Stressor-specific Guidance Document: Collision Risk

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 collision risk.[1] *It is not intended to replace any regulatory requirements or prescribe action for a particular risk.*

Introduction to Stressor

Within the marine environment, there is potential for marine animals to collide with human-made structures, including vessel propellors, anthropogenic debris, or marine renewable energy (MRE) turbine blades, which each pose different levels of risk to marine animals (Garavelli et al. 2024, Schoeman et al. 2020; Dau et al. 2009; Sparling et al. 2020). Collisions have the potential to cause injury, harm, or in severe cases death. Marine mammals, fish, and sea turtles are particularly susceptible to collision risks as they live, forage, migrate, rest, and rear their young in the water column. Diving seabirds may also be susceptible when they forage. Figure 1 shows an abbreviated version of where this stressor fits within the guidance document framework.

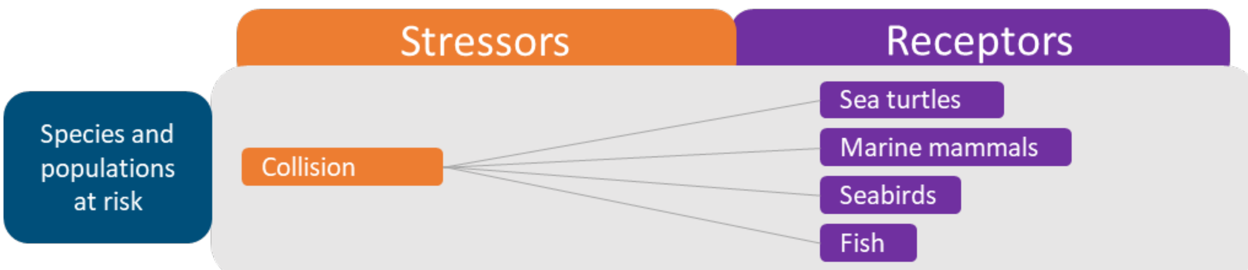


Figure 1. Portion of the guidance document framework depicting collision risk and key receptors, which are relevant under the regulatory category of species and populations at risk. The full framework can be found in the background guidance document.[1]

The presence of MRE devices—particularly tidal, ocean current, or riverine turbines—is thought to pose a risk of collision to marine animals. The concern is that a collision with moving device parts (e.g., turbine blades) or a moving device (e.g., tidal kite) could cause irreversible injuries or death to an individual, which may affect its survival and the long-term status of populations. An animal could come into close contact with an MRE device or its parts in the course of its natural movement, if it is not strong enough to avoid currents, or is attracted to the device for purposes of feeding, seeking shelter, or out of curiosity. Marine mammals, especially protected or threatened populations, endangered or commercially and recreationally important fish species, sea turtles, and endangered seabirds are of greatest concern for collision risk (Figure 2). Even a very low collision rate for species with spatially restricted, declining, or small populations, could result in impacts on long-term population viability (Sparling et al. 2020).

[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.

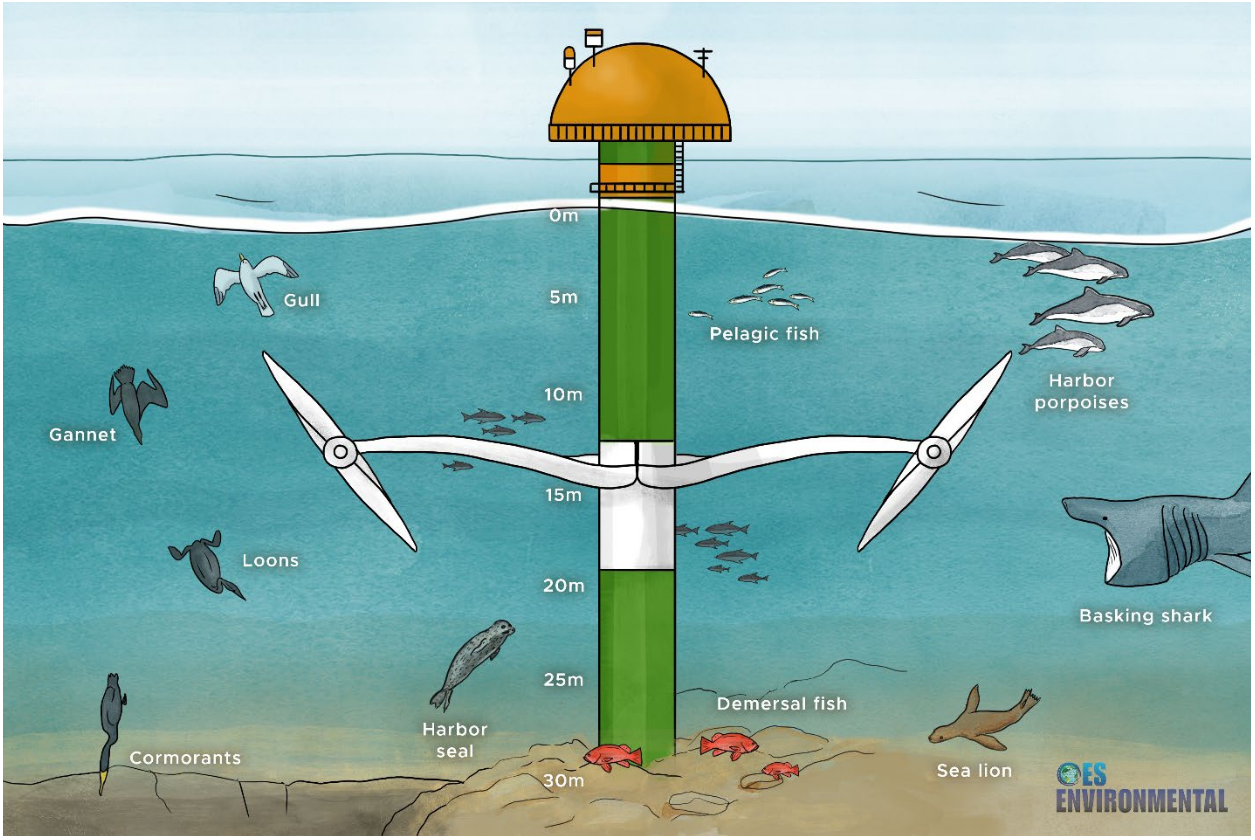


Figure 2. Schematic of a tidal turbine surrounded by marine animals such as diving seabirds, pinnipeds, pelagic and demersal fish, sharks, and small cetaceans. (Illustration by Stephanie King)

Existing Data and Information

2024 State of the Science

Section 3.1 of Chapter 3 of the 2024 State of the Science Report (Garavelli et al. 2024) covers collision risk in detail. It synthesizes research and findings from current MRE projects to provide a comprehensive look at the status of knowledge for collision risk.

Evidence Base

OES-Environmental has developed an evidence base of key research papers and monitoring reports for collision risk that supports understanding of this risk. The evidence base has been recently updated and can be accessed on Tethys[2]: Collision Risk Evidence Base. A limited number of the studies included in the collision risk 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 collision risk, 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

[2] 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.

[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.

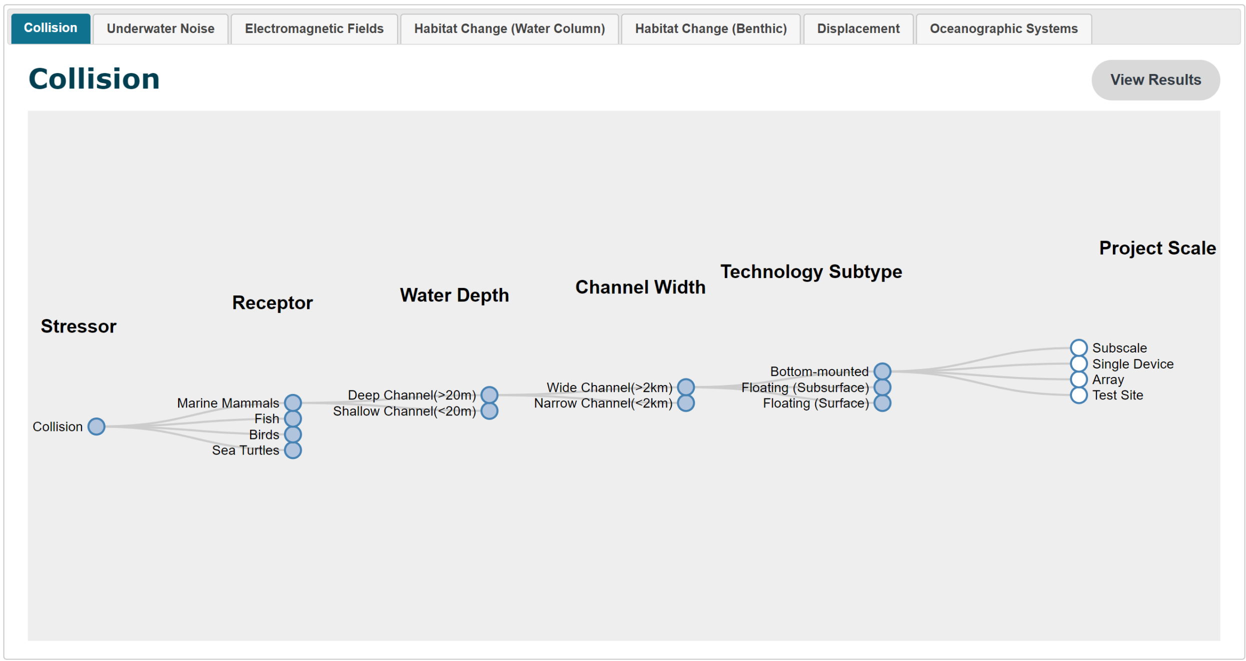
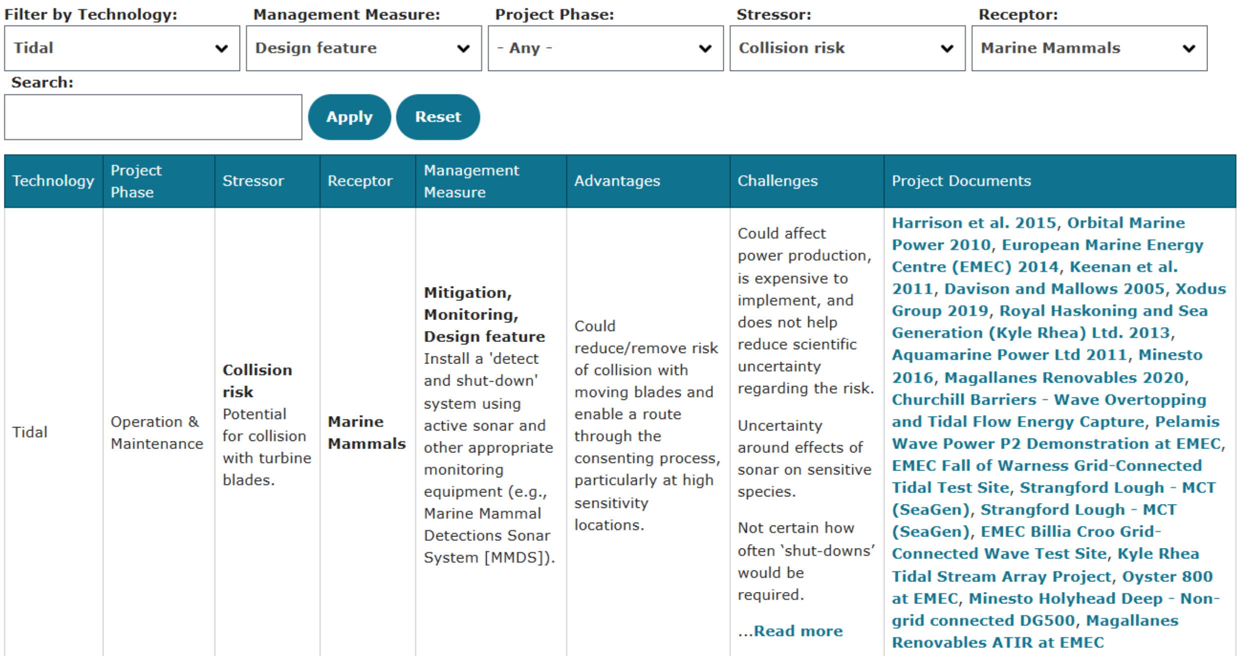


Figure 3. Screenshots of the Monitoring Datasets Discoverability Matrix selections for collision risk on Tethys. Selections under fish, birds, and sea turtles are similar to those shown for marine mammals.

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 collision risk is shown in Figure 4 below.



Technology	Project Phase	Stressor	Receptor	Management Measure	Advantages	Challenges	Project Documents
Tidal	Operation & Maintenance	**Collision risk** Potential for collision with turbine blades.	**Marine Mammals**	**Mitigation, Monitoring, Design feature** Install a 'detect and shut-down' system using active sonar and other appropriate monitoring equipment (e.g., Marine Mammal Detections Sonar System [MMDS]).	Could reduce/remove risk of collision with moving blades and enable a route through the consenting process, particularly at high sensitivity locations.	Could affect power production, is expensive to implement, and does not help reduce scientific uncertainty regarding the risk. Uncertainty around effects of sonar on sensitive species. Not certain how often 'shut-downs' would be required. ...Read more	Harrison et al. 2015, Orbital Marine Power 2010, European Marine Energy Centre (EMEC) 2014, Keenan et al. 2011, Davison and Mallows 2005, Xodus Group 2019, Royal Haskoning and Sea Generation (Kyle Rhea) Ltd. 2013, Aquamarine Power Ltd 2011, Minesto 2016, Magallanes Renovables 2020, Churchill Barriers - Wave Overtopping and Tidal Flow Energy Capture, Pelamis Wave Power P2 Demonstration at EMEC, EMEC Fall of Warness Grid-Connected Tidal Test Site, Strangford Lough - MCT (SeaGen), Strangford Lough - MCT (SeaGen), EMEC Billia Croo Grid-Connected Wave Test Site, Kyle Rhea Tidal Stream Array Project, Oyster 800 at EMEC, Minesto Holyhead Deep - Non-grid connected DG500, Magallanes Renovables ATIR at EMEC

Figure 4. Screenshot of the Management Measures Tool selections for collision risk.

Tethys Knowledge Base

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

Pathway to Risk Retirement

While collision risk has been monitored at several tidal and riverine device sites since 2007, there have been no observations of marine mammals or diving seabirds colliding with devices (Garavelli et al. 2024, Sparling et al. 2020, Copping et al. 2021) and very few examples of fish collisions with an operational riverine turbine (e.g., Courtney et al. 2022). The few laboratory flume experiments undertaken to date have shown little risk of collision for fish, which may be species-dependent (Müller et al. 2023, Yoshida et al. 2020). While behavioral responses of marine mammals to MRE devices may be species-specific, the sensory capabilities of these animals suggest that collisions with turbine blades will be limited (Hastie et al. 2018, Onoufriou et al. 2021). Overall, it is challenging to observe animals in the vicinity of tidal or riverine devices as the probability of witnessing a collision event is low, and the harsh environmental conditions such as very fast-moving currents, often high turbidity, and low light, make monitoring difficult. There is a wide range of monitoring methods used to assess collision risk such as acoustics, video cameras, or animal tagging. These methods have limited applications depending on the study scale or time of day and often require time-consuming analysis (Hasselman et al. 2020).

There are many uncertainties about the effects of collision risk even for small developments[3], and studies are needed to increase our understanding of the various parameters that determine collision risk and the potential consequences on individuals and populations of concern. Numerical models can help

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

fill information gaps when field studies are not possible, but these predictions are sensitive to assumptions made about marine animals' ability to detect, avoid, and evade underwater structures as well as possible consequences of potential collision events, and the existing models have not been validated with field data. A complete list of remaining uncertainties and research needs is available in Section 3.1 of Chapter 3 of the 2024 State of the Science Report (Garavelli et al. 2024). Key examples include the need to:

- Examine and process all available video datasets around turbines with marine animals present.
- Collect data to parameterize and validate numerical models.
- Determine and share information on the most useful instruments and methods for monitoring collision risk in the environments in which devices are deployed.

While the scientific understanding of collision risk is increasing, there is a need for additional data collection and research studies before it can be considered for retirement.

Recommendations

Additional research and monitoring around operational MRE projects, field studies, modeling, and flume studies are needed to advance our understanding of the risk of marine animal collision with MRE devices. Enhanced methods are necessary to improve the ability to observe interactions of marine mammals, fish, diving seabirds, and sea turtles with tidal and riverine devices. Since it is essential to collect information on the occurrence and behavior of marine animals at close range of devices, many improvements on methodologies and instruments are needed (e.g., data collection, storage, sharing, analyzing, autonomous target detection, and image classification). In particular, each time an MRE device is deployed, it is important that observations and data collected aimed at collision risk and other stressor-receptor interactions be considered as an integral part of the deployment. As collision risk models are improved, field monitoring data is needed to validate predictive models. Any data collected around projects and other deployments will continue to inform the understanding of collision risk and improve numerical modeling. There is also a need for increased public awareness around environmental effects of MRE and public education on the actual levels of risk for environmental interactions, including collision. As the MRE industry moves toward array-scale developments, there will also be a need to understand how collision risk to marine animals might scale with larger-scale projects.

Additional Information

The collision risk evidence base consists of key research studies and reports that define the current understanding of the risk of collision with tidal and riverine devices for marine mammals, fish, and diving seabirds. There are currently no studies available on sea turtles. The evidence base for collision risk can be found here.

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

Project/Research Study	Location	Device Type	Conclusion
Survival and Behavioral Effects of Exposure to a Hydrokinetic Turbine on Juvenile Atlantic Salmon and Adult American Shad (Castro-Santos and Haro 2015)	Turners Falls, MA, US	Tidal	Exposure to the turbine elicited behavioral responses from both species, however, with salmon passing primarily over the downrunning blades. Shad movement was impeded by the device, as indicated by fewer attempts of shorter duration and reduced distance of ascent up the flume.
Fish Interactions with a Commercial-Scale Tidal Energy Device in the Natural Environment (Viehman and Zydlewski 2015)	Cobscook Bay, Maine, US	Tidal	This study indicates that fish behavior in response to tidal turbines appears to be similar to responses to obstacles such as trawls and highlights the importance of environmental context in determining the effects of a tidal turbine on fish.
Triton: Igiugig Fish Video Analysis (Matzner et al. 2017)	Igiugig, AK, US	Riverine	On only one occasion was an actual contact confirmed, and this was an adult fish that contacted the camera, not the turbine itself.
Harbour Seals Avoid Tidal Turbine Noise: Implications for Collision Risk (Hastie et al. 2018)	Kyle Rhea River, Eilanreach, Scotland, UK	Tidal	Avoidance of tidal turbine noise suggest that a proportion of seals will exhibit behavioral responses upon encountering a tidal turbine resulting in avoidance of physical injury. In practice, the empirical changes in usage can be used directly as avoidance rates for collision risk models to predict the effects of tidal turbines on seals.
Harbour porpoises exhibit localized evasion of a tidal turbine (Palmer et al. 2021)	Inner Sound, Pentland Firth, Scotland, UK	Tidal	Porpoises were clearly able to detect the presence of the turbine and its support structure and, although there is evidence of some attraction to the turbine support structure, they generally avoided the high-risk rotor region.
Characterizing Sockeye Salmon Smolt Interactions with a Hydrokinetic Turbine in the Kvichak River, Alaska (Courtney et al. 2022)	Kvichak River, AK, US	Riverine	An estimate of 200,000 outmigrating sockeye salmon smolts interacted with the ORPC RivGen. Fish passed the turbine in normal and disoriented ways, and blade strikes were observed at high current speeds. Most fish passage happened during dark hours over a five day period.

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