Stressor-specific Guidance Document: Habitat Change

Updated April 2025

The guidance documents are intended to be available for regulators and advisors as they carry out their decision-making 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 habitat change. [1] *It is not intended to replace any regulatory requirements or prescribe action for a particular risk.*

Introduction to Stressor

Habitats are the natural environments of an organism, comprising the array of physical and biological resources necessary for survival and reproduction, and are the foundation for organisms in the marine environment providing protection, preys to feed on, etc. Structures placed in the marine environment have the potential to alter habitats or impact marine organisms. Habitat alteration, loss, or creation may occur throughout the marine environment, including in benthic (seafloor) or pelagic (water column) environments. Figure 1 shows an abbreviated version of where this stressor fits within the guidance document framework.

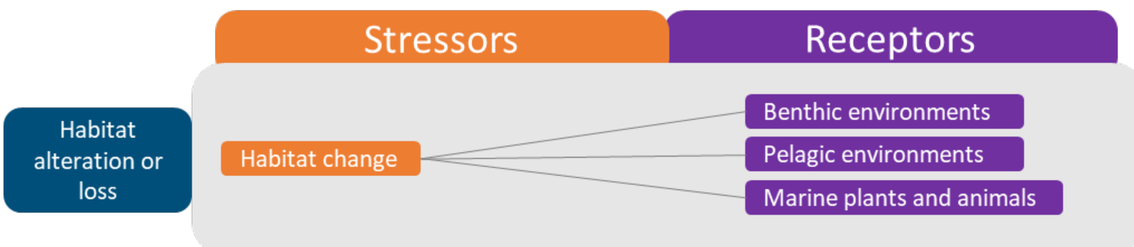

Figure 1. Portion of the guidance document framework depicting habitat change and key receptors, which are relevant under the regulatory category of habitat alterations. The full framework can be found in the background guidance document.[1]

As marine renewable energy (MRE) devices and associated infrastructure are deployed, features of the devices and their associated components may impact marine habitats (Figure 2). MRE devices attached to the seafloor by gravity foundations, pin piles, or anchors, as well as cables and other equipment or infrastructure on the seabed, may alter the benthic habitat; while mooring lines, cables, and the devices themselves placed in the water column may alter the pelagic habitat. Impacts to marine organisms and environments may include negative effects (e.g., loss of habitats), changes that cannot be detected relative to natural variation (e.g., changes in sediment around anchors), or potentially beneficial (e.g., new sources of habitat) or neutral changes, and will depend on a variety of factors. Changes in habitats may occur due to:

- Sediment trenching and digging for cable installation that contributes to localized disturbance; this is limited to a narrow path along cable routes though the site may take months to years to recover depending on the habitat type(s) present (Taormina et al. 2018).
- The hydrodynamic alteration of fast-flowing water and localized turbulence causing sediment removal (i.e., scouring) around artificial structures that contributes to localized disturbance; this may occur around MRE device foundations and anchors and is likely to only impact infauna in the immediate vicinity (Davis et al. 1982; Morrisey et al. 2018).

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

- Installation and removal of bottom structures that resuspends fine sediments (Taormina et al. 2018).
- Loss of habitat immediately under foundations, anchors, and cables; proper siting will avoid the loss of critical habitats (Hemery 2020).
- Turbulence around the base of bottom-mounted devices (i.e., the footprint effect) that can affect benthos (O'Carroll et al. 2017).
- Turbulence and changes in water flow around the floating devices that can affect seabird foraging (Couto et al. 2022).
- New hard-substrate habitat that is created by the presence of MRE devices and associated components; these are likely to be colonized by a diversity of organisms and potentially non-native species. Colonization is influenced by natural variability and existing nearby biofouling communities. Composition and cover by sessile organisms may differ depending on substrate orientation and coating materials used (Macleod et al. 2016; Nall et al. 2022; Want et al. 2023).
- MRE devices and associated structures that may attract mobile organisms such as crabs and fish and create artificial reef and fish aggregating effects (Bender et al. 2020; Taormina et al. 2020a; Taormina et al. 2020b).
- Biofouling and artificial reef effects that may cause local biomass to increase; this can lead to seafloor enrichment in the immediate vicinity due to the accumulation of organic matter from litter falls, with potential impacts to local food webs (Raoux et al. 2017; Wilding 2014).
- Areas surrounding MRE devices that may be closed to fishing and other human activities that can lead to marine reserve effect; this has the potential to benefit the entire food web and nearby areas, as well as increase organism biomass both within the area and outside (i.e., spillover) (Alexander et al. 2016).

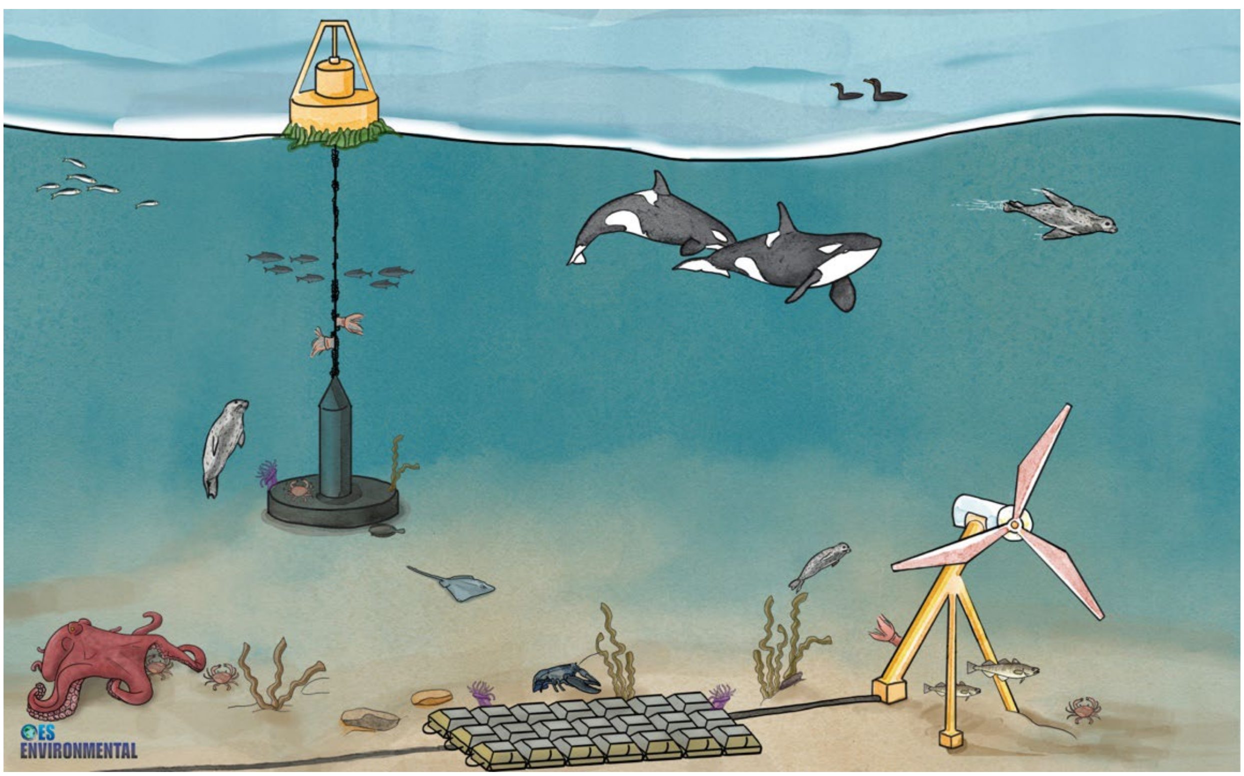


Figure 2. Representation of a temperate ecosystem with benthic and pelagic habitats influenced by a wave energy converter, a tidal turbine, and an export cable protected by a concrete mattress. (Modified from Hemery et al. 2021a)

Existing Data and Information

2024 State of the Science

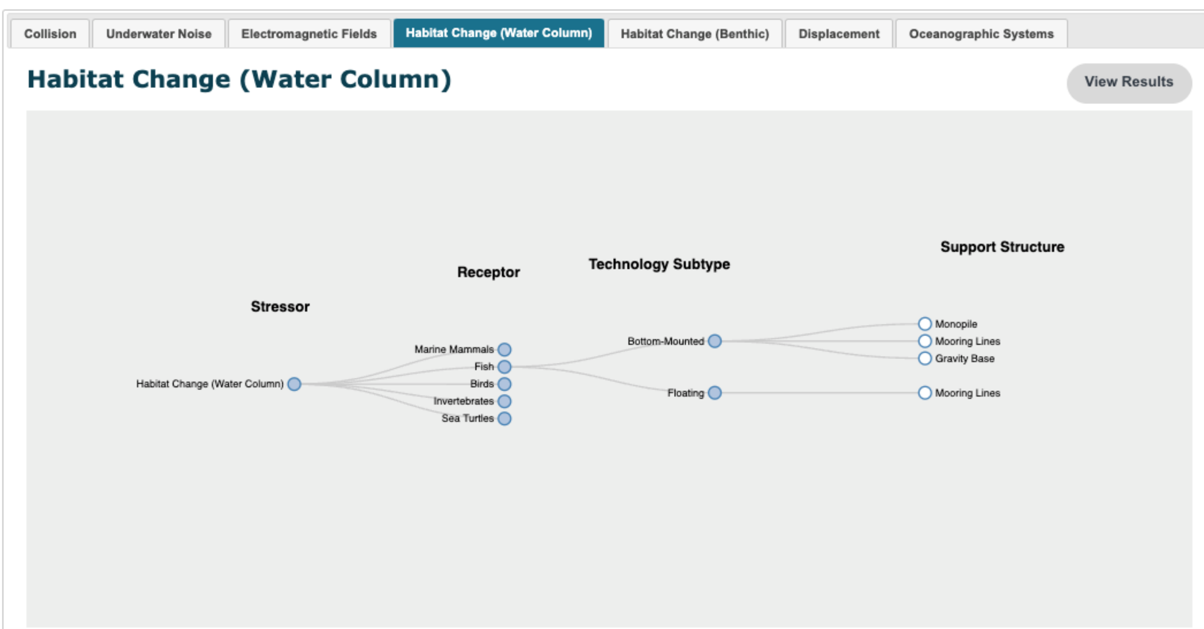
Section 3.4 of Chapter 3 of the 2024 State of the Science Report (Garavelli et al. 2024) covers habitat change in detail. It synthesizes research and findings from current MRE projects to provide a comprehensive look at the status of knowledge for changes in benthic and pelagic habitats.

Evidence Base

OES-Environmental has developed an evidence base of key research papers and monitoring reports for habitat change that supports the understanding and risk retirement for small numbers of MRE devices[2]. The evidence base has been recently updated and can be accessed on Tethys[3]: Habitat Change Evidence Base. A limited number of the studies included in the habitat change evidence base are shown at the end of this document in the Additional Information section (Table 1).

Monitoring Datasets Discoverability Matrix

OES-Environmental has also developed the Monitoring Datasets Discoverability Matrix, an interactive tool that allows the user to locate datasets by stressor, receptor, and other specifications for habitat change, as shown in Figure 3. In addition to the research studies and key documents included in the evidence base, from both MRE and analogous industries, the matrix includes baseline and post-installation monitoring reports. These are compiled from OES-Environmental Metadata, which provides links and contacts to existing datasets from MRE projects and research studies. The metadata includes information solicited from developers and researchers on environmental monitoring for MRE, which is updated annually.



[2] For the purposes of risk retirement, small developments have been defined as one to six devices.
[3] Tethys 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 OES-Environmental initiative. Tethys is developed and maintained by the Pacific Northwest National Laboratory.

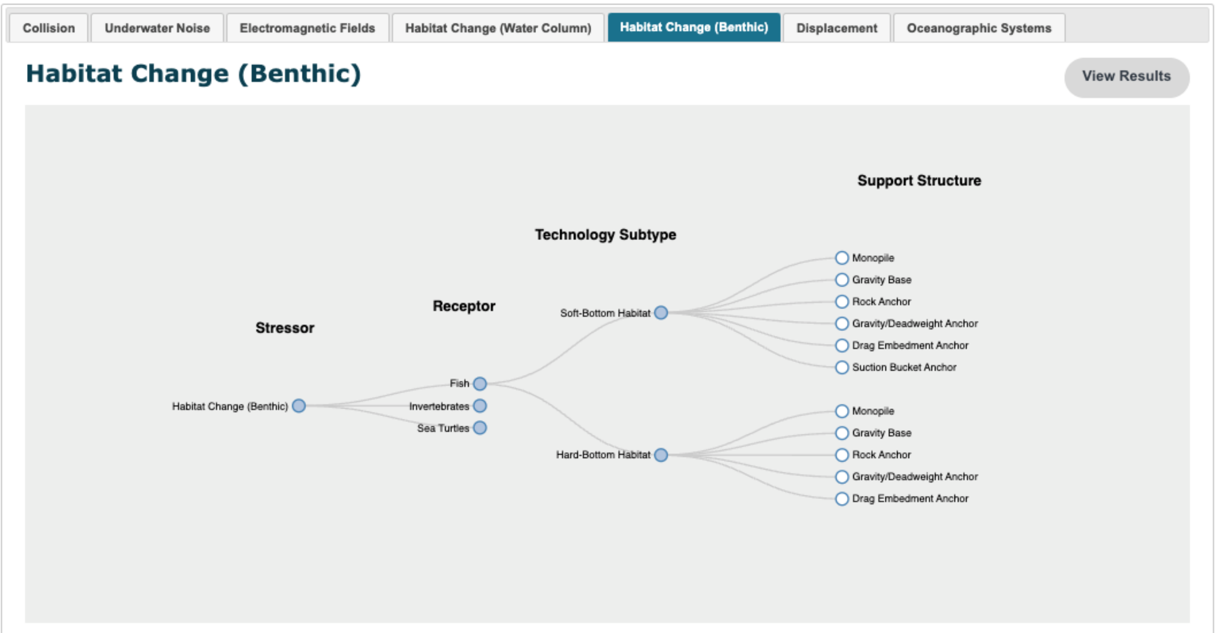


Figure 3. Screenshots of the Monitoring Datasets Discoverability Matrix selections for habitat change on Tethys. Water column habitat change is shown in the top picture and benthic habitat change is shown in the bottom picture. Selections under the other receptors are similar to those shown for fish.

Management Measures Tool

The Management Measures Tool 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 habitat change is shown in Figure 4 below.

Filter by Technology: - Any - | **Management Measure:** - Any - | **Project Phase:** - Any - | **Stressor:** Habitat Loss | **Receptor:** - Any -

Search: Apply Reset

Technology	Project Phase	Stressor	Receptor	Management Measure	Advantages	Challenges	Project Documents
Wave, Tidal	Installation, Decommissioning	**Habitat Loss** Direct loss of protected or sensitive sub-littoral seabed communities due to the presence of devices and associated moorings or support structures on the seabed.	**Habitat** Benthic invertebrates, demersal fish	**Design feature** Site selection to avoid sensitive or protected sub-littoral seabed communities.	Could reduce/remove effects on sensitive habitats.	None identified	**ScottishPower Renewables 2012**, **OpenHydro and SSE Renewables 2013**, **Fox 2019**, **Ness of Duncansby Tidal Array**
Wave, Tidal	Installation, Decommissioning	**Habitat Loss** Direct loss of protected or sensitive sub-littoral seabed communities due to the presence of devices and associated moorings or support structures on the seabed.	**Fish** Demersal fish	**Design feature** Minimize footprint of anchors/foundations.	Could reduce effects on sensitive habitats	May impact technical considerations.	**Aquatera Ltd 2011**, **Xodus Group 2019**, **Federal Energy Regulatory Commission (FERC) 2020**, **Wello Penguin at EMEC**, **EMEC Billia Croo Grid-Connected Wave Test Site**, **PacWave South Test Site**

Figure 4. Screenshot of the Management Measures Tool selections for habitat change, specifically habitat loss.

Tethys Knowledge Base

The Tethys Knowledge Base hosts thousands of documents about the environmental effects of MRE. All documents associated with habitat change can be found here.

Pathway to Risk Retirement

The evidence to date suggests that the impacts from habitat change from single devices or small numbers of MRE devices are well understood and can be retired (Hemery et al. 2021b, Garavelli et al. 2024). Severe habitat change can be avoided or mitigated through identification and avoidance of fragile, unique, or important habitats during site selection. In addition, impacts would only affect a limited area around the footprint of a device/associated infrastructure, or would dissipate quickly (e.g., sediment scouring) or recover quickly from disturbances (e.g., cable laying). Alternatively, developments may provide new habitats for marine organisms (e.g., colonization of hard surfaces or use of as an artificial reef). Habitat change from operational MRE devices are not likely to cause injury or harm to marine organisms. Overall, there is general consensus that habitat change from small-scale MRE developments does not typically pose a significant risk to habitats and marine plants and organisms when sited properly to avoid critical habitats (Hemery et al. 2021b).

Some uncertainties about the effects from habitat change remain, and more studies will be useful to increase understanding. A complete list of remaining uncertainties and research needs is available in Section 3.4 of Chapter 3 of the 2024 State of the Science Report (Garavelli et al. 2024). Key examples include the need to:

- Define guidelines on the appropriate spatial and temporal scales for studying effects, for all phases of development: installation, operation & maintenance, and decommissioning.
- Develop guidelines for the level of biodiversity and species assemblage changes to be considered.
- Identify thresholds for habitat changes, including loss of habitat, as well as the level of colonization and aggregation.
- Continue to increase understanding of community changes over time, including through conducting long-term studies of ecological processes.
- Characterize the diversity and ecological characteristics of biofouling and aggregating species.
- Continue to increase understanding of how habitat changes scale with the area occupied by an array or the number of devices.
- Understand the cumulative effects of MRE devices and other activities occurring in the same areas, particularly for artificial reef and aggregating effects, as well as reserve and stepping-stone effects.

Recommendations

Sharing data, information, and findings across the MRE industry and other marine industries will benefit the general understanding of habitat change, including cumulative effects. MRE project proponents should consult early with actors in targeted areas to identify and assess existing datasets. Additional costs and barriers can be reduced by utilizing automatic algorithm for data processing and by adopting cost-efficient alternative methods, like environmental DNA, to collect data on animal presence in high-energy environments. As the MRE industry progresses, it will be important to continue to consider local conditions, existing sources of habitat impacts, and important species that may be at risk from changes to the habitat, to understand and minimize the risks posed by habitat change. Risk from habitat change for small numbers of devices can be retired, and if an MRE project is sited to avoid important, vulnerable, or unique habitats, studies of habitat at each new proposed project site may not be needed (Hemery et al. 2021b). However, any data collected around projects and other developments will continue to inform understanding of cumulative risks and increase the knowledge of spatial and temporal scales of habitat change.

Additional Information

The evidence base for habitat change can be found at: https://tethys.pnnl.gov/habitat-change-evidence-base

Table 1. A selection of studies from the evidence base for habitat change, in chronological order.

Project/Research Study	Location	Device Type	Habitat Change Type	Conclusion
In-Situ Ecological Interactions with a Deployed Tidal Energy Device; An Observational Pilot Study (Broadhurst et al. 2014)	Orkney, Scotland	Tidal	Fish aggregating effect	Fish (pollack) were observed aggregating in shoals temporarily around the device, with abundance significantly associated to the water velocity rate.
Identifying Relevant Scales of Variability for Monitoring Epifaunal Reef Communities at a Tidal Energy Extraction Site (O'Carroll et al. 2017)	Northern Ireland	Tidal	Footprint effect	Seasonality, rather than the tidal turbine, significantly affected epifaunal community structure and bare rock distributions.
Colonisation of wave power foundations by mobile mega- and macrofauna – a 12-year study (Bender et al. 2020)	Sweden	Wave	Artificial reef effect	The results of this 12-year study show a distinct reef effect on the device foundations, with significant greater species richness and abundance than at control sites.
Shetland Tidal Array Monitoring Report: Subsea video monitoring (Smith 2021)	Scotland	Tidal	Fish aggregating effect	Fish (pollock) were observed around turbine at slack tide or low current speeds, feeding on turbine biofouling. Seabirds (black guillemots and European Shags) were observed diving into the array area more often during slack ebb tides and flood tides.
Tidal streams, fish, and seabirds: Understanding the linkages between mobile predators, prey, and hydrodynamics (Couto et al. 2022)	Scotland	Tidal	Changes in flow	Tidal turbines were shown to affect benthic and pelagic foraging seabird distributions differently. Benthic foraging seabird distributions are associated with changes in sandbanks, sandeel habitats, and pelagic foraging seabird distributions are associated with the presence of fish schools.
No Observed Effects of Subsea Renewable Energy Infrastructure on Benthic Environments (Smyth and Kregting 2023)	Ireland	Tidal	Footprint Effect	After 5 years of tidal kite operation, no significant changes to benthic habitats were detectable.

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