

# U.S. Atlantic Offshore Wind Environmental Research Recommendations Database: ReadMe File

December 14, 2022

Developed by the Regional Synthesis Workgroup of the  
Offshore Wind Environmental Technical Working Group (E-TWG)  
with technical support from the Biodiversity Research Institute  
and the U.S. Offshore Wind Synthesis of Environmental Effects Research group

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## Purpose and Scope

### Purpose

The Regional Synthesis Workgroup, made up of independent scientific experts, was formed by the Offshore Wind Environmental Technical Working Group (E-TWG) to inform and provide guidance for regional-scale research and monitoring efforts in the eastern U.S. in relation to wildlife and offshore wind development. The U.S. Atlantic Offshore Wind Environmental Research Recommendations Database (hereafter ‘Environmental Research Recommendations Database’) is one of the primary products of this effort. The database compiles and synthesizes data gaps and research needs from existing sources (e.g., Hein *et al.* 2021, Southall *et al.* 2021, Cook *et al.* 2021, Carpenter *et al.* 2021, Popper *et al.* 2022, Degraer *et al.* 2021, Gitschlag *et al.* 2021, Kraus *et al.* 2019) such that potential researchers and funders can easily access, sort, and prioritize research needs. The database was developed with technical support from the Biodiversity Research Institute and the U.S. Offshore Wind Synthesis of Environmental Effects Research group (SEER) group including staff from the National Renewable Energy Laboratory and the Pacific Northwest National Laboratory.

Potential end users of this database include states and other government entities who are funding regional research in the next 1-3 years, offshore wind developers who are funding regional research and monitoring efforts, and regional research entities including the Regional Wildlife Science Collaborative for Offshore Wind (RWSC)<sup>1</sup> and the Responsible Offshore Science Alliance (ROSA)<sup>2</sup>, who are discussing research needs and developing science plans. The Environmental Research Recommendations Database was developed to fill an immediate need expressed by end users, and thus will not be updated in its current form; rather, as the above regional efforts continue, the research and monitoring recommendations identified in the database will be incorporated into the RWSC Integrated Science Plan and other products and carried forward in these other venues.

### Scope

The Environmental Research Recommendations Database compiles and synthesizes research and monitoring needs and recommendations identified in a range of source documents published between 2015-2021. Needs and recommendations in the synthesized list are not prioritized, though source documents used to develop the synthesized list may contain their own internal prioritizations. Likewise, recommendations in the database are not differentiated by whether current or planned research may already be beginning to address them. Prioritization, identification of interdependencies across research recommendations, and assessment of the status of recommendation topics (e.g., whether they are already being addressed), are the responsibility of the end user. High-level guidance on prioritization will be provided in an interim guidance document currently in development by the regional synthesis workgroup, and which will be available at <http://nyetwg.com/regional-synthesis-workgroup>. The RWSC taxa-based subcommittees are also using the Environmental Research Recommendations Database in

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<sup>1</sup> More information on the Regional Wildlife Science Collaborative at <https://rWSC.org/>

<sup>2</sup> More information on the Responsible Offshore Science Alliance at <https://www.rosascience.org/>

conjunction with a database of current and planned wildlife and environmental research activities maintained by the RWSC (“Offshore Wind and Wildlife Research Database”) to help assess research and monitoring needs that have not yet been addressed by the research community. The subcommittees will identify these research needs by taxon and region in their Integrated Science Plan (scheduled for release in 2023).

Source documents for the Environmental Research Recommendations Database were derived from a range of geographies but were required to focus at least in part on offshore wind energy development and wildlife, and to include recommendations with relevance to the U.S. Atlantic. Research recommendations included a focus on fish biology and populations, but not research needs specifically focused on fisheries or offshore wind’s effects on fishing communities which are being addressed through concurrent efforts by ROSA.

## Summary of Database Recommendations

A synthesized list of 219 research recommendations is included in the database, representing a range of stressors and topics (Table 1). A further summary of the synthesized topics by taxon/receptor, category of research need, and overarching topics within each category is included in Appendix A; field definitions are included in Table 2, below.

*Table 1. Summary of synthesized research recommendations by stressor/topic. There are a total of 219 synthesized research recommendations categorized by one or more nonexclusive stressor/topics. See Appendix A for an additional summary of research recommendations by taxon, Appendix B for a glossary of terms, and Table 2 for more information on the stressor/topic field in the database.*

Stressor/Topic	# of Research Recommendations
Baseline	40
Abundance and Distribution	20
Movement and Behavior	20
Ecological Drivers	10
Oceanographic/Atmospheric Change	13
Avoidance; Displacement	13
Attraction; Lighting	7
Habitat Change	44
Diet and Food Web Dynamics	12
Turbine Collision	9
Vessel Collision	3
Noise	30
Entanglement	3
Electromagnetic Field (EMF)	7
Physiology and Energetics	14
Cumulative Impacts	14
Population Dynamics	22
Technology/Methods Development	63
Data Management	5

## Using the Database

### Overview

There are three primary tables that make up the database: 1) **Synthesized Research Topics**, 2) **Original Research Topics**, and 3) **Sources**, which all link to the other two via shared columns. **Synthesized Topics** are the primary focus of the database, which have taken **Original Topics** from all reviewed **Sources** and synthesized those to summarize across duplicative and similar topics (see *Database Synthesis* section below for additional detail on this process). Original research recommendations that were combined to form a synthesized topic share the same *Syn #* field value (as well as the same Category, Overarching Topic, and Mechanistic Topic). The topic numbers and source references are also connected via the *Topics* and *Source* fields in the Synthesized Topics table. The *Source* field for both the Synthesized Research Topics and Original Research Topics correspond with the *Abbreviated citation* column in the Sources table (Figure 1).

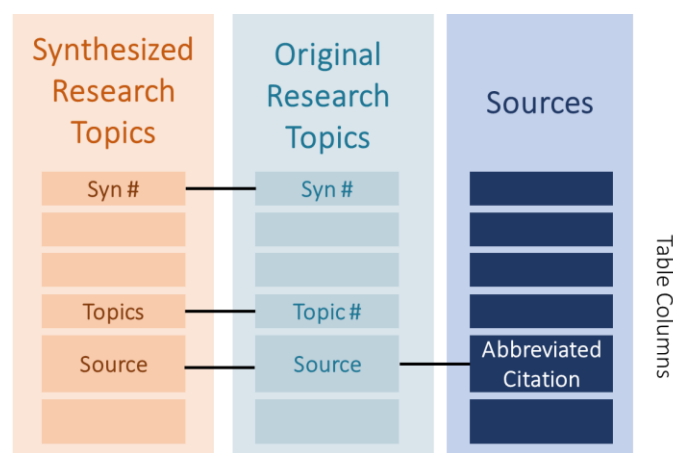


Figure 1. Relationships among tables in the Environmental Research Recommendations Database.

### Field Definitions

Definitions for each field in the Environmental Research Recommendations Database's three primary tables are included below, including synthesized and original research topics (Table 2) and sources (Table 3). Information included in the Synthesized Research Topics table is aimed at providing a higher-level summary of individual research topics identified from various sources. A glossary of additional terms is included in Appendix B. **NOTE: For multi-select columns, options are listed in a specific order (sequential or alphabetical), and order should not be interpreted as level of priority.** In addition, information for all fields is drawn directly from source documents, and as a result, applicability of topics to additional receptors, geographies, scales, etc. may not be fully reflected in the database.

Table 2. Field definitions for Environmental Research Recommendations Database Synthesized Research Topics (S) and Original Research Topics (O) tables. Columns included in each of the two tables indicated by “x”. For definitions of terms used in particular fields, see glossary (Appendix B).

Column	S	O	Description
Syn #	X	X	Unique value for each synthesized topic or group of original topics that were combined into a synthesized topic. The letter at the start of the Syn # indicated the category (see below).
Topic #		X	Unique number assigned to each research recommendation in the original research topics table. These numbers listed in the <i>Topics</i> column of the synthesized research topics table correspond with the <i>Topic #</i> in the original research topics table.
Category	X	X	<p>Category of research recommendation, adapted from Southall et al. (2021) and others, including:</p> <ul style="list-style-type: none"> <li>• <i>Occurrence</i> – basic information on the distribution, abundance, and temporal habitat use of species.</li> <li>• <i>Conditions and Stimuli</i> – information on the characteristics of offshore wind projects and related activities that may affect the taxon of interest.</li> <li>• <i>Exposure and Vulnerability</i> – information on the factors that influence the likelihood of interaction between conditions and stimuli and the taxon of interest and/or relate to sensitivity to effects if exposed.</li> <li>• <i>Response</i> – how animals may be influenced or react to exposure to a stressor.</li> <li>• <i>Consequences</i> – the short- and long-term individual or population-level effects of multiple types of exposures and responses to a stressor.</li> <li>• <i>Methodological</i> – data gaps or needs that are specific to data collection methods and technologies for monitoring and/or mitigation (i.e., validating a new technology)</li> </ul> <p>Original research topics that are synthesized into the same synthesis topic must share the same category.</p>
Stressor/Topic	X		Keywords that are related to stressors and/or topical areas of focus to aid in filtering of the database. Stressor-related options include: Attraction, Avoidance, Oceanographic/atmospheric change, Turbine Collision, Vessel Collision, Displacement, EMF, Entanglement, Habitat Change, Lighting, Noise; Additional topic areas include: Baseline, Abundance and Distribution, Movement and Behavior, Physiology and Energetics, Diet and Food Web Dynamics, Population Dynamics, Ecological Drivers, Data Management (includes standardization and transparency), Technology/Methods Development, Cumulative Impacts.
Overarching Topic	X	X	Overarching topics are defined as general ideas, concepts or major principles related to OSW effects on wildlife, oceanography, and ecosystems, defined based on existing effects and consequences frameworks. Nested within categories. Original research topics that are synthesized into the same synthesis topic must share the same overarching topic.
Mechanistic Topic	X	X	Mechanistic topics serve the purpose of refining the broad, overarching idea in a conceptual sense. Nested within overarching topics. Original research topics that are synthesized into the same synthesis topic must share the same mechanistic topic.
Research Recommendation	X	X	The title of the research recommendation provides additional specificity when compared with the mechanistic topic. In the original topics table, if taken directly from source, quotation marks were used to indicate this.
Goal/Objectives	X	X	The goal and/or objectives of the research topic. In the original topics table, if taken directly from source, quotation marks were used to indicate this.

Column	S	O	Description
Receptor	X	X	General taxonomic/topical category(ies) including the following non-exclusive options: <i>Bats, Benthos, Birds, Ecosystem and/or Oceanographic Processes, Invertebrates, Fishes, Marine mammals, Sea turtles</i> . Habitat-related topics were assigned one or more focal taxa to which that habitat pertained. <b>To aid in filtering, in addition to the receptor column, there are columns for each of the receptors listed above with an “X” indicating applicability to that group.</b>
Additional taxa info	X	X	If the research topic included additional taxonomic specificity such as target species or group of species, this additional information was noted (e.g., Roseate Terns, seabirds, baleen whales).
Spatial scale	X	X	Indication of spatial scale of data collection for the proposed study, including: <ul style="list-style-type: none"> <li>• <i>Site-level</i> – a single offshore wind project.</li> <li>• <i>Multi-site</i> – multiple offshore wind projects.</li> <li>• <i>Regional</i> – includes data collection away from offshore wind project sites in addition to data collection at offshore wind projects.</li> <li>• <i>Off-site</i> – includes both lab work and/or field research; conducted only away from offshore wind projects.</li> </ul> If a study/topic did not require data collection (e.g., desktop study using existing data, model or method development), the spatial scale was indicated as “N/A,” unless specifically defined by the source. If undefined or not apparent from the source, indicated as “Unknown”. In the Synthesis Research Topics table, a topic may list multiple potential spatial scales (this occurs when the original research topics included in a synthesis topic specified different spatial scales).
Temporal scale	X	X	The time required for a proposed study to be conducted to address the research recommendation. This included the number of years of data collection required or other relevant information on timing (e.g., season of interest). If a study did not require data collection (e.g., desktop study using existing data) or if a more general methodological topic (e.g., model development), the temporal scale was indicated as “N/A,” and if undefined, indicated as “Unknown”. In the Synthesis Research Topics table, the temporal scale for a given row is a reflection of the range of scales indicated in the original topics; for example, if original topics specific 6-12 months and 1-2 years, the synthesis topic might specify something like “6 years to 24 months”.
Source region	X	X	The specific geographic focus of the research recommendation. The most specific option was applied that was accurate for the original research topics. If no geographic area was provided for a specific research recommendation, the geographic scope of the source document was used. In the Synthesis Research Topics table, a topic may list multiple geographic areas (this occurs when the original research topics included in a synthesis topic specified different geographic areas of interest for the same overarching and mechanistic topics). Options include: <ul style="list-style-type: none"> <li>• <i>New England</i></li> <li>• <i>Mid-Atlantic</i> - (southern New Jersey to North Carolina)</li> <li>• <i>New York Bight</i> - (New York and northern New Jersey)</li> <li>• <i>South Atlantic</i> - (South Carolina to Florida)</li> <li>• <i>Gulf of Maine</i></li> <li>• <i>Atlantic Coast</i></li> <li>• <i>Pacific Coast</i></li> <li>• <i>U.S.</i></li> <li>• <i>Europe</i></li> </ul>

Column	S	O	Description
Development phase	X	X	Phase(s) of offshore wind energy development during which the research would be carried out. Non-exclusive options included: <i>Pre-construction</i> , <i>Construction</i> , <i>Operations and maintenance</i> , <i>Decommissioning</i> , and <i>N/A</i> . Listed as <i>N/A</i> if no development phase was apparent from the original topic or if related to collecting information off-site only, including desktop studies and methodological developments.
Examples	X		For synthesized research topics that include multiple original topics, examples may be provided to indicate key distinctions among original topics related to taxa, objectives, or other fields. NOTE: Provided for illustrative purposes, not to encompass all sources synthesized. If users are interested in more detail on the original topics encompassed by a synthesis topic, we encourage them to examine the rows with the appropriate "Syn #" in the Original Research Topics table and revisit the original source documents listed in the "Source" field for additional detail (see "Source" and "Quick Reference" fields below).
Topics	X		Corresponds with Topic # in the Original Research Topics table to aid in connecting synthesized and original topics.
Prioritization (if applicable)		X	If a source indicated a relative priority level (Tier 1 of 3, Priority #4 of 8, etc.), it was noted in this field. Additional information on source-specific prioritization processes was included in the "Sources" table.
Source	X	X	Abbreviated citation (e.g., Degraer et al. 2021), which matches the "Abbreviated citation" field in the "Sources" table. For the synthesized research topics, multiple sources within a row are listed in alphabetical order.
Quick reference		X	Information to assist with quickly finding the research topic within the source document, indicated as a page number in a document or line number in a table.



Table 3. Field definitions for Environmental Research Recommendations Database Sources table.

Column	Description
Abbreviated citation	Similar to an in-text citation in a scientific paper. Includes the author’s last name and year (e.g., Degraer 2021) with “et al.” used if three or more authors.
Full citation	Full citation information for a source document. The format varies depending on whether the source is a white paper/report or journal article. <i>For a white paper/report</i> : Last Name, First Initial. Year. Study Number. Institution/Department (or Report by X for X), City, State/County. Pages. <i>For a journal article</i> : Last Name, First Initial. Year. Title. Journal Volume (Issue): Pages.
Link	The URL for the source, if it is available online. If the article is publicly available, the link will take the user straight to the source document. If it is not open access, the link will take the user to a paywall.
Tethys link	The URL for the source on the <a href="#">Tethys Knowledge Base</a>
Goal	The intended use of the research recommendations, e.g., goal of the source document. If taken directly from source, quotation marks were used to indicate this. Note that the overall goal of a source document was likely to be different than the goal/objective for a given research topic.
Prioritization criteria	Detail about the criteria used to prioritize research topics within the source document. Listed as “None” for sources with no prioritization process.
Funding Source	Details about the funder(s) of the effort. Listed as “Unknown” if not provided.
Effort type	The general category of organization/entity that produced the document. Options include: <ul style="list-style-type: none"> <li>• Federal Agency</li> <li>• Intergovernmental Science Organization</li> <li>• NGO (non-governmental organization)</li> <li>• Stakeholder Workgroup</li> <li>• State Agency</li> <li>• University</li> <li>• Wind Industry</li> <li>• Workshop</li> </ul>
Recorder	The initials of the recorder who entered original data for each source. Most sources had a single recorder for all recommendations from that source document.

## Filtering

The Environmental Research Recommendations Database can be filtered by clicking on the arrow in the right corner of the header row for the column by which you wish to filter. For filtering by fields where multiple values may be listed within a row (Spatial scale, geographic area, receptor, development phase, source), we recommend you use the search bar or a custom filter to ensure you capture all topics that include the value of interest (Figure 2). You can use the check boxes to filter as well, but by selecting the “bats” box, for example, you will only be shown topics that ONLY include bats, while topics that contain bats plus other receptors would be excluded. To clear the filter, click the arrow in the right corner of the filtered header row, then select “clear filter”.

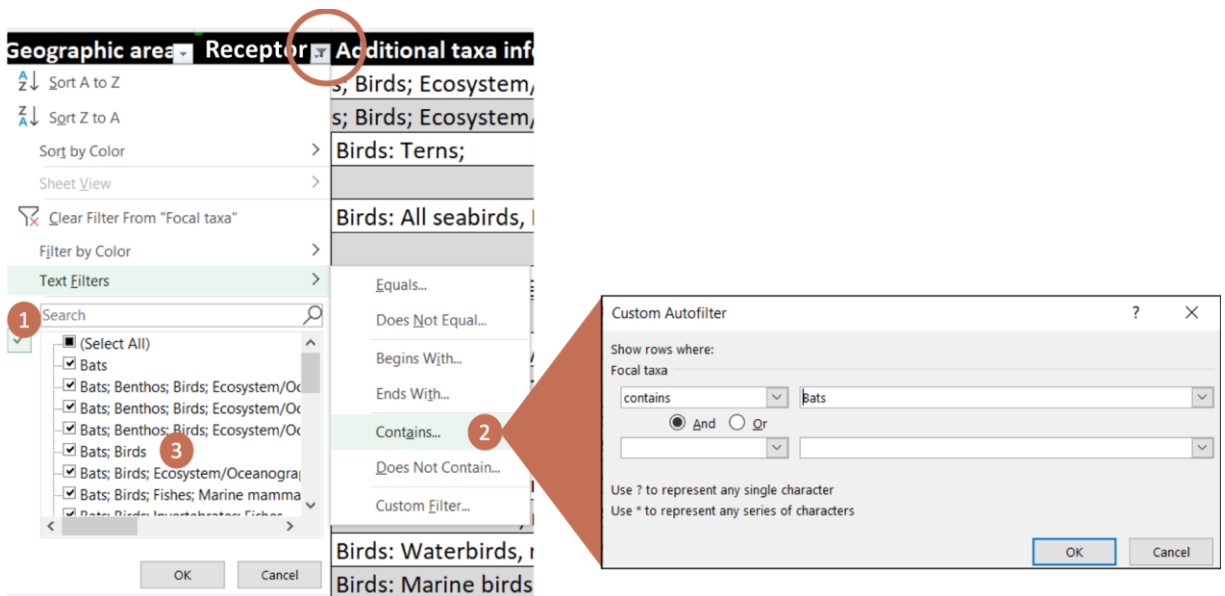


Figure 2. Filtering options for Environmental Research Recommendations Database for fields with multiple categories selected. Options include 1) Putting the topic you would like to filter by into the search bar, 2) create a custom filter by going to 'text filters' in the menu and clicking 'contains' then selecting the topic of interest from the subsequent dropdown, or 3) using check boxes to select the options of interest. Note: Selecting "Bats" from the check boxes (Option 3) will show topics that are ONLY for bats, not all topics CONTAINING bats.

### Filtering Example 1 – Column with single-select options

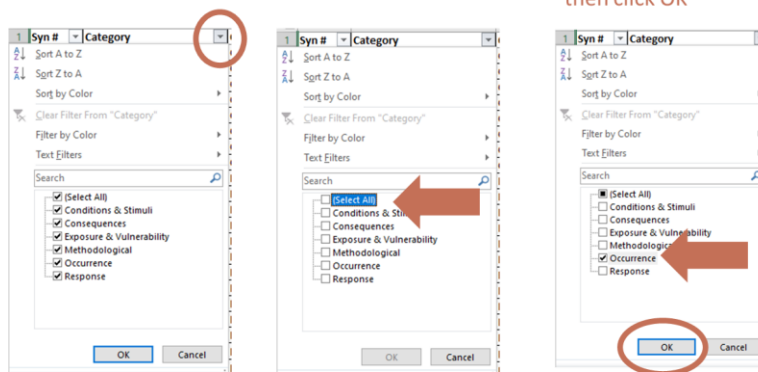
The below example provides step-by-step instructions on how to filter for a column where only one option can be selected (e.g., category, overarching, mechanistic).

Step 1: Click the arrow on the column header by which you want to filter

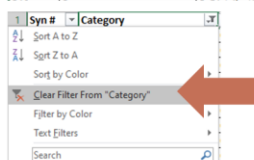
Step 2: Click the check box next to "Select All" to deselect all options

Step 3: Click the check box next to the option by which you would like to filter (example "Occurrence") then click OK

Results



Syn #	Category	Overarching
O1	Occurrence	O-Baseline environmental
O2	Occurrence	O-Baseline environmental
O3	Occurrence	O-Baseline environmental
O4	Occurrence	O-Baseline environmental
O5	Occurrence	O-Behavior
O6	Occurrence	O-Behavior
O7	Occurrence	O-Behavior
O8	Occurrence	O-Behavior
O9	Occurrence	O-Behavior
O10	Occurrence	O-Diet
O11	Occurrence	O-Distribution and Abund
O12	Occurrence	O-Distribution and Abund

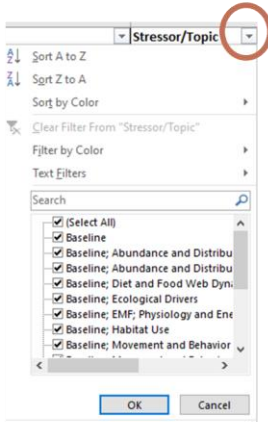


Don't forget to clear the filter if you would like to see all research topics

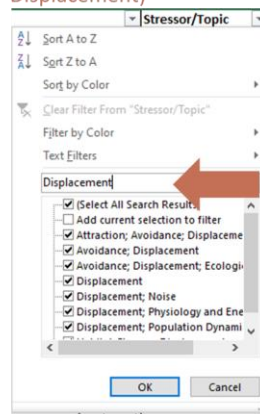
### Filtering Example 2 – Column with multi-select options

The below example provides step-by-step instructions on how to filter for a column where multiple options can be selected (e.g., receptor, stressor/topic, spatial scale).

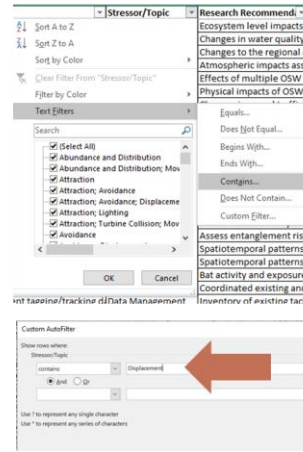
Step 1: Click the arrow on the column header by which you want to filter



Step 2: Type topic you would like to filter by into the search bar (example: Displacement)



OR



Step 2: Select Text Filters → Contains

Step 3: Type topic you would like to filter by in the box next to “contains” then click OK

*Don't forget to select "Clear Filter" from the menu to remove the filter and view all topics*

Stressor/Topic	Research Recommendation	Goal/Objective
Displacement; Physiology and Energetics	Energetic consequences	Assess individual
Displacement	Quantification of displacement	Assess non-bre
Avoidance; Displacement; Ecological Drivers	Effects of environmental	Examine avian
Avoidance; Displacement	Effect of turbine configura	Determine ho
Displacement; Noise	Displacement from noise	Assess displac
Displacement	Changes in displacement	Monitor levels
Displacement; Population Dynamics	Changes in distributions	Determine ho
Attraction; Avoidance; Displacement	Understanding avoidance	Investigate cor
Habitat Change; Displacement	Time for benthos to recol	Better underst

## Database Development

### Source Identification

Research recommendations were compiled from published and gray literature sources, including offshore wind and wildlife stakeholder engagement efforts (e.g., 2020 State of the Science Workgroup reports, NYSERDA Bird and Bat Research Framework, BOEM/MassCEC Protected Species Framework), state-based efforts (e.g., New York Ocean Action Plan, New Jersey draft regional priorities), European research frameworks and other relevant efforts (e.g., WOZEP, Win.Mon.BE), and the scientific literature. Potential sources were identified for inclusion in the Environmental Research Recommendations Database via searches of the Tethys Knowledge Base and Google Scholar, as well as expert solicitation from committee members and support staff, and by stakeholders during the public comment period on the draft database (Appendix C). For all potential sources identified via Tethys and Google Scholar, a review of title and abstract were conducted as an initial evaluation of whether the document met the criteria for source inclusion, below. If in this review there was no clear inclusion of offshore wind development and/or mention of research priorities/knowledge gaps, the potential source was not included. In instances of uncertainty regarding whether the source fit the below criteria, the source document was included for more thorough review.

Following the initial source identification process, 85 source documents were identified, including 47 sources from Tethys Knowledge Base, 16 sources from Google Scholar, 18 sources identified via expert solicitation, and an additional 7 from stakeholders. Following further review, 57 of these source documents were determined to meet the criteria for source inclusion (below), and research recommendations were extracted from each of these source documents and entered into the database of data gaps and research topics.

## Criteria for Source Inclusion

The following criteria were developed to ensure that sources entered into the database were relevant to the goals of the effort. Source documents were required to be:

- Focused at least in part on the offshore wind industry (therefore excluding documents that focused solely on terrestrial wind or offshore oil and gas, for example).
- Relevant to the eastern U.S. “Relevance” entailed either a direct focus on this geography or inclusion of taxa, habitats, and questions germane to the U.S. context.
- Published since 2015, in order to ensure that the topics identified as research priorities were reasonably current. **Note: Given the timing of source searches, those considered for inclusion were published between 2015-2021.**
- Clear delineations of research needs, knowledge gaps, or other funding needs or priorities focused on wildlife and their habitats. Sufficient detail was required regarding each topic’s goals and basic characteristics (such as geographic, temporal, and taxonomic focus) such that it did not require substantial subjective interpretation to enter into the database, and a potential funder or researcher could take up a topic without significant further scoping or interpretation of a topic’s intent.

Some of these criteria (e.g., publication year) were used to narrow database searches during source identification, while others were applied to collated sources to determine eligibility.

## Collating Research Recommendations

A database was developed to collate information on 1) source documents, and 2) individual research recommendations or priorities identified from each source. Database fields included a mix of text fields, drop-down lists (e.g., for fields with a predetermined set of potential answers), and web links. Each source was thoroughly reviewed and information was extracted for each research topic or data gap. See *Field Definitions* (above) for more detailed information on data extracted from each source document.

Once all sources and research topics were entered into the database, we performed a series of quality assurance and quality control (QA/QC) steps (Figure 3) to reduce likelihood of erroneous data and ensure consistency. For further details on this QA/QC process, see Appendix D.

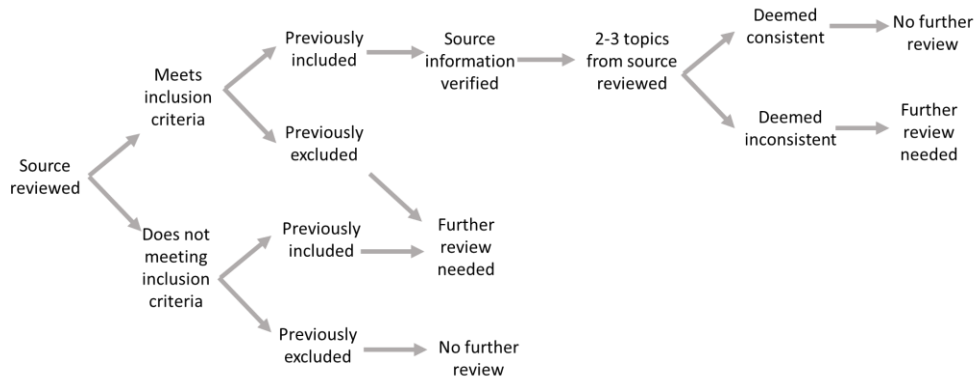


Figure 3. Initial quality assurance and quality control (QA/QC) process conducted by a second independent reviewer for each source document (following initial source identification and research topic entry and prior to database synthesis).

## Database Synthesis

Original topic data entry and QA/QC resulted in 812 research topics from 57 sources. The purpose of database synthesis was to consolidate similar research recommendations identified by different source documents, create a common hierarchy to help standardize level of detail, and aid in the sorting and filtering of data by end users (Figure 4). Thus, a synthesized list of 219 research recommendations is included in the database which links to the full list of original topics extracted from all sources (non-synthesized). Original topics that were combined to form a synthesized topic share the same *Syn #* column value (as well as the same Category, Overarching Topic, and Mechanistic Topic). The topic numbers and source references are also connected via the *Topics* and *Source* columns on the Synthesized Topics table. The *Source* column for both the Synthesized Topics and Original Topics correspond with the *Abbreviated citation* column in the Sources table.

### Identifying Overarching and Mechanistic Topics

Research topics were categorized into two hierarchical levels, overarching topics and mechanistic topics, defined using a modified “hierarchy-of-hypotheses” approach as described in Heger et al. (2021). Overarching topics were defined as general ideas, concepts or major principles related to OSW effects on wildlife, oceanography, and ecosystems, and mechanistic topics refined these broad, overarching ideas in a conceptual sense. Topics were fully nested (e.g., each mechanistic topic could only occur within one overarching topic, which could only occur within one category; see field definitions above).

Overarching topics (Table A1) were defined *a priori* using existing conceptual frameworks (Dannheim et al. 2020, Degraer et al. 2021, Hein et al. 2021, Kraus et al. 2019, Williams and Gulka in prep., Pirota et al. 2018, Southall et al. 2021) and discussion within the regional synthesis workgroup. Overarching topics belonged to one of six categories in the database (Occurrence and Baseline Conditions, Conditions and Stimuli, Exposure and Vulnerability,

Response, Consequences, Methodological). An overarching topic was applied to each original research topic.

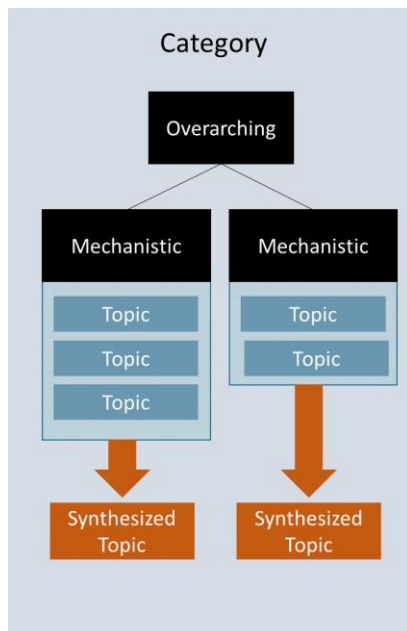


Figure 4. General hierarchical structure of topics in the Environmental Research Recommendations Database. Original topics with the same overarching and mechanistic topic were compiled into a single synthesized topic.

For purposes of QA/QC, topics with multiple receptors were categorized into overarching topics by multiple researchers (2-4) to assess agreement in assignment of overarching topic. Cases of disagreement were resolved via group discussion, and other research topics within the same overarching category were reviewed as necessary.

Following this QA/QC step, topics were sorted by category and mechanistic topics were developed and applied to each topic in the database. Following development and categorization, the full list of overarching and mechanistic topics was reviewed by researchers to resolve any potential areas of overlap.

### Developing Synthesized Research Topics

The final step was to group research topics with the same overarching and mechanistic topics and develop a synthesis of the original research topics within each group. For fields with a pre-defined list of options (e.g., spatial scale, geographic area, receptor, development phase), all options included in original topics were included in the synthesis row. For text fields (temporal scale, additional taxa information), ranges or specific details by group (e.g., receptor) were provided. Examples were added to provide key distinctions among original research topics within a synthesis topic. ***These were provided for exemplary purposes only, and do not encompass all sources synthesized. Users interested in additional detail on a synthesis topic are encouraged to review the topics with the same "Syn #" in the Original Research Topics table as well as the underlying source documents.***

## References

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## Appendix A. Summary of Database Topics by Taxon, Category, and Overarching Topic

The database contains 219 synthesized topics, which were compiled from >800 recommendations and data gaps identified in original source documents. These are summarized in Table A1 by taxon/receptor, category of research need, and overarching topics within each category (field definitions are included in the “Field Definitions” section in the main text).

Table A1. Synthesized topics by taxon/receptor, category of research need, and overarching topic. See Table 2 for category and overarching topic definitions.

Category	Overarching Topic	Bats	Birds	Benthos	Ecosystem/ Oceanographic	Fishes	Inverts	Marine mammals	Sea turtles	Total # Recs.
Occurrence	Baseline environmental conditions			1	2	2	2	2		4
	Behavior		2					3	1	5
	Diet	1	1	1	1	1	1	1	1	1
	Distribution and Abundance	1	1	2		2	3	1	1	4
	Ecological Drivers	1	3	1	2	3	2	2	2	5
	Food web dynamics	1	2	1	1	2	1			3
	Habitat use	1	1	1	1	2	2	2	1	3
	Health and Energetics		1					1	1	3
	Movement patterns	2	2	1		1		1	1	2
	Physiology and stress	1	1	1		2	2	3	2	4
	Population dynamics		3	1		2	1	1		3
	Presence	1	1	1		1	1	1	1	2
	<b>Occurrence Subtotal</b>	<b>9</b>	<b>18</b>	<b>11</b>	<b>7</b>	<b>18</b>	<b>15</b>	<b>18</b>	<b>11</b>	<b>39</b>
Conditions & Stimuli	Changes in biological characteristics of ecosystem			5	2	2	1			5
	Changes in physical and chemical characteristics of ecosystem			3	6	1	1	1		8
	Changes in sound characteristics of ecosystem			1	1	1	1	2	1	2
		<b>Conditions/Stimuli Subtotal</b>			<b>9</b>	<b>9</b>	<b>4</b>	<b>3</b>	<b>3</b>	<b>1</b>
Exposure and Vulnerability	Exposure to changes in sound/vibration			1		1	1	1	1	1
	Exposure to changes in vessel traffic							1	1	1
	Exposure to wind turbine structures	1				1		1	1	3
		<b>Exposure/Vulnerability Subtotal</b>	<b>1</b>		<b>1</b>		<b>2</b>	<b>1</b>	<b>3</b>	<b>3</b>

Category	Overarching Topic	Bats	Birds	Benthos	Ecosystem/ Oceanographic	Fishes	Inverts	Marine mammals	Sea turtles	Total # Recs.
Response	Acoustic response			1		2	2	4		5
	Behavioral response		1	4		4	3	5	3	8
	Changes in food web dynamics		1	3	2	2	2	1		5
	Changes in habitat and resources		4	4		4	3	3	2	9
	Changes in hydrodynamics			2	2	2	1			2
	Distribution change	4	8	9	3	11	7	6	3	19
	Energetic/Body condition response			1		2	2	1		3
	Injury and Mortality	4	3	1		3	1	3		7
	Seafloor disturbance			8	4	2	2			9
	Stress/Physiological/Developmental response			2		3	3	2	1	3
	<b>Response Subtotal</b>	<b>8</b>	<b>17</b>	<b>35</b>	<b>11</b>	<b>35</b>	<b>26</b>	<b>27</b>	<b>9</b>	<b>70</b>
Consequences	Changes in ecosystem structure or function			9	3	5	1	1	1	9
	Changes in habitat use or structure			1		1				2
	Health and Energetics		1	1		2	1	2		3
	Population dynamics		1	2		2	1	3	1	5
	Vital rates	1	1	1	1	1	1	2		2
		<b>Consequences Subtotal</b>	<b>1</b>	<b>3</b>	<b>14</b>	<b>4</b>	<b>11</b>	<b>4</b>	<b>8</b>	<b>2</b>
Methodological	Data standardization/transparency	4	6	4	4	3	3	5	4	6
	Mitigation	8	8	5	4	8	6	7	2	13
	Monitoring/analytical approaches	12	21	10	11	12	10	24	6	42
	Risk assessment processes	1	6	1		3	1	3	1	8
		<b>Methodological Subtotal</b>	<b>25</b>	<b>42</b>	<b>20</b>	<b>19</b>	<b>26</b>	<b>20</b>	<b>39</b>	<b>13</b>
<b>TOTAL</b>		<b>44</b>	<b>79</b>	<b>90</b>	<b>50</b>	<b>96</b>	<b>69</b>	<b>96</b>	<b>39</b>	<b>219</b>

## Appendix B. Glossary of Terms

**Abundance** – The number of individuals from a biological population that are present in a geographic area of interest.

**Atmospheric** - The chemical and physical properties of the Earth’s atmosphere.

**Attraction** – The process by which individuals are drawn towards another object. In the offshore wind context, this includes individual attraction to structures for perceived food, shelter, or other resources, as well as attraction to features of offshore wind infrastructure such as artificial lighting.

**Avoidance** – Changes in directed movements such as migration or daily movements, in which an individual takes evasive action when in proximity to a wind farm to prevent collisions (for volant animals) or maintain a certain distance/separation from a wind farm or its components (for both aquatic and volant animals). Avoidance may occur at the scale of the wind farm (macro-avoidance) or at the scale of the turbine, cable, or other structure (meso-avoidance). For volant animals, micro-avoidance may also occur at the scale of the turbine blade, e.g., a last-minute evasion to prevent collision (NYSERDA 2020). See also “Displacement.”

**Baseline** – The prior state, situation, or conditions in the absence of a stressor that can be used as a reference when determining effects (ROSA 2021). In the U.S. Atlantic Offshore Wind Environmental Research Recommendations Database, this is used to distinguish recommendations related to understanding conditions prior to offshore wind development, in order to detect responses to the development and/or help disentangle the effects of offshore wind development from other stressors.

**Behavior** – A response (action or inaction) of an individual or group in response to internal or external stimuli (Levitis et al. 2009). In the context of effects, behavioral change may indicate response to a stressor.

**Collision** – The instance of an individual striking or being struck by an object, causing potential injury or mortality. In the context of offshore wind energy development, this includes collisions of volant animals with offshore wind infrastructure (including turbine blades and other structures) and collisions of aquatic animals with vessels.

**Conditions and Stimuli** – Characteristics of the range of offshore wind activities that may affect the taxon of interest (e.g., noise, changes in habitat, physical structures). Also known as “hazards” (Crichton 1999), “impact-producing factors” (BOEM 2021), and “stressors” (see below).

**Consequences** – The short- and long-term individual or population-level effects of exposures and responses to offshore wind-related conditions and stimuli (i.e., stressors). Understanding of population-level cumulative consequences requires an understanding of demographic effects of individual responses. Consequences may include how responses to offshore wind development affect fitness through changes in reproduction, growth, or survival (Southall et al. 2021).

**Control** – Selected reference site or condition that is isolated from, but similar to, an affected offshore wind site or condition with regard to biological, physical, and environmental characteristics, as well as other anthropogenic uses (e.g., fishing, shipping activities; ROSA 2021).

**Cumulative Impacts** – The net effect of multiple stressors or disturbances associated with offshore wind development, which may be additive or synergistic to populations, communities, or ecosystems across spatiotemporal scales (Popper et al. 2022; Burton et al. 2020). Cumulative impacts may refer to impacts across multiple anthropogenic activities or specifically related to offshore wind development.

**Data Management** – The process of gathering, organizing, vetting/reviewing, storing, modeling, interpreting, and sharing data. This includes topics related to data transparency and standardization.

**Data Transparency** – Sharing data or otherwise making it available to other users, whether publicly or on request. May include sharing of summary information and/or derived data products such as model outputs as well as sharing of original datasets.

**Development Phase** – Phase(s) of the development of an offshore wind energy project, including pre-construction activities such as seismic surveys, construction activities, operations and maintenance activities, and decommissioning.

**Diet** – The combination of foods typically consumed by a species or group of organisms. May vary by age class, sex, breeding stage, location, etc.

**Distribution** – The pattern by which species, taxon, or individuals are spatially arranged (NYSERDA 2020).

**Disturbance** – Disruption of the structure of the ecosystem, community, population, or individual organism, causing changes to the physical environment, resources/habitat, physiology, behavior, or life history (White and Picket 1985).

**Displacement** – When animals adjust their habitat use, such as foraging or breeding, due to a new feature or disturbance, causing effective habitat loss (NYSERDA 2020). Includes avoidance behavior during directed movements (see “Avoidance”).

**Ecological Drivers** – The natural or human-induced factors that directly or indirectly induce changes individuals, communities, or ecosystems. Often used to refer to environmental and oceanographic conditions that may directly or indirectly influence distributions, movements or behaviors.

**Ecosystem** – A biological community of interacting organisms and their physical environment (Chapin 2011).

**Energetics** – The energy-related properties of animals. Animals have energy “budgets,” in which they must take in sufficient energy to perform necessary activities, such as foraging, reproducing, and migrating. Energetic impacts, or disruptions to these energy budgets, may have short-or long-term influences on individual survival or reproductive success (NYSERDA 2020).

**Entanglement** – The wrapping of lines, netting, or other materials of anthropogenic origin around the body of an animal. Entanglement in commercial fishing and aquaculture gear (both active and derelict) can cause significant injuries and energetic consequences to marine species, affecting their ability to swim and feed.

**Electromagnetic Field (EMF)** – A force field consisting of both electric and magnetic components that can be generated by both natural and anthropogenic sources (in the latter case, generally emanating from man-made equipment that uses or carries electricity). In the offshore wind context, EMF primarily emanates from underwater cables, and may cause behavioral or other responses in species on or near the seabed (Hutchison et al. 2020).

**Effect** – A change that is linked to an exposure to an offshore wind-related activity and that is a departure from a prior state, condition, or situation (called the “baseline” condition; Hawkins et al. 2020). While National Environmental Protection Act (NEPA) regulations consider effect and impact synonymous, for the purposes of this effort, effect and impact are defined differently (see *Impact*), unless in reference to an “Environmental Impact Assessment”.

**Effect Size** – Statistically determined direction and strength of a receptor’s response to a stressor.

**Exposure** – Frequency and duration of contact or co-occurrence between an offshore wind stressor and an environmental receptor that may allow the stressor to act upon the receptor in some way (Goodale and Milman 2016). Exposure represents an aspect of vulnerability.

**Food Web** – The representation of interconnected feeding relationships within a community. It also implies the transfer of food energy from its source in plants through herbivores to carnivores.

**[Project] Footprint** – The project footprint includes areas of offshore wind projects containing turbine and substation structures. The project footprint represents part of the project site (see “Site-specific Scale”).

**Habitat** – The array of physical factors (e.g., temperature, light) and abiotic factors (e.g., presence of predators, availability of food) present in an area that support the survival of a particular individual or species.

**Hypothesis** – An explanation for an observable phenomenon, usually expressed in a testable manner. In the context of offshore wind development, a hypothesis represents a potential explanation for a receptor’s response or a relationship between variables.

**Impact** – An effect that results in a change whose direction, magnitude and/or duration is sufficient to have biologically significant consequences for the fitness of individuals or populations (Hawkins et al. 2020). While National Environmental Protection Act (NEPA) regulations consider effect and impact synonymous, for the purposes of this effort, effect and impact are defined differently (see *Effect*).

**Lighting** – The use of artificial lights to illuminate infrastructure, vessels, planes, and other objects, with the potential to cause attraction in some animals (see “Attraction”).

**Monitoring** – a subset of research that involves collecting repeated systematic observations using the same methods and approaches in an area over time and is focused on improving our understanding of the effects of offshore wind development on wildlife and ecosystems.

**Movement** – A change in the spatial location of an individual organism over time.

**Multi-site Scale** – See “Spatial Scale”

**Noise** – Sounds that are considered loud, disruptive, or unpleasant and can hinder the ability of individuals to detect signals or perform behaviors (Popper and Hawkins 2019). In the U.S. Atlantic Offshore Wind Environmental Research Recommendations Database, the terms “noise” and “sound” are at times used synonymously.

**Occurrence** – Basic information on the distribution, abundance, and temporal habitat use of receptors, including seasonal and interannual variability and elements of behavioral, movement, and acoustical ecology, among other characteristics (Southall et al. 2021). Used to inform understanding of exposure (above).

**Oceanographic** – The geological, chemical, and physical properties of the ocean (NYSERDA 2020).

**Physiology** – The functions and activities of a living organism or its body parts; includes physical, biological, and chemical phenomena (NYSERDA 2020).

**Population Dynamics** – How a population of a species (i.e., a group of individuals of the same species that occupy a specific area over a certain period of time) changes in abundance or density over time. In an ecological context, often used specifically to refer to factors influencing reproductive success, survival, and/or immigration/emigration.

**Power Analysis** – Statistical methods that estimate *a priori* the minimum sample size required to detect a specified amplitude of change with a given degree of confidence (NYSERDA 2020).

**Project (also “Offshore Wind Project”)** – Geographic space and infrastructure that comprise an offshore wind energy facility, includes areas in which environmental effects from the facility occur, including areas outside the actual footprint of the facility.

**Receptor** – Ecological entity, such as an individual, group, population, species, community, or ecosystem, that may be exposed to and/or affected by a stressor. For the purposes of the database, receptors include taxonomic groups (birds, bats, marine mammals, sea turtles, fishes, invertebrates) and well as communities (benthos), and oceanographic and ecosystem dynamics.

**Recommendation** – Data gap and/or research need identified in the existing literature and synthesized in the Environmental Research Recommendations Database. Duplicative recommendations were synthesized within the database but were not further ranked or prioritized.

**Regional Scale** – See “Spatial Scale”.

**Research** – Any type of question-driven scientific study or data collection that improves our understanding of populations and ecosystems, either generally or in relation to the effects of offshore wind development. Monitoring is considered a subset of research.

**Response** – How receptors may be influenced by or react to exposure to a stressor, on either acute or long-term time scales. Responses can include measurable changes in physiological condition or behavior (e.g., communication, navigation, movements, habitat use) of an individual, group, population, or community (Southall et al. 2021).

**Risk** – The probability of an event or outcome occurring in a defined population over a specified time interval. Risk is determined by conditions and stimuli (e.g., stressors) and vulnerability (including both exposure and sensitivity).

**Sensitivity** – Properties of an organism or system that influence relative susceptibility to a stressor. Demographic sensitivity relates to vital rates, ethological sensitivity relates to intrinsic and response behavior, biological sensitivity relates to physical tolerances and habitat specialization, and population sensitivity relates conservation status (Goodale and Stenhouse 2016).

**Site-specific Scale** – See “Spatial Scale”.

**Sound** – Vibrations traveling through air, water, or other media that can be perceived by animals using the sense of hearing. Hearing capacities of species depend on the frequency and magnitude of sound as well as the degree to which sound is detected via pressure or particle motion (Popper and Hawkins 2019). In the U.S. Atlantic Offshore Wind Environmental Research Recommendations Database, the terms “noise” and “sound” are at times used synonymously.

**Spatial Scale** – The spatial extent at which an offshore wind-focused research study is conducted. The three main scales of interest for research and monitoring studies include:

- **Site-specific Scale** – Geographic extent within which effects and responses occur in relation to individual turbines or a single offshore wind project footprint. May also include immediately adjacent areas outside a project footprint.
- **Multi-site Scale** – Geographic extent that is comprised of multiple offshore wind projects. Studies may be required to occur at this scale due to the need for larger sample sizes than can be achieved at a single wind farm, or because the research question of interest includes the examination of variation in effects between locations, time periods, or other characteristics.
- **Regional Scale** – Geographic extent that includes data collection focused outside of offshore wind project areas, instead of (or in addition to) focusing on wind project areas alone. Examples of

regional-scale research include examination of broad-scale population characteristics such as demography or range-wide distributions, or the examination of interactive effects across multiple industries.

**Study Design** – a well-structured plan for implementing research, including topic, purpose, scope, questions and hypotheses, type of study best suited to answer the research question, study methods, and expected outcomes (De Vaus 2001).

**Study Methods** – set of tools, procedures, and approaches used to collect and analyze data to test a specific hypothesis (De Vaus 2001).

**Stressor** – Physical, chemical, or biological factor related to offshore wind development that can affect the health and productivity of a receptor depending on its exposure and vulnerability (NYSERDA 2020). Synonymous with *Conditions and stimuli*, above.

**Technology** – Man-made methods, systems, or devices. In the context of offshore wind energy environmental research needs and data gaps, technologies are generally machines or other devices that allow for or improve the data collection, analysis, and storage of data, or that aim to mitigate the effects of offshore wind energy stressors on wildlife or ecosystems.

**Topic** – See Recommendation

**Variable** – A measured attribute associated with research. Includes independent or “explanatory” variables, dependent or “response” variables, and confounding variables (extraneous variables that relate to the study’s independent and dependent variables and should be controlled for in study design and post-hoc analyses to constrain variance and potential bias of results).

**Vulnerability** – Combination of exposure and sensitivity to encompass the degree to which a receptor or system is susceptible to a stressor.

## Appendix C. Database Source Identification Details

### Tethys Knowledge Base Search

The *Tethys* Knowledge Base provides access to documents and information about the environmental effects of wind energy and provide means for easy filtering based on content type, technology, stressor, and receptor, among other filters. The following filters were applied to identify source documents meeting the above criteria:

- **Content Type:** Journal article, report, conference paper, workshop article
- **Technology:** Wind energy, including Fixed Offshore Wind and Floating Offshore Wind
- **Stressor:** Collision, habitat change, noise, avoidance, displacement, attraction, EMP, Changes in flow, lighting, chemicals, entrapment
- **Receptor:** Birds, bats, marine mammals, fish, invertebrates, physical environment, ecosystem processes, reptiles

Only sources from 2015 or later were considered in this search. In addition to these filters, the following search terms were used to narrow potential sources: “research priorities” OR “knowledge gaps” OR “data needs” OR “research needs”.

### Google Scholar Search

A search was also conducted on Google Scholar using the search terms described below to identify scientific literature for potential inclusion in the database. Combinations of offshore wind, research-related, and topic-related search terms were combined using plus signs. Google Scholar automatically searches for simple singular and plural forms of term, along with additional different endings.

- **Offshore wind search terms:** “offshore wind” OR “OSW” OR “offshore energy”, or “offshore wind farm” OR “offshore turbines” OR “floating wind” OR “floating wind energy” OR “floating offshore wind energy”  
AND
- **Research related search terms:** “research priorities” OR “monitoring priorities\*” OR “research gaps” OR “knowledge gaps” OR “research needs”  
AND
- **Topic related search terms:** “environment” OR “ecosystem” OR “cumulative impacts” OR “cumulative effects” OR “ecological effects” OR “wildlife effects” OR “ecological impacts” OR “wildlife impacts” OR “wildlife” OR “marine mammals” OR “fishes” OR “invertebrates\*” OR “crustaceans” OR “species” OR “sea turtles” OR “bats” OR “birds” OR “seabirds” OR “oceanography\*”

### Expert Opinion

In addition to utilizing the *Tethys* Knowledge Base and Google Scholar, subject matter experts on the regional synthesis workgroup and E-TWG support staff identified several additional sources, such as reports from efforts in which they took part, that had the potential to meet criteria for inclusion.



## Stakeholder Input

During the public feedback period for the draft database, stakeholders identified additional potential source documents for inclusion, as well as topic areas and geographies that they felt were under-represented or missing from the database. To address these comments, several supplementary Google Scholar searches were conducted with targeted keywords. The same offshore wind search terms and research related search terms were used as described in the Google Scholar section above, with the following additional topic related search terms: “Great Lakes” OR “Gulf of Mexico” OR “onshore” OR “landfall” OR “powerlines” OR “cabling” OR “ports” OR “atmospheric” OR “ocean-atmospheric” OR “cumulative construction” OR “concurrent construction impacts” OR “concurrent construction effects”. A total of seven additional sources were identified by stakeholders or via these supplementary literature searches, of which three sources met the inclusion criteria and were added to the database.

## Appendix D. Initial Quality Assurance and Quality Control Process

Once all sources and research topics were entered into the database, but prior to synthesis, we performed a series of QA/QC steps to reduce likelihood of erroneous data and ensure consistency across the database (additional QA/QC steps during the synthesis process are described in the “Database Synthesis” section, above).

All documents considered for inclusion in the database (n=72, excluding sources that did not meet the publication year criteria) were independently reviewed by a second researcher to determine whether they fit the inclusion criteria. Each relevant source document was further reviewed to verify consistency in the entered information for the source itself, as well as the recommendations (e.g., research priorities) identified by each source document. At least two randomly selected research topics were reviewed from each source document and additional review and consultation was conducted as needed.

If there was a mismatch between the determination of the initial review and QA/QC review in whether a source document met the inclusion criteria, further review of that source and a final determination for/against inclusion was made in consultation with the entire data entry team to ensure consistency in the way criteria were applied, particularly related to relevance to the U.S. east coast, clear delineation of research needs, and level of detail included during data entry. If following this review a source that was previously excluded was deemed to meet the criteria, research topics were entered from this source into the database, and QA/QC was performed on these topics as described above.

If the researcher conducting QA/QC reviewed a source’s representation in the database (e.g., the source information and 2-3 research recommendations from that source) and concluded that they would have entered it significantly differently than the initial data entry, the source was flagged for further review. Significant, in this case, is defined such that differences in data entry would alter the meaning and/or interpretation of the research topic. In these cases, the QA/QC reviewer entered information into additional database columns to describe the discrepancy. The individual who originally entered the data then reviewed the QA/QC notes, and if they agreed with the QA/QC reviewer, updated all entries from that source document. If the original recorder did not agree with the QA/QC reviewer on how best to represent the information in the source, or required further clarification, the two individuals discussed and resolved discrepancies in coordination with a third reviewer. If needed, the entire data entry team was briefed and involved with discussion to ensure consistency throughout the database. Following resolution (and updates of all topics from a given source, where necessary), an additional QA/QC review of 3-5 additional topics from that source was conducted by a new individual. If deemed consistent, no further review was needed. If deemed inconsistent, the source was further discussed with the full group of researchers.