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Stressor-specific Guidance Document: Electromagnetic Fields Updated April 2025

The guidance documents are intended to be available for regulators and advisors as they carry out their decisionmaking and for developers and their consultants as they prepare consenting and licensing applications. This stressor-specific document presents an overview of the scientific information that is known for electromagnetic fields.¹ It is not intended to replace any regulatory requirements or prescribe action for a particular risk.

Introduction to Stressor

Anthropogenic electromagnetic fields (EMFs) are emitted from various types of infrastructure in the marine environment such as subsea cables for power and communications, bridges, and tunnels. These emissions may affect several species of marine animals, like those that use the Earth's natural magnetic fields for orientation, navigation, and/or hunting. This includes some species of elasmobranchs, crustaceans, cetaceans, fish, and sea turtles. Figure 1 shows an abbreviated version of where this stressor fits within the guidance document framework.



Figure 1. Portion of the guidance document framework depicting electromagnetic fields and key receptors, which are relevant under the regulatory category of species and populations at risk. The full framework can be found in the background guidance document.¹

Marine renewable energy (MRE) systems emit EMFs from power cables, moving parts of devices, and subsea substations/transformers. These EMFs may affect sensitive species at individual or population levels by causing animals to be attracted to or avoid areas, and/or by interfering with natural magnetic fields used for orientation, navigation, and hunting. However, the impact to animals depends on factors such as the intensity and levels of EMFs emitted (depending on parameters like type of cable or cable configuration and type of burial, armoring, or insulation), local geomagnetic fields, and surrounding environmental factors and the sensitivity of the species to EMF. To accurately assess the environmental impact from EMFs, these factors and others need to be considered, as shown in Figure 2.

¹ This stressor-specific document should be read in conjunction with the background guidance document, which can be found on Tethys: <u>https://tethys.pnnl.gov/guidance-documents</u>.



Stressor-specific Documents

Electromagnetic Fields

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Figure 2. Key elements that need to be considered when assessing the environmental impact of electromagnetic fields. From Gill and Desender (2020), graphic by Robin Ricks.

Existing Data and Information

2024 State of the Science

Section 3.3 of <u>Chapter 3 of the 2024 State of the Science Report</u> (Garavelli et al. 2024) describes EMF in detail, synthesizing research and findings from MRE devices to build on the comprehensive look at the status of knowledge for impacts from EMF from Gill and Desender (2020).

Evidence Base

OES-Environmental has developed an evidence base of key research papers and monitoring reports for EMF that support the understanding and risk retirement for small numbers of MRE devices². The evidence base has been recently updated and can be accessed on Tethys³: <u>EMF Evidence Base</u>. A limited number of the studies included in the EMF evidence base are shown at the end of this document in the Additional Information section (Table 1).

Monitoring Datasets Discoverability Matrix OES-Environmental has developed the <u>Monitoring Datasets Discoverability Matrix</u>, an interactive tool that can be used to locate datasets by stressor, receptor, and other specifications, as shown in Figure 3. In addition to the research studies and key documents included in the evidence base, the matrix includes baseline and post-installation monitoring reports compiled from <u>OES-Environmental Metadata</u>, providing links and contacts to existing datasets from MRE projects and research studies. The metadata includes information solicited from developers and researchers involved in environmental monitoring projects for MRE, which is updated annually.

³ <u>Tethys</u> is the U.S. Department of Energy's online platform that aims to facilitate the exchange of data and information on the environmental effects of wind and MRE, and serves as a commons for the <u>OES-Environmental</u> initiative. Tethys is developed and maintained by the Pacific Northwest National Laboratory.



² For the purposes of risk retirement, small developments have been defined as one to six devices.

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Figure 3. Screenshot of the Monitoring Datasets Discoverability Matrix selections for EMF on Tethys.

Management Measures Tool The <u>Management Measures Tool</u> has been developed by OES-Environmental to show management (or mitigation) measures from past or current MRE projects as a reference to help manage potential risks from future projects. The tool can be filtered by technology (tidal or wave), management measures, project phase, stressor, and/or receptor. An example of management measures returned for EMF is shown in Figure 4 below.

Filter by Technology: - Any -		Management Measure:		Project Phase: - Any - 🗸		Stressor: EMF ¥		Receptor: - Any - 🗸	
Technology	Project Phase	Stressor	Receptor	Management Measure	Advanta	ges	Challenges	Project Documents	
Wave, Tidal	Operation & Maintenance	EMF Impacts of electromagnetic fields from subsea cables on sensitive species.	Habitat Benthic invertebrates	Design feature Install cable protection, armor, rock placement, or other cable protection.	Reduce the level of EMF to surrounding water column and therefore any potential effects. Reduces 'snagging risk' for vessels. Creation of artificial habitat leading to greater fecundity in species.		May have an impact on surrounding benthic habitats and sensitive species. Creation of artificial habitat may cause aggregation effect causing greater impact of EMF. Uncertainty around the need for and efficacy of this measure. Increased cost to project. Read more	Foubister 2005, Orbital Marine Power 2010, MeyGen 2012, ScottishPower Renewables 2010, DP Energy Ltd. 2013, Fox 2019, EMEC Fall of Warness Grid-Connected Tidal Test Site, Orbital Marine Power SR250 at EMEC, MeyGen Tidal Energy Project, Sound of Islay Demonstration Tidal Array, West Islay Tidal Project Energy Park	
Wave, Tidal	Installation	EMF Impacts of electromagnetic fields from landfall cables on sensitive species.	Benthic Benthic invertebrates	Design feature Micrositing of offshore infrastructure to avoid sensitive habitats and minimize footprint.	Could reduce/ effects of sensitive Can ofte with littl addition	remove on e habitats. In be done e al cost	None identified	ScottishPower Renewables 2012, Laminaria 2018, The Marine Institute 2016, EMEC Billia Croo Grid- Connected Wave Test Site, Galway Bay Test Site	

Figure 4. Screenshot of the Management Measures Tool selections for EMF.



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Tethys Knowledge Base The Tethys Knowledge Base hosts thousands of documents about the environmental effects of MRE. All documents associated with EMFs can be found <u>here</u>.

Pathway to Risk Retirement

The evidence base to date suggests that the impacts of EMFs from small-scale MRE developments are limited, and the risk to EMF-sensitive species is low and can be retired. Laboratory and field studies indicate that EMFs are unlikely to harm sensitive species at the levels emitted from MRE power cables (see Additional Information, Table 1). In addition, EMFs from MRE are lower than those from other anthropogenic EMF emissions, including offshore wind power export cables (Thomsen et al. 2015). Overall, there is a general consensus among the scientific community that EMFs from small-scale MRE developments are not harmful and do not pose a risk to marine animals, and therefore should not inhibit the installation of devices or require extensive monitoring (Copping et al. 2020a, Copping et al. 2020b, Garavelli et al. 2024, Gill and Desender 2020).

Some uncertainties remain, and more studies will increase understanding as the MRE industry moves to array-scale development that will have increased EMF emission levels. A complete list of remaining uncertainties and research needs is available in Section 3.3 of <u>Chapter 3 of the 2024 State of the Science</u> <u>Report</u> (Garavelli et al. 2024). Key examples include the need to:

- Validate existing models with field measurements from deployed MRE devices and power transmission cables.
- Increase understanding of responses to EMF at more realistic intensities and temporal patterns
 of power transmission by MRE devices.
- Increase understanding on the interaction of pelagic species (e.g., sharks, marine mammals, or fishes) with dynamic cables (i.e., cables in the water column).

Recommendations

Sharing of data and information across the MRE industry and other industries that deploy subsea transmission cables will benefit general understanding of EMF effects, including the future cumulative effects of EMFs in the ocean. As the MRE industry progresses, it will be important to consider local conditions, existing sources of EMF, and sensitive species, to understand and minimize the risks posed by EMFs. Risk from EMF for small numbers of devices can be retired, and studies of EMF at each new proposed project site may not be needed. However, any data collected around projects and other deployments will continue to inform understanding of cumulative risks and accurate modeling of EMF for arrays.



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Additional Information

The evidence base for EMF can be found at <u>https://tethys.pnnl.gov/emf-evidence-base</u>.

Table 1. A selection of studies from the evidence base for EMF effects on marine animals, in chronological order. These projects and research studies examined undersea cables and surrogates including energized power cables, telecommunications cables, and other electrical infrastructure.

Project/Research Study	Location	Cable or EMF source	EMF measurements	Conclusion
Sub-Sea Power Cables and the Migration Behaviour of the European Eel (Westerberg and Lagenfelt 2008)	Eastern Sweden	130 kV AC cable, unburied.	Acoustic tags were used to track small movements across energized cable.	Eels swam more slowly, but effect was not significant and no evidence of barrier effect.
EMF-Sensitive Fish Response to EM Emissions from Sub-Sea Electricity Cables of the Type Used by the Offshore Renewable Energy Industry (Gill et al. 2009)	Western Scotland	125 kV AC cable, buried 0.5-1 m deep.	Mesocosms were used with both energized and control cables.	No evidence of significant positive or negative effect on catsharks (dogfish). Benthic skates responded to EMF in cable.
Assessment of potential impacts of electromagnetic fields from undersea cable on migratory fish behavior (Kavet et al. 2016)	San Francisco Bay, U.S.	200 kV DC cable, buried.	Tagged fish to track movement and used magnetometer surveys to measure EMF.	Fish (green and white sturgeon, salmon, steelhead smolt) did not appear to be affected. There were large magnetic signatures from bridges and other infrastructure that the cable could not be distinguished from.
Electromagnetic Field (EMF) Impacts on Elasmobranch (shark, rays, and skates) and American Lobster Movement and Migration from Direct Current Cables (Hutchison et al. 2018)	Northeast U.S.	300 kV DC, buried.	Employed an enclosure with animals using acoustic telemetry tags and variable power (0, 100, and 330 MW).	American lobster had a statistically significant, but subtle change in behavior in response to EMF and Little skate had a statistically significant behavioral response to EMF from cable, but the EMF from the cable did not act as a barrier to movement for either species.
Electromagnetic Field Impacts on American Eel Movement and Migration from Direct Current Cables (Hutchison et al. 2021)	Northeast, U.S.	300 kV DC, buried.	Used SEMLA sensor system to characterize EMF emissions and conducted tagging study for eel encounters and responses.	The high voltage DC transmission cable did not present a barrier to migratory American eel movement or migration. However, the eels moved faster when exposed to the DC B-field.
Red rock crab (Cancer productus) movement is not influenced by electromagnetic fields produced by a submarine power transmission cable (Williams et al. 2023)	California, U.S.	34.5 kV AC power transmission cable, exposed.	Used experimental cages to study the response of red rock crabs.	Red rock crab movement or behaviour is not influenced by B-fields at intensities similar to existing MRE projects.



Table 2. EMF measurements taken around high-voltage alternative current (AC) and direct current (DC) subsea cables since 2016. The distances above the seafloor were extracted from studies when provided. The EMF extent refers to the distance that EMF is measurable in relation to the ambient fields perpendicular to the cable axis. From Gill and Desender (2020).

Cable	Current	Location	Magnetic Field	Electric Field	Extent EMF	Reference
			(B-field) (E-field)			
2 - 2.4 amps	DC	South Florida	Max: 150 μT	Max: 60 μV/m	10s m (estimated)	Dhanak et al.
		(U.S.)	Mean: 30 nT	4m above	AC>DC	(2016)
0.98 - 1.59 amps, 60	AC		2.2m above	cable		
Hz			seafloor			
Trans Bay Cable	DC	San Francisco	1.15 – 1.2 μT	n/a	<40 m	Kavet et al.
(200kV, 400 MW, 85		Bay, California	3 m above			(2016)
km)		(U.S.)	seafloor			
Basslink (500kV, 237	DC	Bass Strait,	58.3 μΤ	5.8 μV/m	15 – 20 m	Sherwood et al.
MW, 290 km)		Tasmania				(2016)
		(Australia)				
Cross Sound (300kV,	DC	Connecticut	DC: 0.4 – 18.7 μT	AC: max 0.7	AC-DC B-fields: 5 – 10 m	Hutchison et al.
330 MW, 40 km)		(U.S.)	AC: max 0.15 μT	μV/m		(2018)
Neptune (500kV, 660	DC	New Jersey	DC: 1.3 – 20.7 μT	DC: 0.4 μV/m	AC: max: E-fields up to	Hutchison et al.
MW, 105 km)		(U.S.)	AC: max 0.04 μT		100 m	(2018)
Sea2shore (502	AC	Rhode Island	0.05 – 0.3 μT	1-25 μV/m	AC: B-field up to 10m	Hutchison et al.
amps, 30 MW, 32 km)		(U.S.)			AC: E-field up to 50 m	(2018)
					(estimated)	

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