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Value Mapping Nova Scotia's Offshore Wind Resources

Updated

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net-zero atlantic

Outline

Aegir Insights' value map of Nova Scotia's offshore wind resource indicates economically attractive sites for offshore wind development

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Executive summary

Nova Scotia has world-class offshore wind resources, with mean wind speeds ranging from 9-11 m/s and several sizable shallow water areas.

This report lays out the economic conditions for a potential future scenario with offshore wind development in Nova Scotia. To begin, a value map depicting areas with high and low Levelized Cost of Energy (LCoE) for offshore wind is presented. Using the heatmap, it is possible to discern where the cheapest sites for offshore wind development are. The heatmap considers factors that directly impact the costs, such as wind speed, water depth, distance to a suitable base port for the construction phase, and distance to a grid connection point.

However, while the heatmap indicates where it would be most economical to build offshore wind farms, it does not show where it is realistic to do so. Many other factors than sheer project economy determine where offshore wind farms are built.

This report follows up the economic value map with a preliminary overview of various constraints on the possible locations of future offshore wind farms. While more in-depth studies are needed to clarify the landscape of limitations fully, the quick overview in this report indicates which areas might be complicated to build offshore wind in and which appear relatively straightforward.

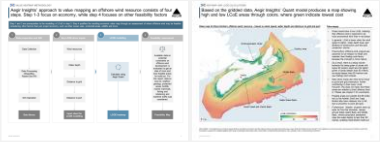
Combining the information from the heatmap with the constraints mapping, a few areas emerge as potential offshore wind development zones. The report proposes four sites, which are then used to simulate offshore wind projects. LCoE-calculations are used to model the attractiveness of these projects. The results show that Nova Scotia could be competitive with most offshore wind markets globally, even in Northwestern Europe.

Reader's guide

Aegir Insights presents its heatmap of Nova Scotia in this report and provides high-level commentary and on its insights as well as major constraints restricting the options for building out regardless of costs as shown on the heatmap, before drawing overall conclusions about the outlook for offshore wind development in Nova Scotia.

The main part of this report is divided into the following four sections:

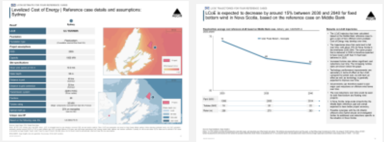
2. Economic value map
This chapter presents the value map and key take-aways from the map.



3. Constraints mapping
This chapter presents potential constraints arising from e.g. geology, protected areas, fishing and more.

4. Conclusion
Combining value map and constraints maps to indicate attractive areas.

5. Appendix:
Design of four reference cases and LCoE calculations and trajectory.



Outline

Aegir Insights' approach to value mapping an offshore wind resource consists of four steps. Step 1-3 focus on economy, while step 4 focuses on other feasibility factors

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Step 1 and 2 are prerequisites to the modelling of LCoE in step 3. Step 4 qualifies the resulting economic value map through an assessment of where offshore wind may be feasible considering other factors than just project economy, such as other ocean uses, protected areas, wildlife and more.

1 Data preparation and GIS

- Data Collection
- Data Processing (Shapefiles, Raster/GeoTiff)
- GIS Operation
- **Data library**

2 Key LCOE driver inputs

- Wind resources
- Water depth
- Distance to grid
- Distance to port
- **Input sheet for LCOE modelling**

3 LCOE modelling

- Calculate using Aegir Quant
- **LCOE heatmap**

4 Feasibility assessment

- Available data on potential constraints on offshore wind development is evaluated to get an idea of more and less feasible areas for build-out. For this report, data on sea ice, seafloor geology, protected areas, birdlife, marine mammals, fishing and lobstering and maritime traffic was considered.
- **Feasibility Map**

For Step 1 and 2, wind and bathymetry data along with basic infrastructure data provide the foundation for LCoE calculations and heatmapping exercise 1/2

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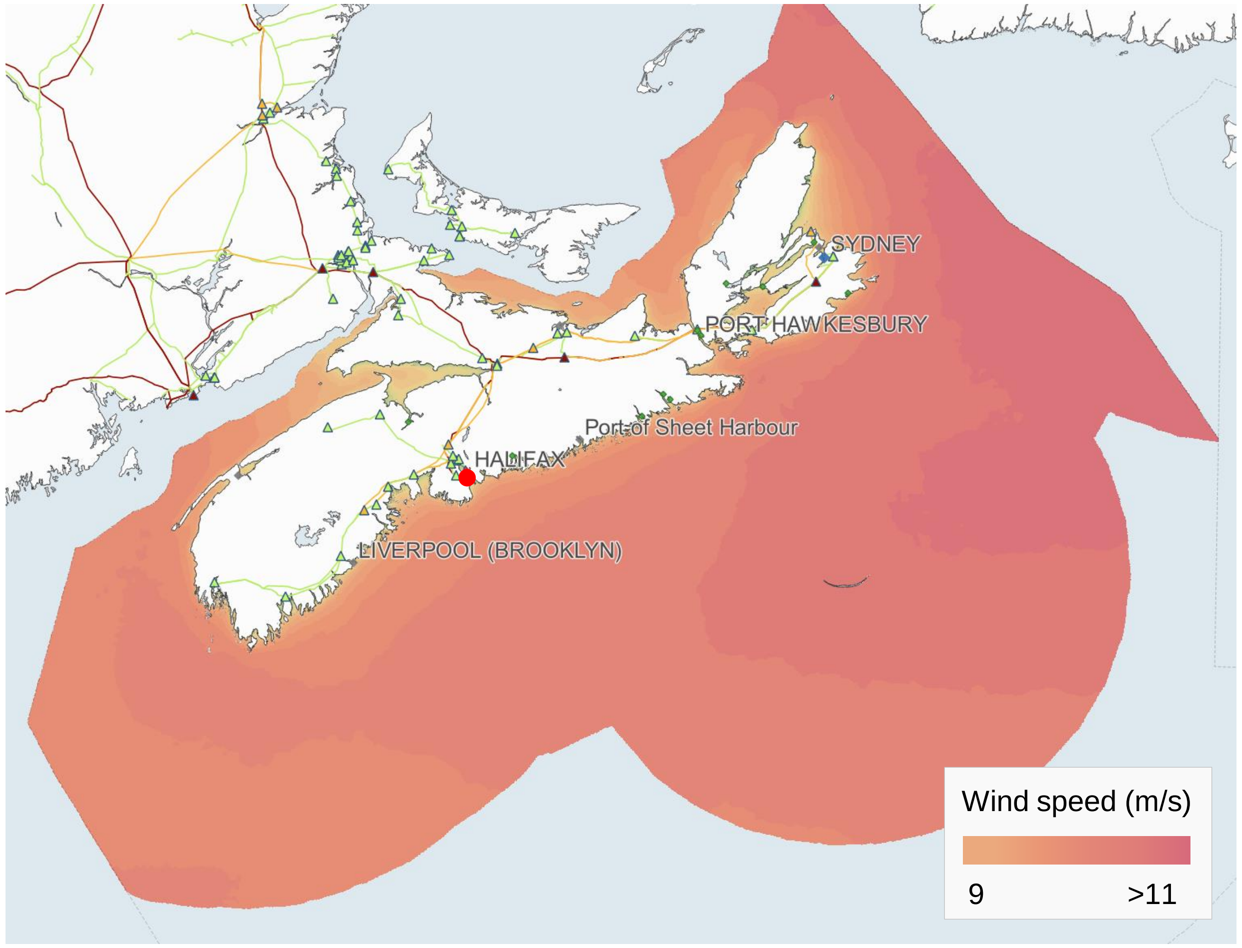
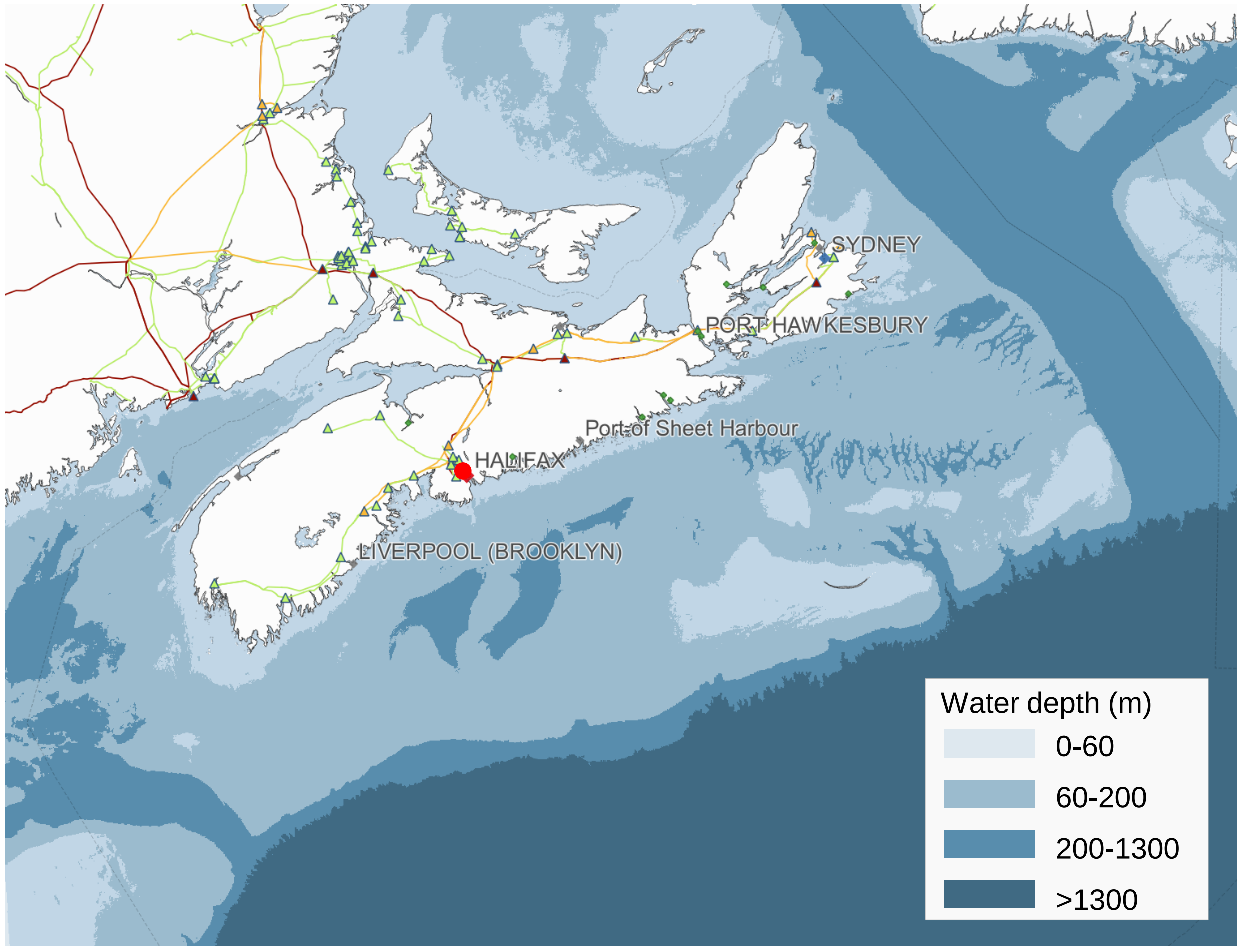
Wind resources in Nova Scotia[1]



- First step is to overlay the map with data on mean wind speeds at a height of a 100 meters.
- Nova Scotia has a world-class wind resource, among the best on the Atlantic coast of the Americas, and little variety in wind speeds between different offshore areas. Almost all areas have between 9 and 11 m/s mean wind speeds.
- The consistent availability of good wind resources across the entire offshore territory means that wind speed will likely not be a restricting factor when it comes to siting offshore wind farms.

Water depth Nova Scotia



- Next step is to add data on water depths, which will determine where fixed-bottom and floating offshore wind could feasibly be installed.
- 0-60 meters are feasible water depths for fixed-bottom offshore wind. This shallow water is mostly found close to shore, however, Nova Scotia also has options for fixed-bottom build-out on sandbanks further out from shore, in Nova Scotia for instance Middle Bank and Sable Island Bank.
- Last but not least, there is substantial acreage with depths suitable for floating foundation concepts at relatively shallow depths of 60-200 metres.

Sources: Aegir Insights database, GEBCO (2020), Global Wind Atlas
Notes: 1) Wind measurement at 100m

For Step 1 and 2, wind and bathymetry data along with basic infrastructure data provide the foundation for LCoE calculations and heatmapping exercise 2/2

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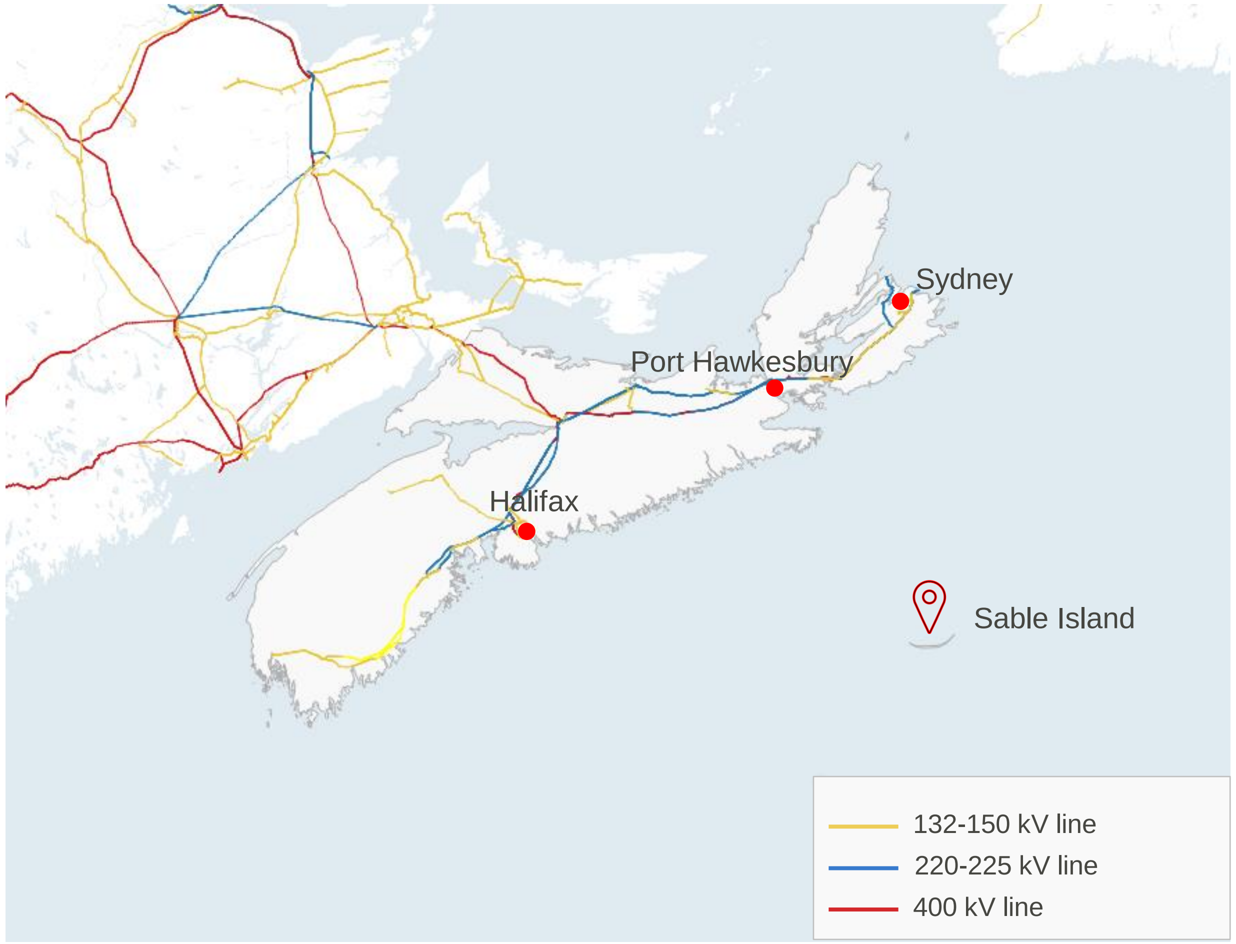
Port map based on World Port Index and Aegir Insights research

- Based on data and research, six ports look promising for offshore wind development and are accepted as either construction or operations and maintenance ports in the Quant model for calculating the LCoE.
- Halifax already played a role in offshore wind project development in the U.S., and the potential of Port of Sheet Harbour to play a role in offshore wind has been investigated in a study commissioned by Net Zero Atlantic.
- Port of Sydney has explicitly announced intentions to become an offshore wind port as part of the Novaporte project.

Transmission map based on Open Street Maps and Aegir Insights research



- Transmission system infrastructure with a voltage of >132 kV is accepted as grid connection points in the model for calculating LCoE.
- Based on the current grid as visualized on the above map, >132 kV grid close to shore is only available close to shore on the southern coast west of Halifax, in Halifax, by the Strait of Canso and in Sydney.
- On top of the currently existing grid connection points, two more points were added in Goldboro and Port Hawkesbury, both to reflect potential build-out of the grid, but also to reflect potential options for offtake to hydrogen projects.

Sources: Aegir Insights' databases, World Port Index, Nova Scotia Utility and Review board

For Step 3, each data layer is overlaid with a fine grid, and key LCoE drivers are computed for each square: Wind speed, water depth, distance to port and grid

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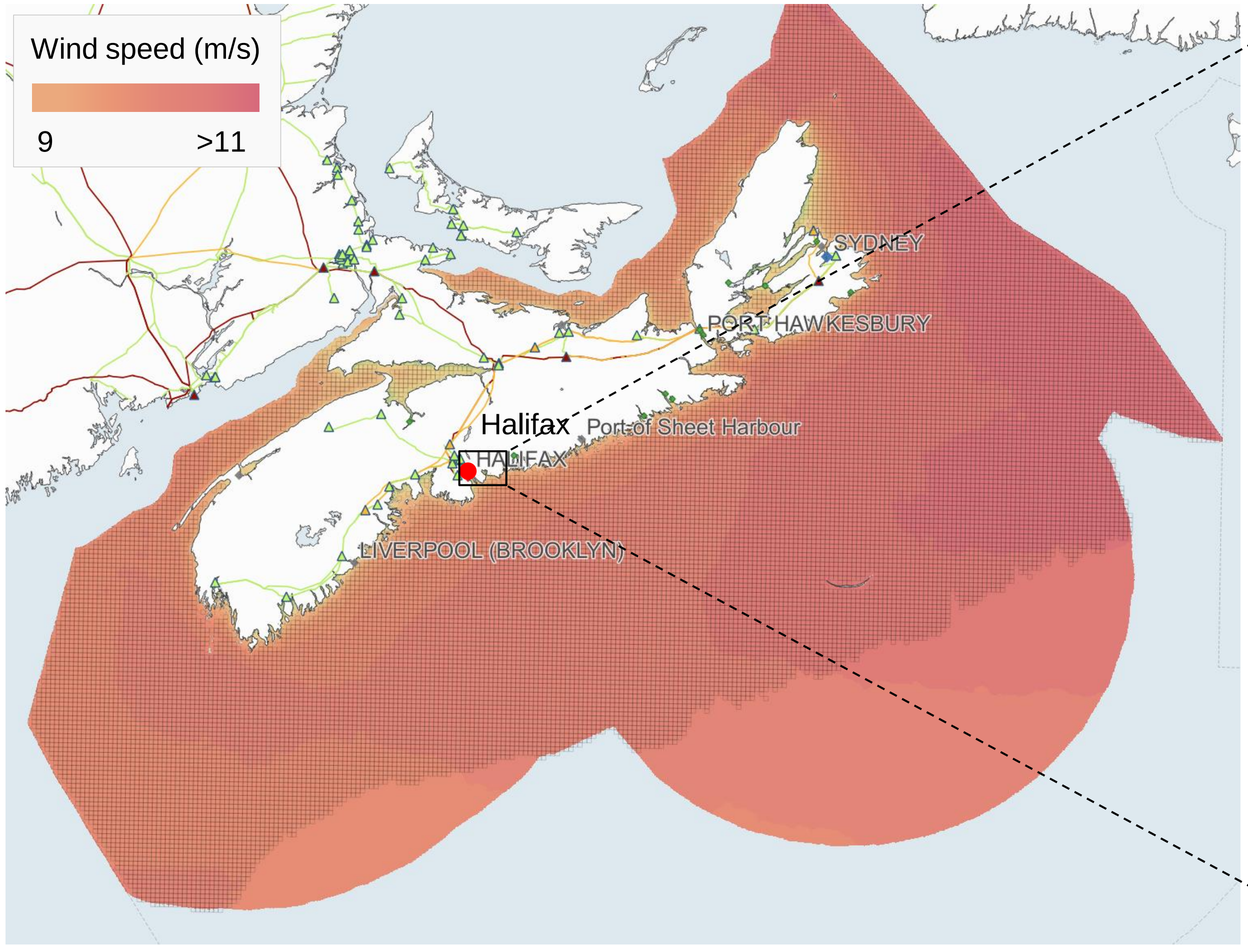
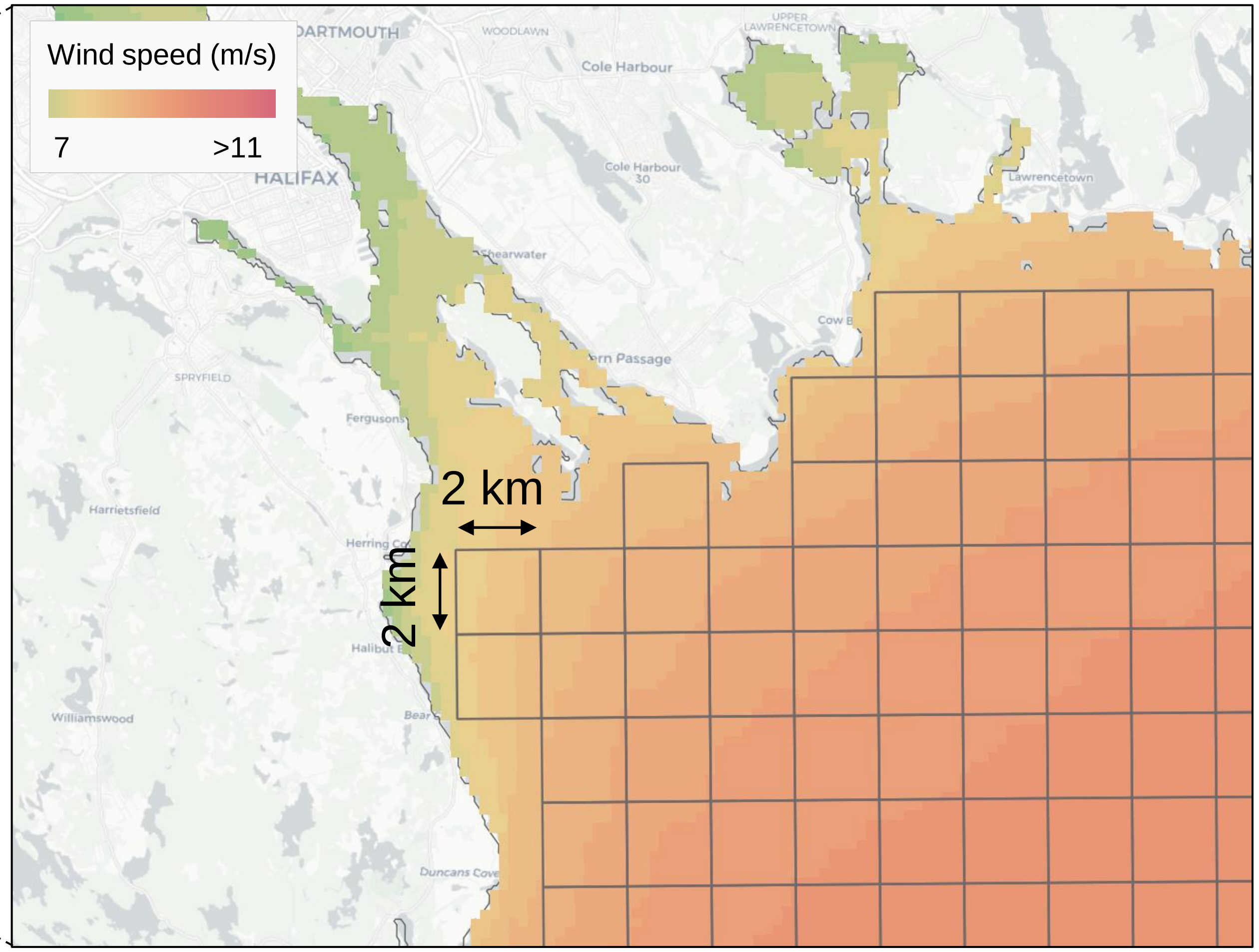
Vector layer with a squared grid covering the offshore region



Statistics of raster layers for each feature of grided vector layer.

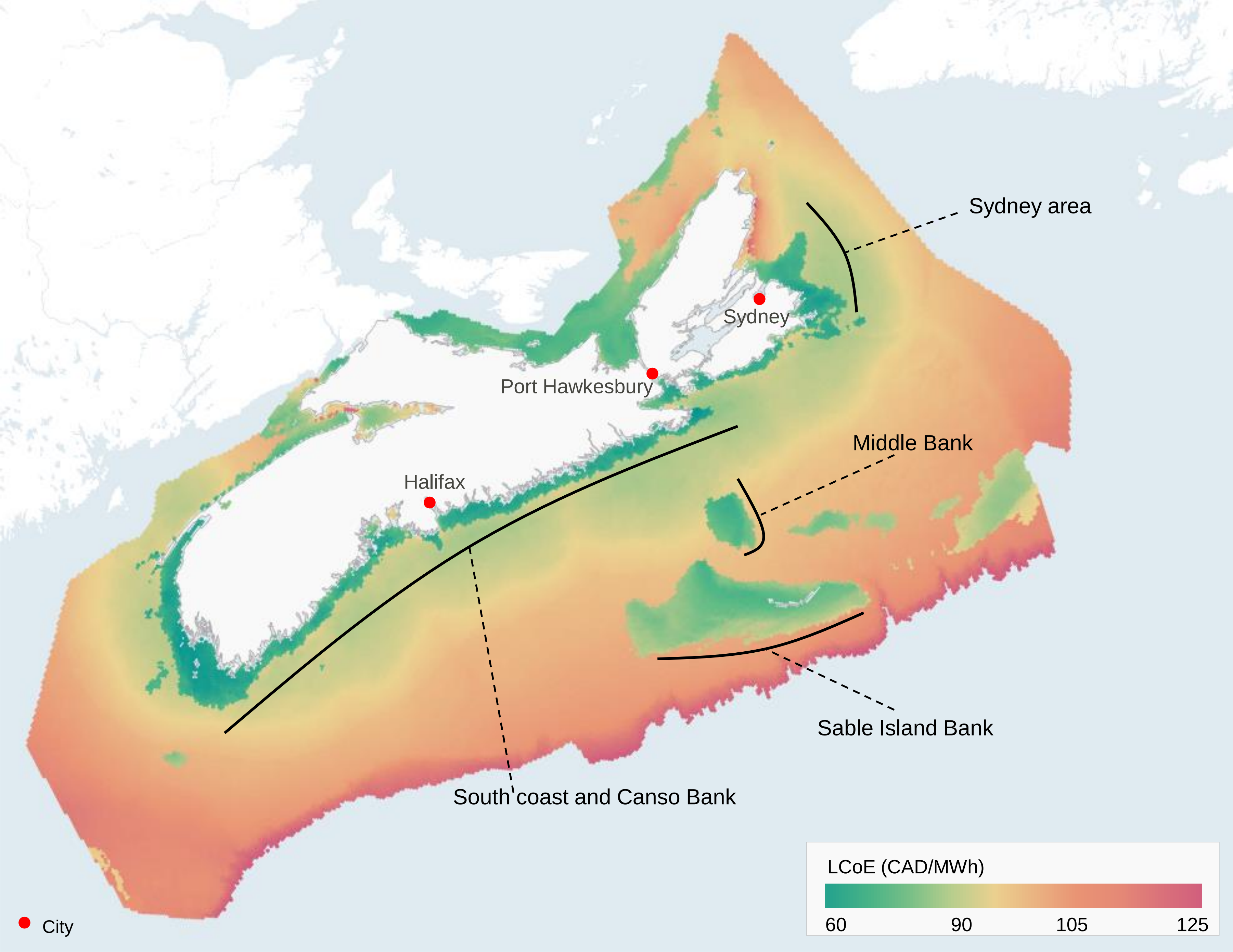


- A grid layer covering the potential offshore wind development region is made.
- The potential offshore wind development region is defined as the total area where mean wind speeds are above 7 m/s and the water depth is between 0 - 1300 meters depth, as wind speeds lower than 7 m/s and waters deeper than 1300 metres are considered uneconomical. In Nova Scotia, almost the entire offshore area fulfills the criteria of wind above 7 m/s and depth below 1300 m.
- Here, the grid layer is shown on top of the wind speed layer, but the grid covers all layers: Wind, depth and infrastructure (port and grid).

- Each element in the grid is a squared polygon. The size of each element in the grid is defined using horizontal and vertical spacing.
- Wind and bathymetry values are calculated for each grid cell.
- Distance to grid is measured from centroid of each grid cell to nearest substations.
- Distance to port is defined as the shortest route from centroid of each grid cell to the nearest harbor traveling only where it is possible to sail.

Based on the gridded data, Aegir Insights' Quant model produces a map showing high and low LCoE areas through colors, where green indicate lowest cost

Value map for Nova Scotia's offshore wind resource – based on wind speed, water depth and distance to grid and port



Take-aways

- Green areas have a low LCoE, meaning that offshore wind is expected to be more economical here than in red areas.
- In general, LCoE is lower when the wind speed is higher, water depth lower and distance to construction port and grid connection shorter. Therefore, areas far from shore tend to be orange/red.
- Fixed-bottom offshore wind is today generally the lower cost technology and assumed applicable up to 60m water depth. Floating has not been deployed at commercial scale, but is assumed to be deployed from 60m or more. Due to fixed-bottom offshore wind being more mature, it is assumed to be lower cost.
- The assumed difference in costs between fixed-bottom and floating wind explains the difference between the deep green of near-shore areas and adjacent lighter green. This is the cut-off of 60 meters' depth. It also explains why Sable Island Bank and Middle Bank are green despite being far from shore – their water is less than 60 m. deep.
- Floating areas just outside the 60 meter-line by the Atlantic Shelf and Cape Breton also have relatively low LCoE due to proximity to ports and grid.
- Areas being green on this value map does not necessarily mean that these areas are fitting for offshore wind. See chapter 3 for a selection of constraints.

DISCLAIMER: This heatmap only considers simple offshore wind farm econometrics and the values are thus calculated using wind speed, water depth and distance to port and grid. The heatmap is not in itself a guide to the placement of offshore wind farms, but must be compared to a weighed against other siting considerations like fishing areas, marine traffic, protected areas and species, tides, geology, sea ice, viewshed issues and more.

Outline

Sea ice is limited around south-western Nova Scotia but could lead to challenges and higher costs for offshore wind farms off the north-eastern shorelines

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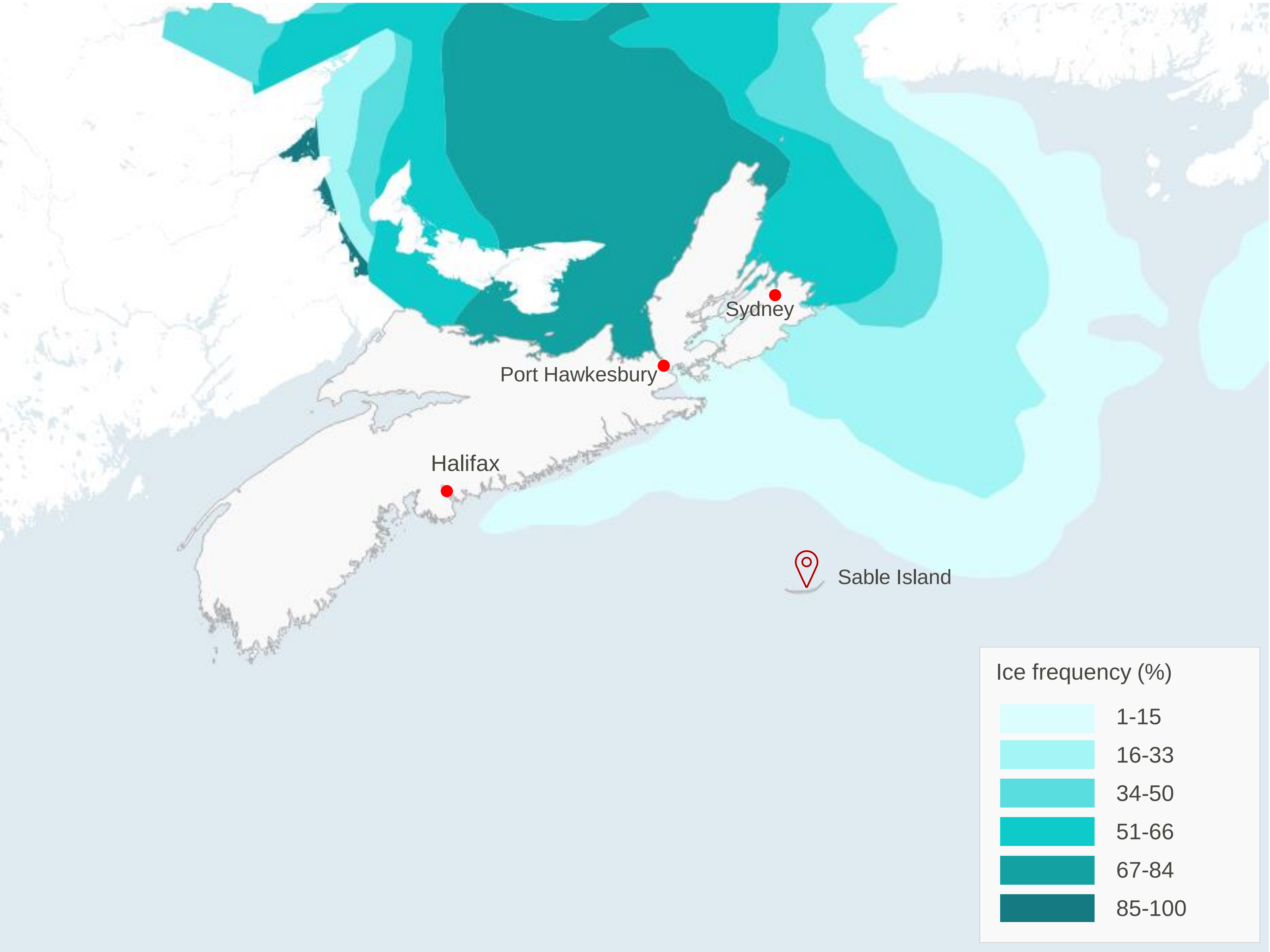
Ice frequency[1]



Take-aways

- Most of the area off the Scotian Shelf is free of sea ice, meaning that for instance the shallow water area on the sandbanks by Sable Island would be a favorable location for offshore wind turbines.
- The area around Cape Breton generally sees much more sea ice, but site-specific measurements would be conducive to determine whether not only the frequency, but also the type and volume of sea ice would pose problems.
- In general, sea ice could be a challenge for areas north and east of Nova Scotia, while large areas to the south and west experience limited sea ice in winter.
- Installing offshore wind in areas with sea ice may require extra attention to the design and appropriate measures such as protective skirts for the turbine foundations. Costs for components and installation are therefore expected to be slightly higher.
- Furthermore, operation and maintenance may be more costly due to icing of the blades and more difficulties getting to and from the turbines during winter.
- However, sea ice does not prevent offshore wind build-out, it only adds some complexity and costs.
- In general, more experience in the field would be beneficial.

Sources: Aegir Insights database, Climatic Ice Atlas 1981-2010 - Canadian Ice Service - Environment Canada - Region: East Coast - Date: March 26

Notes: **1)** Frequency with which sea ice was present in the area on March 26th each year between 1981 and 2010,

Geological conditions restrict near-shore offshore wind development in Nova Scotia, as hard bedrock makes drilling for installation of monopiles uneconomical

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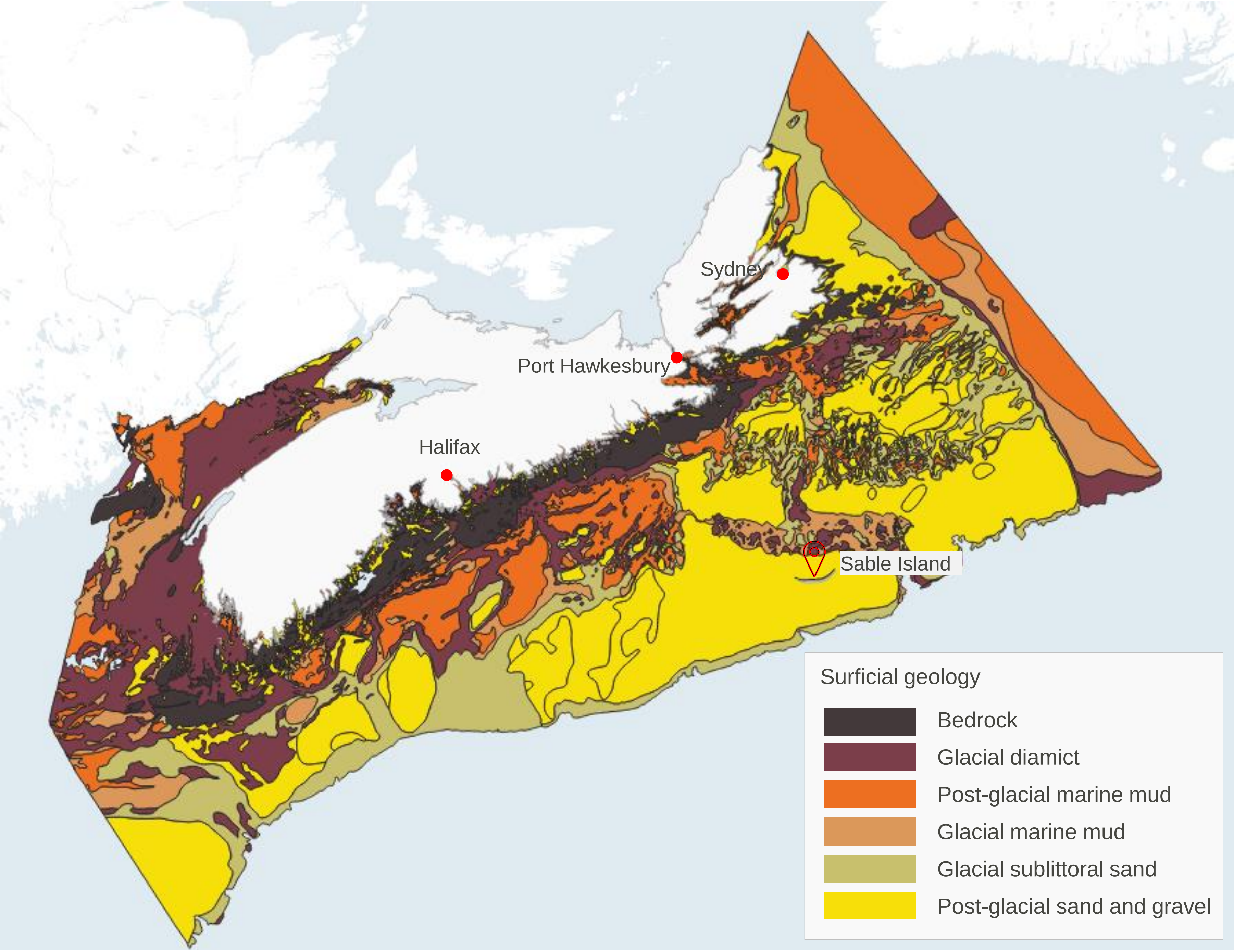
Surficial geology of the Scotian Shelf[1]



Take-aways

- The seabed immediately surrounding Nova Scotia along most of the southern shore is dominated by bedrock, which would require drilling into for securing the most commonly used turbine foundations.
- As the bedrock tends to be present in the same areas as have water depths below 60 meters, this may complicate near-shore build-out. Installation of monopile foundations, the most commonly used foundation at these depths, may be uneconomical in bedrock.
- A step-stone project might be feasible close to shore through for instance the use of gravity-based foundations, but this is a more uncommon type of foundation.
- Therefore, bedrock in near-shore areas is a notable constraint. However, multiple locations further from shore, and, in the case of areas by Sydney, quite close to shore, have sandy seabeds.
- Depending on the depth of sediment, these areas could be relatively more attractive for offshore wind development than the bedrock areas.
- This map does dot indicate depth of sediment, meaning that bedrock can still be present in areas that show up on this map as having other types of seabed geology, just deeper down. It is however likely that sandbanks far from shore have relatively deep layers of sediment.

Sources: Updated surficial geology compilation of the Scotian Shelf bioregion; offshore Nova Scotia and New Brunswick, Canada; G. Phllibert, B.J. Todd, D.C. Campbell, E. L. King, A. Normandeau, S. E. Hayward, E. R. Patton and L. Campbell.

Notes: **1)** Geology map doesn't indicate depth of sediment. Map depicts dominant type of ocean floor material at surface; hence bedrock can be present in all areas deeper down. In general, the bedrock may be buried deeper beneath the sandbanks further from shore (Middle Bank and Sable Island Bank) due the water around the banks being deeper, indicating that the seabed slopes down towards the continental shelf and that the amount of sand on the banks must therefore be significant in order to enable the shallow water levels of the banks.

Nova Scotia has several protected areas which may restrict offshore wind build-out, but many are far from the coast and unlikely to be areas of interest for offshore wind

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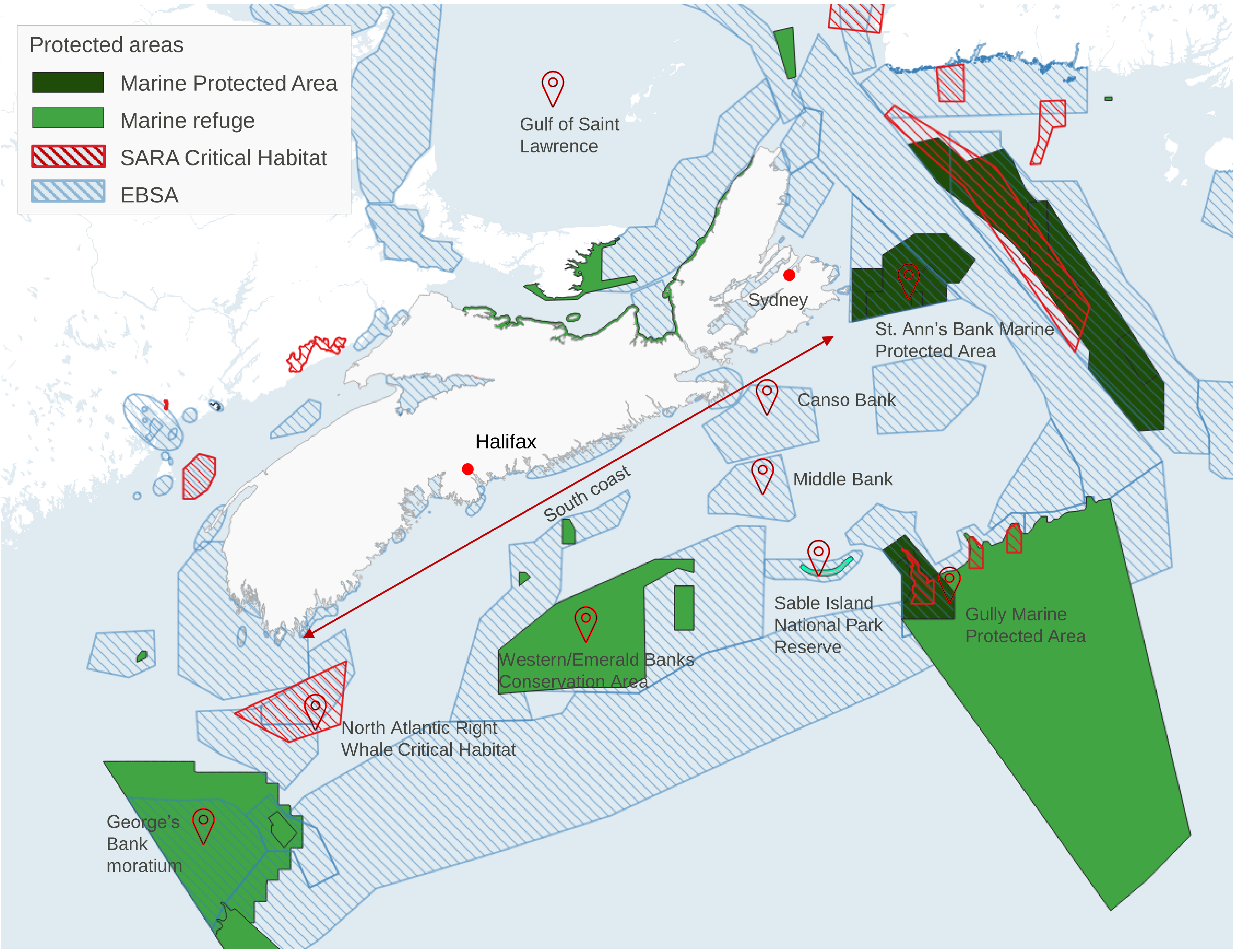
Marine protected areas and refuges



Take-aways

- Nova Scotia has a rich marine ecosystem and several protected areas.
- Under Canada's Oceans Act, some areas are defined as Marine Protected Areas. These have a high level of protection and are not suitable for offshore wind development.
- Marine refuges are areas that are protected for a variety of reasons. George's Bank has been protected from industrial use for many years by a moratium, and Western/Emerald Banks is protected under the Other Effective Area-Based Conservation Measures (OEABCM).
- Offshore wind development is therefore not expected to take place on George's Bank or Western/Emerald Banks. These areas also feature high LCoE levels according to the heatmap and may therefore not be economically attractive.
- The Species at Risk Act (SARA) defines certain areas at Critical Habitat areas, wherein projects might be restricted or made illegal if they destroy the habitat. These areas are best avoided.
- Ecologically and Biologically Significant Areas (EBSAs) should be noted but do not necessarily prevent offshore wind. Therefore, for instance Sable Island, Middle Bank and Canso Bank may be options for offshore wind despite the EBSAs in the areas.

Notes: 1) The Atlantic Mud-Piddock SARA Critical Habitat in the inner Bay of Fundy is not depicted on this map for technical reasons. Further, this map only considers already approved protected areas. More areas may be in the process of becoming protected areas. Thus, this map is not an exhaustive source and should not be treated as such.

The coastline of Nova Scotia is lined with seabird colonies, indicating that birdlife will be a main factor to consider in the siting and design of offshore wind projects

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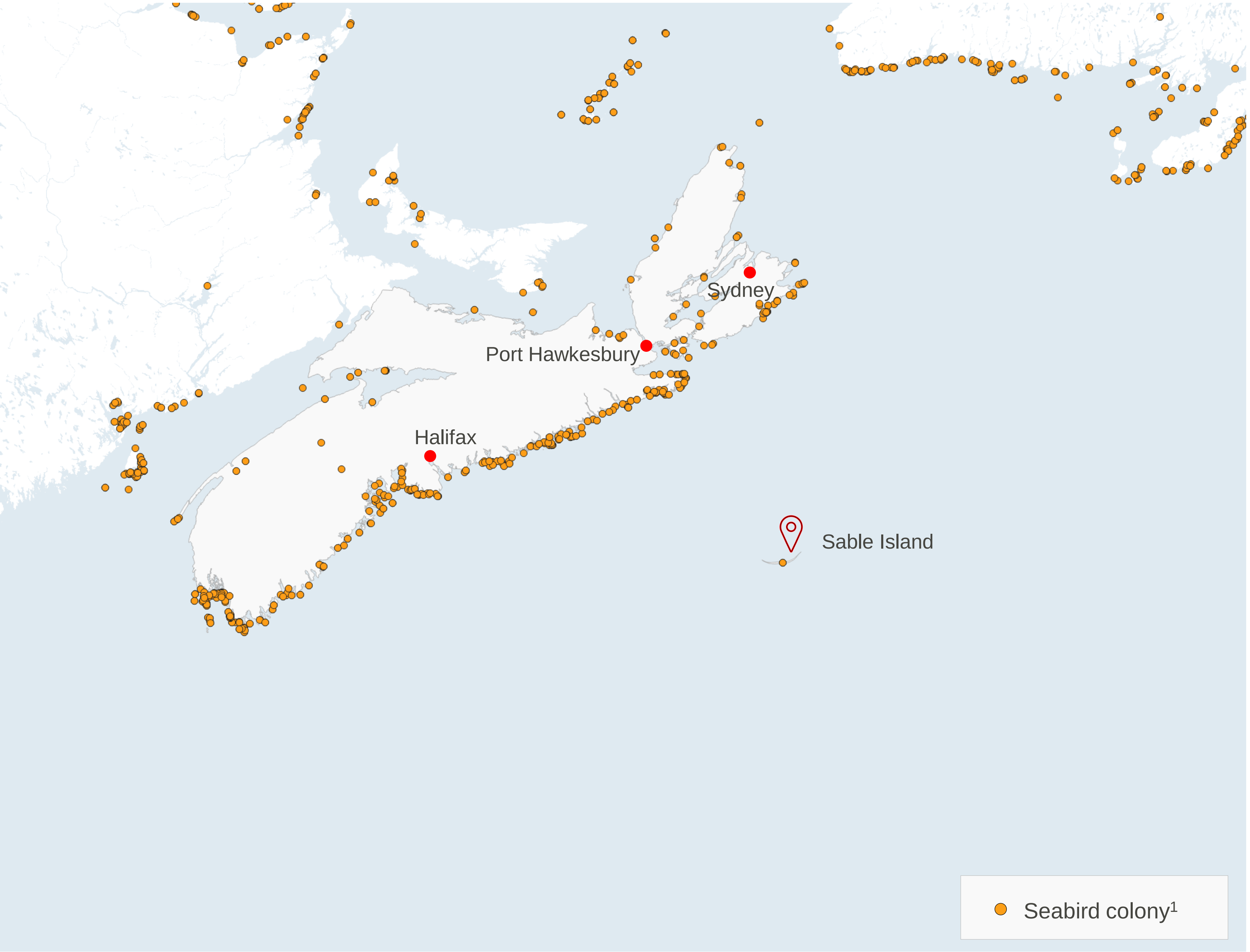
Seabird colonies[1]



Take-aways

- Seabirds are active around Nova Scotia, particularly in summer. Their colonies line the coast and they forage inshore and offshore.
- Furthermore, some birds are migratory and cross the sea on their path.
- The Sable Island Migratory Bird Sanctuary covers the entirety of Sable Island, similar to the Sable Island National Park Reserve and extends into the water with a one-mile buffer zone.
- Bird species on Sable Island include the Ipswich Sparrow and Roseate Tern, both of which are protected under the Species at Risk Act, and a colony of 2500 pairs of terns along with an additional 2500 pairs of gulls which all nest on Sable Island.
- Leach's Storm-Petrel, which has been assessed as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), likewise breeds on Sable Island though in lesser numbers than the above species.
- Apart from the birds on Sable Island, general attention should be paid to the density of colonies along the coast from Halifax to Strait of Canso, as this coastline is potentially of interest for offshore wind development, particularly off the mouth of the Strait of Canso.
- More data gathered with offshore wind in mind would be beneficial.

Sources: The Atlantic Canadian Seabird Viewer. A collaborative project by Bird Studies Canada, Mount Allison University, and World Wildlife Fund Canada.
Notes: **1**) All types of colonies are shown on this map and species are not distinguished between. Refer to data source for more details.
DISCLAIMER: Overview may not be exhaustive. More data on bird and bat patterns could further clarify the picture of birdlife in Atlantic Canada.

Sea bird activity may be lower winter months and mostly concentrated far from shore southwest of Nova Scotia, but more data is needed

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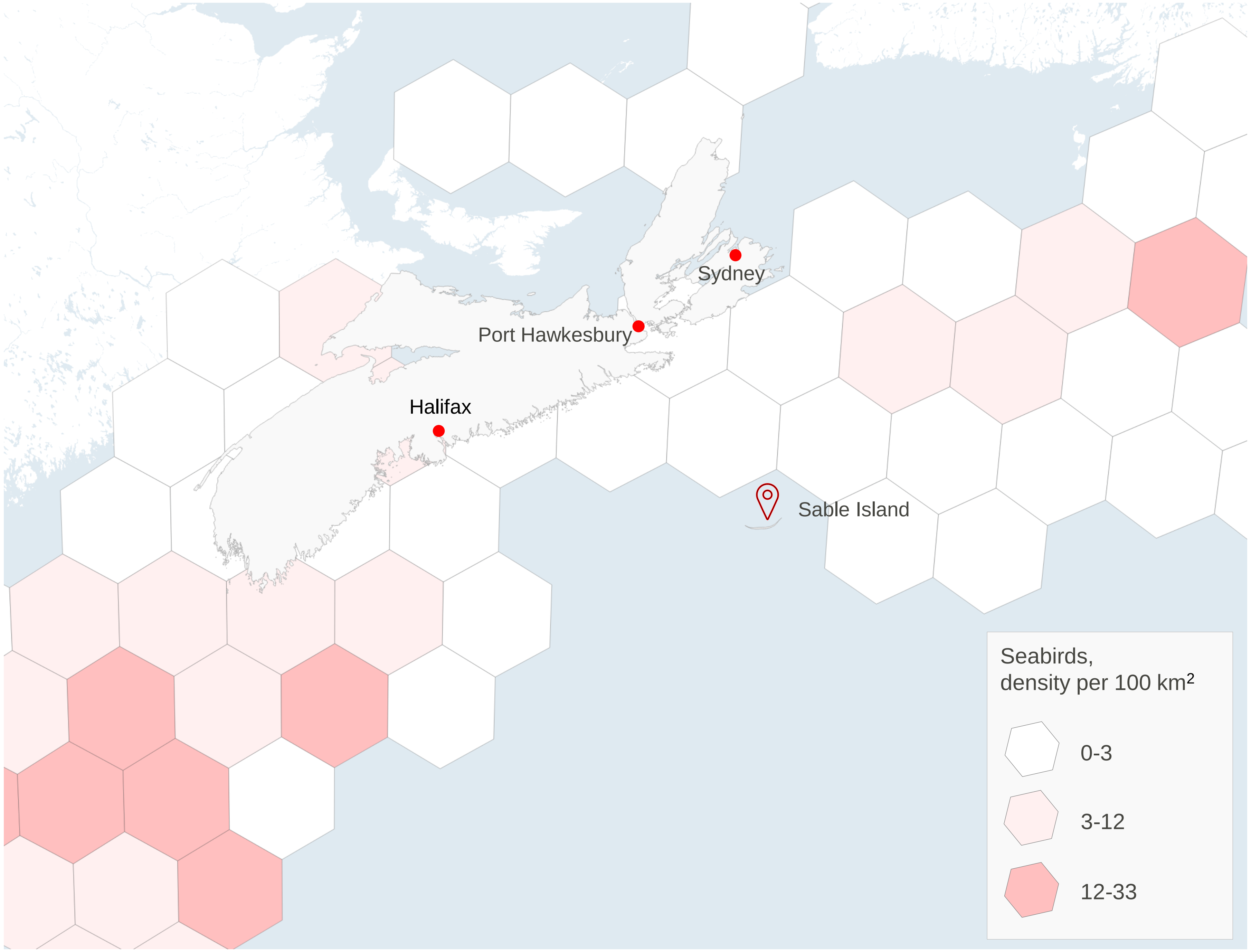
Seabirds at sea, density, 2006-2020. Averages for months December-March[1]



Take-aways

- This map and the two following show density data for seabirds at sea averaged for four-month periods. This map shows the winter months, December to March.
- Survey efforts vary depending on multiple factors. For full overview of the data gathering methods, survey efforts and variability, please refer to the source, Atlas of Seabirds at Sea in Eastern Canada (see footnote).
- The data indicates that seabirds are overall less active around Nova Scotia in winter months than the rest of the year.
- Most activity has been recorded southwest of the peninsula and quite far from shore.
- However, it should be noted that the survey methods favour offshore observations and thus birds in near-shore areas may be underrepresented.
- The areas of interest for offshore wind development such as Sable Island Bank, Middle Bank, the south coast east of Halifax and off the mouth of Strait Canso as well as Sydney all seem to have relatively little activity. However, the lack of activity around Sable Island is due to there being no survey data from that area in winter, so more data is needed.
- In general, data gathered with offshore wind in mind would be beneficial.

Sources: Atlas of Seabirds at Sea in Eastern Canada 2006 – 2020, Canadian Wildlife Service

Notes: **1)** Data collected using ships of opportunity, trained observers, and distance sampling methodology. Data represent density (number of bird sightings per km2) derived from distance sampling models and computed according to period of year, aggregated across all seabird species. Note the months shown on this map are only December-March. See the following pages for the rest of the year. Each hexagon covers an area of 100 km2. For full description of data gathering methodology and measures of uncertainty, please consult the Atlas of Seabirds at Sea in Eastern Canada 2006 – 2020.

Sea bird activity seems to increase in spring and early summer. Around Nova Scotia, there is in particular activity southeast of the peninsula

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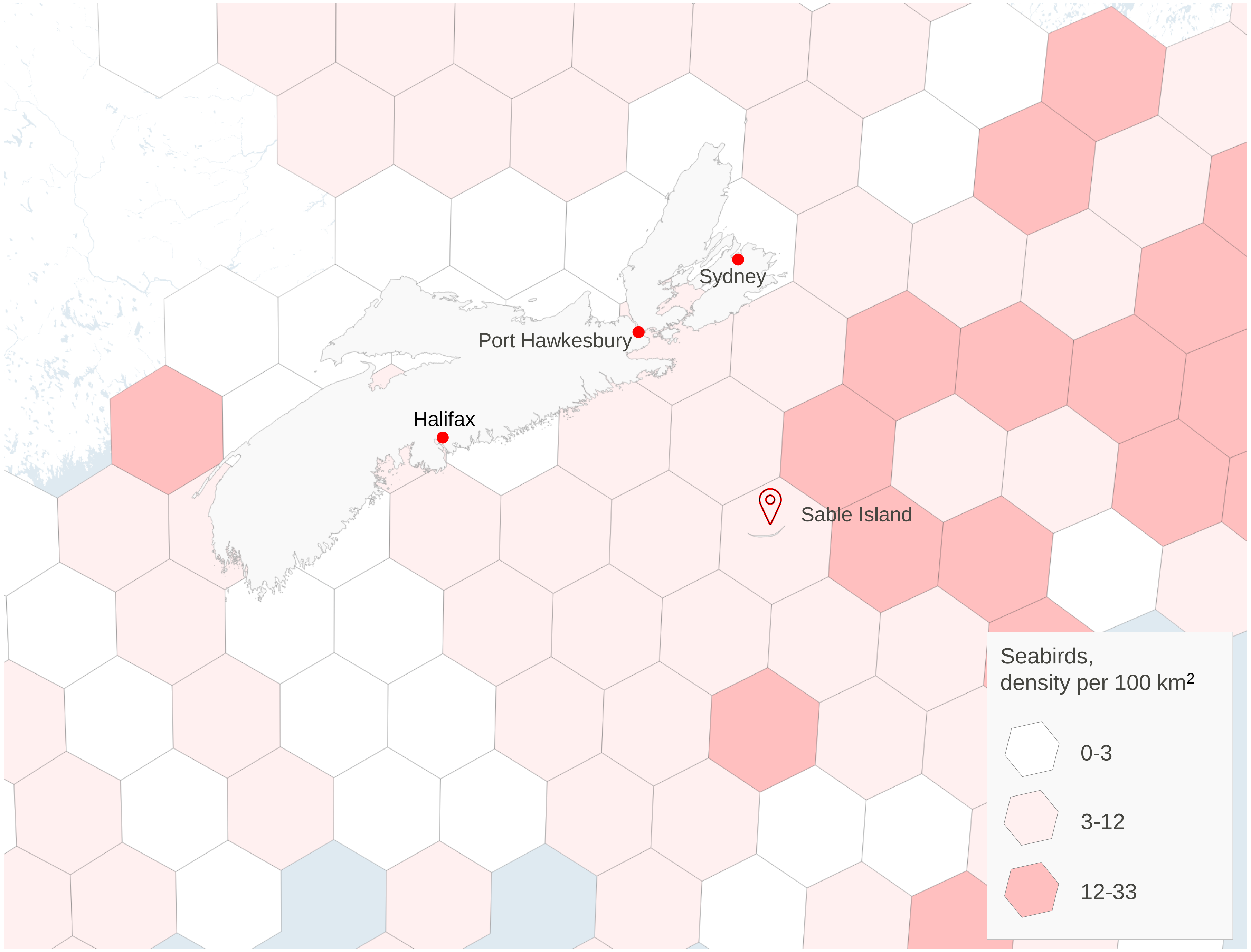
Seabirds at sea, density, 2006-2020. Averages for months April-July[1]



Take-aways

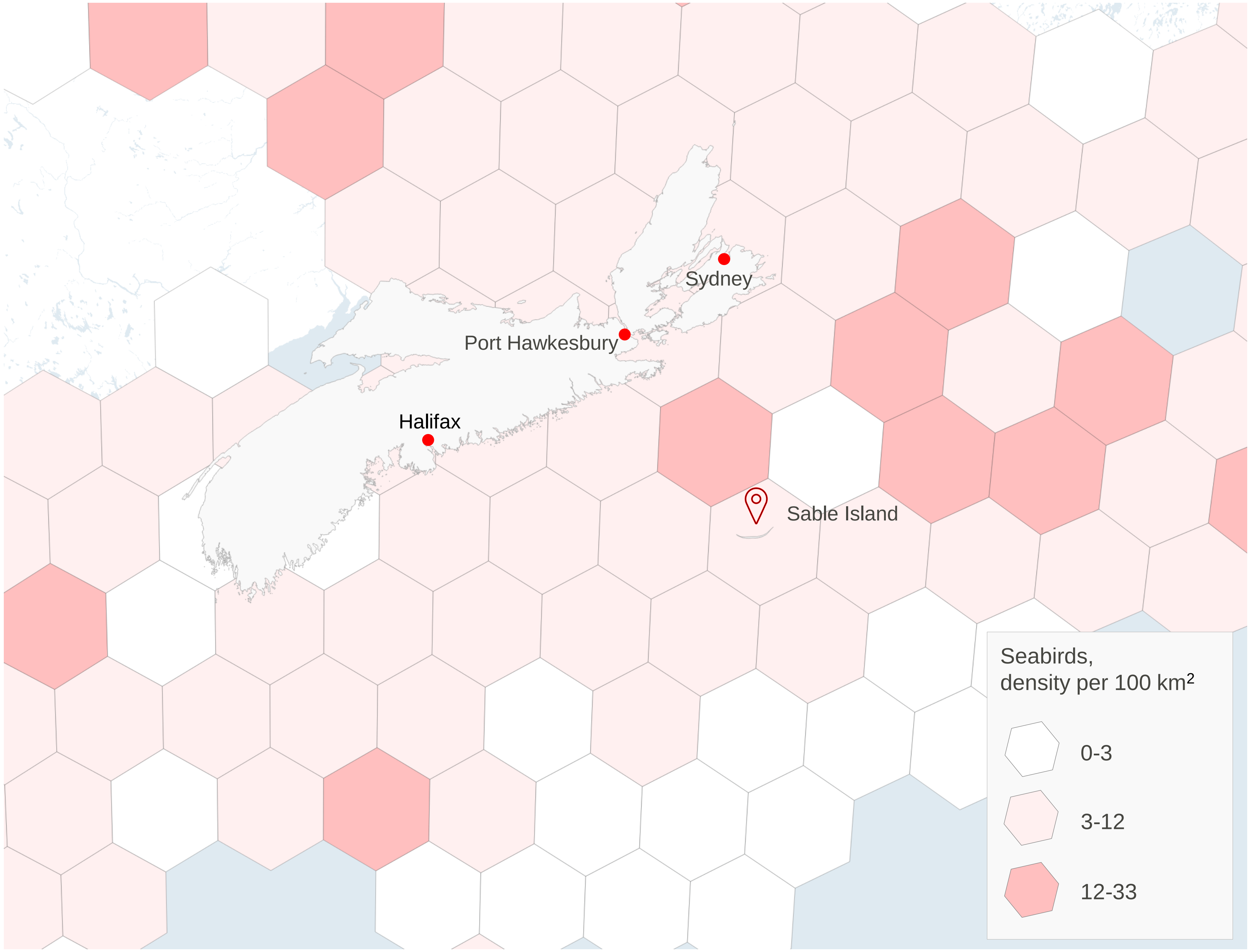
- This map and the two surrounding show data for seabirds at sea averaged for four-month periods. This map shows the spring/summer months, April to July.
- Survey efforts vary depending on multiple factors. E.g., survey methods favour offshore observations and thus birds in near-shore areas may be underrepresented. For full overview of the data gathering methods, survey efforts and variability, please refer to the source, Atlas of Seabirds at Sea in Eastern Canada (see footnote).
- The data indicates more seabird activity around Nova Scotia in spring and summer compared to winter.
- Most activity has been recorded southeast of the peninsula.
- The areas of interest for offshore wind development such as Sable Island Bank, Middle Bank, the south coast east of Halifax and off the mouth of Strait Canso as well as Sydney all have more activity nearby now than they did in winter.
- Particularly Sable Island Bank and Middle Bank areas have more seabird activity at sea, though the most active hexagons east of the island generally do not overlap with the most attractive areas on the economic value map.
- More data gathered with offshore wind in mind would be beneficial.

Sources: Atlas of Seabirds at Sea in Eastern Canada 2006 – 2020, Canadian Wildlife Service

Notes: **1)** Data collected using ships of opportunity, trained observers, and distance sampling methodology. Data represent density (number of bird sightings per km2) derived from distance sampling models and computed according to period of year, aggregated across all seabird species. Note the months shown on this map are only April-July. See surrounding pages for the rest of the year. Each hexagon covers an area of 100 km2. For full description of data gathering methodology and measures of uncertainty, please consult the Atlas of Seabirds at Sea in Eastern Canada 2006 – 2020.

During late summer and fall, seabird activity seems to increase in areas close to Middle Bank that could be of interest to offshore wind development

Seabirds at sea, density, 2006-2020. Averages for months August-November[1]



Take-aways

- This map and the two preceding show data for seabirds at sea averaged for four-month periods. This map shows August to November.
- Survey efforts vary depending on multiple factors. E.g., survey methods favour offshore observations and thus birds in near-shore areas may be underrepresented. For full overview of the data gathering methods, survey efforts and variability, please refer to the source, Atlas of Seabirds at Sea in Eastern Canada (see footnote).
- The data indicates more seabird activity around Nova Scotia in summer and fall compared to winter.
- Most activity has been recorded southeast of the peninsula.
- The areas of interest for offshore wind development such as Sable Island Bank, Middle Bank, the south coast east of Halifax and off the mouth of Strait Canso as well as Sydney all have more seabird activity nearby than in the other months of the year according to this data.
- Particularly the Middle Bank areas has more seabird activity, and one of the most active hexagons overlaps with one the most attractive areas on the economic value map.
- More data gathered with offshore wind in mind would be beneficial.

Sources: Atlas of Seabirds at Sea in Eastern Canada 2006 – 2020, Canadian Wildlife Service

Notes: **1)** Data collected using ships of opportunity, trained observers, and distance sampling methodology. Data represent density (number of bird sightings per km2) derived from distance sampling models and computed according to period of year, aggregated across all seabird species. Note the months shown on this map are only August-November. See the preceding pages for the rest of the year. Each hexagon covers an area of 100 km2. For full description of data gathering methodology and measures of uncertainty, please consult the Atlas of Seabirds at Sea in Eastern Canada 2006 – 2020.

Marine life plays a large role in Nova Scotia's economy, and active fishing grounds are found all over, but particularly around the southwestern part of Nova Scotia

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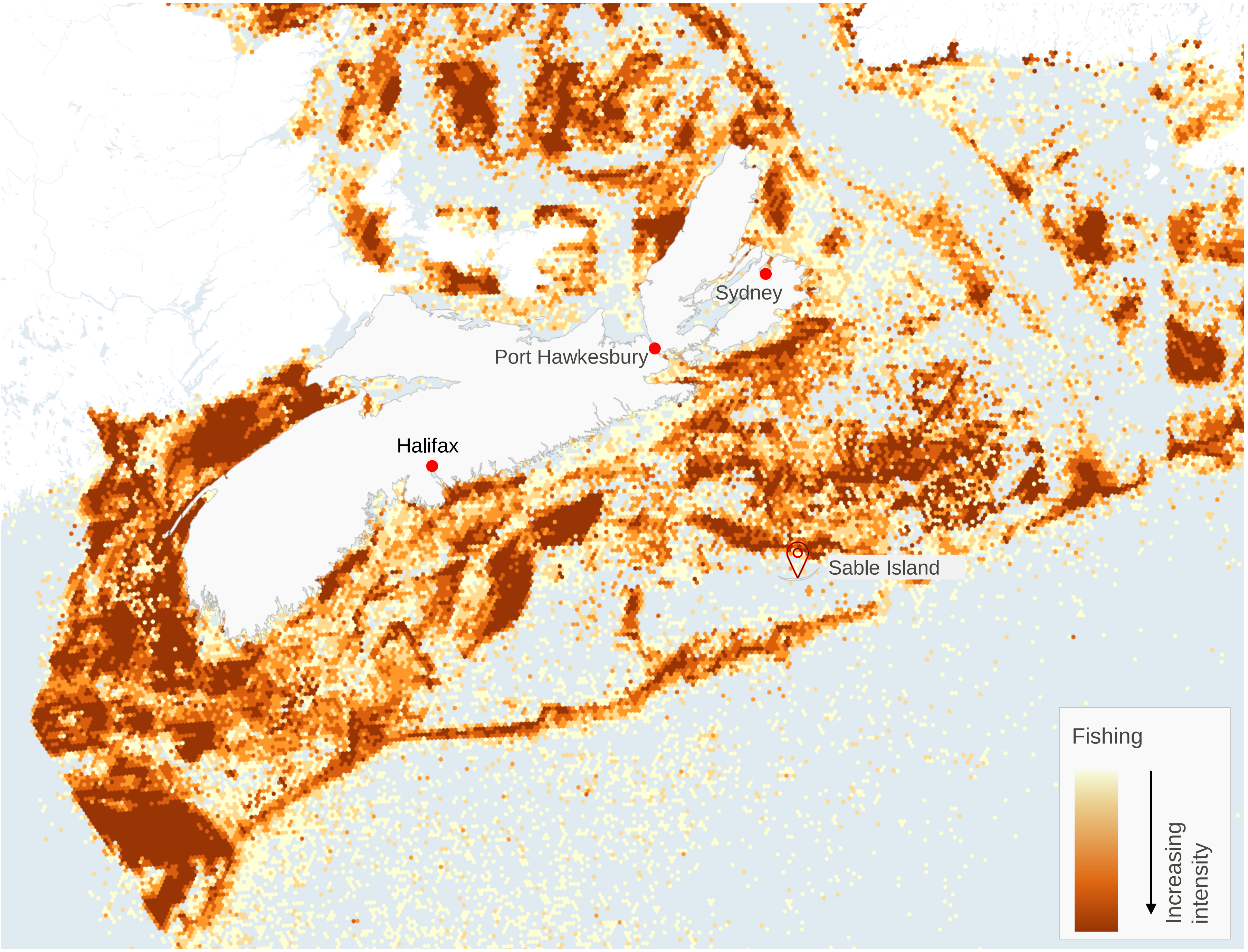
Canada Commercial Fishing (2009-2018)[1]



Take-aways

- The areas around the southwestern shores of Nova Scotia are very active fishing grounds and may not be likely candidates for offshore wind.
- Furthermore, the edge of continental shelf has active fishing grounds.
- There is a lot of fishing off of Halifax, but less when moving up along the coast east of Halifax.
- The area off from the Strait of Canso also has active fishing grounds. However, Canso Bank with shallower water has slightly less fishing according to this data.
- In general, areas that are shallow sandbanks (refer to the geology map on page 12) seem to have less fishing.
- This goes for Middle Bank, Sable Island Bank and the shallow area off Sydney.
- This may be positive for offshore wind development, as the shallow sandbanks could be of particular interest for other reasons as well, e.g. depth and geology.
- In general, it should be noted that this data gives a high-level overview but does not constitute a full picture of localized use patterns or community dependence on fishing. Furthermore, some types of fishing are not recorded in public data, which is for instance the case for sea cucumber landings in the Middle Bank area.

Sources: Government of Canada; Fisheries and Oceans Canada (DFO): Dataset of species/gear type commercial fisheries from 2009 to 2018 in the Eastern Canada Regions.

Notes: 1) This dataset contains errors around Prince Edward Island, leading to a gridded look which does not represent reality. The map should be viewed as indicative and not the full picture.

Inshore lobster fishing likewise takes place all around Nova Scotia, but particularly around the southwestern part of Nova Scotia

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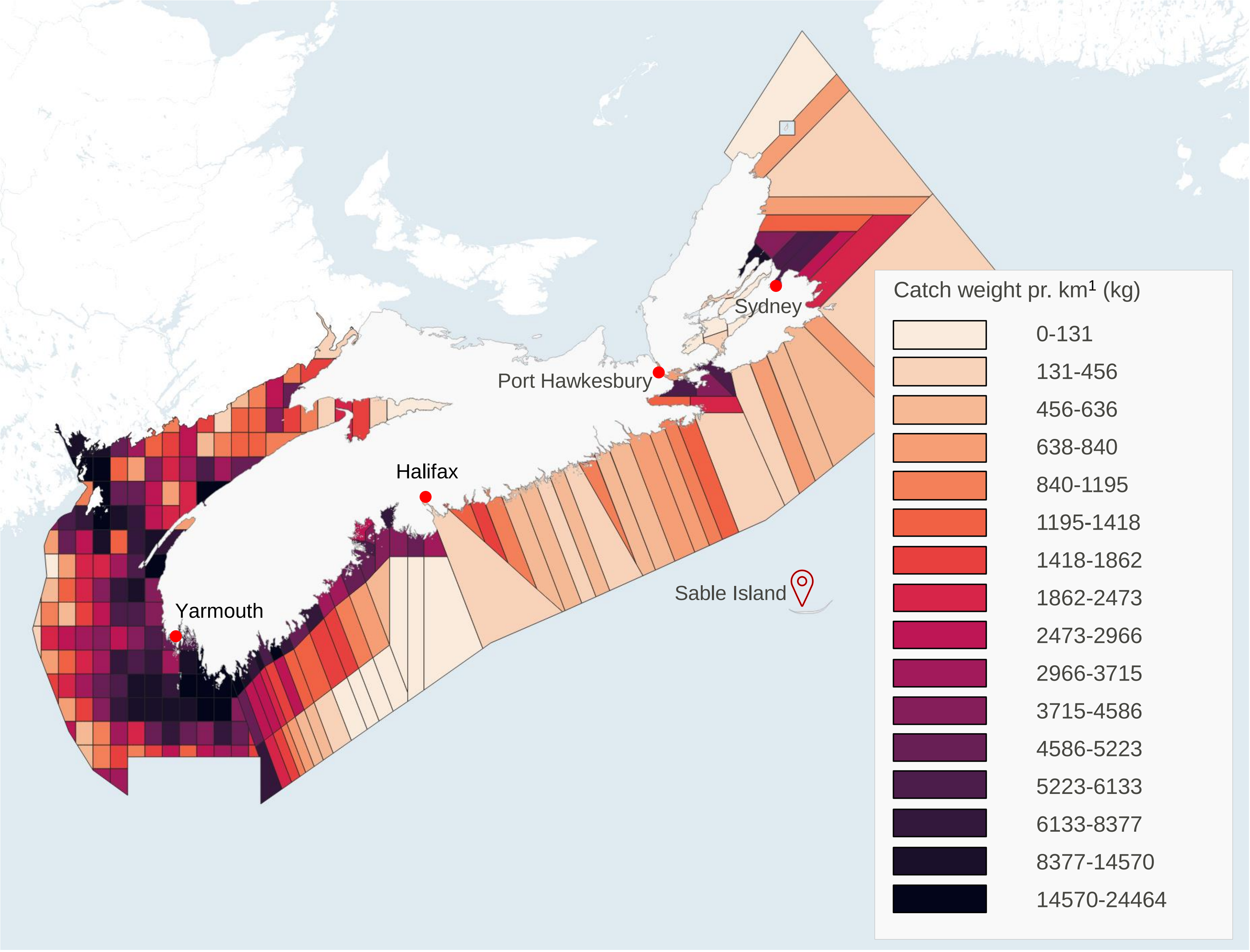
Inshore Lobster Landings and Fishing Effort on a Maritimes Region Statistical Grid (2015–2019)[1]



Take-aways

- Lobster fishing is a highly active industry in Nova Scotia. This map shows data for inshore lobster landings and fishing effort as catch weight per kilometer and can be used to get an early-stage overview of where the most active lobstering grounds are located.
- Like for the commercial fishing data on the previous page, most activity seems to take place around the southwestern end of Nova Scotia by Yarmouth. Some of these areas have recorded more than 24000 kilos of catch weight in the time period covered by this data.
- Note that the upper ranges of the categorization are wider than the lower ranges. This has been done to enable a more detailed overview of less active areas and enable better identification of the areas with the least activity, as these are of most interest to offshore wind.
- This data indicates that areas with the least lobstering include areas far from shore off Port Hawkesbury/Chedabucto Bay, including Canso and Middle Bank as well as Sable Island Bank.
- The areas off of Sydney and Halifax have more lobstering
- In general, it should be noted that this data gives a high-level overview but does not constitute a full picture of localized use patterns or community dependence on lobster fishing.

Sources: Government of Canada; Fisheries and Oceans Canada (DFO): Dataset of Inshore Lobster Landings and Fishing Effort on a Maritimes Region Statistical Grid (2015–2019).

Notes: 1) The areas east of Halifax only extend to 100 m. water depth, which makes the actual areas that the data covers smaller, as the covered areas cut off closer to shore than this map shows.

Pelagic longline fishing mostly takes place far from shore along the continental shelf and off Halifax, and marine mammals are particularly sighted in the Bay of Fundy

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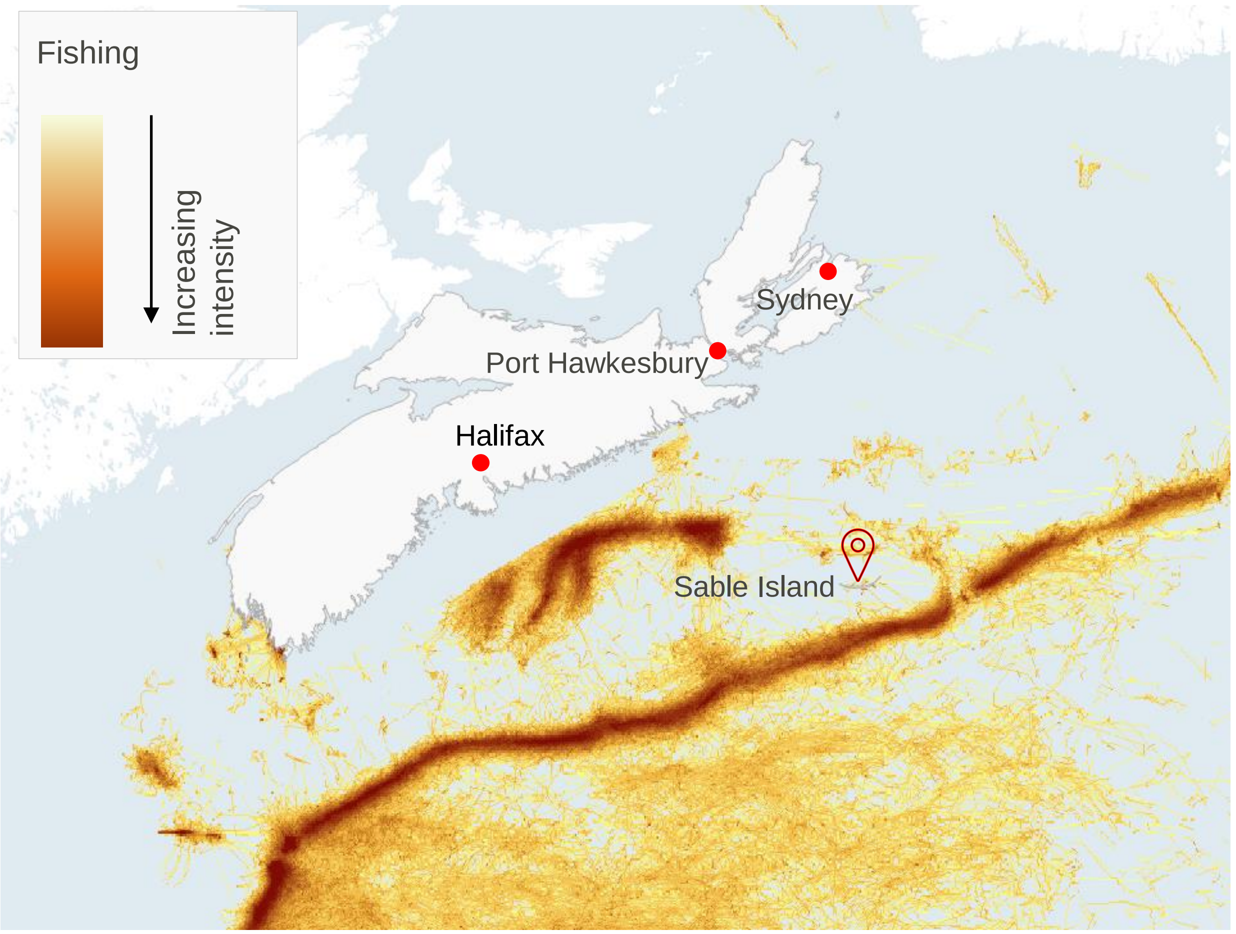
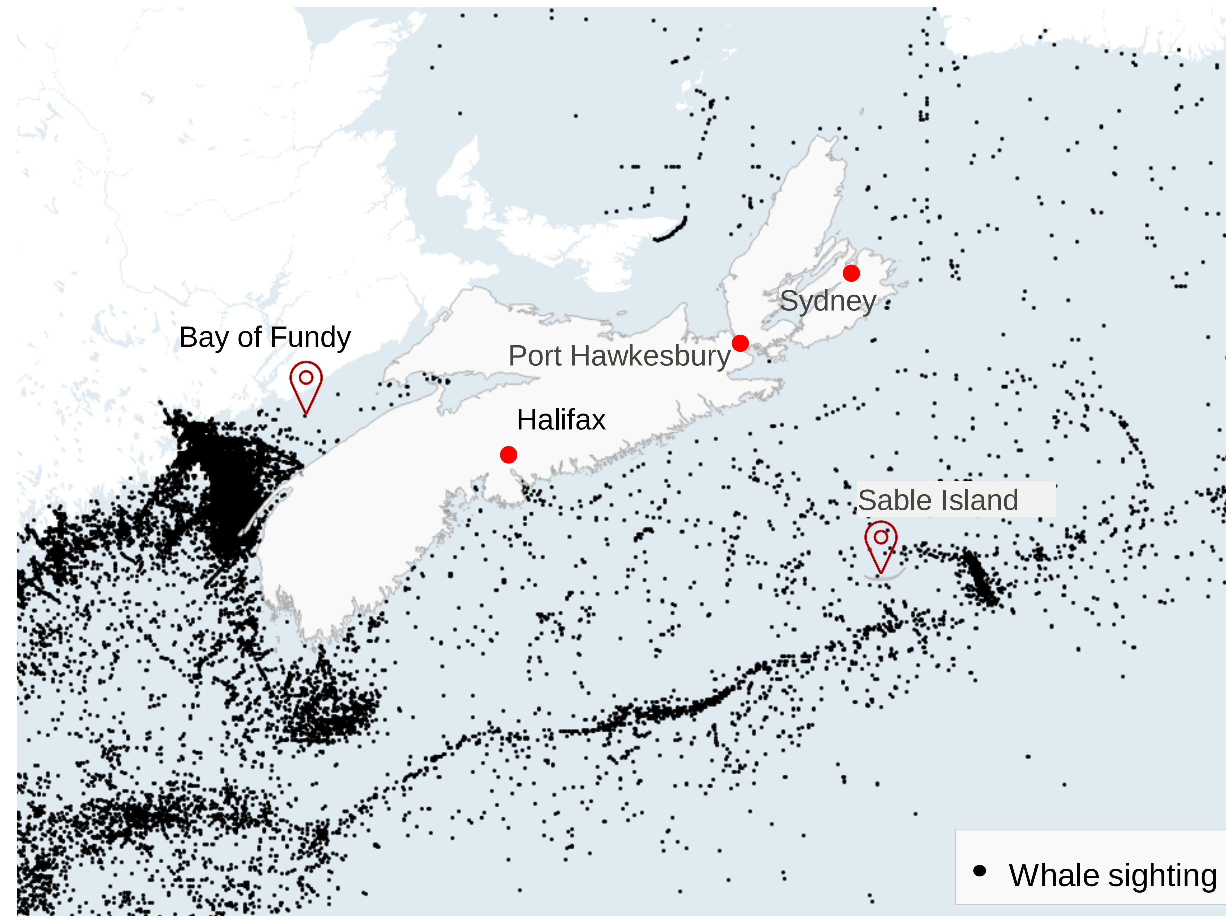
Pelagic longline fishing, vessel minutes, Nova Scotia (2003–2018)



- Pelagic longline fishing mostly takes place around the continental shelf, as well as in an area off Halifax.
- Most of the particularly attractive areas for offshore wind development are not in proximity to pelagic longline fishing areas, with the exception of the Halifax case, which is adjacent to an active area for pelagic longline fishing.
- For instance, there is little activity on the Sable Island Bank and Middle Bank, as well as the area close to Port Hawkesbury and by Sydney.

Whale and porpoise sightings (1975-2015)



- The Nova Scotia region hosts a variety of larger marine wildlife including but not limited to the blue whale and the endangered North Atlantic right whale. This map indicates presence of whales and porpoise through recorded sightings.
- The Bay of Fundy is one of the world's most diverse marine biology ecosystems with a lot of whale activity and many sightseeing tours. Whales also frequent the edge of the continental shelf, where nutritious waters well up from the deep.
- There are fewer sightings around Sable Island and Middle Bank, as well as close to the shore around most of Nova Scotia.[1]

Sources: Government of Canada; Fisheries and Oceans Canada (DFO): Dataset of pelagic longline fishing. Pelagic longline maps aggregate speed-filtered vessel monitoring system (VMS) track lines as vessel minutes per km2 on a base-10 log scale using 2003–2018 data, and DFO Maritimes Whale Sightings Database.

Notes: **1)** This data is based on sightings, which are not necessarily representative of the actual distribution of the animals. Survey efforts may vary across time and geographic locations, as for instance the Bay of Fundy has an active whale tour industry, leading to more sightings.

Some major shipping lanes pass by, to and from Nova Scotia, but most do not cross areas of particular interest for offshore wind development

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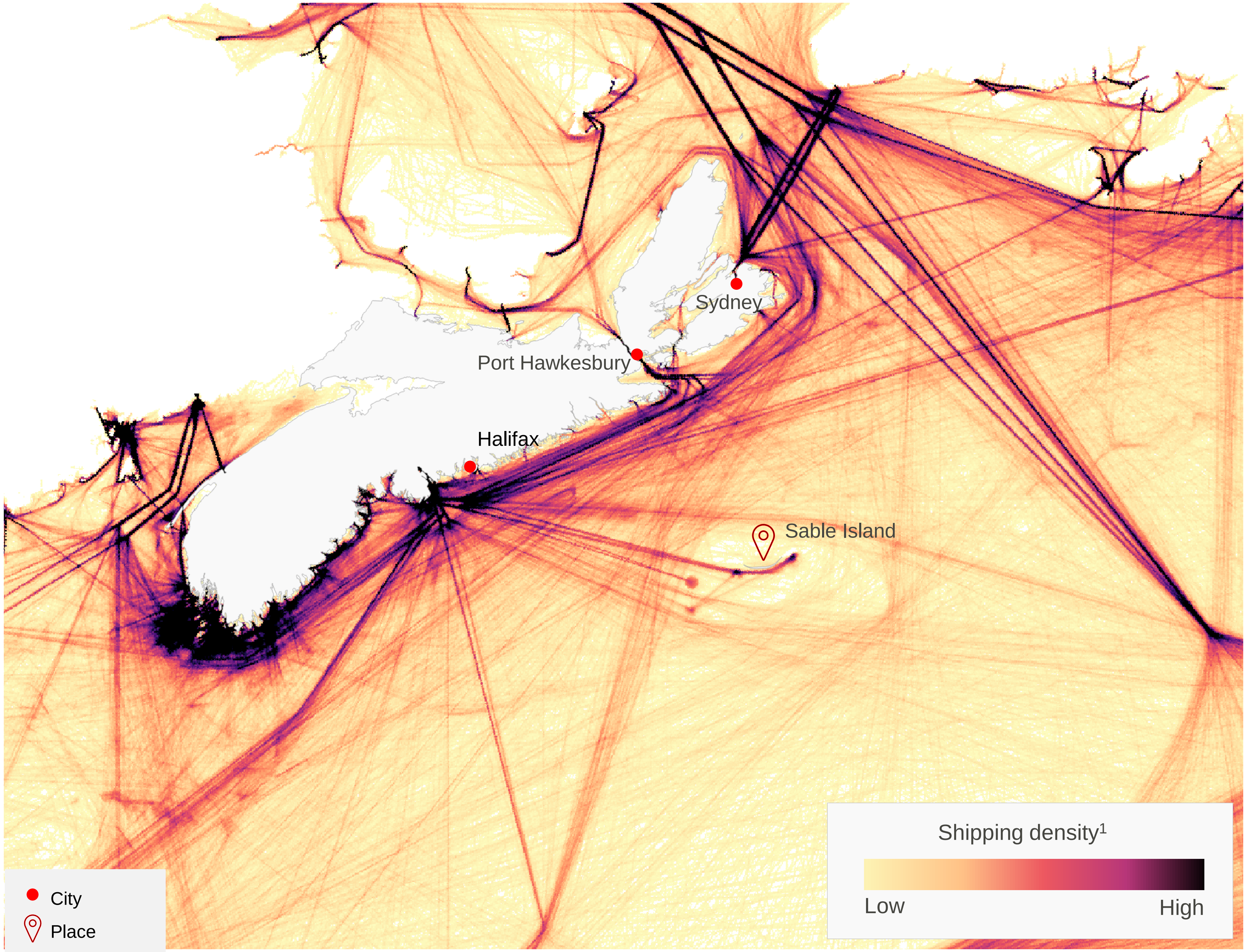
Shipping density, all vessel types[1]



Take-aways

- In general, the amount of traffic around Nova Scotia is not of a volume that would necessarily hinder offshore wind farms, as traffic can often go around or through wind farms via traffic corridors – but areas with less traffic are still more attractive and lanes in and out of ports should be sought avoided.
- Traffic is dense around Yarmouth and Halifax and in general along the shore of much of the southern coast.
- Much traffic close to shore may be from fishing vessels or whale watching tours. How these can pass by or through wind project areas will depend on the kind of vessel and/or fishing method.
- Many vessels cross from Cape Breton to Newfoundland, creating significant traffic along two very distinct lanes in the strait between the two, which could impact offshore wind development opportunities here but would not necessarily prevent it.
- The traffic is limited farther from shore, allowing for large, open areas with relatively little marine traffic around the Sable Island Bank and Middle Bank.
- The traffic indicated by the map close to Sable Island mostly reflects old marine energy infrastructure here, but as the oil/gas development here is now closed down, marine traffic around Sable Island may be more limited today.

Sources: Government of Canada; Fisheries and Oceans Canada (DFO):
Notes: **1**) The shipping density represents AIS-carrying vessels per day pr. km^2 Vessels not carrying AIS will not be featured in this data. The data should not be considered exhaustive.

Outline

Overlaying the heatmap with constraints indicates that Sable Island, Middle Bank and Canso Bank are relatively little constrained (map for illustration only)

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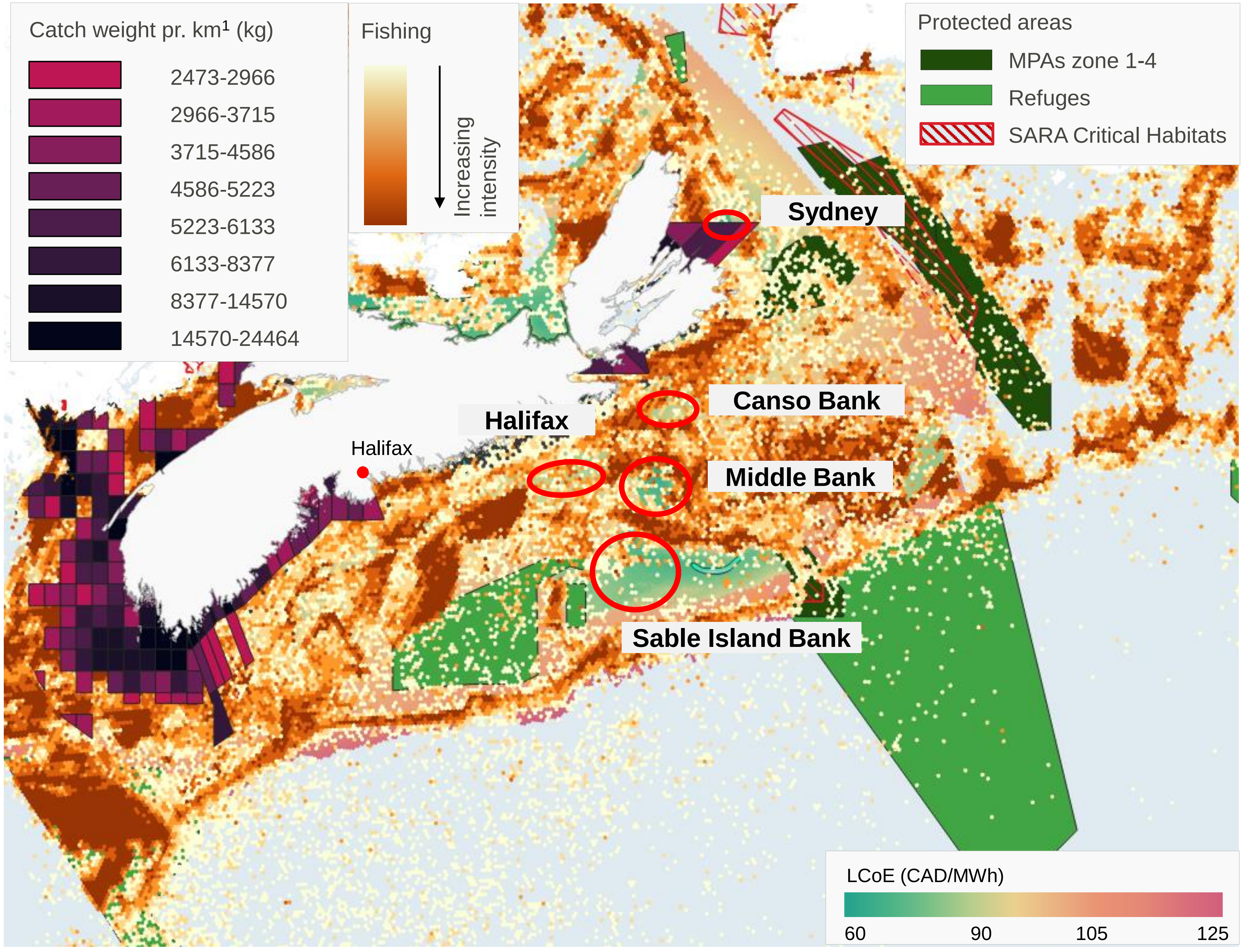
Heatmap overlaid with selected data on fishing, lobstering and protected areas[1]



Areas that stand out:

- This map is a static and therefore limited version of a dynamic GIS-map.
- It does not give the full overview of all constraints. It is meant as illustration of the method used by Aegir Insights to identify areas with relatively few constraints that are also economically attractive according to the value map.
- Sable Island Bank catches attention as it comprises a large area with low LCoE and relatively few constraints.
- Middle Bank has low LCoE and few constraints. It is also on a shallow sandbank with less fishing than other areas, though areas just around the bank are active fishing grounds. No sea ice or bedrock at surface level.
- Canso Bank is another area that stands out with relatively few constraints and attractive LCoE levels.
- Areas close to Sydney and Halifax also emerge with relatively few constraints although more than the three banks described above.
- The area by Sydney has sea ice, active lobstering areas and ferry routes. However, the area has shallow water and a sandy seafloor, and is close to port and grid.
- The area by Halifax has two main constraint; the seafloor is more uncertain with mud and diamict, and there are active fishing areas close by. However, the area has relatively few other constraints and could be relevant for future consideration.

Notes: 1) This map is a static version of the dynamic constraints mapping that Aegir Insights has done using GIS. The static map is highly limited, and only a few constraints can be shown at once. Reference cases and areas of interest have been sited using the full overview in GIS, and this static map is only to illustrate the method. Please reach out to Aegir Insights if interested in the full GIS overview.

The map shows the following layers in the following order, from bottom layer to top layer: Value map, map of protected areas, fishing map, lobstering map. The data has been limited to simplify the map. The lobstering data shows only the most active lobstering areas with a recorded catchweight of more than 2473 kilos, and only the three most protected categories of protected areas are shown. This filtering has been done to enable overview in a static map.

Aegir Insights' heatmap and high-level constraint mapping points to areas where further efforts might be made to de-risk future offshore wind projects

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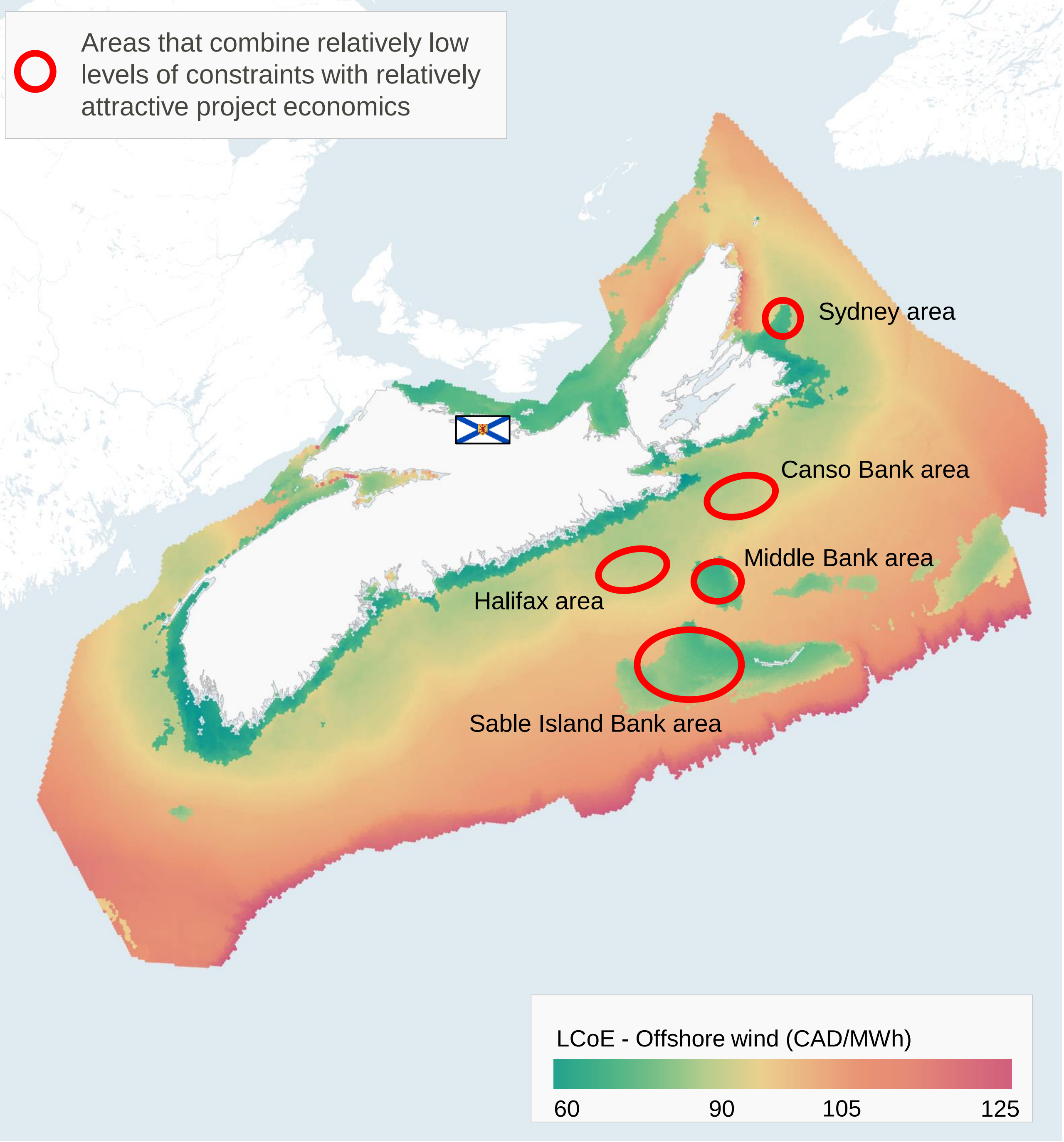
Key points from the report

- Nova Scotia's offshore wind resource is among the best in the world, which could provide a relatively low levelized cost of energy and open up opportunities for offshore wind development.
- Nova Scotia's geology may be restrictive for development of fixed bottom foundations close to shore. Pockets of sedimentation suitable for fixed-bottom turbines near the shore may exist, but further site investigations are needed to (1) establish where offshore wind build-out is possible close to shore and (2) de-risk the areas to enable more attractive bids in a potential auction.
- Fishing and lobstering activity, wildlife, several marine protected areas, maritime traffic and the possibility of sea ice during the winter, are additional factors that should be taken into account when planning a future OSW development.
- Combining the heatmap with various constraints maps has indicated that shallow sandbanks such as Sable Island Bank, Middle Bank, Canso Bank and an area off Sydney as well as another off Halifax are potentially the most suitable for large scale offshore wind development in Nova Scotia. These areas are indicated on the map, and some of them form the basis for reference cases in this report.
- The total area at Sable Island with depth of less than 60 metres comprises more than 8000 km^2. The vast sandbank could potentially be suitable for siting more than 5 GW offshore wind. Apart from substantial benefits of scale, this offers the potential for a large-scale project producing green hydrogen or exporting power.
- The area by Sable Island is an old oil and gas field, meaning that both the area itself and the corridor to shore where the old pipes lay have been investigated and are to some degree known and understood, bringing down risks for offshore wind developers and enabling competitive bidding with resulting lower prices for taxpayers.
- As the area by Sable Island is also away from protected areas, provided a certain distance to Sable Island itself is kept, very active fishing grounds and major shipping lanes, the area seems like the overall least complicated option for offshore wind development. However, Middle Bank and Canso Bank are also attractive options, and Sydney could be attractive for a smaller project.

Heatmap



GENERAL DISCLAIMER: Map information in this report does not imply on the part of Aegir Insights any judgement on the legal status of any territory or the endorsement or acceptance of such boundaries. Market information in this report is based partly on publicly available sources and partly on Aegir Insights industry knowledge. No market information or assessment in this report is exhaustive. Assessments in this report are meant solely as insights and suggestions and should not form the basis of investment decisions.

Outline

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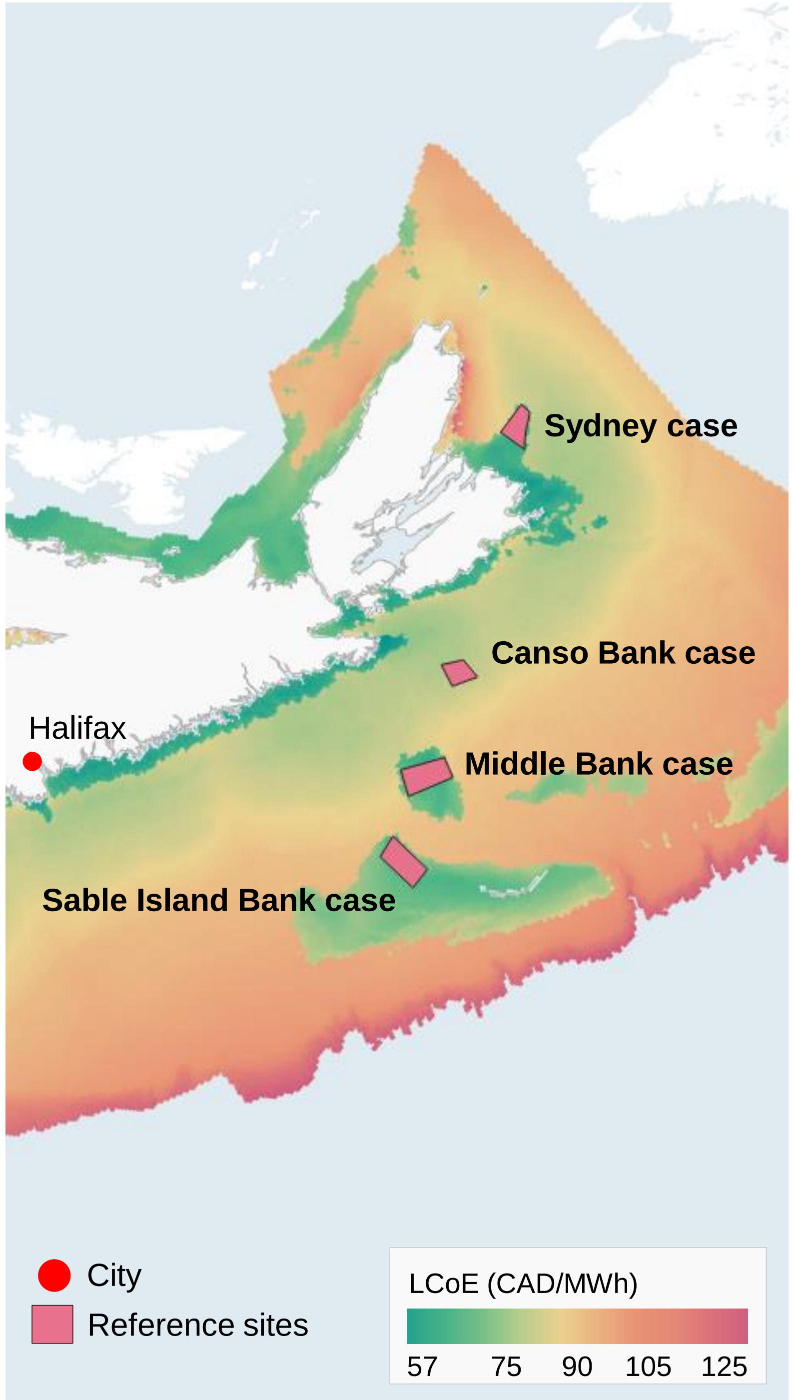
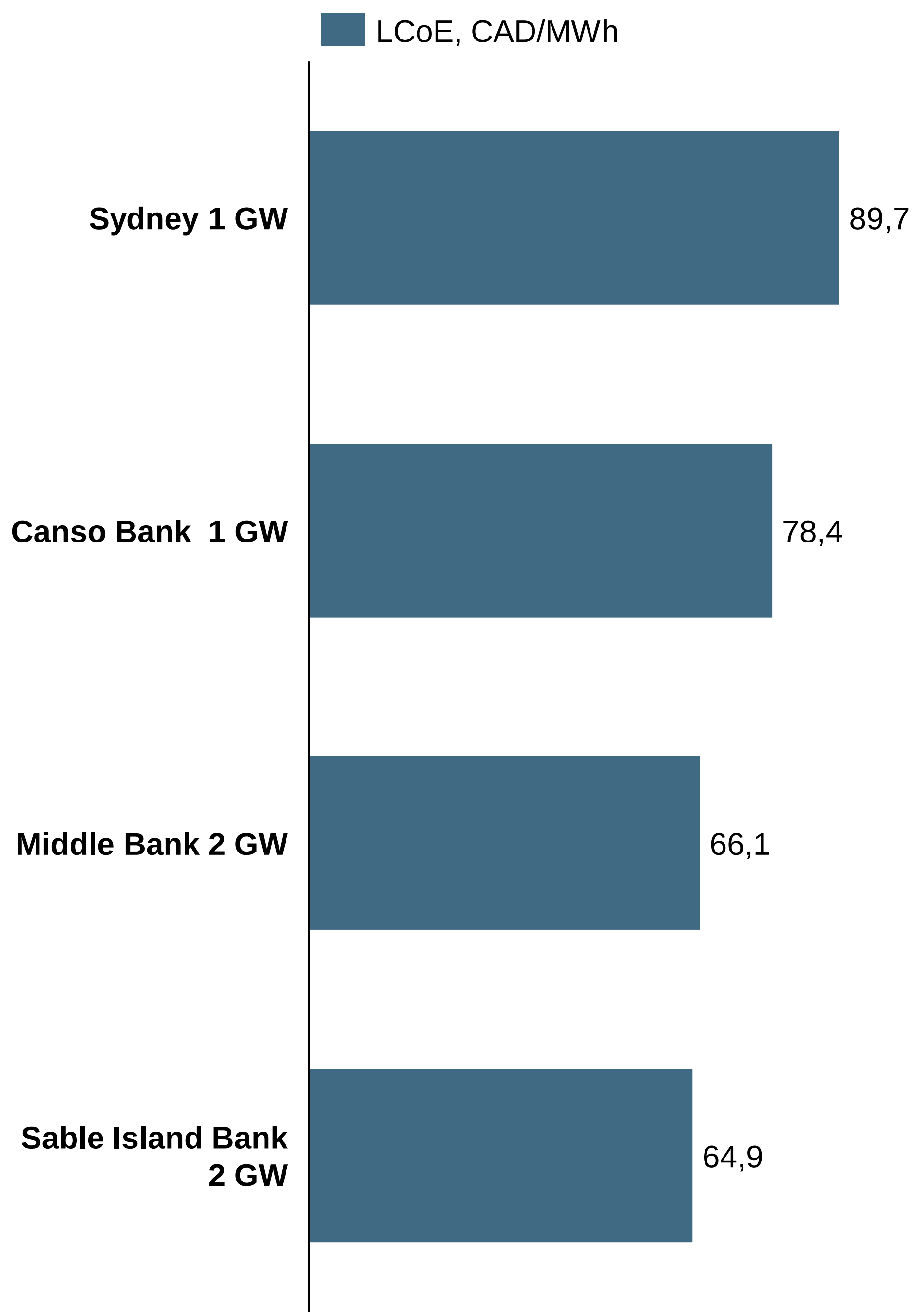
Four reference case offshore wind projects have been designed by Sydney, Strait of Canso, Middle Bank and Sable Island to provide basis for energy cost estimates

LCoE estimates for four offshore wind regerence cases[1], LCoE (CAD/MWh)





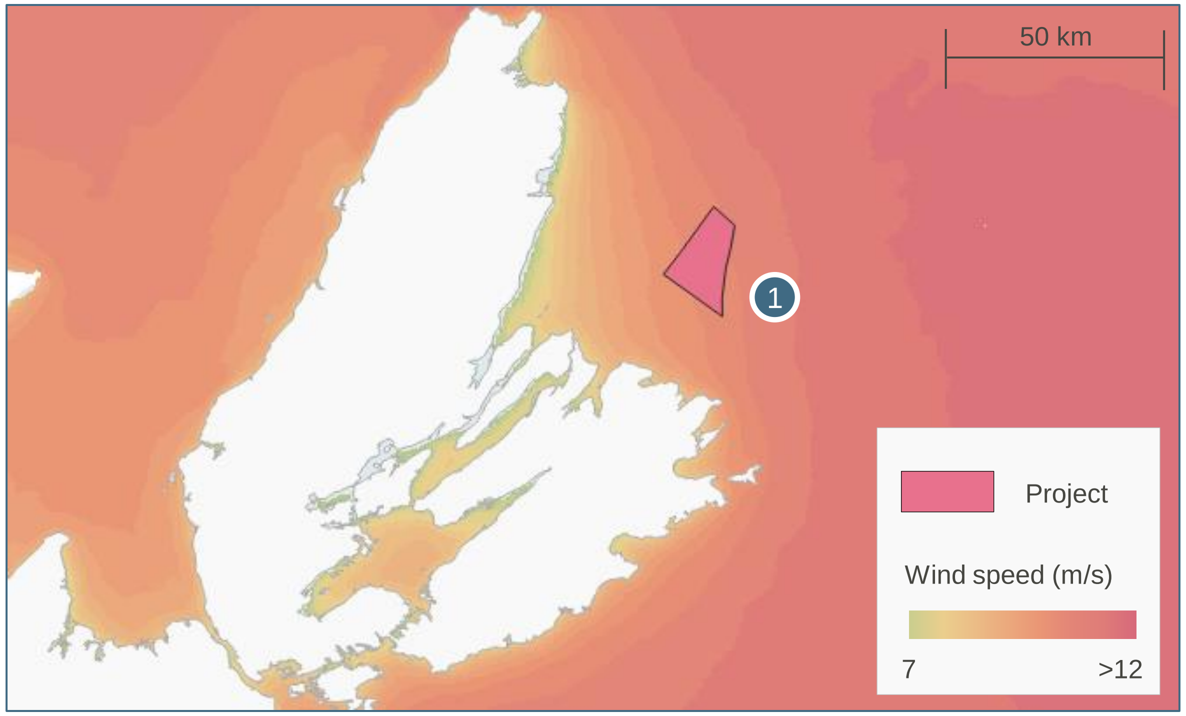
Remarks on LCoE forecasts

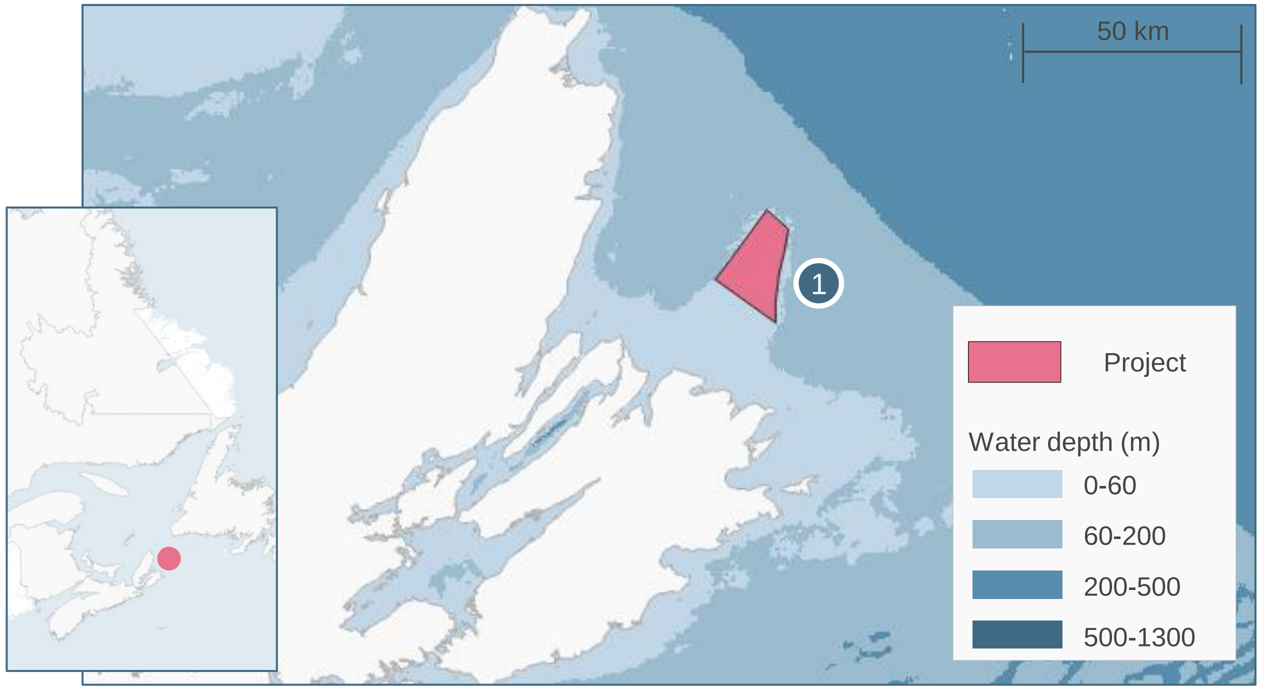
- We have defined four reference cases in Nova Scotia that provide the basis for standardized LCoE forecast estimation.
- At this very early stage of the Nova Scotian market, it is difficult to estimate a realistic year where the wind farms could be in operation. A standard assumption of 2035 was used for Commercial Operation Date (COD).
- The sites were selected considering factors such as wind speed, water depth, geology, distance to port and grid, major shipping lanes and nature parks and fishing efforts.
- The LCoE forecasts show that the cheapest cases are the ones by Sable Island and Middle Bank.
- Sable Island Bank offers relatively low cost considering that the site is far out at sea, away from ports and grid. The low LCoE is driven by shallow water and high wind speeds in combination with opportunities for a bigger project, leading to benefits of scale. This reference case has 2 GW, but there could be options for even larger projects.
- Middle Bank also has an attractive estimated LCoE-level for many of the same reasons as the low LCoE of the Sable Island Bank case.
- Canso Bank has deeper water than the other banks and therefore requires floating wind platforms, driving up costs a little along with a low risk of sea ice.
- The Sydney case is mainly estimated to have higher LCoE due to risk of sea ice and slightly lower wind speed than the rest of the cases.

Notes: **1)** LCoE is estimated based on site selection. LCoE input parameters (other than those specified above) are based on Aegir Quant default settings. Geologic conditions are not included in the calculations of LCoE.

Levelized Cost of Energy | Reference case details and assumptions: Sydney

Result[1]	1 Sydney
LCoE	**62.7 EUR/MWh**
Foundation	
Foundation type	Fixed-bottom (Foundation sourced from East US)
Project assumptions	
COD	2035
Capacity	1000 MW
Site specifications	
Mean wind speed at 100 m	10.3 m/s
Water depth	55 m
Distance to port	45 km (Sydney)
Distance to grid connection	50 km (Sydney)
Transmission system	220kV HVAC (Three cables)
Positions	50
Turbine rating	20 MW (Major components sourced from East US, France)
Special mark-up	35% on monopiles (sea ice risk)
Unique case ID[2]	
Based on the following case IDs	CA-R004-FB-35



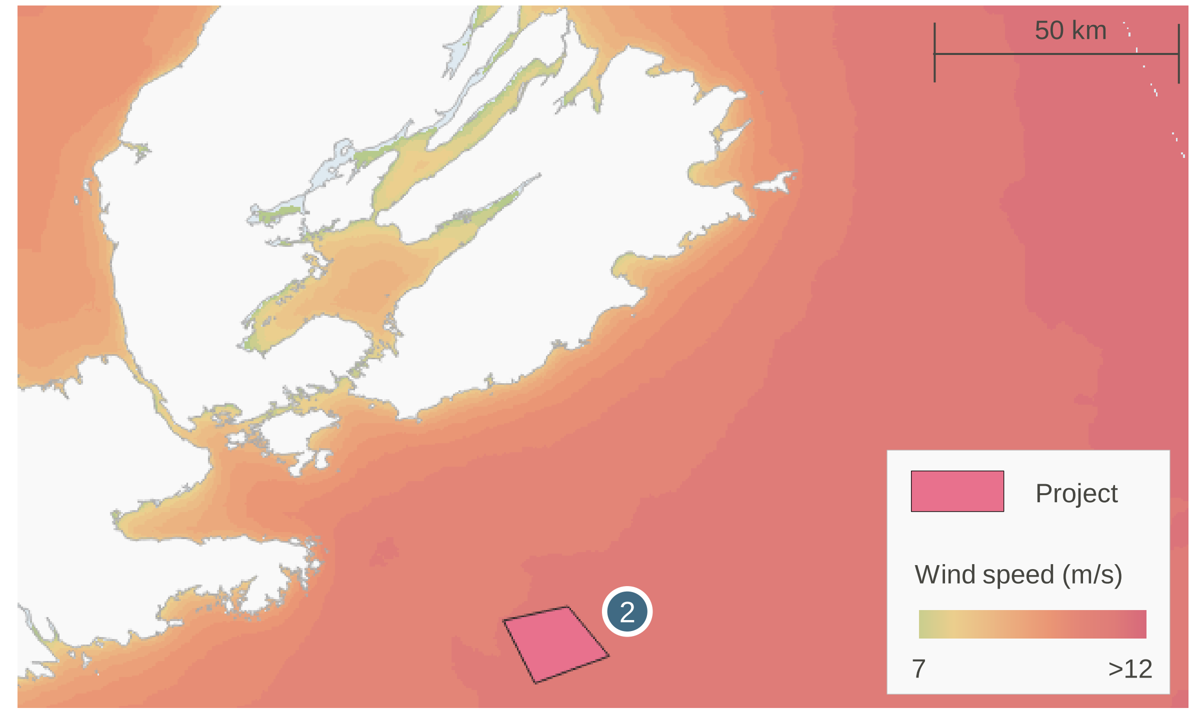


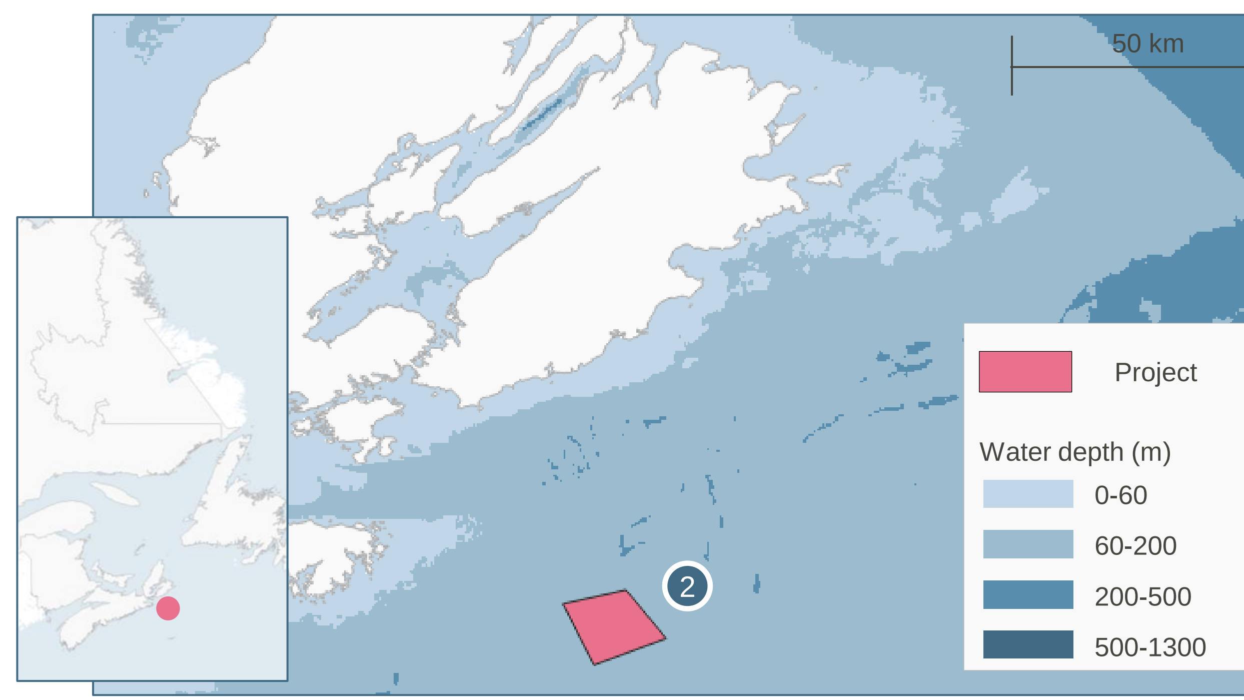
Sources: Aegir Quant, DTU Global Wind Atlas

Notes: **1)** The LCoE numbers are in real 2021 values. LCoE is estimated based on site selection, assumed COD year and project capacity. Other LCoE input parameters are based on Aegir Quant default settings. Unless otherwise indicated herein, the LCoE calculation assumes a pre-tax nominal WACC of 7.5%, a yearly inflation rate of 2%, a project lifetime of 30 years, and a full-scope transmission cost, covering export cable, offshore and onshore substation. A penalty for sea ice was added. **2)** The data used to calculate LCoE values is accessible via Aegir Insights' Quant model. Copy the case ID listed in the table above into the Quant model to automatically collect and input the case assumptions.

Levelized Cost of Energy | Reference case details and assumptions: Canso Bank

	2 Canso Bank
Result[1]	
LCoE	**54.8 EUR/MWh**
Foundation	
Foundation type	Floating (Foundation sourced from Spain)
Project assumptions	
COD	2035
Capacity	1000 MW
Site specifications	
Mean wind speed at 100 m	11 m/s
Water depth	70 m
Distance to port	89.7 km (Port Hawkesbury)
Distance to grid connection	101.1 km (Port Hawkesbury)
Transmission system	220kV HVAC (Three cables)
Positions	50
Turbine rating	20 MW (Major components sourced from East US, France)
Special mark-up	15% on mooring (sea ice risk)
Unique case ID[2]	
Based on the following case IDs	CA-R005-FL-35





Sources: Aegir Quant, DTU Global Wind Atlas

Notes: **1)** The LCoE numbers are in real 2021 values. LCoE is estimated based on site selection, assumed COD year and project capacity. Other LCoE input parameters are based on Aegir Quant default settings. Unless otherwise indicated herein, the LCoE calculation assumes a pre-tax nominal WACC of 7.5%, a yearly inflation rate of 2%, a project lifetime of 30 years, and a full-scope transmission cost, covering export cable, offshore and onshore substation. **2)** The data used to calculate LCoE values is accessible via Aegir Insights' Quant model. Copy the case ID listed in the table above into the Quant model to automatically collect and input the case assumptions.

DISCLAIMER: Aegir Insights does not guarantee the accuracy of the LCoE numbers.

Levelized Cost of Energy | Reference case details and assumptions: Middle Bank and Sable Island

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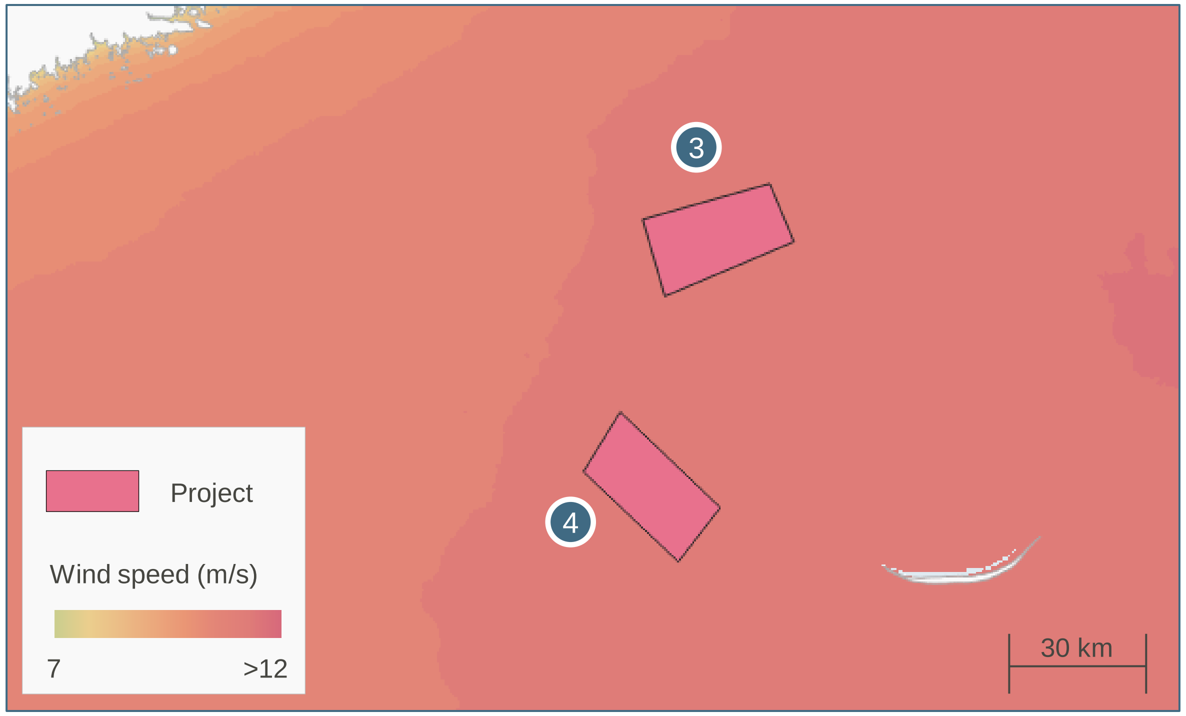
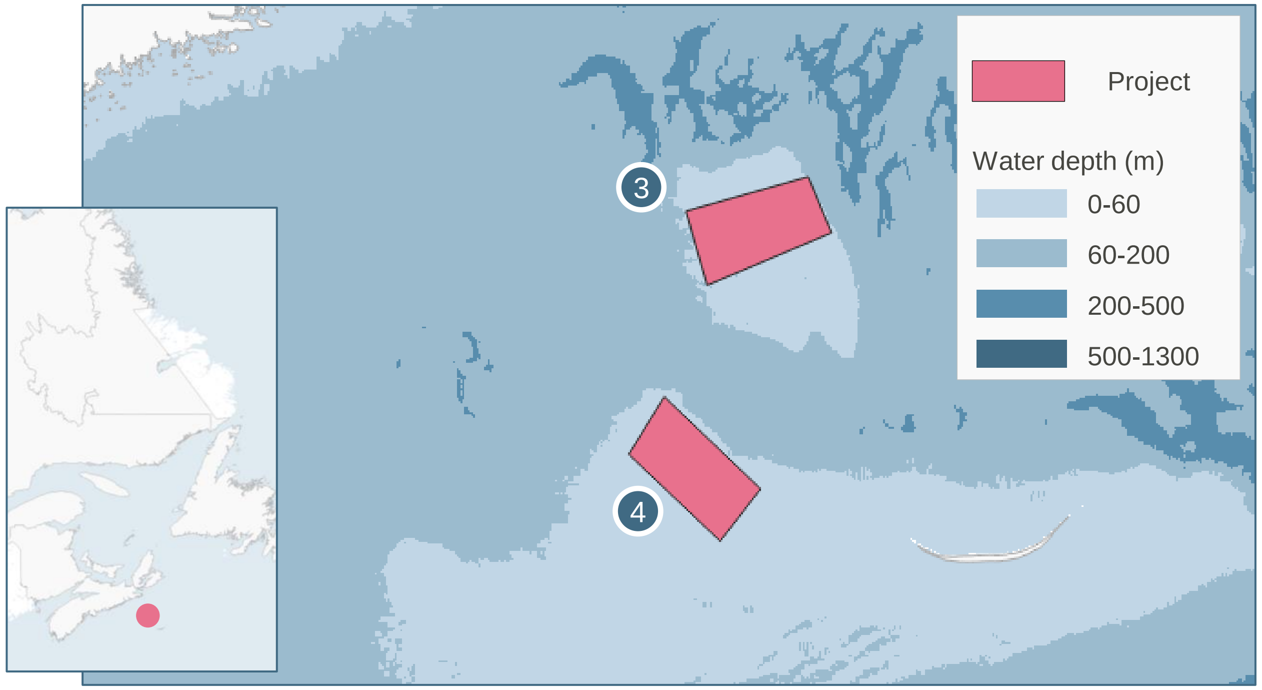
Result[1]	③ Middle Bank	④ Sable Island
LCoE	**46.2 EUR/MWh**	**45.4 EUR/MWh**
Foundation		
Foundation type	Fixed-bottom (sourced from East US)	Fixed-bottom (sourced from East US)
Project assumptions		
COD	2035	2035
Capacity	2000 MW	2000 MW
Site specifications		
Mean wind speed at 100 m	11.2 m/s	11.1 m/s
Water depth	43 m	35 m
Distance to port	140 km (Port of Sheet Harbour)	175 km (Port of Sheet Harbour)
Distance to grid connection	112 km (Goldboro)	140 km (Goldboro)
Transmission system	HVDC (two cables)	HVDC (two cables)
Positions	100	100
Turbine rating	20 MW (sourced: East US, France)	20 MW (sourced: East US, France)
Special mark-up	No	No
Unique case ID[2]		
Based on the following case IDs	CA-R006-FB-35	CA-R005-FB-35





Sources: Aegir Quant, DTU Global Wind Atlas

Notes: **1)** The LCoE numbers are in real 2021 values. LCoE is estimated based on site selection, assumed COD year and project capacity. Other LCoE input parameters are based on Aegir Quant default settings. Unless otherwise indicated herein, the LCoE calculation assumes a pre-tax nominal WACC of 7.5%, a yearly inflation rate of 2%, a project lifetime of 30 years, and a full-scope transmission cost, covering export cable, offshore and onshore substation. **2)** The data used to calculate LCoE values is accessible via Aegir Insights' Quant model. Copy the case ID listed in the table above into the Quant model to automatically collect and input the case assumptions.

DISCLAIMER: Aegir Insights does not guarantee the accuracy of the LCoE numbers.

LCoE is expected to decrease by around 15% between 2030 and 2040 for fixed bottom wind in Nova Scotia, based on the reference case on Middle Bank

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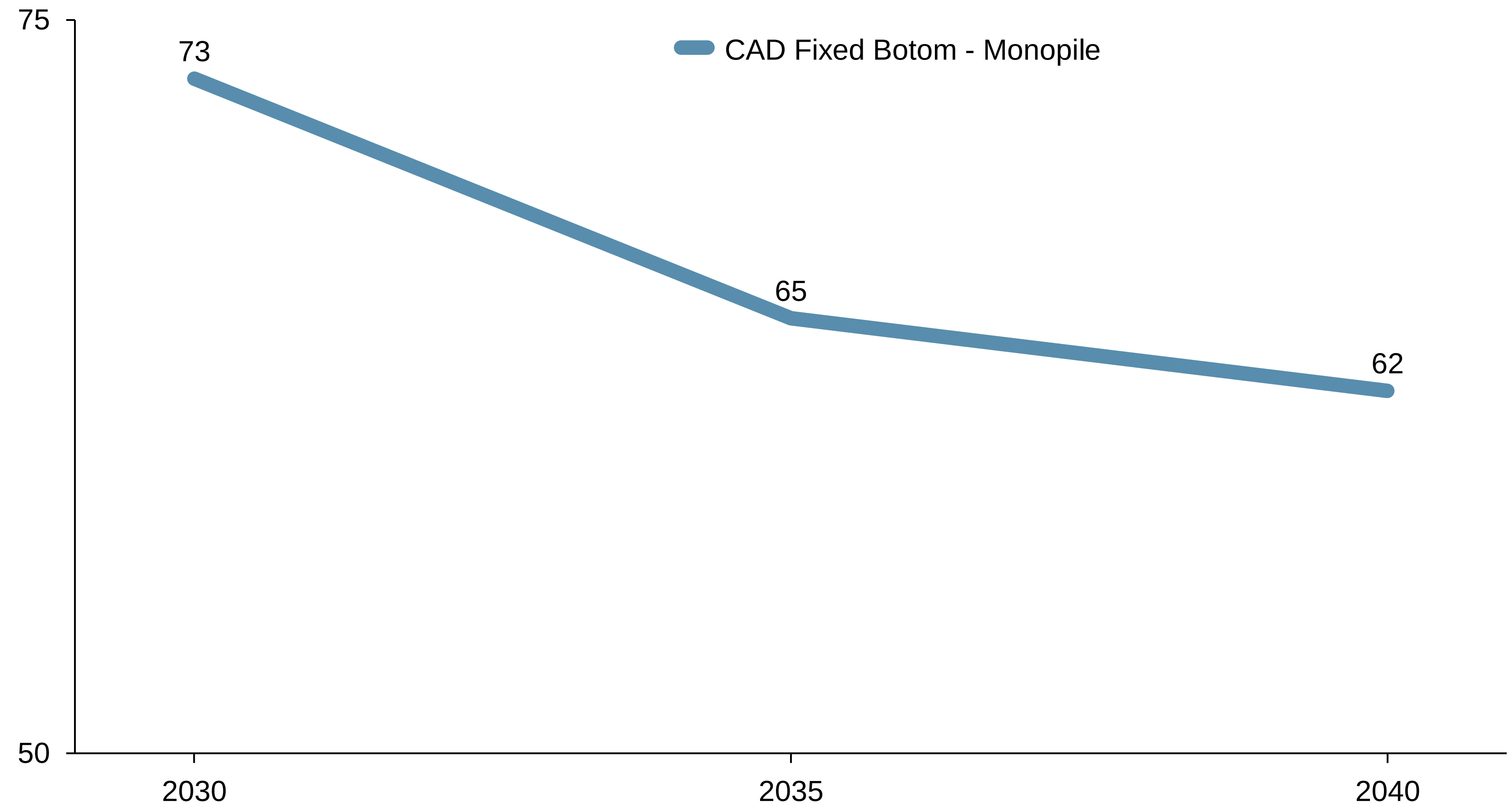
Fixed-bottom average cost reference LCoE based on Middle Bank case, delivery year, CAD/MWh in 2023 prices[1]



	2030	2035	2040
Park (MW)	1008	2000	3014
Turbine (MW)	18	20	22
Rotor (m)	256	270	283

Remarks on LCoE trajectories

- The LCoE trajectory has been calculated based on the Middle Bank reference case to give a view of how offshore wind Levelized Cost of Energy may develop over time.
- The trajectories show that costs tend to fall over time, with about 15% for Nova Scotia in the timeframe 2030-2040. The same project that is delivered in 2040 is therefore expected to have lower LCoE than if it had been delivered in 2030.
- Increased turbine size deliver significant cost reductions over time. The increasing turbine sizes are shown below the graph.
- Technology performance improvements are secondary in terms of effect on the LCoE, compared to turbine size, but still have an effect as well, as technology is generally expected to improve over time.
- Governments can therefore expect to see major cost reductions on offshore wind farms over time.
- The cost reductions over time would be seen for both fixed-bottom and floating wind projects.
- In Nova Scotia, large-scale projects like the Middle Bank reference case are overall expected to have better project economy.
- Possible synergies with the US Atlantic offshore wind market should be investigated further for additional cost reductions specific to the situation in Nova Scotia.

Sources: Aegir database, Aegir analytics

Notes: 1) LCoE numbers include all transmission costs (full scope), and assumes use of the lowest cost option. The turbines are assumed to grow over the years, so that if the project is delivered in 2030, it is using an 18 MW turbine, while a 20 MW turbine is assumed for 2035 and a 22 MW turbine for a project delivered in 2040. WACC is assumed to be 7.5 % across the years. All calculations were done in Euros in Aegir Quant and converted to CAD using a rate of 1 EUR = 1.47 CAD.

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