International Forum on MRE Environmental R&D

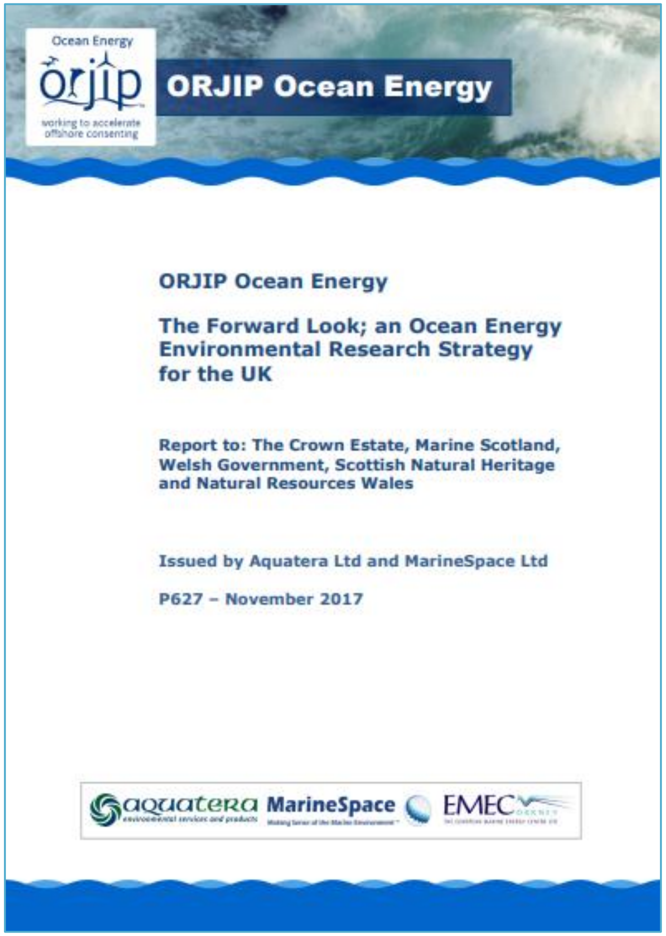
General wave energy monitoring background

23 April 2020

Key evidence gaps for the wave energy sector

Key wave evidence gaps

- Use of wave energy areas by marine wildlife
- Underwater noise
- Displacement effects
- Consolidation of existing evidence


ORJIP Ocean Energy

ORJIP Ocean Energy

The Forward Look; an Ocean Energy Environmental Research Strategy for the UK

Report to: The Crown Estate, Marine Scotland, Welsh Government, Scottish Natural Heritage and Natural Resources Wales

Issued by Aquatera Ltd and MarineSpace Ltd

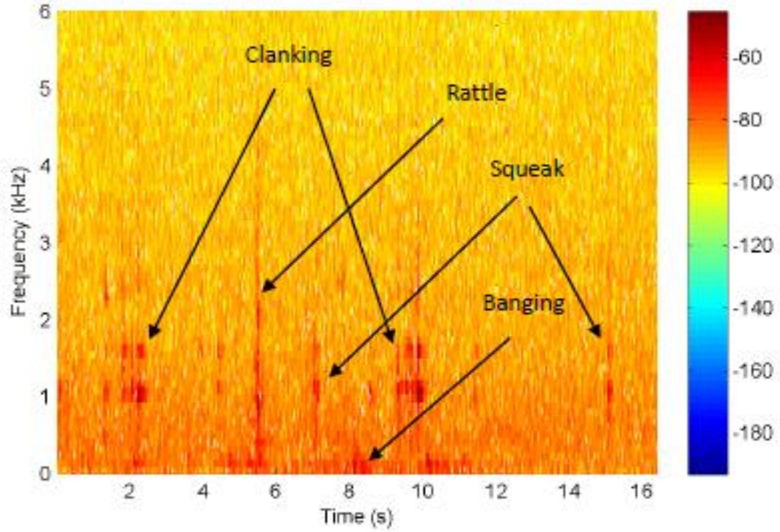
P627 – November 2017

http://www.orjip.org.uk/documents

Pelamis Wave Power; P2

Operational noise assessment on Pelamis P2 at Billia Croo, EMEC (Lepper at al, 2012)

- Development of the **methodology**
- **Conclusions**:
  - Noise was within hearing range of most marine mammals
  - Detectability of noise dependent on varying background noise
  - Shallow water 'ambient' noise is relatively poorly understood



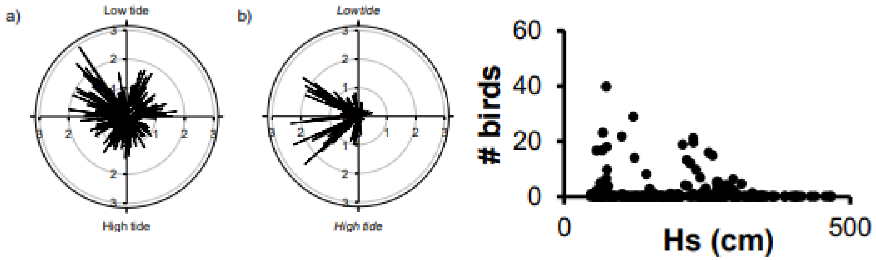
https://tethys.pnnl.gov/publications/annex-summary-operational-underwater-noise-wave-energy-converter-system-emec-wave

Pelamis Wave Power; P2

Surface monitoring of **seabird behaviour** at the Pelamis P2 device (Jackson, 2014)

- Automated stills
- Data on tide, wave height and wind speed recorded
- **Results**:
  - No presence of birds in February- March period
  - Regular use of the machine for resting, roosting in May
  - Weak negative correlation between presence of birds and wave height
  - No correlation between presence of birds and tidal cycle
  - Successful, low cost methodology to monitor behaviour of birds around operational WECs

Arctic terns resting on the P2 machine



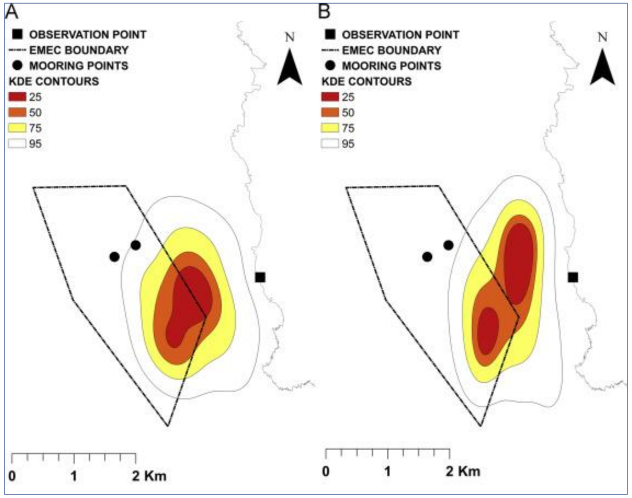
https://tethys.pnnl.gov/publications/riding-waves-use-pelamis-device-seabirds

Pelamis Wave Power; P2

Habitat use by seabirds at a marine renewable wave energy test facility (Leesa et al., 2015)

- Kernel density estimates used
  - Baseline seasonal and interannual variation
  - Change as a result of WEC

- **Results**:
  - High variation in baseline distribution
  - Density at the mooring points of the device increased for certain species at certain times of year
  - No avoidance behaviour or significant change in distribution recorded

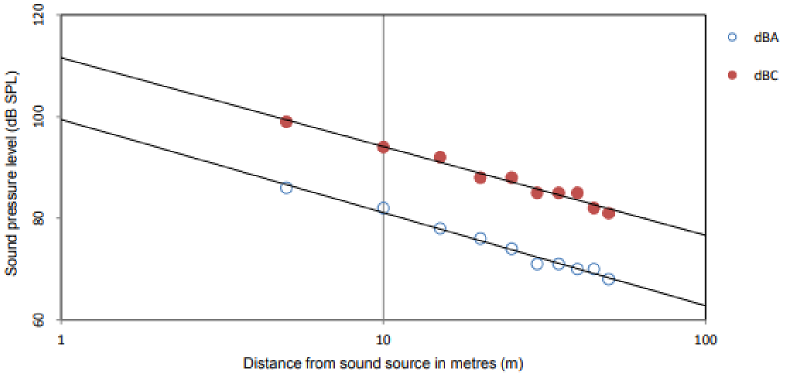


https://tethys.pnnl.gov/publications/using-kernel-density-estimation-explore-habitat-use-seabirds-marine-renewable-wave

Wello; Penguin

Wello Penguin **Cooling System Noise Study** (Beharie & Side, 2012)

- Underwater sound pressure levels measured of two cooling fans and one pump operating continuously
- **Results**:
  - Noise profile successfully measured
  - Ambient background noise expected to be greater than noise profile within 10 m of the device

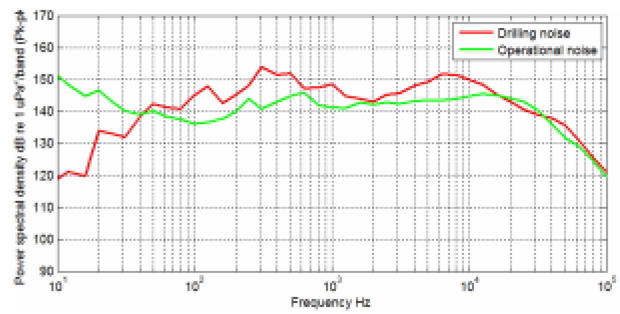


https://tethys.pnnl.gov/publications/acoustic-environmental-monitoring-wello-penguin-cooling-system-noise-study

Aquamarine Power; Oyster 800

Assessing the impact of man-made underwater noise from marine renewables in the Outer Hebrides (Ward, 2014)

- Baseline noise data collected
- Construction (drilling) noise recorded during installation of device at EMEC
- Noise propagation model



Results:

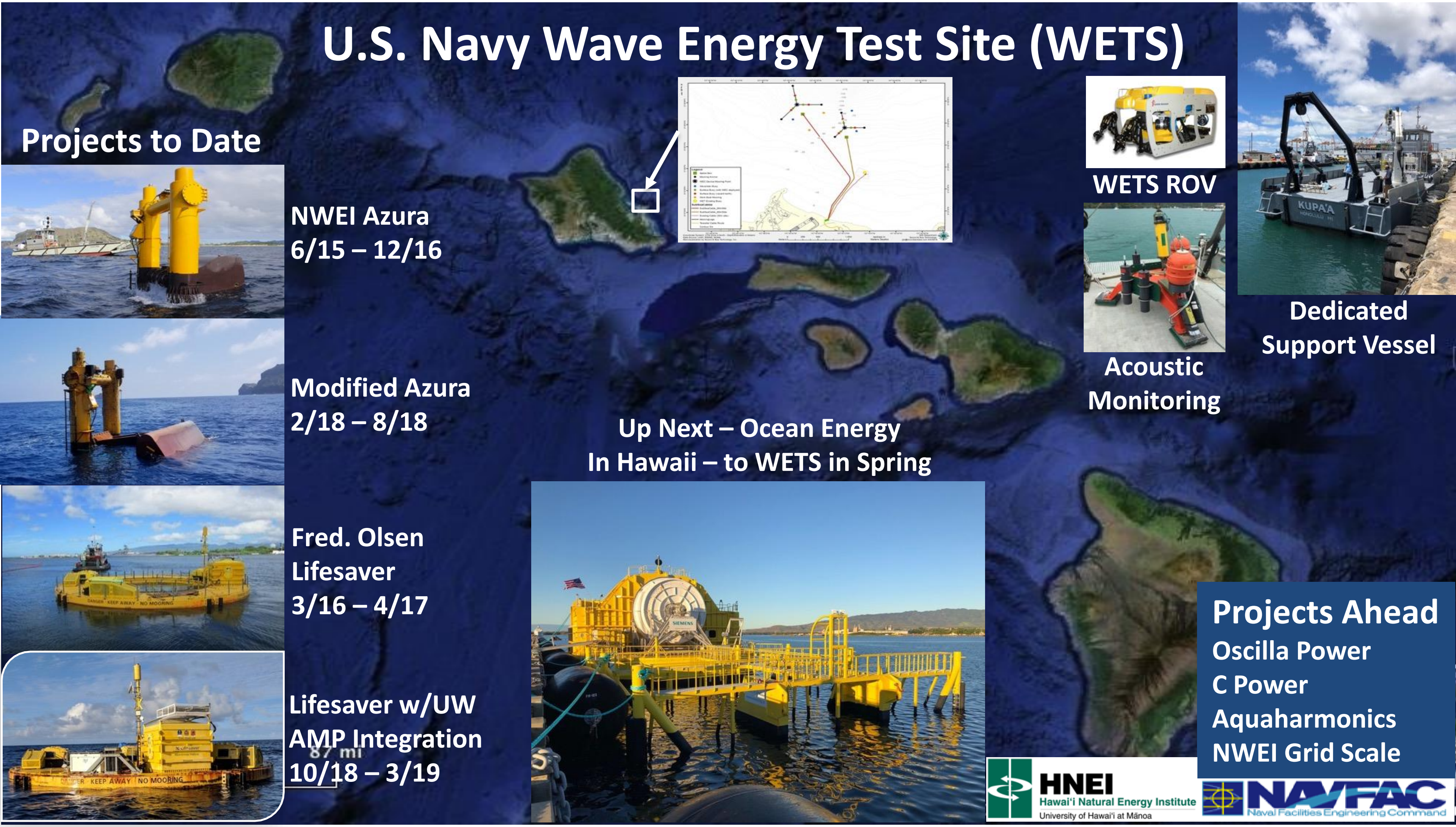
- Low levels of noise generated, propagated short distances before falling below background noise level
- No likely fatality or hearing damage (permanent or temporary)
- Disturbance possible depending on background noise
- Overall impact deemed to be negligible

https://tethys.pnnl.gov/publications/assessing-impact-man-made-underwater-noise-marine-renewable-outer-hebrides

Investigations into Wave Effects

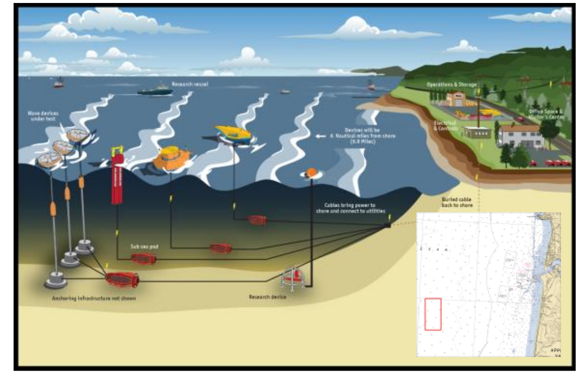
- Effects on benthos
- Noise
- EMF
- Other effects

PNNL is operated by Battelle for the U.S. Department of Energy



Testing underwater noise, benthic community changes, disturbance of marine mammals

PacWave



PacWave is an open-coastal wave energy testing facility at Oregon State University, now operated by the College of Earth, Ocean, and Atmospheric Sciences. It consists of two sites, each located within several miles of the deep-water commercial port of Newport, Oregon

- **Benthic community analyses**
    - Extensive sampling and analysis to set baseline for potential changes due to MRE development
- EMF and underwater noise measurements from small Azura WEC

- **PacWave North**
    - Established autonomous test site for small-scale, prototype, and maritime market technologies
- **PacWave South**
    - An in-development, state-of-the-art, permitted, accredited, grid-connected wave energy test facility. Developed in partnership with US Department of Energy, the State of Oregon and local community

Regulatory Thresholds

- Marine Mammals
  - NOAA Technical Guidance (2018)

Table 6: TTS onset thresholds for non-impulsive sounds.

Hearing Group	*K* (dB)	*C* (dB)	Weighted TTS onset acoustic threshold (SEL cum)
Low-frequency (LF) cetaceans	179	0.13	179 dB
Mid-frequency (MF) cetaceans	177	1.20	178 dB
High-frequency (HF) cetaceans	152	1.36	153 dB
Phocid pinnipeds (underwater)	180	0.75	181 dB
Otariid pinnipeds (underwater)	198	0.64	199 dB

Table 4: Summary of PTS onset thresholds.

	PTS Onset Thresholds* (Received Level)	
Hearing Group	Impulsive	Non-impulsive
Low-Frequency (LF) Cetaceans	*Cell 1* $L_{pk,flat}$: 219 dB $L_{E,LF,24h}$: 183 dB	*Cell 2* $L_{E,LF,24h}$: 199 dB
Mid-Frequency (MF) Cetaceans	*Cell 3* $L_{pk,flat}$: 230 dB $L_{E,MF,24h}$: 185 dB	*Cell 4* $L_{E,MF,24h}$: 198 dB
High-Frequency (HF) Cetaceans	*Cell 5* $L_{pk,flat}$: 202 dB $L_{E,HF,24h}$: 155 dB	*Cell 6* $L_{E,HF,24h}$: 173 dB
Phocid Pinnipeds (PW) (Underwater)	*Cell 7* $L_{pk,flat}$: 218 dB $L_{E,PW,24h}$: 185 dB	*Cell 8* $L_{E,PW,24h}$: 201 dB
Otariid Pinnipeds (OW) (Underwater)	*Cell 9* $L_{pk,flat}$: 232 dB $L_{E,OW,24h}$: 203 dB	*Cell 10* $L_{E,OW,24h}$: 219 dB

- Fish
  - NOAA Fisheries (salmon & bull trout)
  - BOEM Underwater Acoustic Modeling Report (2013)

Table 3. Interim Fisheries Cause and Effect Guidelines

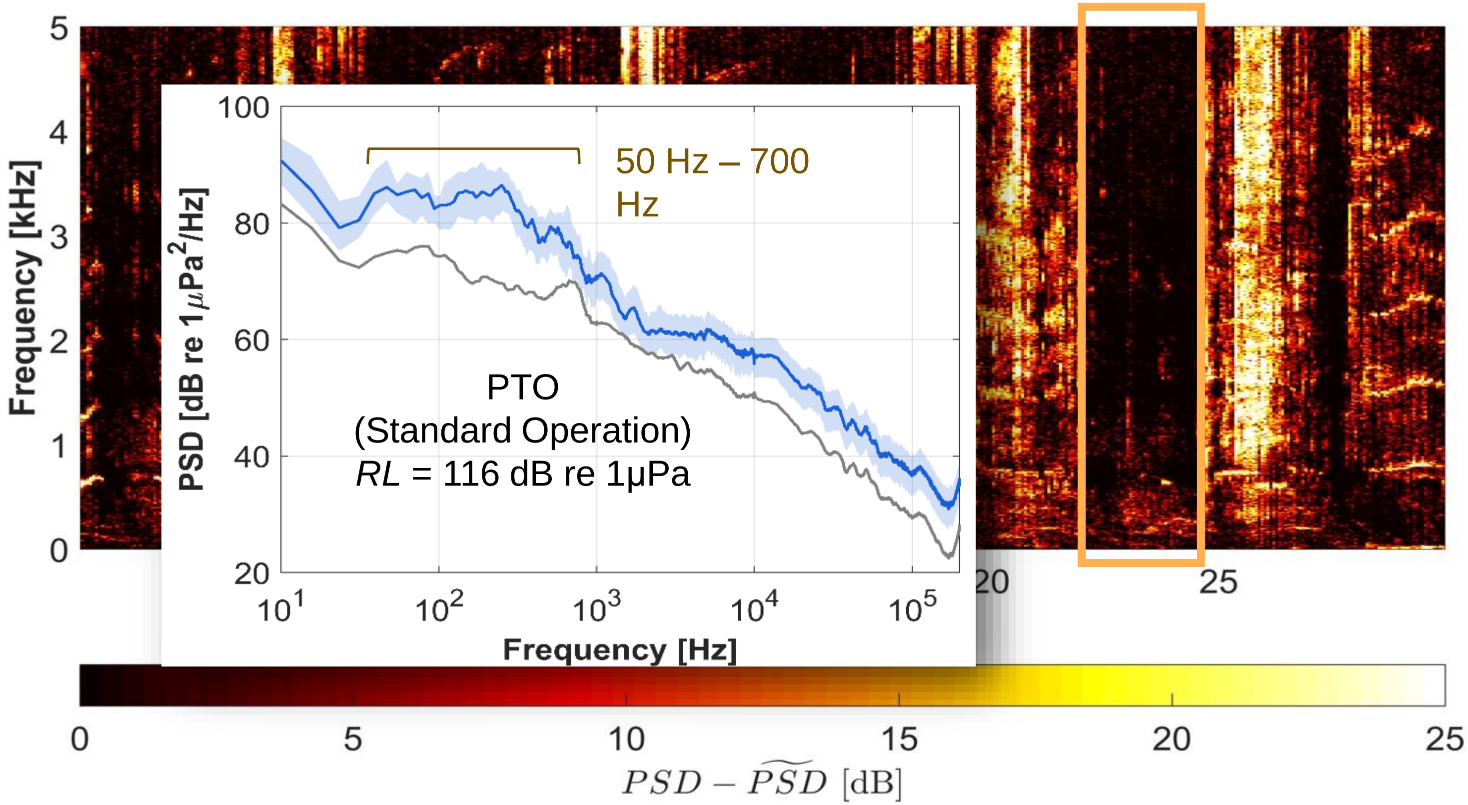
	Criteria Level	Type
Physiological Effects	206 dBL re 1 μPa	Absolute Peak SPL
	187 dBL re 1 μPa²s	SEL_{cum}, For fishes above 2 grams (0.07 ounces)
	183 dBL re 1 μPa²s	SEL_{cum}, For fishes below 2 grams (0.07 ounces)
Behavioral Effects	150 dBL re 1 μPa (RMS)	Absolute
Reference: U.S. Department of the Interior, Bureau of Ocean Energy Management (BOEM). Effects of Noise on Fish, Fisheries, and Invertebrates in the U.S. Atlantic and Arctic from Energy Industry Sound-Generating Activities, Literature Synthesis, 2012		

Fred. Olsen Lifesaver at WETS

- Hawai'i Wave Energy Test Site (WETS), Kaneohe, O'ahu
- Point absorber, floating
- Shallow draft (0.5 m)
- Noise measurements (2016):
  - 3 seabed-mounted hydrophones (3 months)
  - 2 drifting hydrophones (3 drifts)

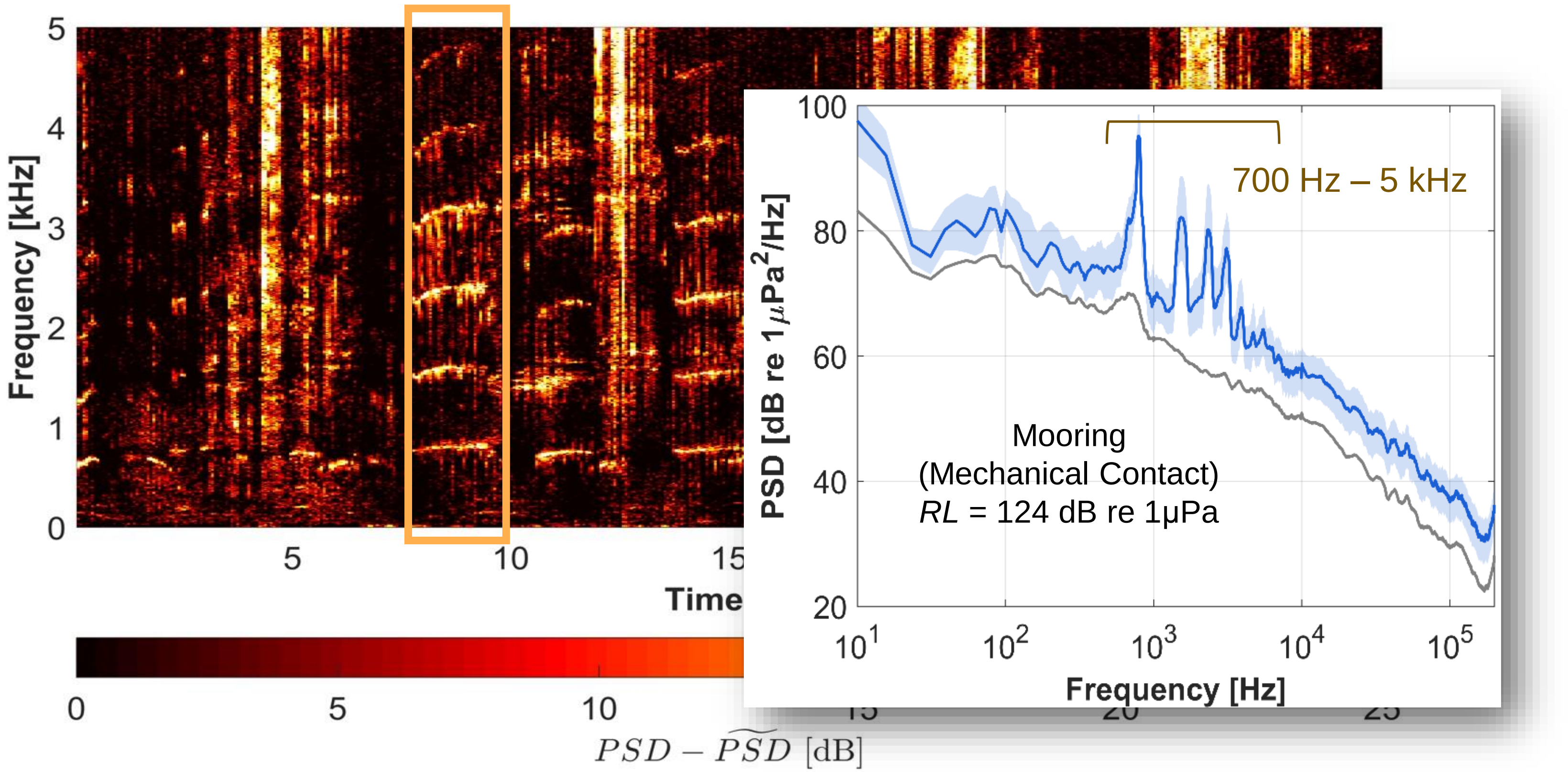
(Polagye et al. 2017, EWTEC)

Fred. Olsen Lifesaver at WETS



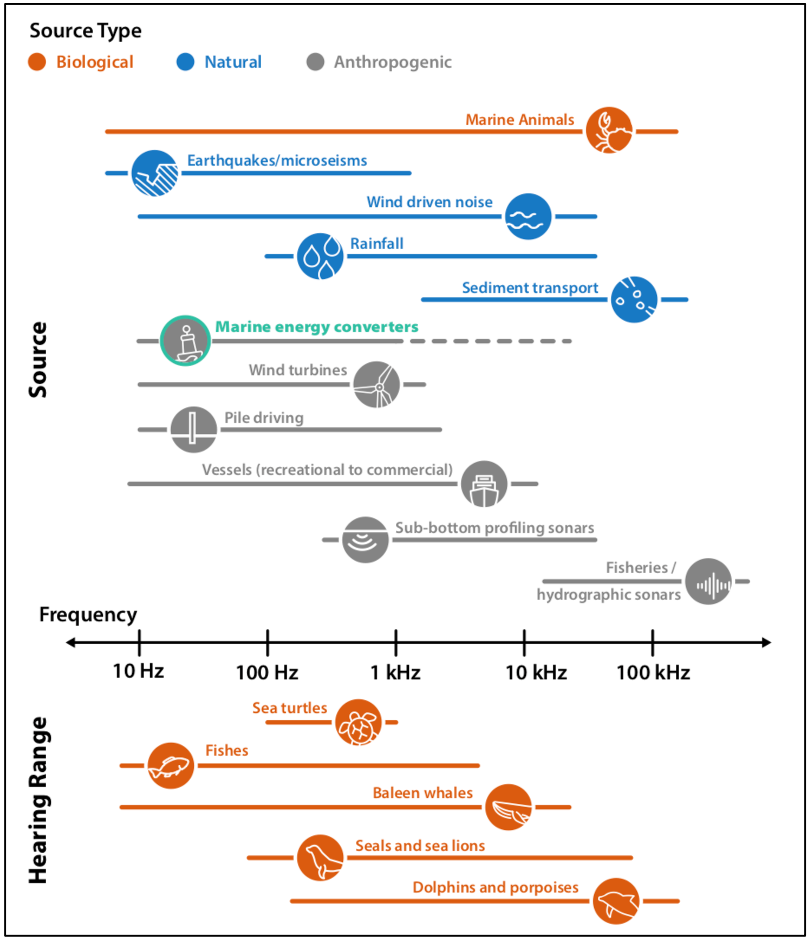
(Polagye et al. 2017, EWTEC)

Fred. Olsen Lifesaver at WETS



(Polagye et al. 2017, EWTEC)

Hearing thresholds for marine animals and underwater noise levels

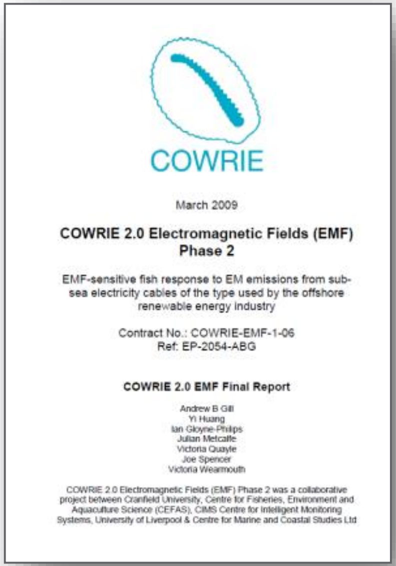


EMF Fields Studies

EMF-sensitive fish response to EM emissions from subsea electricity cables

- West Scotland, 2007, 10-15m deep, 125 kV AC cable buried 0.5-1m
- Mesocosms with energized and control cables (3 trials)
- No evidence of positive or negative effect on catsharks (dogfish)
- Benthic elasmobranchs (skates) responded to EMF in cable

(Gill et al. 2009)


COWRIE

March 2009

COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2

EMF-sensitive fish response to EM emissions from sub-sea electricity cables of the type used by the offshore renewable energy industry

Contract No.: COWRIE-EMF-1-06
Ref: EP-2054-ABG

COWRIE 2.0 EMF Final Report

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Joe Spencer
Victoria Wearmouth

COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2 was a collaborative project between Cranfield University, Centre for Fisheries, Environment and Aquaculture Science (CEFAS), CIMS Centre for Intelligent Monitoring Systems, University of Liverpool & Centre for Marine and Coastal Studies Ltd


Fisheries Management and Ecology

Sub-sea power cables and the migration behaviour of the European eel

H. WESTERBERG & I. LAGENFELT

Sub-sea power cables and the migration behaviour of the European eel

- East Sweden, 2006, unburied 130 kV AC cable
- Used acoustic tags to track small movements of 60 eels across energized cable
- Eels swam more slowly over energized cable
- Effect was small, no evidence of barrier effect

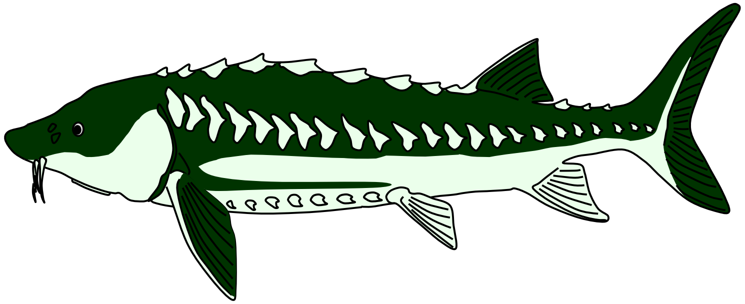
(Westerberg and Lagenfelt 2008)

EMF Fields Studies

Assessment of potential impact of electromagnetic fields (EMF) from undersea cable on migratory fish behavior

- West U.S., 2014, buried 200 kV DC cable
- HVDC cable in San Francisco Bay, parallel or perpendicular to green & white sturgeon, salmon, steelhead smolt migrations
- Tagged fish, magnetometer surveys
- Outcome – such large magnetic signatures from bridges, other infrastructure, could not distinguish cable!
- Fish did not appear to be affected

(Kavet et al., 2016)



EMF Fields Studies

Potential impacts of submarine power cables on crab harvest

- NW U.S. and SW U.S., 2015, 10-13m deep, unburied power cables
- Will rock crab (Santa Barbara channel) and Dungeness crab (Puget Sound) cross a power cable?
- Rock crabs cross an unburied 35 kV AC power cable
- Dungeness crabs cross an unburied 69 kV AC power cable to enter baited commercial traps

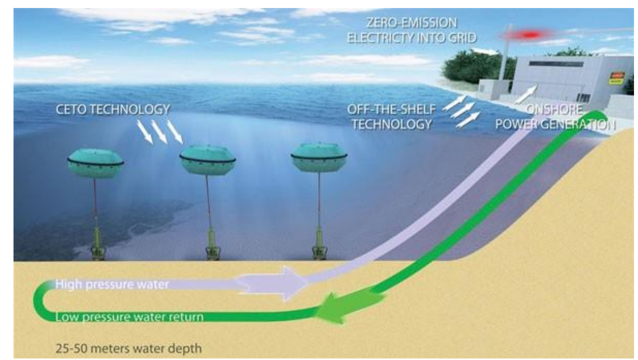
(Love et al., 2017)

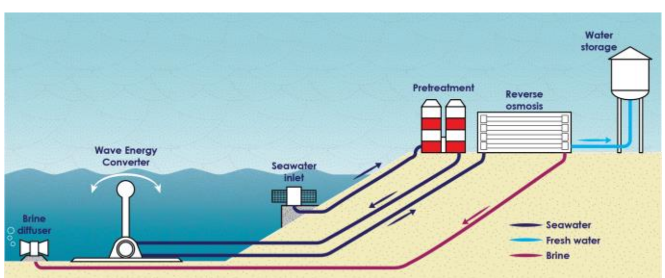
EXPERIMENTAL SET UP IN BOTH STUDY AREAS

12 units, 3 replicates of each of 4 test conditions, were randomly placed along the cable

Other Potential Wave Effects

- Carnegie (Western Australia)
  - Concerns over entanglement
  - Desalination brine return
- Resolute Marine (Cape Verde Islands)
  - Desalination brine return





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