Effects of electromagnetic fields (EMF) on marine animals

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What we know about EMF

http://www.twotan.com

http://geophysics.ou.edu/solid_earth/notes/mag_earth/magnetic_field_a.gif

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

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
Where animals inhabit and move through

Source: Atlantic Salmon Federation [http://www.asf.ca/about_salmon.php](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...
    - ...and induces a second electric field outside the cable
- Induced Electrical Field (iE field)
Sensory behaviour - lab studies

Kimber et al (2009) *Anim Behav*
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
Marine Renewable Energy Devices
Environmental effects framework
(from Boehlert & Gill 2010)

<table>
<thead>
<tr>
<th>Marine Renewable Energy (Level 1)</th>
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<tbody>
<tr>
<td>Wind</td>
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<td>Wave</td>
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<tr>
<td>Near Shore Tidal</td>
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<td>Ocean Current</td>
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<td>Ocean Thermal</td>
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**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
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

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

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

Before interval: UNREWARDED

After interval: REWARDED

Catshark Blue 1501
Taking the lab into the field

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

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://www.mbari.org/twenty/images/mars/MARS_illustration.jpg

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
What Questions Remain

- Power system behavior w.r.t. environmental conditions

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