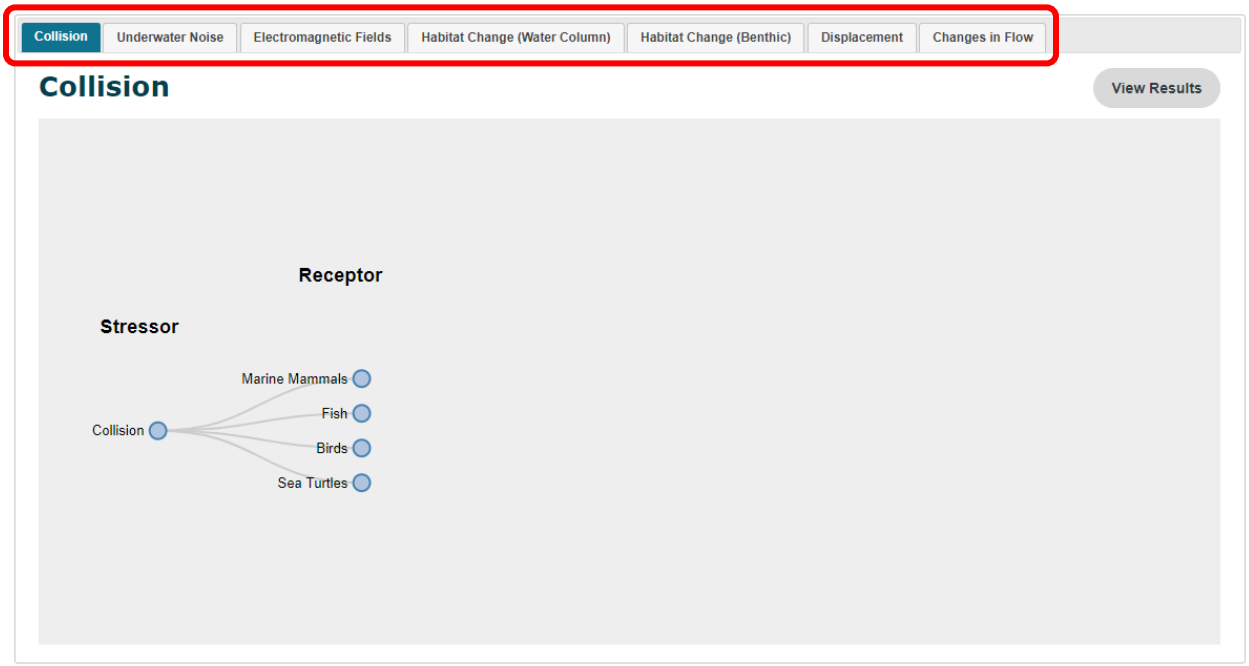
Monitoring Datasets Discoverability Matrix - Instructions

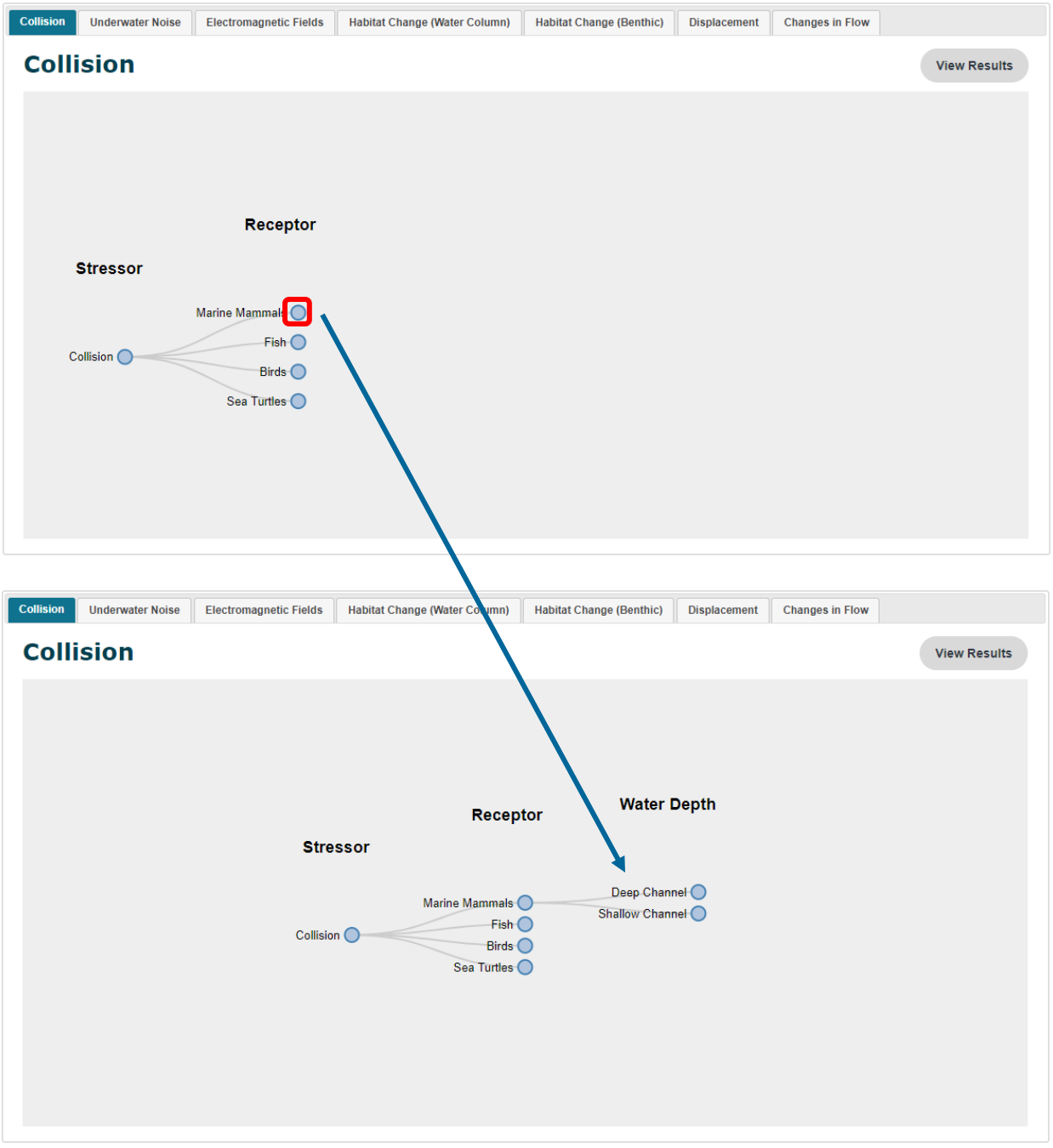
The Monitoring Datasets Discoverability matrix is an interactive tool that classifies monitoring datasets from already consented/permitted projects. This document describes instructions for using the matrix, as well as a few possible examples of how someone might use it.

At the top of the matrix, you will find tabs for six key environmental effects (or stressors): collision, underwater noise, electromagnetic fields, habitat change (split by water column and benthic), displacement, and changes in flow. Stressors are the parts of an MRE system that may cause harm or stress to a marine animal, habitat, or ecosystem process.

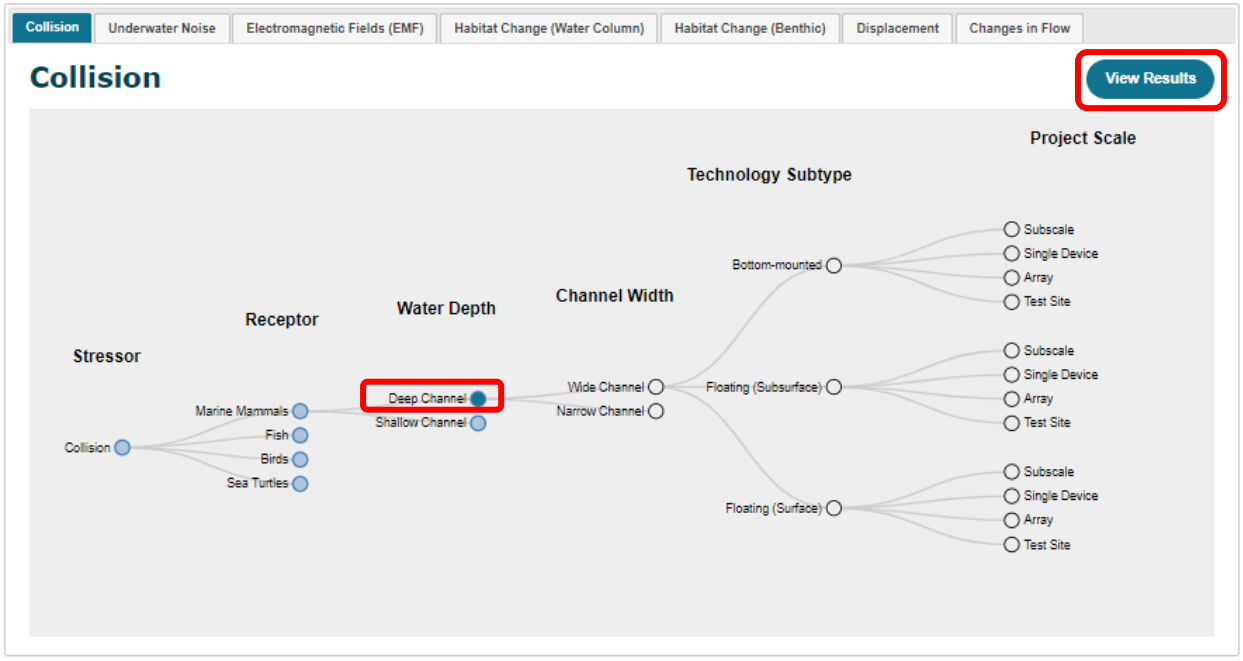


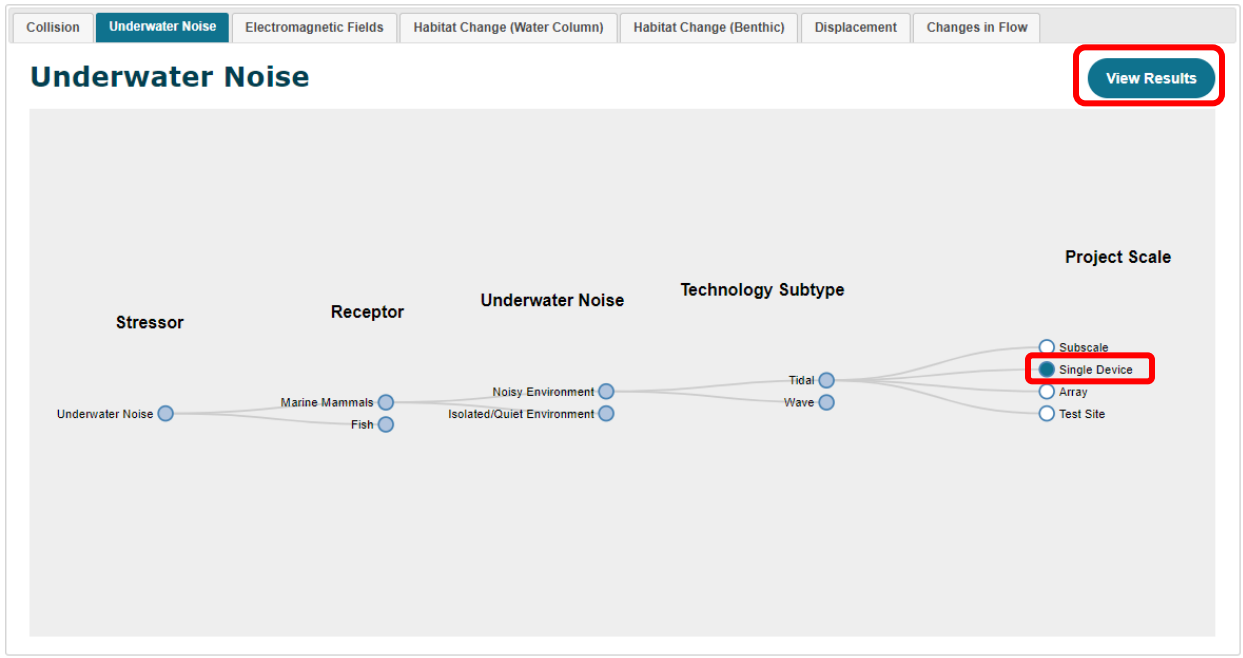
Once you click on a tab, a matrix tree for that stressor will open below in the green box. The matrix begins with the stressor and then allows you to sort based on specific characteristics. Some characteristics are consistent across the stressors (such as receptor, technology, and project scale) and others are unique to a specific stressor.

To move through the matrix, click on the blue circle next to the characteristics to find the data you are looking for. As you select different characteristics, the matrix will expand and allow you to filter as you go.



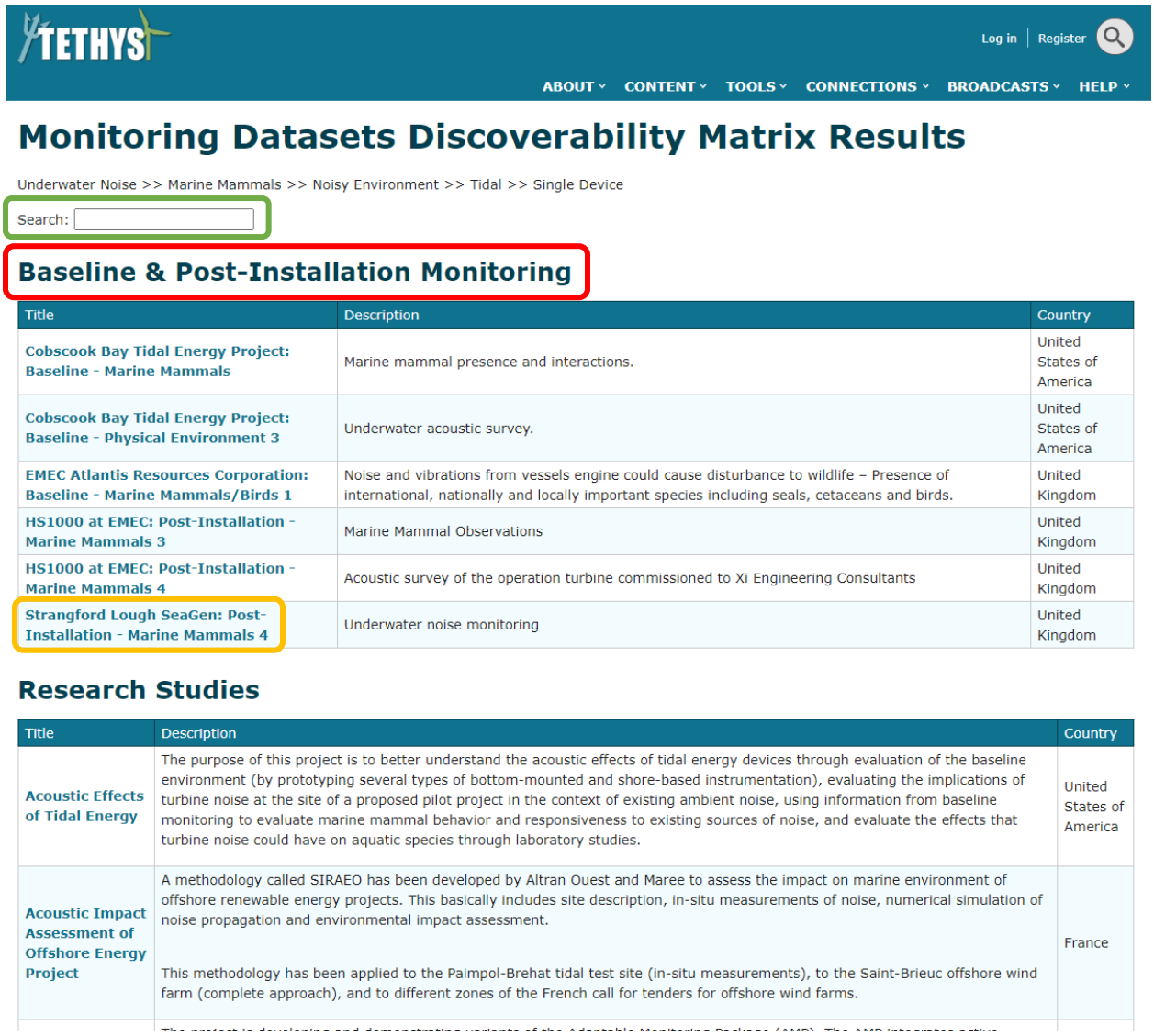
At any point in the matrix you can make selections and view results. To do so, click on the text (i.e., "marine mammals" or "single device") to highlight your selection (which includes all sub-options to the right of your selection). This will change the dot to dark blue and the "View Results" button will now be highlighted. You can de-select any options by clicking on the text again, returning the dot to its default color. Select the “View Results” button to view results in a separate tab. The first example below shows selections part way through the matrix and the second example shows this at the end of the matrix.





Once you have selected the characteristics of interest and have clicked “View Results”, your results will open in a new tab. The results are split into two different types of information: 1) baseline and post-installation monitoring data; 2) research studies; and 3) key documents. These results are also searchable using the “Search” box at the top of the page, shown in green below.

1) **Baseline & post-installation monitoring data** (identified in red) are collected from marine renewable energy project sites as [OES-Environmental metadata](). On the results page you can preview each dataset, including the project name, a brief description, and the country.



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ABOUT CONTENT TOOLS CONNECTIONS BROADCASTS HELP

Monitoring Datasets Discoverability Matrix Results

Underwater Noise >> Marine Mammals >> Noisy Environment >> Tidal >> Single Device

Search:

Baseline & Post-Installation Monitoring

Title	Description	Country
Cobscook Bay Tidal Energy Project: Baseline - Marine Mammals	Marine mammal presence and interactions.	United States of America
Cobscook Bay Tidal Energy Project: Baseline - Physical Environment 3	Underwater acoustic survey.	United States of America
EMEC Atlantis Resources Corporation: Baseline - Marine Mammals/Birds 1	Noise and vibrations from vessels engine could cause disturbance to wildlife – Presence of international, nationally and locally important species including seals, cetaceans and birds.	United Kingdom
HS1000 at EMEC: Post-Installation - Marine Mammals 3	Marine Mammal Observations	United Kingdom
HS1000 at EMEC: Post-Installation - Marine Mammals 4	Acoustic survey of the operation turbine commissioned to Xi Engineering Consultants	United Kingdom
Strangford Lough SeaGen: Post-Installation - Marine Mammals 4	Underwater noise monitoring	United Kingdom

Research Studies

Title	Description	Country
Acoustic Effects of Tidal Energy	The purpose of this project is to better understand the acoustic effects of tidal energy devices through evaluation of the baseline environment (by prototyping several types of bottom-mounted and shore-based instrumentation), evaluating the implications of turbine noise at the site of a proposed pilot project in the context of existing ambient noise, using information from baseline monitoring to evaluate marine mammal behavior and responsiveness to existing sources of noise, and evaluate the effects that turbine noise could have on aquatic species through laboratory studies.	United States of America
Acoustic Impact Assessment of Offshore Energy Project	A methodology called SIRAEO has been developed by Altran Ouest and Maree to assess the impact on marine environment of offshore renewable energy projects. This basically includes site description, in-situ measurements of noise, numerical simulation of noise propagation and environmental impact assessment. This methodology has been applied to the Paimpol-Brehat tidal test site (in-situ measurements), to the Saint-Brieuc offshore wind farm (complete approach), and to different zones of the French call for tenders for offshore wind farms.	France

Baseline & post-installation monitoring example: Clicking on the **Strangford Lough SeaGen: Post-Installation – Marine Mammals 4** entry (shown in yellow above) will open up the metadata page.

Stressor	Receptor	Study Description	Design and Methods	Results	Status
Collision, Displacement, Habitat Change	Marine Mammals	Harbour seal telemetry	they detached during the annual moult. They captured location data and information on animals' diving and haulout behaviour. The 3 deployments took place in 2006 (April-July, pre-installation), 2008 (March – July, during installation and commissioning) and in 2010 (April-July, operation). The seals were captured at sites in Strangford Narrows and the southern islands in Strangford Lough. The three groups of animals tagged contained similar mixes of ages and sexes.	relatively higher rate during periods of slack tide, indicating avoidance but also this slack water window when the turbine is not operating or is moving very slowly, ensures that there is always an opportunity for transit past the turbine.	Completed (2010)
Noise	Marine Mammals	Underwater noise monitoring	Underwater noise measurements were undertaken in Strangford Lough on 23th April 2008 between 09:00 and 21:00 during drilling operations. Background underwater noise measurements were also carried out during periods when no drilling was taking place in order to determine the pre-existing noise levels in the Strangford Lough region.	No major impacts on marine mammals have been detected across the 3 years of post-installation monitoring. Findings are described in more detail in the EMP	Completed (2010)
Habitat Change	Invertebrates	Benthic hard communities	Four relocatable sample stations were established by installing Ultra Short Baseline (USBL) transceivers. Three stations were placed in line with the rotational axis of the east turbine at 20m, 150m and 300m down/upstream to the south-east (approx.) of the	The data collection and analysis are robust in determining that the changes observed appear to be gradual and in line with natural variation. Colonisation of the device since its installation has replaced the community lost at the device foundations during construction.	Completed (2010)
Displacement	Marine Mammals	Shore based survey	Observations carried out between May 2005 and December 2010 from a fixed point on the east shore of the Narrows 10m above Mean High Water. Observations of birds and mammals were recorded along with their location using laser range finding binoculars. During each month a total of 8x3-hour watches were carried out under different tidal states and at different times of the day.	Porpoise activity declined during installation; however there have been no long term changes in abundance of either seals or porpoises which can be attributed to the presence or operation of the device.	Completed (2010)
Displacement	Marine Mammals	Passive acoustic monitoring (T-PODs)	The TPOD ('Timing Porpoise Detector') is a self-contained submersible unit that includes a hydrophone element, an amplifier, analogue electronic filters and a digital processor, as well as a battery pack and memory. worked by logging the start and end of echolocation clicks of porpoises and dolphins. The basic metric they generated was expressed at detection positive minutes (DPM) which consists of any minute in which a porpoise click train was detected. TPODS	Seals and porpoises regularly transit past the operating turbine, clearly demonstrating a lack of any barrier effect.	Completed (2010)

The findings from that particular study are automatically highlighted in yellow. In the results column, we see that the findings are described in more detail in the EMP (Environmental Monitoring Programme).

By scrolling up to the top of the metadata page, we find several additional sections about the Strangford Lough – MCT (Seagen) project, including description, location, licensing, project progress, key environmental issues, and links to papers, reports, and research studies. Under this last section we see a link to the SeaGen Environmental Monitoring Programme: Final Report (shown in yellow). Clicking this link will open a new tab with access to the EMP document (shown in green) for additional information about the marine mammal monitoring that was done for underwater noise. If you have a user account for *Tethys* and are logged in, you will also be able to view contact information (shown in red) to request additional data and information.

OES-Environmental distributes metadata forms (questionnaires) to solicit information from developers involved in environmental monitoring around marine renewable energy project sites around the world. This page provides project descriptions, baseline assessment, post-installation monitoring, and links to available data and reports. Content is updated on an annual basis.

Strangford Lough - MCT (SeaGen)

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Description

SeaGen is a twin turbine system with a mobile cross arm on a single supporting pile 3m in diameter and 9m above the average sea level. The twin rotors have an 8m radius and will begin to generate electricity once the tide runs faster than 1m/s. At maximum speed the tips move at around 12m/s, approximately 1/3 of the average wind turbine speed.

Location

Strangford Lough, Northern Ireland

Licensing Information

The final Environmental Impact Study was submitted to the regulatory authority, the Environment and Heritage Service (EHS) in Northern Ireland in June 2005. The FEPA license for the temporary installation for the SeaGen system for a 5-year duration was first issued in December 2005, revised in February 2007 and again in February 2008. Pre-installation environmental monitoring commenced in May 2004. A baseline report has been completed and was submitted to EHS in August 2006. The environmental impact of SeaGen will be continuously monitored by independent science team throughout the licensed 5-year installation period.

Project Progress

Royal Haskoning Ltd. was appointed in early 2004 to provide support to the EIA process. The scoping consultation was completed in mid-2004, and the EIA commenced late 2004. The final EIA was submitted in July 2005, with the initial FEPA license being granted in December 2006. These were revised to accommodate necessary changes in installation methodology in February 2007, and again in February 2008.

Installation of the moorings for anchoring the SeaGen deployment vessel commenced in February 2008 and was completed in March 2008. The SeaGen structure was positioned on the seabed on April 2, 2008 by the crane barge, Rambiz. Drilling for the pin piles, grouting, and completion of assembly was achieved using the crane barge, Missing Link, which was on location from mid-April to late May 2008.

Commissioning of SeaGen commenced in July 2008, culminating in full 1.2MW power generation to the grid in December 2008. Operation is continuing within the constraints of the FEPA license with the environmental monitoring programme results contributing to an adaptive management strategy where findings are periodically reviewed and improvements to the application of the FEPA restrictions are proposed.

In January 2016, it was announced that Atlantis (the company which now owns MCT) would begin decommissioning the device in summer 2016 after much knowledge had been gained during its operation. Specialist UK-based marine business Keynvor MorLift ltd. (KML) was appointed as the Principal Contractor to carry out the decommissioning engineering, planning and offshore works. The first phase of decommissioning SeaGen started in May 2016 with the removal of the system's two 600kW powertrains. In August 2018 the topsides and crossbeam were removed, and final works were completed with the successful removal of the remaining tower and subsea structure in July 2019.

Key Environmental Issues

Strangford Lough has been identified as a site which supports internationally important examples of particular marine and coastal habitat and species features and has accordingly been given the dual status of a European Special Area of Conservation (SAC) and a European Special Protected Area (SPA). Three of the site features have been identified as potentially vulnerable to activities and impacts associated with the installation of the SeaGen turbine.

The EIA process identified various levels of uncertainty surrounding potential impacts on key marine species and features within the Strangford Lough Special Area of Conservation (SAC), they include:

- Effects of installation and operation on the integrity of the breeding harbour seal population.
- Collisions of marine mammals, fish and diving birds with the turbine rotors.
- Effects on the abundance, diversity, integrity and extent of the benthic biological communities associated with the submerged rocky reefs.
- Effects of installation and operation on the breeding bird population.

Papers, Reports, Research Studies

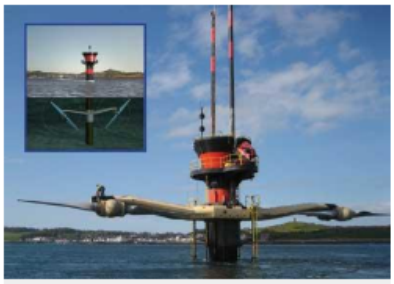
- Keenan, G.; Sparling, C.; Williams, H.; Fortune, F. (2011). **SeaGen Environmental Monitoring Programme: Final Report**. Report by Royal Haskoning. pp 81.
- Davison, A.; Mallows, T. (2005). **Strangford Lough Marine Current Turbine: Environmental Statement**. Report by Royal Haskoning. pp 141.

Project Site

Title:	Strangford Lough - MCT (SeaGen)
Status:	Device no longer in the water
Tech Developer:	**Marine Current Turbines (MCT)**
Website:	**External Link**
Start Date:	December 1, 2008
End Date:	June 1, 2016
Info Last Updated:	November 11, 2019
Contact:	**Joseph Kidd**

Details

Technology:	**Marine Energy (General), Tidal**
Technology Subtype	**Bottom-Mounted**
Support Structure:	**Monopile**
Project Scale:	**Single Device**
Installed Capacity:	1.2 MW
Electrical Infrastructure:	**Buried Seafloor Cables**
Country:	**United Kingdom**
Physical Site:	**Constricted Channel, Shallow Channel (<40m), Narrow Channel (<2km), Noisy Environment (>80 dB)**
Water Depth:	24 m
Channel Width:	~0.6 km



SeaGen

SeaGen Environmental Monitoring Programme: Final Report

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Abstract

The SeaGen tidal turbine is a free stream tidal energy device that converts energy from tidal flow into electricity. The device comprises twin 16m diameter rotors connected to a generator through a gearbox, with a rotor system supported on the end of a cross beam. The cross beam is, in turn, supported by a 3m diameter pile. The cross beam can slide vertically up and down the pile to allow access to the rotors, generator and gearbox for servicing and inspection.

In 2004, Marine Current Turbines Ltd (MCT) identified the Narrows of Strangford Lough, Northern Ireland as their preferred location for the deployment of the SeaGen device. An Environmental Impact Assessment (EIA) was undertaken by Royal Haskoning, and completed in June 2005 with the production of an Environmental Statement (ES).

Based on the consultation responses and requirements of EU Directives and Northern Ireland environmental legislation, a conditional FEPA marine construction license was issued to MCT on 15 December 2005. Subsequent variations of the license have taken into account the increased scientific knowledge built up through the ongoing monitoring program and the adaptive management approach adopted by MCT.

The issue of the license required MCT to establish an Environmental Monitoring Plan (EMP) and a number of mitigation measures. Data collection began, pre-installation, in April 2005 and formed the basis of an Environmental Baseline Report, against which all future monitoring during installation, commissioning and decommissioning could be compared.

The results from each of monitoring strands of the EMP were evaluated regularly to ensure that any impact of SeaGen on the marine environment in Strangford Lough could be detected at an early stage. Using an adaptive management approach, the data collected has provided evidence to support reduction in mitigation requirements.

A small dedicated 'Science' Group was set up to advise on the detailed management of the EMP and mitigation measures, while a wider 'Liaison' Group was established, to whom progress on the project and decisions of the Science Group would be reported.

Both Science and Liaison groups have operated well since 2006, meeting the requirements of both their memberships, and of the project. The SeaGen EMP was designed to:

- Detect, prevent or minimize environmental impact attributable to the turbine installation and operation; and
- Provide an ongoing monitoring strategy to determine any immediate or emerging adverse impacts on the habitats, species and physical environment of Strangford Lough.

Report

Title:	SeaGen Environmental Monitoring Programme: Final Report
Author:	Keenan, G.; Sparling, C.; Williams, H.; Fortune, F.
Publication Date:	January 16, 2011
Pages:	81
Affiliation	Royal Haskoning
Sponsoring Organization:	Marine Current Turbines (MCT)
Technology:	Tidal, Marine Energy (General)
Receptor:	Human Dimensions, Environmental Impact Assessment

Document Access

Attachment: Access File
Notice: This material may be protected by Copyright Law.

Citation

Keenan, G.; Sparling, C.; Williams, H.; Fortune, F. (2011). SeaGen Environmental Monitoring Programme: Final Report. Report by Royal Haskoning. Report for Marine Current Turbines (MCT).

2) **Research studies** contain key research projects that have been described with **OES-Environmental metadata** forms pertaining to the stressor and receptors you filtered for. On the results page you can preview the title, a brief description, and the country.

Monitoring Datasets Discoverability Matrix Results

Underwater Noise >> Marine Mammals >> Noisy Environment

Search:

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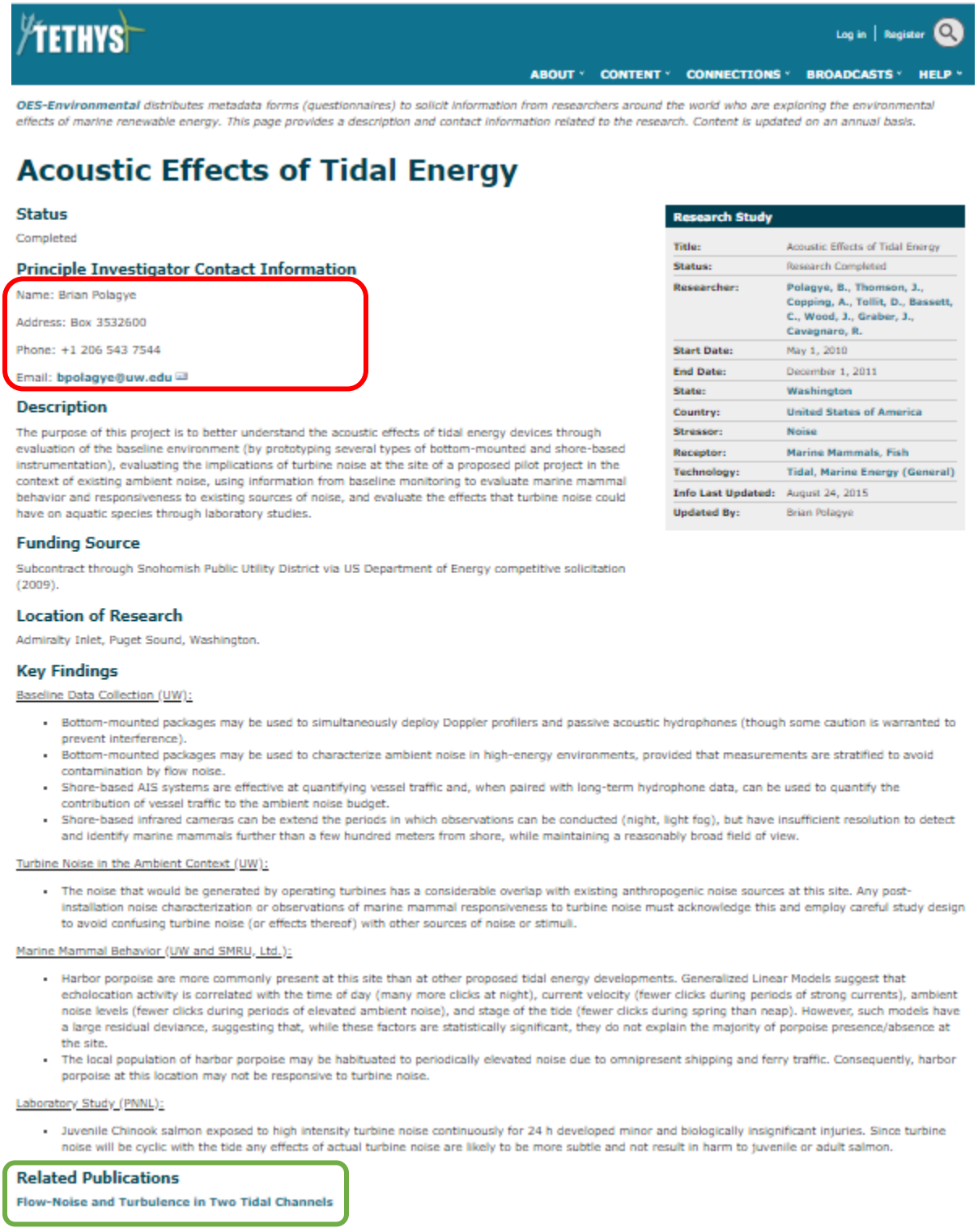
Research Studies

Title	Description	Country
Acoustic Effects of Tidal Energy	The purpose of this project is to better understand the acoustic effects of tidal energy devices through evaluation of the baseline environment (by prototyping several types of bottom-mounted and shore-based instrumentation), evaluating the implications of turbine noise at the site of a proposed pilot project in the context of existing ambient noise, using information from baseline monitoring to evaluate marine mammal behavior and responsiveness to existing sources of noise, and evaluate the effects that turbine noise could have on aquatic species through laboratory studies.	United States of America
Acoustic Impact Assessment of Offshore Energy Project	A methodology called SIRAEO has been developed by Altran Ouest and Maree to assess the impact on marine environment of offshore renewable energy projects. This basically includes site description, in-situ measurements of noise, numerical simulation of noise propagation and environmental impact assessment. This methodology has been applied to the Paimpol-Brehat tidal test site (in-situ measurements), to the Saint-Brieuc offshore wind farm (complete approach), and to different zones of the French call for tenders for offshore wind farms.	France
Adaptable Monitoring Package (AMP)	The project is developing and demonstrating variants of the Adaptable Monitoring Package (AMP). The AMP integrates active acoustic, passive acoustic, and optical sensors into a single instrumentation package that can be cabled to shore or operated autonomously. By simultaneously observing rare, but potentially significant, interactions between marine life and marine energy converters with multiple sensor modalities,detection and interpretation of such events is likely to be improved. Automatic detection and classification algorithms now allow the system to make continuous observations without incurring a "data mortgage" and automatic sensor control allows such observation to occur without biasing marine animal behavior. **Interesting Video Archive:** https://www.youtube.com/channel/UCqR-J-6LOLjsHCjO285jBbA/	United States of America
Bayesian Integration for Marine Spatial Planning and Renewable Energy Siting	To create a decision support system (DSS) to be used by federal, state, and regional siting programs for evaluating marine renewable energy project proposals. The DSS will integrate oceanographic, ecological, human use data, stakeholder input, and cumulative impacts using probabilistic statistical methods to identify the optimal course of action regarding siting of marine renewable energy projects in the context of coastal and marine spatial planning. This system is expected to increase social and economic benefits by reducing uncertainty regarding the impacts of ocean renewable energy projects on marine ecosystems and coastal communities in the Pacific Northwest, improving stake-holder and community involvement in siting decisions, and assessing the cumulative impacts of ocean renewable energy projects.	United States of America

Research study example: Clicking on the **Acoustic Effects of Tidal Energy** entry (shown in yellow above) will open the metadata page for the research study selected. This research study page has key findings from the study described, as well as contact information from the researcher (shown in red) and a link to the related publication (shown in green).



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ABOUT CONTENT CONNECTIONS BROADCASTS HELP

OES-Environmental distributes metadata forms (questionnaires) to solicit information from researchers around the world who are exploring the environmental effects of marine renewable energy. This page provides a description and contact information related to the research. Content is updated on an annual basis.

Acoustic Effects of Tidal Energy

Status

Completed

Principle Investigator Contact Information

Name: Brian Polagye

Address: Box 3532600

Phone: +1 206 543 7544

Email: bpolagye@uw.edu

Description

The purpose of this project is to better understand the acoustic effects of tidal energy devices through evaluation of the baseline environment (by prototyping several types of bottom-mounted and shore-based instrumentation), evaluating the implications of turbine noise at the site of a proposed pilot project in the context of existing ambient noise, using information from baseline monitoring to evaluate marine mammal behavior and responsiveness to existing sources of noise, and evaluate the effects that turbine noise could have on aquatic species through laboratory studies.

Research Study

Title:	Acoustic Effects of Tidal Energy
Status:	Research Completed
Researcher:	Polagye, B., Thomson, J., Copping, A., Tollit, D., Bassett, C., Wood, J., Graber, J., Cavagnaro, R.
Start Date:	May 1, 2010
End Date:	December 1, 2011
State:	Washington
Country:	United States of America
Stressor:	Noise
Receptor:	Marine Mammals, Fish
Technology:	Tidal, Marine Energy (General)
Info Last Updated:	August 24, 2015
Updated By:	Brian Polagye

Funding Source

Subcontract through Snohomish Public Utility District via US Department of Energy competitive solicitation (2009).

Location of Research

Admiralty Inlet, Puget Sound, Washington.

Key Findings

Baseline Data Collection (UW):

- Bottom-mounted packages may be used to simultaneously deploy Doppler profilers and passive acoustic hydrophones (though some caution is warranted to prevent interference).
- Bottom-mounted packages may be used to characterize ambient noise in high-energy environments, provided that measurements are stratified to avoid contamination by flow noise.
- Shore-based AIS systems are effective at quantifying vessel traffic and, when paired with long-term hydrophone data, can be used to quantify the contribution of vessel traffic to the ambient noise budget.
- Shore-based infrared cameras can be extend the periods in which observations can be conducted (night, light fog), but have insufficient resolution to detect and identify marine mammals further than a few hundred meters from shore, while maintaining a reasonably broad field of view.

Turbine Noise in the Ambient Context (UW):

- The noise that would be generated by operating turbines has a considerable overlap with existing anthropogenic noise sources at this site. Any post-installation noise characterization or observations of marine mammal responsiveness to turbine noise must acknowledge this and employ careful study design to avoid confusing turbine noise (or effects thereof) with other sources of noise or stimuli.

Marine Mammal Behavior (UW and SMRU, Ltd.):

- Harbor porpoise are more commonly present at this site than at other proposed tidal energy developments. Generalized Linear Models suggest that echolocation activity is correlated with the time of day (many more clicks at night), current velocity (fewer clicks during periods of strong currents), ambient noise levels (fewer clicks during periods of elevated ambient noise), and stage of the tide (fewer clicks during spring than neap). However, such models have a large residual deviance, suggesting that, while these factors are statistically significant, they do not explain the majority of porpoise presence/absence at the site.
- The local population of harbor porpoise may be habituated to periodically elevated noise due to omnipresent shipping and ferry traffic. Consequently, harbor porpoise at this location may not be responsive to turbine noise.

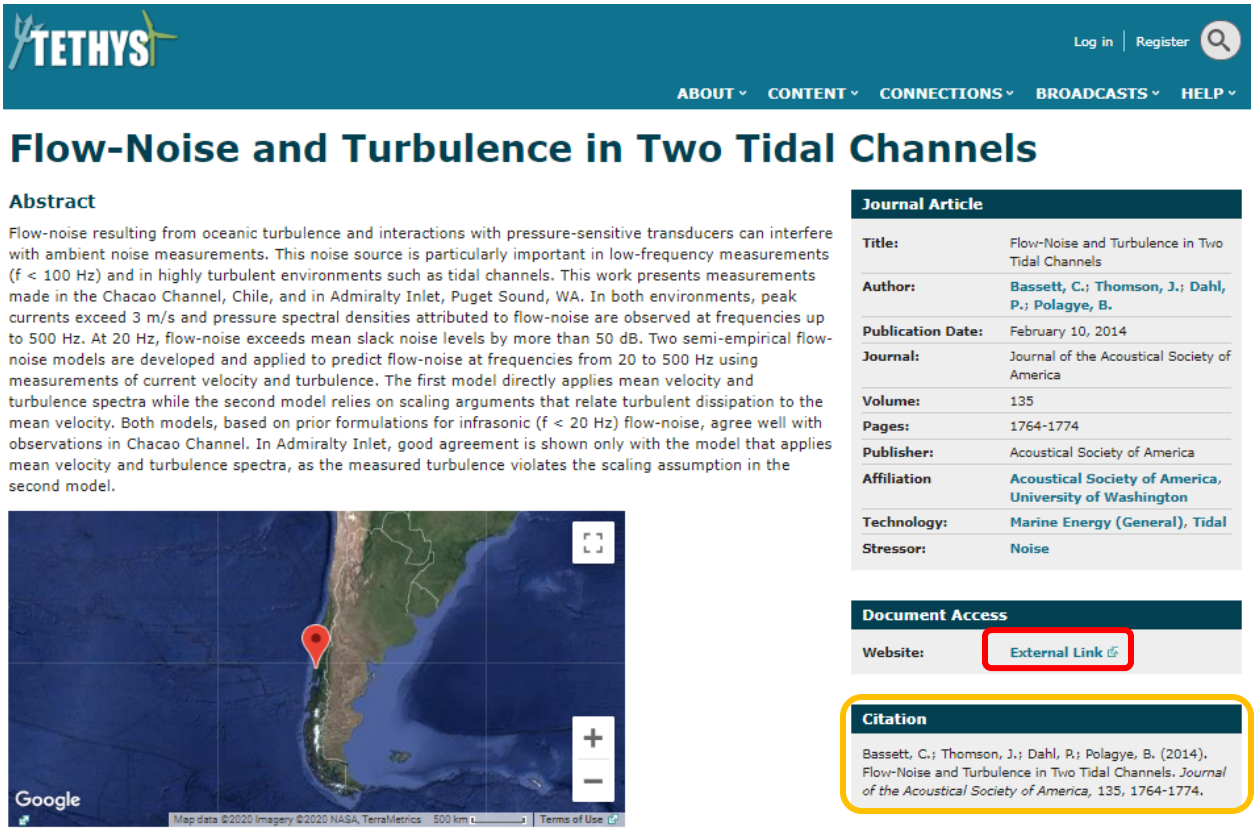
Laboratory Study (PNNL):

- Juvenile Chinook salmon exposed to high intensity turbine noise continuously for 24 h developed minor and biologically insignificant injuries. Since turbine noise will be cyclic with the tide any effects of actual turbine noise are likely to be more subtle and not result in harm to juvenile or adult salmon.

Related Publications

Flow-Noise and Turbulence in Two Tidal Channels

Clicking the link for **Flow-Noise and Turbulence in Two Tidal Channels** (shown in green) will open a new tab with a link to the publication (shown in red) and citation information (shown in yellow).



3) **Key documents** are publications or technical reports that have been identified as central or foundational to the knowledge base for several key stressors. Not all stressors have key documents associated with them at this time.

Monitoring Datasets Discoverability Matrix Results

Underwater Noise >> Marine Mammals >> Noisy Environment

Search:

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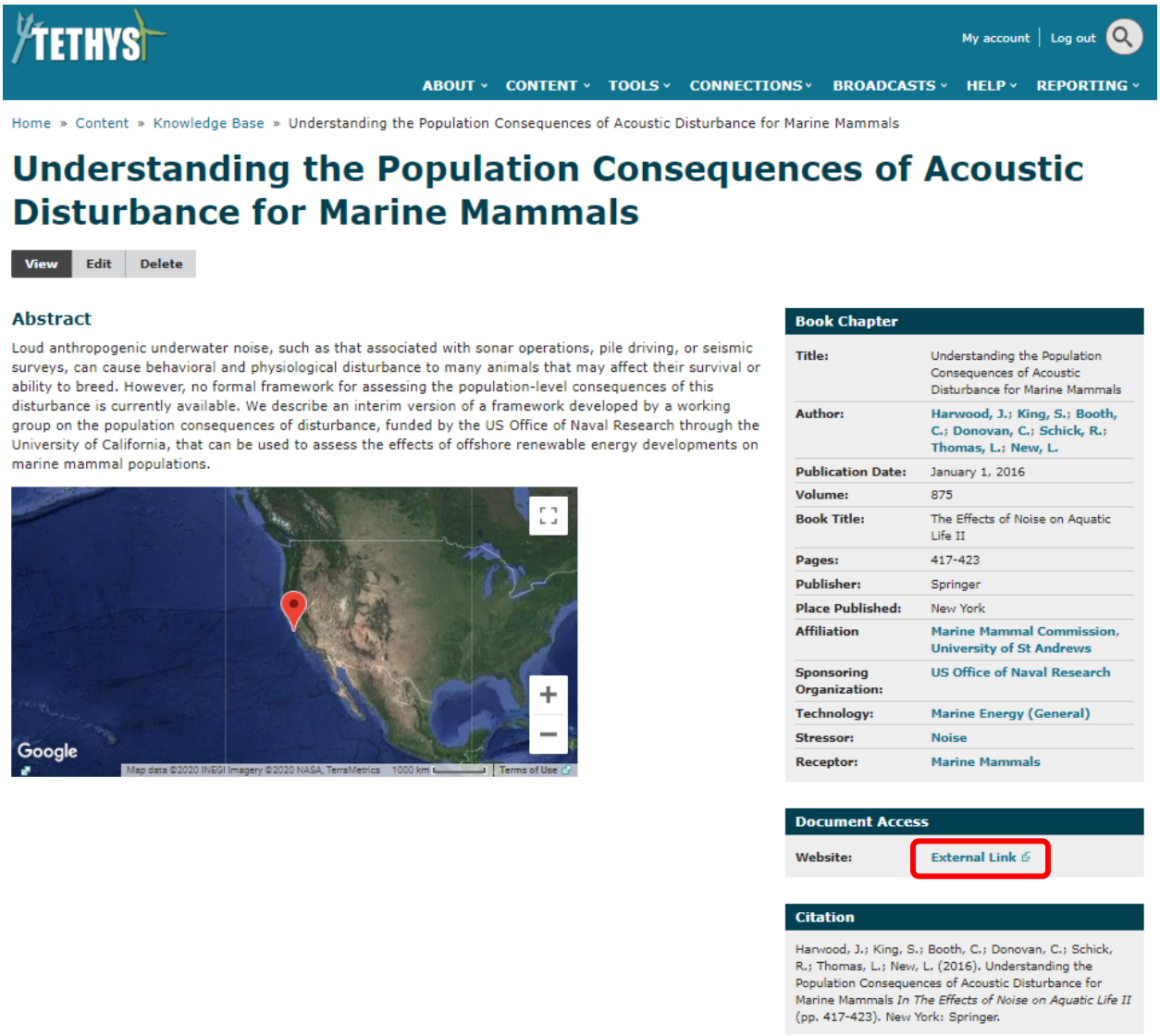
Key Documents

Title	Author	Date	Country
2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts	National Marine Fisheries Service	April 2018	
Acoustic Masking In Marine Ecosystems: Intuitions, Analysis, And Implication	Clark, C., Ellison, W., Southall, B., Hatch, L., Van Parijs, S., Frankel, A., Ponirakis, D.	December 2009	United States of America
Assessing Underwater Noise Levels during Pile-Driving at an Offshore Windfarm and its Potential Effects on Marine Mammals	Bailey, H., Senior, B., Simmons, D., Rusin, J., Picken, G., Thompson, P.	June 2010	United Kingdom
Discussion of the Effects of the Underwater Noise Radiated by a Wave Energy Device - Portugal	Cruz, E., Simas, T., Kasanen, E.	September 2015	Portugal
Harbour Seals Avoid Tidal Turbine Noise: Implications for Collision Risk	Hastie, G., Russell, D., Lepper, P., Elliot, J., Wilson, B., Benjamins, S., Thompson, D.	March 2018	
Marine Mammal Behavioral Response to Tidal Turbine Sound	Robertson, F., Wood, J., Joslin, J., Joy, R., Polagye, B.	June 2018	United States of America
Overview Of The Impacts Of Anthropogenic Underwater Sound In The Marine Environment	Götz, T., Hastie, G., Hatch, L., Raustein, O., Southall, B., Tasker, M., Thomsen, F., Campbell, J., Fredheim, B.	January 2009	
Providing ecological context to anthropogenic subsea noise: Assessing listening space reductions of marine mammals from tidal energy devices	Pine, M., Schmitt, P., Culloch, R., Lieber, L., Kregting, L.	April 2019	Ireland
Understanding the Population Consequences of Acoustic Disturbance for Marine Mammals	Harwood, J., King, S., Booth, C., Donovan, C., Schick, R., Thomas, L., New, L.	January 2016	United States of America
Underwater Noise from a Wave Energy Converter Is Unlikely to Affect Marine Mammals	Tougaard, J.	July 2015	Denmark
Underwater operational noise level emitted by a tidal current turbine and its potential impact on marine fauna	Lossent, J., Gervaise, C., Iorio, L, Folegot, T., Clorennec, D., Lejart, M.	June 2017	

Key Document Example: Clicking on the **Understanding the Population Consequences of Acoustic Disturbance for Marine Mammals** entry (shown in yellow above) will open the document page as shown below. Following the external link (shown in red) will provide access to the full journal article.



There are many possible uses for the Monitoring Datasets Discoverability matrix. If you have additional questions, please contact ***tethys@pnnl.gov****.*