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Effects of electromagnetic fields (EMF) on marine animals

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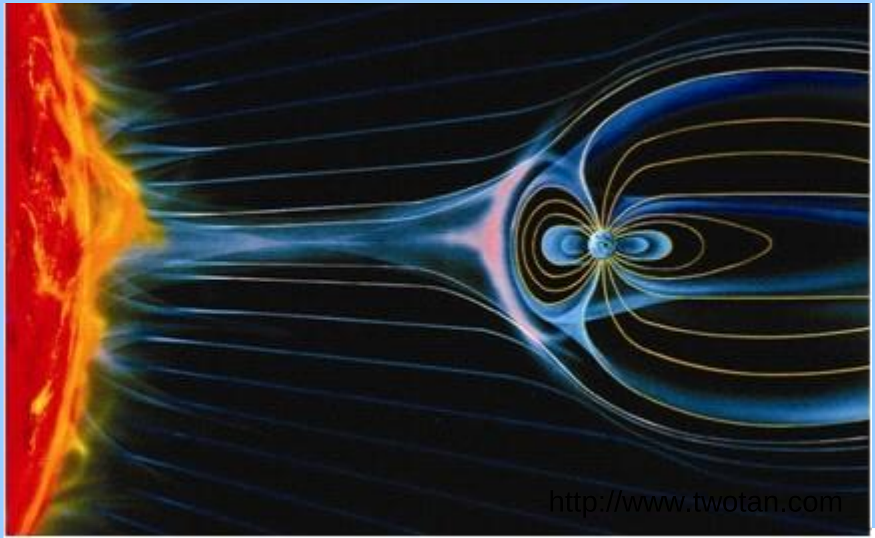
What we know about EMF



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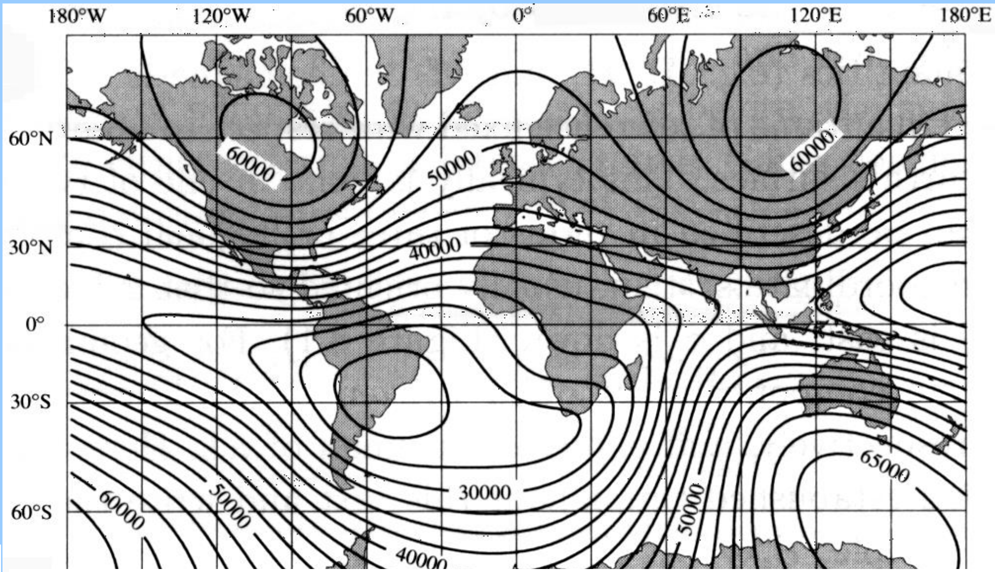

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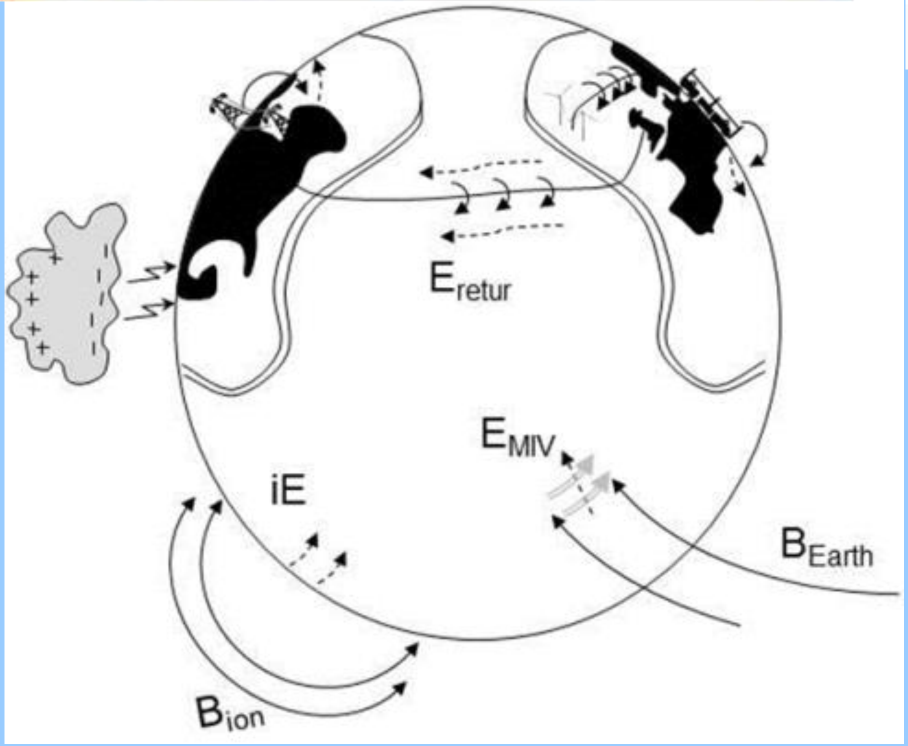
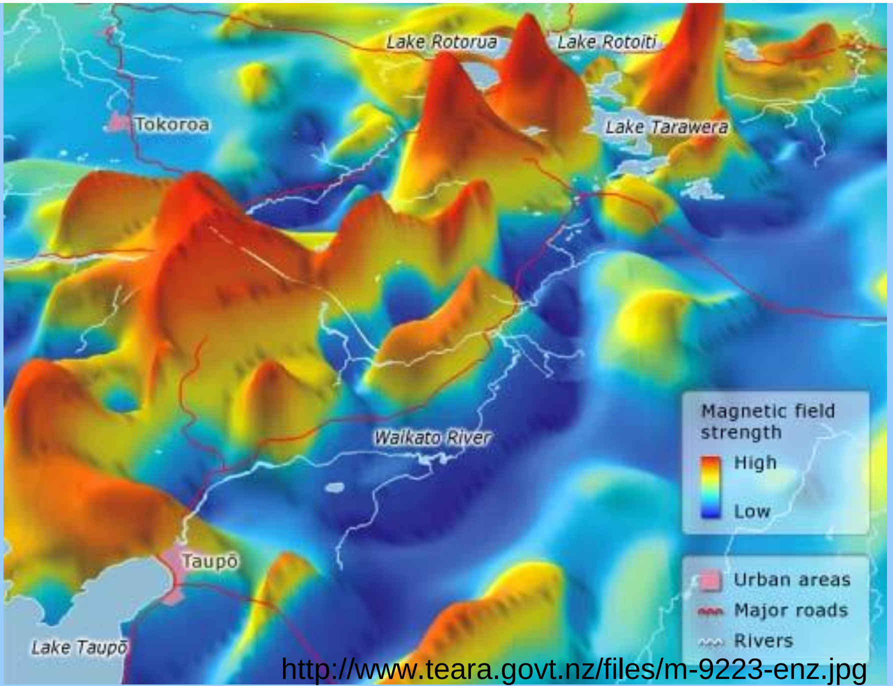




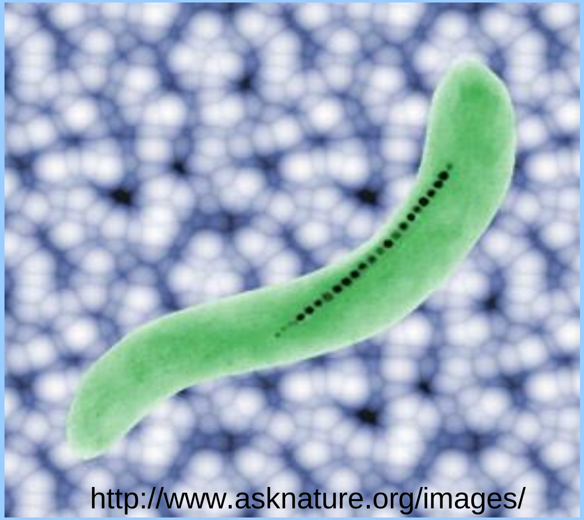
http://www.teara.govt.nz/files/m-9223-enz.jpg

EM sensitive animals

- Ability to sense and respond to EMF is widespread across taxonomic groups, ranging from bacteria to whales.

Interest tends to be focussed on:

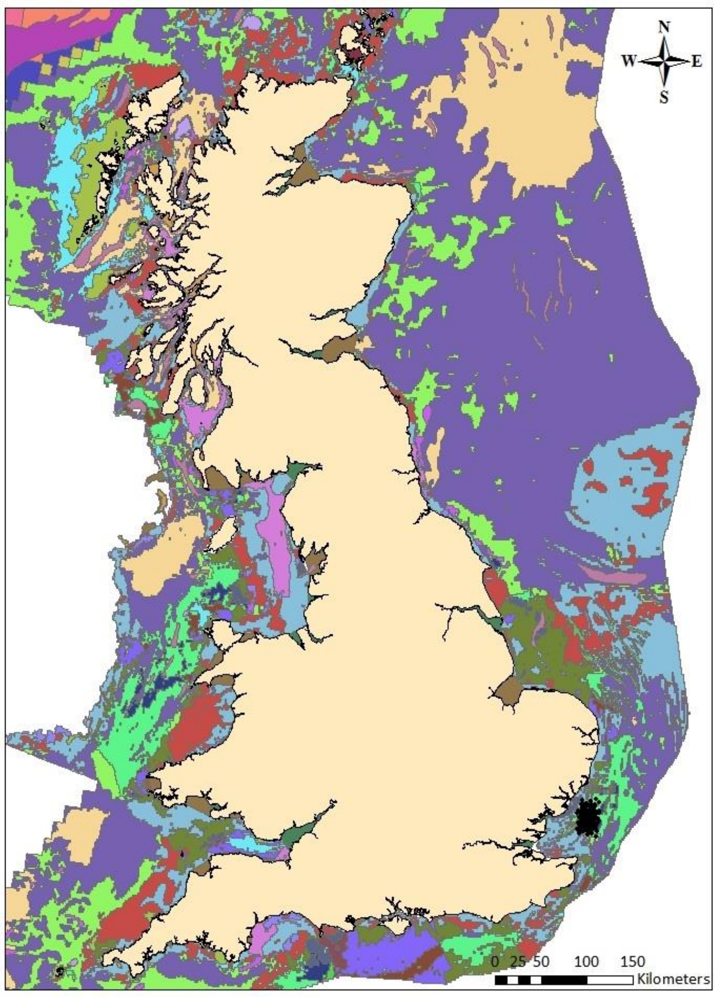
- elasmobranchs (sharks, skates and rays)
- agnatha (lampreys)
- crustacea (lobsters and prawns)
- mollusca (snails, bivalves, cephalopods)
- cetacea (whales and dolphins)
- bony fish (teleosts and chondrosteans)
- marine turtles

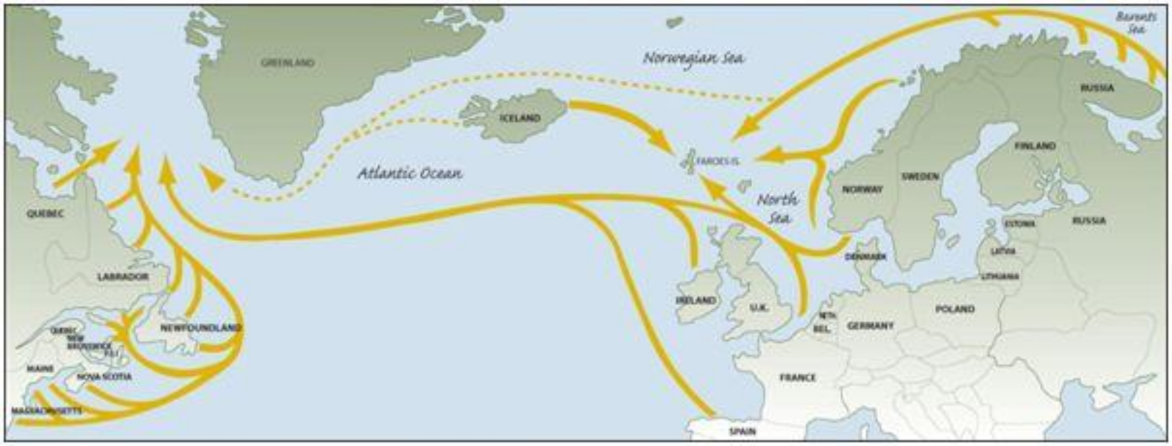


http://www.asknature.org/images/

http://left-out.net/photo/content/2015/5/blue-whale

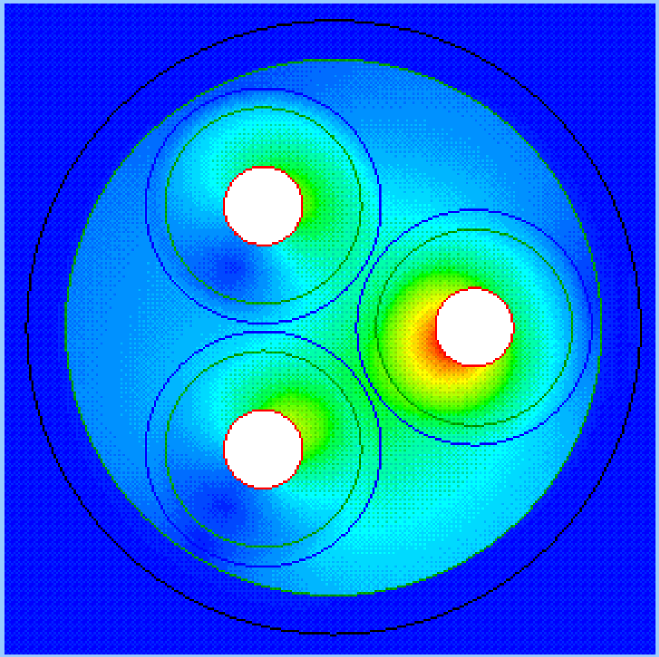
Where animals inhabit and move through



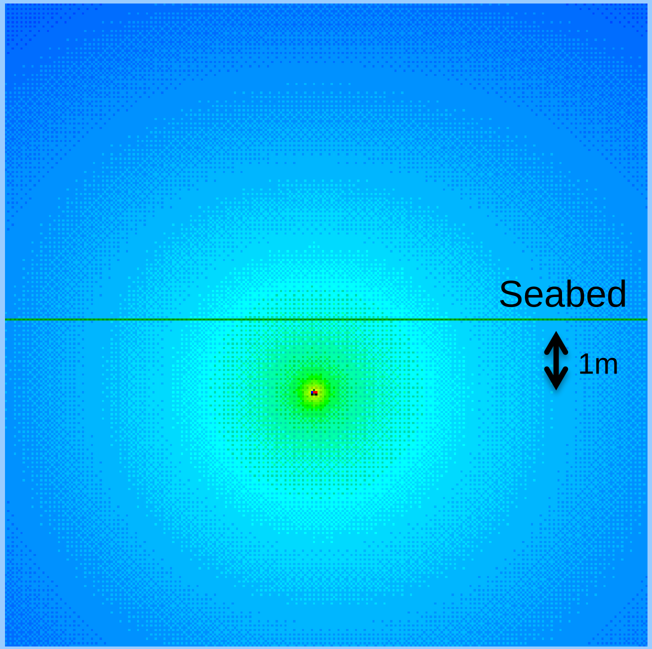


Source: Atlantic Salmon Federation http://www.asf.ca/about_salmon.php

Electromagnetic field (EMF) emissions from subsea cables - predicted



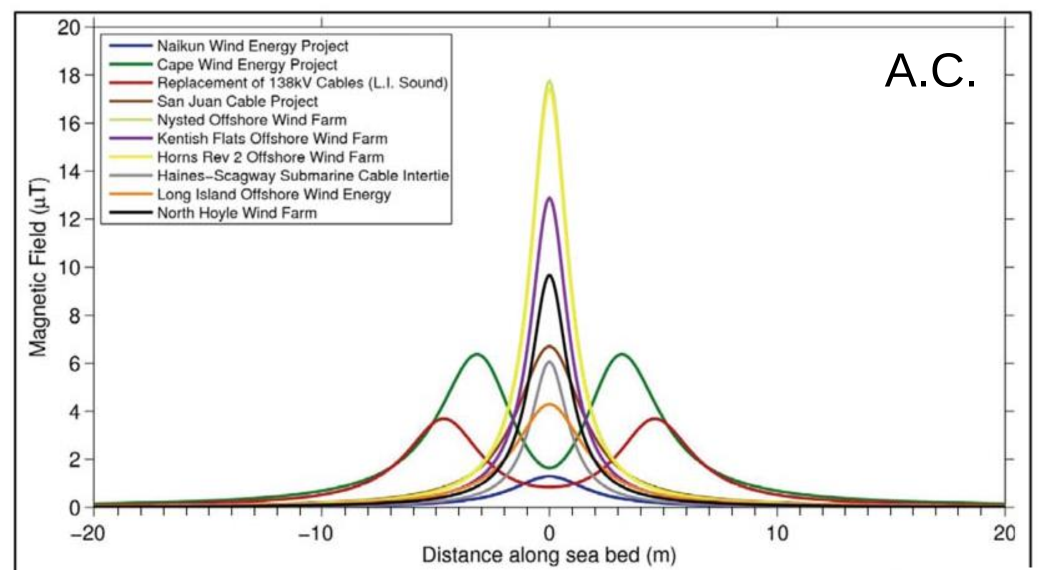
X-section AC cable (internal) – magnetic field

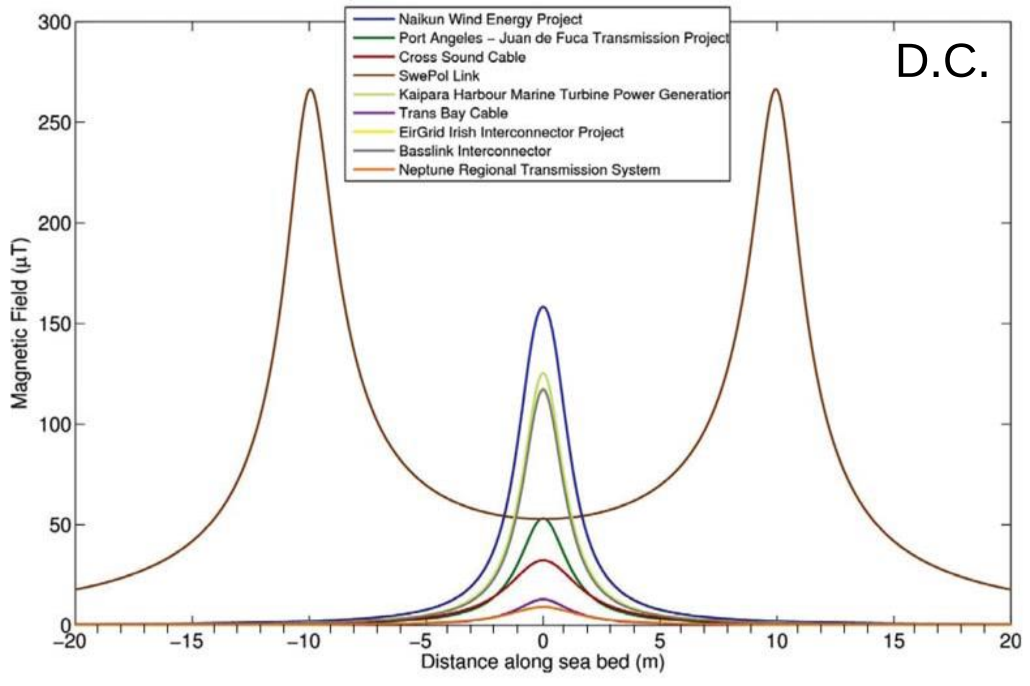


X-section cable (external) - magnetic field

A.C. – time varying
D.C. – static (i.e. 0 or 1)

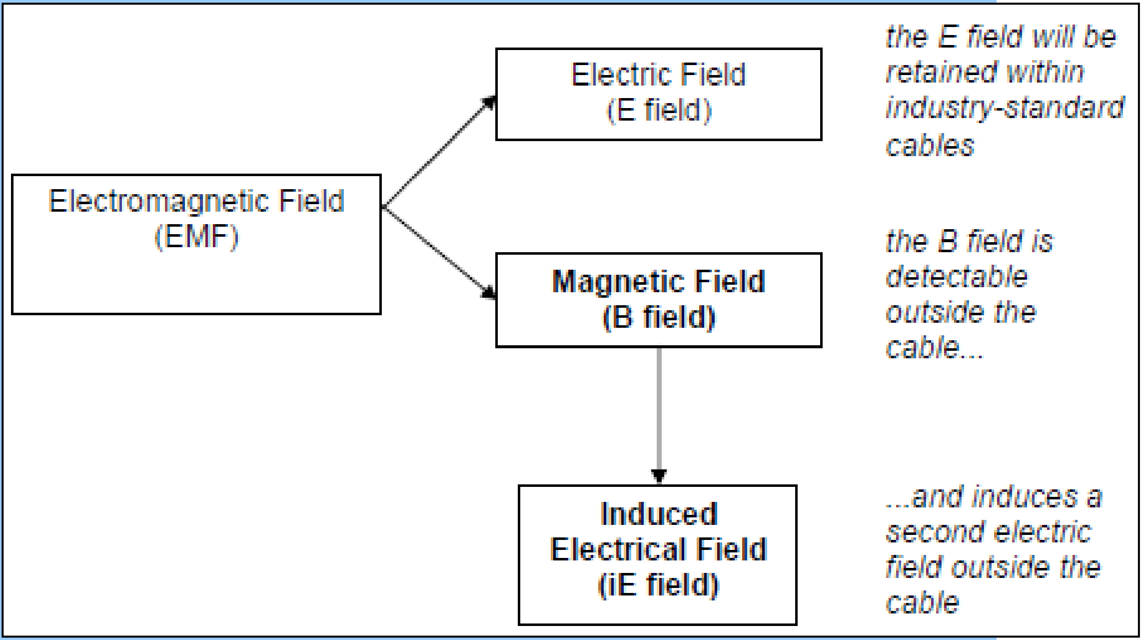
EMF dissipation





From: Normandeau et al 2011

Defining the EMF – AC and DC



Electromagnetic Field (EMF)

Electric Field (E field)

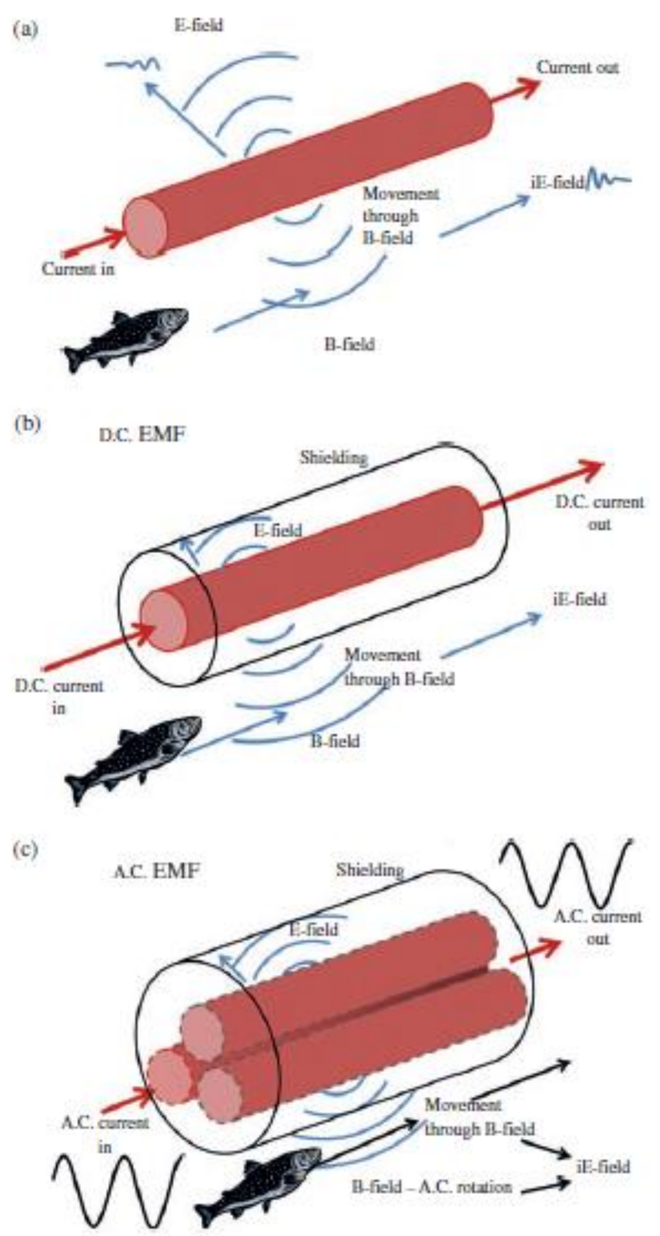
the E field will be retained within industry-standard cables

Magnetic Field (B field)

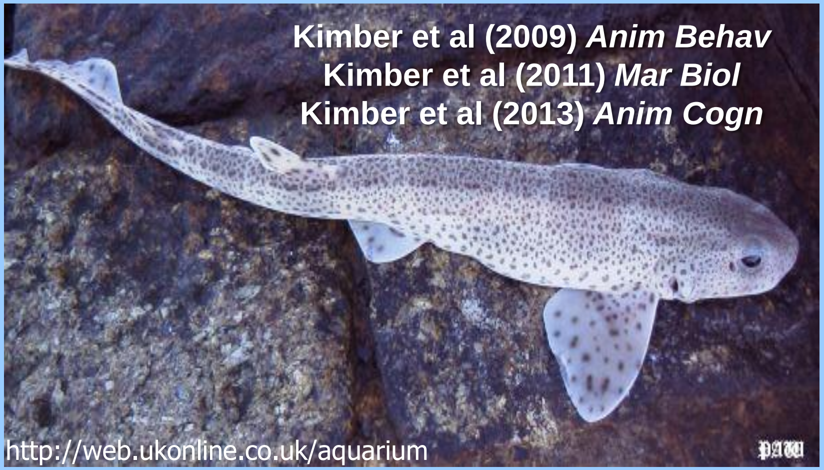
the B field is detectable outside the cable...

Induced Electrical Field (iE field)

...and induces a second electric field outside the cable

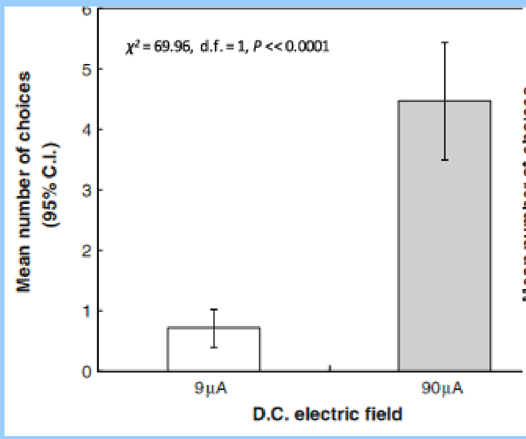


Sensory behaviour - lab studies

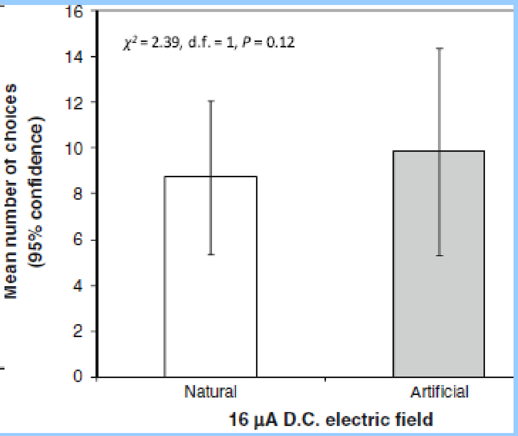


Kimber et al (2009) *Anim Behav*
Kimber et al (2011) *Mar Biol*
Kimber et al (2013) *Anim Cogn*

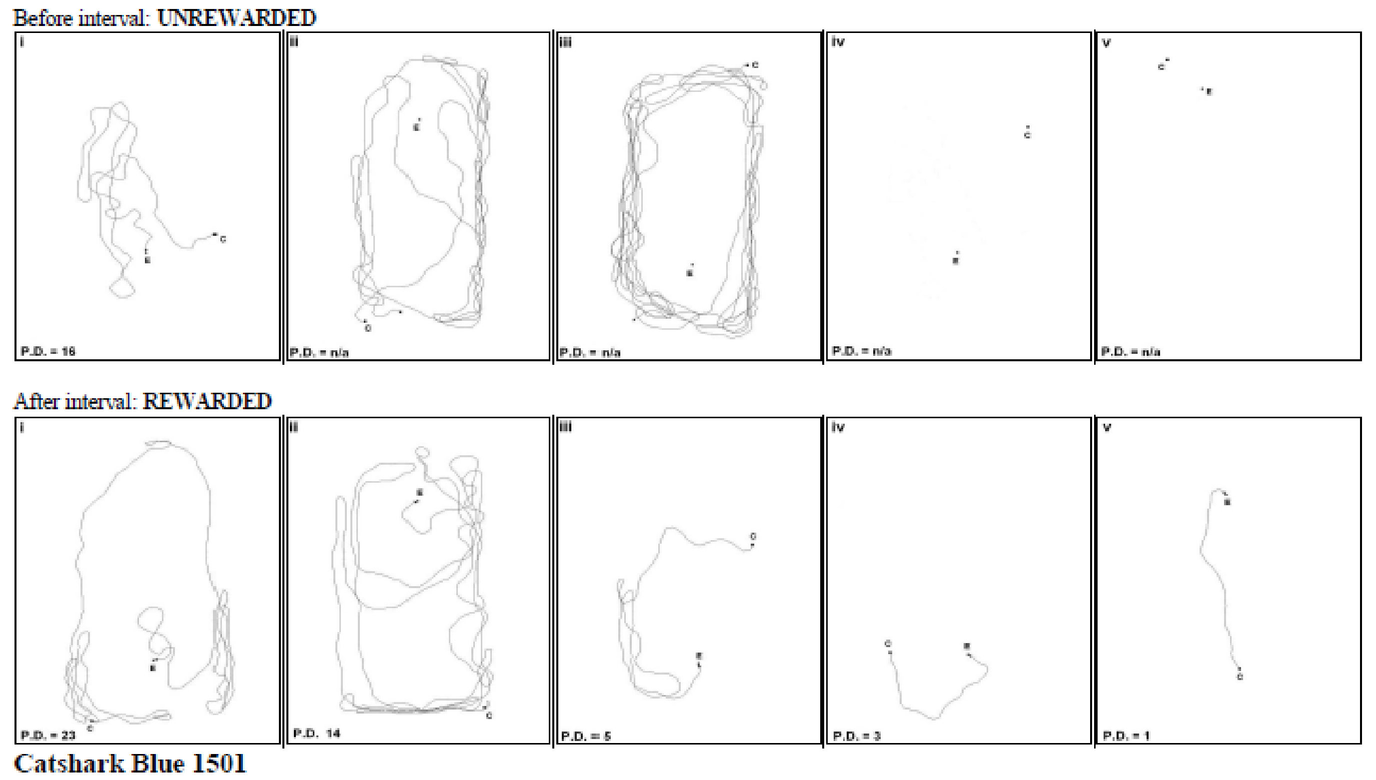
http://web.ukonline.co.uk/aquarium



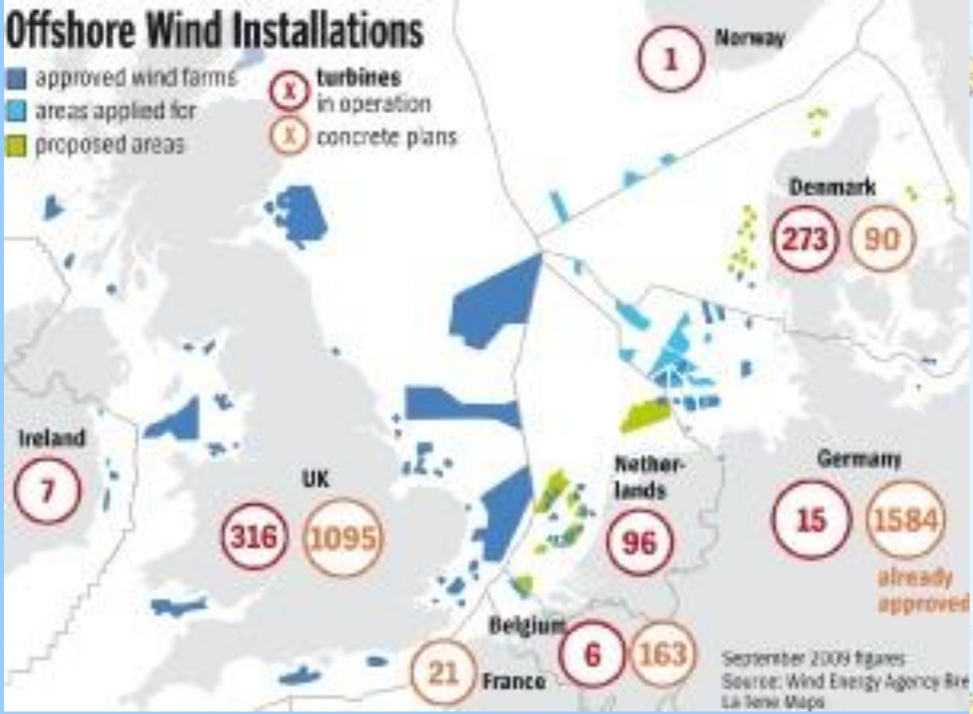
n = 24, 134 responses



n = 36, 679 responses



Offshore wind and subsea cable networks



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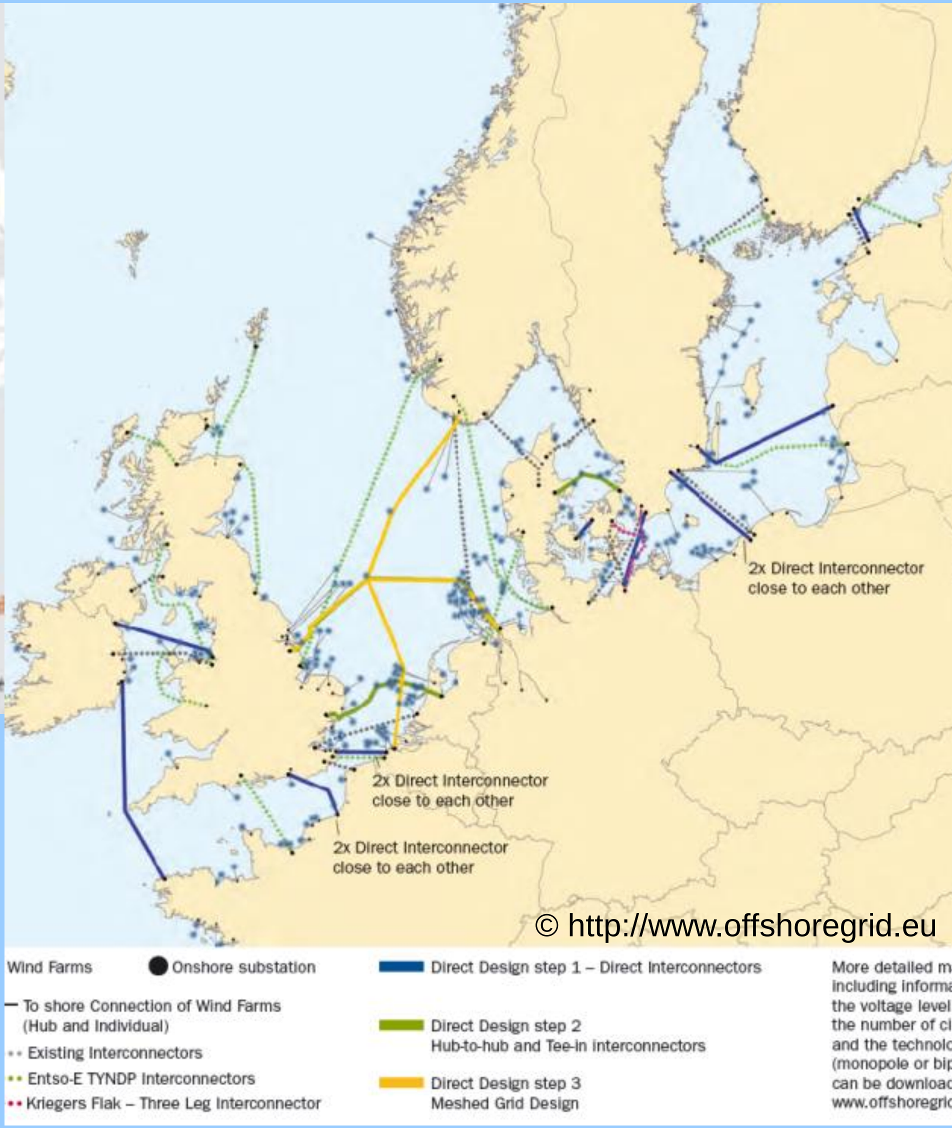

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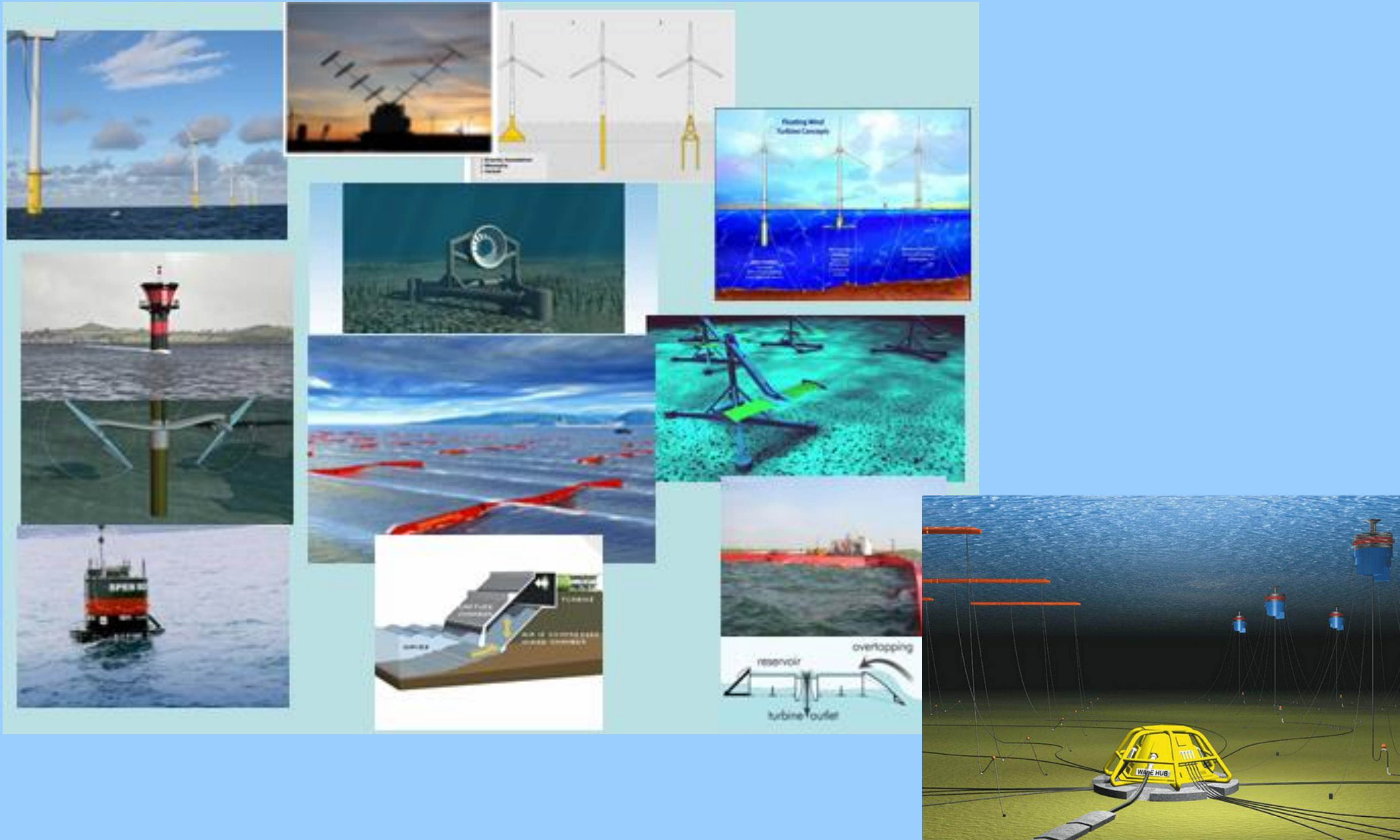
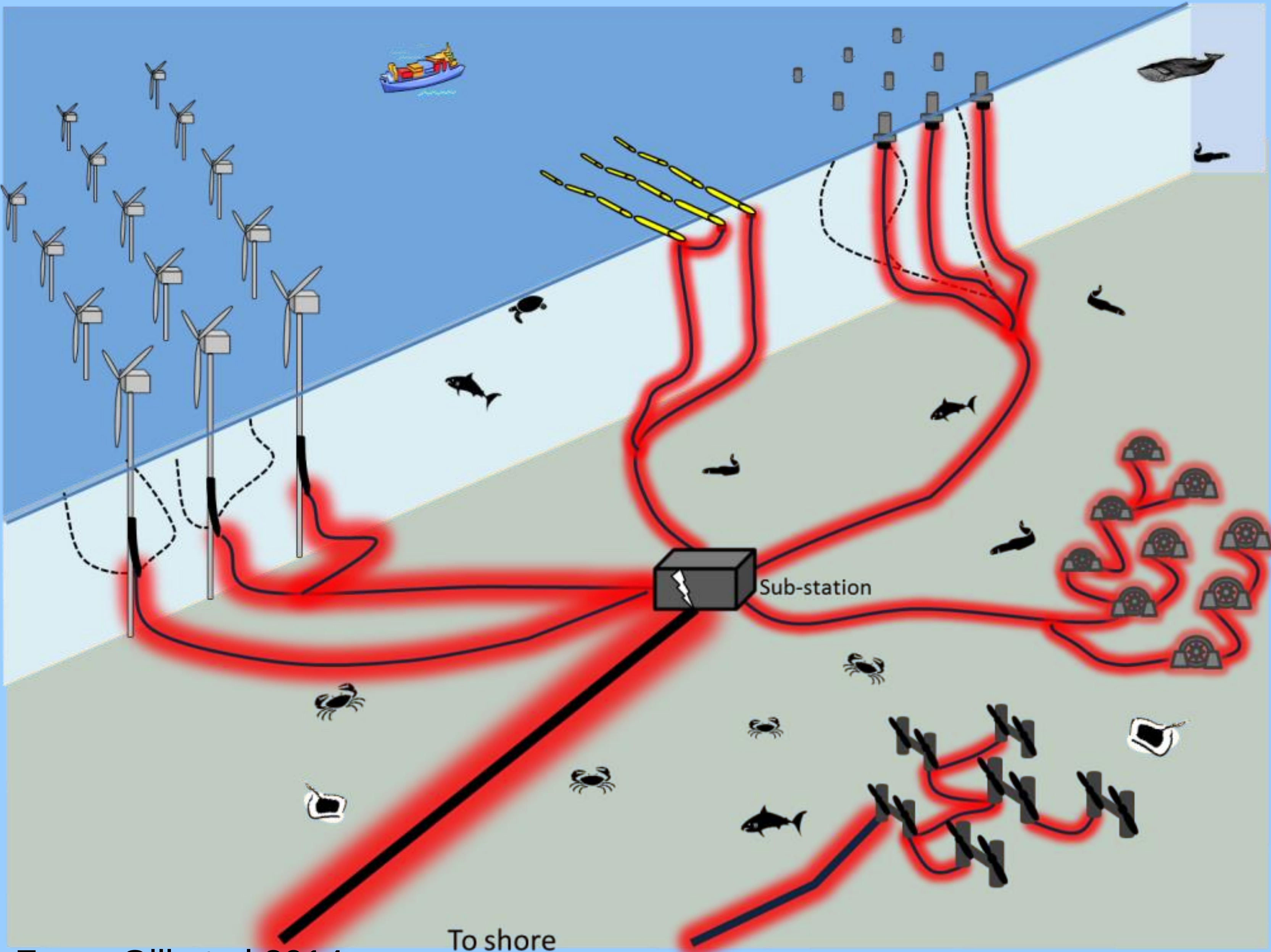
Marine Renewable Energy Devices



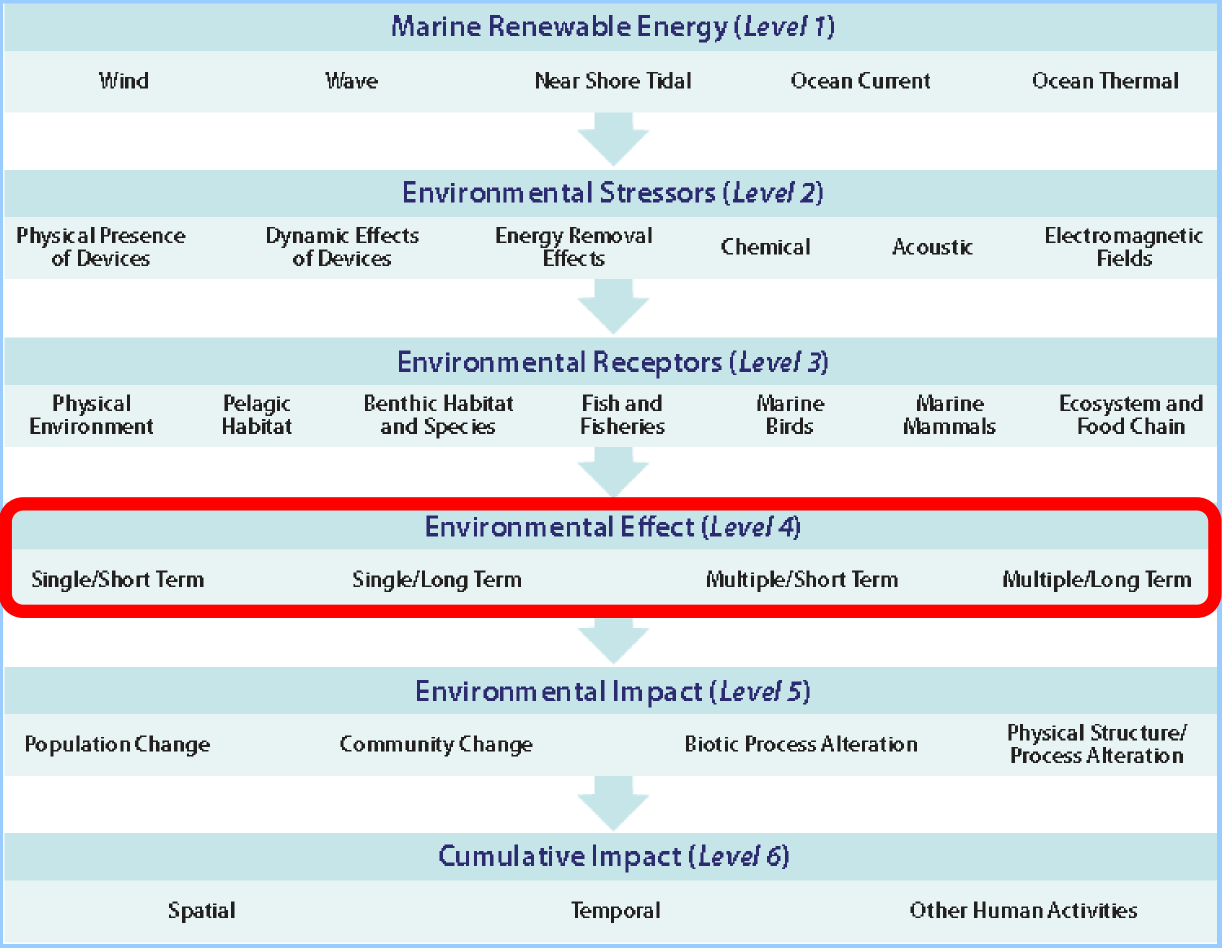
EMF sources from MREDs



From: Gill et al 2014

Environmental effects framework

(from Boehlert & Gill 2010)



Marine Renewable Energy (*Level 1*)

Wind
Wave
Near Shore Tidal
Ocean Current
Ocean Thermal

Environmental Stressors (*Level 2*)

Physical Presence of Devices
Dynamic Effects of Devices
Energy Removal Effects
Chemical
Acoustic
Electromagnetic Fields

Environmental Receptors (*Level 3*)

Physical Environment
Pelagic Habitat
Benthic Habitat and Species
Fish and Fisheries
Marine Birds
Marine Mammals
Ecosystem and Food Chain

Environmental Effect (*Level 4*)

Single/Short Term
Single/Long Term
Multiple/Short Term
Multiple/Long Term

Environmental Impact (*Level 5*)

Population Change
Community Change
Biotic Process Alteration
Physical Structure/ Process Alteration

Cumulative Impact (*Level 6*)

Spatial
Temporal
Other Human Activities

- **Effect**

- response/change/outcome of a stressor by a receptor

- **Impact**

- effect/change of a magnitude deemed of ***significance***
- i.e. biological/ecological/ technological

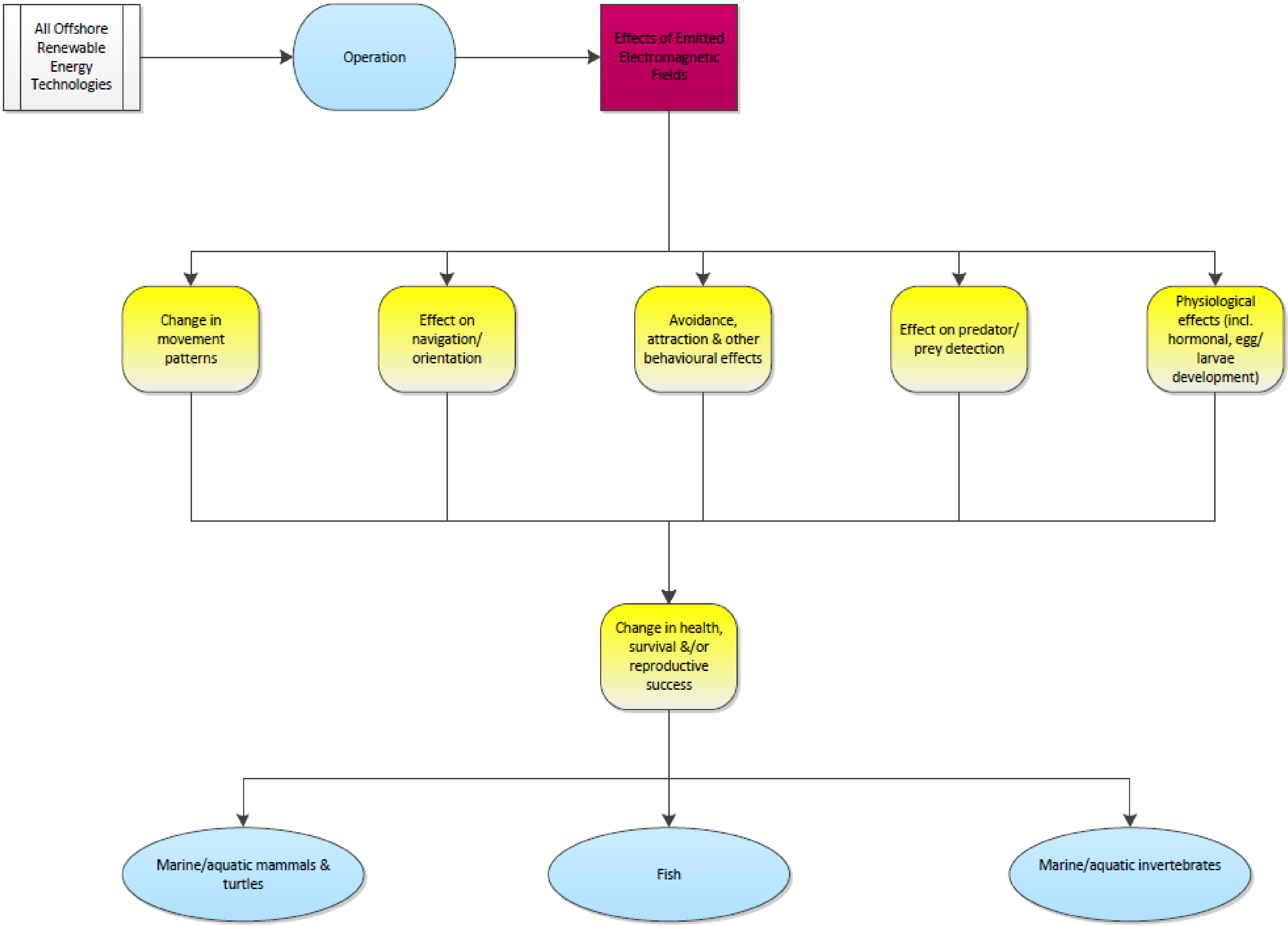


Figure 7: PoE Model for Electromagnetic Field Stressor in Operations Phase

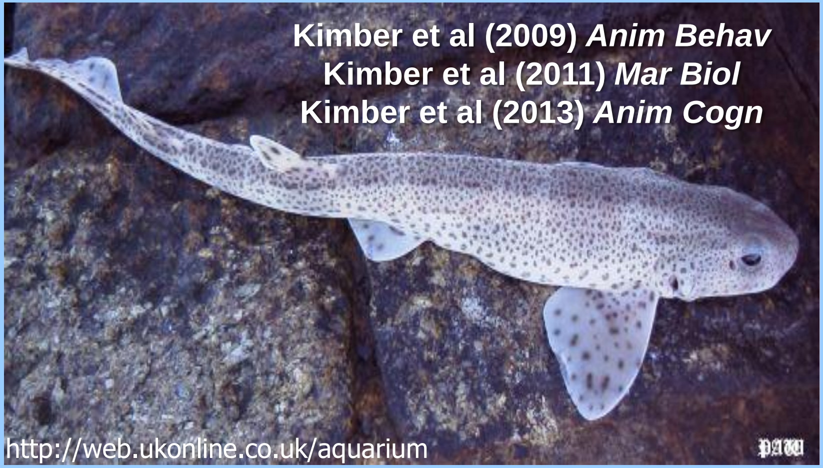
Measured and Observed Impacts of cable Electromagnetic Fields (EMFs)

- Electrosensitive species can detect EMFs both DC and AC cables with higher sensitivity to DC cables. Most highly sensitive taxa -elasmobranchs and jawless fish (Agnathans)
- Magnetosensitive species are likely to be able to detect EMFs from DC cables and potentially AC cables, but to a lesser degree
- Behavioural responses, such as attraction to EMFs from subsea cables, have been demonstrated but extrapolation to impacts of MRED power cables on sensitive receptors would be speculative
- As the main source of the EMF is the cable, benthic and demersal species, which are closer to the source, are considered to be more likely to be exposed to higher field strengths than pelagic species.

PNNL + Oakridge lab studies:

- Coho salmon alarm response experiments identified some decreased swimming activity
- Hormonal tests did not give any evidence of stress, but some decreases in melatonin levels in Coho salmon
- Rainbow trout eggs exposed to EMF of 3mT showed some developmental delay
- Atlantic halibut showed reduced growth and development following late exposure to EMF of 3mT
- However no noticeable effects on growth or development of California halibut

Sensory behaviour - lab studies



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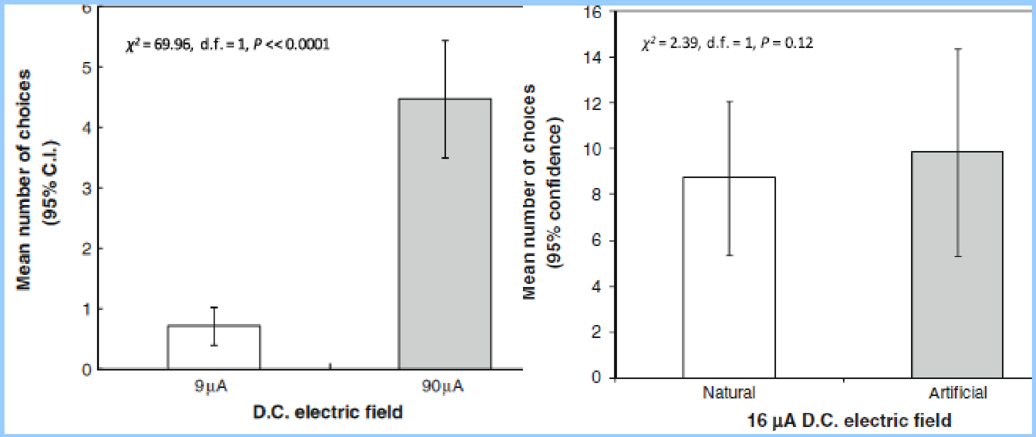
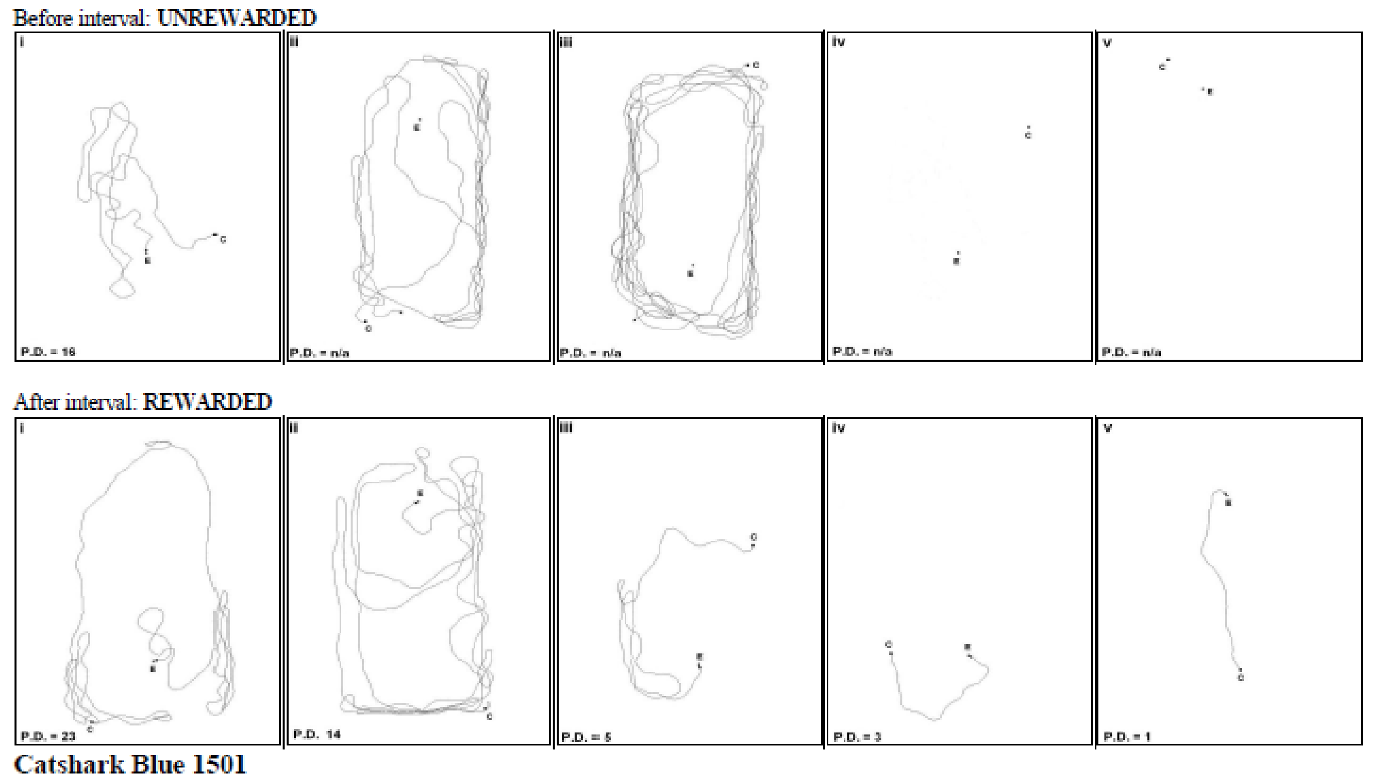
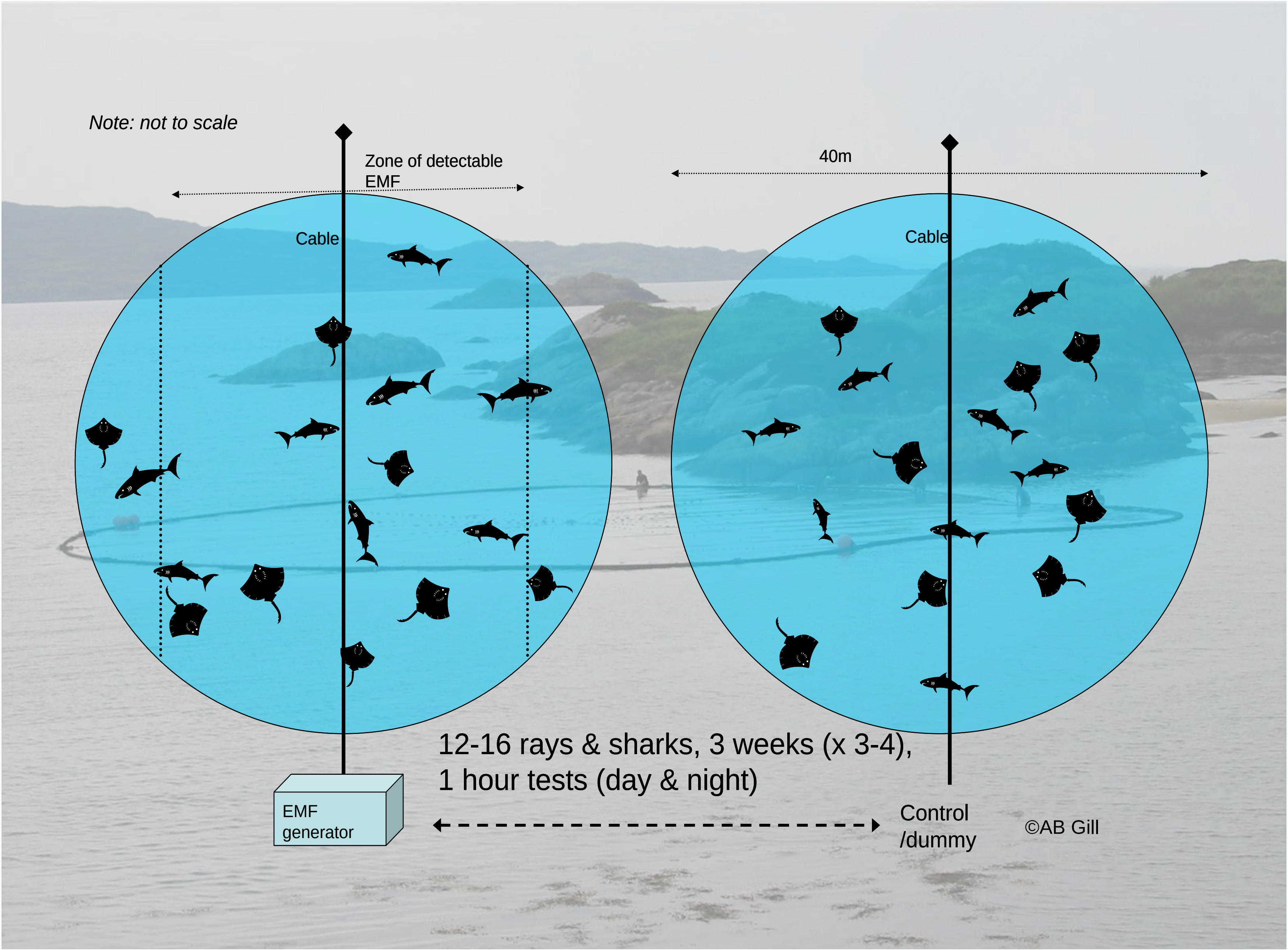




Taking the lab into the field



Note: not to scale

Zone of detectable EMF

40m

Cable

Cable

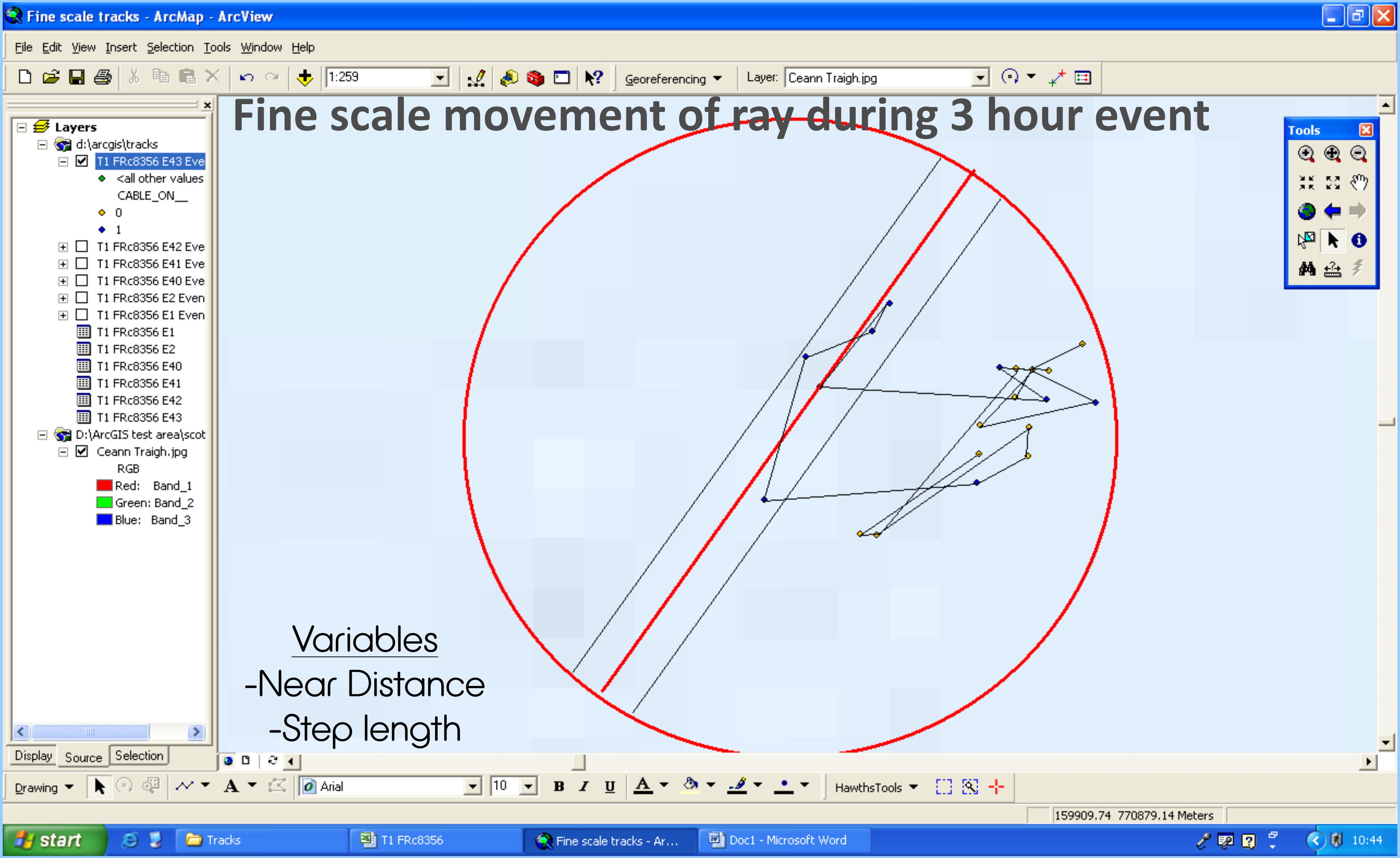
12-16 rays & sharks, 3 weeks (x 3-4),
1 hour tests (day & night)

EMF generator

Control /dummy

©AB Gill

Taking the lab into the field - results



Fine scale movement of ray during 3 hour event

Variables

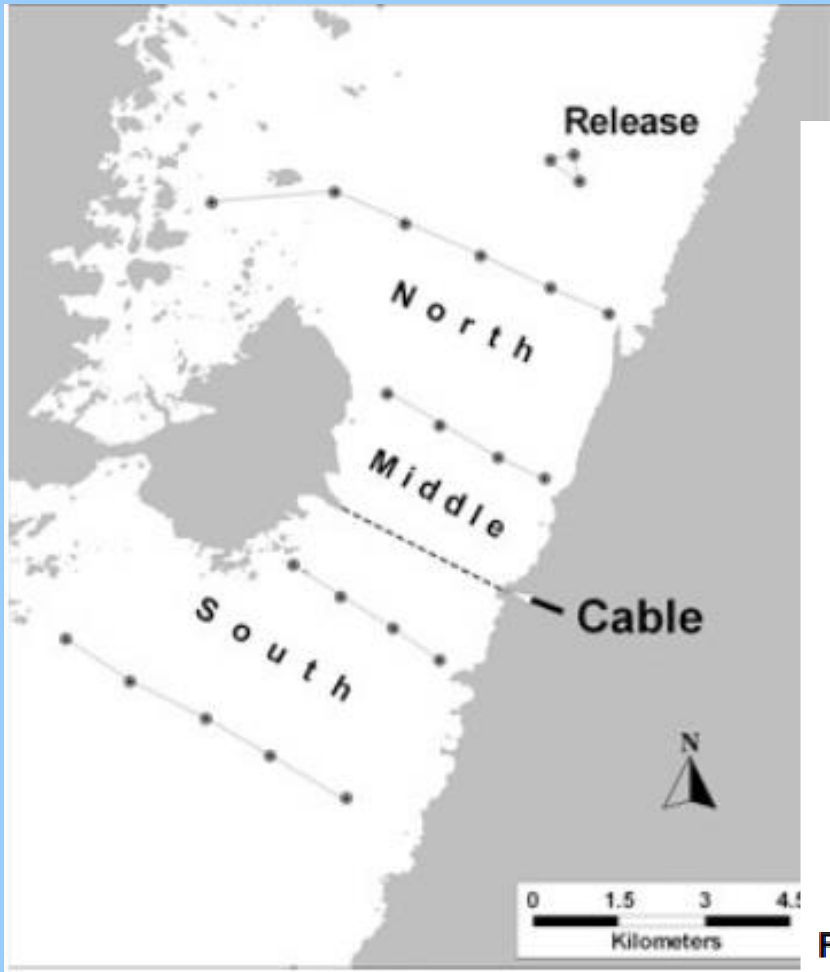
-Near Distance

-Step length

- Benthic catshark non-random distribution - more likely in cable zone when energised. (Gill et al 2009)

Field study evidence

Westerberg & Lagenfelt 2008



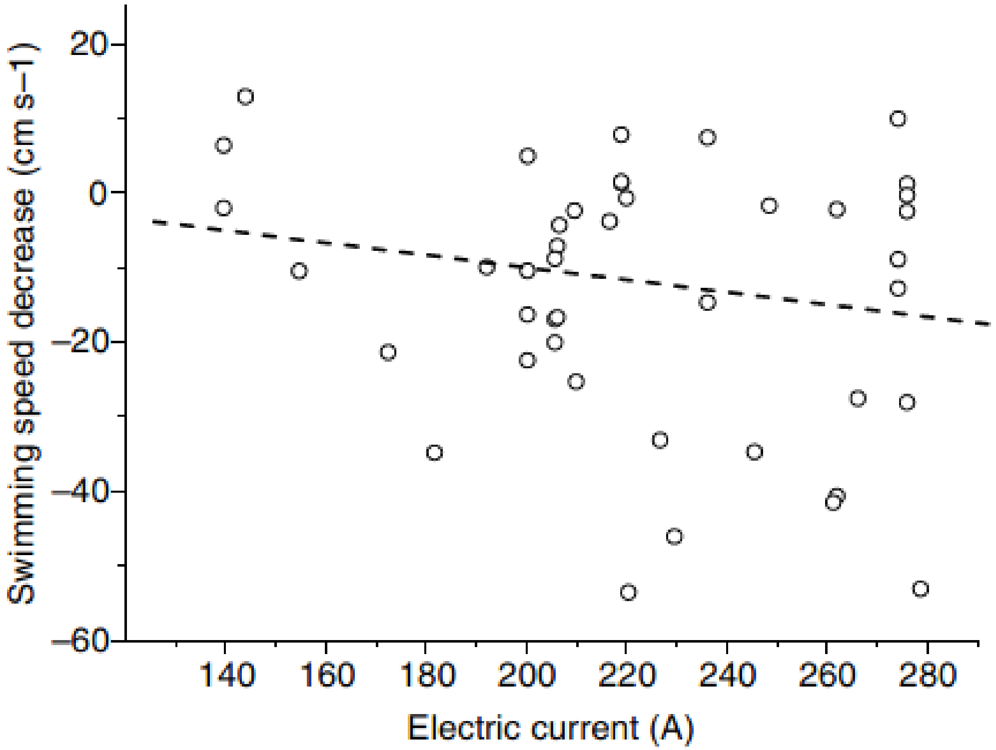


Figure 5. Linear regression of speed deficit and the simultaneous, root mean square, current in the sub-sea cable. The deficit is the decrease of swimming speed in the middle (cable) interval compared with the mean swimming speed of the same eel in the northern and southern intervals.

Measured and Observed Impacts of cable Electromagnetic Fields (EMFs)

Summary

- Some studies (field, experimental and anecdotal) that indicate response to cables (D.C. and A.C.)
- Extremely low confidence in knowledge about any actual impacts (effect v impact)
- Results are generally applicable to other MHK technologies and devices - scalable

Regulatory context (e.g.)

- EU's Marine Strategy Framework Directive (MSFD) for inputs of energy Article 11

> *'Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment'*

- EMF status within EIAs

MaRVEN: Environmental Impacts of Noise, Vibrations and Electromagnetic Fields from Marine Renewable Energy Developments

DHI

Cranfield UNIVERSITY

FOI

Cefas

museum
Operational Directorate Natural Environment
OD Nature | OD Natuur | DO Nature

SAMS

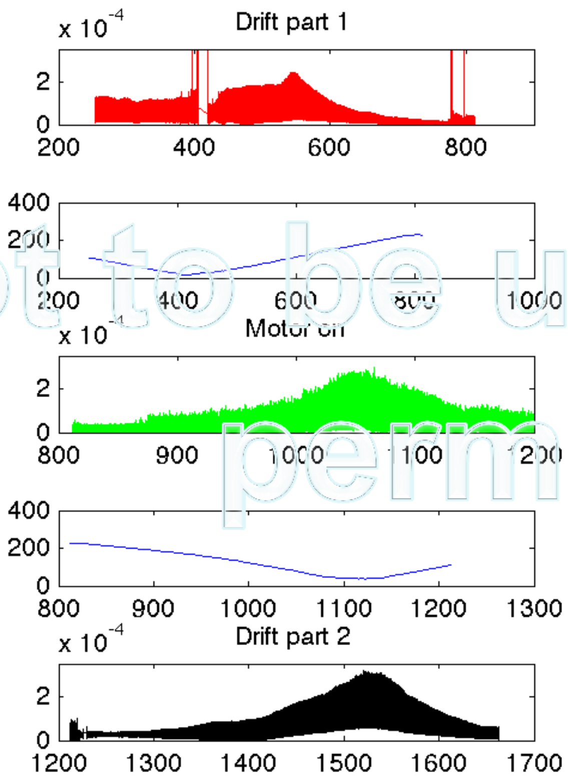
DEWI

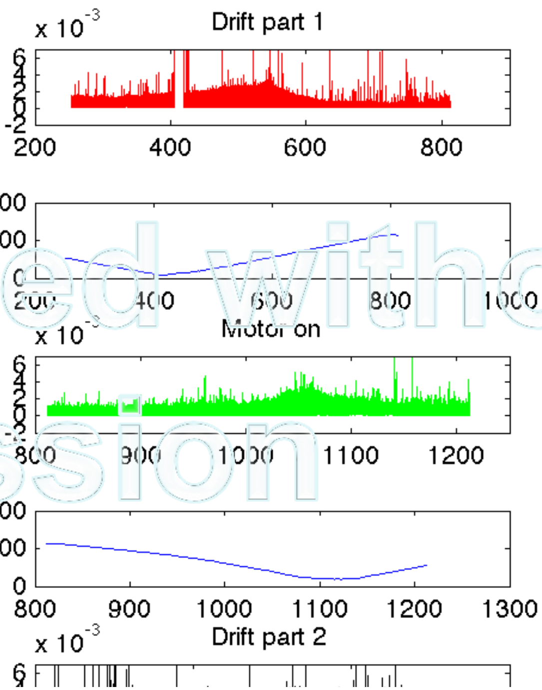
UPC

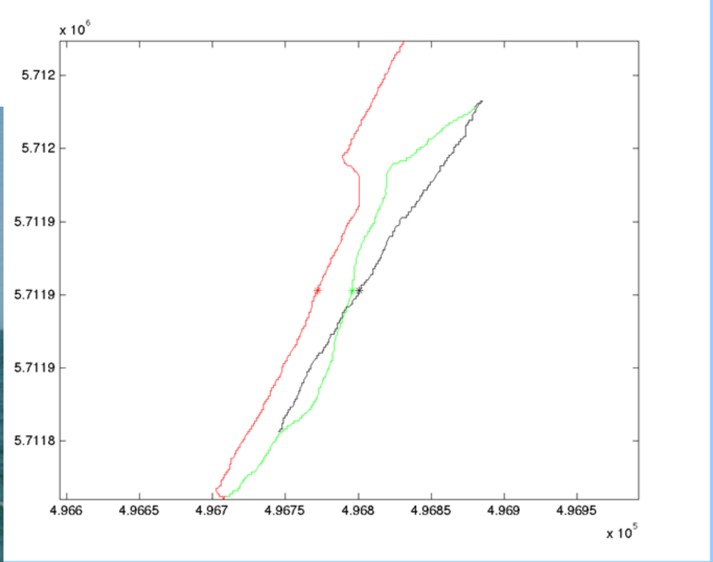
Quiet oceans
Technology for Sustainable Oceans

http://marven.dhigroup.com/

EMF at Belgian wind farm

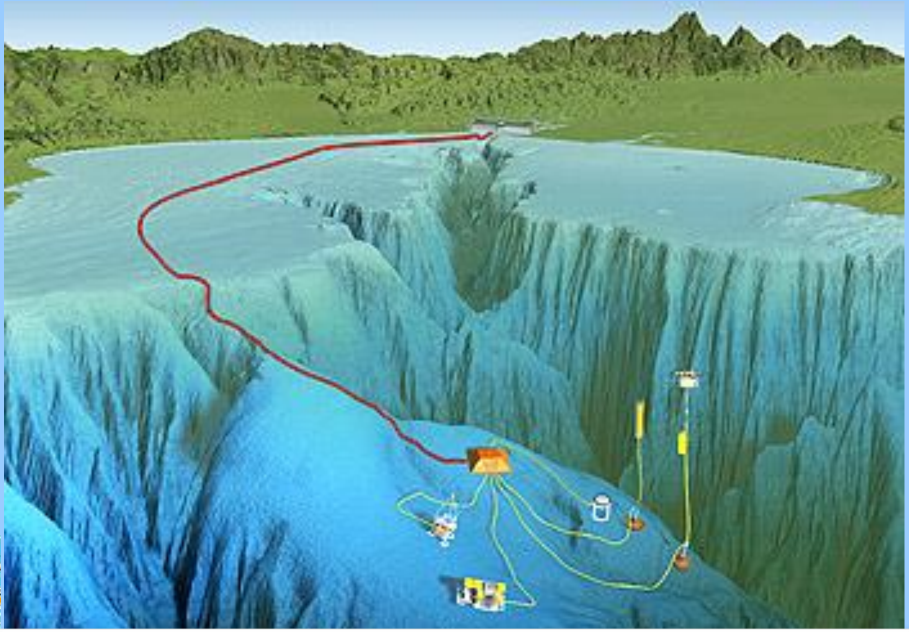






Crossover from Other Industries

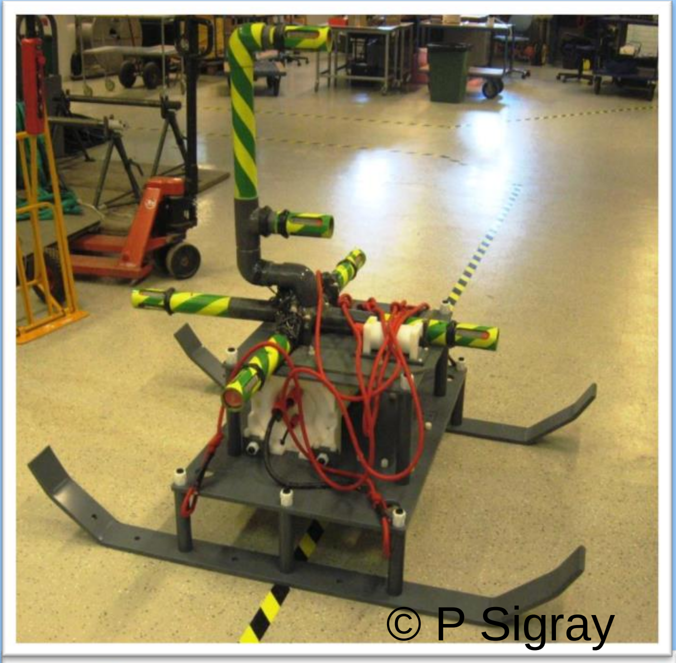
- Power generation companies
- Sub-sea cable companies and networks
- How relevant is this information?



http://subseaworldnews.com/

Measurement Technology and Protocols

- Large uncertainty about the actual levels of EMF emitted from the MRED cables
- Cables vary according to different manufacturing process and different cable characteristics and deployments (e.g. burial v rock armouring). Creates uncertainty in emitted levels that cannot be modelled owing to lack of baseline data.
- If dose response studies highlight that exposure of marine organism to EMF is an issue then the understanding gained from field measurement programme will feed directly into considerations of how to mitigate the effects.
- Current measurement technology
    - B fields – available but restricted sensitivity
    - E fields - extremely limited
- Technologies “in development” associated costs unknown



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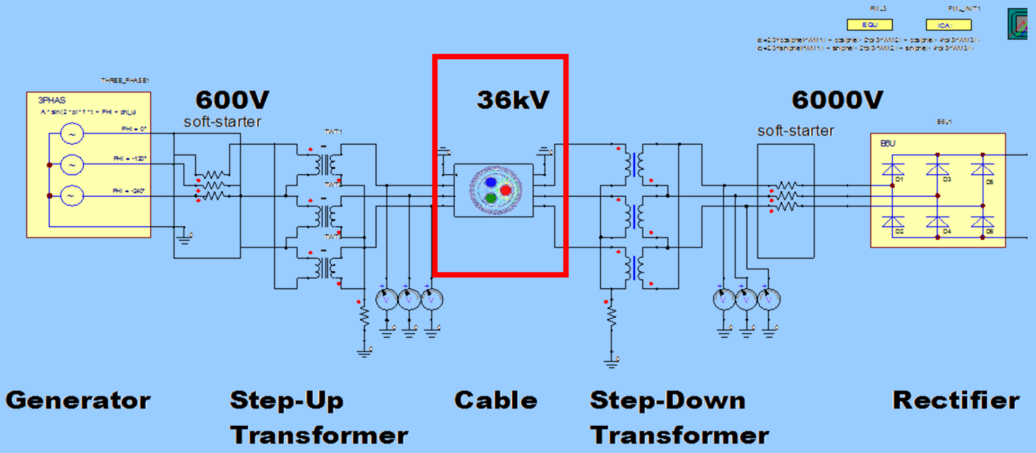
What Questions Remain 1

- Power system behavior w.r.t environmental conditions



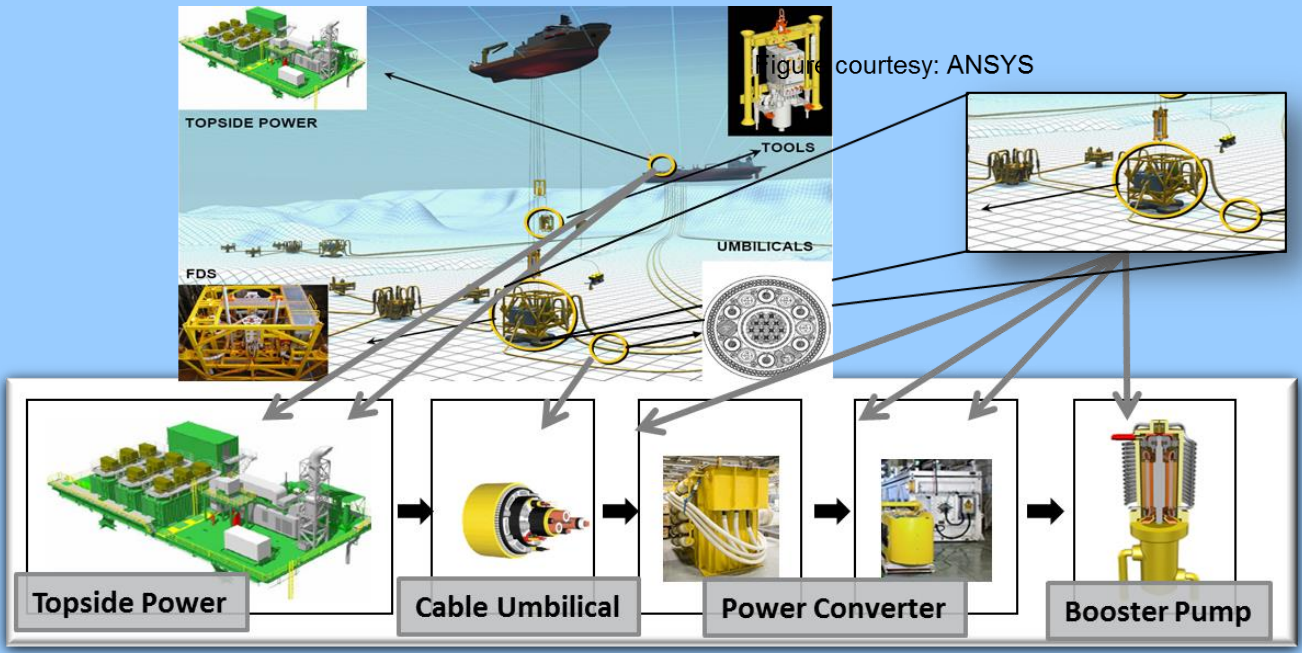


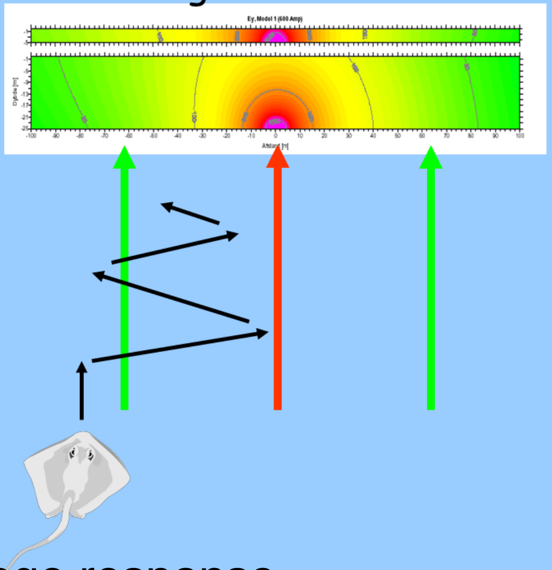
Figure courtesy: ANSYS

An example of subsea power distribution network (Figure courtesy: ANSYS)

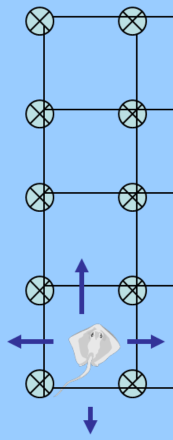
What Questions Remain 2

- Behavioural response – emergent properties + biologically significant effect i.e. impact

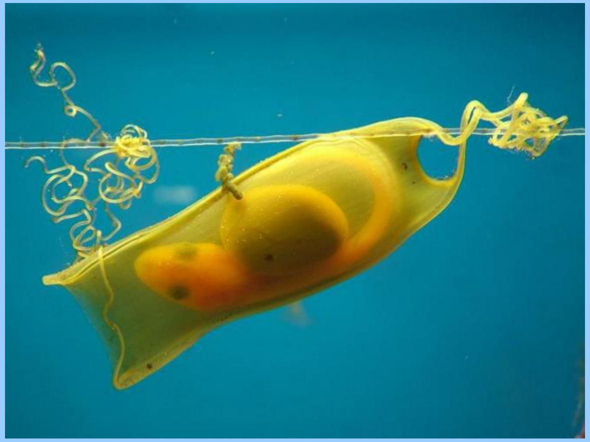
Along the cable trace



Within the cable array



- Early life stage response



- Migratory life stage response

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