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Preliminary Considerations Analysis of Offshore Wind Energy in Atlantic Canada

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Executive Summary

Canada has tremendous offshore wind resources that can contribute to its clean energy and climate objectives. In preparation for its future potential development in Canada, Natural Resources Canada (NRCan) has committed to advancing the collective understanding of spatial planning considerations for offshore wind energy. To this end, CanmetENERGY-Ottawa (CE-O), a federal laboratory within NRCan, undertook a preliminary analysis of relevant considerations for offshore wind, with an initial focus on Atlantic Canada. To conduct the analysis, CE-O used geographic information system (GIS) software and methods and engaged with multiple federal government departments to acquire relevant data and obtain insights from subject matter experts on the appropriate use of these data in the context of the analysis.

The purpose of this work is to support the identification of candidate regions within Atlantic Canada that could become designated offshore wind energy areas in the future. These areas would define the boundaries within which developers could bid on the rights to develop offshore wind projects. These candidate regions may be included in government-led regional assessments and may also become the focus of further characterization of various geophysical, socio-economic, and environmental considerations.

The study area for this analysis includes the Gulf of St. Lawrence, the western and southern coasts of the island of Newfoundland, and the coastal waters south of Nova Scotia. Twelve input data layers representing various geophysical, ecological, and ocean use considerations were incorporated as part of a multi-criteria analysis (MCA) approach to evaluate the effects of multiple inputs within a consistent framework. Six scenarios were developed to allow for visualization of a range of outcomes according to the level of influence accorded to the input layers and the elements within them.

This preliminary assessment resulted in the identification of several areas which could be candidates for future designated offshore wind areas, including areas of the Gulf of St. Lawrence off the western coast of the island of Newfoundland and north of Prince Edward Island (PEI), portions of the Northumberland Strait portions of Sable Island Bank, Middle Bank and Banquereau Bank off the southern coast of Nova Scotia, and sections of Browns Bank and Georges Bank. However, further work is needed to assess various additional factors not considered in this analysis including, but not limited to, temporal and cumulative effects, socio-economic considerations, provincial electricity policies, proximity to port facilities and interconnection points, correlation to domestic electricity demand profiles and opportunities for energy export.

This work is meant to serve as an initial analysis and does not constitute Government of Canada direction on the designation of offshore wind energy areas. NRCan encourages and welcomes other federal departments, provincial governments, Indigenous communities and governments, and other interested stakeholders to contribute further information to expand the collective understanding of spatial considerations for potential future offshore wind areas in Atlantic Canada.

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1. Introduction

Offshore wind offers an opportunity for a significant source of clean energy and has been successfully deployed by many countries around the world. Given the complexity of determining appropriate locations for offshore wind projects, many jurisdictions have conducted a range of spatial planning assessments to better understand the variety of human and ecological considerations in ocean spaces prior to establishing designated offshore wind areas and reviewing applications for development [1]. In the United States, the Bureau of Ocean Energy Management (BOEM), as part of its “Area Identification” process to establish Wind Energy Areas, assesses a variety of considerations to identify and exclude areas deemed to be incompatible with wind energy development. This initial screening work, which seeks to “identify suitable areas for wind energy leasing consideration through collaborative, consultative, and analytical processes” falls under the first phase of BOEM’s Wind Energy Commercial Leasing Process, called the Planning and Analysis Phase, which occurs in advance of the Leasing Phase [2]. In the United Kingdom, the Crown Estate has undertaken resource and constraint assessments to determine seabed areas with high technical potential and minimal constraints, generating “Characterisation Areas” in which detailed consideration and analysis work was subsequently performed. Through further classification and exclusions, “Bidding Areas” were established within which prospective developers could propose project sites through a series of “Leasing Rounds” [3].

In Canada, while interest has been expressed in offshore wind, no projects have been constructed to date. However, activities currently underway indicate that offshore wind developments will be given serious consideration in the future. For example, the Impact Assessment Agency of Canada has been tasked with undertaking regional assessments for offshore wind development in the provinces of Newfoundland and Labrador and Nova Scotia [4]. These two provinces, as part of a joint agreement with the federal government, have also announced an expansion of the mandate of the offshore petroleum boards in each jurisdiction to include the regulation of offshore renewable energy development and a renaming of the boards to reflect this new mandate [5][6].

NRCan has committed to advancing its understanding of spatial planning considerations for offshore wind energy in a Canadian context and to disseminate relevant findings to stakeholders. To support this goal, CE-O undertook a preliminary analysis of considerations for offshore wind in Atlantic Canada using geographic information system (GIS) software and methods. CE-O leveraged working relationships with multiple federal government departments to acquire relevant regional data and obtain insights from subject matter experts on the appropriate use of this data in the context of this analysis.

2. Objectives

The primary objective of this work is to support the identification, by means of a high-level analysis of available and geospatially referenced data, of candidate areas within Atlantic Canada that could become designated wind energy areas in the future. Should Canada follow a similar path as other jurisdictions that have proceeded with the development of offshore wind energy projects, these designated areas would define the boundaries within which developers would be allowed to bid on and receive exclusive rights to use the seabed and the overlying water column for future offshore wind projects. Recipients would then be positioned to apply to the lifecycle regulator for authorizations for site characterization, and project construction and operation activities. These candidate areas may be included in government-led regional assessments and may also become the focus of further characterization of various geophysical, social, and environmental considerations.

This work is meant to serve as an initial analysis and does not constitute Government of Canada direction on offshore wind energy development. NRCan welcomes other federal departments, provincial governments, Indigenous communities and governments, and other stakeholders to contribute further information to expand the collective understanding of spatial considerations for potential offshore wind projects in Atlantic Canada.

The intention is that this study will contribute to broader initiatives underway or upcoming, such as the Impact Assessment Agency of Canada's Regional Assessments in Nova Scotia and Newfoundland and Labrador, and the Marine Spatial Planning (MSP) process for Atlantic Canada led by Fisheries and Oceans Canada (DFO). Together with these efforts, this work is intended to improve the understanding of areas within Atlantic Canada that could be favourable for offshore wind development while balancing existing human activities and the need to protect marine ecosystems.

2.1 Study Area

The study area for this analysis, shown in Figure 1, covers roughly 540,000 km^2 and includes the Gulf of St. Lawrence, the western and southern coasts of the island of Newfoundland, and the southern coast of Nova Scotia, up to a distance of roughly 400 km from shore and water depth of 2000 metres. In an attempt to limit the overall size of the study area, several areas were omitted from this initial assessment. These include the St. Lawrence Estuary, which is expected to be more constrained due to significant vessel traffic, the Bay of Fundy, which may have additional physical constraints due to high tidal forces, and the eastern coast of the island of Newfoundland, whose distance from larger population centres and loads made this region a less likely candidate for offshore wind development. The primary focus of this study was on offshore wind for electricity generation, either for domestic use or for export. Offshore wind projects developed for other purposes, such as producing hydrogen for domestic use or for export to European markets, may be better situated in locations beyond the study area used here and should be examined as part of future studies. Saint Pierre and Miquelon, a territorial collectivity of France, shown in grey on the map in Figure 1, was excluded from the analysis [7].

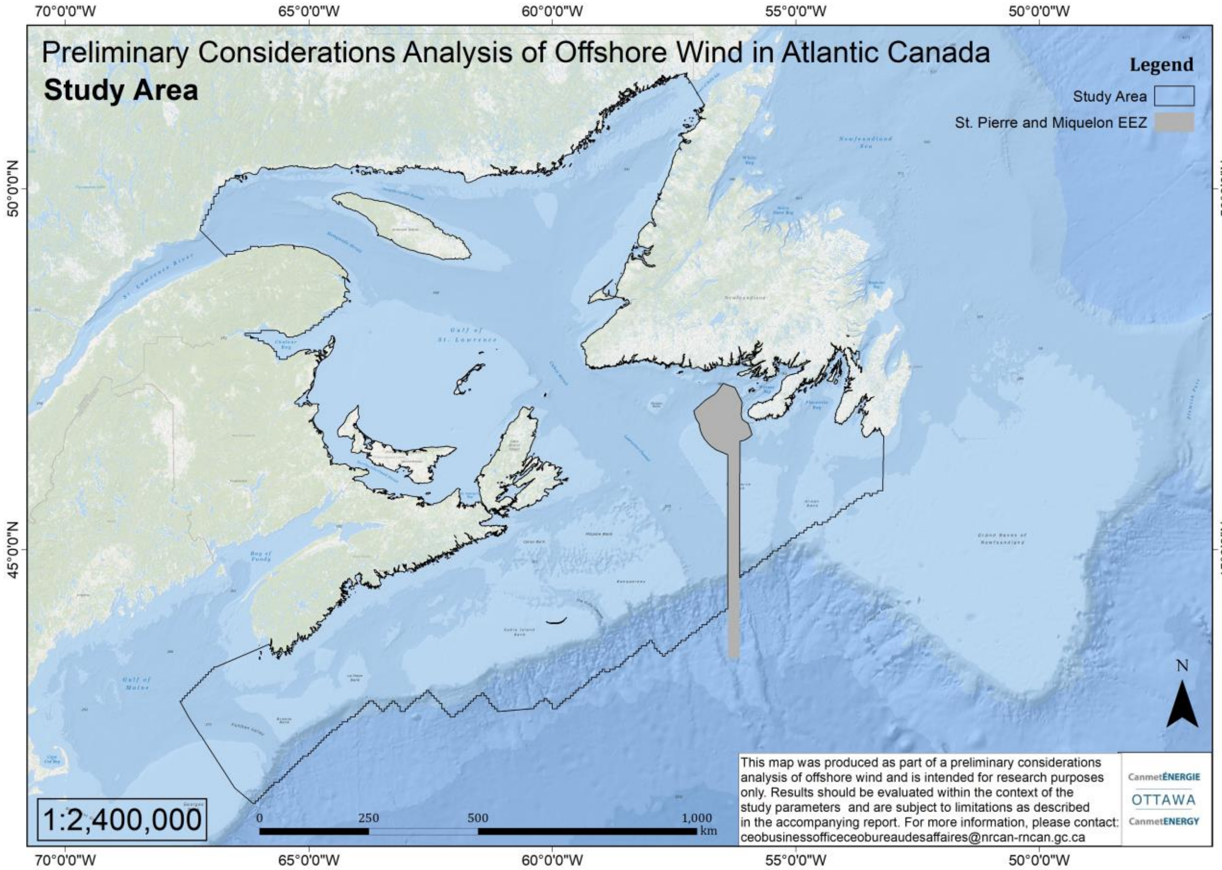

Figure 1: Study area used in the offshore wind considerations analysis. The Exclusive Economic Zone (EEZ) of the French territory of St. Pierre and Miquelon was omitted from the analysis.

3. Methodology

3.1 Overview

Multi-criteria analysis (MCA) is a commonly used technique to evaluate the effects of multiple inputs within a consistent framework and is frequently applied using Geographic Information System (GIS) methods to support environmental decision-making [8]. The MCA approach has been used previously by various jurisdictions to help identify designated areas for offshore wind and is often applied as part of marine spatial planning exercises. For example, the Marine Resources System employed by the UK's Crown Estate applied MCA techniques as part of offshore wind area definition [3].

For this analysis, CE-O adapted the MCA approach to conduct a preliminary considerations analysis to support the future identification of offshore wind areas in Atlantic Canada. This was accomplished by means of the Weighted Overlay tool within ESRI's ArcGIS software suite. As the inputs for the considerations analysis include a diversity of data layers, from physical properties such as bathymetry and geology to anthropogenic usage like vessel traffic, or environmental considerations such as marine habitat, a tool that facilitates a comparison of all inputs on the same scale was required. The Weighted Overlay tool accomplishes this by allowing a user to assign scores to data values within a given layer, and to assign an influence or weighting factor to the layer as a whole. For example, the input layers can be weighted equally, or they can be weighted differently to view the impact of a higher or lower influence of a particular layer or group of layers on the end result. Figure 2 provides a schematic of the weighted overlay process used in the analysis.

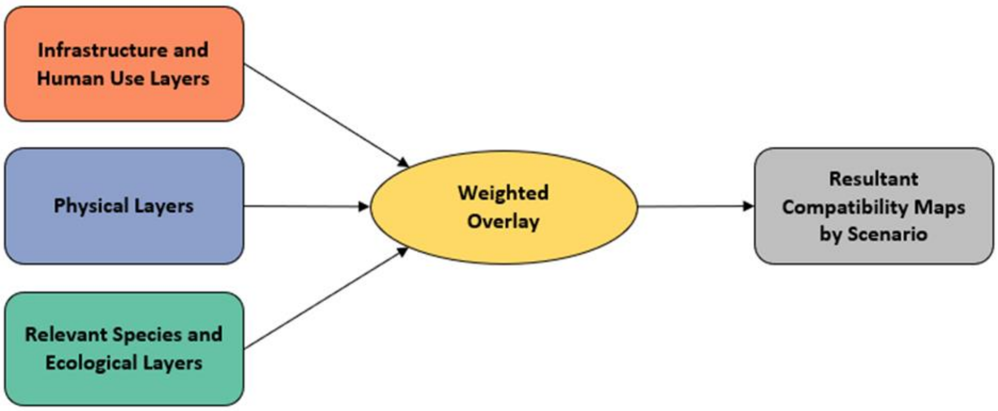

Figure 2: Weighted Overlay process diagram.

In this analysis, twelve primary geospatial data layers representing various physical, ecological, and ocean use considerations were used as inputs to the Weighted Overlay procedure. These datasets were procured through public repositories or were provided to CE-O by federal stakeholders. These data layers, listed in Table 1, represent key considerations expected to be relevant for potential future offshore wind projects in Atlantic Canada. These layers were grouped into three main categories: Infrastructure and Human Use, Physical, and Relevant Species and Ecological Areas. Many of the primary input layers were formed by combining multiple datasets; further details on the composition of each data layer can be found in Section 3.5.

Table 1: Data layers used in the analysis.

Layer No.	Layer	Description	Category
1	Vessel Density	Shipping vessel traffic obtained through satellite-based Automatic Identification System (AIS) in units of vessels per day per km^2	Infrastructure and Human Use
2	Ocean Usage	Known ocean space uses for transportation (e.g. traffic separation zones, ferry routes), infrastructure (e.g. pipelines, cables) and others	
3	Fishing Effort	Cumulative fishing intensity over a 15-year period derived from combined Vessel Monitoring System (VMS) and logbook data, expressed as a percentile	
4	Inshore Lobster	Composite catch weight for the Maritimes Region Inshore Lobster fishery over the period 2015-2019, in units of kg/km^2	
5	Distance from Coast	Distance from the coastline of the four Atlantic provinces' (NB, NS, PE, NL) mainland, excluding other islands, in nautical miles	Physical
6	Geology	Classification of seabed areas in accordance with expected compatibility with different offshore wind foundation types	
7	Ice Cover	Median ice concentration (percentage of an area covered with sea ice during a given time of year)	
8	Water Depth	Water depth at a given ocean location, in metres	
9	Wind Speed	Average annual wind speed at 100 metres above sea level, in m/s	
10	Defined Ecological Areas	Compilation of six areas: Significant Benthic Areas (SiBA), Areas of Interest (AOI), Marine Protected Areas (MPA), Other Effective Area-Based Conservation Measures (OECM), Species at Risk Act (SARA) Designated Critical Habitats, and Ecologically and Biologically Significant Marine Areas (EBSA)	Relevant Species and Ecological Areas
11	Important Habitat	Areas identified by federal stakeholders as important habitat for key species, but not currently designated as Species at Risk Critical Habitat	
12	Risk to Marine Birds	Estimated species-specific sensitivity to offshore wind development, compiled from sea survey data, tracking data and the draft Sea Duck Key Sites Atlas	

Six different scenarios were developed for this analysis, as listed in Table 2. The scenarios are intended to establish a range of outcomes to demonstrate how the perceived compatibility of offshore wind in a particular location can be affected by the value placed on different considerations. While each scenario used the same set of input layers, the influence assigned to each layer as well as the scoring of elements within the layers, were varied. Additional details of the layer influence factors assigned to each scenario are described in Section 3.6. Each scenario produced a corresponding resultant map which are presented and discussed in Section 4.

Table 2: Overview of scenarios developed for the analysis.

Scenario No.	Scenario Name	Description
1	Baseline	Intended as a well-balanced scenario to which other scenarios can be compared. The three categories of consideration layers (Infrastructure, Physical and Ecological) were weighted equally.
2	Infrastructure and Human Use Influence	Layers in the Infrastructure and Human Use category given a total of 50% weighting with the remainder split between the other two categories
3	Physical Influence	Layers in the Physical category given a total of 50% weighting with the remainder split between the other two categories
4	Relevant Species and Ecological Influence	Layers in the Relevant Species and Ecological Areas category given a total of 50% weighting with the remainder split between the other two categories
5	Restricted	Intended to represent a conservative approach to wind energy area designation, where considerations that could create significant conflict with various stakeholders were given reduced scoring
6	Floating Wind	Intended to depict favourable areas for floating turbine foundations, as opposed to fixed bottom

3.2 Application of the Weighted Overlay

The Weighted Overlay tool allows the user to adjust two sets of parameters – the influence factor, which affects the significance of each layer relative to the other layers, and the compatibility score, which applies to data categories or bins within a given layer.

3.2.1 Influence Factor

Within each scenario, each input layer was assigned an influence factor, as a percentage ranging from 0% to 100%, representing the layer's level of significance relative to the other input data layers. The sum of the influence factors for each scenario totaled 100%. Details of the influence factor assigned to each layer, for each scenario, are presented in Section 3.6.1.

3.2.2 Compatibility Score

Within each of the twelve input data layers, each categorical value or bin was given a compatibility score ranging from 0 to 9, where a score of 0 corresponds to being *least compatible* with offshore wind development and a score of 9 corresponds to being *most compatible*. A visual representation of the compatibility scale is shown in Figure 3. Compatibility scores for each input layer, and for each scenario, were selected through a combination of stakeholder input, a review of offshore wind siting practices in other jurisdictions, and a critical assessment of existing wind energy technologies in a Canadian context. Further details on the selection of compatibility scores are provided in Section 3.6.

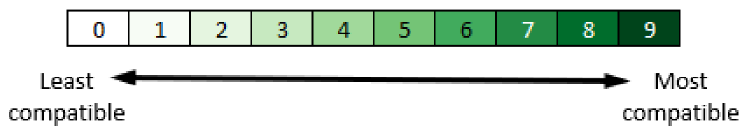

Figure 3: Compatibility scale used in the analysis

3.3 Data Sources and Stakeholder Engagement

In 2020, CE-O initiated a series of federal stakeholder engagement activities to support offshore wind considerations mapping in Atlantic Canada. The goals of the engagement were to obtain relevant data for the considerations analysis, gain perspectives from subject matter experts on the appropriate use of the data, and to provide information to stakeholders on offshore wind projects and technologies deployed in other countries and begin discussing their potential relevance to Canada.

Stakeholders consulted included representatives from the Fisheries and Oceans Canada (DFO), Environment and Climate Change Canada (ECCC), Transport Canada, Parks Canada Agency, Infrastructure Canada, the Canada Energy Regulator (CER), the Canada Nova Scotia Offshore Petroleum Board (C-NSOPB) and the Canada Newfoundland & Labrador Offshore Petroleum Board (C-NLOPB). Activities undertaken include an initial stakeholder survey and dissemination of preliminary results, followed by a second round of engagement with targeted discussion sessions. Each activity is briefly described below.

3.3.1 Stakeholder Survey and Initial Results

An initial survey was circulated to federal stakeholders in October 2020 to gain insights on how different offshore wind considerations could intersect with various departmental mandates, and on available data that could inform the analysis. Survey responses were compiled alongside information from other jurisdictions into a single framework. Initial scenarios were developed, and preliminary compatibility maps were generated for discussion.

3.3.2 Second Round of Engagement

Through a series of follow-up meetings with stakeholder groups from April-May 2021, and a presentation at the Atlantic Coordination Table (ACT) on June 3, 2021, feedback was obtained on the initial scenarios and compatibility maps. While feedback on the methodology of the study was mostly positive, some uncertainty and differing recommendations were expressed on the treatment of certain considerations in the analysis, particularly the treatment of important species and ecologically relevant areas. Various defined ecological areas were identified with potential relevance to offshore wind within the study area, including Significant Benthic Areas (SiBAs), Areas of Interest (AOIs), Marine Protected

Areas (MPAs), Other Effective Area-Based Conservation Measures (OECMs), Species at Risk Critical Habitat, and Ecologically and Biologically Significant Areas (EBSAs). It was recognized that further discussion through a multi-departmental workshop could help to resolve the question of how to treat these different areas within the context of the analysis.

3.3.3 Ecological Workshop

A dedicated workshop on ecological considerations was held with representatives from various groups within DFO and ECCC in June 2021. Existing work on the considerations analysis was presented before discussing how to proceed. During the discussion, it was acknowledged that attempting to represent the full breadth of ecological risk posed by offshore wind developments was outside of the scope of this analysis and would require more baseline and site-specific research to properly assess. For this analysis, ecological considerations were proposed to be re-framed from the perspective of developer risk such that areas established through legislation, such as MPAs and Critical Habitat areas, would be scored as less compatible with offshore wind than areas without legislation, such as EBSAs.

3.3.4 Incorporation of Feedback and Data

Datasets provided and referenced by federal stakeholders, and feedback on methodology was incorporated into the analysis to the greatest extent possible. This was reflected in the development of the six scenarios presented in this report and the associated influence factors and compatibility scores applied to each input layer.

3.4 Data Format

Geospatial information can be represented by several data types including vectors and raster images. Vectors are defined by ESRI as “a coordinate-based data model that represents geographic features as points, lines, and polygons”, while the definition for raster is “a spatial data model that defines space as an array of equally sized cells arranged in rows and columns and composed of single or multiple bands. Each cell contains an attribute value and location coordinates” [9]. The Weighted Overlay tool can only accept input data layers in raster format. Any data layers that were not originally in raster format were converted from vector to raster format using the conversion tool within ArcMap. Raster layers were re-sampled as necessary so that each of the primary layers used as inputs to the Weighted Overlay procedure had a consistent cell size of 2000 m by 2000 m (4 km^2). When converting from a polygon with finer resolution than 2000 m x 2000 m to a raster, there is an inevitable loss of information that occurs along the boundary of the shape, which can result in a “sawtooth” pattern. Given the preliminary nature of this analysis and the large size of the study area, this effect is expected to have limited influence on the overall results of the study but should be examined further in smaller regional assessments where such information loss may have more significance. Any data outside of the study area shown in Figure 1 were excluded from the analysis.

3.5 Data Layer Composition and Classification

Input data layers used in this analysis can be separated into two main types: categorical data, where the value of each raster cell is assigned to a discrete category, and continuous data, where values vary continuously throughout the layer. Five of the input layers consisted of categorical data (Ocean Usage, Geology, Defined Ecological Areas, Important Habitat and Risk to Marine Birds), while the remaining seven layers consisted of continuous data. Several of the continuous data layers were re-classified into bins, in order to reduce the number of different values and thereby facilitate their use in the Weighted Overlay. In GIS terms, the data categories or bins within each layer are called raster classes, but in this analysis they are referred to as layer elements for simplicity. Maps of the individual input layers, along with descriptions detailing how any re-classification was performed, are provided below.

3.5.1 Vessel Density

The vessel density layer, provided by DFO, contains ocean vessel traffic data in the form of vessels per km^2 per day, with a resolution of 1 km x 1 km. Data was obtained through Satellite-based Automatic Identification System (AIS) and covers a one-year time period from January 1, 2019 to December 31, 2019 [10]. The original dataset included five categories of vessels: Cargo, Fishing, Passenger, Tanker and Other. For this analysis, the Fishing category of vessels was removed to avoid duplication with the Fishing Effort layer. CE-O re-classified the original DFO dataset into nine bins using the Jenks Natural Breaks classification method [11]. The re-classified layer is shown in Figure 4.

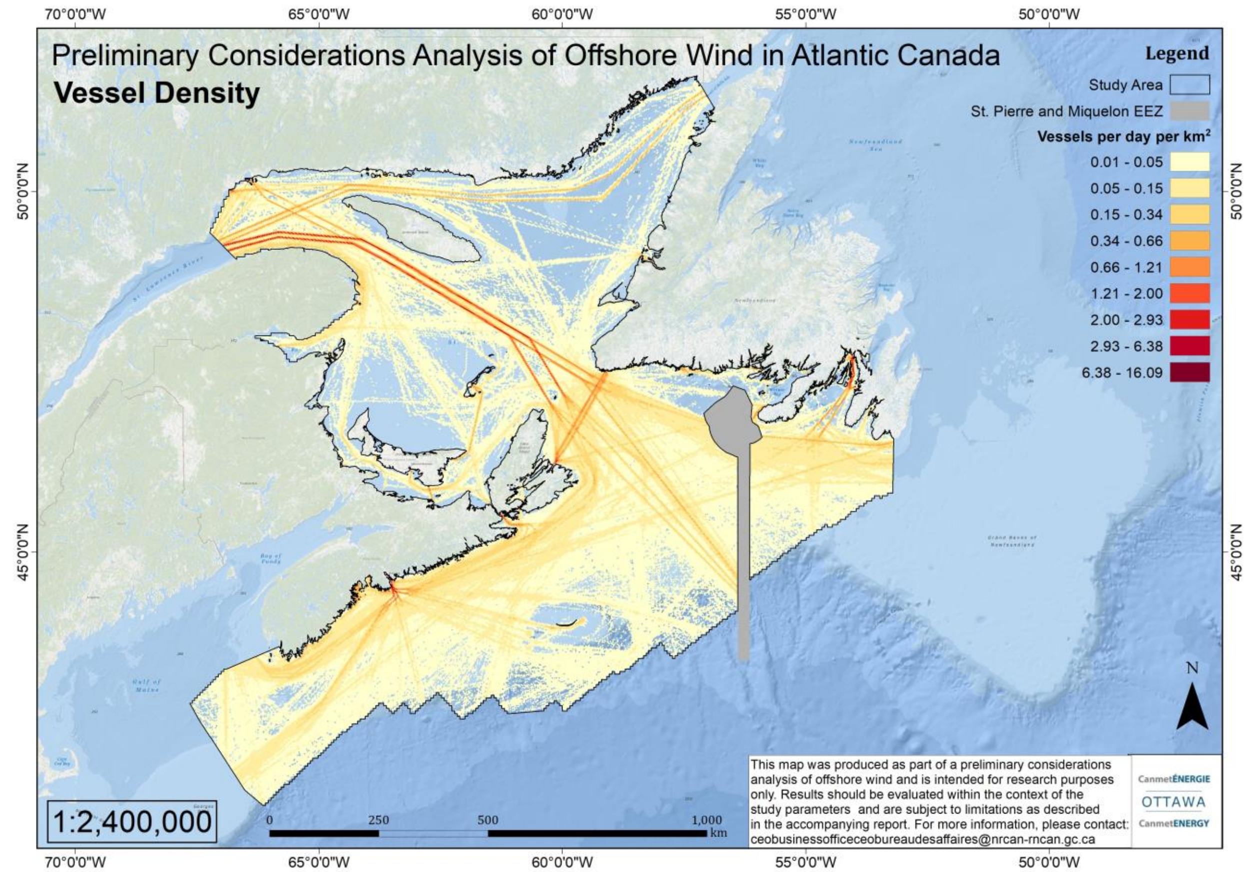

Figure 4: Vessel Density input layer in vessels per day per km^2, reclassified into nine bins.

3.5.2 Ocean Usage

The ocean usage input layer shown in Figure 5 contains ten distinct elements, and was compiled by CE-O using data obtained from the Canadian Hydrographic Service (CHS) [12], specifically two nautical charts, V-ATL-A Gulf of St. Lawrence, and V-ATL-B Nova Scotia – Bay of Fundy, which together cover the study area. Ten different ocean uses were included in this layer: Marine Farms, Obstructions, Pipelines, Active Submarine Cables, Donkin Coal Block, Dumping Grounds and Wrecks. Submarine cables were verified against the TeleGeography database [13] to determine which are in active use. Non-active cables were removed from the analysis. Buffer distances around the various elements in the layer, informed by practices in other jurisdictions [1], were applied as follows: five nautical miles around pipelines, two nautical miles around ferry routes and traffic separation zones, and one nautical mile around the remaining elements.

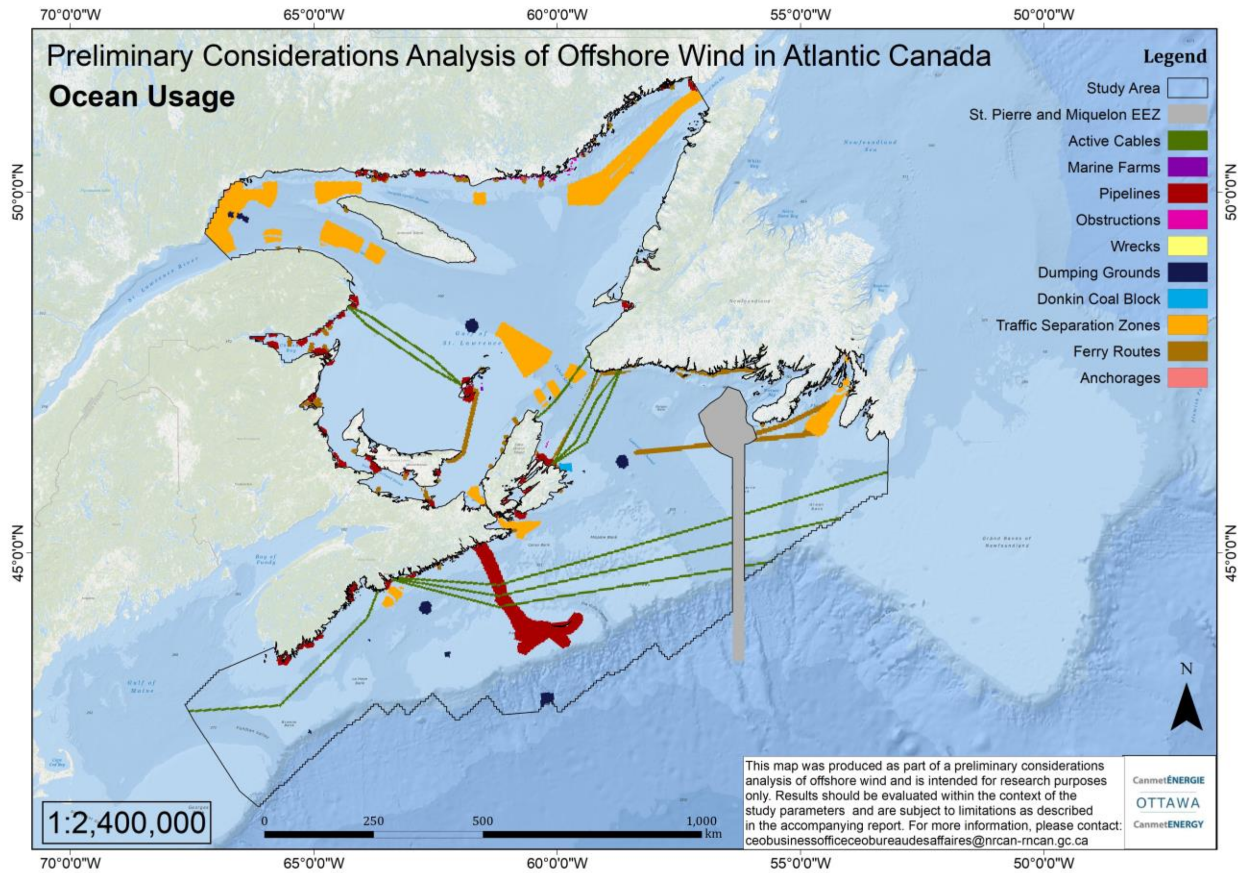

Figure 5: Ocean Usage input layer, with 10 categories of infrastructure and human use considerations.

3.5.3 Fishing Effort

The fishing effort layer, shown in Figure 6, was compiled from the Eastern Canada inter-regional, merged fisheries VMS/Logbook dataset for 2005-2019 [14]. This layer includes all fisheries, and all gear types (fixed and mobile), and combines data from three regions (Newfoundland Labrador, Scotian Shelf and Gulf of St. Lawrence). Data is expressed in the form of percentiles, where the value of each cell in the raster layer contains a value of 0 to 100 representing the cumulative intensity of effort in that cell over a 15-year period. Low numbers represent high effort intensity, and high numbers represent low effort intensity. Additional information on this layer is contained in an accompanying research document [15]. Data was reclassified by CE-O into nine bins using the Jenks Natural Breaks technique [11].

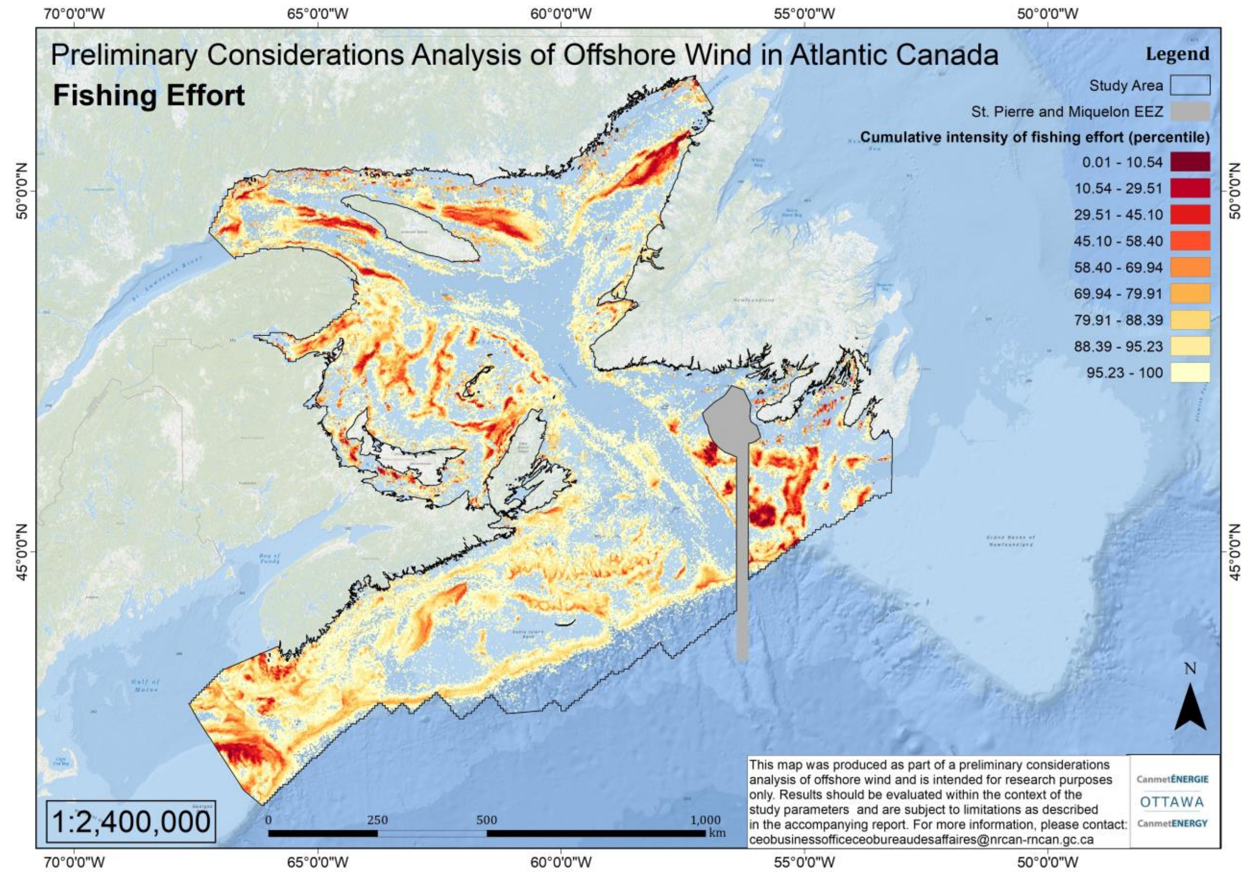

Figure 6: Fishing Effort input layer, expressed as cumulative intensity of fishing effort in percentile. Combined VMS/logbook data from 2005-2019. Includes all fisheries, and both mobile and fixed gear. Low numbers represent high fishing effort intensity, and high numbers represent low fishing effort intensity.

3.5.4 Inshore Lobster

The Inshore Lobster layer, shown in Figure 7, was compiled from the Maritimes Region Inshore Lobster dataset, which comprises composite lobster catch weight standardized by area (kg/km^2) over the period 2015 to 2019 [16]. The dataset contains five bins of increasing catch weight and was not reclassified for this analysis. Lobster catch data were not available for the other two DFO Regions intersecting the study area (Gulf and Newfoundland-Labrador) at the time of study but are under development and should be incorporated into future studies.

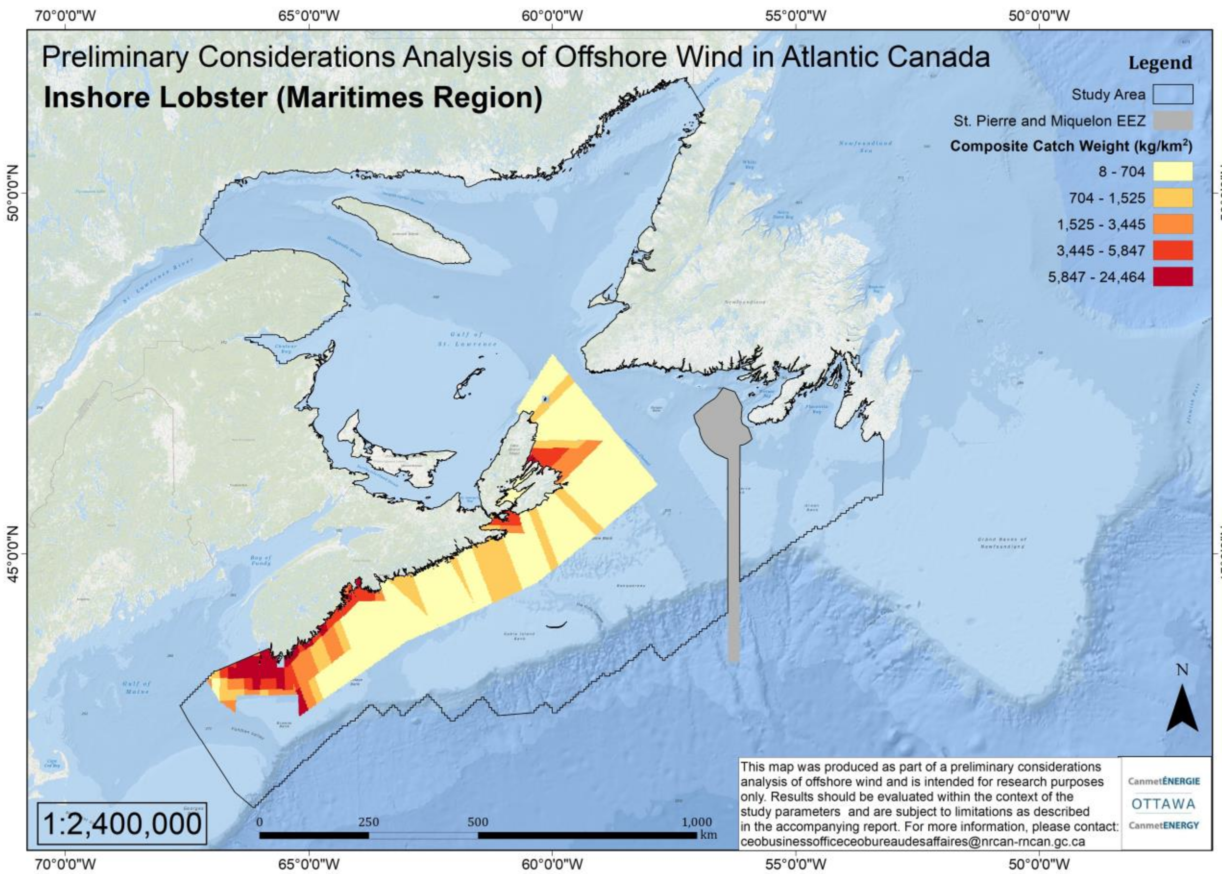

Figure 7: Inshore Lobster input layer, expressed as composite catch weight standardized by area (kg/km^2) for the Maritimes Region Inshore Lobster fishery, 2015-2019.

3.5.5 Distance from Coast

The Distance from Coast layer, shown in Figure 8, was created using a reference coastline boundary shapefile [17]. Distance offsets, or buffers, were applied to the coastline to create four bins of increasing distance from shore, measured in nautical miles. The purpose of this layer was to evaluate how project cost and complexity can vary with distance from electricity grid interconnection points and large port facilities. Therefore, any islands within the study area were removed before buffers were applied, except for Prince Edward Island and Cape Breton Island, which have large populations compared to the smaller islands, are relatively close to the Nova Scotia and New Brunswick mainland and could conceivably host an interconnection site.

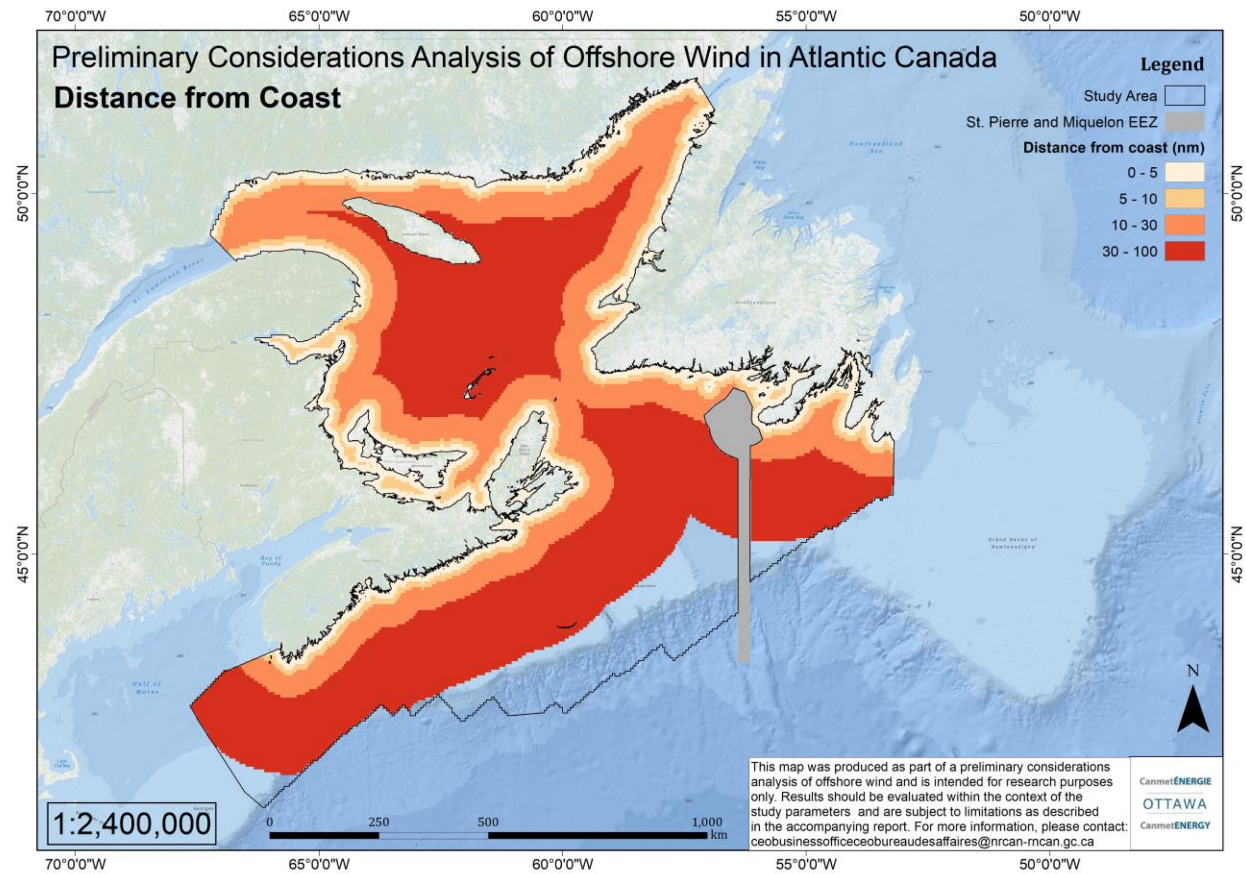

Figure 8: Distance from Coast input layer. Distances in nautical miles from the nearest coastline, with all islands besides Prince Edward Island and Cape Breton Island removed.

3.5.6 Geology

The Geology input layer, shown in Figure 9, was provided by the Geological Survey of Canada (GSC) for the purpose of this analysis, and represents a high-level characterization of the seabed within the study according to the expected compatibility with different offshore wind foundation types [18]. The layer includes five foundation technology compatibility categories. The Subsurface category is expected to be only compatible with fixed-bottom foundation types which penetrate the ocean floor, such as monopiles and jacketed foundations. The Gravity category is expected to be only compatible with foundations that rest on top of the ocean floor such as gravity base and suction caisson foundation types. The Gravity or Subsurface category could conceivably accommodate either Gravity or Subsurface fixed-bottom foundation types. The Floating Only category depicts areas that are likely not compatible with fixed bottom foundations but that could be amenable to floating foundation anchors, depending on further developments in anchors and moorings, and additional geological data collection in these areas. The "Challenges" category applies to areas where the presence of geohazards, high slopes, or a heterogenous seabed present challenging conditions to either fixed or floating foundations, or where there was insufficient data available to classify these areas into one of the defined categories.

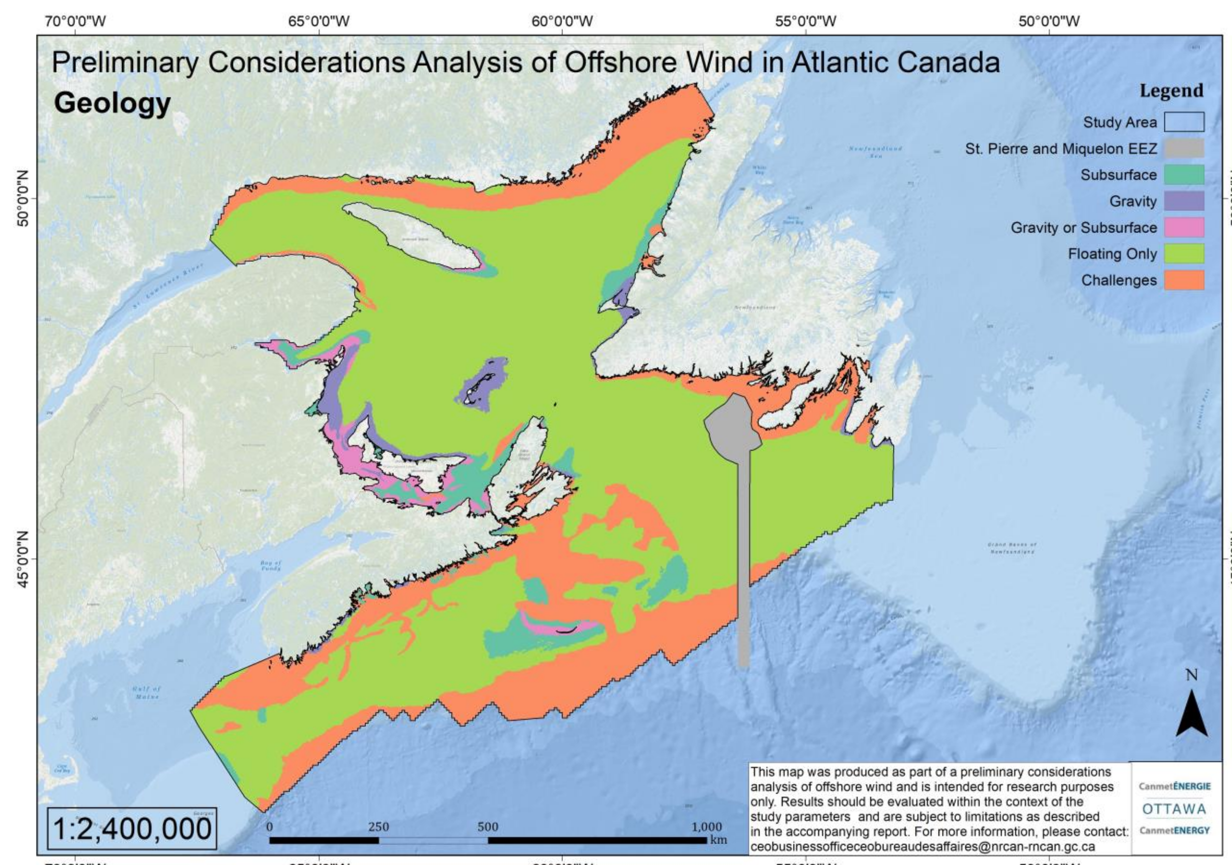

Figure 9: Geology input layer, based on preliminary assessment of compatibility of subsea geological characteristics to common wind turbine foundation types completed by GSC.

3.5.7 Ice Cover

The Ice Cover input layer shown in Figure 10 was generated using data from the Canadian Ice Service (CIS) [19]. Data is presented in the form of Median Ice Concentration, or the percentage of an area that is covered with sea ice at a given time during the year. This data was available from CIS at weekly intervals. The week of March 5th was selected for this analysis as it showed the greatest sea ice extent in the Atlantic region compared to any other week and was intended to represent the highest degree of potential conflict with offshore wind farms. Data was re-classified by CE-O into eight bins of increasing ice concentration.

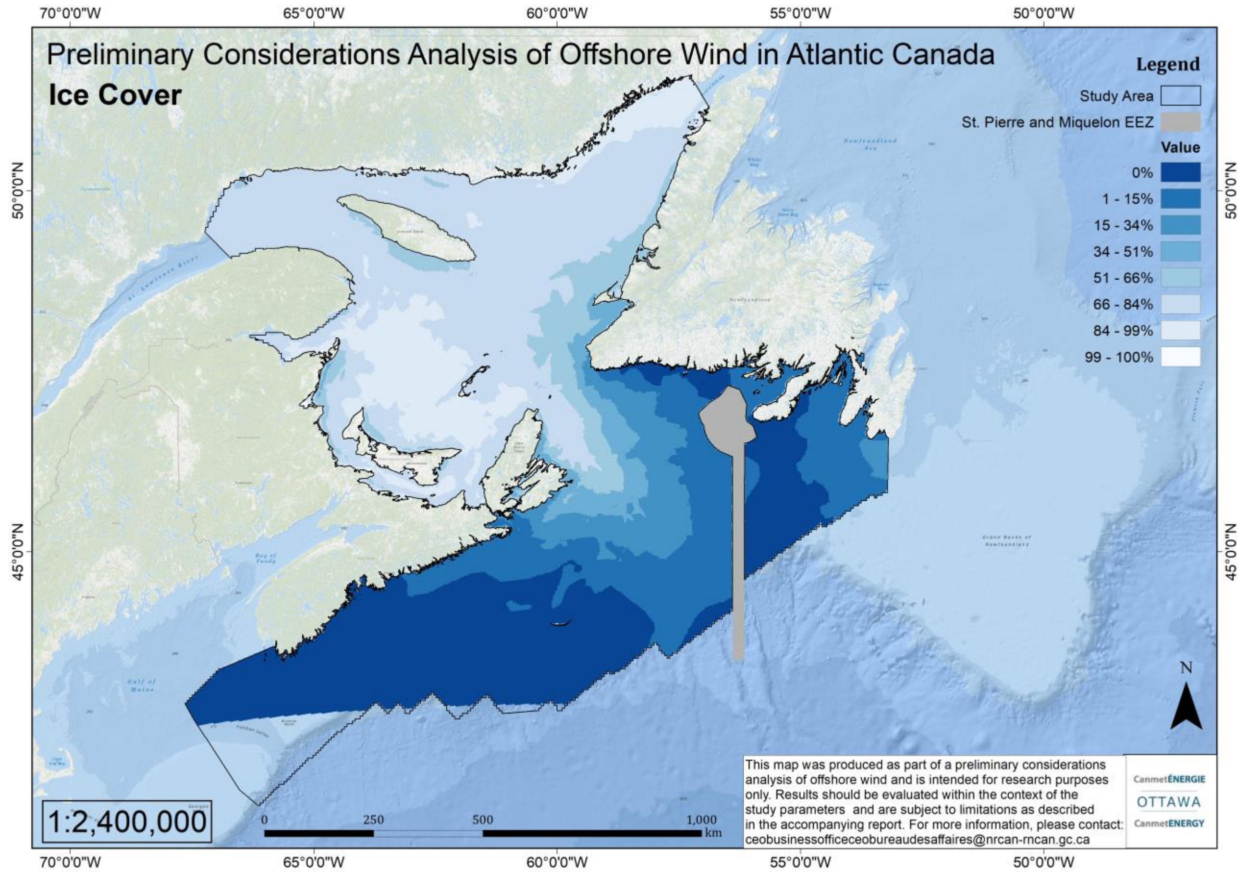

Figure 10: Ice Cover input layer, comprising median ice concentration from 1981-2010 during the week of March 5th.

3.5.8 Water Depth

The Water Depth layer, shown in Figure 11, was compiled using data obtained from the General Bathymetric Charts of the Ocean published by the British Oceanographic Data Centre [20]. Data was re-classified by CE-O into six bins for this analysis, ranging from 0 to 5464 metres below sea level.

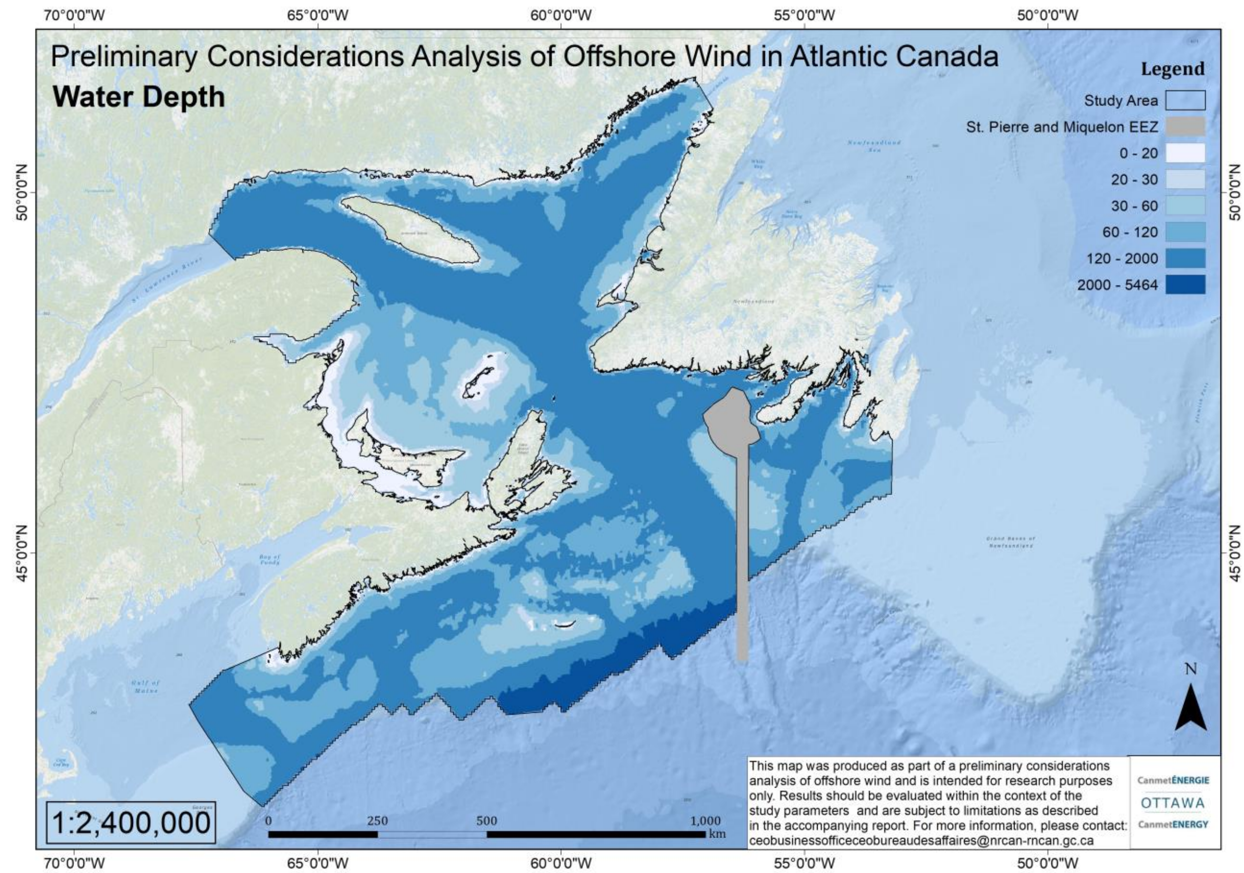

Figure 11: Water Depth input layer comprising water depth in metres, classified into six bins.

3.5.9 Wind Speed

The Wind Speed layer, shown in Figure 12, was compiled using average annual wind speed point data obtained from the Wind Atlas of Canada [21]. The data was transformed into raster format and re-classified by CE-O into five bins ranging from four to 12 metres per second.

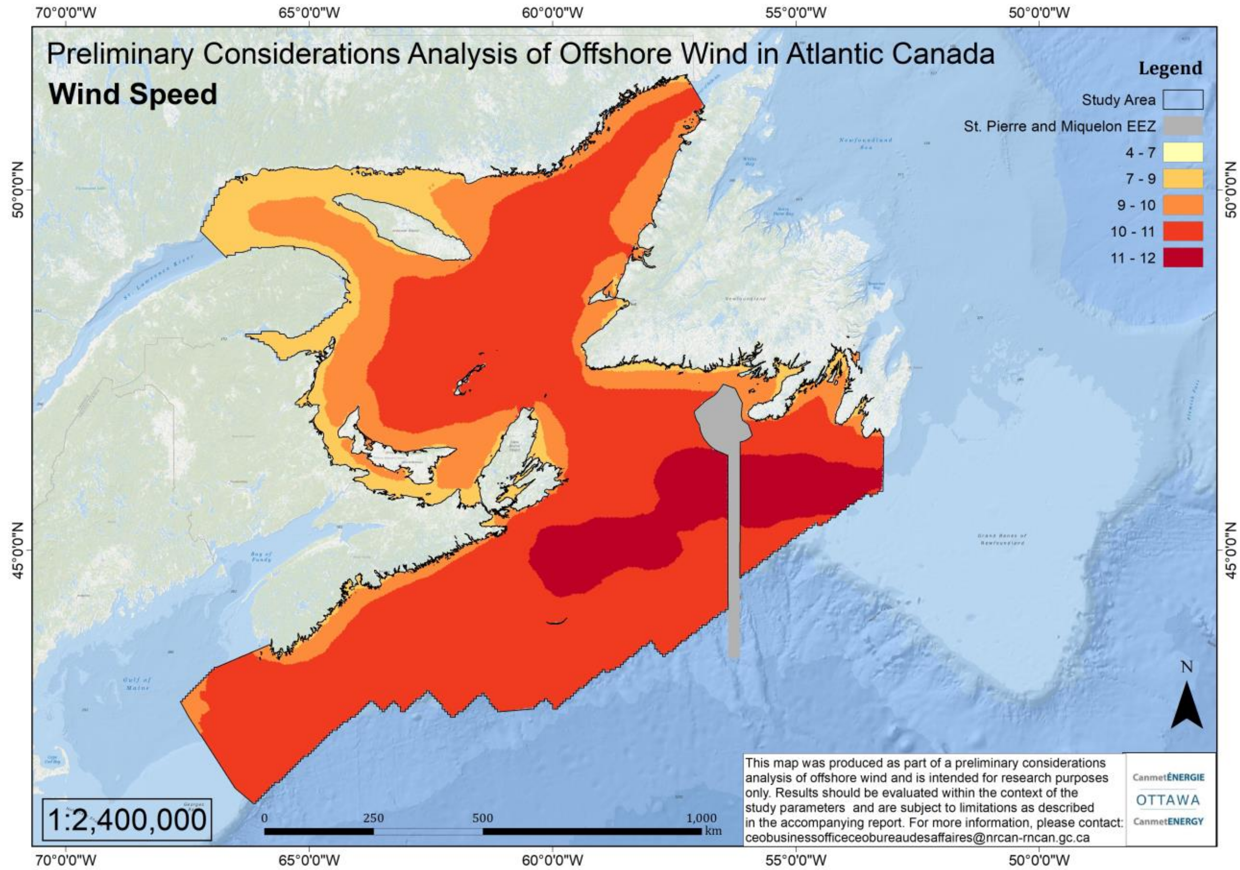

Figure 12: Wind Speed input layer, consisting of average annual wind speed at 100 metres above sea level, measured in metres per second, classified into five bins.

3.5.10 Defined Ecological Areas

The Defined Ecological Areas input layer shown in Figure 13 was compiled from data associated with six different categories: Significant Benthic Areas (SiBAs) [22], Areas of Interest [23], Marine Protected Areas (MPAs) [24], Other Effective Area-Based Conservation Measures (OECMs) [25], DFO Species at Risk (SAR) Critical Habitat [26], and Ecologically and Biologically Significant Marine Areas (EBSAs) [27]. Five MPAs were identified within the study area: Banc-des-Américains, Laurentian Channel, St. Anns Bank, Gully, and Basin Head. A total of 28 OECMs were identified, spanning four DFO bio-regions (Quebec, Gulf, Maritimes, and Newfoundland and Labrador). For the purpose of this analysis, a one nautical mile buffer around the Sable Park Island National Reserve, where petroleum work or activity is currently prohibited under the Canada National Parks Act [28], was included under the OECM layer. Areas of DFO SAR Critical Habitat for four species were included: Spotted Wolffish [29], Northern Wolffish [30], Northern Bottlenose Whale [31] and North Atlantic Right Whale [32]. Four classes of SiBAs were identified: Large and Small Gorgonians, Sea Pens, and Sponges. Two AOIs were identified: Fundian Channel-Browns Bank and Eastern Shore Islands. Shediac Valley, an area within the Gulf of St. Lawrence bio-region off the coast of New Brunswick, was previously designated as an AOI, but is no longer an AOI in practice according to DFO. There were 71 EBSAs identified that are situated fully or partially within the study area – nine in the Gulf Region [33], 56 in the Maritimes Region [34], and six in the Newfoundland and Labrador Region [35]. In cases of overlap between ecological layers, those with legislative backing (MPAs, OECMs and Critical Habitat) were given priority in this analysis, and these areas appear on top in Figure 13. The order of priority in the map image is as follows: MPAs, OECMs, DFO SAR Critical Habitat, SiBAs, AOIs and finally EBSAs. Additional maps showing the individual elements of this layer are shown in Appendix B.

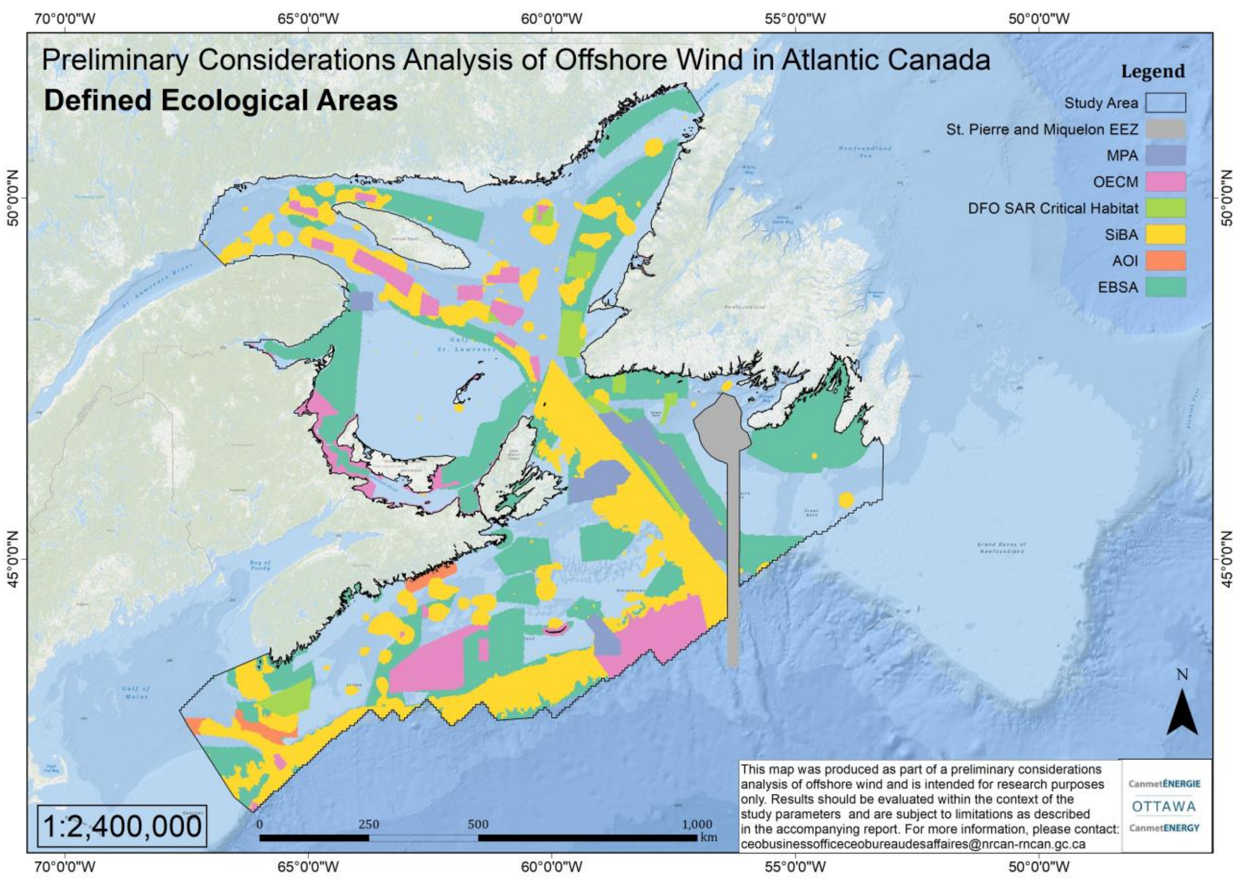

Figure 13: Defined Ecological Areas input layer containing six different types of designated areas.

3.5.11 Important Habitat

The important habitat layer, shown in Figure 14, contains critical habitat for migratory birds and a buffer around that habitat, important habitat for whales and turtles, and important spawning areas. The composite raster layer contains six categories, as shown in the map. Locations of Atlantic Herring spawning grounds in spring and fall were provided by DFO Gulf Region for this analysis in the form of point data, and were converted into polygons by CE-O using a buffer of 2 km. Leatherback Turtle Habitat data was provided by the Marine Planning and Conservation Aquatic Ecosystems Branch of DFO [36]. A polygon representing important areas for Blue Whale feeding, foraging and migration was obtained from the Open Data portal [37]. Important habitat for Northern Bottlenose Whales that is additional to the DFO SAR Critical Habitat polygon was also included here [38]. The migratory bird polygon was prepared by the Canadian Wildlife Service, ECCC, for use in this analysis, and delineates important habitat for five migratory bird Species at Risk present in the study area that use marine waters and that are protected under the Migratory Birds Convention Act (MBCA): Roseate Tern, Piping Plover, Bank Swallow, Red Knot, and Horned Grebe [39]. The polygon includes buffered areas around proposed and currently defined critical habitat extending to the marine zone, buffered areas around fall and spring stopover sites and additional marine areas predicted to be important foraging habitat based on colony location and foraging ranges informed by tracking data. In cases of overlap between migratory bird Species at Risk and aquatic species polygons, the aquatic species were positioned on top in the raster layer, however both categories were given equal compatibility scores in every scenario in this study.

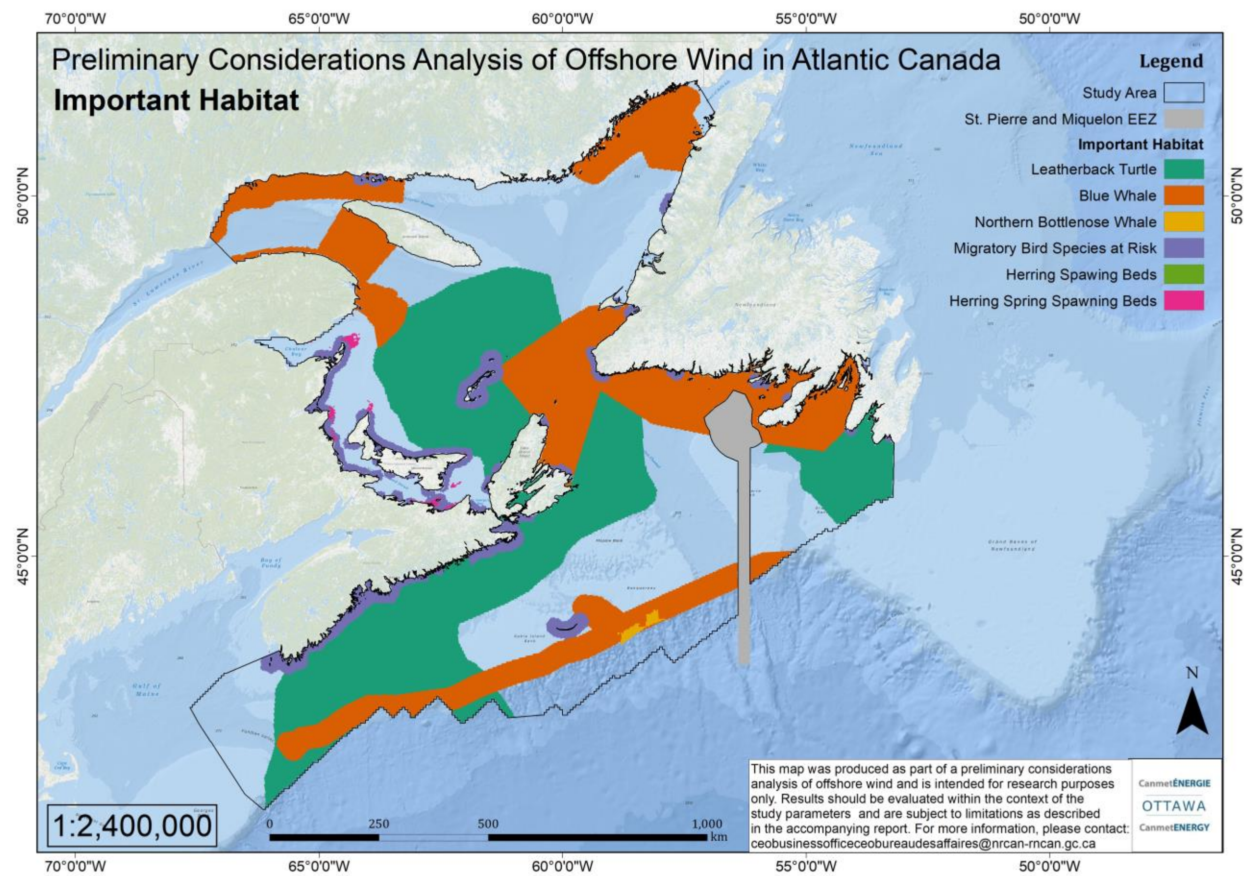

Figure 14: Important Habitat input layer, including migratory bird species at risk and marine species (cetaceans, turtles and fish).

3.5.12 Risk to Marine Birds

Understanding the spatial distribution of marine birds at sea, including key migratory routes and important foraging, staging and moulting areas can reduce the risk of interactions between migratory birds and offshore wind turbines [40]. Given the significant potential for interactions with marine birds to constrain development of offshore wind farms, as evidenced by other jurisdictions [41], a dedicated layer was developed for marine birds in this analysis. Migratory bats are another source of potential conflict with offshore wind [42] but were not included in this analysis due to lack of available data.

The Risk to Marine Birds layer shown in Figure 15 was prepared by the Canadian Wildlife Service, ECCC, specifically for use in this analysis. The layer addresses important foraging, staging and moulting areas, the latter being specific to sea ducks, and to some extent migratory routes of marine birds. To identify marine areas of very high, high and moderate risk to marine birds from offshore wind development, occurrence and density (i.e. vulnerability) of marine birds and species-specific sensitivity to offshore wind development were considered. Species considered in the risk layer were those considered moderate, high or very high risk to offshore wind in recent peer-reviewed literature: Northern Gannet, Black-legged Kittiwake, Red-throated Loon, Razorbill, Common Eider, gulls, murres, terns and scoters. To quantify the high use areas of sensitive species, three sources of information were used: at-sea survey data from the Atlas of Seabirds at Sea [43], tracking data including predictive foraging layers during the breeding season [44], and the Sea Duck Key Sites Atlas [45]. The Sea Duck Key Habitat sites delineates important habitats for sea ducks, which are not adequately captured in at-sea surveys and for limited tracking data were available.

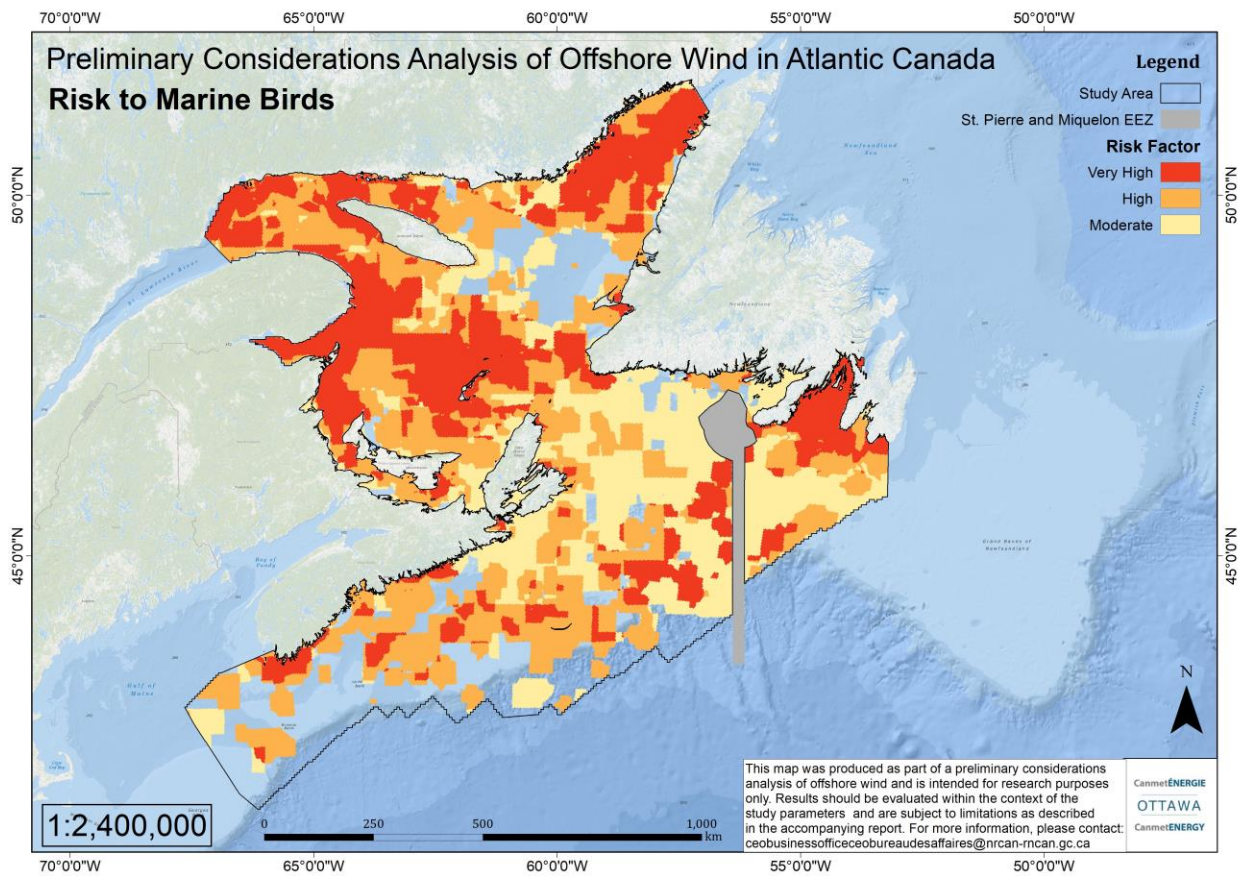

Figure 15: Risk to Marine Birds input layer, prepared by CWS for use in this study, classifying ocean areas into three categories of risk of offshore wind to marine birds.

Tracking data helps to identify important marine areas for marine birds during the winter, a time period for which at-sea survey effort is limited. At-sea survey data ensures non-breeding marine birds and those from all potential colonies are considered since tracking data only includes those breeding birds from limited numbers of colonies. Separate maps from each data source were produced by considering high marine use and sensitivity to offshore wind. These three maps were summed to produce the final risk map in Figure 15 with risk levels defined by terciles. This map therefore reflects areas where multiple data sources indicated high risk to marine birds.

3.6 Scenario Development

3.6.1 Influence Factors

To examine the effects of the significance attributed to each consideration layer on the resultant offshore wind compatibility maps, six different scenarios were developed, as listed in Table 2. The influence factors assigned to layers within each scenario are provided in Figure 16. Tabular values of influence factors are provided in Appendix A, along with compatibility scores for each scenario and layer.

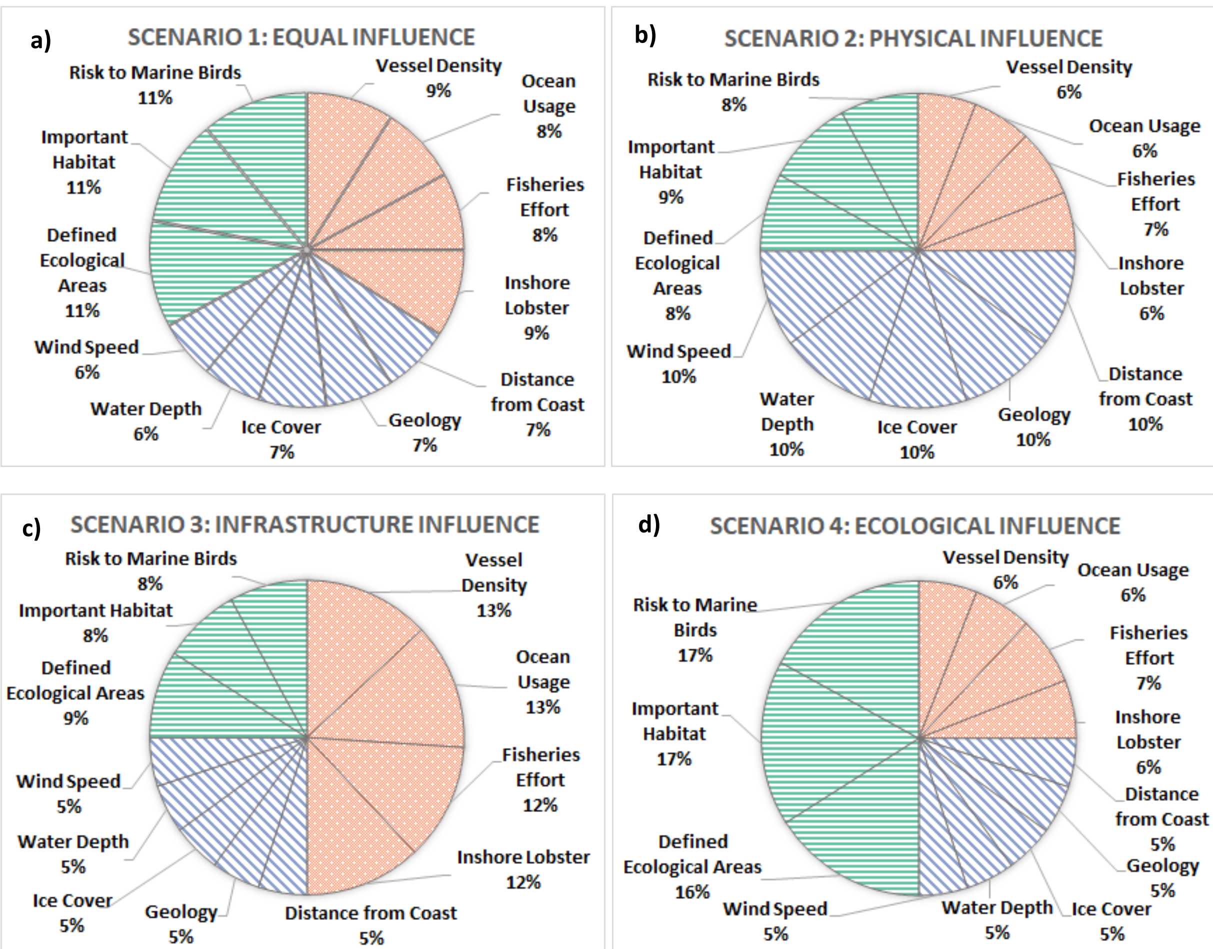

Figure 16: Influence factors used in the analysis: a) Equal Influence was applied to Scenarios 1, 5 and 6, b) Physical Influence was applied to Scenario 2, c) Infrastructure Influence was applied to Scenario 3, d) Ecological Influence was applied to Scenario 4. Colours and shading indicate the layer category: Infrastructure and Human Use (red, dotted), Physical (blue, diagonal stripes), and Relevant Species and Ecological Areas (green, horizontal stripes).

Scenarios 1 to 4 have the same compatibility scoring applied within the input layers but differ in the weighting factors applied to the input layers themselves. Scenarios 1 to 5 give preference to fixed-bottom wind turbine foundations, with compatibility scores applied to favour shallower depths and areas of the seabed with deeper sediments. Scenario 6, on the other hand, is intended to depict how compatibility could be affected if floating foundations become more competitive with fixed foundations in the future, resulting in increased deployment. Scenario 6 therefore has fewer constraints regarding water depth and seabed geology.

Scenario 1 is intended as a baseline scenario and distributes the influence factors equally across the three categories of inputs, such that the Infrastructure and Human Use, Physical, and Relevant Species and Ecological Areas categories each receive one third of the total influence. Some influence factors were adjusted by ± 1% to ensure the totals added up to 100%. The layers that received an increase or decrease of 1% influence in each scenario were assigned randomly. Given that the Physical category has five input layers, under Scenario 1 each layer contributes around 7% of the total influence while layers in the Infrastructure and Human Use category contribute 8% or 9% each and layers in the Relevant Species and Ecological Areas categories contribute 11% of the total influence. Scenario 2 allocates 50% of the influence to the physical layers, emphasizing the impacts of water depth, wind speed, geology, ice cover, and proximity to the shoreline. Scenario 3 allocates 50% of the influence to the Infrastructure and Human Use category, emphasizing potential conflicts from fishing, vessel traffic, and ocean usage, while Scenario 4 allocates 50% of the influence to the Relevant Species and Ecological Areas category, emphasizing potential conflicts related to ecological areas and important species.

3.6.2 Compatibility Scores for Scenarios 1 to 4 – Infrastructure and Human Use Considerations

The Vessel Density layer (see Figure 4) was classified into nine bins of increasing levels of vessel traffic. In the context of this analysis, the presence of vessel traffic in a given area is expected to increase the cost and complexity of an offshore wind project, compared to an area with relatively little vessel traffic. Therefore, cells with higher levels of vessel traffic were given progressively lower compatibility scores in all scenarios.

The Ocean Usage layer (see Figure 5) consists of various sub-sea infrastructure such as pipelines and cables, obstructions, wrecks and dumping grounds, as well as designated areas for human use such as vessel traffic separation zones and ferry routes. It is expected that these considerations will be difficult to mitigate in the context of offshore wind and were therefore assigned low compatibility scores. While not considered as part of the compatibility scoring in this analysis, the potential for leveraging existing pipeline or cabling routes could ultimately improve the attractiveness of offshore wind projects located near these areas.

The Fishing Effort layer was classified into nine bins of increasing levels of fishing intensity (see Figure 6). Compatibility scores were assigned such that areas of higher fishing activity received lower compatibility scores, as these areas were expected to have a higher likelihood of conflict with offshore wind projects.

The Inshore Lobster layer was classified into five bins according to increasing catch weight (see Figure 7). Areas with higher recorded catch weight were assigned progressively lower compatibility scores.

3.6.3 Compatibility Scores for Scenarios 1 to 4 – Physical Considerations

Compatibility of physical considerations within the study area was generally evaluated by assigning higher scores to conditions expected to be technically and economically favourable, either by reducing construction and maintenance costs or improving operational efficiency.

The distance from coast consideration, while placed in the Physical category, has ecological, economic, and social implications. Areas within a few nautical miles from the coast are often associated with many important ecological activities and are more likely to have greater cultural, recreational, and aesthetic importance to nearby communities. A previous CE-O study of practices in other jurisdictions showed that these effects are typically most pronounced within five nautical miles from the coastline [1]. On the other hand, costs associated with cabling and transmission will increase with distance from shore, and construction and accessibility challenges are more likely. In an attempt to balance these factors, the Distance from Coast layer (see Figure 8) was divided into four bins, and areas less than five nautical miles from shore received the lowest compatibility scores. Areas within 5-10 nautical miles (~ 9-18 km) from shore received the highest scores, and areas beyond 10 nautical miles received progressively lower compatibility scores.

The Geology layer (see Figure 9) comprises a preliminary characterization of the seabed within the study area based on expected compatibility with different offshore wind foundation types. Areas expected to be compatible with either sub-surface or gravity foundations were given high compatibility scores in all scenarios, including Scenario 6, as these areas should also be decent candidates for floating anchors. Areas characterized as “Floating Only” were given the highest compatibility scores in Scenario 6, although further site-specific geotechnical work will be required to confirm whether floating foundations are appropriate for these locations. The “Challenges” category refers to areas where geological conditions were not well aligned with any of the predominant existing foundation types, or where there was insufficient data available to classify the areas into one of the defined categories. Low compatibility scores were applied to this category in all scenarios. Technological advances or detailed site-specific geotechnical studies may help to mitigate risks of development in these areas.

The Ice Cover layer (Figure 10) assigns a compatibility score based on the probability of sea ice covering a given ocean space at some point during the year. Mitigating the negative impacts of sea ice during part of the year is expected to increase the cost and complexity of an offshore wind installation. As such, areas with little statistical probability of sea ice formation were given the highest compatibility scores, and scores were reduced as the likelihood of sea ice increased. Challenges posed by other cold climate considerations such as icebergs and freezing spray, which are not common in other jurisdictions with offshore wind projects, were not included in this study, and will require further assessment.

The Water Depth layer (see Figure 11) consists of six different bins ranging from 0 to 2000 metres below surface level. The majority of fixed bottom turbines installed to date have been in depths of less than 60 metres and there is a good understanding of the technology and engineering involved in this application. In this analysis, compatibility scores in Scenarios 1-4 were gradually decreased with increasing water depth, representing the increased cost and complexity of deeper water installations. Scores in Scenario 6 (Floating Wind) were also decreased gradually, but to a lesser extent, with depths of up to 120 metres receiving the highest score of 9, and depths between 120 and 2000 metres receiving a score of 5. In all scenarios, depths greater than 2000 metres received a score of 1.

The wind speed input layer (see Figure 12) is used in this analysis as a rough proxy for the amount of electricity that can be generated at a given location. The typical wind speed threshold used to determine technical viability based on current technology is an annual average of at least 7 m/s at a height of 100 m, and this standard was adopted here [46]. While 7 m/s is considered a minimum, many of the operating projects in Europe are located in areas with average wind speed of 8 to 9 m/s [47]. In all scenarios in this analysis, a score of 7 was assigned to areas with an annual average wind speed between

7 and 9 m/s, a score of 8 was assigned to areas between 9 and 10 m/s, a score of 9 was assigned to areas with greater than 10 m/s, while areas with wind speeds less than 7 m/s were given a score of 1.

3.6.4 Compatibility Scores for Scenarios 1 to 4 – Ecological Considerations

Compatibility for the ecological considerations in this analysis was evaluated on the basis of the potential risk from an offshore wind developer point of view in the context of existing and identified environmental regulations and sensitivities, as opposed to specific ecological risks posed by a project. A comprehensive evaluation of the potential impacts of offshore wind development on ecosystems, that properly accounts for temporal and cumulative impacts, while integral to informing wind energy area definition and subsequent project development, is beyond the scope of this analysis.

The Defined Ecological Areas layer (see Figure 13) contains six different categories of named areas. In this study, areas supported by legislation, such as MPAs, OECMs, and Species at Risk Critical Habitat received the lowest compatibility scores, as they are expected to present higher risks of ecological damage should development proceed in these areas, and from a developer's point of view, would likely represent a higher regulatory burden. In Scenarios 1 to 4, MPAs, OECMs and Critical Habitat were given scores of 1, SiBAs and AOIs were given scores of 4, and EBSAs were given scores of 5.

The process of identifying EBSAs has involved multiple criteria, some of which will be more relevant to offshore wind than others [27]. Given the large number of EBSAs within the study area, a detailed examination of potential conflict with offshore wind was not possible for this study but should be examined in the future.

The Important Habitat layer (see Figure 14) includes areas identified by federal stakeholders as being important for various species of fish, cetaceans, turtles and birds, but which are not already listed as Critical Habitat under SARA. Under Scenarios 1 to 4, these areas were each assigned a score of 4, intended to represent a lower degree of compatibility with offshore wind but to a lesser extent than the areas backed by legislation in the Defined Ecological Areas layer.

The Risk to Marine Birds layer (see Figure 15) assigns risk levels to marine and migratory birds from offshore wind development based on marine distribution and density of multiple bird species and their sensitivity to offshore wind. The layer identifies potential risk of harm to marine bird populations from offshore wind, using three categories: Very High, High and Moderate risk. Under Scenarios 1 to 4, the Very High risk category was assigned a score of 1, the High category was assigned a score of 4 and the Moderate category was assigned a score of 7. The No Data category was given a score of 9 (highly compatible), however this does not mean that there is no risk of conflict with migratory birds in these areas. Scoring for the No Data category is further described in Section 3.6.7.

The set of compatibility scores for the 12 input layers used for Scenarios 1 to 4 is shown in Figure 17.

Figure 17: Compatibility scores for Scenarios 1-4 (Baseline, Physical Influence, Infrastructure Influence, Ecological Influence).

3.6.5 Compatibility Scores for Scenario 5 (Restricted)

Scenario 5 is intended to depict a more conservative approach to identifying areas for offshore wind. In this scenario, the compatibility scores were adjusted from the scoring used in Scenarios 1-4 in four input layers (Ocean Usage, Distance from Coast, Defined Ecological Areas and Risk to Marine Birds). For these four layers, specific elements were assigned a score of zero, which results in a score of zero for that cell in the resultant map, regardless of the scores applied to the same cell in any of the other input layers. The modified scoring for these four layers is shown in Figure 18. Scoring for all other layers remained the same as the scoring for Scenarios 1-4.

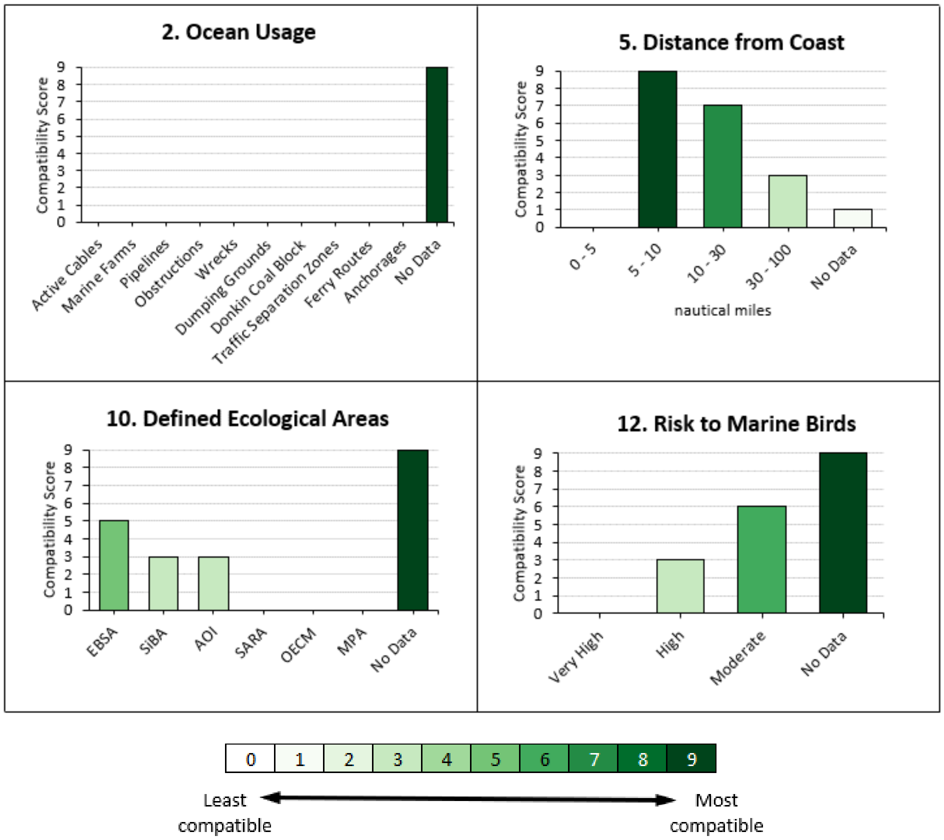

Figure 18: Compatibility scores for layers with modified scoring under Scenario 5 (Highly Restricted).

3.6.6 Compatibility Scores for Scenario 6 (Floating)

Scenario 6 is a floating wind scenario, where compatibility scores were adjusted for specific elements within the Ocean Usage, Geology, Water Depth and Defined Ecological Areas layers. The modified scoring for this scenario is shown in Figure 19. It was assumed that all other considerations would apply equally to floating wind and therefore scoring for all other layers remained the same as the scoring applied to Scenarios 1-4. In the Ocean Usage layer, scoring for four elements (Active Cables, Pipelines, Obstructions and Wrecks) was increased slightly to represent the expectation that seabed hazards would be less of an impediment to floating anchors than they would be to fixed bottom foundations. In the Geology layer, the Floating-Only category received a score of 9, matching the score given to the fixed-bottom areas in the other scenarios. Similarly, the restrictions on the Water Depth layer were loosened such that depths of up to 120 metres were given a score of 9, while depths between 120 and 2000 metres received a score of 5. Previous studies have described a practical depth limit for floating wind in the range of 700 to 1300 metres, but this may change as the technology continues to evolve [48]. Scoring for the SiBA element within the Defined Ecological Areas layer was increased from 3 to 7, given the expectation of reduced seabed disturbance associated with floating anchors compared to fixed bottom foundations.

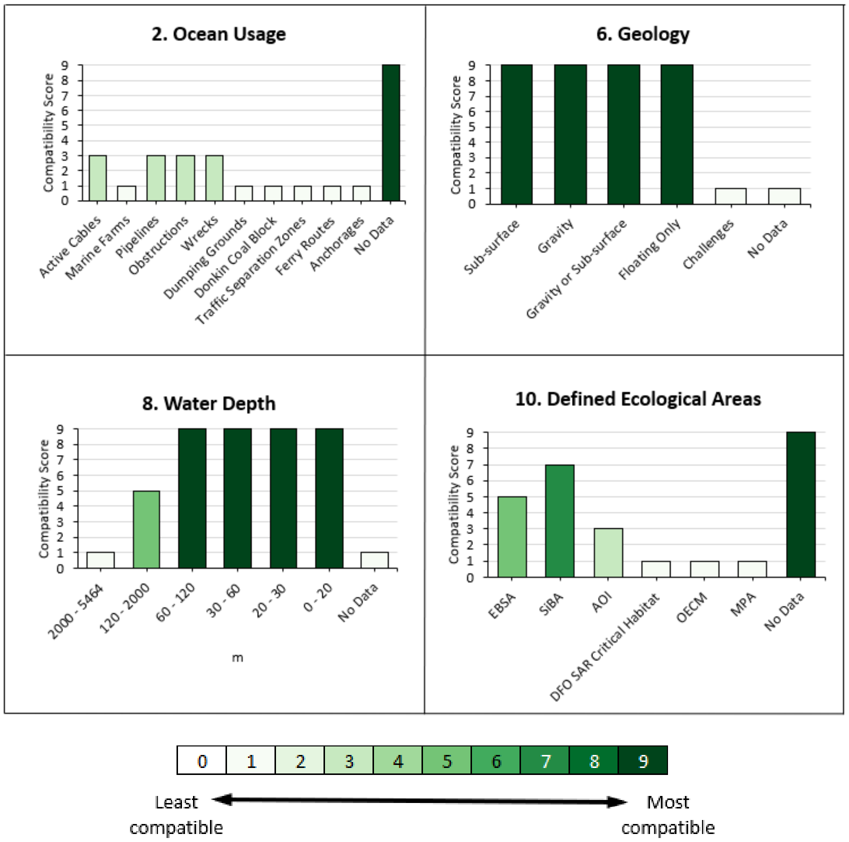

Figure 19: Compatibility scores for layers with modified scoring under Scenario 6 (Floating Wind).

3.6.7 Use of No Data Class in Compatibility Scores

In the context of this study, No Data refers to cells within a given raster layer that do not have an assigned value. For categorical data layers, this includes cells that are not assigned to any of the defined categories, and for continuous data, cells that do not belong to any of the defined bins. In order for the Weighted Overlay tool to produce a valid result, a compatibility score from 0-9 must be assigned to the No Data category of each input layer.

The number of cells in the No Data category varies significantly between input layers. In the Water Depth layer for example, every cell within the study layer falls into one of the six defined bins, therefore there are no instances of No Data in this layer and the compatibility scoring applied to the No Data category in the Weighted Overlay tool will not have any impact on the resultant map. This is also the case for the Geology and Wind Speed layers. The Distance from Coast layer was only populated with data up to 100 nautical miles from the coastline, which put any other raster cells into the No Data category by default. The Defined Ecological Areas layer, on the other hand, contains many raster cells that do not fall into one of the six defined categories (AOI, EBSA, MPA, OECM, SARA and SiBA), and each of these non-assigned cells therefore lands in the No Data category. The compatibility scores for nine input layers with a non-zero number of cells in the No Data category, along with the rationale for the selection of those scores, are presented in Table 3.

In the context of this study, the absence of information in a particular cell generally implies a reduced risk of conflict with offshore wind and therefore merits a higher compatibility score for the No Data category. However, it must be emphasized that the assignment of cells into the No Data category does not imply that there is no risk of harm or conflict from wind energy development in these areas, only that, within a given raster layer, there was no information available for these cells that could reasonably be incorporated into this analysis at the time of the study.

Table 3: Compatibility Scores Applied to No Data Category

Input Layer	Compatibility Score for No Data Category	Rationale
Vessel Density	9	Areas with lower vessel traffic are generally expected to be more compatible with offshore wind areas
Ocean Usage	9	Areas that are absent of existing infrastructure or human uses are expected to be more compatible
Fishing Effort	9	Areas with lower fishing effort intensity are expected to be more compatible
Inshore Lobster	9	Areas with lower levels of lobster fishing are expected to be more compatible
Distance from Coast	1	Areas more than 100 nautical miles from the coastline are expected to be less compatible
Ice Cover	9	Areas with no median ice concentration are expected to be more compatible
Defined Ecological Areas	9	Areas that do not fall within a designated ecological area are expected to be more compatible
Important Habitat	9	Areas that were not identified as important habitat for key species are expected to be more compatible
Risk to Marine Birds	9	Areas not identified as Very High, High or Moderate risk to marine birds are expected to be more compatible

4. Results and Discussion

4.1 Compatibility Results for Scenarios 1 to 6

The results for each scenario are presented below. As in the case of the input layers presented in Section 3.5, each pixel in the resultant maps represents an area of 2 km x 2 km (4 km^2). In the Scenario 1 results, shown in Figure 20, several areas of higher compatibility appear along the southern portion of the study area including around Sable Island, in parts of the Northumberland Strait and off the Northwestern coast of Prince Edward Island, as well as areas off the southern and western coasts of the Island of Newfoundland. These are areas where relatively little fishing effort and vessel traffic were identified and which generally have fewer known protected areas. Less compatible areas shown in the map include the highly trafficked Cabot Strait between Cape Breton, Nova Scotia and the island of Newfoundland as well as the St. Lawrence Estuary. The southern coast of Nova Scotia also contains areas of lower compatibility due to the presence of ecological areas as well as important habitat for aquatic and bird species.

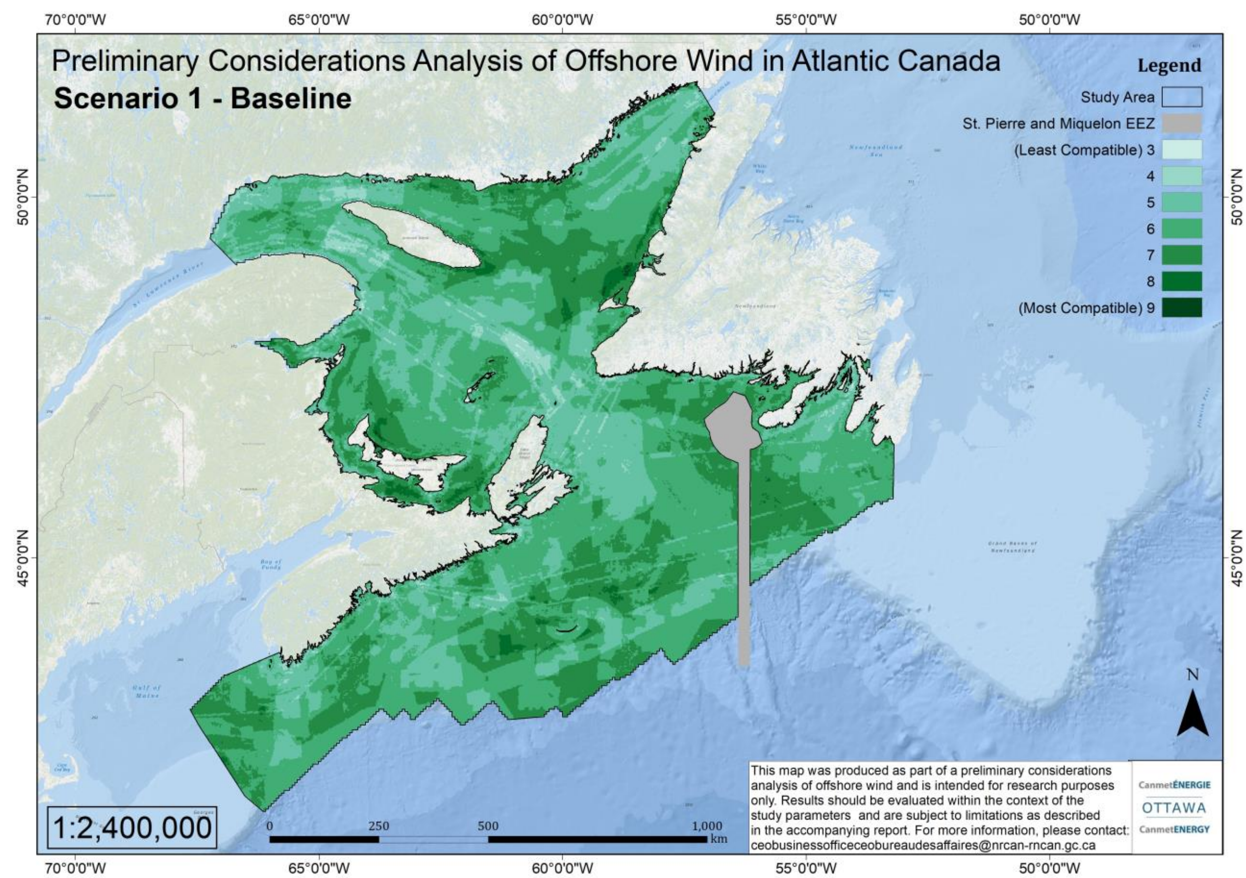

Figure 20: Results for Scenario 1 - Baseline. In this scenario, the three categories of input layers (Relevant Species and Ecological Areas, Infrastructure and Human Use, and Physical) were given equal influence in the weighted overlay process.

Because the weighted overlay process acts as a weighted average of the scores applied to the input raster layers, resultant compatibility scores tend to follow a normal distribution, where scores of 5, 6 and 7 are most common, and values of 1 and 9 are rare. In Scenario 1, the most common resultant score is 6, covering about 49% of the study area, or roughly 267,000 km^2. By contrast, scores of 8 covered only about 2% of the study area, or 8,300 km^2. The full set of weighted overlay results showing the distribution of compatibility scores by pixel and by area for each scenario is provided in Appendix A.

Scenario 2, shown in Figure 21, assigned more weight to the physical layers, increasing the influence given to water depth, wind speeds, ice cover, geology and distance from shore. While overall trends are similar to Scenario 1, a few minor differences can be observed. The most common score is still 5, again covering about 49% of the study area, but coverage for scores of 5 increased to 38% compared to 24% in Scenario 1. The total area containing scores of 8 was reduced slightly from Scenario 1, to 4,900 km^2 (1%). Compared to Scenario 1, there is a tighter concentration of scores of 8 in regions with a combination of geology compatible with fixed bottom foundations, relatively shallow water depths and high wind speeds. These include areas around Sable Island, areas off the northwest coast of PEI, and off the northwest coast of the Island of Newfoundland.

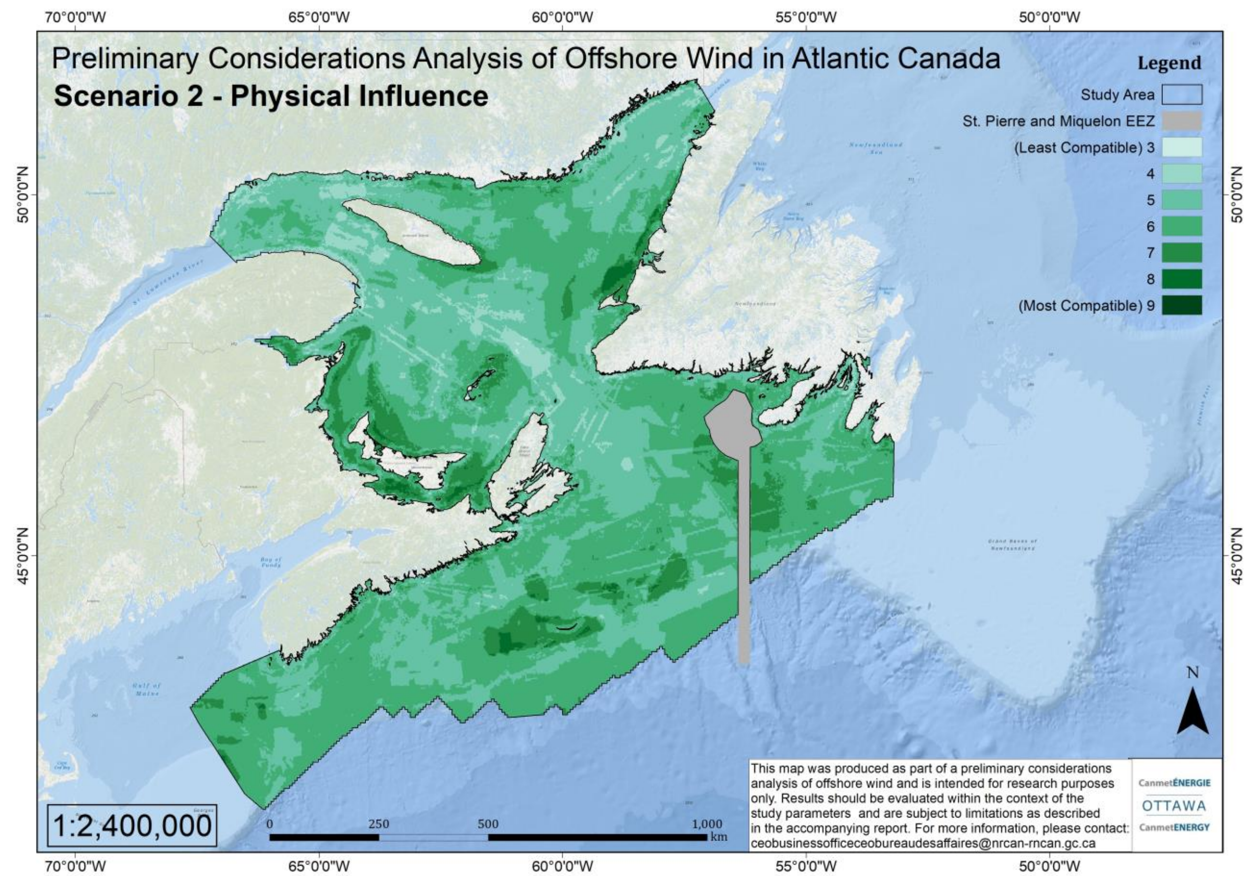

Figure 21: Results for Scenario 2 - Physical Influence. In this scenario, 50% of the weighting was assigned to the Physical category, while the other categories received 25% each.

Scenario 3, shown in Figure 22, emphasizes the influence of subsea infrastructure, designated traffic zones, fishing and vessel traffic density and other anthropogenic uses. Compared to Scenario 1, areas with more of these considerations, such as the Honguedo Strait and Jacques Cartier Passage on either side of Anticosti Island, the Cabot Strait between Cape Breton and Newfoundland, and areas surrounding Halifax harbor, had lower compatibility scores. Compared to Scenario 1, the number of cells with scores of 7 increased to 50% of the study area (269,000 km^2) and cells with scores of 8 increased to 6% (34,500 km^2).

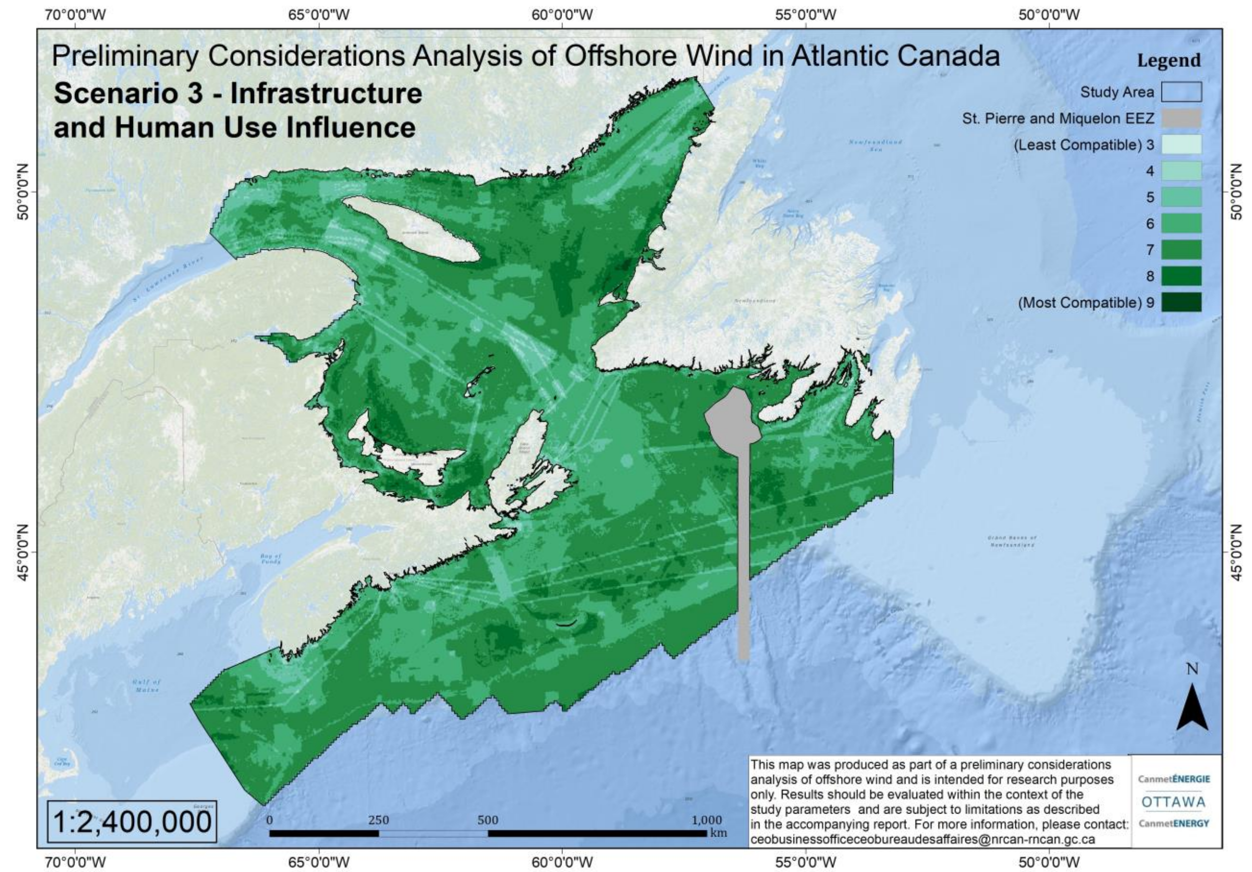

Figure 22: Results for Scenario 3 - Infrastructure & Human Use Influence. In this scenario, 50% of the weighting was assigned to the Infrastructure and Human Use category, while the other categories received 25% each.

In Scenario 4, shown in Figure 23, increased influence was given to defined areas of ecological significance for both aquatic and bird species. Compared to Scenario 1, Scenario 4 has a slightly higher concentration of scores of 5 (31% vs. 24%), a lower concentration of scores of 6 (37% vs. 49%), and a similar concentration of scores of 7 and 8. Areas represented in the Defined Ecological Areas layer, that overlapped with areas of important habitat for aquatic species and areas where offshore wind poses a high or very high risk to migratory birds, received the lowest compatibility scores in this scenario. These include areas northeast of the Magdalen Islands, areas of the Laurentian Channel, parts of the Scotian Shelf, and the Eastern side of Sable Island Bank.

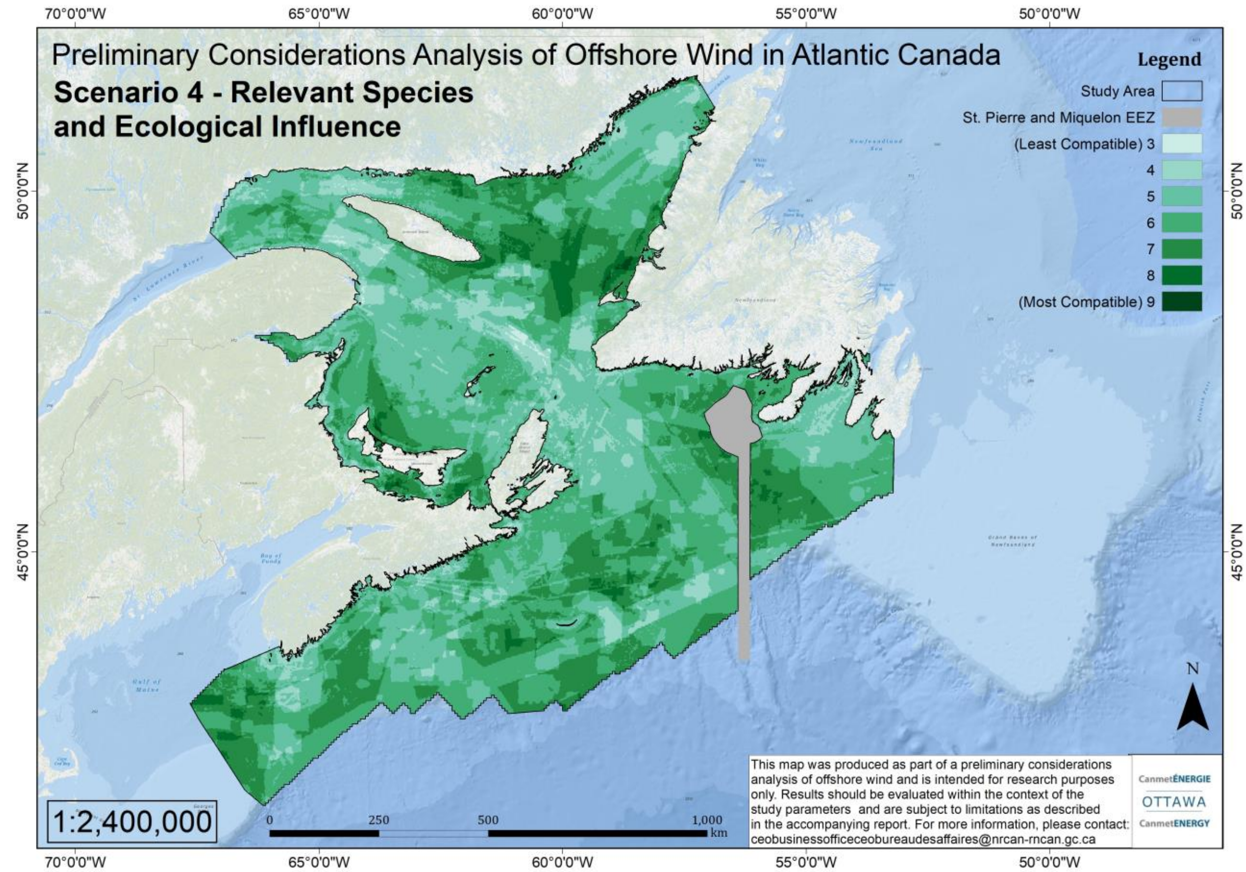

Figure 23: Results for Scenario 4 - Relevant Species & Ecological Influence. In this scenario, 50% of the weighting was assigned to the Relevant Species and Ecological Areas, while the other categories received 25% each.

The results of Scenario 5 are shown in Figure 24. As described in Section 3.6.5, several elements within four of the input layers (Ocean Usage, Distance from Coast, Risk to Marine Birds and Defined Ecological Areas) were given compatibility scores of zero, which appear as white areas in the map. While the compatibility scores in the four layers were adjusted, the influence factors from Scenario 1 to allow for comparison against it. In the Scenario 5 map, scores of zero accounted for 47% of the study area (253,000 km^2), while scores of 8 accounted for only 1.3% of the study area (7,200 km^2). Notably, certain areas that appeared as highly compatible with offshore wind in Scenario 1 continued to show promise in Scenario 5. These include areas off Cascumpec Bay off the northwest coast of PEI, areas off the western coast of the island of Newfoundland north of Port au Port Bay, and parts of Sable Island Bank.

Scenario 5 was designed to depict a conservative approach to compatibility, where considerations with a higher likelihood of conflict with offshore wind were removed from the analysis. These areas are more likely to face more challenges and longer development timelines, and in some cases, may never be appropriate for offshore wind if the risk of ecological damage or conflict with existing ocean space users is deemed to be too high.

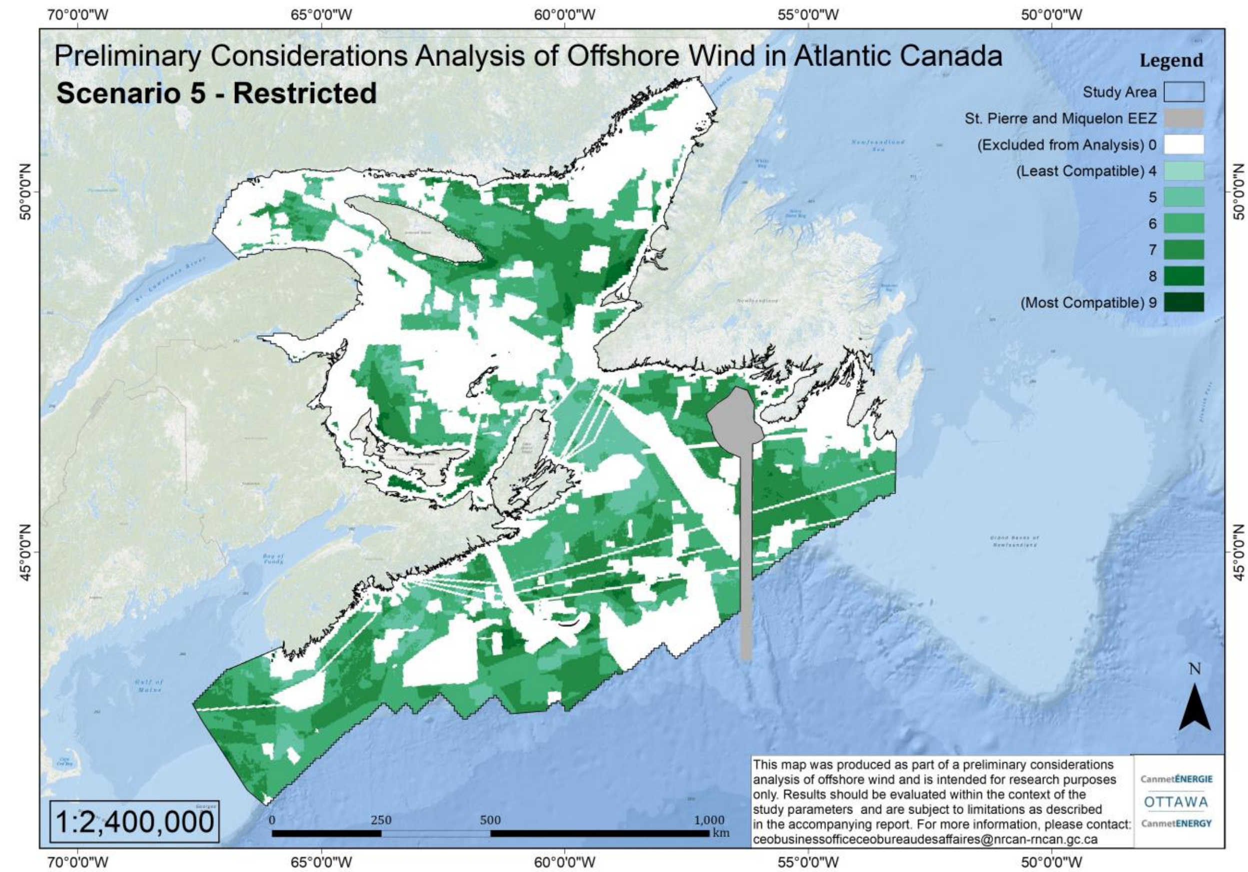

Figure 24: Results for Scenario 5 - Restricted. This scenario shows the impact of restricting specific elements within the Ocean Usage, Distance from Coast, Defined Ecological Areas, and Risk to Marine Birds layers.

Scenario 6 is a floating wind scenario, intended to depict changes in the resultant compatibility map if floating foundation technology is used, rather than fixed-bottom foundations, as was the case in Scenarios 1 through 5. The map for Scenario 6 is shown in Figure 25. Similar to Scenario 5, while compatibility scores were changed within four input layers (Ocean Usage, Geology, Water Depth and Defined Ecological Areas), as described in Section 3.6.6, the influence factors were identical to those in Scenario 1, thereby allowing for comparison against the Scenario 1 results. These changes resulted in higher overall compatibility scores compared to the other scenarios. In the Scenario 6 map, scores of 7 covered 48% of the study area (261,000 km^2), while scores of 8 covered 14% (77,000 km^2), the highest proportion among the six scenarios.

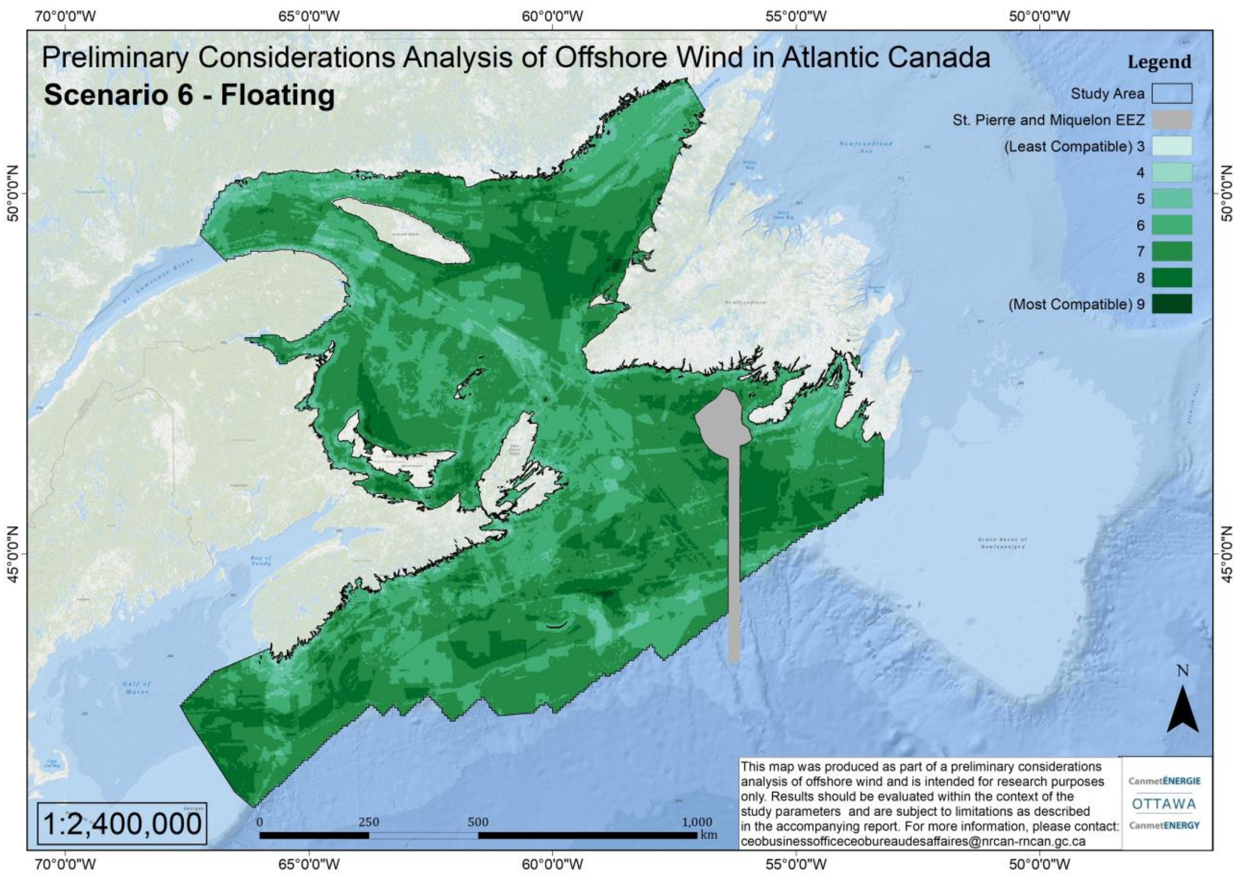

Figure 25: Results for Scenario 6 - Floating. This scenario shows the impact of relaxing the constraints (increasing the compatibility scores) associated with specific elements within the Ocean Usage, Geology, Water Depth and Defined Ecological Areas layers.

4.2 Results Compiled from Multiple Scenarios

To illustrate the results of multiple scenarios on a single map, the average compatibility scores from Scenarios 1, 2, 3, and 4 were computed for each raster cell. The average scores ranged from 3 to 8. The resulting compilation map is shown in Figure 26 with scores of 7 and 8 isolated (shown individually) to better highlight the areas where those scores appear. Highlighted scores of 5 and 6 are shown in Figure 27, while highlighted scores of 3 and 4 are shown in Figure 28.

In Figure 26, scores of 7 occupy 8.2% of the study area (44,460 km^2), while scores of 8 cover 0.7% (3,700 km^2). The map shows several large areas of higher compatibility that may be promising areas for future study, including:

- Areas of the northern Gulf between Anticosti Island and Port au Port Bay off the western coast of the island of Newfoundland
- Large areas within St. Pierre Bank off the southern coast of the Island of Newfoundland, smaller areas within Green Bank, and areas closer to the coast between Burgeo Bank and Fortune Bay
- Other areas of the Gulf off the coast of New Brunswick and the northern coast of PEI
- Sections of the Northumberland Strait between Nova Scotia and PEI
- Large portions of Sable Island Bank, Middle Bank, and Banquereau Bank off the southern coast of Nova Scotia
- Sections of Browns Bank and Georges Bank, in the southwest corner of the study area

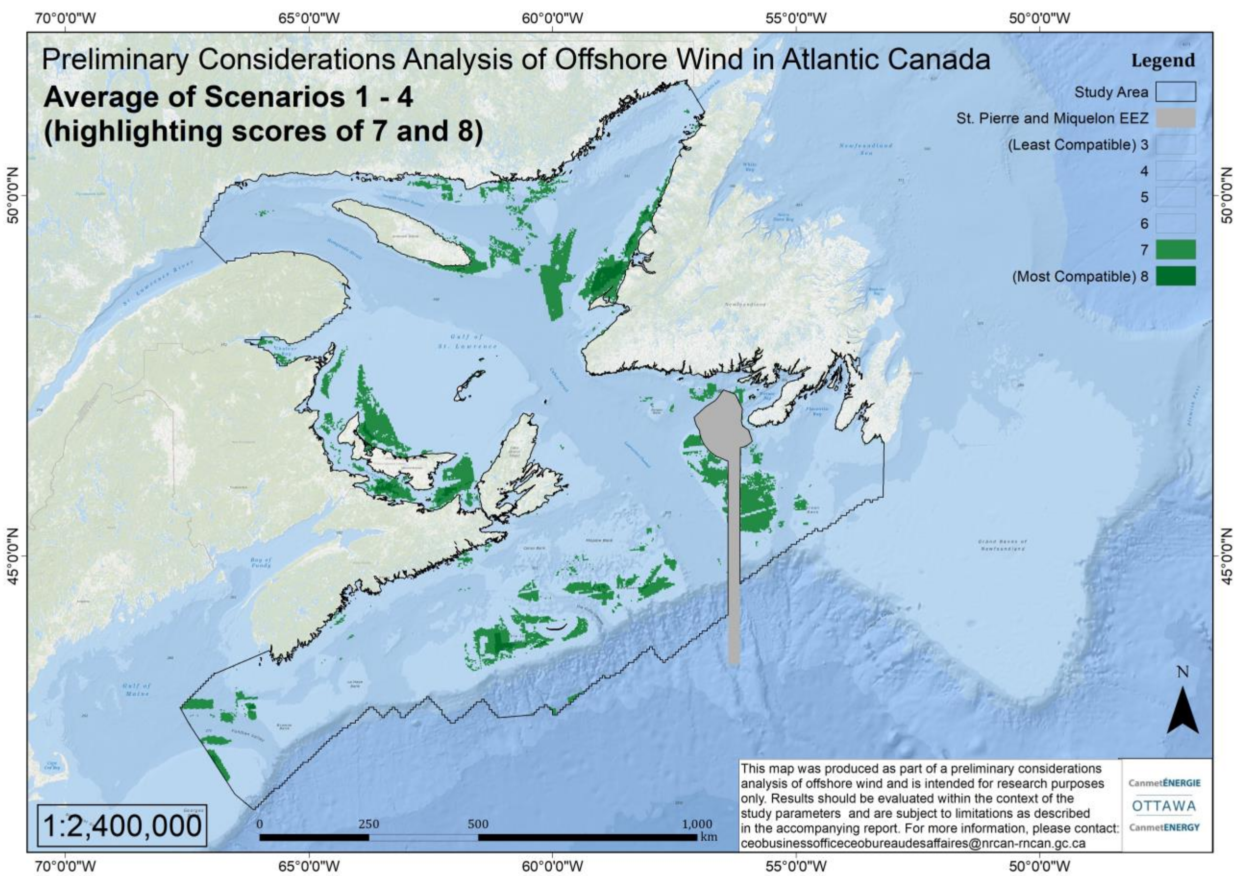

Figure 26: Compilation map based on the average compatibility scores from Scenarios 1 to 4. Scores of 7 and 8 isolated for clarity.

In Figure 27, scores of 5 cover 35.5% of the study area (191,800 km^2) while scores of 6 cover 50.3% (272,000 km^2). This map highlights areas that, according to this analysis, are more likely to have increased risk of conflict with offshore wind compared to the areas in Figure 26, but could still have reasonably good potential for development. Some of these challenges might be overcome by various interventions – technology improvements in the case of physical considerations, increased stakeholder consultation in the case of human use considerations, and effective mitigation in the case of ecological and species-related considerations. Additional research is likely required to understand the ecological stresses that may be caused by offshore wind in these locations and to determine the most effective mitigation strategies.

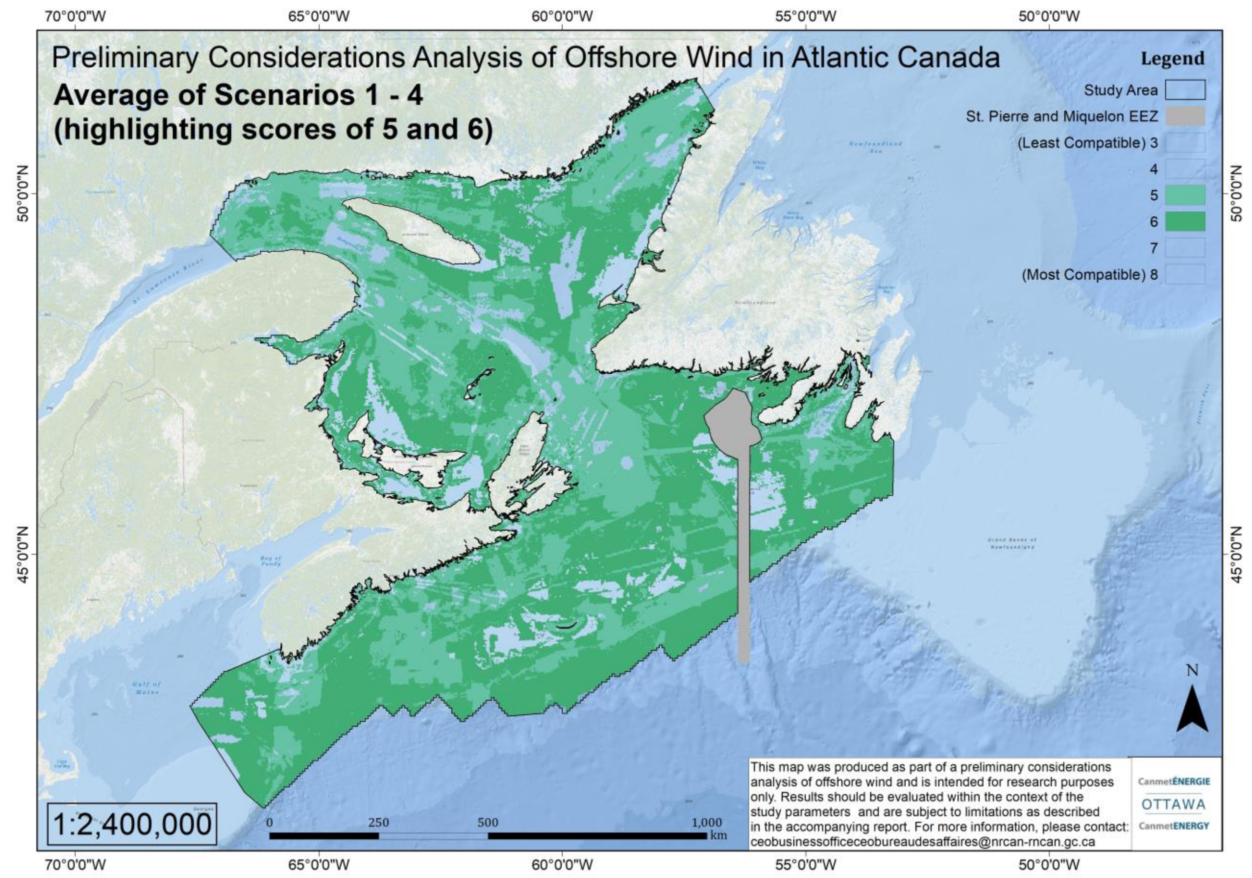

Figure 27: Compilation map based on the average compatibility scores from Scenarios 1 to 4. Scores of 5 and 6 isolated for clarity.

Figure 28 shows areas with average compatibility scores of 3 and 4. Here, scores of 3 occupy only 0.17% percent of the study area (904 km^2), while scores of 4 cover 5.1% (37,600 km^2). These are areas that, according to this analysis, are generally less compatible from a physical standpoint and have a high chance of conflict with offshore wind from multiple human use or ecological perspectives. While it may be possible to mitigate some of these risks in some areas, other areas may not be compatible with offshore wind if there is a high possibility of negatively impacting listed at-risk species or degrading designated critical habitat, for example.

Some of the prominent areas identified in this map include the Honguedo Strait, the Jacques Cartier Passage, the coastal waters off the eastern tip of Gaspé Peninsula, areas near the Strait of Belle Isle, the Cabot Strait, parts of Placentia Bay, the vicinity of Halifax Harbour, and areas off the south-eastern tip of Nova Scotia.

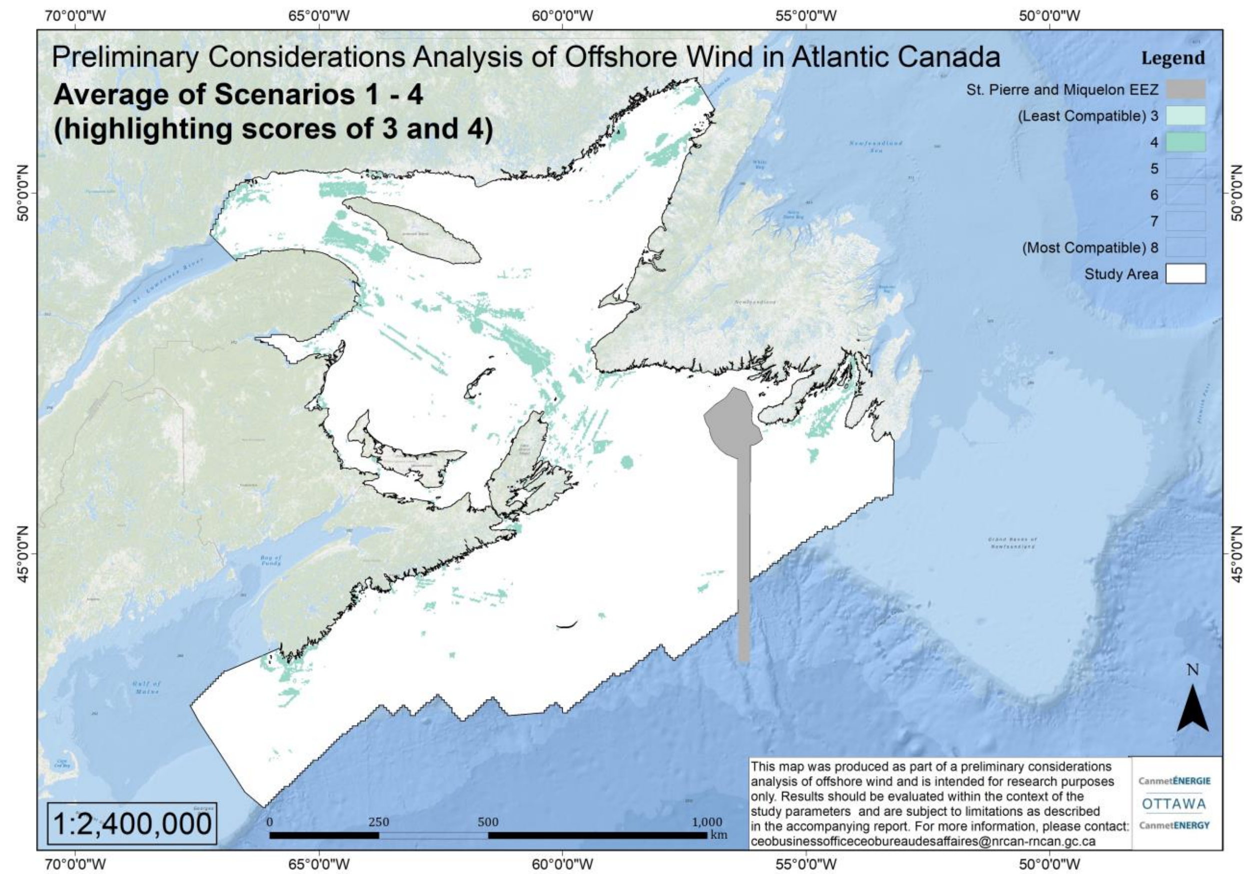

Figure 28: Compilation map based on the average compatibility scores from Scenarios 1 to 4. Scores of 3 and 4 isolated for clarity, and study area background colour modified to improve contrast.

4.3 Power Production Estimates

To further refine the areas of higher compatibility, a compilation map was created to illustrate areas that consistently scored an 8 or 9 in *each* of the Scenarios 1 through 4. This map, shown in Figure 29, was created by identifying areas that received a score of either 8 or 9 in each Scenario 1 through 4 and extracting these areas to their own layers. The intersecting areas were then combined into a single layer. Smaller areas with only a few pixels were removed from the map, to focus on promising areas of a more significant size. The total coverage area of these polygons is approximately 5,920 km^2.

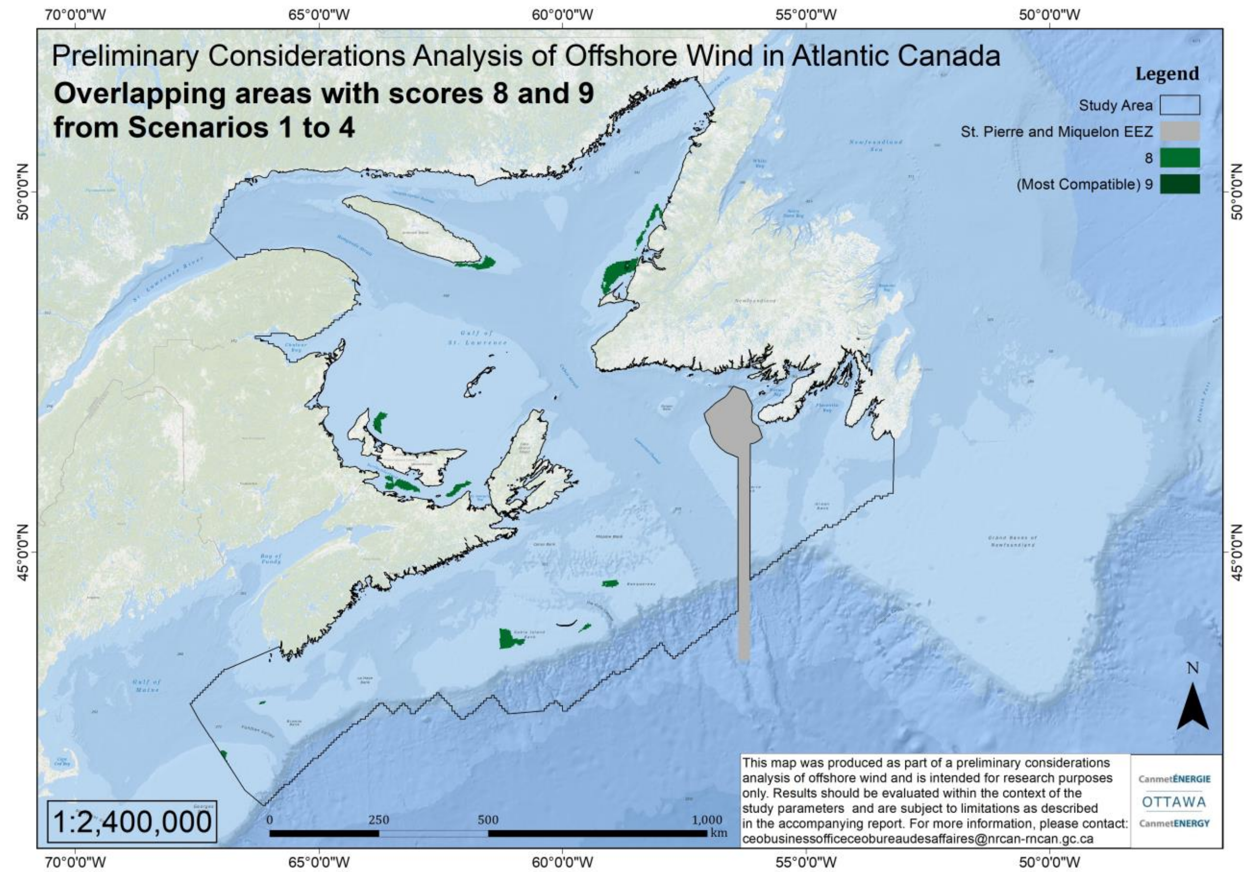

Figure 29: Compilation map based on overlapping areas of compatibility scores of 8 and 9 from Scenarios 1 to 4.

The areas in Figure 29 were separated into 11 distinct polygons, and labelled according to their region, as shown in Figure 30. A close-up view of these polygons is shown in Figure 31. If wind farms were developed to the full extent of each polygon, the total ocean area of 5,156 km^2 could potentially support between 15 and 26 GW of installed offshore wind capacity, and between 54,000 and 90,000 GWh of electricity generation annually, as shown in Table 4. To produce these estimates, two different estimates of capacity density, 3 MW/km^2 and 5 MW/km^2 were applied, along with an annual capacity factor of 40%. These values were roughly based on a study that examined measured data from seven European offshore wind farms during the period 2016-2018 [49]. While capacity factor and capacity density can both vary considerably according to the project location, wind farm configuration, turbine technology and other factors, these values can serve as a useful starting point for estimating theoretical power production. For reference, Canada had 15.1 GW of installed onshore wind capacity as of December 2022 [50]. Canada generated roughly 39,060 GWh of electricity from onshore wind in 2021 [51], while

Canada's total electrical demand in 2022, calculated as consumption plus imports minus exports, was around 540,000 GWh [52].

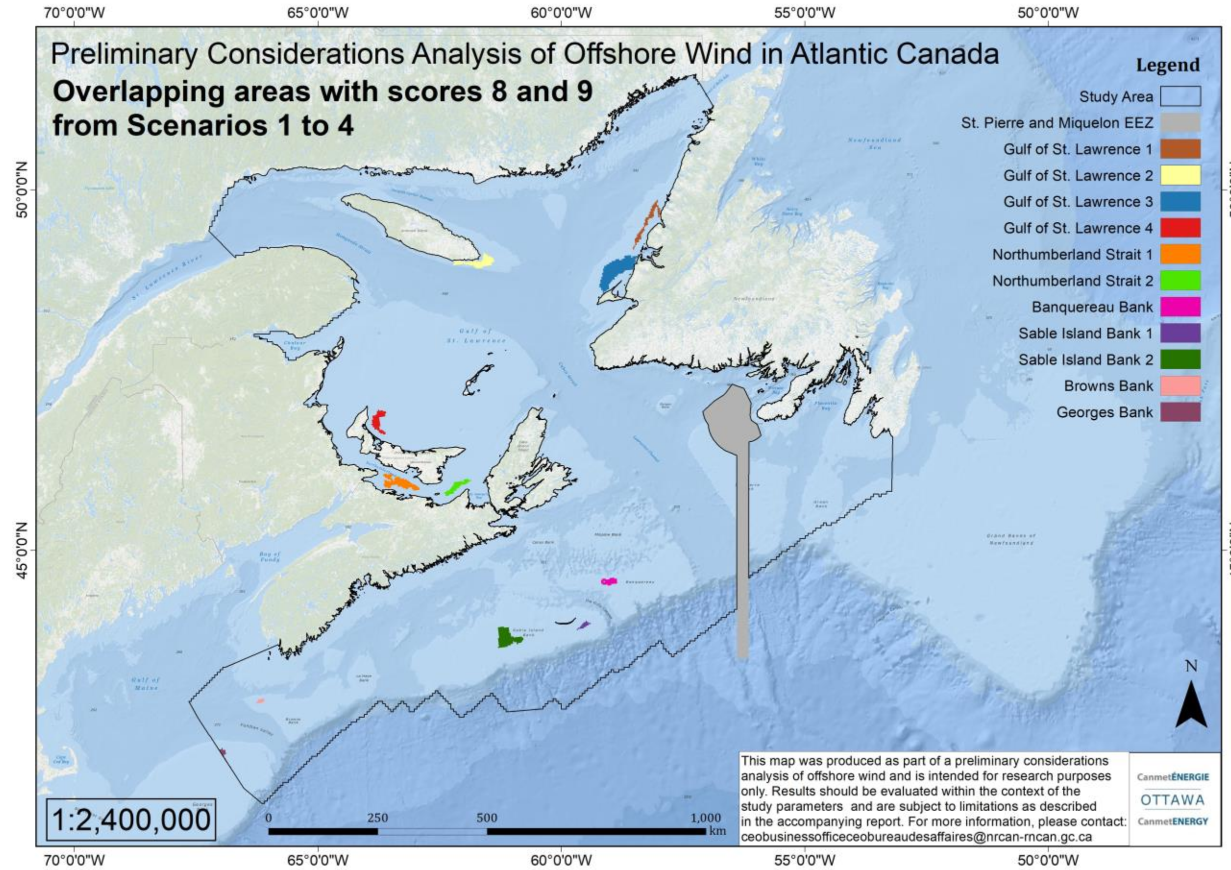

Figure 30: Labelled polygons derived from overlapping areas of scores of 8 and 9.

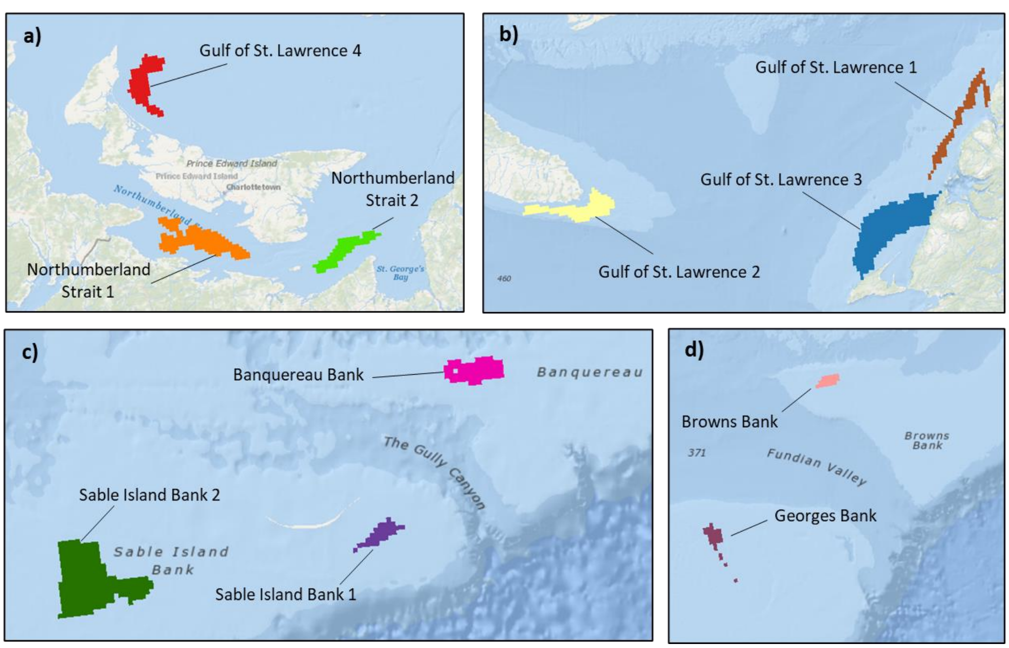

Figure 31: Close-up view of labelled polygons derived from overlapping areas of scores of 8 and 9.

Table 4: Theoretical Potential Installed Capacity and Annual Power Output for Labelled Polygons

		Capacity Density 3 MW/km²		Capacity Density 5 MW/km²	
Region	Area (km²)	Installed Capacity (GW)	Annual Generation (GWh)	Installed Capacity (GW)	Annual Generation (GWh)
Gulf of St. Lawrence 1	424	1.3	4,457	2.1	7,428
Gulf of St. Lawrence 2	532	1.6	5,592	2.7	9,321
Gulf of St. Lawrence 3	1352	4.1	14,212	6.8	23,687
Gulf of St. Lawrence 4	424	1.3	4,457	2.1	7,428
Northumberland Strait 1	712	2.1	7,485	3.6	12,474
Northumberland Strait 2	344	1.0	3,616	1.7	6,027
Banquereau Bank	240	0.7	2,523	1.2	4,205
Sable Island Bank 1	116	0.3	1,219	0.6	2,032
Sable Island Bank 2	836	2.5	8,788	4.2	14,647
Browns Bank	68	0.2	715	0.3	1,191
Georges Bank	108	0.3	1,135	0.5	1,892
Total	5,156	15.5	54,200	25.8	90,333

5. Limitations

This study comprised a multi-criteria analysis that attempted to accommodate a wide range of input considerations, and as such is subject to a number of limitations. These limitations can be classified into three main categories: data availability, temporal and cumulative effects, and subjectivity of the weighted overlay scoring scheme. Each of these are discussed in further detail below.

The purpose of this analysis was to identify areas that are more likely to be serious candidates for offshore wind in Atlantic Canada based on a combination of relevant factors. In conjunction with other information, this analysis can aid in defining offshore wind areas that can best meet the needs of a wide group of stakeholders. It is not meant to take the place of environmental assessments at either the regional or project level. However, it is anticipated that identifying existing data gaps and prioritizing areas where new information should be collected can aid in addressing the current limitations to the extent possible before offshore wind projects are deployed.

5.1 Data Availability

While efforts were made to compile data layers that are expected to be relevant to future potential offshore wind in Atlantic Canada, there are undoubtedly relevant datasets that were not considered. In some cases relevant datasets were identified but could not be effectively incorporated into the analysis. Data limitations related to each of the main categories of data layers used in this analysis (Infrastructure and Human Usage, Physical, and Relevant Species and Ecological) are discussed in turn.

Starting with Infrastructure and Human Use considerations, the Vessel Density layer is a high-resolution dataset with original sample size of 1 km x 1 km, and fully encompasses the study area. However, it only spans one year (2019), and therefore can not account for year-to-year variation. The original dataset includes five categories of vessel (Cargo, Fishing, Passenger, Tanker, Other). In this analysis, after removing the fishing vessels to prevent double counting with the Fishing Effort layer, the remaining four groups were treated as a single layer and no distinction was made between categories of vessels with respect to compatibility scoring. Further work is required to differentiate between different types and sizes of vessels when it comes to compatibility with offshore wind farms.

Most of the data in the Ocean Usage layer were obtained from the CHS Nautical Charts, however these are not expected to capture all potential obstacles posing hazards to offshore wind, and some information may be out of date. The CHS data included some submarine cables known to be decommissioned, for example, which were removed in this analysis as they were deemed less likely to be a source of conflict with offshore wind. Buffer distances applied to pipelines, submarine cables, and other infrastructure were based on best practices from other jurisdictions and may be higher or lower than what will be ultimately mandated under Canadian regulations or agreed to through stakeholder consultation. Military uses beyond what was available from the Nautical Chart data were not explicitly sought out and may pose further restrictions to offshore wind development. Some information on Department of National Defence practice and exercise areas is publicly available, but little detail is provided apart from an indication that many portions of the study area may be used for sub-surface operations, making it difficult to estimate the level of potential conflict with offshore wind at this time [53]. While ocean vessel density and traffic separation zones were included in the analysis, aviation traffic and flight paths were not. While transatlantic flights tend to travel over land rather than the open ocean as much as possible, there may be restrictions on where turbines can be sited due to potential interference with flight paths or radar communications. Ocean areas with recreational or cultural significance were not addressed explicitly in this analysis. While these are expected to generally be within five nautical miles from coast, and therefore covered to some extent by the scoring applied to the Distance from Coast layer, this may not always be the case. Future analysis should incorporate additional human use considerations such as offshore oil and gas, aquaculture, marine tourism and Indigenous uses.

The fishing intensity data used to inform the Fishing Effort layer is a compilation of 15 years' worth of fishing intensity data, which is useful to gain broad insights on historical fishing patterns but may not accurately reflect recent trends. In its original form, the fishing data is available broken out by fishery class (e.g. groundfish, pelagic, crab, echinoderm, scallop, shrimp and whelk) and gear type (fixed vs. mobile). However, given the preliminary nature of this study, it was elected to use the highest quantity of information available, and including all types of fisheries and gear was determined to be the most appropriate option for this analysis. Additional work should be done to understand how different types of fishing vessels and equipment may conflict with offshore wind installations in Atlantic Canada, and how these risks can be mitigated.

At the time of this study, lobster catch weight data was only available for the Maritimes region. Despite not covering the full study area, Inshore Lobster was included as an input layer given the economic importance to the region. Discussions with DFO indicate that additional data for the Gulf and the Newfoundland and Labrador regions are forthcoming and should be incorporated into future studies.

Regarding Physical considerations, the Distance from Coast layer was used as a proxy for several factors, each of which deserve further attention. These include proximity to port facilities with sufficient capacity to accommodate large vessels and equipment, proximity to feasible grid interconnection sites, and the logistics involved with transporting personnel and equipment to project sites. The capital and operating costs associated with building and maintaining offshore wind projects, while not the focus of this study, are likely to have a material impact on which locations are deemed more favourable from a developer's perspective.

The Geology layer used in this analysis is arguably an over-simplification of the geological characterization of the region and falls short of the level of rigour required to appropriately site offshore wind projects. While it serves an essential purpose in the context of this analysis to narrow down areas meriting further study, there is currently a relative scarcity of accurate, high-resolution geological data within the study area, which must be overcome given Atlantic Canada's variable and unique seabed geology as well as the importance of seabed geology on offshore wind foundation stability, safety, and viability. Recent work published by the GSC which could not be used in this study due to time limitations, but should be incorporated into future studies, includes additional geological characterization work [54], and a seabed disturbance model [55][56].

The Ice Cover layer only includes data on sea ice concentration but does not account for atmospheric conditions that could lead to ice adhering to turbine blades, affecting aerodynamic performance, nor does it account for freezing spray, which may affect portions of the foundation structure. Icebergs, while not common within the study area, may pose a hazard to offshore wind turbines and should be examined further.

The Water Depth layer used data from the GEBCO global dataset with original grid spacing of 15 arc-seconds (roughly 327 metres at 45° latitude), which was a sufficient resolution for this preliminary study. Higher resolution data (10 m and 100 m) bathymetry data is published by CHS [57] but was not available over the entirety of the study area. This data should nevertheless prove valuable for more detailed regional studies.

Wind speed data used in the Wind Speed layer is the annual average wind speed and does not take into account year to year variation nor does it account for extreme weather events such as hurricanes and tropical storms. Furthermore, the complex relationship between wind, wave and ice was also not accounted for and deserves further study.

Turning to Relevant Species and Ecological considerations, the Defined Ecological Areas layer only includes areas defined at the federal level at the time of the analysis and does not include provincial or municipally designated sites. The layer includes 71 EBSAs and 28 OECMs, each of which were established for a specific region, and attempting to determine which were more likely to conflict with offshore wind could not be reasonably addressed within the timeline of this study. Scoring for Significant Benthic Areas was adjusted in Scenario 6 (Floating), but no distinction was made between different types of fixed bottom foundations.

The Important Habitat layer was included to account for areas identified by federal stakeholders as being important for various species, but that weren't already included as designated areas in the Defined Ecological Areas layer. The layer includes habitat for four aquatic species and five species of migratory birds, but is not exhaustive, and further effort is required to identify important habitats that could be disrupted by offshore wind development. Some observation data was available for whales [58] but could not be effectively incorporated into the analysis given its point data format. The presence of marine mammals and the potential impacts of wind farm construction and operation should be studied further in the Canadian context.

The Risk to Marine Birds layer was developed for this analysis in part due to the significant influence that birds have had on offshore wind project development in other jurisdictions, as well as onshore wind projects in Canada. This layer is an initial attempt to rigorously quantify the risk to marine birds from offshore wind in Canada, and additional data collection and analysis is required to validate these findings. Migratory pathways for passerines and shorebirds were not included in the analysis due to lack of data within the study area but should be considered going forward. Risk to migratory bats was also not included due to the present lack of data within the study area but should be examined in future studies given the risk of negative interactions with wind turbines.

Data limitations including those described above can have a significant influence on the outcomes of a multi-criteria analysis. In this analysis, areas of No Data in a given input layer correspond to those areas without a known source of conflict, and were given higher compatibility scores, as described in Section 3.6.7. While this aligns with the intention of the study, the accuracy of the outcome relies on the assumption that all sources of conflict are perfectly identified and characterized within the input layers, which is unlikely to be the case in reality. To better understand the effects of missing information on the resultant compatibility maps in Scenarios 1 to 6, areas of No Data from four input layers with significant proportions of cells in the No Data category (Fishing Effort, Defined Ecological Areas, Important Habitat, and Risk to Marine Birds) were superimposed using partial transparency. Areas of No Data on the individual layers are shown in Figure 32, and the superimposed image is shown in Figure 33. The darkness of the shading in Figure 33 increases with the number of overlapping layers, and the darkest regions generally coincide with the higher areas of compatibility indicated in Figure 26. This result highlights the need for further work to rigorously assess all potential sources of conflict before designating an area as appropriate for offshore wind development.

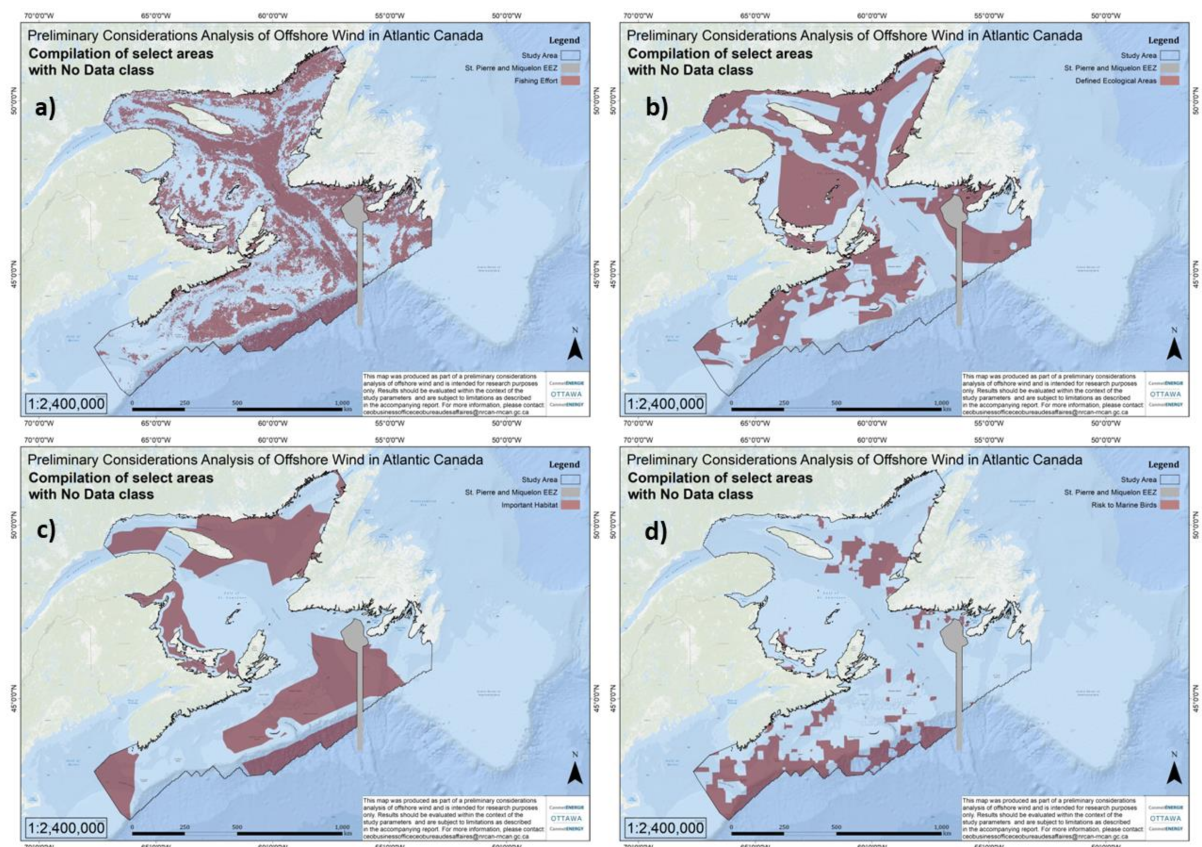

Figure 32: Maps showing area covered by the No Data category for four input layers: a) Fishing Effort, b) Defined Ecological Areas, c) Important Habitat, and d) Risk to Marine Birds.

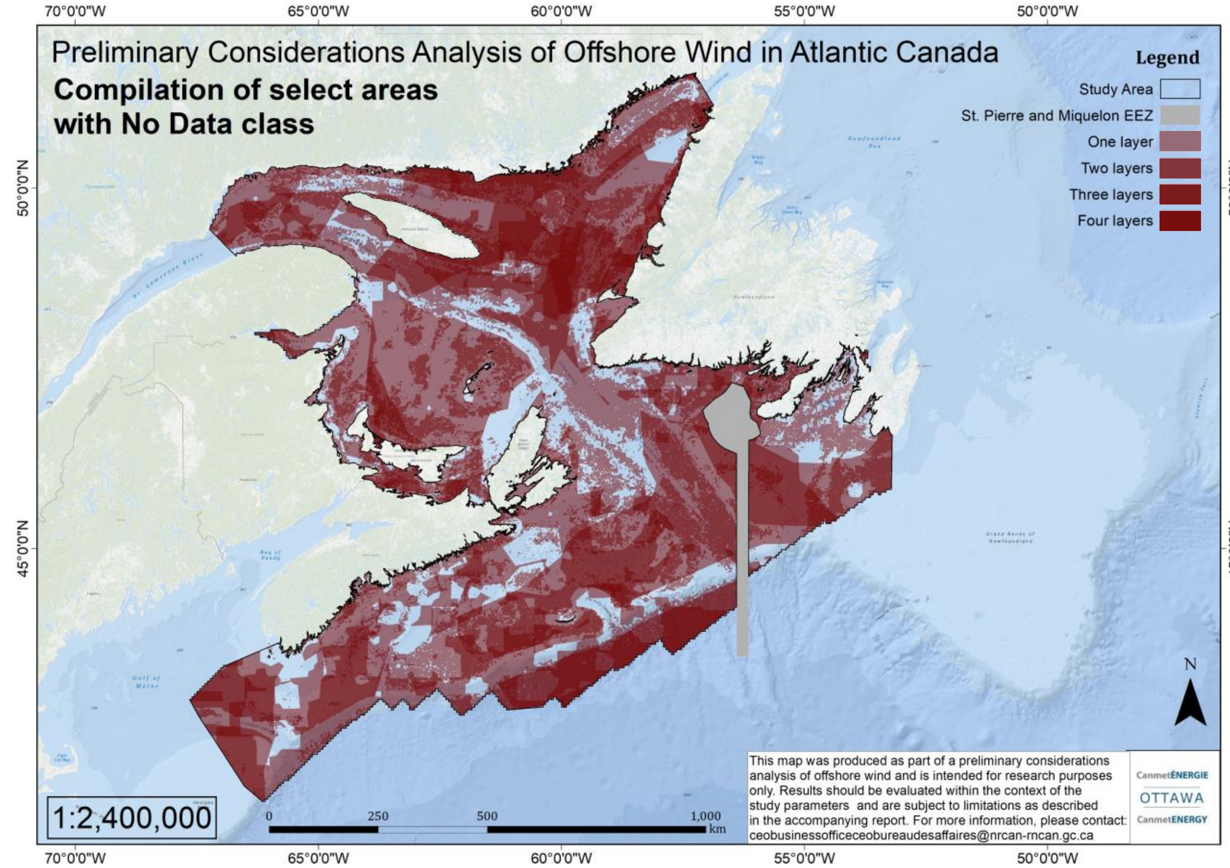

Figure 33: Compilation map showing overlapping areas of No Data category across four input layers (Fishing Effort, Defined Ecological Areas, Important Habitat, and Risk to Marine Birds). Darker shades depict areas with a higher number of overlapping layers.

5.2 Temporal and Cumulative Effects

Temporal effects, which concern effects that vary over time, and cumulative effects, which concern the combined effects of past, present and possible future activities, could not be effectively accommodated in this analysis and require further study.

The polygon-based approach used in this analysis has the inherent disadvantage of only being able to represent data as snapshots in time and cannot properly account for seasonal effects or other variations over time. This limitation applies mainly to dynamic layers, which represent data that change over time (e.g. Vessel Density, Fishing Effort, Inshore Lobster, Important Habitat and Risk to Marine Birds) as opposed to the remaining layers, which could be classified as static, or less subject to frequent change. Even if multiple years of data are aggregated into a single dataset, as is the case with the Fishing Effort layer, the data does not show trends where fishing intensity is increasing or decreasing over time. Furthermore, even the static layers have elements that are likely to change over time, albeit on longer timeframes. Some elements of the Ocean Usage layer, such as the locations of undersea pipelines, cables and ferry routes will change over time, and as new data is collected, the boundaries within the Defined Ecological Areas are also likely to change. Some physical layers, such as Ice Cover, and even Wind Speed, will likely see variation due to climate change.

Cumulative impacts, whereby the degree to which existing or emerging stressors, including climate change, on species, habitats, migration corridors and ecosystems could be compounded by offshore wind development, were also not assessed in this study, and merit further attention.

5.3 Subjectivity of Compatibility Scores

Assigning numerical weightings and scores to complex systems can be highly subjective. The influence factors and compatibility scores assigned in this analysis as part of the weighted overlay procedure are at best approximations and are not capable of fully reflecting real-world circumstances. Attempting to quantify or compare the value of different species, for example, or the optimal balance between economic and environmental considerations, are questions that cannot be answered objectively. As an attempt to alleviate some of the effects of this subjectivity, multiple scenarios were established to illustrate a range of possible outcomes depending on how different considerations are valued. The different weightings for each of the three main data categories used in Scenarios 1 to 4, and the restrictive scoring scheme applied in Scenario 5 together enable the visualization of a range of possibilities rather than a single result.

For internal consistency, a framework based on the perceived risk of conflict from an offshore wind developer's perspective was adopted for this analysis, and the compatibility scores for each scenario were selected to align with this construct. However, successful designation of offshore wind areas will require many different views to be taken into account. It is anticipated that the results of this study will be combined with the perspectives of other stakeholder groups to inform future decisions regarding the selection of areas designated for offshore wind deployment.

6. Conclusions and Future Work

The goal of this desktop considerations analysis was to identify areas within Atlantic Canada that merit further scientific investigation based on a combination of factors expected to be relevant to offshore wind development. This study does not constitute Government of Canada direction on the designation of offshore wind areas, but may be used as part of future decision-making, in conjunction with other data and studies. Twelve different input data layers were used in the analysis, representing a range of physical, ecological, and human-use considerations. Six different scenarios were established, intended to depict a range of outcomes in response to the level of significance assigned to the input layers and to elements within the layers. A map was generated for each scenario that visualizes the compatibility scores for each grid cell in the study area on a numerical scale. Compatibility scores were selected through a combination of stakeholder input, a review of offshore wind siting practices in other jurisdictions, and a critical assessment of offshore wind energy technologies applied theoretically to the Canadian context. Generally, higher scores were awarded to areas where there were fewer known conflicts with shipping routes, fishing activity and existing infrastructure, where geophysical characteristics were expected to be more compatible with existing offshore wind technologies, and to areas with fewer known environmental sensitivities.

Based on the results of the preliminary compatibility analysis, an initial list of sites exhibiting consistently high compatibility was identified. These sites, which are expected to be promising candidates for further study, include areas of the northern Gulf of St. Lawrence between Anticosti Island and Port au Port Bay off the western coast of the island of Newfoundland, areas within St. Pierre Bank off the southern coast of the Island of Newfoundland, smaller areas within Green Bank, and areas closer to the coast between Burgeo Bank and Fortune Bay, areas of the Gulf off the coast of New Brunswick and the northern coast of PEI, sections of the Northumberland Strait between Nova Scotia and PEI, portions of Sable Island Bank, Middle Bank, and Banquereau Bank off the southern coast of Nova Scotia, and sections of Browns Bank and Georges Bank off the southwest coast of Nova Scotia.

This study is subject to several limitations, namely missing and incomplete data, lack of emphasis on temporal and cumulative effects, and the subjectivity of the compatibility scoring scheme applied throughout the analysis. Further work is necessary to address data gaps and take ecosystem wide impacts into account before deployment of offshore wind projects in Canada's coastal waters.

Despite these limitations, it is expected that this compatibility analysis and the data compiled in its preparation can aid in identifying promising locations for further review. Offshore wind represents a potentially significant source of low-carbon energy, and ensuring that relevant, high-quality data and scientifically sound analyses are brought forward into decision-making processes will increase the chances of success for any future deployment of offshore wind in Canada.

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Appendix A: Influence Factors and Compatibility Scores

Table A1: Influence Factors for Scenarios 1 (Baseline), 5 (Restricted) and 6 (Floating)

Scenario 1: Equal Influence			
Layer	Layer Influence	Category	Category Influence
Vessel Density	9.0%	Infrastructure & Human Use	34%
Ocean Usage	8.0%		
Fisheries Effort	8.0%		
Inshore Lobster	9.0%		
Distance from Coast	7.0%	Physical	33%
Geology	7.0%		
Ice Cover	7.0%		
Water Depth	6.0%		
Wind Speed	6.0%		
Defined Ecological Areas	11.0%	Relevant Species & Ecological Areas	33%
Important Habitat	11.0%		
Risk to Marine Birds	11.0%		

Table A2: Influence Factors for Scenario 2 (Physical Influence)

Scenario 2: Physical Influence			
Layer	Layer Influence	Category	Category Influence
Vessel Density	6.0%	Infrastructure & Human Use	25%
Ocean Usage	6.0%		
Fisheries Effort	7.0%		
Inshore Lobster	6.0%		
Distance from Coast	10.0%	Physical	50%
Geology	10.0%		
Ice Cover	10.0%		
Water Depth	10.0%		
Wind Speed	10.0%		
Defined Ecological Areas	8.0%	Relevant Species & Ecological Areas	25%
Important Habitat	9.0%		
Risk to Marine Birds	8.0%		

Table A3: Influence Factors for Scenario 3 (Infrastructure and Human Use Influence)

Scenario 3: Infrastructure and Human Use Influence			
Layer	Layer Influence	Category	Category Influence
Vessel Density	13.0%	Infrastructure & Human Use	50%
Ocean Usage	13.0%		
Fisheries Effort	12.0%		
Inshore Lobster	12.0%		
Distance from Coast	5.0%	Physical	25%
Geology	5.0%		
Ice Cover	5.0%		
Water Depth	5.0%		
Wind Speed	5.0%		
Defined Ecological Areas	9.0%	Relevant Species & Ecological Areas	25%
Important Habitat	8.0%		
Risk to Marine Birds	8.0%		

Table A4: Influence Factors for Scenario 4 (Ecological Influence)

Scenario 4: Relevant Species & Ecological Areas Influence			
Layer	Layer Influence	Category	Category Influence
Vessel Density	6.0%	Infrastructure & Human Use	25%
Ocean Usage	6.0%		
Fisheries Effort	7.0%		
Inshore Lobster	6.0%		
Distance from Coast	5.0%	Physical	25%
Geology	5.0%		
Ice Cover	5.0%		
Water Depth	5.0%		
Wind Speed	5.0%		
Defined Ecological Areas	16.0%	Relevant Species & Ecological Areas	50%
Important Habitat	17.0%		
Risk to Marine Birds	17.0%		

Table A5: Compatibility Scores for Infrastructure and Human Usage Category

Category: Infrastructure and Human Usage						
	Compatibility Score by Scenario					
Value	**1** Baseline	**2** Physical	**3** Infrastructure	**4** Ecological	**5** Restricted	**6** Floating
Vessel Density (log (vessel minutes / km^2))						
0 - 0.05	9	9	9	9	9	9
0.05 - 0.15	8	8	8	8	8	8
0.15 - 0.34	7	7	7	7	7	7
0.34 - 0.66	6	6	6	6	6	6
0.66 - 1.21	4	4	4	4	4	4
1.21 - 2.00	2	2	2	2	2	2
2.00 - 2.93	1	1	1	1	1	1
2.93 - 6.38	1	1	1	1	1	1
6.38 - 16.09	1	1	1	1	1	1
No Data	9	9	9	9	9	9
Ocean Usage						
Active Cables	1	1	1	1	0	3
Marine Farms	1	1	1	1	0	1
Pipelines	1	1	1	1	0	3
Obstructions	1	1	1	1	0	3
Wrecks	1	1	1	1	0	3
Dumping Grounds	1	1	1	1	0	1
Donkin Coal Block	1	1	1	1	0	1
Traffic Separation Zones	1	1	1	1	0	1
Ferry Routes	1	1	1	1	0	1
Anchorages	1	1	1	1	0	1
No Data	9	9	9	9	9	9
Fishing Effort (percentile)						
0 - 10.54	1	1	1	1	1	1
10.54 - 29.51	1	1	1	1	1	1
29.51 - 45.10	1	1	1	1	1	1
45.10 - 58.40	2	2	2	2	2	2
58.40 - 69.94	3	3	3	3	3	3
69.94 - 79.91	5	5	5	5	5	5
79.91 - 88.39	6	6	6	6	6	6
88.39 - 95.23	7	7	7	7	7	7
95.23 - 100	8	8	8	8	8	8
No Data	9	9	9	9	9	9

Inshore Lobster (kg / km^2)						
8 - 704	7	7	7	7	7	7
704 - 1,525	5	5	5	5	5	5
1,525 - 3,445	3	3	3	3	3	3
3,445 - 5,847	1	1	1	1	1	1
5,847 - 24,464	1	1	1	1	1	1
No Data	9	9	9	9	9	9

Table A6: Compatibility Scores for Physical Category

Category: Physical						
	Compatibility Score by Scenario					
Value	**1** Baseline	**2** Physical	**3** Infrastructure	**4** Ecological	**5** Restricted	**6** Floating
Distance from Coast (nm)						
0 – 5 nm	1	1	1	1	0	1
5 – 10 nm	9	9	9	9	9	9
10 – 30 nm	7	7	7	7	7	7
30 – 100 nm	3	3	3	3	3	3
No Data	1	1	1	1	1	1
Geology						
Floating	9	9	9	9	9	9
Sub-surface	9	9	9	9	9	9
Gravity	9	9	9	9	9	9
Gravity / sub-surface	1	1	1	1	1	9
Challenges	1	1	1	1	1	1
No Data	1	1	1	1	1	1
Ice Cover (%)						
0	9	9	9	9	9	9
1-15	8	8	8	8	8	8
16 - 33	7	7	7	7	7	7
34 - 50	6	6	6	6	6	6
51 - 66	5	5	5	5	5	5
67 - 84	3	3	3	3	3	3
85 - 99	2	2	2	2	2	2
100	1	1	1	1	1	1
No Data	9	9	9	9	9	9
Water Depth (m)						
0 – 20	9	9	9	9	9	9
20 – 30	8	8	8	8	8	9
30 – 60	7	7	7	7	7	9
60 – 120	1	1	1	1	1	9
120 – 2000	1	1	1	1	1	5
2000 – 5464	1	1	1	1	1	1
No Data	1	1	1	1	1	1
Wind Speed (m/s)						
4-7	1	1	1	1	1	1
7-9	7	7	7	7	7	7
9-10	8	8	8	8	8	8
10-11	9	9	9	9	9	9
11-12	9	9	9	9	9	9
No Data	1	1	1	1	1	1

Table A7: Compatibility Scores for Relevant Species and Ecological Areas Category

Category: Relevant Species and Ecological Areas						
	Compatibility Score by Scenario					
Value	**1** Baseline	**2** Physical	**3** Infrastructure	**4** Ecological	**5** Restricted	**6** Floating
Defined Ecological Areas						
EBSA	5	5	5	5	5	5
SiBA	3	3	3	3	3	7
AOI	3	3	3	3	3	3
DFO SAR Critical Habitat	1	1	1	1	0	1
OECM	1	1	1	1	0	1
MPA	1	1	1	1	0	1
No Data	9	9	9	9	9	9
Important Habitat						
Leatherback Turtle	3	3	3	3	3	3
Blue Whale Important	3	3	3	3	3	3
Northern Bottlenose Whale	3	3	3	3	3	3
Migratory Bird Species at Risk	3	3	3	3	3	3
Herring Spring Spawning Beds	3	3	3	3	3	3
Herring Fall Spawning Beds	3	3	3	3	3	3
No Data	9	9	9	9	9	9
Risk to Marine Birds						
Very High	1	1	1	1	0	1
High	3	3	3	3	3	3
Moderate	6	6	6	6	6	6
No Data	9	9	9	9	9	9

Table A8: Weighted Overlay Results in Coverage Area, by Scenario

	Area by Scenario (km²)					
Compatibility Score	**1** **Baseline**	**2** **Physical**	**3** **Infrastructure**	**4** **Ecological**	**5** **Restricted**	**6** **Floating**
0	0	0	0	0	252,944	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	172	200	44	1,068	0	4
4	10,360	22,676	3,536	40,228	156	960
5	130,348	205,868	37,852	168,384	39,140	27,944
6	266,716	262,124	195,304	199,944	146,880	172,664
7	123,964	43,956	268,364	113,216	93,544	260,640
8	7,532	4,476	33,772	15,980	6,428	76,128
9	208	0	428	480	208	960
Total	539,300	539,300	539,300	539,300	539,300	539,300

Table A9: Weighted Overlay Results in Percentage Coverage of Study Area, by Scenario

	Percentage Coverage of Study Area by Scenario					
Compatibility Score	**1** **Baseline**	**2** **Physical**	**3** **Infrastructure**	**4** **Ecological**	**5** **Restricted**	**6** **Floating**
0	0%	0%	0%	0%	47%	0%
1	0%	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%
4	2%	4%	1%	7%	0%	0%
5	24%	38%	7%	31%	7%	5%
6	49%	49%	36%	37%	27%	32%
7	23%	8%	50%	21%	17%	48%
8	1%	1%	6%	3%	1.2%	14%
9	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%

Appendix B: Elements of Defined Ecological Areas Layer

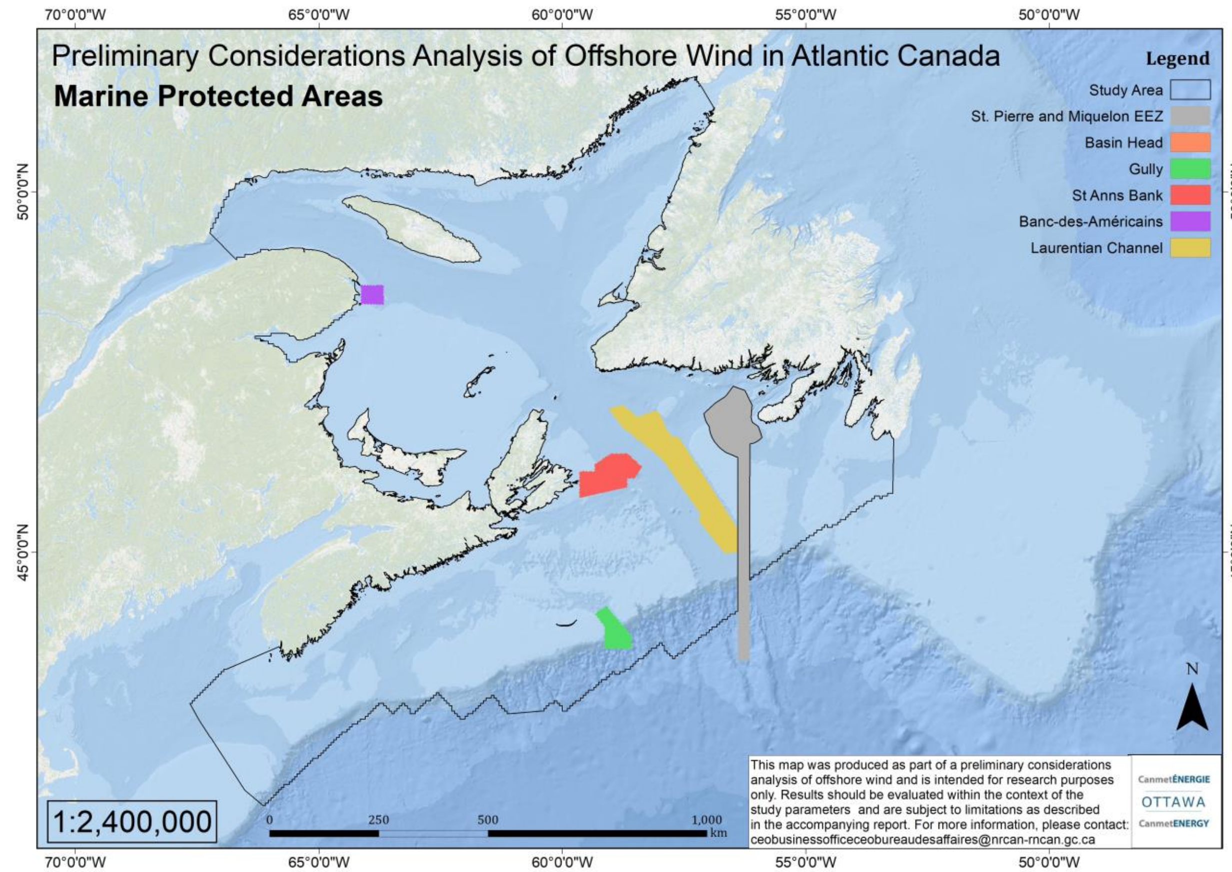

Figure B1: Marine Protected Areas.

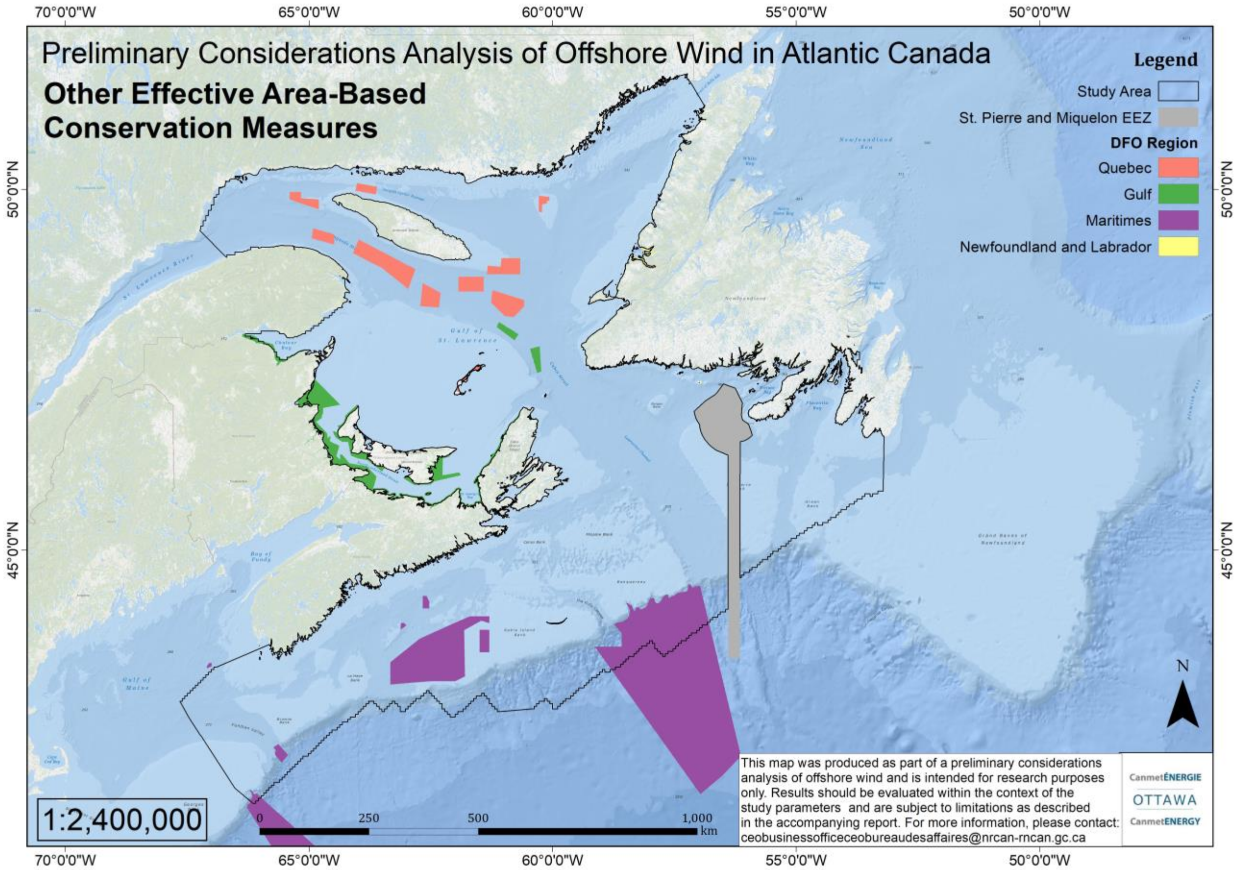

Figure B2: Other Effective Area-Based Conservation Measures.

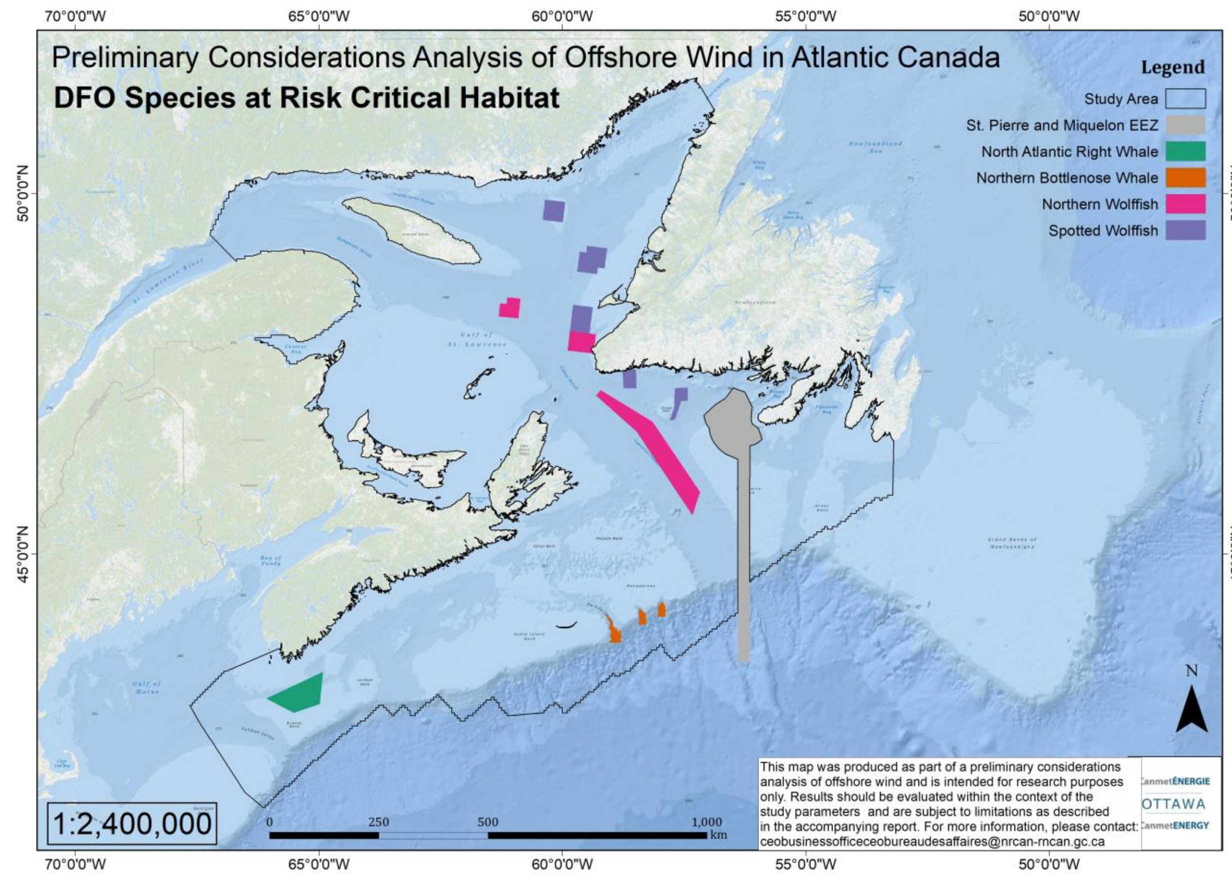

Figure B3: DFO Species at Risk Critical Habitat.

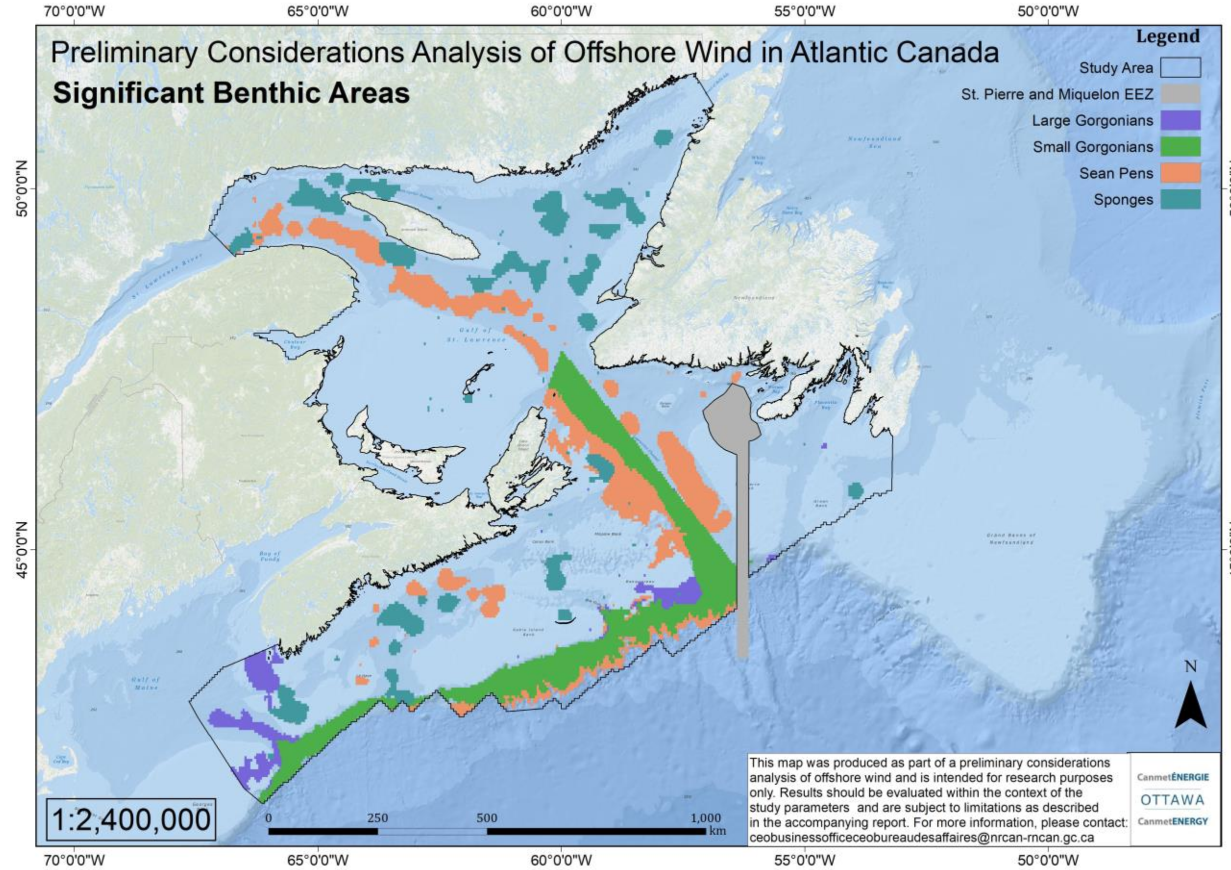

Figure B4: Significant Benthic Areas.

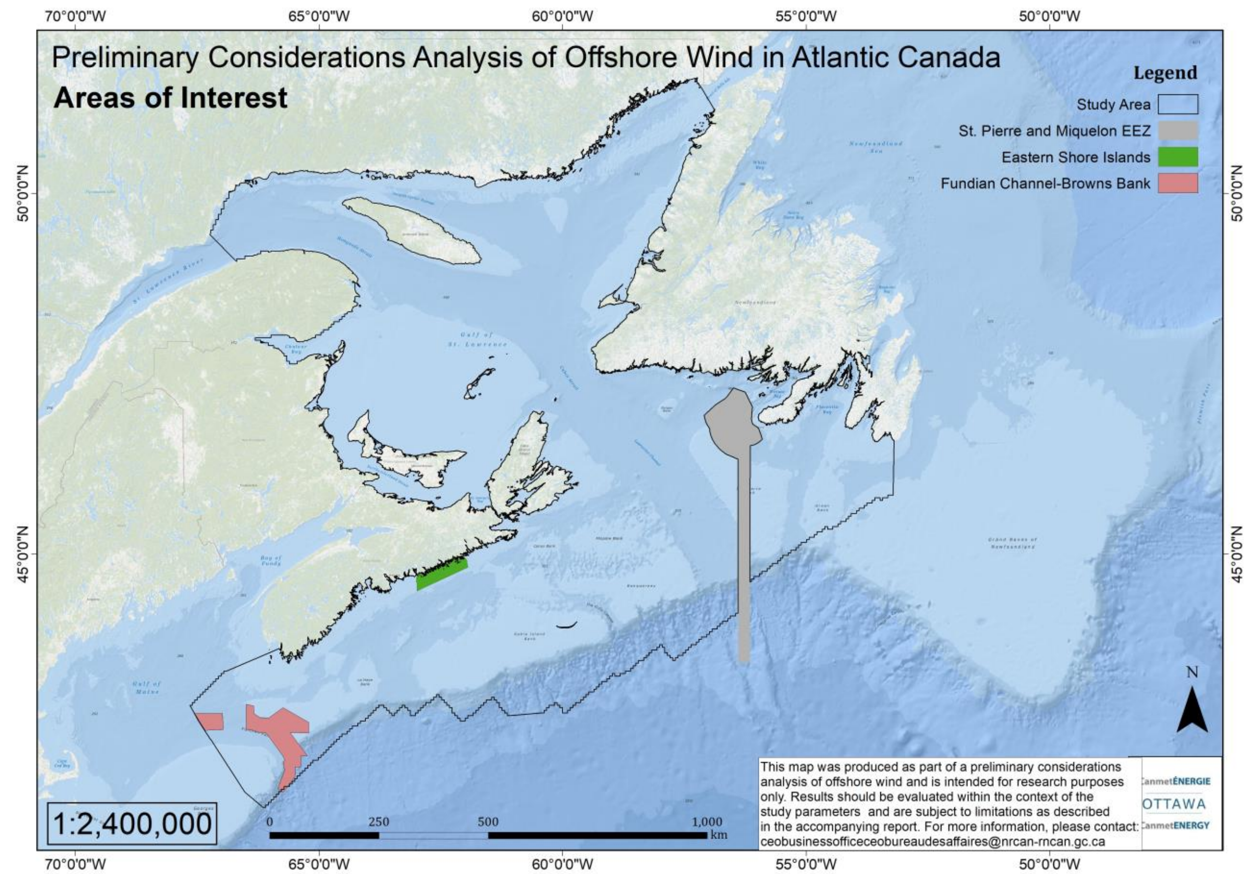

Figure B5: Areas of Interest.

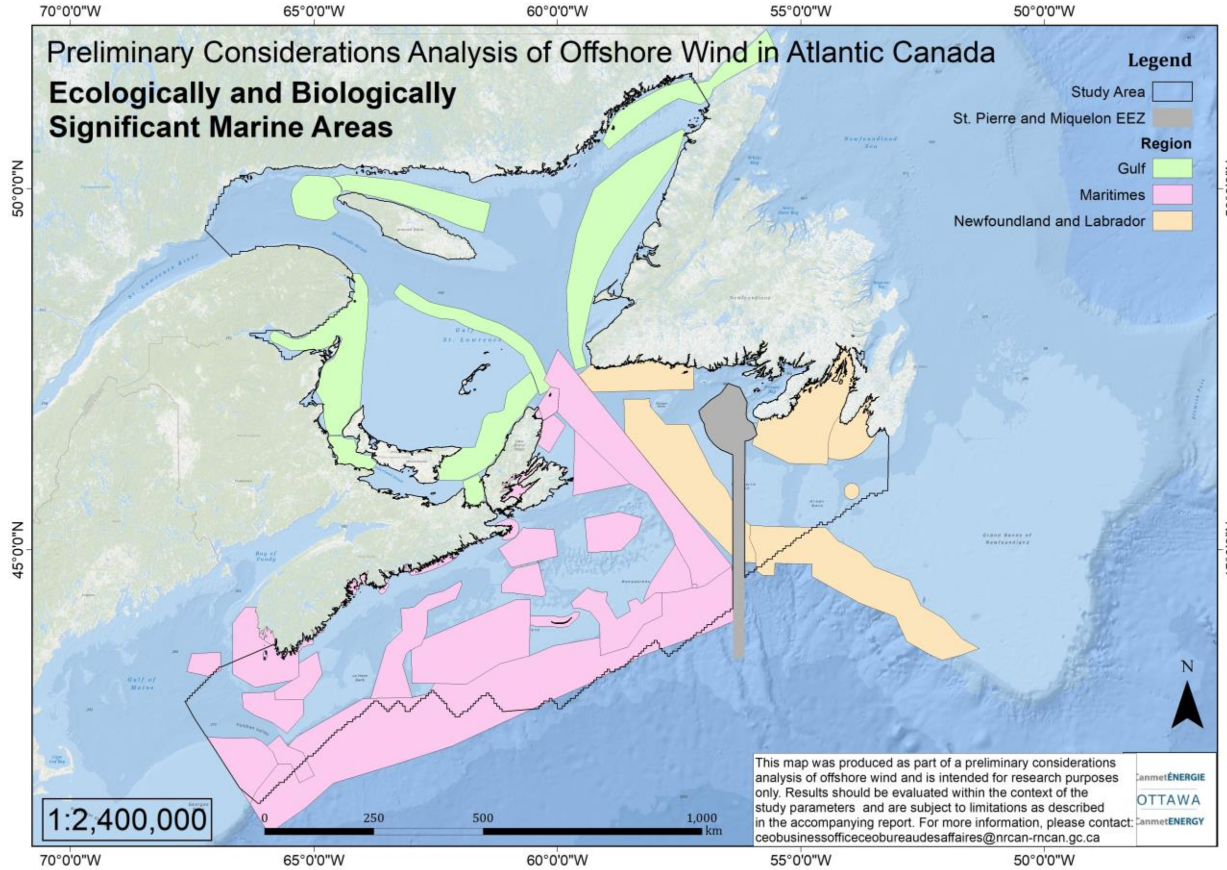

Figure B6: Ecologically and Biologically Significant Areas.

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About CanmetENERGY
Natural Resources Canada's CanmetENERGY is the Canadian leader in clean energy research and technology development. Our experts work in the fields of clean energy supply from fossil fuel and renewable sources, energy management and distribution systems, and advanced end-use technologies and processes. Ensuring that Canada is at the leading edge of clean energy technologies, we are improving the quality of life of Canadians by creating a sustainable resource advantage.

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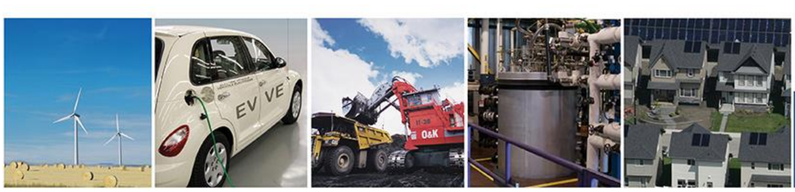
Canada	Canada	Canada	Canada
K1A 0E4	T9G 1A8	K1A 1M1	J3X 1S6



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