inform us of the likely encounter rate?

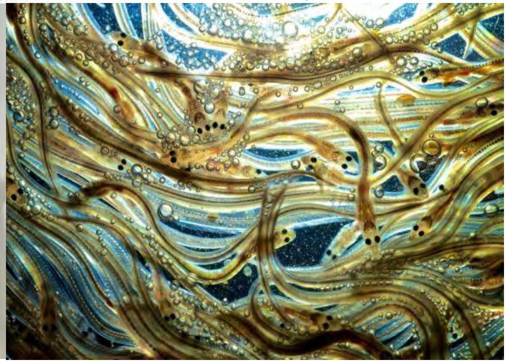
- Vertical & horizontal spatial variability
- Temporal variability

- How often?
- Previous experience?



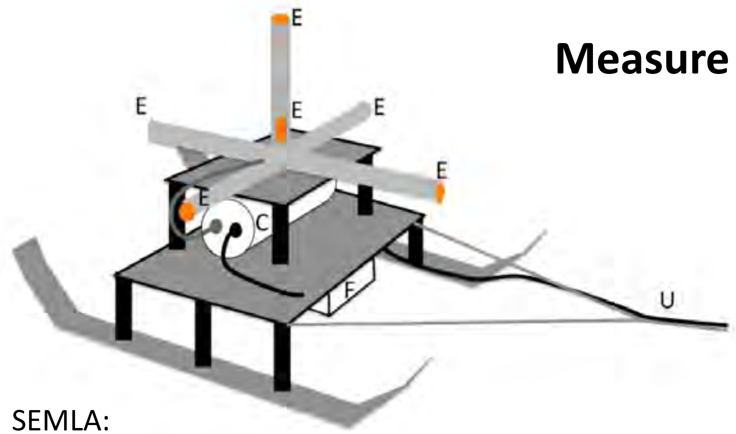
Beguer-Pon et al., 2015

Z. Hutchison



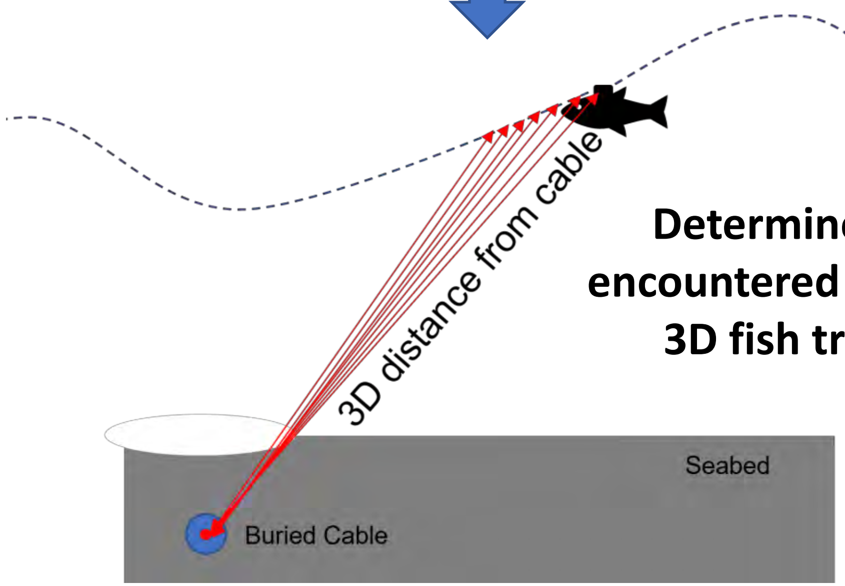
© Heather Perry, Yale

Determining the encountered EMF

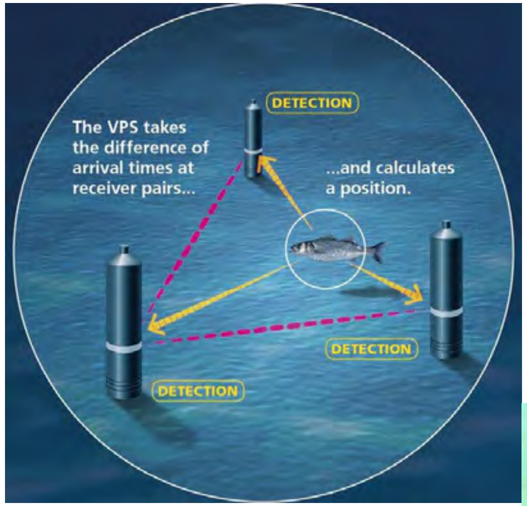


SEMLA:
Swedish Electromagnetic Low-noise Apparatus

Measure and model the EMF



Determine the encountered EMF for 3D fish tracks



3D movements of fish

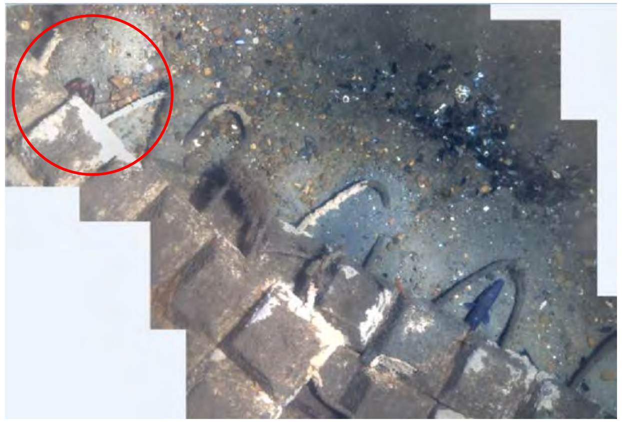
Hutchison et al., 2021, BOEM 2021-83

Encountering an EMF

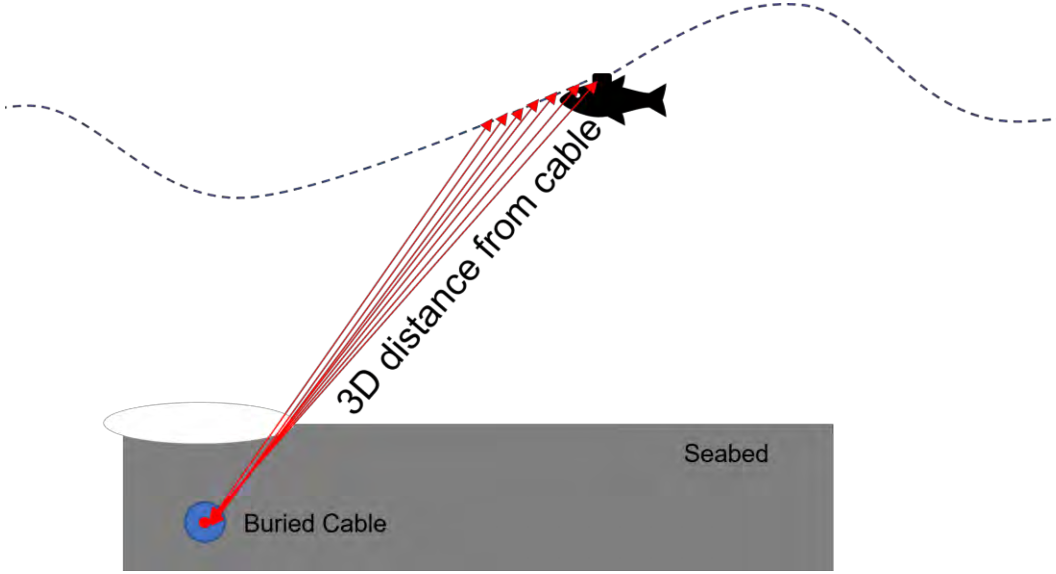
- A general assumption that is made is that closer to the cable will result in strongest EMF exposure but several factors influence the exposure to EMF

1. Temporal changes in power levels
2. Burial depth & fish position = distance from source
3. Temporal extent of exposure
    - Potential for aggregations around artificial reef effect/ dynamic cabling
    - Potential for multiple encounters

Taormina et al., 2020 Mar. Environ. Res.



HDR, 2020, BOEM Report No. 2020-044



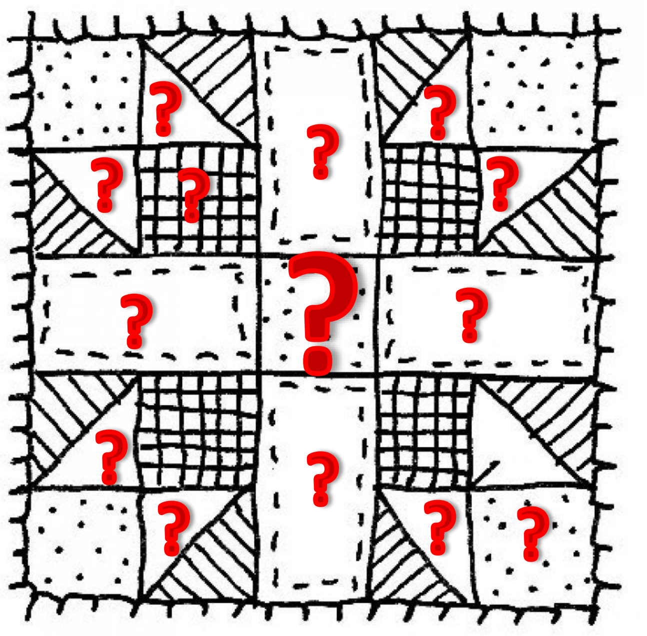
Hutchison et al., 2021, BOEM 2021-83

Patchwork of Information

Numerous species & a variety of endpoints

Range of techniques

- In situ free-ranging
- In situ mesocosm
- Aquarium



Range of exposures

- AC, DC, GMF
- Intensity
- Spatially variable
- Temporally variable

Key Question: Relevance to Offshore Wind

Known effects on invertebrate species

- Magnetoreception is widespread across taxa, even bacteria respond to magnetic fields
- Biofilms may be influenced too
- Invertebrates have been shown to change burrowing behaviour in response to MFs
- Cytotoxic and genotoxic responses have been shown in bivalves in response to MFs
- Aquarium studies, focussed on MFs of 1mT or higher

Kirschvink, 1980
Harsanyi et al., MASTS 2020

Stankevičiūtė et al., 2019, Aq. Tox.
Jakubowska et al., 2019, Mar. Env. Res

Stankevičiūtė et al., 2019, Aq. Tox.

Malagoli et al., 2004, Comp. Biochem. Phys. C.

Image sources: asknature.org, Wikipedia, Marlin-MBA, Hans Hillewaert

Known effects on invertebrate species

- Best understanding of true navigation is from the Caribbean Spiny lobster
- Crabs and lobsters have been a strong focus of recent research – behavioural, physiological, and stress response studies
- *In situ* exposures to cable EMFs (AC & DC)
- Aquarium studies using exposures to a range of MFs using solenoid magnets and helmoltz coils (µT – mT)
- Range of life-stages, including recent work on crab and lobster larvae

Scott et al., 2018, Mar. Poll. Bul.
Scott et al., 2021, J., Mar. Sci. Eng.

Love et al., 2015, Bull. Southern California Acad. Sci.
Love et al., 2017 Cont. Shelf. Res.

Boles and Lohmann, 2003, Nature
Ernst and Lohmann, 2018, J. Exp. Biol.

Hutchison et al., 2020, Sci. Rep.

Taormina et al., 2020, Aq. Tox.
Harsanyi et al., 2022, J. Mar. Sci. Eng.

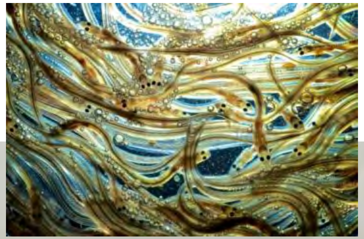
Image sources: Christian Ferrer, Jorge E. Gonzalez Photography, Soffía K. Magnúsdóttir

Known effects on migratory species

- Focus on behaviour and movement studies
- Best understanding of salmonid response comes from the study of non-UK species
- Focus on salmonid natural use of geomagnetic field
  - Migrations correlate with geomagnetic field variations
  - Juveniles use the geomagnetic field to orientate
  - The vertical component helps orientate hatching
- Salmonid smolts showed a degree of misdirection and increased transit time in response to HVDC cable EMF (nT)
- Anguillid studies also making progress in the UK and US
- Glass eels respond to geomagnetic field alterations; evidence of a circa-tidal influence
- Silver eels changed swimming speed in response to a HVDC cable EMF (nT)

Putman et al., 2013, Cur. Biol.
Putman et al., 2018, Biol. Lett.
Putman et al., 2020, J. Exp. Biol.

Wyman et al., 2018, Mar. Biol.

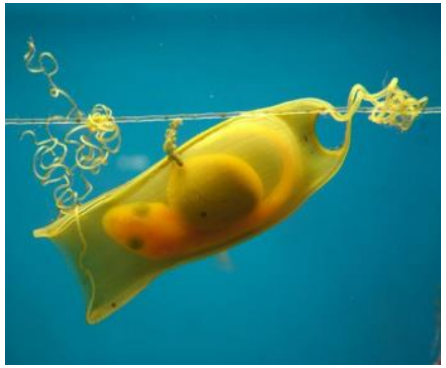


Cresci et al., 2019 Comm. Biol.
Westerberg & Lagenfelt, 2008, Fish. Manag. Ecol.
Hutchison et al., BOEM, 2021

Image sources: William Rosmus (CC), salmonfactswork.weebly.com (representative smolt), glass eels by Heather Perry, Yale, & personal photo of adult eels

Known effects on elasmobranchs

- Response to bioelectric fields is established to be active in the very early life-stages
  - Important for predator detection
- Catsharks are able to differentiate between AC and DC but not between artificial and natural EFs
- Catsharks are only capable of short-term memory of prior EF exposure
- In situ mesocosm experiments have occurred with elasmobranchs – both AC and DC
- Increased exploration and foraging behaviours in response to cable EMFs (nT to µT range)
- Elasmobranchs are responsive to both magnetic and electric fields



Ball et al., 2016, Dev. Neur.
Sisneros et al., 1998, J. Comp. Phys. A

Kimber et al., 2011, 2014

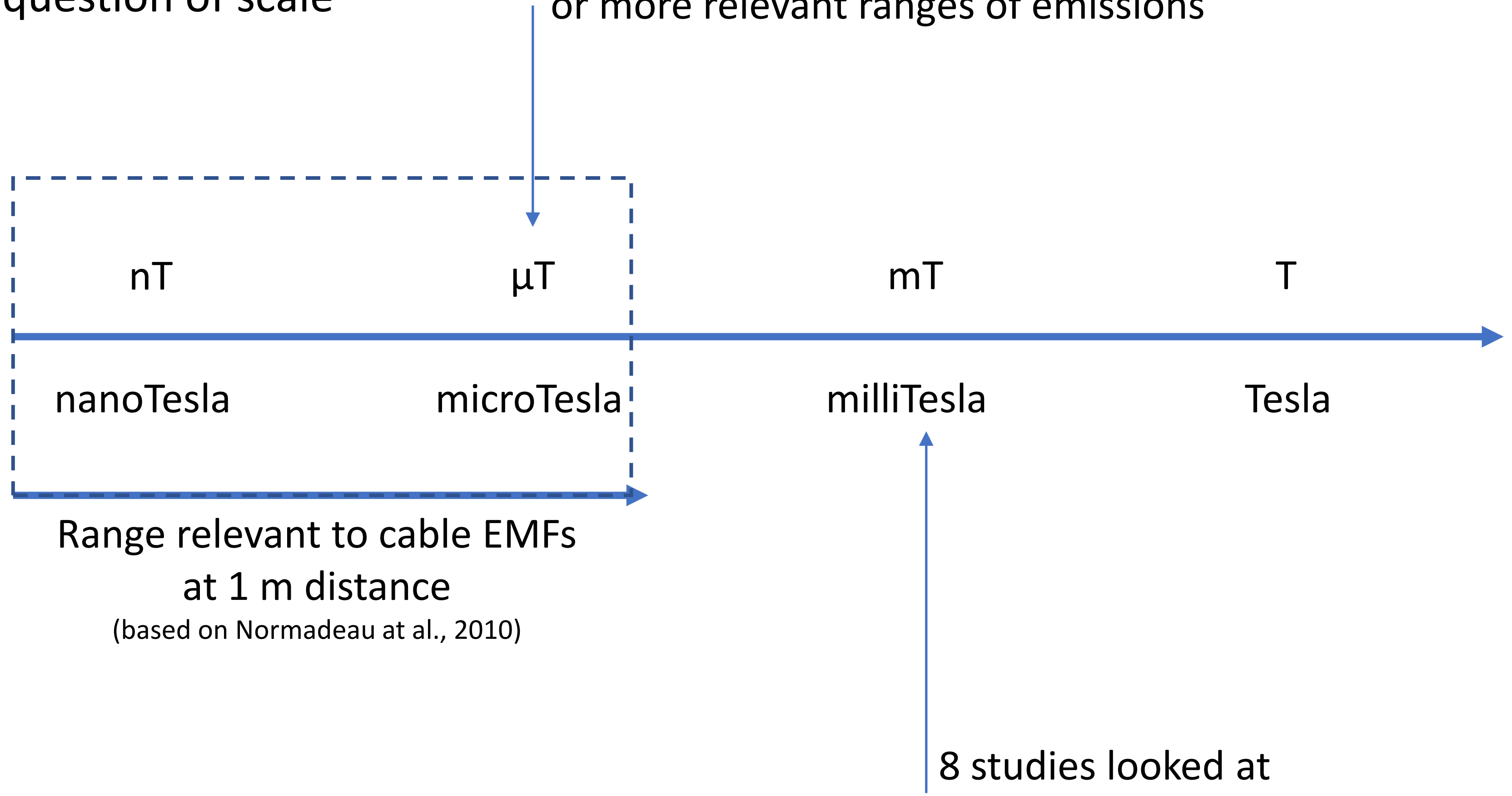
Gill et al., 2009, COWRIE
Hutchison et al., 2020, Sci. Rep.

Image sources: All things Ocean, The Wildlife Trust, Jorge E. Gonzalez Photography

Exposure levels

- A question of scale

7 studies focussed on cable EMF emissions
or more relevant ranges of emissions



8 studies looked at
1 mT or higher (up to 40 mT)
EMF levels

What’s needed?

➢ ***Defining species & life-stages are most relevant?***

Understand encounter rates

- 2D data will provide the potential to encounter a cable EMF but fine-scale 3D data is required to establish the encountered EMF; and
- Must be combined with industry data on temporal nature of power level indicative of EMF emissions
- Better understanding of variation in EMF along cable route, as perceived by the species
- Specific to the species & life-stage of interest
    - e.g. larvae, migratory adult fish, brooding crustacean
- Consideration of non-EM-receptive species
    - e.g. potential effects on aggregating fish

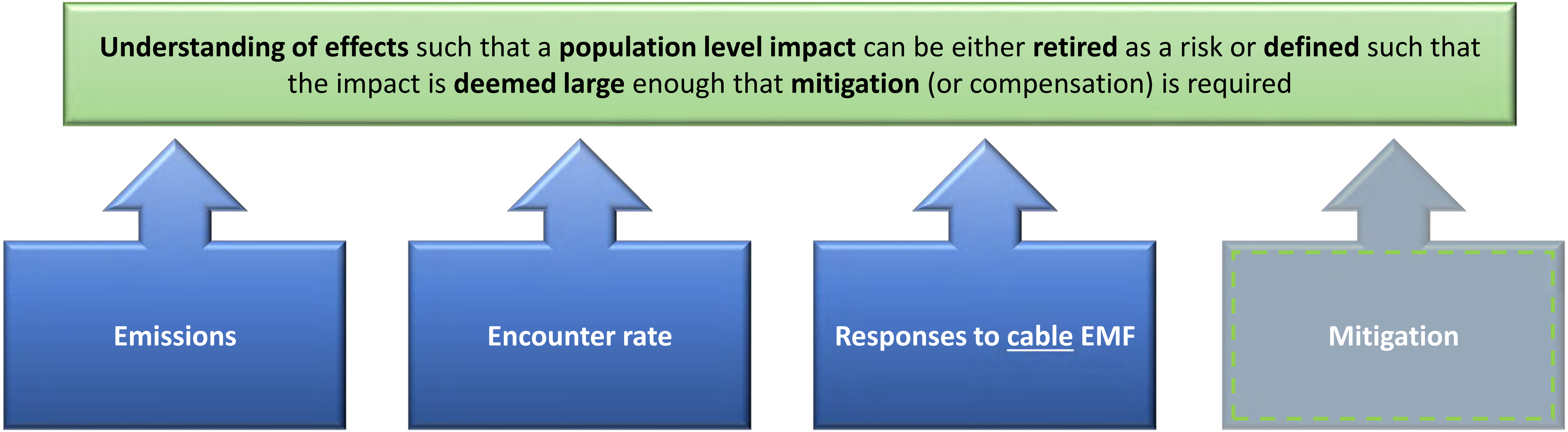
Realistic exposures

- Better understanding of how relevant the non-cable MF studies are to cable EMFs
- Establish suitable exposure intensities with consideration of species specific interactions
    - e.g. lobster will be different to a migratory fish
- Consideration of life-stage
    - Egg/embryo, larvae, juvenile, adult, migration
    - Most critical response stage/most likely encounter
- Careful consideration of most relevant metric
- How do we move data on a response into a model which informs population level impacts?

Not just the effect but also the potential for cumulative effects leading to impact

EMF knowledge road map

- Is there an impact?



Thanks

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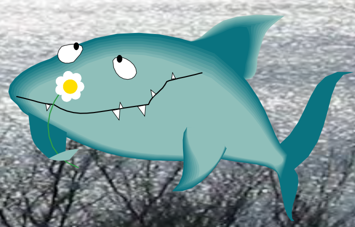
Very happy to talk further :



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