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June 24, 2025

The Honourable Kent Smith, E.C.N.S.
Minister of Fisheries and Aquaculture
1741 Brunswick Street, Suite 410
Halifax, NS B3J 3X8

Dear Minister Smith:

Re: Nova Scotia Aquaculture Science Advisory Committee Science Advice on the Review and Validation of the Spatial Suitability Analysis Completed for the Aquaculture Coastal Classification System (CCS) Project (NSASAC-2025-01)

On behalf of the Nova Scotia Aquaculture Science Advisory Committee (the Committee), please accept this submission of Science Advice on the review and validation of the spatial suitability analysis completed for the aquaculture Coastal Classification System (CCS) project.

The Committee was first engaged on this project in 2024 and provided Science Advice on the Recommended Criteria for Inclusion for Coastal Classification in Nova Scotia (NSASAC-2024-01) on October 16, 2024. The Committee received the present Request for Science Advice (NSASAC-2025-01) from the Department on April 1, 2025, and began its review of the reports and supporting documentation.

The Committee met on April 30, 2025, and June 13, 2025, to discuss the findings of their review, request clarification where needed, and deliver its science-based recommendations in response to the issue requiring science advice. The Department of Fisheries and Aquaculture (the Department) and the Centre for Marine Applied Research (CMAR) were present to provide clarification as required. Input was provided by all committee members, and the advice has been formulated by consensus. No conflict of interest was identified throughout this review process.

Please find enclosed the originating Request for Science Advice from the Department and the resulting Science Advice from the Committee for your consideration.

Yours sincerely,

Stefanie Colombo

Dr. Stefanie Colombo
Chair, Nova Scotia Aquaculture Science Advisory Committee

Enclosures

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NOVA SCOTIA AQUACULTURE SCIENCE ADVISORY COMMITTEE
REQUEST FOR SCIENCE ADVICE

☒ NEW REQUEST **REQUEST ID#:** NSASAC-2025-01
☐ PREVIOUS REQUEST (CARRY-OVER)

Title of Request:
Review and validation of the spatial suitability analysis completed for the aquaculture Coastal Classification System (CCS) project.

REQUEST DETAILS

Issue Requiring Science Advice (to be posed as a question):
Do you agree with the process used to complete the spatial suitability analysis (including key development decisions and assumptions made during the structuring, scoring, weighting and aggregation phases) for the aquaculture coastal classification system project?

Select Committee Mandate(s) Applicable to the Request:	
☒	Advise and provide recommendations to the Minister of Fisheries and Aquaculture related to science pertaining to the aquaculture regulatory framework to ensure a sustainable, responsive, and prosperous industry.
☒	Facilitate ongoing consultation with experts on the science of aquaculture informing regulation.
☐	Address specific issues or questions identified by the Minister, through work with the Nova Scotia Aquaculture Regulatory Advisory Committee, stakeholders or Department staff, relating to the science of aquaculture on an ongoing basis.
☐	Identification and interpretation of relevant issues for discussion of science-based evidence for development of the aquaculture regulatory framework.
☐	Advise on existing and emerging science in the aquaculture industry.

Rationale and Background Information:
To guide planning for responsible and sustainable aquaculture development, the Nova Scotia Government is creating an aquaculture coastal classification mapping tool that will screen coastal waters to help identify areas that may be suitable for different types of aquaculture development.

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Centre for Marine Applied Research (CMAR) has been engaged to complete the spatial suitability screening assessments and to develop a new mapping tool to display the results. CMAR is using a Geographic Information System-Multicriteria Decision Analysis (GIS-MCDA) process to complete the suitability screening assessments. The GIS-MCDA process can be divided into the following phases:

STRUCTURING:
This phase involves determining the scope, goal, and objectives of the assessments. It also includes the process of selecting the criteria that will be used for the assessments. *Note: Request No. NSASAC-2024-01 was previously submitted to the Nova Scotia Aquaculture Science Advisory Committee (NSASAC) for technical review and validation of this phase of the work.*

SCORING:
The second phase involves reclassifying the criteria to a consistent scale. Reclassification is the process of transforming data from many different sources and units to a common format or normalized scale that will enable meaningful comparison, analysis, and interpretation.

WEIGHTING AND AGGREGATION:
The third and fourth phases involve decisions relating to how criteria are combined to produce final potential suitability ratings.

At this time, the Department is seeking technical review and validation from the Nova Scotia Aquaculture Science Advisory Committee (NSASAC) on all the key decisions and assumptions made during the scoring, weighting and aggregation phases of the suitability assessments.

The following CMAR reports will be provided for technical review and validation:

1. *Recommendations on Scoring of Criteria* - providing an overview of the scoring phase **(Attachment 1).**
2. *Recommendations on Weighting and Aggregation of Criteria* - providing an overview of the weighting and aggregation phases **(Attachment 2).**
3. *Final Summary Report* - providing an overview of any changes made based on the interim science advice received, as well as a summary of the final products **(Attachment 3).**

The reports will be shared with the Committee, and advice received, following the agreed upon timeline **(Attachment 4).**

Supporting Documentation (attachment or link):	
1	*Recommendations on Scoring of Criteria. A report in support of the aquaculture coastal classification system project.*

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2	*Recommendations on Weighting and Aggregation of Criteria. A report in support of the aquaculture coastal classification system project.*
3	*Final Summary Report. A report in support of the aquaculture coastal classification system project.*
4	Request for Science Advice Timeline Overview

Timelines for Receiving Science Advice:
Final advice to Minister: June 30, 2025

REQUESTING ADVICE

Name of Director (or Delegated Authority)	**Request Date**
Hilary Steele	April 1, 2025
Name of Coordinator/NSDFA Staff	**Date Submitted to Committee**
Jennifer Feehan	April 1, 2025

CENTRE FOR MARINE APPLIED RESEARCH

2025-Final.v.1.0.

Recommendations on scoring of criteria

A report in support of the aquaculture coastal classification system project

March 28, 2025

Prepared by:

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Version Control			
Status	**Version**	**Date**	**Rationale**
Draft	0.1	June 13, 2024	First draft
Draft	0.2	September 3, 2024	Adjustments made to incorporate feedback from advisory committee review and discussions with network partners
Draft	0.3	December 31, 2024	Refinements to reflect feedback from advisory committees on draft v.0.2
Draft	0.4	March 24 ,2025	Refinements to reflect feedback from advisory committees on draft v.0.3
Final	1.0	March 28, 2025	Final version to be circulated to Nova Scotia Science Advisory Committee

1 Introduction

To support the objectives of the Coastal Classification System (CCS) for aquaculture in Nova Scotia, the Centre for Marine Applied Research (CMAR) is completing high-level assessments to classify coastal areas based on their potential for finfish and shellfish[1] aquaculture. To assess the potential of areas for aquaculture development, multiple evaluation criteria will be evaluated and rated within a Geographic Information System (GIS) tool, applying established techniques for Multicriteria Decision Analysis (MCDA)[2]. These assessments will be combined into an online mapping tool for users to view spatial information about potential aquaculture development opportunities in Nova Scotia. The outputs of these assessments include maps showing a combined rating indicating the potential suitability for aquaculture development as well as data layers of supporting information.

For this assessment, the GIS-MCDA process focuses on defining, rating, and combining multiple evaluation criteria relevant to assessing the potential of an area for aquaculture development. GIS-MCDA has been widely used to explore aquaculture potential (Chentouf et al., 2023) in what can generally be referred to as a “suitability assessment”. These techniques have been used in similar global initiatives to assess suitability for aquaculture (Falconer et al., 2013; Porporato et al., 2020) and develop mapping tools[3] to help identify where opportunities for aquaculture could exist (Aguilar-Manjarrez et al., 2008). Here, we use these processes to perform an analysis of aquaculture development potential (or “suitability”).

In this type of GIS-MCDA process, scoring is the second phase of the assessment (**Figure 1**), which involves reclassifying criteria[4] to a consistent scale. Reclassification is the process of transforming/converting data from many different sources and units into a common/consistent format or normalized scale that will enable meaningful comparison, analysis, and interpretation. Through a scoring process, reclassification (also sometimes called standardization or normalization) allows for multiple, often diverse criteria, to be easily compared and combined. The scoring phase also involves decisions that guide how each criterion is considered within the assessment. Decisions at this phase will generally outline what and how criteria are included in the assessment. Additional methodological decisions relating to how criteria are combined to produce final suitability classifications will be outlined in subsequent reporting on weighting[5] and aggregation.

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[1] Considering key species cultured in Nova Scotia: Atlantic salmon (*Salmo salar*), Rainbow trout (*Oncorhynchus mykiss*), Eastern blue mussel (*Mytilus edulis*), and American oyster (*Crassostrea virginica*).

[2] See “Methods Review for Spatial Suitability Analysis in the context of the Coastal Classification System (CCS)” for more information about general approach and methodology.

[3] For example, see Palau Aquaculture Suitability Tool and AquaVIS (Gangnery et al., 2021).

[4] Criteria are defined broadly as considerations that are evaluated to determine how well different areas meet various suitability objectives.

[5] Weighting is the process of determining and applying levels of importance (weights) to factors being evaluated (Malczewski and Rinner, 2015).

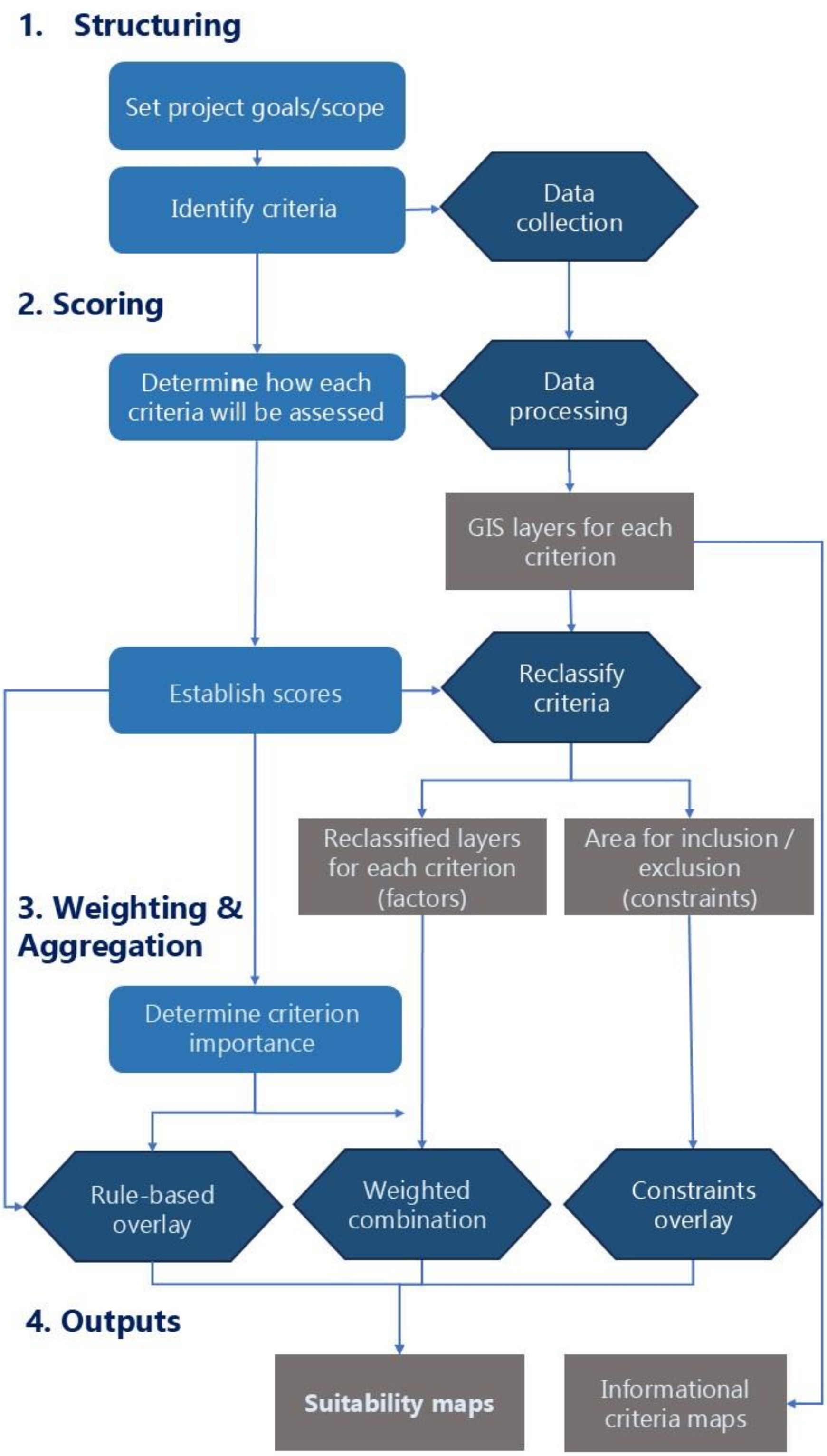

Figure 1. Key decisions, methods, and outputs across the four main phases of the GIS-MCDA assessment of aquaculture development potential to produce final suitability maps.

1.1 Purpose of report

This report aims to provide information to guide the decisions regarding how each criterion will be scored for inclusion in the assessment of aquaculture development potential in Nova Scotia. Here, we provide an overview of the scoring process used within the aquaculture suitability assessment, including how data was acquired and processed and how criteria were scored (**Section 2**). The proposed scores for each criterion are described for each species assessment (**Section 3**). Supplementary information on the criteria details, including sources and processing of datasets, scoring rationales, and criterion maps can be found in **Appendix i**. As this is an interim report, any feedback, adjustments, or refinements will be reflected in subsequent reporting. How criteria will be combined into the final tool will be described in subsequent reports.

2 Scoring (reclassification) process

Scoring was done through an evidence-based and collaborative process to propose scientifically valid and expert-informed scores, relevant to the project's specific objectives and scope. Scoring involved collaboration with network partners (i.e., Nova Scotia Department of Fisheries and Aquaculture; Fisheries and Oceans Canada (DFO), Transport Canada), and other subject-matter experts, brought together as part of the advisory committees established under the CCS project[6]. This process reflects best practices from MCDA literature (Belton and Stewart, 2002; Malczewski and Rinner, 2015; Cinelli et al., 2020; Dean, 2022). Recognizing that no universally applicable approach exists, the best methods should be tailored to meet project needs and contexts.

Criteria scoring involves assigning ratings to individual criterion values, which reclassifies (normalizes) data into a common scale. The scoring phase consists of two main steps required to transform criteria data into a format that can be aggregated in the final stages of the assessment (**Figure 2**). In Step 1, criteria must be prepared to understand how they will be scored and aggregated, and to ensure that they are in proper format and units which can be reclassified for analysis. In Step 2, we classify the values of each criterion based on how criteria influence the potential for aquaculture development.

[6] Which include a Technical Oversight Committee (TOC) and three Data Committees (DCs).

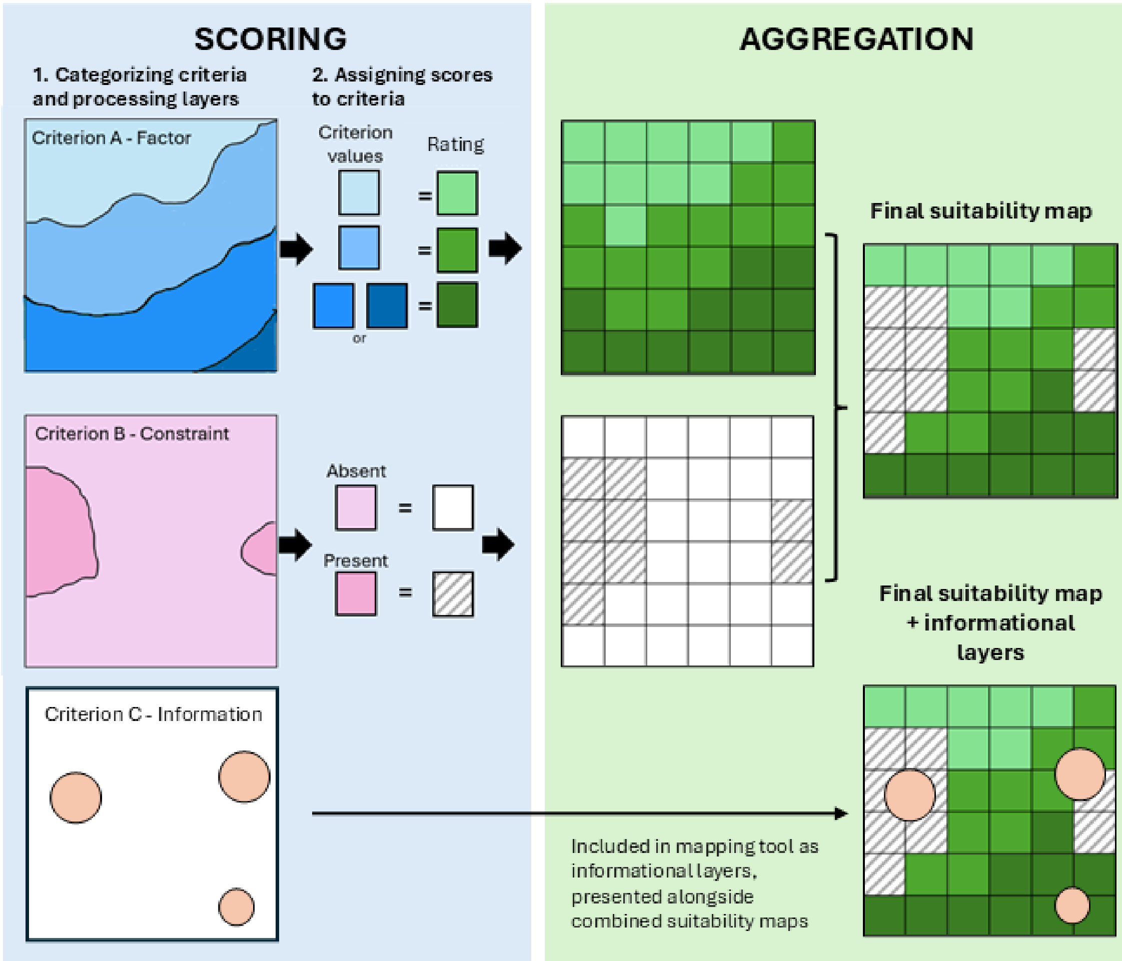

Figure 2. The process of scoring different types of criteria, showing how data layers are reclassified in preparation to be combined during aggregation. Note: The aggregation phase is shown for illustrative purposes only. How layers get incorporated will depend on the weighting (importance) of each layer, which will be further discussed in subsequent reports.

2.1 Step 1 – Criteria preparation

2.1.1 Categorizing criteria to determine how they will be used in the assessment

There are several different ways criteria may be incorporated into the assessment of aquaculture development potential which can be differentiated based on the type of criteria. **Index criteria**, which include criteria used to calculate the final combined score for aquaculture development potential, can be distinguished into hard 'constraints' and soft 'factors', which influences how they are aggregated with other information (Eastman, 2009). The aggregation process will be further discussed in subsequent reports.

Factors are criteria that can either enhance or detract from the potential for aquaculture development in an area. Factor values get scored into three ratings ("limited", "moderate", or "good" potential for aquaculture), and data becomes reclassified and aggregated alongside other factors[7].

Constraints are criteria that identify areas of exclusion for aquaculture development. To be considered a constraint, the criterion must identify a region or feature that would absolutely exclude aquaculture development, either due to direct spatial overlaps with infrastructure (e.g. submerged cables and pipelines), interference with already designated activities or uses (e.g. anchorage areas), or areas generally considered legislatively restrictive (e.g. Marine Renewable Energy Areas[8]). In the context of scoring, constraints serve to limit the areas under consideration[9].

Informational criteria are identified as criteria that provide important knowledge to understanding aquaculture development potential but cannot be scored as factors due to a lack of reliable, consistent knowledge on the appropriate scores. A criterion is designated as an informational criterion if there is a lack of reliability in the knowledge or information to score criteria or if there is significant variability in what would make the criteria "suitable" for aquaculture (e.g. highly dependent on local contexts). These criteria will not be included in the overall calculation for aquaculture development potential. Rather, these criteria will be incorporated within the mapping tool as information-only datasets that can be viewed alongside final aggregated maps (**Figure 2**).

To determine each criterion's type, a series of questions related to the criterion's reliability (i.e., there must be adequate knowledge/information to consistently and confidently score criteria into ratings), applicability (e.g. whether criterion impacts can be generalized), and restrictiveness (e.g. whether the criterion would be exclusionary for aquaculture development) were posed. The criterion type was then determined based on their taxonomy across the three features of reliability, applicability, and restrictiveness (**Figure 3**).

[7] Combined through a Weighted Linear Combination (WLC) aggregation method, which will be further detailed within a subsequent report.

[8] As per the Marine Renewable-energy Act, MREAs can not be designated in areas permitted or leased for aquaculture.

[9] Constraints are represented in a binary way to be overlaid on top of factor maps, such that any area present within a constraint will be rated as "restricted".

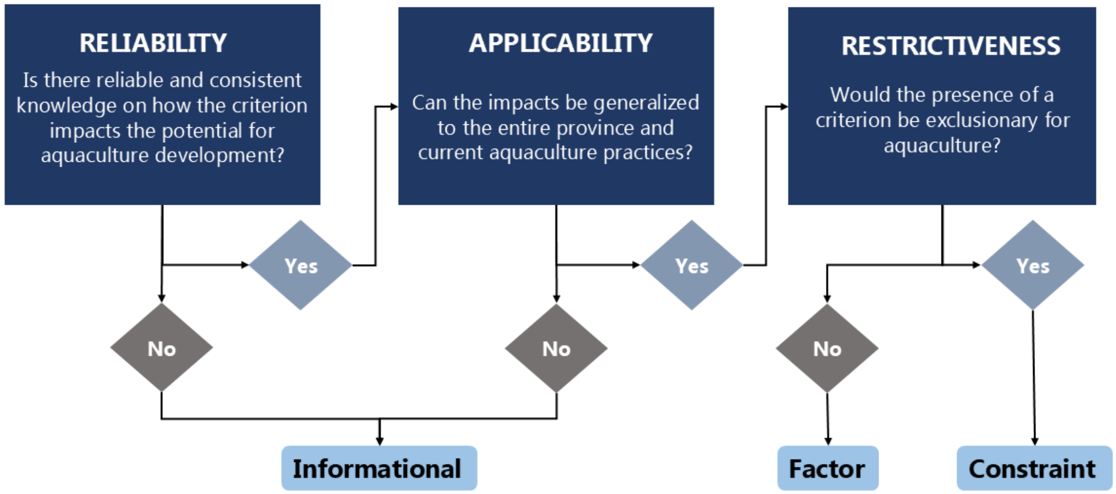

Figure 3. Guiding questions to determine whether criteria are to be included as a factor, constraint, or informational criterion.

For this assessment, a total of 10 criteria were categorized as factors (**Table 1**). An additional 5 criteria will be incorporated as constraints, which represent areas that are exclusionary of aquaculture activities. After consideration of the evidence and knowledge available to score criteria, 8 criteria will be incorporated as informational datasets. For more details on the rationale for categorizing, see **Appendix i**.

Table 1. Categorization of criteria types and their applicability across shellfish and finfish aquaculture.

Criterion	Criterion Type	Finfish		Shellfish	
		Salmon	Trout	Mussels	Oysters
Extreme cold exposure	Factor	✓	✓		
Extreme heat exposure	Factor	✓	✓	✓	
Bathymetry	Factor	✓	✓	✓	✓
Ice conditions	Factor	✓	✓	✓	✓
Wind and wave conditions	Factor	✓	✓	✓	✓
Critical habitat for species at risk	Factor	✓	✓	✓	✓
Marine protected and conserved areas	Factor	✓	✓	✓	✓
AIS vessel density patterns	Factor	✓	✓	✓	✓
VMS fishing vessel density patterns	Factor	✓	✓	✓	✓
Public coastal access	Factor	✓	✓	✓	✓
Anchorage areas	Constraint	✓	✓	✓	✓
Designated navigation features	Constraint	✓	✓	✓	✓
Marine Renewable Energy Areas	Constraint	✓	✓	✓	✓
Submerged cables and pipelines	Constraint	✓	✓	✓	✓
At-sea disposal sites	Constraint	✓	✓	✓	✓
MSX Declaration areas	Informational				✓
Shellfish Harvest Area Classification	Informational			✓	✓
Wild salmon rivers	Informational	✓			
Coastal wetlands	Informational	✓	✓	✓	✓
Terrestrial protected areas and parks	Informational	✓	✓	✓	✓
Important bird habitat	Informational	✓	✓	✓	✓
Existing aquaculture leases	Informational	✓	✓	✓	✓
Water lots	Informational	✓	✓	✓	✓
Crown leases, easements and permits	Informational	✓	✓	✓	✓

2.1.2 Data collection and processing

To effectively score and combine criteria, criteria datasets must represent the specific measures appropriate for evaluating criteria for aquaculture development potential. Datasets were chosen based on their availability and relevance to the identified species-specific criteria and whether they are considered as a factor, constraint, or informational criterion. Furthermore, criteria may often be represented by "proxy" measures, or indirect measures used to represent criteria that are difficult to measure directly. For example, direct measurement of wind and wave exposure is challenging and likely requires complex oceanographic models and integration of multiple factors. Instead, we use maximum significant wave height data from wind and wave exposure modelling as a proxy to identify areas that would be more or less exposed to extreme wind and wave conditions. Therefore, proxy measures must appropriately and adequately capture or represent the criteria being assessed.

In many cases, data was retrieved from publicly accessible sources or provided through collaboration with network partners. Some criteria data were produced for this project through sub-contractors or in-house resources. Data quality and completeness are being assessed to ensure the most authoritative, highest (appropriate) resolution and up-to-date sources are used.

Original base data may not always be in appropriate formats or units for measuring criteria. In these cases, appropriate criteria maps showing what we are interested in measuring may need to be derived. For example, to measure potential overlaps with public access to coastal waters, we compiled point locations of key access points (such as beaches, boat launches, and marinas). As this assessment evaluates suitability based on potential access overlaps, not the location themselves, maps need to be derived that act as a proxy for potential overlaps, such as by calculating the distance to access points. Processing allows raw datasets to be transformed into appropriate criteria units, representing the specific criteria values that will be scored. This preparation could include cleaning, re-sampling, combining, or analyzing raw datasets to produce rasterized (gridded) criterion maps across the area of assessment (AOA).

The data sources and processing procedures applied to all criteria are presented in **Table 2**. More detailed notes on data sources and processing, along with all criterion maps, can be found in **Appendix i**. Data that requires a high level of processing (such as those created in-house for this assessment) will be detailed further in the final reporting. Some data received was in mostly 'ready-to-use' formats from publicly available data or existing layers. To learn more about the data or methods, see links to original data sources (**Table 2**). Informational criteria will be presented largely as unprocessed original data.

Table 2. The criteria units (what is being scored) and the sources and processing of data for criteria.

Criteria	Unit	Data source (s)	Data processing for source map
Extreme cold exposure	Extreme cold exposure risk rating	Coastal Monitoring Program data - CMAR, supplemented by GHRSST Level 4 MUR Global Foundation Sea Surface Temperature	Risk ratings were determined by classifying the annual likelihood of extreme cold exposure, which was calculated by how often temperatures reached at or below -0.7 °C and interpolated across the area of assessment (AOA). sea surface data points were added for complete coverage.
Extreme heat exposure	Extreme heat exposure risk rating	Coastal Monitoring Program data - CMAR, supplemented by GHRSST Level 4 MUR Global Foundation Sea Surface Temperature	Risk ratings were determined by classifying the likelihood of exposure to extreme heat, which was calculated by how often heat stress events occurred in an area, defined by the length of time water temperatures reached a critical temperature for species, and interpolated across the AOA. Sea surface data points were added for complete coverage.
Bathymetry	Bathymetry (m)	General Bathymetric Chart of the Oceans (GEBCO); Canadian Hydrographic Service Non-Navigational (NONNA) Bathymetric Data	Elevation data from NONNA bathymetry was extracted for marine areas to identify water depths below sea level. Data gaps were filled with GEBCO datasets.
Ice conditions	Ice exposure risk	Ice products produced by NSCC's Applied Geomatics Research Group CMAR	Ice exposure risk was based drift ice observations reported between 2014 – 2024, compiled through historical ice conditions across the AOA. Drift ice observations were classified into ice frequency classes. In the case of shellfish aquaculture, risk was determined by considering drift ice frequency as well as whether the bathymetry would be sufficient to avoid maximum drift ice thickness, or whether there is sheltering within the bay.
Wind and wave conditions	Maximum significant wave height (m)	Nova Scotia Wind-generated Wave Exposure Atlas - DSA Ocean for CMAR	Based on wind-derived wave exposure modelling that identifies maximum wave height (m) reported across a 10-year period (2014-2024).
Critical habitat for species at risk	Presence / Absence	Critical Habitat for Aquatic Species at Risk - Canada ; Critical Habitat for Species at Risk National Dataset - Canada	Critical habitat for species at risk in marine waters was identified. Any area beyond the boundaries of critical habitat was reclassified as "absent".

Criteria	Unit	Data source (s)	Data processing for source map
Marine protected and conserved areas	Presence / Absence	Canadian Protected and Conserved Areas Database (CPCAD); Protected beaches and Wildlife Management Areas were provided at the request of the Nova Scotia Department of Natural Resources (DNR)	The presence of a marine protected and conserved area was identified by extracting any 'marine' area within the datasets. Any area beyond the boundaries of these areas was reclassified as "absent".
AIS vessel density patterns	Navigation channel class	Automatic Identification System (AIS) track line data from 2019, 2020, and 2021 provided by DFO	Classes of navigation channels were identified based on calculating the density of AIS track lines and applying spatial analysis to identify density clusters.
VMS Fishing vessel density patterns	Density class	Vessel Monitoring System (VMS) data from 2019, 2020, and 2021 provided by DFO	Fishing vessel traffic density classes were identified by calculating the density of VMS data points. Data was reclassified based on quartile distribution into evidenced-based density classes.
Public coastal access	Proximity to coastal access points (m)	Multiple coastal access point data: • Coastal beaches (Ecological Land Classification, Protected beaches provided by Nova Scotia DNR) • Small craft harbours (DFO) • Public boat launch sites (NSDFA) • Marinas and yacht clubs (CMAR)	The distance (m) of areas to the nearest public coastal access point was calculated for each public access point site.
Anchorage areas	Presence / Absence	Canadian Anchorages and Anchorage areas	Anchorage area points were extracted. No additional processing was required.
Designated navigation features	Presence / Absence	Vessel traffic routes - CHS/DFO	Multiple features designated for navigational safety were compiled and include: traffic separation zones, ferry routes, navigational sight lines, and recommended routes.
Marine Renewable Energy Areas	Presence / Absence	Provided by Nova Scotia Department of Energy	Maps were brought into GIS. No additional processing was required.
Submerged cables and pipelines	Presence / Absence	Provided by DFO	Known active Subsea cables and pipelines were provided by network partners.
At-sea disposal sites	Presence / Absence	Active and Inactive Disposal at Sea Sites in Canadian Waters	Active at-sea disposal sites were extracted. No additional processing was required.

Criteria	Unit	Data source (s)	Data processing for source map
MSX Declaration Areas	Presence	CFIA Map of Declared Areas for Molluscan Diseases (Cape Breton)	The MSX-declared areas were identified through maps of declared areas for MSX, which were digitized into GIS.
Shellfish Harvest Area Classifications	Presence	Shellfish Water Classification Program – Shellfish Harvest Area Classification in Canada	Harvest Classification areas were extracted. No additional processing was required.
Wild salmon rivers	Presence	River significance levels from wild salmon river assessment - CMAR	River significance levels for wild Atlantic salmon plotted for rivers across Nova Scotia.
Important bird habitat	Presence	Multiple datasets include: i) Significant Species and Habitat Database (NSDNR), ii) Important Bird Areas (IBA) BirdLife International, iii) Critical Habitat for Species at Risk National Dataset (ECCC), iv) Migratory Bird Sanctuaries from the Canadian Protected and Conserved Areas Database.	Bird habitat datasets within 100 m from the coast were extracted and combined into a single layer.
Coastal wetlands	Presence	Canadian National Wetlands Inventory	Wetlands within 100 m from the coast were extracted. No additional processing was required.
Terrestrial protected areas/parks	Presence	The Nova Scotia Protected Areas System; Protected beaches and Wildlife Management Areas were provided at the request of the Nova Scotia Department of Natural Resources (DNR)	Terrestrial protected areas and parks within 100 m from the coast were extracted. No additional processing was required.
Existing aquaculture leases	Presence	Aquaculture lease mapping tool (Nova Scotia)	Existing aquaculture areas were extracted and partitioned based on issued leases.
Water lots	Presence	PID Data provided by GEONova	Extracted privately and government-owned parcels. No additional processing was required.
Crown leases, easements and permits	Presence	Crown lease, easement and coastal permit data were provided at request by the Nova Scotia Department of Natural Resources (DNR).	Extracted crown lease, easement and coastal permit data in the marine environment. No additional processing was required.

2.2 Step 2 - Determining scores

2.2.1 Determining factor scores

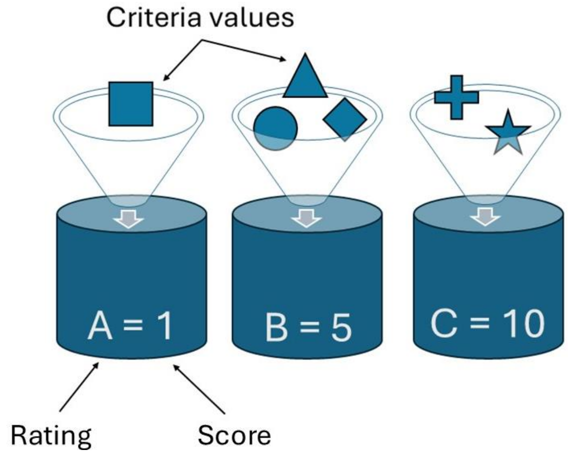

Figure 4. Graphic representation of discrete scoring whereby different criteria values are partitioned into 'bins', each of which has a designated rating and numerical score.

Since each factor is measured with different units, factors must be reclassified to be combined to produce an overall score of aquaculture development potential. A variety of procedures for reclassification within MCDA exist[10] (Cinelli et al., 2020). Among the most popular is discrete scoring, which scores criterion values directly into distinct criterion ratings (**Figure 4**). Through this method, the suitability scores can capture some nuance across suitability implications, while providing a structure for justifying the categorization. Factors were scored discretely into one of three ratings[11], representing if the criterion has conditions that would be "limited", "moderate", or "good" for aquaculture development potential.

Scoring was determined by exploring how each criterion impacts aquaculture development potential, considering potential impacts on planning objectives (i.e., aquatic animal health and welfare, conservation, and multi-user overlaps), as well as regulatory restrictions associated with aquaculture development. Criteria were thus scored based on potential impacts and the need for management or mitigation, by prospective producers. In this way, higher ratings do not reflect "optimal" conditions for development but rather identify where potential impacts, mitigations, or development challenges might be lowest. Conversely, lower ratings do not represent conditions that would not allow for aquaculture development but reflect conditions that would have greater potential limitations, impacts, or development challenges.

To guide the scoring process, clear rating descriptions were developed so that ratings were consistent and comparable across criteria (**Table 3**). These descriptions are generalized to provide a consistent lens for scoring criteria, which was important for both interpreting and communicating proposed scores. As what makes an area "limited", "moderate", or "good" for aquaculture development potential ultimately varies for each criterion and species, scoring rules were considered for each criterion and species. Effectively, proposed scores should reflect rating descriptions so that the implications of suitability ratings are consistent across criteria.

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[10] Other forms of reclassification include more mathematically based approaches used as scaling based on modelling relationships with data or 'fuzzy' membership scaling.

[11] Each rating will be associated with a numerical score. The numerical values (i.e., the scale) will be determined based on the utility needs of the assessment and outputs and will be described further in subsequent reports.

Table 3. Rating descriptions to guide criteria scoring.

Rating	Description
Limited	Conditions that are generally expected to create substantial challenges for aquaculture development and would require significant management or mitigation.
Moderate	Conditions that are generally expected to be reasonable for aquaculture development, with further investigation needed to explore potential impacts or appropriate management and mitigation.
Good	Conditions that are generally expected to be well suited for aquaculture development and potential challenges would be expected to be minimal.

To assign scores to criteria, we explored the scientific literature, regulatory and legislative requirements, and industry practices and guidelines. Scoring also incorporated input from subject matter experts, who provided valuable insights[12] and helped refine the scores to ensure they are practical and relevant. This approach ensures that scoring is thorough, evidence-based, and relevant to planning considerations by government and industry so that proposed scores:

1. Have a scientific basis, drawing on established threshold and/or advice from the scientific literature, where available[13];
2. Fit within management best-practices, considering existing regulations and/or guidelines, where relevant; and
3. Are relevant to current aquaculture sector practices in Nova Scotia and needs in the context of planning for aquaculture development.

Criteria were scored to reflect industry practices and management requirements that are currently used[14] and widely adopted[15] within Nova Scotia's aquaculture sector. As this assessment is designed to be a high-level screening of aquaculture potential, production characteristics were not specified, and this assessment does not presume a certain size or density of farms within a given area, nor the implementation of specific mitigation or management practices. While many management and mitigation practices are common in Nova Scotia, their use can not be presumed. However, this assessment does assume that scoring is based on year-round production[16] of all species. Only suspended oyster culture is considered in this assessment, with the practice of submerging infrastructure part of widely adopted practice.

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[12] Particularly in cases with limited scientific or regulatory guidance on scoring.
[13] Scientific evidence may draw from studies in other aquaculture jurisdictions; particularly if the interaction or threshold has not been locally explored.
[14] This excludes emerging technologies or practices, such as stocking with triploid fish or closed containment structures.
[15] Would be applied to most producers, regardless of local conditions, production requirements, or time of year.
[16] Seasonal production or shortened production periods may be currently used among some operators. This is considered the implementation of a management practice and not standard practice.

2.2.2 Determining constraint scores

Constraints were scored in a binary manner, based on the spatial boundaries of constraint features. For example, all areas designated as anchorage areas or anchorage points are considered constraint features. During final aggregation, these areas would be automatically assigned an exclusionary score (0 or 'restricted')[17].

3 Proposed scoring

Scoring rules are proposed for each criterion and discussed separately for each cultured species; salmon (**Table 4**), trout (**Table 5**), mussels (**Table 6**), and oysters (**Table 7**). A description of the rationale for all proposed scores is detailed in **Appendix i**.

Table 4. Proposed scoring rules for partitioning criteria values into ratings for the assessment of aquaculture development potential for Atlantic salmon (*Salmo salar*).

Criteria	Unit	Rating		
		Limited	Moderate	Good
Extreme cold exposure	Extreme cold exposure risk	High	Medium	Low
Extreme heat exposure	Extreme heat exposure risk	High	Medium	Low
Bathymetry	Bathymetry (m)	< 10 m	N/A	> 10 m
Ice conditions	Ice exposure risk	High	Medium	Low
Wind and wave conditions	Maximum significant wave height (m)	> 5.5 m	4 – 5.5 m	< 4 m
Critical habitat for species at-risk	Presence	N/A	Present	Absent
Marine protected and conserved areas	Presence	Present	N/A	Absent
AIS vessel density patterns	Navigation channel class	On-channel	Near-channel	Off-channel
VMS fishing density patterns	Fishing traffic density class	High traffic	Medium traffic	Low traffic
Public coastal access	Proximity (m)	< 300 m	N/A	> 300 m

[17] Additional details on how considerations for constraints will be incorporated during final aggregation will be further expanded on in a subsequent report.

Table 5. Proposed scoring rules for partitioning criteria values into ratings for the assessment of aquaculture development potential for Rainbow trout (*Oncorhynchus mykiss*).

Criteria	Unit	Rating		
		Limited	Moderate	Good
Extreme cold exposure	Extreme cold exposure risk	High	Medium	Low
Extreme heat exposure	Extreme heat exposure risk	High	Medium	Low
Bathymetry	Bathymetry (m)	< 10 m	N/A	> 10 m
Ice conditions	Ice exposure risk	High	Medium	Low
Wind and wave conditions	Maximum significant wave height (m)	> 5.5 m	4 – 5.5 m	< 4 m
Critical habitat for species at-risk	Presence	N/A	Present	Absent
Marine protected and conserved areas	Presence	Present	N/A	Absent
AIS vessel density patterns	Navigation channel class	On-channel	Near-channel	Off-channel
VMS fishing density patterns	Fishing traffic density class	High traffic	Medium traffic	Low traffic
Public coastal access	Proximity (m)	< 300 m	N/A	> 300 m

Table 6. Proposed scoring rules for partitioning criteria values into ratings for the assessment of aquaculture development potential for blue mussels (*Mytilus edulis*).

Criteria	Unit	Rating		
		Limited	Moderate	Good
Extreme heat exposure	Extreme heat exposure risk	High	Medium	Low
Bathymetry	Bathymetry (m)	< 5 m	N/A	> 5 m
Ice conditions	Ice exposure risk	High	Medium	Low
Wind and wave conditions	Maximum significant wave height (m)	> 3 m	2 - 3 m	< 2 m
Critical habitat for species at-risk	Presence	N/A	Present	Absent
Marine protected and conserved areas	Presence	N/A	Present	Absent
AIS vessel density patterns	Navigation channel class	On-channel	Near-channel	Off-channel
VMS fishing density patterns	Fishing traffic density class	High traffic	Medium traffic	Low traffic
Public coastal access	Proximity (m)	< 300 m	N/A	> 300 m

Table 7. Proposed scoring rules for partitioning criteria values into ratings for the assessment of aquaculture development potential for American oysters (*Crassostrea virginica*).

Criteria	Unit	Rating		
		Limited	Moderate	Good
Bathymetry	Bathymetry (m)	< 2 m	N/A	> 2 m
Ice conditions	Ice exposure risk	High	Medium	Low
Wind and wave conditions	Maximum significant wave height (m)	> 3 m	2 - 3 m	< 2 m
Critical habitat for species at-risk	Presence	N/A	Present	Absent
Marine protected and conserved areas	Presence	N/A	Present	Absent
AIS vessel density patterns	Navigation channel class	On-channel	Near-channel	Off-channel
VMS fishing density patterns	Fishing traffic density class	High traffic	Medium traffic	Low traffic
Public coastal access	Proximity (m)	< 300 m	N/A	> 300 m

4 Conclusions

In consideration of the need to normalize multiple criteria for aggregation, this report outlines a proposed evidence-based and expert-informed scoring approach and presents proposed scoring rules for each criterion. The proposed scoring approach combines factors, which are scored into three ratings of "limited", "moderate", and "good" aquaculture development potential, constraints (which will be identified as "restricted" in the final maps), and informational criteria (which are included within the mapping tool but not scored or included in the suitability analysis). Proposed scoring rules were considered separately for each species being evaluated and represent best scientific knowledge and policy relevance, drawing on industry, expert, and network partner engagements. This approach represents a clear, consistent framework for scoring criteria into meaningful ratings relevant to assessing the potential for aquaculture development in Nova Scotia.

Given the scale of this assessment, a few key limitations must be noted. Many of the criteria included in this assessment are interrelated and may be influenced by various compounding factors that cannot be captured in this assessment. Furthermore, many have localized spatial and temporal dynamics that can not effectively be captured at a provincial scale. Data is largely unavailable at this scale and often requires complex modeling efforts to effectively include. As such, the data layers and scoring presented in this assessment are designed to offer a generalized suitability and do not preclude the need for further assessment at smaller, more localized scales.

Additionally, it is important to note that both the categorization of criteria and proposed scores could be adjusted as new information is made available. Aquaculture policies and legislation around aquaculture may change. Furthermore, additional data and knowledge on appropriate scores may enable informational criteria to be reassessed for scoring and inclusion as an index criterion. As such, the proposed scoring rules are based on published data and decisions available at the time of their development.

5 References

Aguilar-Manjarrez, J. et al. (2008). The potential of spatial planning tools to support the ecosystem approach to aquaculture. In *Expert Workshop* (Vol. 17, pp. 176). Rome, Italy: FAO.

Andrews, J. D., Wood, J. L. (1967). Oyster mortality studies in Virginia. VI. History and distribution of Minchinia nelsoni, a pathogen of oysters, in Virginia. *Chesapeake Science, 8*(1), 1-13. https://link.springer.com/article/10.2307/1350351

Azra, M. N. et al. (2021). The Contributions of Shellfish Aquaculture to Global Food Security: Assessing Its Characteristics From a Future Food Perspective. *Frontiers in Marine Science, 8*(365). doi:10.3389/fmars.2021.654897

Baltic Blue Growth project. (2019). Advice for the future Baltic mussel farmer - a summary of lessons learned from the BBG project. EU strategy for the Baltic Sea region.

https://interreg-baltic.eu/wp-content/uploads/2021/10/38-BalticBlueGrowth_Factsheet_Advice_for_future_farmers.pdf

Barber, B. et al. (1997). Haplosporidium nelsoni (MSX) epizootic in the Piscataqua river estuary (Maine/New Hampshire, USA). *The Journal of Parasitology*, 148-150. https://www.jstor.org/stable/3284334

Barbier, E. et al. (2024). Atlantic salmon in chronic turbulence: Effects on growth, behaviour, welfare, and stress. *Aquaculture, 582*, 740550. https://www.sciencedirect.com/science/article/pii/S0044848624000115

Barnes, P. (2006). Shellfish culture and particulate matter production and cycling: a literature review. *BC Aquaculture Research & Development Committee. AE*, 02.03-02. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=b8ec653fb50e303312a726d47e678ae8f5708660

Bath, G. E. et al. (2023). A global review of protected species interactions with marine aquaculture. *Reviews in Aquaculture*, 1-34. https://repository.library.noaa.gov/view/noaa/49809

Beemelmanns, A. et al. (2021). The transcriptomic responses of Atlantic salmon (Salmo salar) to high temperature stress alone, and in combination with moderate hypoxia. *BMC Genomics, 22*. doi:10.1186/s12864-021-07464-x

Belton, V., Stewart, T. (2002). Multiple criteria decision analysis: an integrated approach Springer Science and Business Media.

Bradbury, I. R. et al. (2020a). Beyond hybridization: the genetic impacts of nonreproductive ecological interactions of salmon aquaculture on wild populations. *Aquaculture Environment Interactions, 12*, 429-445. https://www.int-res.com/abstracts/aei/v12/p429-445/

Bradbury, I. R. et al. (2020b). Model-based evaluation of the genetic impacts of farm-escaped Atlantic salmon on wild populations. *Aquaculture Environment Interactions, 12*, 45-59. doi:10.3354/aei00346

Brewer-Dalton, K. e. et al. (2015). Oceanographic conditions of salmon farming areas with attention to those factors that may influence the biology and ecology of sea lice, *Lepeophtherius salmonis* and *Caligus* spp., and their control.

Bridger, C. J. et al. (2015). Physical containment approaches to mitigate potential escape of European-origin Atlantic salmon in south coast Newfoundland aquaculture operations Canadian Science Advisory Secretariat (CSAS).

Brister, D. J., Kapuscinski, A. R. (2000). Environmental Assessment Tool for Cage Aquaculture in the Great Lakes Version 1.1. *Prepared for the Great Lakes Fishery Commission by the University of Minnesota Institute for Social, Economic and Ecological Sustainability. St Paul, Minnesota.(Available on the Internet at: http: www. glfc. org)*. https://www.glfc.org/pubs/clc/envir1.pdf

Burreson, E. M. et al. (2000). Increased virulence in an introduced pathogen: *Haplosporidium nelsoni* (MSX) in the Eastern Oyster *Crassostrea virginica*. *Journal of Aquatic Animal Health, 12*, 1-8.

Calado, R. et al. (2021). Summer is Coming! Tackling ocean warming in Atlantic salmon cage farming. *Animals, 11*, 1-18.

Campbell, M. D., Hall, S. G. (2019). Hydrodynamic effects on oyster aquaculture systems: a review. *Reviews in Aquaculture, 11*(3), 896-906.

Canadian Food Inspection Agency. (2022). Aquatic animal domestic movements. https://inspection.canada.ca/en/animal-health/aquatic-animals/domestic-movements

Canadian Wildlife Service. (2016). Critical habitat identification toolbox: Species at Risk Act guidance. https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/critical-habitat-descriptions/identification-toolbox-guidance.html

CFIA. (2019). Canadian Shellfish Sanitation Program (CSSP). Accessed March 19, 2020. https://inspection.gc.ca/preventive-controls/fish/cssp/eng/1563470078092/1563470123546

CFIA. (2020). Canadian Shellfish Sanitation Program Manual. Government of Canada. https://inspection.gc.ca/food-safety-for-industry/food-specific-requirements-and-guidance/fish/canadian-shellfish-sanitation-program/eng/1527251566006/1527251566942?chap=0#c1

Chamberlain, J. et al. (2001). Impacts of biodeposits from suspended mussel (Mytilus edulis L.) culture on the surrounding surficial sediments. *ICES Journal of Marine Science, 58*(2), 411-416. https://academic.oup.com/icesjms/article/58/2/411/617839

Chentouf, S. et al. (2023). GIS-Based Multi-Criteria Evaluation (MCE) Methods for Aquaculture Site Selection: A Systematic Review and Meta-Analysis. *ISPRS International Journal of Geo-Information, 12*(10), 439. https://www.mdpi.com/2220-9964/12/10/439

Cinelli, M. et al. (2020). How to support the application of multiple criteria decision analysis? Let us start with a comprehensive taxonomy. *Omega, 96*, 102261. doi:https://doi.org/10.1016/j.omega.2020.102261

Clarke, S. B. et al. (Under Review,). Turning up the heat: Differential responses of blue mussels (*Mytilus edulis*) in Atlantic Canada to thermal stress. *Conservation Physiology*.

Clements, J. C. et al. (2018). Increased mortality of harvested eastern oysters (Crassostrea virginica) is associated with air exposure and temperature during a spring fishery in Atlantic Canada. *Fisheries Research, 206*, 27-34.

Connor-McClean, B. (2020). Offshore aquaculture in New Zealand and its potential effects on seabirds. Wildlife Management International Ltd. https://www.mpi.govt.nz/dmsdocument/50257-Offshore-aquaculture-in-New-Zealand-and-its-potential-effects-on-seabirds

Cranford, P. J. et al. (2011). Bivalve filter feeding: variability and limits of the aquaculture biofilter. In S. E. Shumway (Ed.), *Shellfish aquaculture and the environment* (pp. 81-124).

Crowell, P. (2023). Protecting the Spaces We Love: NOVA SCOTIA'S PROTECTED AREAS NETWORK. *Ecology Action*. Retrieved from https://ecologyactionca.f.civicrm.ca/sites/default/files/2023-03/MagazineSpring2023_protectedspaces.pdf

Currie, S. et al. (2000). The effects of heat shock and acclimation temperature on hsp70 and hsp30 mRNA expression in rainbow trout: in vivo and in vitro comparisons. *Journal of Fish Biology, 56*(2), 398-408.

Davis, M. W. (2010). Fish stress and mortality can be predicted using reflex impairment. *Fish and Fisheries, 11*(1), 1-11. https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1467-2979.2009.00331.x

Dean, M. (2022). A practical guide to multi-criteria analysis. *Bartlett School of Planning, University College London*, 1-85.

Dempsey, D. P. et al. (2023). Estimating stocking weights for Atlantic salmon to grow to market size at novel aquaculture sites with extreme temperatures. *Frontiers in Marine Science, 10*. doi:10.3389/fmars.2023.1094247

Department of Fisheries and Aquaculture. (2017). Workshop: MSX workshop. https://www.dfo-mpo.gc.ca/aquaculture/rp-pr/acrdp-pcrda/projects-projets/MG-02-11-002-eng.html

Drapeau, A. et al. (2006). Association between longline design and mussel productivity in Prince Edward Island, Canada. *Aquaculture, 261*(3), 879-889. http://www.sciencedirect.com/science/article/B6T4D-4KKFXKP-1/2/b96846f722b35ea6470ef6f095bf817d

Du, Z. et al. (2024). A risk assessment model for navigation safety of maritime aquaculture platform based on AIS ship trajectory. *Journal of Electrical Systems, 20*(3), 116-123. https://www.proquest.com/openview/af963763d05ac8c9dea68b90b4eace5d/1?pq-origsite=gscholar&cbl=4433095

Eastman, J. R. (2009). DRISI Taiga Guide to GIS and Image Processing. Clark University.

Environment and Climate Change Canada. (2017). Disposal at sea: program information. https://www.canada.ca/en/environment-climate-change/services/disposal-at-sea/information.html

Environment and Climate Change Canada. (2020). Canadian Environmental Sustainability Indicators: Monitoring disposal at sea. https://www.canada.ca/content/dam/eccc/documents/pdf/cesindicators/mdisposal-at-sea/2020/Monitoring-disposal-sea-en.pdf

European Boating Association. (2021). EBA Position Statement - Marine Aquaculture. https://eba.eu.com/wp-content/uploads/site-documents/eba-position-statements/eba-position-aquaculture.pdf

European MSP Platform. Conflict fiche 6: Aquaculture and maritime tourism. https://maritime-spatial-planning.ec.europa.eu/sites/default/files/6_aquaculture_tourism_5.pdf

Falconer, L. et al. (2013). Using physical environmental parameters and cage engineering design within GIS-based site suitability models for marine aquaculture. *Aquaculture Environment Interactions, 4*(3), 223-237. http://www.int-res.com/abstracts/aei/v4/n3/p223-237/

Fiendel, N. (2020). Affidavit of Nathaniel Fiendel. Nova Scotia Aquaculture Review Board. https://arb.novascotia.ca/sites/default/files/hearing/documents/nsarb_2020_001-003_feindel_affidavit_vol_1_dfa_0.pdf

Fisheries and Oceans Canada. (2003). Profile of the Blue Mussel (Mytilus edulis) - Gulf Region. Policy and Economics Branch, Gulf Region; Department of Fisheries and Oceans. https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/270029-e.pdf

Fisheries and Oceans Canada. (2022). Ice Navigation in Canadian Waters. Fisheries and Oceas Canada, Canadian Coast Guard. Ottawa, Canada. https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/41087380.pdf

Ford, J. S., Myers, R. A. (2008). A global assessment of salmon aquaculture impacts on wild salmonids. *PLoS.Biol., 6*(2), e33. doi:06-PLBI-RA-1949 [pii];10.1371/journal.pbio.0060033 [doi]

Ford, S. et al. (1999). Modeling the MSX parasite in eastern oyster (Crassostrea virginica) populations. I. Model development, implementation, and verification. *Journal of Shellfish Research, 18*(2). https://digitalcommons.odu.edu/ccpo_pubs/78/

Ford, S. E., Haskin, H. H. (1982). History and epizootiology of *Haplosporidium nelsoni* (MSX), an oyster pathogen in Delaware Bay, 1957-1980. *Journal of Invertebrate Pathology, 40*, 118-141.

Gamperl, A. K. et al. (2020). The impacts of increasing temperature and moderate hypoxia on the production characteristics, cardiac morphology and haematology of Atlantic Salmon (*Salmo salar*). *Aquaculture, 519*, 734874. doi:https://doi.org/10.1016/j.aquaculture.2019.734874

Gangnery, A. et al. (2021). Web-based public decision support tool for integrated planning and management in aquaculture. *Ocean & Coastal Management, 203*. doi:https://doi.org/10.1016/j.ocecoaman.2020.105447

Gardner, I. et al. (2014). *Pathogen Exchange between Wild and Farmed Finfish: Evidence to Assess Pathogen Source and Factors Associated with Clinical Disease Occurrence*. Paper presented at the Aquaculture Canada 2013, Guelph, Ontario.

Getchis, T. et al. (2015). A New Resource to Aid in the Identification and Management of Aquaculture Production Hazards (Vol. 34).

Government of Canada. (2024, 2024-12-10). Movement control map for MSX. https://inspection.canada.ca/en/animal-health/aquatic-animals/diseases/reportable-diseases/multinucleate-sphere-unknown#a2

Hargrave, B. T. et al. (2005). Assessing and Managing Environmental Risks Associated with Marine Finfish Aquaculture. In (pp. 433-461).

Hartstein, N. D., Stevens, C. L. (2005). Deposition beneath long-line mussel farms. *Aquacultural Engineering, 33*(3), 192-213. http://www.sciencedirect.com/science/article/B6T4C-4G05MC5-1/2/8e809e45b5840ed766c25793e712205b

Hatcher, A. et al. (1997). Seasonal changes in the metabolism of cultured mussels (Mytilus edulis L.) from a Nova Scotian inlet: the effects of winter ice cover and nutritive stress. *Journal of Experimental Marine Biology and Ecology, 217*(1), 63-78. https://www.sciencedirect.com/science/article/pii/S0022098197000427

Iacarella, J. C. et al. (2020). Vessel Tracking Datasets For Monitoring Canada's Conservation Effectiveness. Fisheries and Oceans Canada. https://publications.gc.ca/collections/collection_2021/mpo-dfo/Fs97-6-3387-eng.pdf

Jensen, Ø. et al. (2010). Escapes of fishes from Norwegian sea-cage aquaculture: causes, consequences and prevention. *Aquaculture Environment Interactions, 1*(1), 71-83. doi:10.3354/aei00008

Jiang, X. et al. (2021). Effects of temperature, dissolved oxygen, and their interaction on the growth performance and condition of rainbow trout (Oncorhynchus mykiss). *Journal of Thermal Biology, 98*, 102928.

Johannesen, Á. et al. (2022). Waves and currents decrease the available space in a salmon cage. *Plos One, 17*(2). doi:10.1101/2021.07.23.453560

Johannesen, Á. et al. (2020). How caged salmon respond to waves depends on time of day and currents. *PeerJ, 8*. doi:https://doi.org/10.7717/peerj.9313

Johansen, L. H. et al. (2011). Disease interaction and pathogens exchange between wild and farmed fish populations with special reference to Norway. *Aquaculture, 315*(3), 167-186. doi:https://doi.org/10.1016/j.aquaculture.2011.02.014

Jossart, J. et al. (2020). Applications of Spatial Autocorrelation Analyses for Marine Aquaculture Siting. *Frontiers in Marine Science, 6*(806). doi:10.3389/fmars.2019.00806

Karathanasi, F. E. et al. (2022). Wave Analysis for Offshore Aquaculture Projects: A Case Study for the Eastern Mediterranean Sea. *Climate, 10*(1), 2. https://www.mdpi.com/2225-1154/10/1/2

LGL Limited. (2019). Placentia Bay Atlantic Salmon Aquaculture Project Environmental Effects Monitoring Plan: Climate and Weather. https://www.gov.nl.ca/ecc/files/env-assessment-projects-y2016-1834-feb-2020-plans-approved-fa0159f-griegnl-eemp-climate-and-weather-11-dec.-19.pdf

Li, S. et al. (2022). Physiological responses to heat stress in the liver of rainbow trout (Oncorhynchus mykiss) revealed by UPLC-QTOF-MS metabolomics and biochemical assays. *Ecotoxicology and Environmental Safety, 242*, 113949.

Li, X. et al. (2018). Coastal wetland loss, consequences, and challenges for restoration. *Anthropocene Coasts, 1*(1), 1-15. https://cdnsciencepub.com/doi/pdf/10.1139/anc-2017-0001

Malczewski, J., Rinner, C. (2015) Multicriteria Decision Analysis in Geographic Information Science. In, *Advances in Geographic Information Science*. New York: Springer.

Marsden, B. (2021). *Limitations of Ice Accretion on Offshore Aquaculture Facilities.* UiT The Arctic University of Norway, Retrieved from https://munin.uit.no/bitstream/handle/10037/25364/thesis.pdf?sequence=2

Metcalfe, K. et al. (2018). Using satellite AIS to improve our understanding of shipping and fill gaps in ocean observation data to support marine spatial planning. *Journal of Applied Ecology, 55*(4), 1834-1845. https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2664.13139

Minnhagen, S. et al. (2019). Results from Baltic Blue Growth Project's mussel farms and way forward for mussel farming in the Baltic Sea. *Report from Baltic Blue Growth, EU Interreg-project*. https://submariner-network.eu/wp-content/uploads/2024/01/37_BBG_GoA32_mussel_farms_20190423-3_compressed.pdf

Mordecai, G. J. et al. (2021). Aquaculture mediates global transmission of a viral pathogen to wild salmon. *Science Advances, 7*(22), eabe2592. doi:10.1126/sciadv.abe2592

Morris, J. A. et al. (2021). An Aquaculture Opportunity Area Atlas for the Southern California Bight.

Morro, B. et al. (2021). Offshore aquaculture of finfish: Big expectations at sea. *Reviews in Aquaculture, n/a*(n/a). doi:https://doi.org/10.1111/raq.12625

Oppedal, F. et al. (2011). Environmental drivers of Atlantic salmon behaviour in sea-cages: A review. *Aquaculture, 311*(1–4), 1-18. doi:http://dx.doi.org/10.1016/j.aquaculture.2010.11.020

Ottinger, M. et al. (2016). Aquaculture: Relevance, distribution, impacts and spatial assessments – A review. *Ocean & Coastal Management, 119*, 244-266. doi:http://dx.doi.org/10.1016/j.ocecoaman.2015.10.015

Paddle Canada. (2013). Lake Program Manual. Paddle Canada. https://paddle-canada.s3.amazonaws.com/70340584963c0a671f4b4399ee43305e.pdf

Perez, O. M. et al. (2003). Use of GIS-Based Models for Integrating and Developing Marine Fish Cages within the Tourism Industry in Tenerife (Canary Islands). *Coastal Management, 31*(355-366).

Porporato, E. M. D. et al. (2020). Site Suitability for Finfish Marine Aquaculture in the Central Mediterranean Sea. *Frontiers in Marine Science, 6*(772). doi:10.3389/fmars.2019.00772

Porter, G. (2003). Protecting Wild Atlantic Salmon from Impacts of Salmon Aquaculture:A Country-by-country Progress Report. World Wildlife Fund, Atlantic Salmon Federation. https://wwfeu.awsassets.panda.org/downloads/osloresprogfinal3.pdf

Porter, G. (2006). An Audit of the Management of Salmon Aquaculture for the Protection of Wild Salmon in British Columbia. https://www.watershed-watch.org/wp-content/uploads/2011/08/Exh-1631-CAN040202.pdf

Province of Nova Scotia. (2013). Our Parks and Protected Areas: A Plan for Nova Scotia.

Province of Nova Scotia. (2019). Parks and Protected Areas. https://novascotia.ca/parksandprotectedareas/

Province of Nova Scotia. (2023). Collaborative Protected Areas Strategy - An Action Plan for Achieving 20 percent. https://novascotia.ca/nse/protectedareas/docs/collaborative-protected-areas-strategy-en.pdf

Ross, J. et al. (2020). Pilot Marine Spatial Assessment Tool : Evaluating options for assessing and balancing marine use change within Tasmanian coastal waters using a spatial assessment tool. https://salmoninteractionsteam.org/research-insights-faq/

Ryan, J. (2004). Farming the deep blue. In *Bord Iascaigh Mhara Technical Report*. Dublin, Ireland.

Sagar, P. (2013). Literature Review of Ecological Effects of Aquaculture: Seabird Interactions. Cawthron Institute. https://www.mpi.govt.nz/dmsdocument/3754-Literature-Review-of-Ecological-Effects-of-Aquaculture-Chapter-6-Seabird-Interactions

Sajid, Z. et al. (2024). An aquaculture risk model to understand the causes and consequences of Atlantic Salmon mass mortality events: A review. *Reviews in Aquaculture, 16*(4), 1674-1695. doi:https://doi.org/10.1111/raq.12917

Shafer, C. S. et al. (2010). Examining Residents' Proximity, Recreational Use, and Perceptions Regarding Proposed Aquaculture Development. *Coastal Management, 38*, 559-574. doi:10.1080/08920753.2010.511700

Stantec. (2009). Road map for aquaculture Investment in Nova Scotia. https://novascotia.ca/fish/documents/roadmapforaquaculture-rpt2010.pdf

Sun, M. et al. (2024). China's mariculture net cages in typhoon and sea ice disasters: challenges and prevention strategy. *Sea Exploitation and Environment, 1*(01). http://www.irdpub.com/index.php/sea/article/view/32

Surman, C., Dunlop, J. N. (2015). Impact assessment of aquaculture on seabird communities of the Abrolhos Islands, to support the Mid-West Aquaculture Development Zone proposal. Halfmoon Biosciences.

Szewczyk, T. M. et al. (2024). Interactive effects of multiple stressors with significant wave height exposure on farmed Atlantic salmon (Salmo salar) welfare along an inshore-offshore gradient. *Aquaculture, 579*, 740184. https://www.sciencedirect.com/science/article/pii/S0044848623009584

Theuerkauf, S. J. et al. (2021). Habitat value of bivalve shellfish and seaweed aquaculture for fish and invertebrates: Pathways, synthesis and next steps. *Reviews in Aquaculture*, 1-19. doi:https://doi.org/10.1111/raq.12584

Tlusty, M. F. et al. (2018). Co-occurrence mapping of disparate data sets to assess potential aquaculture sites in the Gulf of Maine. *Reviews in Fisheries Science & Aquaculture, 26*(1), 70-85. https://www.tandfonline.com/doi/abs/10.1080/23308249.2017.1343798

Transport Canada. (2020). Understanding anchorages in Canada. https://tc.canada.ca/en/marine-transportation/ports-harbours-anchorages/understanding-anchorages-canada

Traves, J. (2023). Initiation for MPS amendments to restrict water lot infilling on the Northwest Arm. In: Halifax Regional Council.

Wang, X. et al. (2023). Experimental investigation of the hydrodynamic characteristics of longline aquaculture facilities under current and wave conditions. *Fishes, 8*(4), 204. https://www.mdpi.com/2410-3888/8/4/204#B29-fishes-08-00204

Warren-Myers, F. et al. (2022). Full production cycle, commercial scale culture of salmon in submerged sea-cages with air domes reduces lice infestation, but creates production and welfare challenges. *Aquaculture, 548*, 737570.

Westoby, E. (2023). The US Aquaculture Industry: Evaluating navigational risk posed by fish farming in the marine environment. *Coast Guard Journal of Safety & Security at Sea, Proceedings of the Marine Safety & Security Council, 80*(1). https://trid.trb.org/View/2292550

Wiber, M. G. et al. (2012). Impact of aquaculture on commercial fisheries: fishermen's local ecological knowledge. *Human Ecology, 40*(1), 29-40. doi:10.1007/s10745-011-9450-7

Yoo, S.-L., Jeong, J.-C. (2020). Safe navigation distance between marine routes and aquaculture farms in South Korea using Gaussian mixture model. *Sensors, 20*(5), 1246.

Zhang, M. et al. (2024). Analysis of aquaculture safety in marine cage culture area of Maniao bay under the effect of typhoon. *Applied Ocean Research, 144*, 103902.

Appendix i. Criteria Layer Details and Scoring

A summary of details for criteria included in the assessment is provided, including descriptions of data layers and any processing required to transform data for scoring. We also include criteria maps showing the values of each criterion across the area of assessment (AOA).

The description of datasets and processing applied is provided at a summary-level. Some data layers required more extensive data analysis or processing. More thorough description of these layers and how they were developed will be provided during the final project reporting.

The dataset analysis and data layers presented herein should be considered preliminary (draft). Quality assurance and quality control (QAQC) procedures on data and analysis are currently ongoing. Data sources and datasets may be altered as the assessment progresses.

Any changes, refinements, or additions made to the datasets and processing will be highlighted in subsequent reports.

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FACTORS

Extreme cold exposure

Importance: Identifying areas likely to experience extreme low water temperatures is important for aquaculture as extreme low temperature conditions (<-0.7°C[18]) can kill finfish, even in brief occurrences lasting only a few hours.

Data Source: Temperature data was obtained from continuous temperature monitoring sensors deployed within the Centre for Marine Applied Research's (CMAR) Coastal Monitoring Program (CMP). Data-poor areas were supplemented with Sea Surface Temperature (SST) data from the GHRSST Level 4 MUR Global Foundation Sea Surface Temperature Analysis.

Data Description and Processing: Exposure to extreme cold was measured by calculating a risk rating to bring together considerations of the likelihood of extreme cold temperatures, the severity of impacts, and the inherent uncertainty in the datasets[19]. First, the number of years where water temperatures were observed to at least once in the year, reach at or below -0.7°C[20] during winter months (January, February, and March) was identified. This was calculated for CMP temperature monitoring stations (measured at ~5m water depth at low tide[21]) with at least two years of data. Stations vary in data length, ranging from 2 to 7 years, with data collected between 2017 and 2023. For data-poor areas, additional "stations" were added to the dataset by drawing from multiple years (2018 – 2023) of SST data. An annual likelihood value was then calculated (0 to 1) based on the number of extreme cold years over the total number of years of data for each station. Likelihood values from point locations were then interpolated spatially to achieve coverage across the entire AOA. Risk ratings were assigned based on annual likelihood, such that:

- **Low risk:** Extreme cold temperatures occur rarely, if at all (< 0.1 annual likelihood). While producers should monitor temperatures, it is unlikely to significantly disrupt operations.
- **Medium risk:** Extreme cold temperatures may occur, potentially 1-2 times every 10 years (0.1 - 0.25 annual likelihood). While these events pose a substantial risk, these less frequent events are potentially more manageable with careful planning, monitoring, and implementation of mitigation measures.
- **High risk:** Extreme cold temperatures are highly likely (>0.25 annual likelihood). In these cases, producers must plan for multiple events over the lifespan of their operation (Hargrave et al., 2005). In these areas, operations could be exposed to two or more extreme

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[18] Only temperatures below -0.7°C are considered, as cold-related impacts above this threshold do not pose the same level of urgent or severe risk.

[19] Derived data products have some inherent uncertainty due to limitations in original data sources as well as assumptions made during processing. Risk ratings and likelihood calculations were based on interpolated values from point data, which may be poorly represented in some areas due to lack of full province coverage of data points. Local-scale temperature variability may not be reflected accurately through interpolated models at this scale.

[20] Determined as the temperature at which fish die from cold temperatures, applicable to both Atlantic salmon and trout (Saunders et al., 1975; Fletcher et al., 1988; LGL Limited, 2019).

[21] 5 m temperature measurements are taken to be representative of conditions at cage depth.

cold temperature events within each 10-year licensing period and could potentially impact every other production cycle[22].

This approach was taken for the entire AOA, except within the Bras d'Or area. The Bras d'Or is a highly complex environmental area where temperature profiles have significant spatial variability across its diverse subregions. In the Bras d'Or, there is a lack of reliable high-resolution temperature data across all subregions to adequately capture temperature dynamics in this area. Here, the entire region[23] was given a medium-risk rating[24], indicating that further evaluation is needed to understand specific risks within the area.

Scoring: Since extreme cold temperatures result in significant mortality of both Atlantic salmon and trout, similar scores were proposed for both species.

Scoring			
Type	**"Limited"**	**"Moderate"**	**"Good"**
Salmon	High risk	Medium risk	Low risk
Trout	High risk	Medium risk	Low risk
Mussels	N/A	N/A	N/A
Oysters	N/A	N/A	N/A

Rationale for Scoring: Although mitigation measures to reduce mortality from extreme cold exposure events, such as using deeper netting and pausing activities that bring fish to the surface, may help reduce exposure, they come with challenges and limitations (LGL Limited, 2019). While fish naturally avoid cold surface waters by swimming deeper, prolonged submergence at greater depths can result in poor growth and welfare conditions, as well as increased mortality (Warren-Myers et al., 2022). Modifying cage systems for deeper netting or submerged use can require significant investment and may increase operational complexities. Depth strategies may only work if there is temperature stratification with a 'warmer band' of water. As such, the most effective approach remains avoiding placing sites in areas with a history of extreme cold (Dempsey et al., 2023).

Regions with **high risk** are rated as **"limited"** for aquaculture development due to the considerable risk of recurring extreme cold events and their potentially severe or catastrophic effects on fish health and welfare as well as the lack of effective mitigation options. Likewise, areas with **medium risk** are scored as **"moderate"** for aquaculture development, reflecting the potential risks and challenges as well as the reduced likelihood of an event. Areas with **low risk** are scored as **"good"** for aquaculture as extreme low temperatures are likely rare in these areas.

[22] For example, given an 18-month grow out period and 3 month-fallow cycle for salmon.
[23] The Bras d'Or region was delineated based on aquaculture regions boundaries outlined in Stantec (2009).
[24] Industry data from current lease areas highlight that extreme cold temperatures are unlikely but may have been observed within the last 10 years.

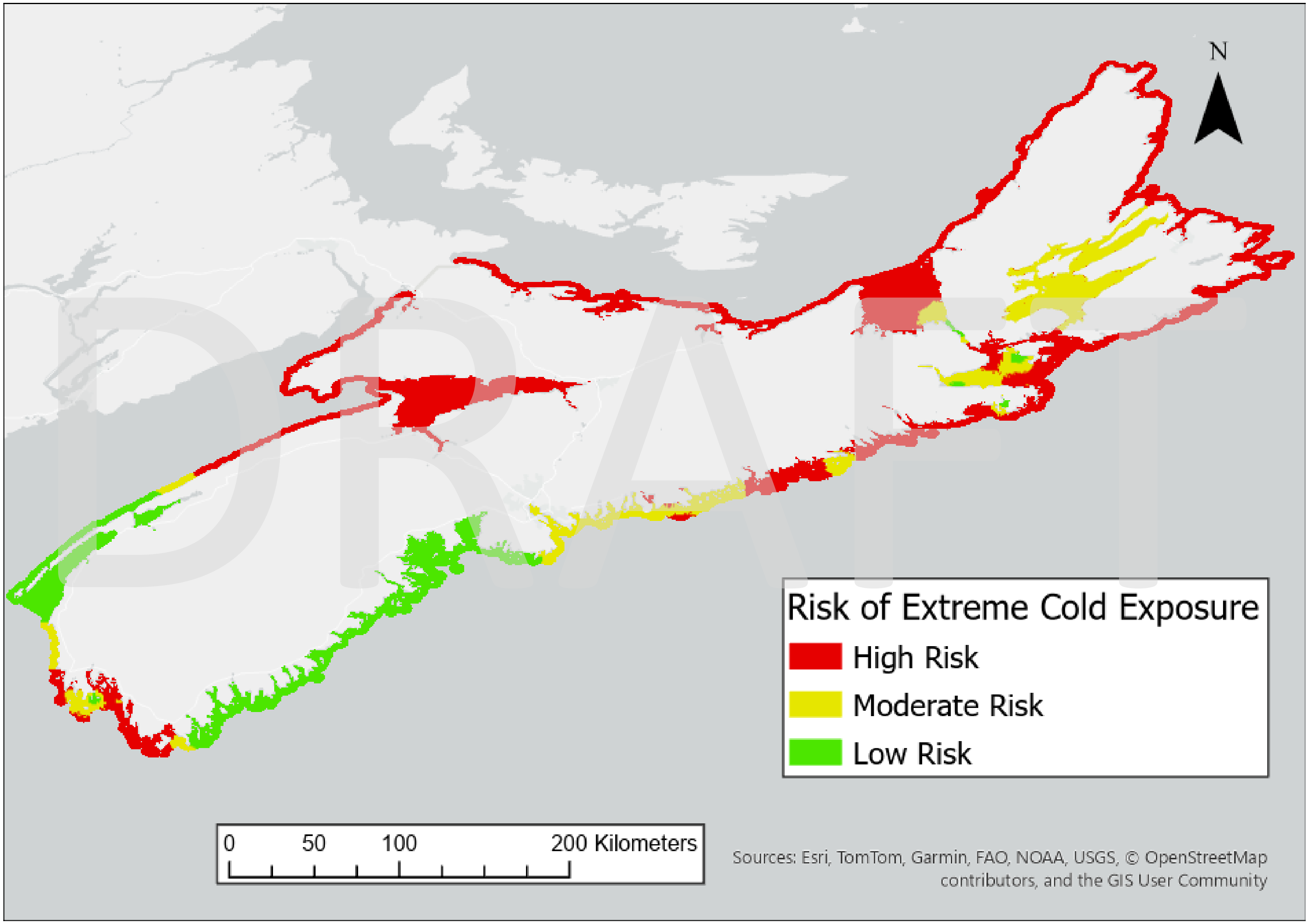

Figure A1. Distribution of exposure to extreme cold risk across the area of assessment (AOA) for finfish.

Extreme heat exposure

Importance: Identifying areas where heat stress is likely to occur is important for aquaculture as elevated heat events can harm fish and shellfish (mussels), and in extreme or prolonged cases, lead to mortalities (Thyholdt, 2014; Forseth et al., 2017). Heat stress may lead to negative health effects and poor welfare outcomes, including increased stress, impaired growth, and reduced immunity to diseases (Gamperl et al., 2020; Beemelmanns et al., 2021; Jiang et al., 2021).

Data Source: Temperature data was obtained from continuous temperature monitoring sensors deployed within the Centre for Marine Applied Research's (CMAR) Coastal Monitoring Program (CMP). Data-poor areas were supplemented with Sea Surface Temperature data from the GHRSST Level 4 MUR Global Foundation Sea Surface Temperature Analysis.

Data Description and Processing: Exposure to extreme heat was measured by calculating a risk rating to bring together considerations of the likelihood of heat stress occurring, the severity of impacts, and the inherent uncertainty in temperature datasets[25]. The risk of exposure to extreme heat was determined based on identifying heat stress events present within summer months (July, August, and September) for all CMP temperature monitoring stations (measured at ~5m water depth at low tide). For data-poor areas, additional "stations" were added to the dataset by drawing from multiple years of Sea Surface Data. For each species[26], a heat stress event was defined as:

- Salmon: 24 hours following a temperature observation ≥ 18°C (Dempsey et al., 2023)
- Trout: 24 hours following a temperature observation ≥ 20°C (Currie et al., 2000; Jiang et al., 2021; Li et al., 2022)
- Mussels: Temperatures were at or above 25°C, for 5 or more consecutive days (Clarke et al., Under Review,)

The likelihood of heat stress (0-1) was then calculated based on the total number of days within a heat stress event period over all potential heat stress days available for that station[27]. Likelihood values from point locations were then interpolated spatially to achieve coverage across the entire AOA. Risk ratings were then determined based on annual likelihood, such that:

- **Low risk:** Heat stress events seldom occur (< 0.25 likelihood), minimizing the need for intervention, making it easier to maintain growth and welfare.

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[25] Derived data products have some inherent uncertainty due to limitations in original data sources as well as assumptions made during processing. Risk ratings and likelihood calculations were based on interpolated values from point data, which may be poorly represented in some areas due to lack of full province coverage of CMP data points. Furthermore, temperature has inherent natural variability at local scales which may not accurately be reflected through interpolated models.

[26] Defined differently for each species, as species have different thermal tolerances

[27] This approach only considers the total number of heat stress days and does not account for the differing welfare impacts of prolonged versus short-duration heat stress events.

- **Medium risk:** Heat stress events may be a regular occurrence (0.25 – 0.75 likelihood) but may not be widespread or persistent. While still potentially impactful, these conditions are likely more manageable with proper planning and existing mitigation strategies.
- **High risk:** Summer temperatures regularly and consistently reach stressful conditions for species beyond their preferred range (likelihood above 0.75). Management of prolonged or chronic heat stress may require long-term adaptation strategies, such as technological advancements or selective breeding (Calado et al., 2021).

This approach was taken for the entire AOA, except within the Bras d'Or area. The Bras d'Or is a highly complex environmental area where temperature profiles have significant spatial variability across its diverse subregions. In the Bras d'Or, reliable high-resolution temperature data across all subregions is not available to appropriately capture temperature dynamics in this area. The entire region[28] was given a risk rating based on relevant data specific to each species[29] and considering the need for further evaluation to understand specific risks within the area.

Scoring: As the definition of heat stress events was defined for each species, the risk of extreme heat exposure can be scored similarly for all species.

Scoring			
Type	**"Limited"**	**"Moderate"**	**"Good"**
Salmon	High risk	Medium risk	Low risk
Trout	High risk	Medium risk	Low risk
Mussels	High risk	Medium risk	Low risk
Oysters	N/A	N/A	N/A

Rationale for Scoring: The marine-based aquaculture industry has limited capacity to influence water temperatures, and mitigation measures, such as supplemental oxygenation, modified feeding, providing deeper nets (or sinking gear), and ensuring nets have been cleaned (increasing water flow through the cage), may not always be effective (Sajid et al., 2024). As such, it is recommended that producers avoid sites with high likelihoods of encountering heat stress conditions.

Areas with **high risk** to heat exposure are rated as **"limited"** potential for aquaculture development due to the significant risks posed to the health and welfare of cultured species, as well as the limited capacity to mitigate these impacts effectively over time without significant effort and financial investments (Gamperl et al., 2020; Beemelmanns et al., 2021; Jiang et al., 2021). **Medium risk** areas are scored as **"moderate"** potential as conditions potentially present fewer and less severe risks to aquaculture compared to higher-stress areas. Areas of **low risk** are **"good"** for aquaculture potential, as temperature conditions pose significantly less heat-related risks.

[28] The Bras d'Or region was delineated based on aquaculture regions boundaries outlined in Stantec (2009).
[29] For example, current temperature data (from CMP and SST datasets) indicates currently no areas in the province likely to be exposed to heat stress for mussels. There is no evidence to suggest the Bras d'Or is at any higher risk. In this case, the Bras d'Or was rated as "low risk".

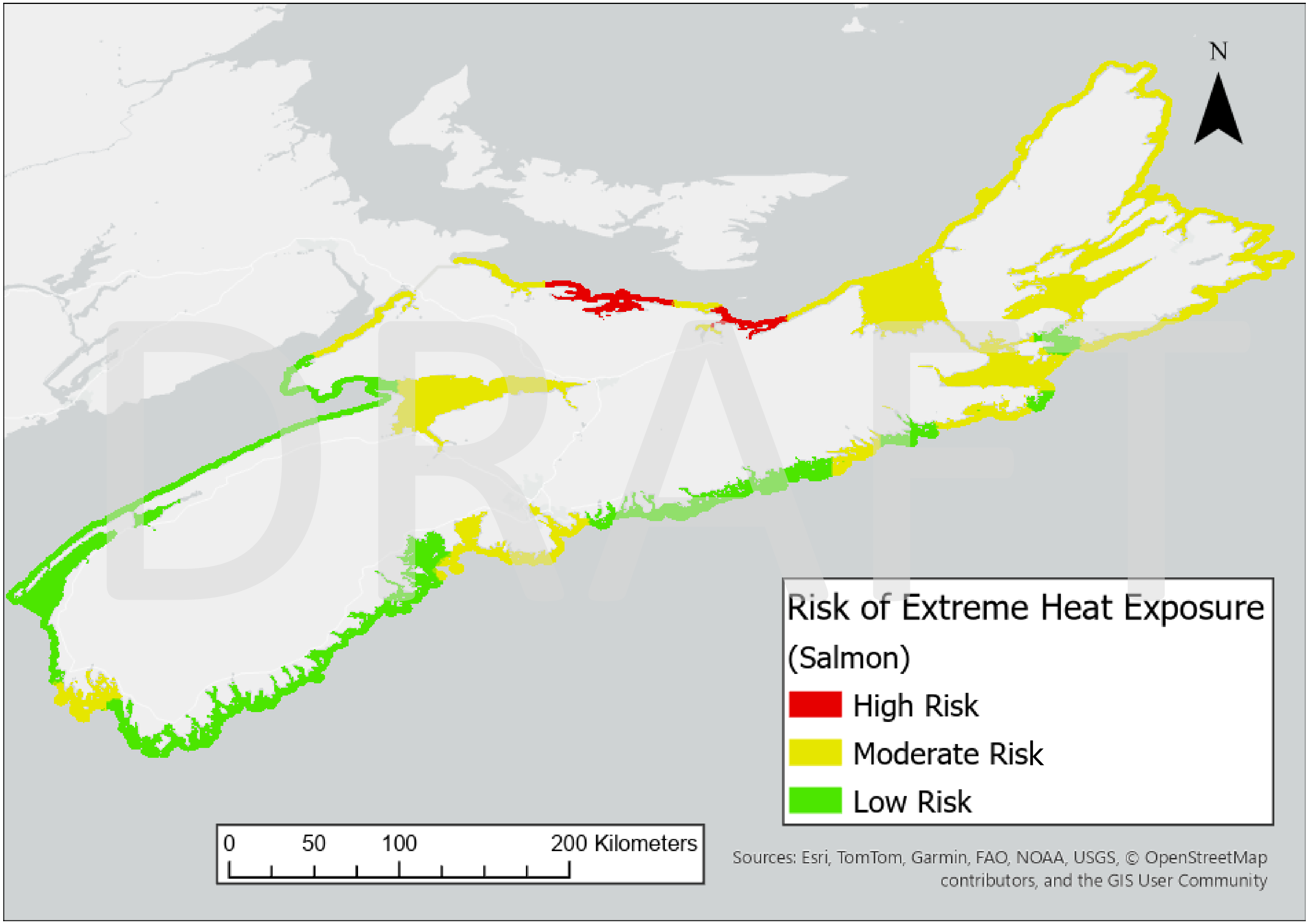

Figure A2. Distribution of exposure to extreme heat risk across the area of assessment (AOA) for salmon.

Bathymetry

Importance: Water depth is an important consideration for aquaculture, as it acts as a compounding factor, and influences oxygen availability, temperature stability, and water flow which can influence the health and welfare of cultured species.

Data Source: Bathymetric data was obtained from the General Bathymetric Chart of the Oceans (GEBCO) and the Canadian Hydrographic Service Non-Navigational (NONNA) Bathymetric Data.

Data Description and Processing: GEBCO's global gridded bathymetric data measures the underwater topography and water depth of the seabed at 15 arc-second intervals (~300m resolution). NONNA data provides high-resolution water depths at 10 m resolutions. Tidal variations are not captured by either data source.

An updated bathymetry (in meters below sea level at low tide) spatial layer (**Figure A3**) was developed for this assessment by combining GEBCO and NONNA-10m datasets. The NONNA-10m bathymetry dataset served as the primary source of data within the AOA. Areas with missing data, amounting to 5% of the study area, were filled using bathymetry from the GEBCO world dataset. Inverse path distance weighting (IPDW) interpolation[30] was then applied to create a continuous, smooth surface, resulting in a final grid resolution of 10 m by 10 m.

Scoring: The effects of depth (and their interactions with other biophysical criteria) on the health, welfare, and infrastructural needs of both Atlantic salmon and trout aquaculture are similar. As such, the same scoring was applied to both finfish species.

Scoring			
Type	**"Limited"**	**"Moderate"**	**"Good"**
Salmon	<10 m	N/A	>10 m
Trout	<10 m	N/A	>10 m
Mussels	<5 m	N/A	>5 m
Oysters	<2 m	N/A	>2 m

Rationale for Scoring: No 'moderate' depths were proposed for any of the species, as the primary considerations for potential 'moderate' depths were largely related to cost and infrastructure requirements[31] or were more closely related to consideration with exposure, which are considered within other criteria. While there may be additional variability in suitability beyond the depth thresholds presented here, these are best captured in site-level or bay-level assessments.

[30] The IPDW method, an extension of inverse distance weighting (IDW), was chosen as it is a well-known and relatively simple, deterministic spatial interpolation method. This extension modifies the IDW method, which is typically unsuitable for coastal applications due to its inability to differentiate between land and water, by incorporating land as a barrier (i.e., making the cost of travelling over land is prohibitive), thus making it suitable for coastal applications.

[31] Which are factors considered beyond the scope of this assessment.

Salmon and Trout

In Nova Scotia, most finfish producers operate with net depths of 8 to 10 m, (Brewer-Dalton et al., 2015) but require water depths of at least 7 m to accommodate sub-surface netting (Stantec, 2009). Producers must also consider depth-related risks to fish health and welfare. As coastal waters frequently stratify, siting farms in shallow depths may limit fish access to deeper, more temperature-stable waters (LGL Limited 2019, Warren-Myers et al. 2022, Sajid et al. 2024), reducing the ability of fish to avoid potentially harmful surface water temperatures in both summer (Remen et al. 2016, Wade et al. 2019) and winter (Bui et al. 2020, Warren-Myers et al. 2022). Depth is also often positively correlated with water flow, which is important for the thermal regulation of finfish, especially in stratified conditions (Oppedal et al., 2011). Additionally, shallow depths can hinder organic matter dispersal, potentially increasing waste accumulation near cages and negatively impacting benthic environments, local water quality, and fish welfare (Holmer and Kristensen 1992, Hargrave 1994, Holmer et al. 2005). Consequently, finfish aquaculture generally requires a minimum depth of 10 meters to reduce health and welfare risks and accommodate gear. As such **depths below 10 meters** are considered **"limited"**, while conditions **beyond 10 metres,** can be considered **"good"** for finfish aquaculture.

Mussels

Mussel longlines typically range in length from 1 to 3 meters (Drapeau et al., 2006); yet, depth considerations also include risks to mussel health and welfare. At shallow depths, producers may have limited abilities to lower gear potentially increasing exposure to elevated surface temperatures and ice-related risks. Shallow depths also raise the risk of longlines contacting the seabed, which may heighten starfish predation (Fisheries and Oceans Canada, 2003; Minnhagen et al., 2019). Furthermore, bio-deposition, which can negatively affect benthic environments and water quality, is heavily influenced by hydrodynamic conditions and depth, with shallow areas at greater risk of accumulation and adverse effect (Chamberlain et al., 2001; Hartstein and Stevens, 2005; Barnes, 2006). Consequently, a minimum depth of 5 meters may reduce health and welfare risks and accommodate longlines, beyond which can be considered **"good"** for mussel aquaculture. As such **depths below 5 meters** are considered **"limited".**

Oysters

Suspended oyster culture can operate in very shallow waters, yet might be exposed to depth-related risks to oyster health and welfare. In shallow waters, oysters are more vulnerable to temperature fluctuations and exposure to air during hot summer months, which can lead to mortality (Clements et al., 2018). Additionally, shallow depths limit producers' ability to sink gear effectively[32], increasing the risk of ice-related harm. Consequently, a minimum depth of 2 meters is typically necessary to reduce welfare risks. As such, **depths below 2 meters** are considered **"limited"**, while conditions **beyond 2 metres** can be considered **"good"** for oyster aquaculture.

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[32] A minimum of 2 meters depth is generally required for effective gear sinking (Fiendel, 2020).

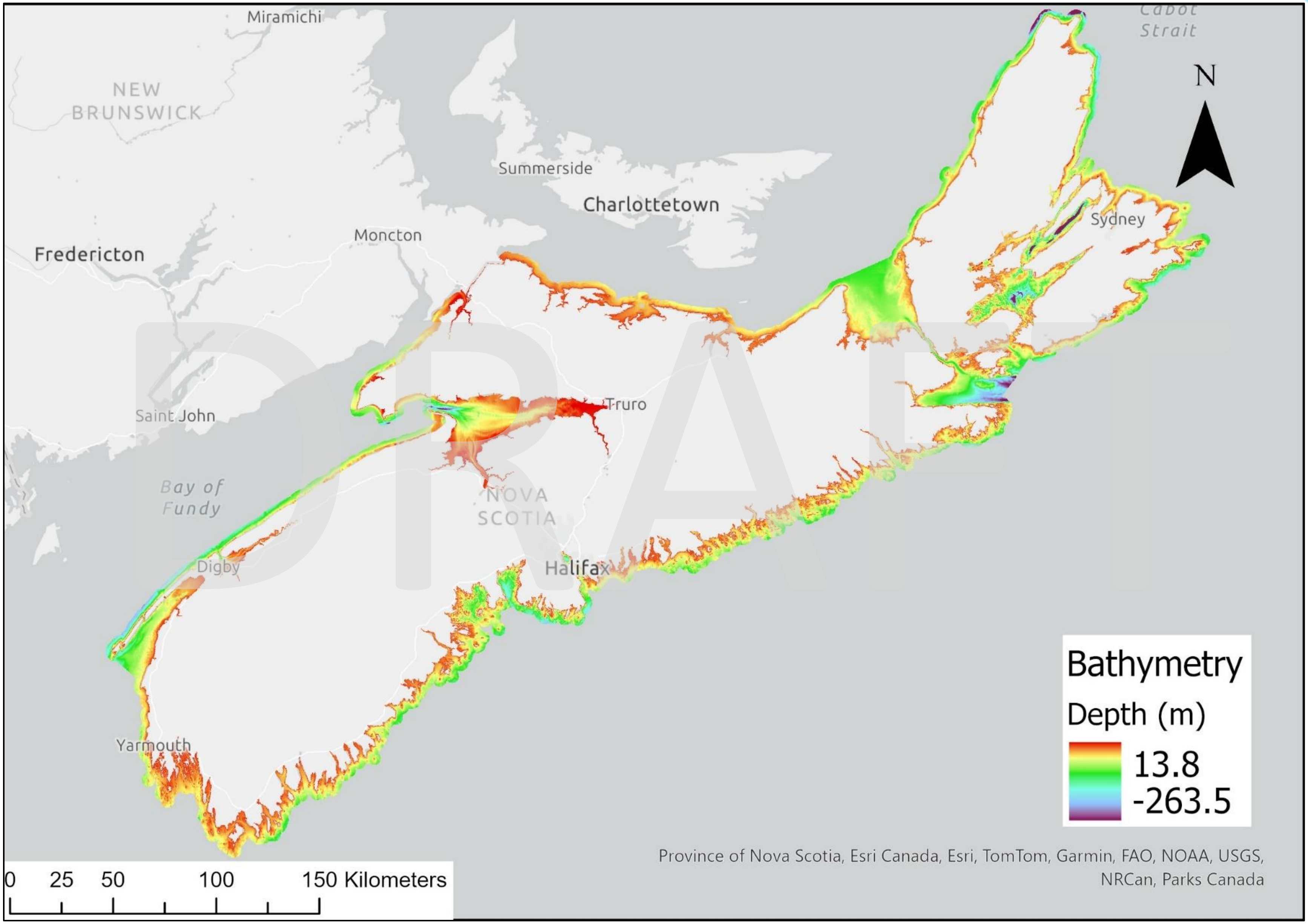

Figure A3. Water depth (at low tide) in metres below sea level (negative values) across the area of assessment (AOA).

Ice Conditions

Importance: Risks from sea ice, particularly from drift ice[33], can threaten infrastructure and affect aquatic animal health and welfare in aquaculture. Damage and/or failure of cage infrastructure can result in economic losses for producers or accidental escape of farmed fish into the marine environment. For shellfish, ice can scour equipment and crush the animals, leading to mechanical damage and mortality of shellfish.

Data Source: Sea ice data was retrieved from the International Ice Charting Working Group for the World Meteorological Organization as vectorized Sea Ice Grid (SIGRID-3) layers representing Canadian Ice Service weekly maps from 2006 to 2023. Data was acquired and processed by the Nova Scotia Community College's Applied Geomatics Research Group (NSCC-AGRG).

Data Description and Processing: Total observations of drift ice were compiled through historical sea ice charts and derived data (compiled by NSCC-AGRG) across the AOA. A total of 394 weekly ice charts were compiled and extracted onto a 100 m x 100 m grid to identify ice observations within the last 10-years (2014-2024). Due to missing spatial coverage of original datasets (e.g. original sea ice charts), the ice observation dataset was interpolated into select nearshore areas to ensure complete coverage of ice frequency across the AOA. Ice frequency data was then reclassified to identify "low ice" (0-2 observations), "medium ice" (2-28), and "high ice" (28-162) areas (**Figure A4**). To inform shellfish risk ratings, the maximum ice thickness[34] of drift ice across the AOA was extracted.

Ice exposure risk was calculated for each species, based on the type and considerations for ice risks. For salmon and trout, risk ratings were assigned based on frequency distribution of ice classes to account for risks due to present by all types of drift ice[35]. To assign risk for oysters and mussels, we considered: a) the frequency of drift ice, b) whether there is sufficient bathymetry in the area to avoid the thickest[36] ice, based on species-specific culture practices[37], and c) whether the area may be 'sheltered'[38] from drift ice intrusion. For each species, the ice exposure risk was then categorized into "high risk", "medium risk", and "low risk" classes.

Scoring: Scoring was based on generalized exposure to drift ice and the increased risk and need for mitigation and management in ice-prone areas. As species-specific considerations for risks

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[33] Drift ice (or pack ice) is mobile and drifting, and can be distinguished from fast ice which remains fixed to the coast (Fisheries and Oceans Canada, 2022)
[34] As a proxy for keel depth (i.e., the depth of ice below the water's surface) during ice break up.
[35] All types of drift ice were considered, as any thickness of drift ice poses a risk to surface-based aquaculture gear.
[36] Here, the maximum ice thickness is used as a precautionary proxy to account for 'worst-case' conditions, recognizing there is likely spatial and temporal variability in what a specific area may experience.
[37] A minimum water depth of 3 m for mussels and 1 m for oysters was determined to be required below ice to effectively sink gear.
[38] In highly sheltered bays, surrounding land masses may prevent drift ice from entering the bay, reducing potential exposure to drift ice.

from ice are considered in how the ice risk was calculated, the proposed scoring for suitability assessment applies to all species.

Scoring			
Type	**"Limited"**	**"Moderate"**	**"Good"**
Salmon	High	Medium	Low
Trout	High	Medium	Low
Mussels	High	Medium	Low
Oysters	High	Medium	Low

Rationale for Scoring: Scoring drift ice frequency into suitability classifications is proposed based on the classification of ice exposure risk specific to each species assessment. In general, we assume higher ice exposure areas may produce greater risks for producers and require additional mitigation strategies, ultimately being more limiting for aquaculture.

For shellfish, moving ice can scour equipment and crush animals, leading to mechanical damage and mortality of shellfish. In addition, mussels exposed to ice-cover have been shown to display signs of nutritional stress and reduced respiration rates (Hatcher et al., 1997). Ice can damage cages through accumulation on structures, collisions, or ice flow impingement; all of which can reduce the structural stability of cage systems, leading to deformation, shifting, or even collapse (Marsden, 2021; Sun et al., 2024). These impacts are of particular concern as cage damage or deformation can negatively impact the health and welfare of cultured species through injuries and increased stress (Jensen et al., 2010; Sun et al., 2024). Additionally, if damage is severe enough there is also the risk of fish escapes (Getchis et al., 2015; Sun et al., 2024). In areas where drift ice can be expected to occur, producers must be well-prepared.

High-risk areas are those where drift ice occurs regularly and persistently, or in the case of shellfish (mussels and oysters) aquaculture, where bathymetry is also within depths where aquaculture would be exposed to drift ice scouring potential equipment. As such, these areas are at the highest risk from ice-related impacts on aquaculture and animal health and are scored as **"limited"**.

Medium-risk areas are those where drift ice occurs very infrequently but has been observed on occasion within the last 10 years. In the case of shellfish, these areas have moderate drift ice frequency and bathymetry within ranges where drift ice could impact animals. In these areas, producers would need to be aware of and monitor risks, though ice will not be a regular occurrence. As such, these areas would be **"moderate**" for aquaculture development.

Low-risk areas for finfish (salmon and trout) are identified where drift ice is rare (low ice frequency). In the case of shellfish (oysters and mussels), this may occur when either a) shellfish may be exposed due to bathymetry but are in low ice areas, or b) where bathymetry is sufficient to avoid risks posed by thick drifting ice (even in high ice areas). As risks are expected to be minimal, these areas are thus scored as **"good"** suitability for aquaculture.

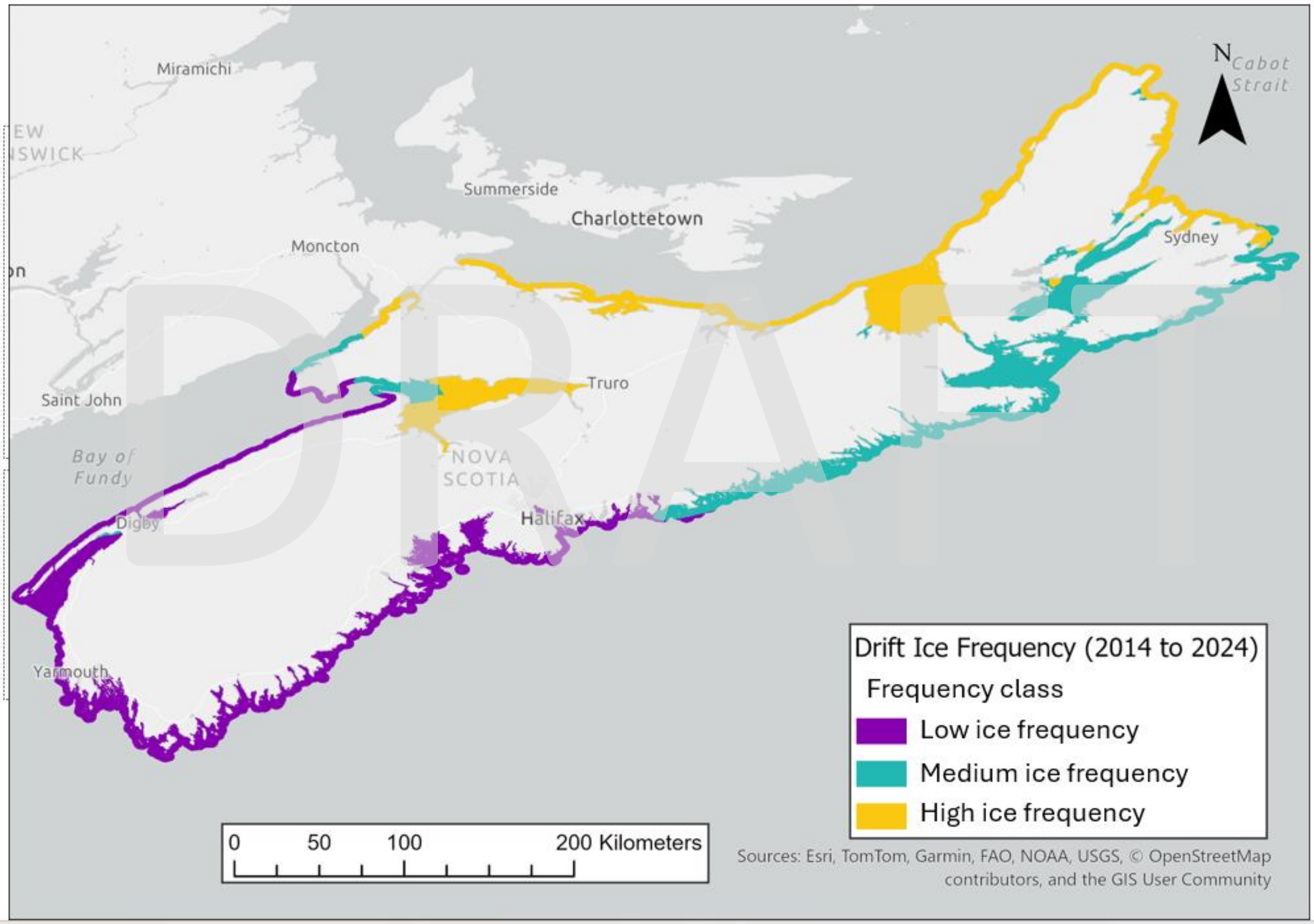

Figure A4. Drift ice frequency classes based on observations of drift ice between 2014 and 2024 in Atlantic Canada.

Wind and wave conditions

Importance: Understanding how 'exposed' an existing or potential site is to waves and wind is important, as strong waves can create stress for aquatic animals, disrupt feeding or behaviour of animals, and influence water quality (Johannesen et al., 2020; Johannesen et al., 2022). For finfish, exposure can damage cages and lead to fish escapes (Dempster et al., 2018). For shellfish aquaculture, exposure can negatively affect shellfish growth, as strong wave movements can affect shellfish feeding or lead to shell damage (Campbell and Hall, 2019). Exposure to strong wind and waves may also exert excess stress on aquaculture systems (i.e., cages, long lines, etc.). This excess stress can potentially result in damage to the system, escapes of cultured organisms, and health and safety risks for employees (Brister and Kapuscinski, 2000). As such, it is crucial to consider wind and wave exposure conditions at potential sites as these environmental factors directly impact engineering and design requirements and investment needed.

Data Source: Wind and wave exposure data was obtained from the Nova Scotia Wind-generated Wave Exposure Atlas produced by DSA Ocean for CMAR.

Data Description and Processing: The wave exposure levels were evaluated based on 10-year maximum significant wave heights (m) calculated from wind speeds (obtained from an ECMWF ERA5 dataset)[39]. Wave exposure was modelled for coastal waters up to 5 km off Nova Scotia and mapped at a 25 m resolution. The wave exposure dataset was updated to include the most recent data, representing 10-yr significant wave heights[40] based on data from 2013-2023 and expanded to include all areas within our AOA (**Figure A5**).

The 10-year maximum significant wave heights (m) identified serve as a proxy to understand wind and wave exposure at this scale of assessment. While not representative of daily conditions these wave heights provide an estimate of the highest wave heights producers may encounter under relatively normal conditions. There are many other exposure-relevant considerations, such as swell, fetch, and depth, that are not included, as they require more fine-scale hydrodynamic modelling that is not available at this scale. Additionally, storm events are not considered, as their intensity, frequency, and location are unpredictable.

Scoring: Different scores were proposed for finfish and shellfish due to varying impacts on animal health and welfare and different exposure impacts on infrastructure. At a species-level, impacts are similar within finfish and shellfish species, meaning that salmon and trout are scored similarly, as are oysters and mussels.

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[39] The influence of ocean swell is not considered in this model, but swell information was used to help validate the model (using MSC 50 wave hindcast model in select areas).

[40] 10-year significant wave heights are defined as the average height of the highest one-third of all waves that occur within a 10-year period.

Scoring			
Type	**"Limited"**	**"Moderate"**	**"Good"**
Salmon	> 5.5 m	4 – 5.5 m	< 4 m
Trout	> 5.5 m	4 – 5.5 m	< 4 m
Mussels	> 3 m	2 - 3 m	< 2 m
Oysters	> 3 m	2 - 3 m	< 2 m

Rationale for Scoring:

Scoring was generally guided by considerations that increased significant wave heights can be associated with increased risk of exposure-induced stress, physical injuries, and potential for infrastructure damage. While Nova Scotia's leasing regulations do not provide specific guidance regarding appropriate levels of wind and wave exposure, the Norwegian government has developed a classification system for aquaculture sites based on significant wave height, categorizing the degree of exposure as medium (1–2 m), high (2 –3 m), and extreme (>3 m) (Ryan, 2004; Wang et al., 2023).

<u>Salmon and trout</u>

Exposure to strong wind and waves may exert excess stress on aquaculture systems, potentially resulting in infrastructure damage, escapes of cultured organisms, and health and safety risks for employees (Brister and Kapuscinski, 2000). There is no universal 'safe' maximum significant wave heights for marine aquaculture cages, although some studies suggest that damage and deformation may occur when maximum significant wave heights reach 5.5 meters or more (Zhang et al., 2024). Beyond gear-related risks, producers must consider exposure-related risks to fish health and welfare. Strong waves can deform cages, decreasing the space available to the fish (Johannesen et al., 2022). Additionally, it has been suggested that increased wave exposure may act as a chronic stressor, contributing to the accumulation of allostatic load in farmed fish and increased mortality (Davis, 2010; Szewczyk et al., 2024). For example, turbulent and chaotic water conditions created by waves near the surface may force collisions between animals or between an animal and the net (Johannesen et al., 2020; Barbier et al., 2024), potentially leading to physical injuries. These turbulent conditions could also impact appetite and feeding (Barbier et al., 2024). Wave-related welfare impacts may be intensified in more exposed or offshore conditions (i.e., areas with significant wave heights of ≥5 m) than in coastal environments (i.e., areas with significant wave heights ≤4 m) (Bridger et al., 2015; Morro et al., 2021). As such, **significant wave heights below 4 meters** are considered **"good"** for finfish aquaculture development as they represent lower welfare and infrastructural risks. **Significant wave heights exceeding 5.5 meters** are considered **"limited"** due to the increased health and welfare risks and the potential for infrastructure damage or deformation. Significant wave heights between 4 and 5.5 meters still present potential challenges that require management and careful planning, however, infrastructure is expected to withstand these wave heights and conditions potentially present fewer and less severe risks to health and welfare (Karathanasi et al., 2022). As such, areas with

significant wave heights between 4 and 5.5 meters are scored as having **“moderate”** suitability for salmon and trout aquaculture.

Mussels and oysters

Exposure to strong wind and waves may result in damage to shellfish culture systems and health and safety risks for employees (Brister and Kapuscinski, 2000). Beyond gear-related risks, producers must consider exposure-related risks to the cultured species' health and welfare. Strong waves can contribute to turbulent conditions that may dislodge shellfish from substratum (Baltic Blue Growth project, 2019), reduce feeding efficiency, and cause shellfish to collide with each other or with rearing infrastructure (i.e., cages) potentially leading to damage of shells, poor growth, and reduced harvests (Cranford et al., 2011; Campbell and Hall, 2019). The risks posed by exposure to strong waves are further supported by Wang et al. (2023), who investigated the effects of current and wave exposure on longline shellfish culture systems and found that welfare declines began at significant wave heights of 2 meters. Given the risk to cultured species' health and welfare and the existing guidance provided by the Norwegian exposure classification system, **significant wave heights exceeding 3 meters** are considered **“limited”**, while **significant wave heights less than 2 meters** can be considered **"good"** for shellfish aquaculture While significant wave heights of 2 to 3 meters pose some risk to producers and cultured species’ health and welfare, this risk is likely able to be managed during operation and through proper planning and mitigation measures, such as allowing for slack in suspended lines[41]. As such, areas with **significant wave heights of 2 to 3 meters** are scored as **“moderate”** suitability for shellfish aquaculture.

[41] Slack reduces the force experienced on the lines and anchors, reducing the risk of losing gear.

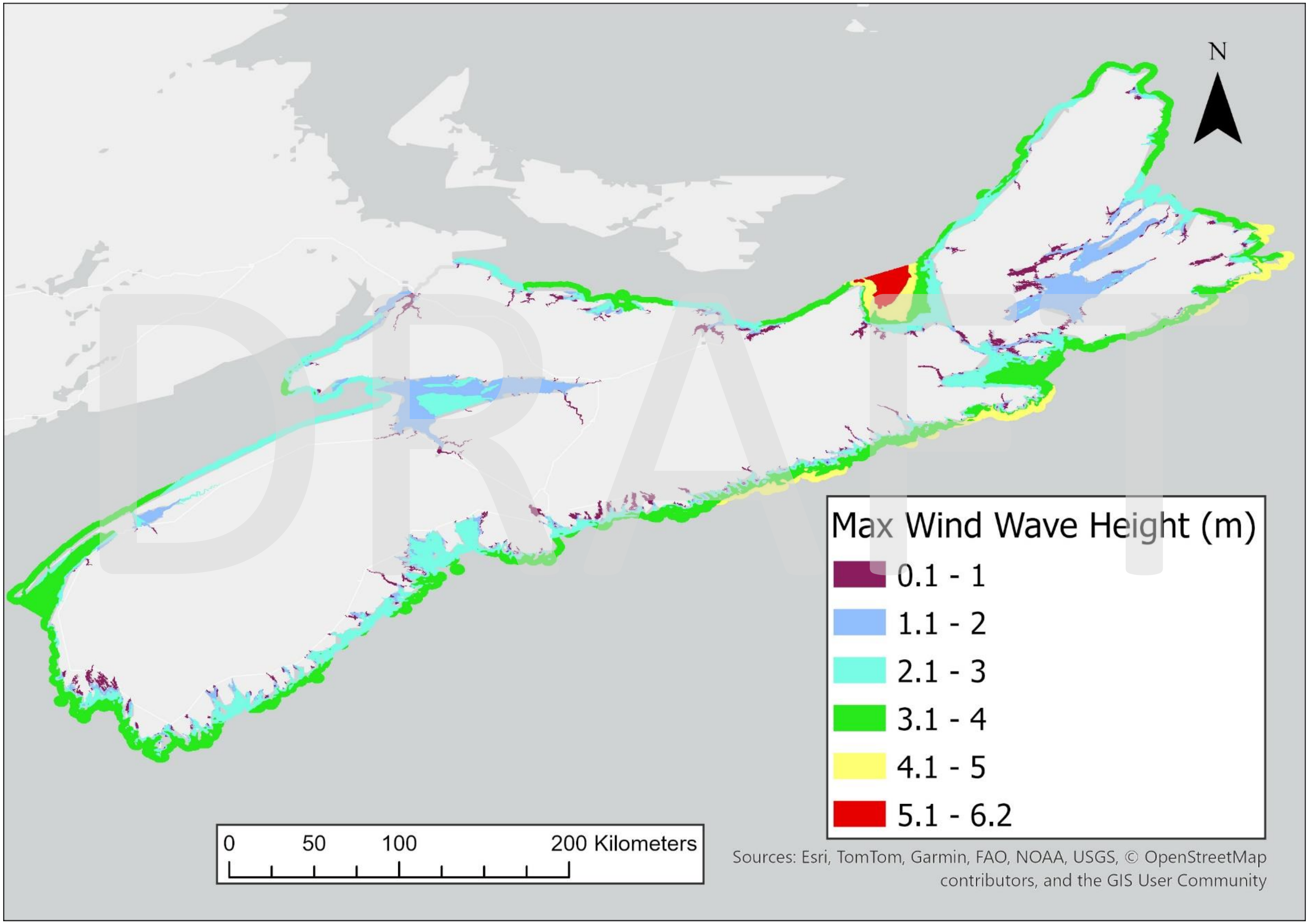

Figure A5. Maximum significant wave height (m) across the area of assessment (AOA).

Critical habitat for Species at Risk

Importance: Under the *Species at Risk Act* (SARA), critical habitat is defined as "the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or action plan for the species", making them crucial in supporting conservation efforts (Canadian Wildlife Service, 2016). Marine species listed as threatened or endangered under SARA have critical habitats identified and are legally protected from activities that could impact said habitat.

Data Source: Data on defined critical habitats within the marine environment were retrieved from the Open Government Data Portal and includes: Critical Habitat for Aquatic Species at Risk - Canada, and Critical Habitat for Species at Risk National Dataset - Canada.

Data Description and Processing: SARA critical habitat areas are defined by relevant authoritative bodies including DFO, Environment and Climate Change Canada (ECCC), and Canadian Wildlife Services (CWS) (**Figure A6**). Critical habitats with areas in the marine environment were extracted[42] across the AOA, which included some marine areas for migratory birds. This layer does not include SAR distribution ranges. Areas identified as critical habitat were reclassified as "present", and any area beyond the habitat boundaries was reclassified as "absent".

Scoring: Since the implications and requirements for operating in these areas are similar across all types of aquaculture, the criterion can be scored uniformly for all species.

Scoring			
Type	**"Limited"**	**"Moderate"**	**"Good"**
Salmon	N/A	Present	Absent
Trout	N/A	Present	Absent
Mussels	N/A	Present	Absent
Oysters	N/A	Present	Absent

Rationale for Scoring: Critical habitats for species at risk (SAR) are legally protected under *SARA*, which restricts activities that could lead to habitat destruction. Aquaculture may not necessarily create negative impacts on protected species or lead to habitat destruction, and any interactions are highly location and species-specific. However, there is evidence that negative interactions are possible. For example, marine aquaculture can introduce risks to nearby bird populations through exclusion from critical habitats, altered prey availability, and benthic disturbances that increase turbidity and reduce foraging success (Sagar, 2013; Bath et al., 2023). As such, within areas containing critical habitat for species at risk, additional assessment and consideration would be needed to understand potential risks for negative interactions between aquaculture operations and protected species. Therefore, these areas are rated as **"moderate"** suitability for aquaculture. In areas where **critical habitats for SAR are absent,** conditions can be considered "**good**" for aquaculture as potential risks to critical habitats and species at risk are expected to be low.

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[42] Included areas within 100m from the coastline, but excluded critical habitats meant to identify freshwater or inland aquatic critical habitats, such as those for wild Atlantic salmon.

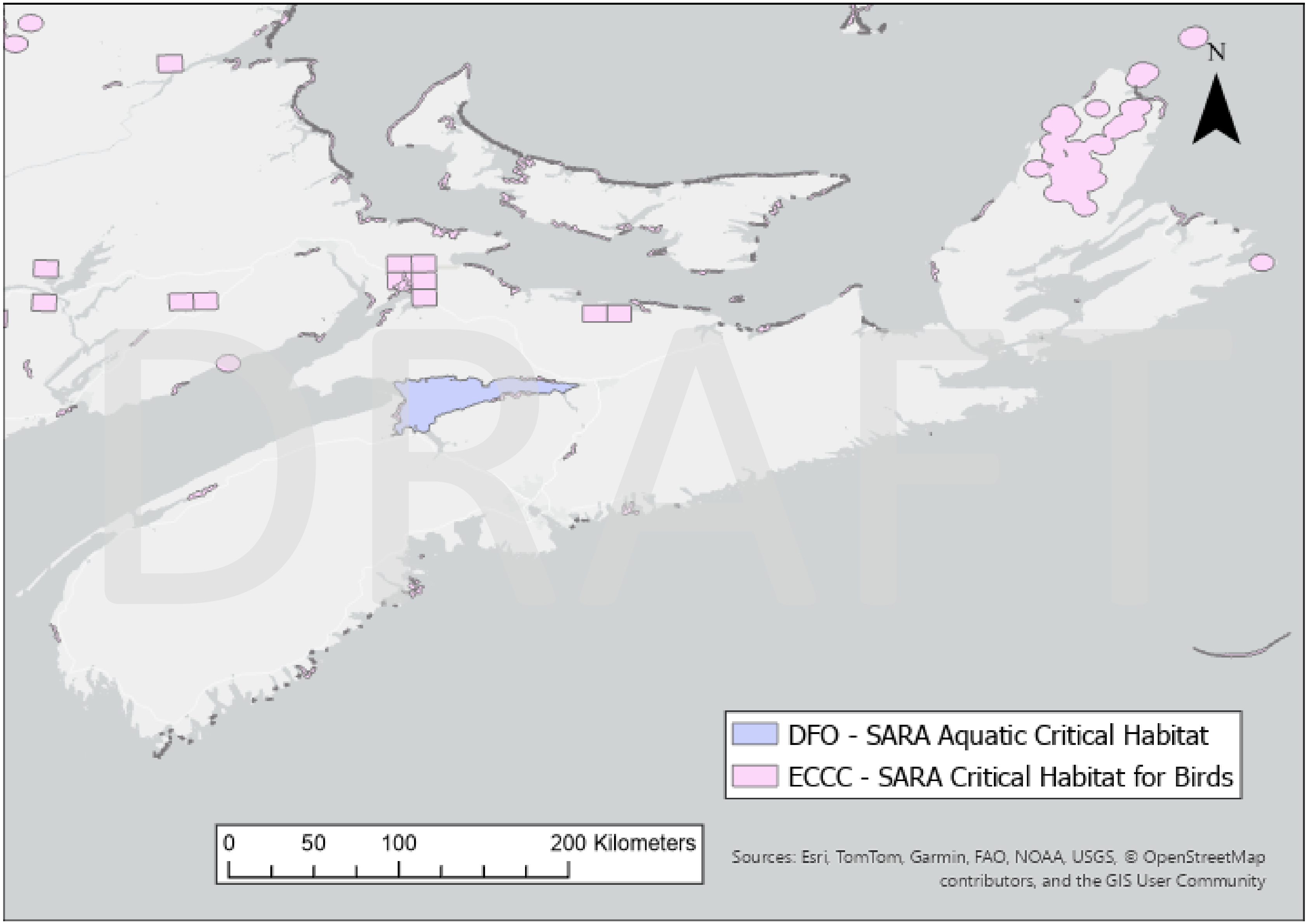

Figure A6. Areas designated as Critical Habitat for Species at Risk within Nova Scotia's coastal waters.

Marine protected and conserved areas

Importance: Protected and conserved areas encompass protected areas as defined by the International Union for Conservation of Nature (IUCN), as "a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values". As such, these areas are an important consideration in aquaculture suitability assessments[43]. and to acknowledge the conservation objectives relevant to aquaculture planning in Nova Scotia.

Data Source: Marine protected and conserved areas were identified through the Canadian Protected and Conserved Areas Database (CPCAD) and through data provided by the Nova Scotia Department of Natural Resources (DNR).

Data Description and Processing: The CPCAD consists of the most up-to-date spatial data on marine and terrestrial protected areas compiled and managed by Environment and Climate Change Canada (ECCC), in collaboration with federal, provincial, territorial, and other reporting authorities that provide the data. The presence of a marine protected and conserved area was identified by extracting any protected area with boundaries within the marine environment, and within our AOA[44]. Within the AOA, protected and conserved areas included those designated as National Wildlife Areas (NWAs), Migratory Bird Sanctuaries (MBS), and *Oceans Act*'s Marine Protected Areas (MPAs)[45] (**Figure A7**). The dataset also includes Other Effective Area-based Conservation Measures (OECMs) across the country, but these were excluded as they are designed to provide highly specified protections and restrictions[46]. Provincial Wildlife Management Areas and Protected Beaches (DNR) with boundaries within marine waters are also included[47]. Areas identified as protected or conserved were reclassified as "present" and any area beyond the protected area boundaries was reclassified as "absent".

Scoring: Potential risks to species and habitats within marine protected and conserved areas from aquaculture differ between finfish (salmon and trout) and shellfish (mussels and oysters) culture, resulting in different scores between these broad types.

Scoring			
Type	**"Limited"**	**"Moderate"**	**"Good"**
Salmon	Present	N/A	Absent
Trout	Present	N/A	Absent
Mussels	N/A	Present	Absent
Oysters	N/A	Present	Absent

[43] Protected and conserved areas are commonly considered a constraint in most aquaculture suitability assessments (e.g.,(Morris et al., 2021); Petrosillo et al., 2023; Porporato et al., 2020; Ross et al., 2020; Silva et al., 2011; Vianna & Filho, 2018), with the exclusion of aquaculture (specifically finfish) being recommended by international conservation groups (e.g., CPAWS) and incorporated in certification standards (e.g., ASC).
[44] As the database also includes terrestrial protected areas
[45] Although all existing *Oceans Act*'s Marine Protected Areas in Nova Scotia are in waters offshore, beyond the AOA.
[46] Currently in Nova Scotia, none of the OECM restrictions apply to aquaculture.
[47] The data is currently being processed and explored and is not displayed in Figure 12.

Rationale for Scoring: Areas containing marine protected and conserved areas, which may present potential risks for negative interactions between aquaculture operations and protected species or habitats, require additional evaluation, attention, and mitigation based on regulatory standards and policies specific to each protected area. Other regulations may have preclusions for aquaculture or restrictions determining the activities allowed in designated areas.

Salmon and Trout

In MPAs, aquaculture is not explicitly prohibited; however, the *Marine Protected Areas (MPA) Protection Standards* prohibit activities that pose risks to achieving their conservation objectives, including dumping, depositing, or discharging any substance that could harm organisms or habitats. Finfish aquaculture may introduce waste, feed, and chemicals (i.e., pesticides and drugs) that may meet the definition of "deleterious substances"[48]. Furthermore, finfish aquaculture would be unlikely to be permitted within NWAs, as *Wildlife Area Regulations* permits other activities only if there is a benefit to the conservation of wildlife within an NWA. Likewise, aquaculture within an MBS would require a permit or would have to implement mitigation to ensure no disturbance[49]. As such, areas where **marine protected and conserved areas are present** are rated as **"limited"** potential for finfish aquaculture due to legal restrictions and the critical importance of these areas. In areas where **marine protected and conserved areas are absent,** conditions can be considered **"good"** for finfish aquaculture.

Mussels and Oysters

Shellfish farming, including mussels and oysters, is a less intensive practice, as it does not require external inputs such as feed or other deleterious substances that could potentially be prohibited under MPA regulations. Furthermore, shellfish aquaculture can have positive environmental effects[50], promoting biodiversity when managed sustainably. As such, shellfish farming is likely more compatible with MPA conservation efforts however, it will still require additional evaluation and attention and may pose fewer risks to protected and conserved species and habitat. Obtaining approval to operate in these areas would still be assessed on a case-by-case basis, requiring additional effort to ensure farming practices align with the specific environmental and regulatory conditions of the protected area. As such, in **areas where marine protected and conserved areas are present,** conditions can be considered **"moderate"** for shellfish aquaculture. In areas where **marine protected and conserved areas are absent** conditions can be considered **"good"** for shellfish aquaculture.

[48] May not apply to all operations but would need to be evaluated in specific applications.

[49] Which would need to be carefully evaluated and further assessed during site-specific applications.

[50] Bivalves, like mussels and oysters, can serves as bio-filters, improving water quality, and can enhance the structure and function of faunal communities by creating structured habitats (Azra et al., 2021; Theuerkauf et al., 2021)

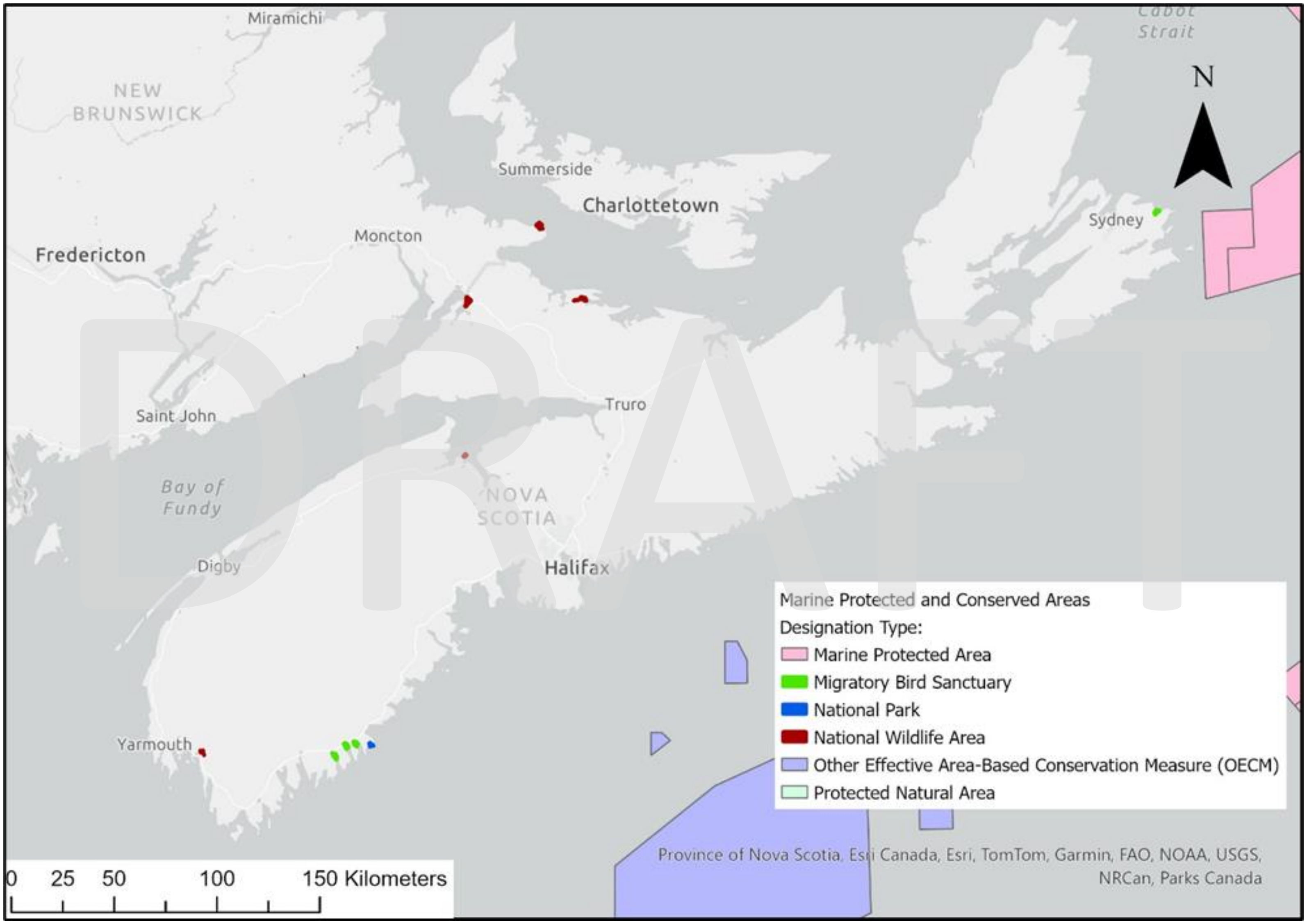

Figure A7. Location of marine protected and conserved areas within Nova Scotia. Note: Marine Protected Areas (MPAS) are shown on the map but do not intersect our area of assessment (AOA).

Automatic Identification System (AIS) vessel density patterns

Importance: Aquaculture activities in heavily navigated areas can increase the risk of maritime accidents (Yoo and Jeong, 2020; European Boating Association, 2021). Inadequate spacing between an aquaculture site and established shipping routes or navigable channels may lead to collisions between vessels and the aquaculture infrastructure (Du et al., 2024). Such spatial overlaps could result in damage to equipment, safety risks, operational disruption, and potential loss of stock, but also potentially increase liability risks for operators.

Data Source: Marine traffic data was obtained from Automatic Identification System (AIS) data collected by the Department of Fisheries and Oceans (DFO).

Data Description and Processing: Navigation routes were derived from track lines captured in AIS transponders for the years 2019 to 2021[51]. The AIS system consists of very high frequency (VHF) transponder units that automatically collect data on the location and characteristics of vessels and was initially developed to support maritime safety and promote ship collision avoidance. Under the *Navigation Safety Regulations (2020)*, vessels requiring AIS include those over 20 meters (excluding pleasure crafts), with a capacity of greater than 50 passengers, transporting dangerous goods or pollutants, posing a collision hazard (i.e., dredges), engaged in non-sheltered voyages, or towboats over 8 meters. AIS data can thus be used to identify routes used by commercial vessels and estimate patterns in navigation traffic[52]. To identify navigation routes that represent areas used most frequently by vessels to safely traverse waterways, the density of track lines was calculated across the AOA. Using a modified landform analysis tool within GIS, we created a layer showing whether areas within the AOA were within or near main navigation routes (**Figure A8**).

Scoring: Since the implications and requirements for operating in these areas are similar across all types of aquaculture, they can be scored uniformly for all species. Scoring is based on the intensity of navigation activity occurring in the area.

Scoring			
Type	**"Limited"**	**"Moderate"**	**"Good"**
Salmon	On-channel	Near-channel	Off-channel
Trout	On-channel	Near-channel	Off-channel
Mussels	On-channel	Near-channel	Off-channel
Oysters	On-channel	Near-channel	Off-channel

[51] For privacy and confidentiality purposes, all identifying information was removed from data. As such, we are unable to separate vessels by type or size.

[52] While some fishing vessels carry AIS systems, this is not required for all vessels.

Rationale for Scoring: Vessel traffic data from AIS is commonly used to identify and minimize potential navigation-related spatial overlaps among ocean industries/user groups (i.e., commercial shipping, fishing, recreation, etc.) and marine aquaculture[53], ensuring that vessel-related factors are properly incorporated into spatial analyses (Metcalfe et al., 2018; Tlusty et al., 2018; Jossart et al., 2020). This practice is particularly relevant for assessing aquaculture potential in Nova Scotia, where the public's right to navigable waters is protected under the *Canadian Navigable Waters Act* (CNWA) and is a key consideration in siting decisions under Nova Scotia's *Aquaculture License and Lease Regulations*. If aquaculture is proposed in navigable waters, operators must comply with the CNWA and apply for approval from Transport Canada to ensure that navigation rights are upheld, and safety concerns are adequately addressed.

On-channel areas represent main transportation and navigation corridors where data shows that navigation is most densely concentrated. In these areas, commercial vessel traffic can be expected and is likely a regular occurrence. Aquaculture within on-channel areas would have significantly increased risk of maritime accidents and associated safety, operational damage, containment management risks, or hinder other users' right to navigable waters, and thus represent **"limited"** potential for aquaculture development.

Near-channel areas represent waters positioned near densely navigated channels. These areas experience a fair amount of marine traffic and may act as thoroughfares to main navigation channels. As these areas reflect key areas for navigation and would likely meet conditions for being defined as 'navigable waters', near-channel areas reflect **"moderate"** potential for aquaculture as producers would still need to consider how operations influence navigational safety and overlaps with navigational users.

Off-channel areas represent waters that are not densely navigated and are thus scored as **"good"** for aquaculture development. With fewer navigation concerns, these areas offer a safer environment for aquaculture operations, reducing the potential for accidents or conflicts with other users' rights to navigable waters.

[53] To note, AIS is carried by some boats used in existing aquaculture, and so marine traffic channels may also identify traffic around existing sites.

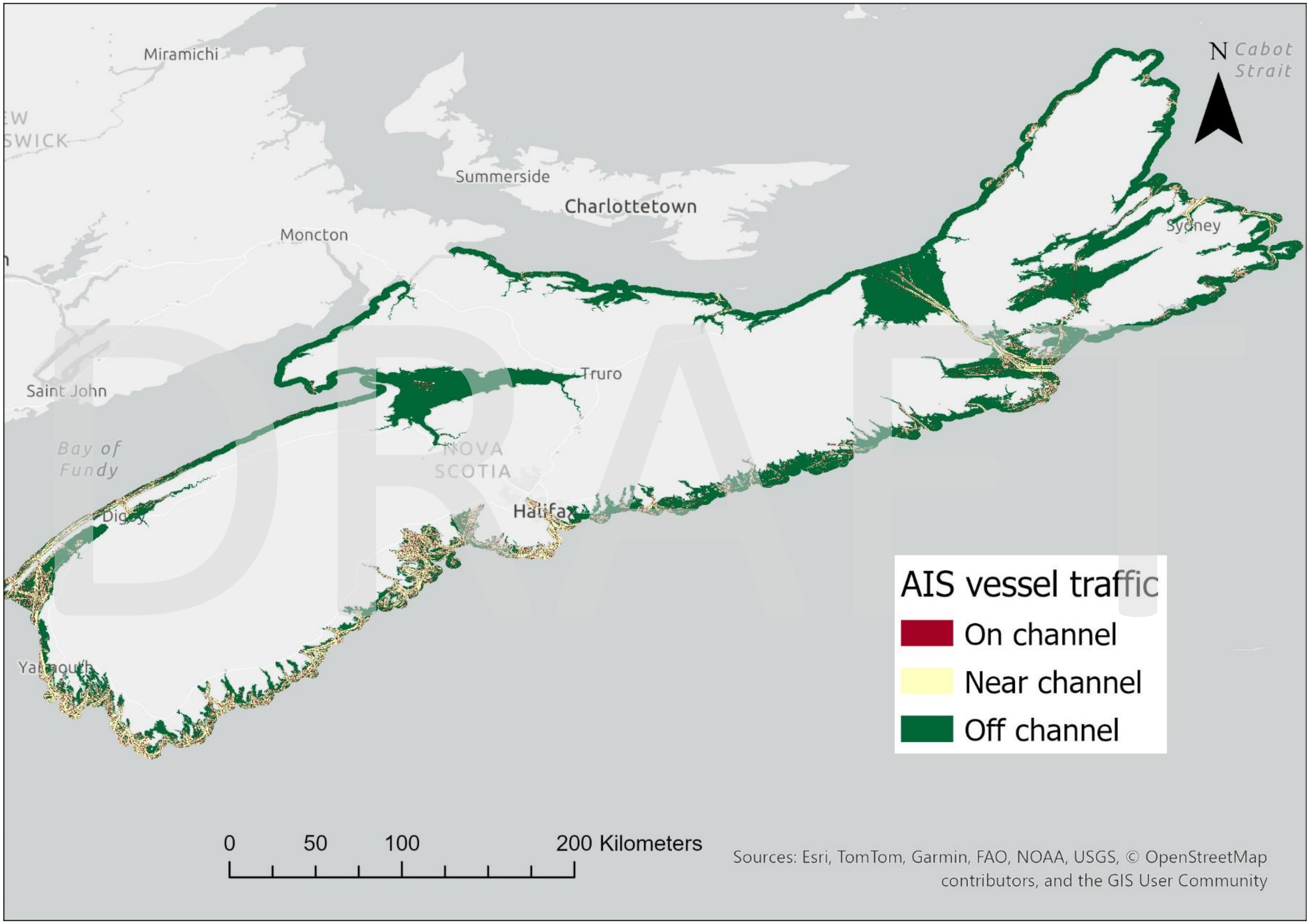

Figure A8. Navigation channels across the area of assessment (AOA), based on track line density from Automatic Identification Systems (AIS) data between 2019 and 2021.

Vessel Monitoring System (VMS) fishing vessel density patterns

Importance: Aquaculture siting should consider the space necessary to accommodate navigation in high-use areas for fishing vessels. The development of aquaculture sites can limit access to potentially valuable fishing areas and/or displace existing fishing activities (Wiber et al., 2012). Additionally, aquaculture gear, such as anchorage chains, mussel rafts, and floating/sinking oyster cages, can create navigational hazards (European MSP Platform; Westoby, 2023). These navigational hazards can result in increased maritime accidents potentially damaging aquaculture infrastructure and/or fishing vessels (European MSP Platform; Westoby, 2023). Other gear conflicts include potential damage to fishing gear from aquaculture vessels (Wiber et al., 2012).

Data Source: Vessel Monitoring System (VMS) data from 2019, 2020, and 2021 provided by DFO

Data Description and Processing: Fishing traffic data is derived from positional data points captured in VMS records for the years 2019 to 2021[54]. VMS is a satellite-based vessel tracking monitoring system that captures the location of commercial fishing vessels at regular (often every hour) intervals. These systems are required by DFO for most fishing vessels in Nova Scotia[55]. The density of VMS points within a 250-meter grid cell was calculated to identify areas where fishing vessels frequently travel. Data were then reclassified based on quartile distribution into meaningful density classes, representing relative levels of fishing vessel traffic into "high" (>3 observations), "medium" (1-3 observations), and "low" (0 observations) traffic classes (**Figure A9**).

Scoring: Since the implications of fishing traffic on aquaculture siting are similar across all types of aquaculture, they can be scored uniformly for all species. Scoring is based on the intensity of fishing activity/traffic occurring in the area.

Scoring			
Type	**"Limited"**	**"Moderate"**	**"Good"**
Salmon	High traffic	Medium traffic	Low traffic
Trout	High traffic	Medium traffic	Low traffic
Mussels	High traffic	Medium traffic	Low traffic
Oysters	High traffic	Medium traffic	Low traffic

Rationale for Scoring: Vessel traffic information identified from VMS data is often used to characterize and minimize navigation-related spatial overlaps of ocean uses (Tlusty et al., 2018; Jossart et al., 2020). Quantifying vessel traffic from VMS data ensures vessel-related factors are properly incorporated into spatial analyses (Metcalfe et al., 2018; Tlusty et al., 2018; Jossart et al., 2020). This practice is particularly relevant for assessing aquaculture potential in Nova Scotia, where the right to navigable waters is protected under the *Canadian Navigable Waters Act* and is

[54] For privacy and confidentiality purposes, all identifying information was removed from data. As such, we are unable to calculate track lines that show the specific paths of individual vessels.

[55] Captures many, but not all fishing vessels. For description of which commercial fishing vessels require VMS, see Iacarella et al. (2020).

a key consideration in siting decisions under Nova Scotia's *Aquaculture License and Lease Regulations*. If aquaculture is proposed in navigable waters, operators must comply with the CNWA and apply for approval from Transport Canada to ensure that navigation rights are upheld and that safety concerns are adequately addressed. It is important to note that while VMS data included in this assessment can identify areas used by fishing vessels, it is used only to indicate potential marine space use overlaps and is not used to assess potential interactions on commercially fished species or effects on fishing catches.

High traffic density areas, which represent key areas where fishing vessel traffic congregates, are scored as having **"limited"** suitability for aquaculture due to increased potential for spatial and navigational overlaps. The presence of aquaculture in these areas can limit access to important fishing grounds, disrupt fishing operations, or create hazards for both activities.

In **medium traffic areas,** fishing vessels are present in relatively low densities. As VMS systems capture positional data at semi-regular intervals (often once every hour), medium traffic areas may represent waters where vessels are navigating to or from or transiting between fishing spots. While these do not represent the most highly used areas, there is still some potential for spatial overlap with aquaculture activities that producers should consider, making medium traffic areas **"moderate"** for aquaculture development.

Low traffic areas represent waters with no observed vessel traffic density across the dataset. These areas can thus be considered rarely trafficked. These areas likely present minimal safety concerns, navigational overlaps or spatial conflicts with fishing vessels, and can be considered **"good"** for aquaculture development.

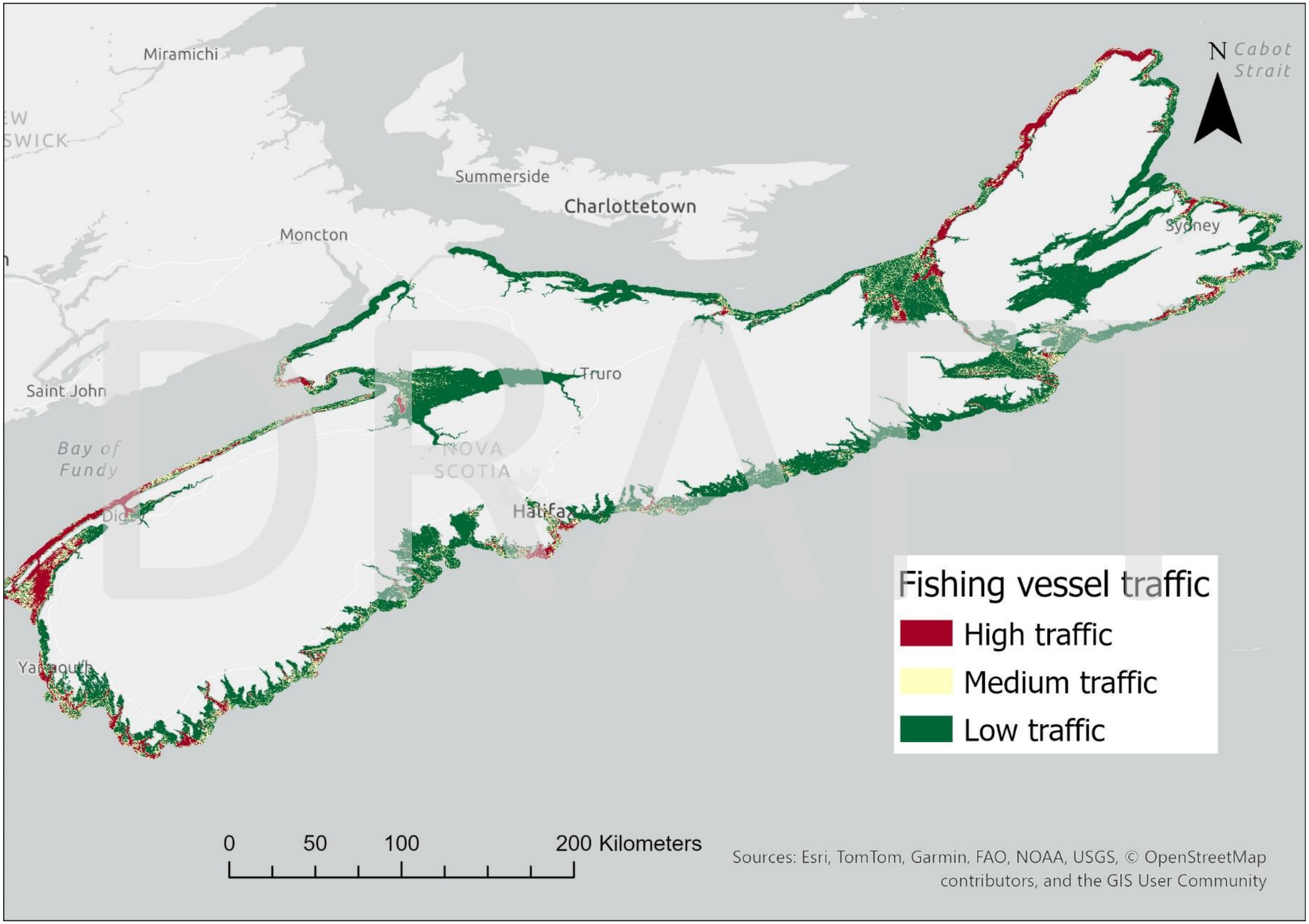

Figure A9. Density of vessel traffic from Vessel Monitoring System (VMS) data between 2019 and 2021 across the AOA.

Public coastal accessibility

Importance: Aquaculture introduces structures in the marine environment and on adjacent lands that can potentially impact the public's access to important marine waters, potentially displacing existing recreational and tourism users (Shafer et al., 2010). Therefore, considering key areas that provide coastal access to the public, for recreation, tourism, or other activities can provide an indicator of potential overlap with other users, and is thus an important criterion for the overall suitability of aquaculture (Perez et al., 2003).

Data Source: Coastal access data was obtained from multiple sources to identify areas that provide public access to marine waters. Coastal access points included were:

- Coastal beaches – Ecological Land Classification and protected beaches provided by Nova Scotia Department of Natural Resources (DNR)
- Small craft harbours (Fisheries and Oceans Canada)
- Public boat launch sites – provided by the Nova Scotia Department of Fisheries and Aquaculture
- Marinas and yacht clubs – point locations digitized from Google Maps

Data Description and Processing: Locations of coastal access points from multiple sources were compiled into a single data layer. The distance (m)[56] to the nearest public coastal access point was calculated across the AOA (**Figure A10**).

It is important to note that the data included in this layer represents locations where the public may have the opportunity to access the coast. The areas represented do not consider the differences in social/cultural value of specific locations, the specific user groups utilizing areas, how many people or how often people use the access sites, or other site-level considerations. These factors are important but must be explored at a bay or site-level assessment.

Scoring: Since the implications of public access points on aquaculture siting are similar across all types of aquaculture, they can be scored uniformly for all species.

	Scoring		
Type	**"Limited"**	**"Moderate"**	**"Good"**
Salmon	< 300 m	N/A	> 300 m
Trout	< 300 m	N/A	> 300 m
Mussels	< 300 m	N/A	> 300 m
Oysters	< 300 m	N/A	> 300 m

Rationale for Scoring: Potential impacts from aquaculture on coastal accessibility refers to potential interactions and overlaps that may impact the ease of access for public users in the

[56] Using Distance Accumulation tool, which calculates 'as the fish swims' distances.

marine coastal environment. Consideration of other users of the public waters and the public right of navigation are both acknowledged as required considerations in decisions related to marine aquaculture sites under Nova Scotia's *Aquaculture License and Lease Regulations*. Nova Scotia's leasing regulations do not include specific requirements regarding the proximity of aquaculture operations to coastal access points. However, Maine's *Aquaculture Lease Regulations* require an assessment of the potential impact or interference of leases located within 1000 feet (~300 meters) of public use or enjoyment of coastal access points, such as beaches, parks, and docking facilities.

Coastal access sites provide the public with access to use of marine waters for activities such as kayaking, canoeing, paddleboarding, and swimming. While public users may occasionally travel considerable distances from access points, they typically remain close to the shoreline for safety reasons and easy access to land (Paddle Canada, 2013). Even when traveling beyond coastal access points, these areas represent key junctures that boaters and recreational users must transit. As such, it has been assumed that potential impacts to access and spatial overlap with users are highest in closer proximity to access points (Ross et al., 2020).

Since public users generally tend to remain close to the shoreline, areas **within 300 meters[57] of access points** are scored as **"limited"** suitability for aquaculture. This is due to the high potential for spatial overlap with public users. Within this proximity, aquaculture infrastructure and vessels are very close to areas where the public access and use marine spaces, posing the greatest risk of navigational and safety hazards to public users, and potentially reducing or limiting safe access to coastal access points. **Beyond 300 meters,** conditions are considered **"good"** for aquaculture.

[57] This distance may be adjusted based on ongoing discussions and policy guidance with NSDFA.

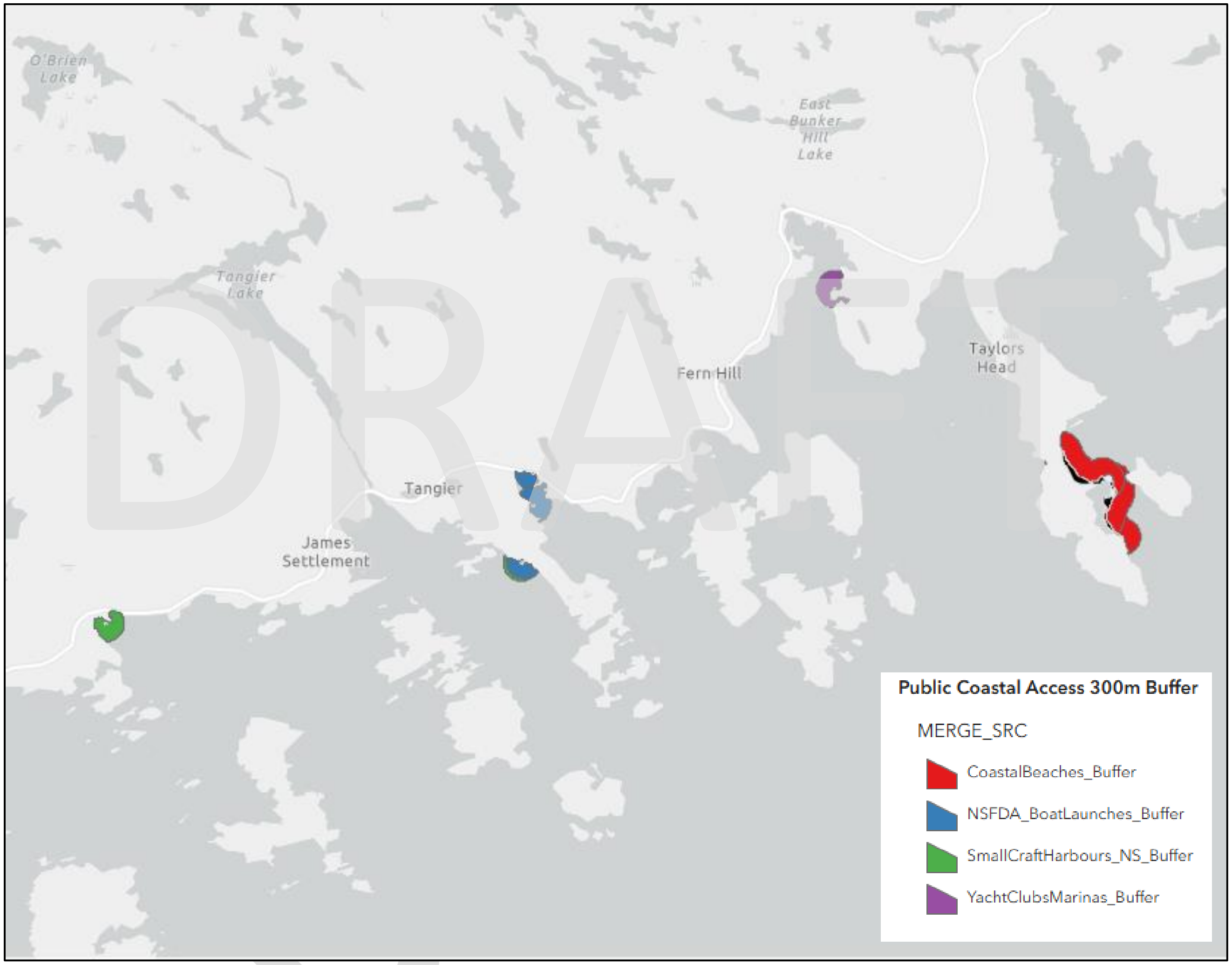

Figure A10. Location of public access points including a 300 m buffer, zoomed in to a particular place on the coast to show different features, which are difficult to see at a province-wide view.

CONSTRAINTS

All constraints are scored similarly across all types of aquaculture and represent areas that would be restricted. To view the spatial extent of identified constraints, see a map of combined constraint criteria in **Figure A11**.

Anchorage areas

Importance: Anchoring is a critical and legally protected (under *The Common Law Right of Navigation*) activity for commercial, recreational, and governmental vessels (Transport Canada, 2020). Specified anchorage areas have restricted access and are not suitable for co-location with aquaculture due to potential spatial conflicts with anchored vessels.

Data Source: Anchorage areas and single ship anchorages were retrieved from data files on the Open Government Data Portal (Canadian Anchorages and Anchorage Areas).

Data Description and Processing: Anchorage areas are designated zones on navigational charts where vessels can anchor, and includes anchorage areas and single-ship anchorages. These files are a comprehensive dataset of anchorages and anchorage areas in Canadian navigable waters. No additional processing was required.

Scoring: These features represent areas already designated for other uses (i.e., anchoring of commercial and/or public vessels), and thus represent a constraint for aquaculture development.

Designated navigational features

Importance: In Nova Scotia, the public's right to navigable waters is protected under the *Canadian Navigable Waters Act* and is a key consideration in siting decisions under Nova Scotia's *Aquaculture License and Lease Regulations*. Designated navigational features represent defined, delineated features that represent key navigational safety uses, and include traffic separation zones, recommended routes, sight lines between navigational aids, and ferry routes.

Data Source: Designated navigational features were identified from Vessel traffic routes - CHS/DFO datasets available on the Open Government Data Portal.

Data Description and Processing: Established and mapped designated navigational features by the Canadian Hydrographic Service included: i) traffic separation zones, ii) sight lines between navigational aids such as lighthouses and radar beacons, iii) recommended traffic routes[58], and iv) ferry routes. No additional processing was required.

Scoring: These features represent areas already designated for other uses (i.e., navigational safety), and therefore represent a constraint for aquaculture development.

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[58] Which identify tracks recommended for certain or all vessels.

Marine Renewable Energy Areas

Importance: Several areas in Nova Scotia are allocated as Marine Renewable Energy Areas (MREA) for exploration of energy production. As per the *Marine Renewable-energy Act*, MREAs can not be designated in areas permitted/leased for aquaculture. Consequently, new aquaculture developments are would not be permitted in existing MREAs, reflecting these areas as constraints.

Data Source: Boundaries of existing MREAs were provided as digital maps by the Nova Scotia Department of Energy[59]. This does not include Offshore Wind Areas which are beyond the area of assessment.

Data Description and Processing: MREAs are large areas designated by the provincial government to allow companies to explore and establish marine renewable energy production. Currently, four areas have been designated in Nova Scotia; FORCE Marine Renewable-electricity Area, Digby Gut Marine Renewable-electricity Area, Grand Passage Marine Renewable-electricity Area, and Petit Passage Marine Renewable-electricity Area. Digitized map images were brought into GIS. No additional processing was required.

Scoring: MREAs represent areas are considered legislatively restrictive and therefore represent a constraint for aquaculture development.

Submerged cables and pipelines

Relevance: Aquaculture development should avoid areas where underwater cables and pipelines are present to prevent damage, avoid conflict with maintenance activities, minimize potential safety hazards to operators[60], and to avoid potentially significant disturbances that may arise from damage to the cables or pipelines. As submerged cables and pipelines would pose a direct overlap with aquaculture mooring and anchoring infrastructure, aquaculture should be constrained around or overtop these features.

Data Source: The location of known active[61] telecom and power cables were provided by the Department of Fisheries and Oceans (DFO).

Data Description and Processing: Submerged pipelines and cables used for power transmission, telecommunication, or other activities were included. Spatial files for cables making landfall in Nova Scotia were extracted from data files provided.

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[59] These areas do not include the larger Areas of Marine Renewable Energy Priority (AMREP) which do not have similar regulatory restrictions.

[60] Cutting of high voltage submarine cables poses serious risk of loss of life or severe burns.

[61] This dataset does not represent a complete list of potential submerged cables and pipelines. Additional cables are identified on DFO's Electronic Navigational Chart (ENC) Maritime Chart Service. However, these cables can not be included in this layer, as there is no data available on which are currently active, or which have been decommissioned or removed. Further consideration for these features should be evaluated during a site level assessment.

Scoring: These features represent areas posing direct spatial overlaps with submerged cables and pipelines, and therefore represent a constraint for aquaculture development.

At-sea disposal

Relevance: Areas demarcated for "at-sea disposal" are areas legally permitted for dumping of dredged and other approved materials (i.e., fish processing waste, ships or platforms, inert inorganic geological matter, uncontaminated organic matter of natural origin, and bulky substances primarily composed of iron, steel, concrete or other similar) (Environment and Climate Change Canada, 2017). Developing aquaculture in these zones could interfere with disposal of materials, as well as the monitoring and management of the disposed materials.

Data Source: Data on at-sea disposal sites were retrieved from Active and Inactive Disposal at Sea Sites in Canadian Waters.

Description: At-sea disposal sites are designated areas for the disposal of various substances in the ocean, such as dredging material. These areas have been determined to be the most environmentally preferable and practical alternative to disposal, and are regulated to prevent contamination, protect marine habitats, and avoid adverse effects on the marine ecosystem (Environment and Climate Change Canada, 2017; Environment and Climate Change Canada, 2020). Active at-sea disposal sites were extracted. No additional processing was required.

Scoring: These features represent areas already designated for other uses (i.e., disposal activities), and therefore represent a constraint for aquaculture development.

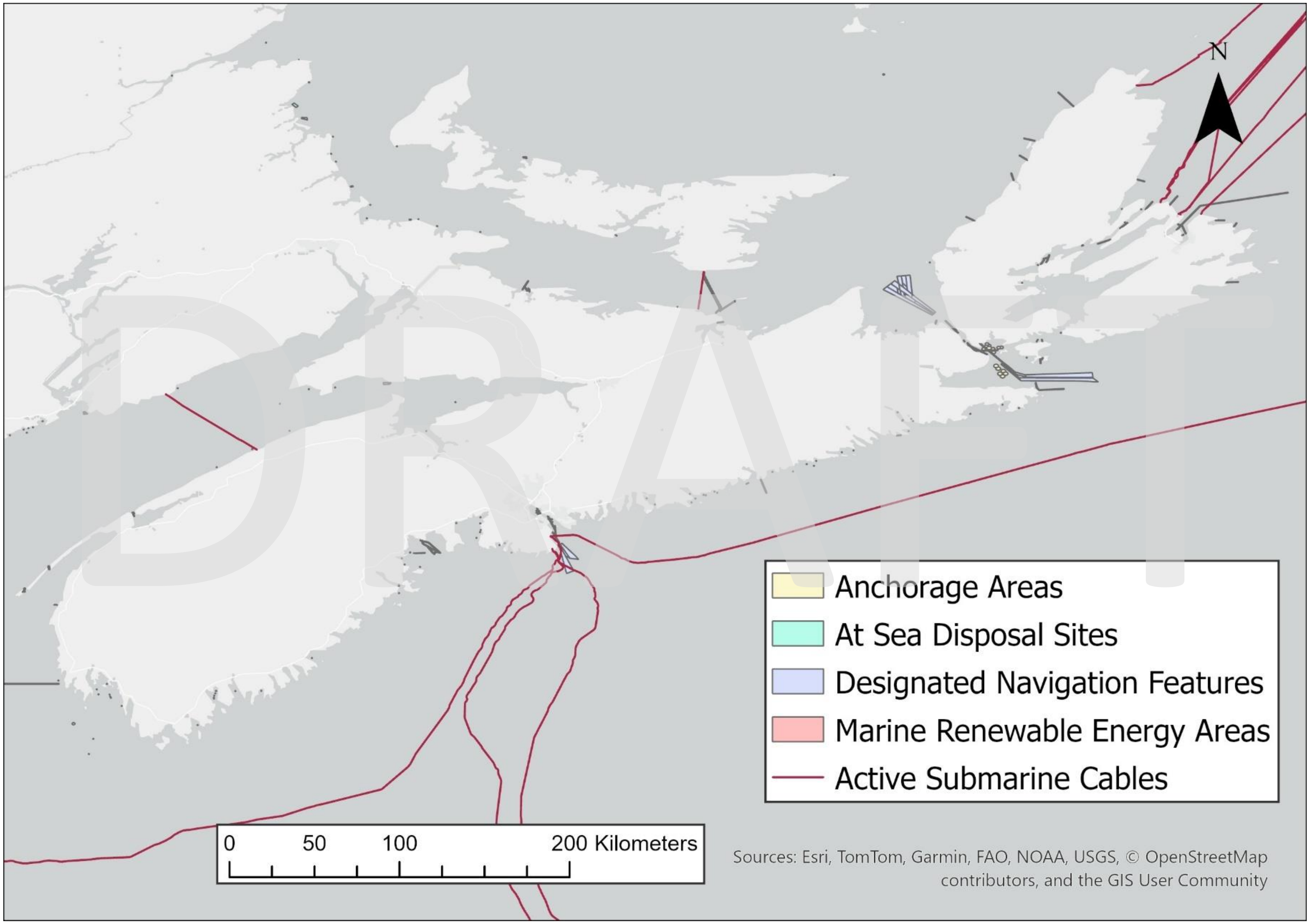

Figure A11. Location of all constraint criteria (designated as restricted for aquaculture activities in final suitability maps).

INFORMATIONAL CRITERIA

MSX exposure

Relevance: Multinuclear sphere unknown (MSX; *Haplosporidium nelsoni*) is a parasitic disease that leads to high incidence of mortalities in oysters and has been a major issue for oyster growers and harvesters in the Bras d'Or Lake and has recently been identified in Prince Edward Island and New Brunswick (Department of Fisheries and Aquaculture, 2017; Government of Canada, 2024). While MSX causes mortality in both juvenile[62] and adult oysters, cohorts over 2 years old are more affected, with mortality rates reaching 90 to 95 % (Andrews and Wood, 1967; Barber et al., 1997). Areas within declared infected zones may pose significant challenges for oyster aquaculture due to the high risk of mortality posed by MSX as well as the significant effort that would be required to achieve a commercial operation that adheres to mandated CFIA disease containment protocols (Ford and Haskin, 1982; Burreson et al., 2000). Operating within a CFIA-declared infected zone imposes significant restrictions on producers seeking to grow and harvest shellfish. Producers are prohibited from moving susceptible animals out of the infected area for depuration, relay, dry storage, wet storage, or commercial processing (Canadian Food Inspection Agency, 2022). Any such activity must be conducted within the infected zone or another area infected with the same disease. This requires producers to establish or utilize designated processing facilities within infected zones. While CFIA-declared zones delineate areas where the disease is known to occur, they do not adequately capture spatial variability in the presence, prevalence, and exposure risk of MSX. This lack of detailed spatial data limits the ability to assess and address the varying levels of risk MSX poses to aquatic animal health across the span of the declared zones. As a result, the current zoning framework may fail to identify localized hotspots of disease presence or areas that may present lower risk, leading to significant knowledge gaps regarding exposure risk. As such, MSX exposure could not be consistently and reliably scored but should be included as important information for aquaculture development.

Data Description and Processing: Declared infected areas were obtained through maps produced by the Canadian Food Inspection Agency (CFIA). CFIA declares infected zones based on historical occurrence and monitoring of aquatic animal health diseases across Nova Scotia. Declaration areas were imported into GIS and mapped within our AOA. Areas beyond the boundaries of declared infected zones were assigned "not declared" for MSX.

Shellfish Harvest Classifications

Relevance: In Nova Scotia, shellfish aquaculture water quality is regulated under the Canadian Shellfish Sanitation Program (CSSP). Under the CSSP shellfish harvest areas are classified as to their suitability for harvesting shellfish, according to water quality standards and sanitary

[62] Juvenile oysters can be heavily infected with MSX spores, as these spores are predominantly produced in smaller oysters due to their growth efficiency, however, the pathogenic effects may not manifest until later life stages (Ford et al., 1999).

conditions (CFIA, 2019). The CSSP recognizes five classification categories: approved, conditionally approved, restricted, conditionally restricted, and prohibited (CFIA, 2020). These harvest area classifications have significant implications for producers, potentially affecting their ability to harvest, and imposing requirements for mitigation measures, such as relay or depuration (CFIA, 2020). Shellfish intended for human consumption cannot be harvested from prohibited, nor from areas that have not been classified by CFIA. As there is potential variability and uncertainty in the water quality of unclassified areas, it is unclear how to appropriately score these areas, meaning shellfish classification areas are more appropriately included as an informational layer.

Data Description and Processing: Shellfish harvest area classifications were identified through the Shellfish Water Classification Program – Shellfish Harvest Area Classification in Canada. Waters within the area of assessment that are not classified as per the Shellfish Water Classification Program were labeled as "unclassified".

Wild salmon rivers

Relevance: The sustainability of wild salmon is a required consideration in decision-making related to marine aquaculture siting under Nova Scotia's *Aquaculture Licence and Lease Regulations*. Through accidental escapes (from cage damage or inclement weather), farmed salmon can enter freshwater rivers, where they may compete with wild salmon for resources, or may interbreed and lead to genetic changes in natural populations (Bradbury et al., 2020a; Bradbury et al., 2020b). Escaped salmon pose the greatest risk in areas near rivers supporting wild populations, as their numbers and survival generally decrease with distance from aquaculture sites. The proximity of aquaculture sites to wild salmon rivers may also increase the risk of bilateral disease and parasite spread (i.e., transmission from wild to farmed; and farmed to wild) (Johansen et al., 2011; Gardner et al., 2014; Mordecai et al., 2021). Although proximity to wild salmon populations is not a definitive measure of potential impacts, it is a key indicator of increased risk, making consideration of the distance between aquaculture operations and wild salmon rivers an important consideration for the conservation of wild salmon. However, provincial regulations in Nova Scotia do not prescribe recommended distances from salmon rivers, and existing guidance from other regions[63] and scientific literature[64] is highly variable (Porter, 2003; Porter, 2006). As such, proximity to wild salmon rivers could not be consistently and reliably scored. Furthermore, many rivers could not be evaluated for significance due to lack of data available, leading to gaps in data coverage across the AOA. Still, understanding the significance of rivers in Nova Scotia for wild Atlantic salmon can provide important information for understanding the potential risks of aquaculture development.

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[63] For example, previous guidance in British Columbia stated aquaculture should be sited at least 1 km from the mouth of a salmonid bearing stream determined as significant in consultation with DFO and the province. However, this recommendation is largely out of date, and in review was considered to be inadequate and lack scientific backing (Porter, 2006).

[64] Within scientific literature the extent of aquaculture impacts on wild salmon is largely debated (Ford and Myers, 2008).

Data Description and Processing: To explore potential implications for aquaculture and wild salmon interactions, CMAR assessed wild salmon rivers across Nova Scotia to understand the significance of rivers based on multiple criteria relevant to the viability, importance, and status of rivers. Data on the significance of wild Atlantic salmon rivers in Nova Scotia was compiled by CMAR for this assessment through a combination of desktop research[65] and field data collection. In this context, significance refers to the role of the river in supporting the long-term viability of salmon populations and the broader sustainability goals associated with their conservation and management. The assessment aggregated numerous indicators across five significance criteria, including measures of river habitat, abundance, barriers, importance, and threats. The final significance ratings of 287 rivers across Nova Scotia range from low to high, with some remaining unclassified due to insufficient data.

Coastal wetlands

Relevance: Wetlands play an important role in coastal ecosystems by providing habitat for wildlife, improving water quality, and protecting shorelines from erosion, and deliver other valuable ecosystem services (Li et al., 2018). Many coastal wetlands around Nova Scotia are protected provincially (Nova Scotia Wetland Conservation Policy) or federally (The Federal Policy on Wetland Conservation). Human activities such as fisheries and aquaculture should be located to minimize the potential for interaction with sensitive coastal wetland habitats. However, current, guidance on appropriate buffers or setbacks applies only to terrestrial developments. There are no specific buffers established for fisheries, aquaculture or other marine sectors. The potential for interaction is considered highly variable as it depends on the wetland ecosystem type, location and the proposed activities. Consequently, there is no overarching guidance, and licence applications are considered on a case-by-case basis by NSDFA and network partners. As a result, wetlands can not be reliably scored but are included as important information for aquaculture development.

Data Description and Processing: Coastal wetlands were identified through the Canadian National Wetlands Inventory (CNWI). CNWI is a publicly available national geodatabase consisting of the best available wetland maps. The database was developed by the Canadian Wildlife Services (CWS), in collaboration with various government levels (i.e., federal, provincial, territorial), academia, Indigenous groups, and non-governmental organizations (NGOs). Only wetlands within 100m of the coast were extracted.

Terrestrial protected areas and parks

Relevance: Terrestrial protected areas and parks serve to protect wildlife, natural features, ecological processes (Province of Nova Scotia, 2019), and are important for land conservation and biodiversity goals (Province of Nova Scotia, 2013; Province of Nova Scotia, 2019). While legal

[65] Compiling existing publicly available published datasets.

protections and restrictions vary based on the designation (i.e., Provincial Nature Reserve versus National Parks), these areas are protected due to their natural heritage, scenery, and significant ecological value (Crowell, 2023; Province of Nova Scotia, 2023). As such, human activities such as aquaculture should be sited to minimize the potential for interaction with these areas. However, there is currently limited scientific knowledge on recommended buffer to reduce interaction potential with protected, coastal terrestrial ecosystems. The potential for interaction or impacts is highly variable and situation specific depending on ecosystem type[66], resident species and proposed adjacent activity, such as aquaculture. As a result, this criterion could not be consistently and reliably scored but warrants inclusion as important information for aquaculture development.

Data Description and Processing: Terrestrial protected areas and parks were obtained from Nova Scotia Environment and Climate Change's Protected Areas System database. These lands help preserve Nova Scotia's natural values through a blend of legislation, ownership, and management. Included here are: National Parks, National Wildlife Areas, Provincial Wilderness Areas, Provincial Nature Reserves, selected Provincial Parks, land trust properties, and easements. Protected beaches and terrestrial Wildlife Management Areas and Game Sanctuaries provided by NSDNR were also included. Only protected areas and parks within 100 m of the coast were extracted.

Important bird habitat

Relevance: Marine activities (such as fishing, aquaculture, oil and gas) can introduce disturbances to nearby bird populations through exclusion from critical habitats, alter prey availability, ingestion of foreign objects, the threat of entanglement or collision with infrastructure and netting (Sagar, 2013; Bath et al., 2023) and potential disturbances to breeding (Connor-McClean, 2020). These risks are largely mitigated through effective management[67] and by situating farms away from seabird colonies and key foraging areas, especially those identified as critical or sensitive (Surman and Dunlop, 2015; Connor-McClean, 2020; Bath et al., 2023). Consequently, it is important that aquaculture site decisions consider the potential for interaction with birds and their habitats. As per ECCC Guidelines to avoid harm to migratory birds, buffers and set-back distances are evaluated on a case-by-case basis. Recommended on-water setbacks described within the scientific literature are inconstant due to the variable nature of different species, habitat types (nesting, migrating, foraging), and proposed activities. As a result, this criterion could not be consistently and reliably scored but is important information to include for aquaculture development.

Data Description and Processing: Important bird habitats are areas that are crucial for bird nesting, feeding, and migration. These areas have been recognized locally, nationally, or

[66] For example, a low energy area may be more susceptible to the dispersal of nutrients and smothering as compared with a protected area with a predominantly high-energy rocky coastline.
[67] Such as wildlife interaction protocols in the mandatory Farm Management Plan.

internationally to represent important areas that support coastal birds[68]. Bird habitat datasets were extracted and combined into a single layer. Important bird habitats are identified from various sources, including: the Nova Scotia Significant Species and Habitat Database by The Department of Natural Resources and Renewables, Important Bird Areas (IBA) Program coordinated by BirdLife International, Critical Habitat for Species at Risk (ECCC), and Migratory Bird Sanctuaries Only habitat areas within 100m of the coast were extracted.

Existing aquaculture leases

Relevance: New aquaculture developments cannot be sited in areas already leased to other shellfish or finfish aquaculture operators due to interference with infrastructure and designation of lease areas. However, the suitability of areas with existing aquaculture would vary significantly based on whether the proponent wants to expand their existing lease area, or if an additional party is looking to develop a separate site. Furthermore, new sites should consider proximity to existing sites for disease management and to account for overall carrying capacity of the surrounding environment. Currently, policies in Nova Scotia have not prescribed specific buffers or recommended setbacks between sites, and proximity should be considered best at a site level to consider broader application-specifics like stocking densities, disease management, and carrying capacity of a given waterbody.

Data Description: Locations of existing marine aquaculture leases were obtained from publicly available data provided by the Nova Scotia Department of Fisheries and Aquaculture's Aquaculture lease mapping tool (Nova Scotia).

Water lots

Relevance: Water lots are specific parcels of land located on a lake or the coast that are either entirely or partially submerged underwater (Traves, 2023). These lots are distinct in that their ownership titles can be individually conveyed, similar to land-based properties (Traves, 2023). Essentially, water lots represent sections of the seabed that are treated as property. Ownership of these lots is not limited to private individuals; water lots in the province are also held by a variety of entities, including different government departments and corporations. Water lots may include boundaries delimiting small craft harbours, commercial ports/activities, and privately owned sections of water. As these lots are already owned or leased to specific entities for particular activities or uses, the suitability of areas within water lots would vary significantly based on whether the aquaculture operator owns the lot or if the lot owner is willing to sell or lease it to the aquaculture operator. As a result, water lots could not be consistently and reliably scored but should be included as important information for aquaculture development.

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[68] While recognized as key areas for birds, the designated areas included are not legislatively protected through regulations. However, this information may be used by network partners when evaluating a site application to assess potential impacts on protected bird species.

Data Description and Processing: Locations of privately-owned and federally owned (Crown) parcels were identified from Parcel Identification (PID) data provided by GEONova. Only lots within the marine environment were extracted.

Crown leases, easements, and coastal permits[69]

Relevance: Submerged land along the coast of Nova Scotia is owned by the province as provincial Crown Land, unless it has already been sold by way of a provincial or federal grant, or it is a federal public harbour. Submerged land can be leased by the Nova Scotia Department of Natural Resources for commercial purposes such as a wharf, marina, tidal power generation, or utility cable landing site. Furthermore, the province may issue easements for submerged utility cables or bridges and utility services to private properties. Within existing Crown leases, easements, and coastal permits aquaculture development may not be permitted, although the restrictions would vary depending on the proposed operation and the type of lease, easement or permit.

Data description and Processing: Datasets regarding issued Crown leases, easements, and coastal permits were provided at request by the Nova Scotia Department of Natural Resources (NSDNR).

[69] This dataset has only recently been received and is still being reviewed and may be updated.

CENTRE FOR MARINE APPLIED RESEARCH

2025-DRAFT.v.1.0.

Recommendations on Weighting and Aggregation of Criteria.

A report in support of the aquaculture coastal classification system project.

April 14, 2025

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Table of Contents

1. Introduction

In supporting the objectives of the *Coastal Classification System (CCS)* for aquaculture in Nova Scotia, the *Centre for Marine Applied Research (CMAR)* is completing high-level assessments to classify coastal areas based on their potential for finfish and shellfish[1] aquaculture. To assess the potential of areas for aquaculture development, multiple evaluation criteria will be evaluated and rated within a Geographic Information System (GIS) tool, applying techniques from Multicriteria Decision Analysis (MCDA)[2]. These assessments will be combined into an online mapping tool for users to view spatial information about potential aquaculture development opportunities in Nova Scotia. The outputs of these assessments include maps showing a combined rating indicating the potential suitability for aquaculture development as well as data layers of supporting information.

For this assessment, the GIS-MCDA process focuses on defining, rating, and combining multiple evaluation criteria relevant to assessing the potential of an area for aquaculture production. GIS-MCDA has been widely used to explore aquaculture potential (Chentouf et al., 2023) in what can be generally referred to as a "suitability assessment". These techniques have been used in similar global initiatives to assess suitability for aquaculture (Falconer et al., 2013; Porporato et al., 2020) and develop mapping tools[3] to help identify where opportunities for aquaculture could exist (Aguilar-Manjarrez et al., 2008). Here, we use these processes to perform an analysis of aquaculture development potential (or "suitability").

In this type of GIS-MCDA process, weighting and aggregation is the penultimate phase of the assessment (**Figure 1**). Weighting is a critical step that involves considering the level of importance (and weights), of criteria being evaluated (Malczewski and Rinner, 2015). In this assessment, the consideration for criterion importance guides decisions around how criteria are aggregated, through a combination of Weighted Linear Combination (WLC), rule-based overlay, and/or constraints overlay. Combining these three methods, final suitability maps classify areas into four ratings: "restricted", "limited", "moderate", or "good" for potential aquaculture development. This multi-methods approach to aggregation ensures that important limitations and restrictions are not diluted, while producing final classification ratings that reflect a combination of important variables influencing suitability.

[1] Considering key species cultured in Nova Scotia: Atlantic salmon (*Salmo salar*), Rainbow trout (*Oncorhynchus mykiss*), Eastern blue mussel (*Mytilus edulis*), and American oyster (*Crassostrea virginica*).
[2] See "Methods Review for Spatial Suitability Analysis in the context of the Coastal Classification System (CCS)" for more information about general approach and methodology.
[3] For example, see *Palau Aquaculture Suitability Tool* and AquaVIS (Gangnery et al., 2021).

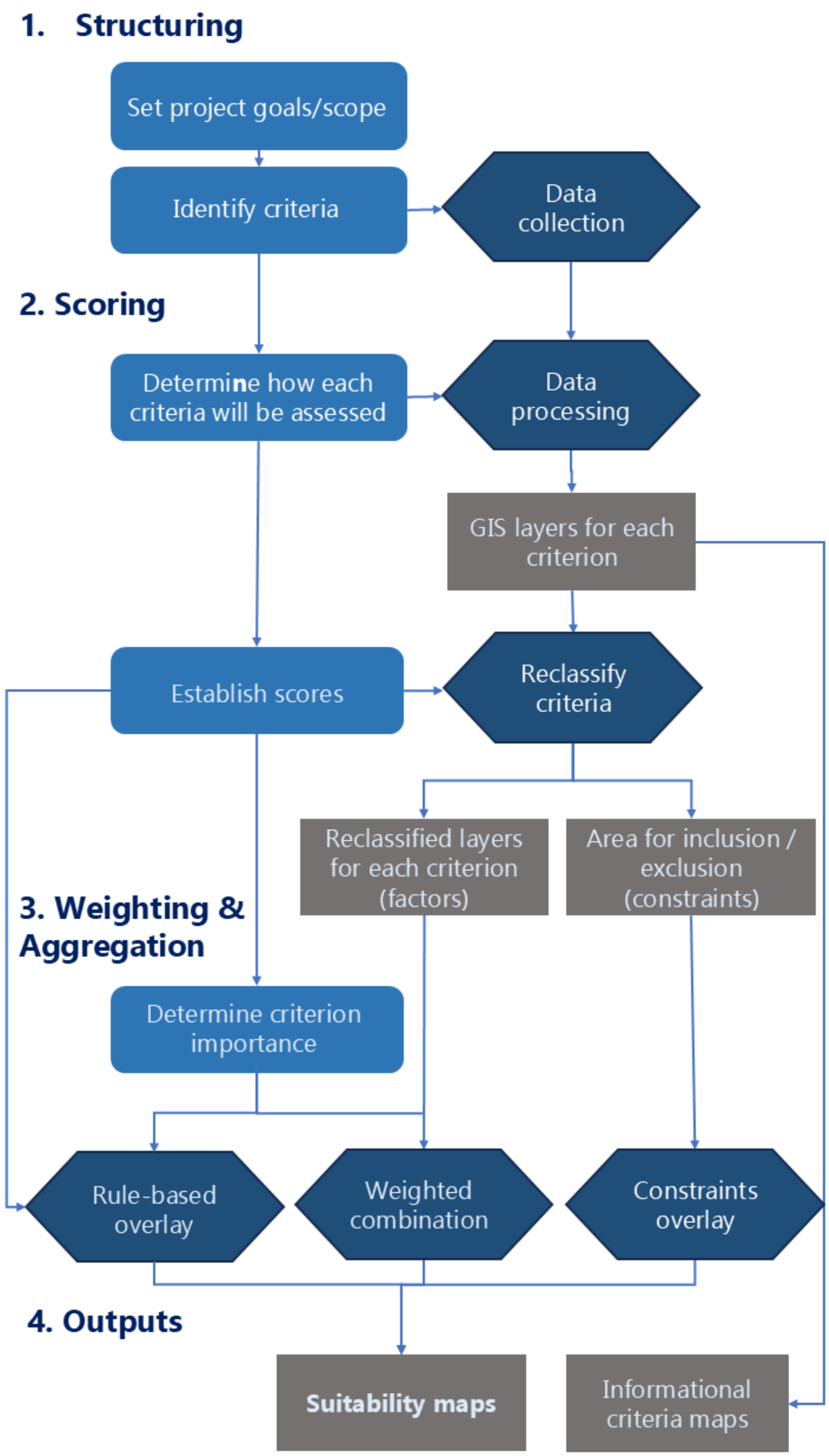

Figure 1. Key decisions, methods, and outputs across the four main phases of the GIS-MCDA assessment of aquaculture development potential to produce final suitability maps.

1.1 Purpose of report

This report provides information to guide the decisions regarding how each criterion will be weighted and aggregated in the assessment of aquaculture development potential. It also outlines the methods, tools, and key considerations in guiding aggregation (**Section 2**) of criteria. In addition, key information relating to additional steps in creating outputs, such as how results are going to be visualized (**Section 3**), as well as model validation, are also provided (**Section 4**). This is an interim report, and any feedback, adjustments, or refinements will be reflected in subsequent reporting. Finally, information about how the online decision-support tool was developed and what information it will show will be detailed in subsequent reporting.

2. General approach - Aggregation

Aggregation involves the methods and processes used to combine criteria to produce the final classification of areas. As a broad and diverse field, MCDA aggregation methods are varied, and are not always mutually exclusive, with projects often employing multiple aggregation methods depending on the needs of the assessment (Cinelli et al., 2020). Our proposed assessment applies three fundamental MCDA methods to classify an area for suitability, including **WLC**, **rule-based overlay**, and **constraints overlay** (**Box 1**).

Box 1. The final suitability rating at a given location will be based on combining the different MCDA methods outline below which set out conditions for classification:

- **Weighted Linear Combination (WLC)**: combines factors through a weighted sum of scores, so that final ratings reflect the suitability of areas when considering multiple factors.
- **Constraints overlay**: identifies areas that will be automatically assigned a “restricted” rating due to the presence of exclusionary restrictions that would preclude aquaculture.
- **Rule-based overlay**: identifies areas that will be automatically assigned a “limited” or “moderate” rating due to the presence of critical conditions that would influence the suitability, regardless of the presence of any other criteria.

Final assessment ratings thus reflect either:

- A combination of factors that make an area have a specific overall rating for development potential, as determined through WLC; or
- The presence of a key condition that influences aquaculture development potential, which is independent of any other criterion, as determined through constraints or rule-based overlay.

As the different methods may produce different final ratings, the lowest score derived from any of the discussed methods will be used as the final suitability rating[4]. The result of the aggregation is a final map that shows each area as one of four classifications:

- **Restricted**: Unsuitable for aquaculture development.
- **Limited**: Generally expected to have substantial challenges for aquaculture development and would require significant management or mitigation.
- **Moderate**: Generally expected to be reasonable for aquaculture development, with further investigation needed to explore potential impacts or appropriate management and mitigation.
- **Good**: Generally expected to be well suited for aquaculture development.

The result of the aggregation within GIS is a single suitability classification for each area across the area of assessment (AOA). The areas will be delineated based on a gridded area of analysis, which divides the study area into equally sized areas ("cells") that cover the AOA (**Figure 2**). The grid cell size was determined largely based on the spatial resolution of the underlying data but also consider factors such as processing time and relevance to the analysis. The grid size will ultimately be limited by the coarsest available dataset, as significant downscaling is not recommended and can lead to inaccuracies in the final product. Furthermore, at very high-resolution, processing time increases significantly and would result in slower platform response, potentially decreasing user experience. Finally, as this analysis is designed as a regional-level analysis, too fine-scale resolutions are not appropriate, as the outputs can not inform on fine-scale local dynamics[5]. As such, a spatial resolution of 100 metres[6] was determined based on the datasets used and the goals of the assessment.

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[4] For example, if a criterion is rated as "limited" from WLC but there is a decision rule that might rate it as "moderate", the WLC rating would supersede.
[5] Fine-scale local dynamics are most appropriate for site scoping as per *Aquaculture Management Regulations.*
[6] A spatial resolution of 100 metres means that the dimensions of each "cell" would be 100m x 100m.

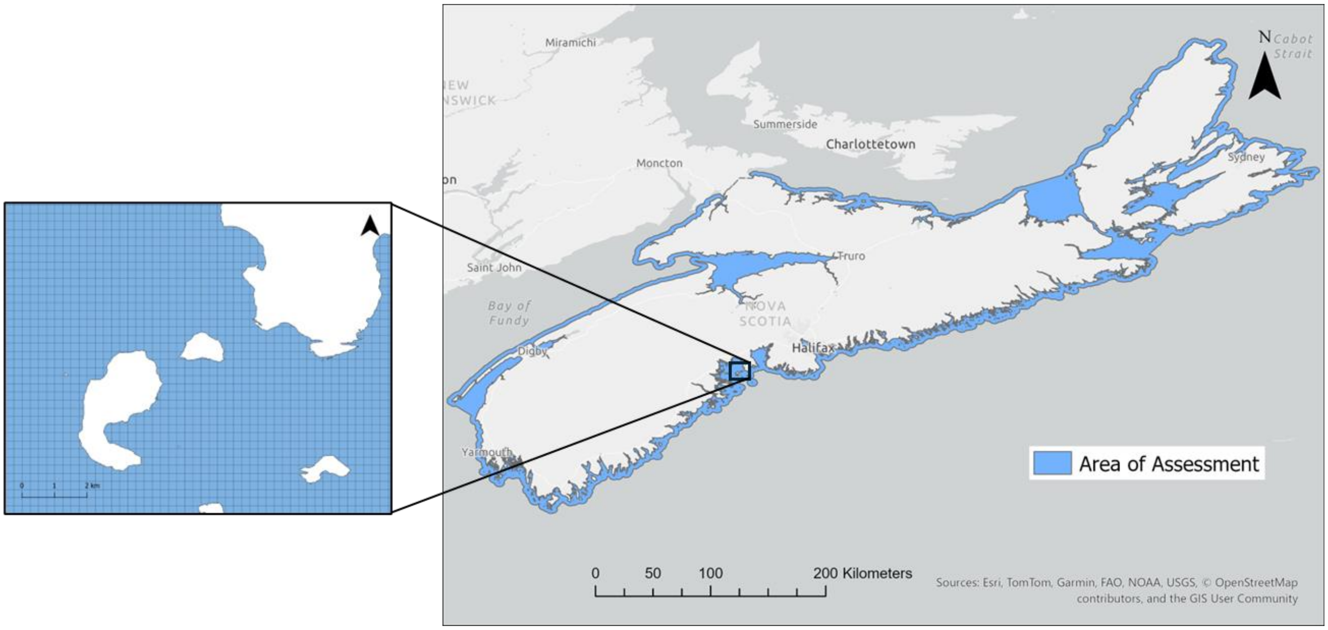


Figure 2. Area of assessment gridded to show the units of assessment as an area defined by multiple equal-sized "cells" within a larger grid.

The relative importance of each criterion to the overall assessment was explored to determine the method or methods used to aggregate criteria to form the final suitability rating. The methods applied were based on three conditions, including a) the type of criteria, b) whether the criteria can be accepted to be compensatory to the overall process, and c) the way in which the criterion was scored (**Figure 3**).

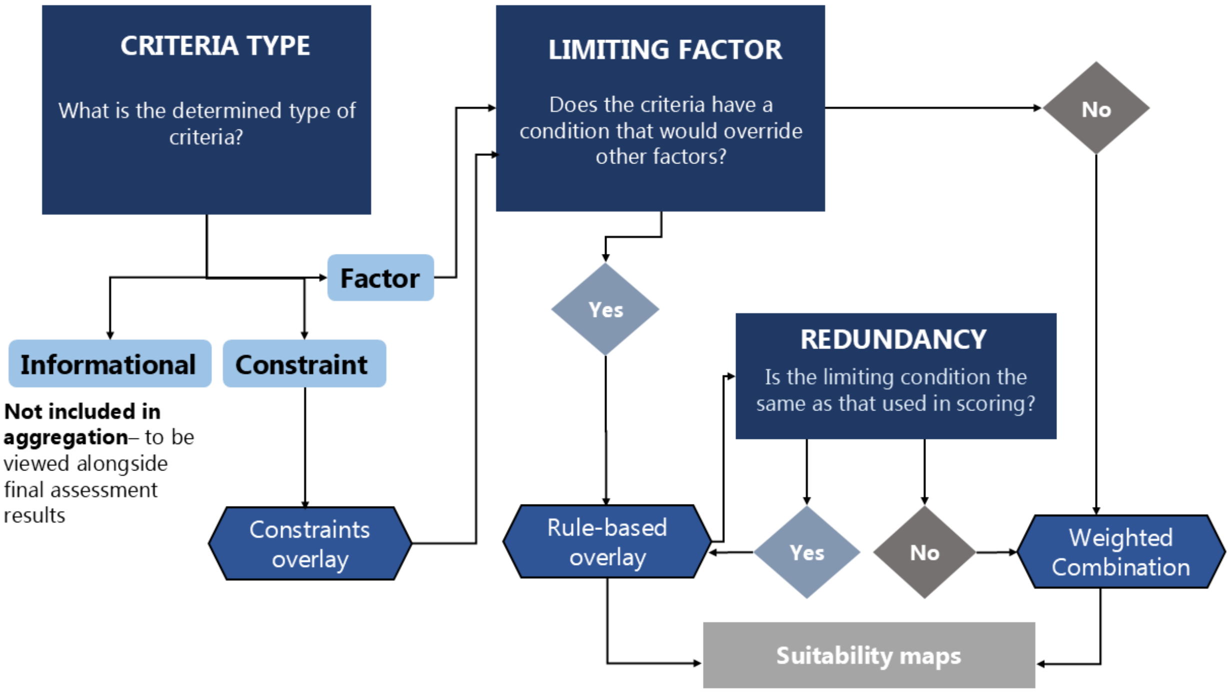


Figure 3. Decision flowchart describing considerations when determining the aggregation method(s) applicable to a given criterion.

Aggregation methods are applicable to different criteria, based on how important certain conditions are to influencing the development potential for aquaculture (**Table 1**). For example, only constraints are assessed through constraint overlay. Rule-based overlay may apply to both constraints and factors, depending on the presence of a condition that would be considered to automatically rate an area a given classification. Factors may also be included in both WLC and rule-based overlay, in situations where limiting conditions are different than thresholds used to score the factor for WLC. If a factor was scored in a binary way (only one of two possible ratings), and one of those thresholds was determined to be a decision rule, that factor will only be included through rule-based overlay.

Table 1. Summary of proposed aggregation method (s) for each criterion.

Criterion	Aggregation method			Rationale
	WLC	Rule-based overlay	Constraint overlay	
Extreme cold exposure	✓	✓		High risk areas pose significant mortality risks for finfish
Extreme heat exposure	✓			Factor
Bathymetry	✓	✓		There are minimum functional requirements for infrastructure at shallow depths
Ice conditions	✓	✓		For shellfish, high drift ice risks can be substantial for industry
Wind and wave conditions	✓	✓		For shellfish, high wind and wave conditions can be significantly detrimental to animal health
Critical habitat for species at-risk		✓		Binary scoring based on regulatory requirement to consider potential interactions
Marine protected and conserved areas		✓		Binary scoring based on regulatory requirement to consider potential interactions
AIS vessel density patterns	✓	✓		On 'Important Vessel Routes' (i.e., very high traffic areas), substantial navigational overlaps are likely to limit potential aquaculture development opportunities
VMS fishing vessel density patterns	✓			Factor
Public coastal accessibility	✓	✓		Very close proximity to public coastal access points could create user overlaps
Anchorage areas		✓	✓	Constraint criterion; areas around anchorage points should account for navigation around potentially inaccurate point geometries
Designated navigation features		✓	✓	Constraint criterion; areas around line data should account for navigation around potentially inaccurate line geometries
Marine Renewable Energy Areas			✓	Constraint criterion
Submerged cables and pipelines		✓	✓	Constraint criterion; areas around line data should account for navigation around potentially inaccurate line geometries
At-sea disposal sites			✓	Constraint criterion
Shellfish Harvest Area Classification	NA	NA	NA	Informational criterion

Criterion	Aggregation method			Rationale
	WLC	Rule-based overlay	Constraint overlay	
MSX Declaration areas	NA	NA	NA	Informational criterion
Wild salmon rivers	NA	NA	NA	Informational criterion
Coastal wetlands	NA	NA	NA	Informational criterion
Terrestrial protected areas/parks	NA	NA	NA	Informational criterion
Important bird habitat	NA	NA	NA	Informational criterion
Existing aquaculture	NA	NA	NA	Informational criterion
Crown leases, easements, and permits	NA	NA	NA	Informational criterion
Water lots	NA	NA	NA	Informational criterion

2.1 Weighted Linear Combination (WLC)

While various methods exist for aggregating multiple criteria, WLC is the most common in MCDA (Malczewski and Rinner, 2015), and is regularly applied in other aquaculture contexts (Dapueto et al., 2015; Morris et al., 2021; Petrosillo et al., 2023). WLC allows for a nuanced assessment of suitability, by considering the scoring and weighting of criteria for a combined suitability assessment. WLC calculates a suitability index (*S*) whereby the suitability scores for each criterion are multiplied by their weights and summed (see **Box 2**).

Box 2. The suitability index (S) is based on the summed product of weighted criteria scores across all factors, following the equation:

$$S = \sum_{i=1}^{n} w_i \times c_i$$

S = Suitability index
w_i = Weight assigned to criterion i
c_i = Score of criterion i
n = Total number of criteria

For WLC, factor scores are assigned numerical values for aggregation based on a pre-determined scale. For this assessment, we use a simple scale from 1-3, where: 'limited' = 1, 'moderate' = 2, and 'good' = 3. This scale assumes that the difference between each rating is 'equal'.

The primary assumption of WLC is that criteria are considered compensatory, in that a high score for one criterion (e.g. navigation) can offset a low score for another (e.g. water depth). If conditions exist that would invalidate this assumption, other aggregation methods (see **Section 2.2.**) are explored.

2.1.1 Determining factor weights

To combine factors[7] through WLC, weights are required to determine how important each factor is to the overall assessment of aquaculture development potential. The weighting processes and considerations are reflective of best practices from MCDA literature (Belton and Stewart, 2002; Malczewski and Rinner, 2015; Cinelli et al., 2020; Dean, 2022). There is no single universally appropriate approach[8], and methods should be tailored to meet project needs and contexts. Choosing an appropriate weighting method largely depends on the structure of the MCDA application (Cinelli et al., 2022), and should consider the resources available for the elicitation process and minimize cognitive burden (Németh et al., 2019; Ezell et al., 2021). Consequently, the

[7] Only factors (not constraints nor information criteria), which are combined through WLC, require consideration for weighting.
[8] The weighting methods outlined here only represent a subset of potentially diverse techniques that can be applied to different MCDA contexts (Cinelli et al., 2022).

proposed approach considers project goals, chosen criteria, and desired outputs which have been selected in consultation with the CCS Advisory Committees[9].

General approaches to weighting methods can broadly be categorized into either uniform weighting or subjective weighting (see **Appendix i** for brief advantages of different weighting approaches). In subjective weighting, relative weights are assigned to criteria based on their value, importance, or relevance to the overall suitability assessment. As this is ultimately a judgement process, subjective weighting presumes weights to be based on the expertise, interests, and goals of those involved in determining weights.

A uniform, or 'equal' weighting, method is where criteria are automatically assigned equivalent weights, based on the critical assumption that each criterion contributes equally to the total suitability (Ezell et al., 2021). Uniform weighting is a popular method used in other aquaculture suitability assessments (Longdill et al., 2008; Silva et al., 2011; Morris et al., 2021). Often, this is done to reduce bias of results based on the membership of individuals deciding weights. Previously, even aquaculture experts with similar backgrounds have been found to have inconsistencies in their assignment of weights (Aguilar-Manjarrez, 1996), resulting in variable outcomes on the final suitability maps. Equal weighting thus minimizes potential concerns around subjectivity, volatility, and variability in weighting while offering a straightforward and easy to apply method. A uniform approach is simple, easy to apply and communicate, and reduces the potential for bias. It is also the most flexible for future iterations of the assessment; if criteria are added or removed, equal weighting would eliminate the need for elicitation processes.

In a uniform weighting approach, criteria weights do not need to be "assigned", as they are automatically given equal weights depending on the total number of criteria included in the assessment. Weights of criteria are calculated as a percentage (out of 100%) divided by the total number of criteria. However, how criteria are organized (**Figure 4**) has implications for how criteria are weighted and aggregated. In a flat structure, there are no subdivisions or groupings of criteria, and each criterion is given the same weight[10]. A flat hierarchy has a simple organization and is particularly appropriate when criteria are limited in number or complexity. In a hierarchical structure, criteria are organized into multiple levels, with broader criteria (parent criteria) at the top and more specific sub-criteria at lower levels. In a hierarchical weighting, equal weights may be given to each parent, and then each sub-criterion inherits the weights from their parents, divided by how many total sub-criteria exist under that parent[11]. The hierarchical grouping may enhance the manageability of the data and allow conceptual clustering into categories (Marttunen

[9] Including the Technical Oversight Committee and three advisory Data Committees.
[10] For example, if the assessment has 10 criteria, each will contribute 10% to the overall assessment.
[11] For example, if a sub-criterion is one of two criteria under a parent criterion that is weighted at 10%, each sub-criterion will have a weight of 5%.

et al., 2018), which may be beneficial for exploring a nuanced assessment of suitability and communicating outputs.

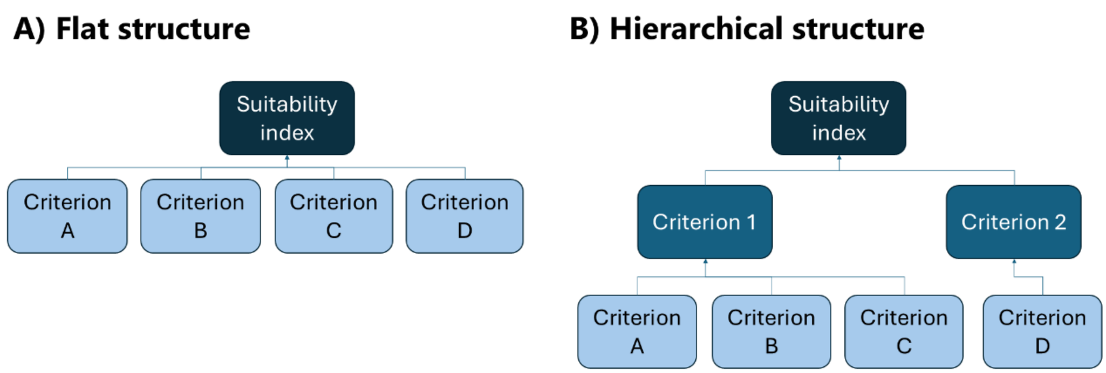


Figure 4. Criteria can be organized into either a A) flat structure, or a B) hierarchical structure.

We propose a uniform weighting approach based on a flat hierarchy, where each criterion is assigned an equal weight, determined by the total number of criteria being assessed. The proposed approach is based on the results of a sensitivity analysis given our proposed scores and aggregation methods described herein (see **Section 4.2**).

2.1.2 Classifying scores from WLC

The result of WLC aggregation is a continuous score from 1-3, based on the weighted sum of several factor scores. An equal interval reclassification is used to transform combined WLC scores into discrete suitability ratings ("limited", "moderate", or "good") (**Table 2**). The equal interval approach divides the range of possible continuous scores (1 through 3) into equal-sized subranges.

Table 2. Classification of potential suitability index scores calculated through WLC.

Suitability rating	WLC suitability index score
"Limited"	1 – 1.66
"Moderate"	1.67 – 2.33
"Good"	2.34 – 3

2.2 Rule-based overlay and decision rules

Within the suitability assessment, a rule-based overlay is applied to certain criteria that were identified as influencing the potential for aquaculture development independently of any other criteria. Rather than having scores aggregated alongside other factors, these criteria can not be compensated for. A rule-based overlay procedure can be used to enforce specific conditions into the assessment by introducing decision rules for classification (often through a series of "if then" statements) (Greco et al., 2016). This process ensures that areas meeting specific conditions (decision rules) are automatically assigned a given rating ("limited", "moderate", or "good").

Decision rules are introduced alongside WLC so that critical thresholds are enforced, and essential limitations are not overlooked, regardless of the classification from the WLC.

2.2.1 Proposed decision rules

Some factors may be appropriately considered as decision rules, as they have conditions that can be considered key determinants of overall suitability. For example, water depth reflects a key limiting factor for aquaculture, as it represents a key requirements for aquaculture infrastructure (e.g, netting, mooring). Other criteria have regulatory implications that may require management or further exploration, regardless of the suitability of any other criteria. In these cases, the scoring of that criterion should not be diluted or compensated for by other criteria.

Some constraints may also have additional conditions that could be considered key determinants of overall suitability. Constraint features represented on maps as either points or lines may not represent the full real-world spatial extent of features[12]. There may be additional spatial 'footprints' of these areas that might create use overlaps that may influence the suitability of aquaculture. For example, movement or drift of vessels secured to anchorage points may not be fully captured in mapped point data. Still, these areas should be avoided to allow sufficient navigational safety for anchored vessels. Therefore, it would be appropriate to consider a relevant distance around mapped anchorage points that would be limited for aquaculture, but not necessarily restricted. As such, these areas should be considered as automatically "limited" for aquaculture to appropriately reflect potential data inaccuracies.

Seven factors and three constraints are proposed to be incorporated through rule-based overlay to designate as area as "limited" (**Table 3**). Two factors are proposed to designate an area as "moderate" (**Table 4**). In cases where the decision rule has the same threshold as was determined during scoring and the criterion was scored into only two ratings (such as presence/absence), that criterion will be only incorporated through decision-rules (and not through WLC). Further rationale and justification for proposed decision rules is described in **Appendix ii**.

[12] Point and line geometries in GIS are 'scalable' in that there is no defined "spatial extent" (i.e., width) of the line and points, which increase, or decrease based on the zoom level in the map. Features represented as polygons have distinct spatial boundaries.

Table 3. Criteria selected for rule-based overlay and the conditions that would assign it a **"limited"** classification.

Criterion	Species			
	Salmon	Trout	Mussels	Oysters
Extreme cold exposure	High risk	High risk	NA	NA
Bathymetry	<10 m	<10 m	NA	NA
Wind and wave conditions	NA	NA	<2 m	<2 m
Ice conditions	NA	NA	High risk	High risk
Marine protected and conserved areas[13]	Present	Present	Present	Present
AIS vessel traffic routes	Important vessel routes[14]	Important vessel routes	Important vessel routes	Important vessel routes
Coastal access	<100 m	<100 m	<100 m	<100 m
Designated navigation features	<200 m of ferry routes, navigational aid sight lines, and recommended routes			
Anchorages	<200 m of anchorage points			
Submerged cables and pipelines	<500 m of submerged cables			

Table 4. Criteria selected for rule-based overlay and the conditions that would assign it a **"moderate"** classification.

	Salmon	Trout	Mussels	Oysters
Critical habitat for species at risk	Present	Present	Present	Present

[13] Includes Marine Protected Areas, Migratory Bird Sanctuaries, National Parks, and National Wildlife Areas.
[14] Important vessel routes were identified by mapping on-channel lanes entering and exiting major public ports in Nova Scotia (see Appendix iii).

2.3 Constraints overlay

Constraints identify exclusionary areas to be assigned as "restricted". To view an overview of constraints, see **"Recommendations on Scoring of Criteria"** report. For constraints, only the original mapped features as provided through external data sources will be rated as "restricted". For those features represented as point and line geometries, the spatial extent will be surrounding 100m^2 areas containing that feature[15].

3. Visualizing final results

Results can be communicated through a combination of descriptive, visual, and/or numerical terms, depending on the goals of the project (as an example see **Table 5**). In descriptive terms, final ratings can be visualized by distinct colours (or shades of the same colour) on the map, which can be associated with classifications such as "restricted", "limited", "moderate", and "good". In numerical terms, outputs can also be represented by their numerical suitability score, visualized as discrete values[16] across a defined scale. For ease of interpretation, we apply descriptive terms to final classifications, where the four classification ratings are associated with a relevant colour on the map.

Table 5. Potential options for communicating final classifications on mapped outputs.

Rating (Descriptive)	Rating (Visual)	Rating (Numerical)
Restricted	(red)	0
Limited	(yellow)	1
Moderate	(teal)	2
Good	(purple)	3

[15] This represents the spatial resolution of the assessment. We assign a 'one-cell' area for these features because point and line geometries in GIS are 'scalable' in that there is no defined "spatial extent" (i.e., width).

[16] A continuous range of values is possible for outputs of the WLC but would not be congruent with categorical assignment of ratings from rule-based overlay.

4. Validation processes

4.1 Sensitivity analysis of WLC

To explore the robustness of assessment outputs, a sensitivity analysis will examine how variations in input parameters influence the final suitability results. Sensitivity analysis can assess uncertainties within the MCDA procedure and examine the robustness of the outputs (Malczewski and Rinner, 2015). In this way, sensitivity analysis serves as a quality assurance and quality control (QAQC) measure. This is particularly relevant to suitability scores determined through weighted linear combination, as outputs can be highly variable depending on weighting and scoring decisions. Sensitivity analysis can help determine if any criterion dominates or is supressed in the overall assessment and identify overall assessment limitations and assumptions. Sensitivity analysis will identify these limitations and may inform decisions to support more balanced outputs. Specifically, sensitivity analysis will be performed on suitability maps produced through WLC to ask two questions:

1. How sensitive are results to the proposed weighting of criteria?
2. How sensitive are results to individual criteria?

Within MCDA methods, the most common sensitivity analysis procedure is using a one-at-a-time approach to vary selected input components, rerun the model, and record the corresponding changes in the result (Lilburne and Tarantola, 2009). To explore the sensitivity of weighting, variations in criterion weights will be used to explore whether the weighting approach significantly influences final ratings, to guide decisions around which weighting approach to use. To explore the sensitivity of an individual criterion, the suitability assessment will be re-run by sequentially removing one criterion at a time. Through this process, we can identify whether specific criteria disproportionately affect the final suitability index, or if they contribute very little to the overall assessment.

To assess sensitivity, we will calculate the change in the final suitability rating (limited, moderate, good) between initial (baseline) suitability scores and those produced by each scenario. For all scenarios, the constraints overlay, and decision rules will apply and remain consistent, to identify areas that would change only due to variations in WLC weights. The change between any two scenarios can be mapped by subtracting baseline suitability scores from scores of each scenario to highlight areas that might be more sensitive to changes.

Across the AOA, if more than 25% of cells change final ratings, the results can be considered to have "high sensitivity" and should be considered carefully. High sensitivity is not inherently problematic but would indicate conditions where the weights applied need to be carefully considered and justified to ensure reliability and confidence in outputs.

4.2 Results of preliminary sensitivity analysis for weighting

A preliminary sensitivity analysis for weighting was conducted to explore the implications of the two potential uniform weighting approaches presented in (**Figure 4**):

Scenario A: Each criterion is weighted equally, based on a 'flat' structure

Scenario B: Some criteria are clustered into a 'hierarchy', whereby sub-criteria inherit weights from their parent criterion

This analysis used proposed scoring (see **"Recommendations on Scoring of Criteria"** report) and weights outlined in **Table 6**. Constraints and rule-based overlay (as proposed herein) are also applied for both scenarios. Weighting sensitivity analysis will also be repeated at the end of the assessment to discuss findings and offer additional insights into variations in weighting.

Table 6. Specific weights assigned to each criterion for proposed hierarchy groupings versus alternative flat structure weighting to inform sensitivity analysis. Note that weights are rounded but the total adds up to 100%. N/A = Not applicable to the assessment.

Criteria group	Criteria	Salmon		Trout		Mussels		Oysters	
		A	B	A	B	A	B	A	B
Extreme cold	Extreme cold exposure	12.5%	16.67%	12.5%	16.67%	N/A	N/A	N/A	N/A
Extreme heat[17]	Extreme heat exposure	12.5%	16.67%	12.5%	16.67%	0%*	0%*	N/A	N/A
Water depth	Bathymetry	12.5%	16.67%	12.5%	16.67%	16.67%	25%	16.67%	25%
Exposure	Wind and wave exposure	12.5%	8.33%	12.5%	8.33%	16.67%	12.5%	16.67%	12.5%
	Ice conditions	12.5%	8.33%	12.5%	8.33%	16.67%	12.5%	16.67%	12.5%
Protected ocean habitats[18]	Critical habitats for species at risk	0%	0%	0%	0%	0%	0%	0%	0%
	Marine protected and conserved areas	0%	0%	0%	0%	0%	0%	0%	0%
Vessel traffic	AIS vessel traffic channels	12.5%	8.33%	12.5%	8.33%	16.67%	12.5%	16.67%	12.5%

[17] No weight (0%) is applied for this layer for mussels given some current challenges in the data layer.
[18] No weight (0%) is applied since these criteria are to be aggregated solely through rule-based overlay.

	VMS vessel traffic density	12.5%	8.33%	12.5%	8.33%	16.67%	12.5%	16.67%	12.5%
Public coastal access	Proximity to coastal access	12.5%	16.67%	12.5%	16.67%	16.67%	25%	16.67%	25%
	Total	100%	100%	100%	100%	100%	100%	100%	100%

Results of the preliminary sensitivity analysis shows very little difference in final ratings across the AOA. In all cases, ratings only change by one score (e.g., good to moderate, or moderate to limited). For all species assessed, ratings changed in **less than 1%** of the AOA when comparing the 'flat' structure and 'hierarchical' structure scenarios. Therefore, based on preliminary draft scenarios, results have very low sensitivity to weighting. As such, an equal weighting based on a 'flat' structure (scenario A) can be strongly justified.

This preliminary sensitivity analysis was done to help guide the general approach to weighting, and is based on draft scores, weights, and decision rules that are subject to change. The exercise will be also re-run on final products.

Additional details on the sensitivity analysis process and results are available upon request.

4.3 Multi-user and expert feedback

A feedback process is integral to quality control and validation efforts, ensuring that the assessment is aligned with real-world priorities and based on strong scientific rigor. Throughout the assessment, a combination of technical and scientific experts, industry members, network partners, and government decision-makers provided input on the relevance, scoring, and weighting of criteria, the appropriateness of constraints, and interpretation of preliminary results. Feedback was incorporated iteratively throughout all stages of the assessment by validating criteria selection, adjusting aggregation methods to reflect practical considerations, and identifying potential gaps or uncertainties.

5. Conclusion

In conclusion, this proposed weighting and aggregation approach balances ease of use and communication, reducing bias, and promoting flexibility of the assessment findings. Rule-based overlay is introduced in aggregation to reflect the importance of some conditions and criteria that may supersede an otherwise combined rating. The combination of weighted linear combination with overlay of decision rules and constraints allows for a more accurate and practical classification of areas. The final classification of areas is determined by the combined effect of multiple variables, while acknowledging critical limiting factors and constraints to potential aquaculture development.

While we acknowledge potential nuance that may not be captured, this approach is appropriate for this regional-level assessment and draws on similar assessments of this type in aquaculture.

6. References

Aguilar-Manjarrez, J. (1996). *Development and evaluation of GIS-based models for planning and management of coastal aquaculture: a case study in Sinaloa, Mexico.* (PhD). University of Stirling, Scotland, UK.

Aguilar-Manjarrez, J. et al. (2008). The potential of spatial planning tools to support the ecosystem approach to aquaculture. In *Expert Workshop* (Vol. 17, pp. 176). Rome, Italy: FAO.

Belton, V., Stewart, T. (2002). Multiple criteria decision analysis: an integrated approach Springer Science and Business Media.

Chentouf, S. et al. (2023). GIS-Based Multi-Criteria Evaluation (MCE) Methods for Aquaculture Site Selection: A Systematic Review and Meta-Analysis. *ISPRS International Journal of Geo-Information, 12*(10), 439. *https://www.mdpi.com/2220-9964/12/10/439*

Cinelli, M. et al. (2022). Proper and improper uses of MCDA methods in energy systems analysis. *Decision Support Systems, 163*, 113848.

Cinelli, M. et al. (2020). How to support the application of multiple criteria decision analysis? Let us start with a comprehensive taxonomy. *Omega, 96*, 102261. doi:*https://doi.org/10.1016/j.omega.2020.102261*

Dapueto, G. et al. (2015). A spatial multi-criteria evaluation for site selection of offshore marine fish farm in the Ligurian Sea, Italy. *Ocean & Coastal Management, 116*, 64-77. doi:*http://dx.doi.org/10.1016/j.ocecoaman.2015.06.030*

Dean, M. (2022). A practical guide to multi-criteria analysis. *Bartlett School of Planning, University College London*, 1-85.

Ezell, B. et al. (2021). Methods for Weighting Decisions to Assist Modelers and Decision Analysts: A Review of Ratio Assignment and Approximate Techniques. *Applied Sciences, 11*. doi:*https://doi.org/10.3390/app112110397*

Falconer, L. et al. (2013). Using physical environmental parameters and cage engineering design within GIS-based site suitability models for marine aquaculture. *Aquaculture Environment Interactions, 4*(3), 223-237. *http://www.int-res.com/abstracts/aei/v4/n3/p223-237/*

Gangnery, A. et al. (2021). Web-based public decision support tool for integrated planning and management in aquaculture. *Ocean & Coastal Management, 203*. doi:*https://doi.org/10.1016/j.ocecoaman.2020.105447*

Greco, S. et al. (2016). Decision Rule Approach. In *Multiple Criteria Decision Analysis: State of the Art Surveys* (pp. 497-552). New York, NY: Springer New York.

Lilburne, L., Tarantola, S. (2009). Sensitivity analysis of spatial models. *International Journal of Geographical Information Science, 23*(2), 151-168.

Longdill, P. C. et al. (2008). An integrated GIS approach for sustainable aquaculture management area site selection. *Ocean & Coastal Management, 51*(8), 612-624. doi:*https://doi.org/10.1016/j.ocecoaman.2008.06.010*

Malczewski, J., Rinner, C. (2015) Multicriteria Decision Analysis in Geographic Information Science. In, *Advances in Geographic Information Science*. New York: Springer.

Marttunen, M. et al. (2018). Are objectives hierarchy related biases observed in practice? A meta-analysis of environmental and energy applications of Multi-Criteria Decision Analysis. *European Journal of Operational Research, 265*(1), 178-194. doi:*https://doi.org/10.1016/j.ejor.2017.02.038*

Morris, J. A. et al. (2021). An Aquaculture Opportunity Area Atlas for the Southern California Bight.

Németh, B. et al. (2019). Comparison of weighting methods used in multicriteria decision analysis frameworks in healthcare with focus on low- and middle-income countries. *Journal of Comparative Effectiveness Research, 8*(4), 195–204. doi:10.2217/cer-2018-0102

Petrosillo, I. et al. (2023). Towards sustainable marine spatial planning of aquaculture. *Ecological Indicators, 154*, 110542. doi:*https://doi.org/10.1016/j.ecolind.2023.110542*

Porporato, E. M. D. et al. (2020). Site Suitability for Finfish Marine Aquaculture in the Central Mediterranean Sea. *Frontiers in Marine Science, 6*(772). doi:10.3389/fmars.2019.00772

Silva, C. et al. (2011). Site selection for shellfish aquaculture by means of GIS and farm-scale models, with an emphasis on data-poor environments. *Aquaculture, 318*(3–4), 444-457. doi:*http://dx.doi.org/10.1016/j.aquaculture.2011.05.033*

	Uniform Weighting	Subjective Weighting
Key considerations	• Assumes all criteria are equally important • No detailed analysis required • No subjective judgement required	• Based on the expertise and experiences of those assigning weights • Total weights sum to a fixed number
Advantages	• Simple and easy to apply • Quick to implement • Easy to adjust • Minimizes subjective bias	• Flexible and adaptable • Can incorporate stakeholder input • Acknowledges different importance of criteria to assessment
Disadvantages	• May not reflect true preferences • Ignores differences in criteria importance	• Subjective and may introduce bias • Requires careful consideration and expertise • Time consuming and requires careful justification • Cognitive burden with many (>10) criteria • With many criteria, lower-weighted criteria can be overshadowed, diminishing their impact on the final score
When to use	• When criteria are of similar importance • Limited time or resources	• When judgements on importance are reliable • When detailed information on criteria importance is known • When criteria importance varies significantly

Appendices

Appendix i – Considerations for weighting methods

Table A1.1. Summary of weighting methods and considerations for their use in the assessment.

Appendix ii – Justification of proposed decision rules

Table A2.1. Decision rules and rationale for conditions that would rate an area as **"limited"**.

Criteria	Decision rule	Salmon	Trout	Mussels	Oysters	Rationale
Extreme cold exposure	High risk	✓	✓			High risk areas identify conditions with high likelihood of regular occurrences of extreme cold, posing significant mortality risks for finfish.
Bathymetry	<10m	✓	✓			Represents minimum functional requirements for standard cage infrastructure and considerations for fish health and welfare.
Wind and wave conditions	>2m			✓	✓	Represents wave heights that can be considered 'extreme' exposure, and may pose considerable animal health and welfare risks to cultured species.
Ice conditions	High risk			✓	✓	High risk areas for shellfish have areas exposed at depths where thick drift ice is likely to scour and damage equipment, posing animal health risks that cannot be mitigated by sinking gear.
Marine protected and conserved areas	Present	✓	✓	✓	✓	Higher potential for interactions with protected species and habitats; proponents must investigate potential interactions and likely need substantial mitigation.
AIS Vessel traffic patterns	Important vessel routes	✓	✓	✓	✓	Important vessel routes represent key navigation channels of major public ports, where navigational overlaps would be significant, with little opportunity for mitigation.
Designated navigation features	<200m	✓	✓	✓	✓	Mapped line data is potentially inaccurate to the real-world spatial extent of features. Distances provide an additional margin of safety for vessel traffic overlaps and are calculated through the average width of traffic around features, as estimated by AIS data.
Anchorage areas (points)	<200 m	✓	✓	✓	✓	Mapped point data is potentially inaccurate to real-world spatial extent of features. This distance provides sufficient space for the movement or drift of vessels around

						anchorages and accommodates vessels approaching and leaving anchorage areas.
Submerged cables and pipelines	<500 m	✓	✓	✓	✓	Canadian Hydrographic Service advises fishing gear to maintain 1/4 nautical mile from surface buoys marking cables. This distance ensures adequate space for necessary vessel access for maintenance and repairs, and accounts for potential inaccuracies in line data.

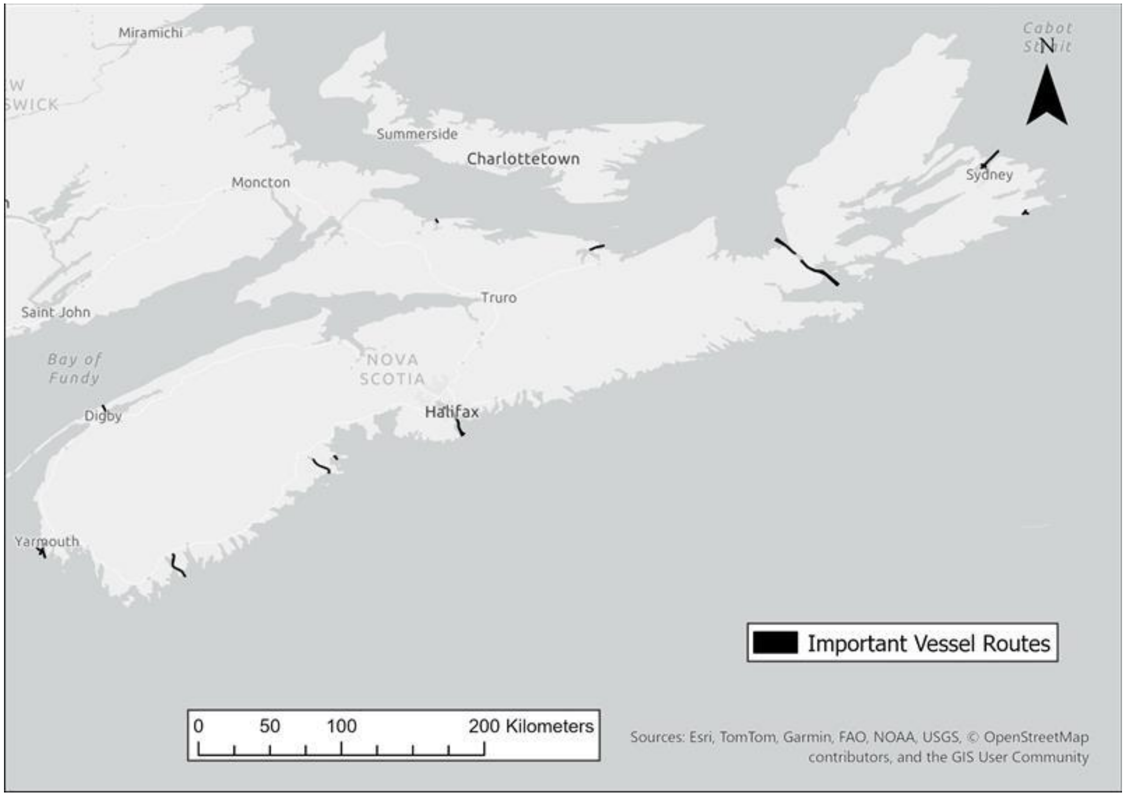
Table A2.2. Decision rules and rationale for conditions that would rate an area as **"moderate"**.

Criteria	Decision rule	Salmon	Trout	Mussels	Oysters	Rationale
Critical habitat for species at risk	Present	✓	✓	✓	✓	Within these areas, proponents would be required to investigate potential interactions with relevant species and habitats.

Appendix iii. Mapping Important vessel routes

"Important vessel routes" were identified using AIS vessel traffic data that identifies main navigation channels based on density of tracklines provided from Department of Fisheries and Oceans AIS data from 2019, 2020, and 2021.

The original dataset identifies on-channel areas across the entire province. However, major high-traffic ports in Nova Scotia have significant marine traffic density such that routes approaching or exiting these ports would be considered.



The bounds of the on-channel traffic lanes entering and exiting ports[19] were mapped manually for eleven ports, including:

- Halifax
- Straight of Canso
- Sydney
- Yarmouth
- Shelburne
- Bridgewater
- Louisbourg
- Pictou
- Digby
- Lunenburg
- Pugwash

[19] Identified as where the central lane of traffic dissipates, splits into multiple routes, or becomes a traffic separation zone

Final v.0.1

Final Summary Report

A report in support of the aquaculture coastal classification system project

May 26, 2025

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Table of Contents

1. Introduction

The location and siting of aquaculture is one of the most important factors in determining the overall sustainability of aquaculture activities in coastal areas. In addressing the critical importance of proper site selection of marine finfish aquaculture, the 2014 *Final Report of the Independent Aquaculture Regulatory Review for Nova Scotia* (henceforth, the "Doelle-Lahey report") recommends the development of a Coastal Classification System for marine finfish aquaculture (Doelle and Lahey, 2014). Following the recommendations in the Doelle-Lahey report, in 2021, the Premier of Nova Scotia mandated the Minister of Fisheries and Aquaculture to create a classification system under which coastal areas would be rated based on their suitability for (finfish) aquaculture (Honourable Tim Houston, 2021).

In supporting the objectives of the *Coastal Classification System (CCS)* for aquaculture in Nova Scotia, the *Centre for Marine Applied Research (CMAR)* is completing large-scale provincial assessments to classify coastal areas based on their potential for finfish and shellfish aquaculture. To assess the potential of areas for aquaculture development, multiple evaluation criteria will be evaluated and rated within a Geographic Information System (GIS) tool, to perform spatial "suitability assessments" for Atlantic salmon (*Salmo salar*), Rainbow trout (*Oncorhynchus mykiss*), Blue mussel (*Mytilus edulis*) and suspended American oyster (*Crassostrea virginica*) culture. The findings from these assessments will be combined into an online mapping tool for users to view spatial information about potential aquaculture development opportunities in Nova Scotia. The outputs include maps showing a combined rating indicating the potential suitability for aquaculture development, as well as data layers of supporting information.

These spatial assessments focus on defining, rating, and combining multiple evaluation criteria relevant to assessing the potential of an area for aquaculture production. These types of assessments have been widely used to explore aquaculture potential (Chentouf et al., 2023) in similar global initiatives to assess suitability for aquaculture (Falconer et al., 2013; Porporato et al., 2020) and develop mapping tools to help identify where opportunities for aquaculture could exist (Aguilar-Manjarrez et al., 2008).

1.1 Purpose of report

This report provides a summary overview of the suitability assessment process. **Section 2** is designed to highlight any changes, adjustments, or alterations that have been made because of ongoing discussions with advisory committees and in response to feedback from the Nova Scotia Aquaculture Science Advisory Committee. In **Section 3**, final outputs of the suitability assessment are presented, including aggregated suitability maps. Finally, **Section 4** presents details on how the online decision-support tool was developed and how assessment results will be integrated and made publicly available.

2. Summary of assessment inputs and methods

The suitability assessments drew on techniques and methods from multicriteria decision analysis (MCDA) (Malczewski and Rinner, 2015) to evaluate the overall potential for aquaculture development in Nova Scotia. This process (**Figure 1**) is a systematic approach to rate and combine multiple important factors that influence aquaculture potential.

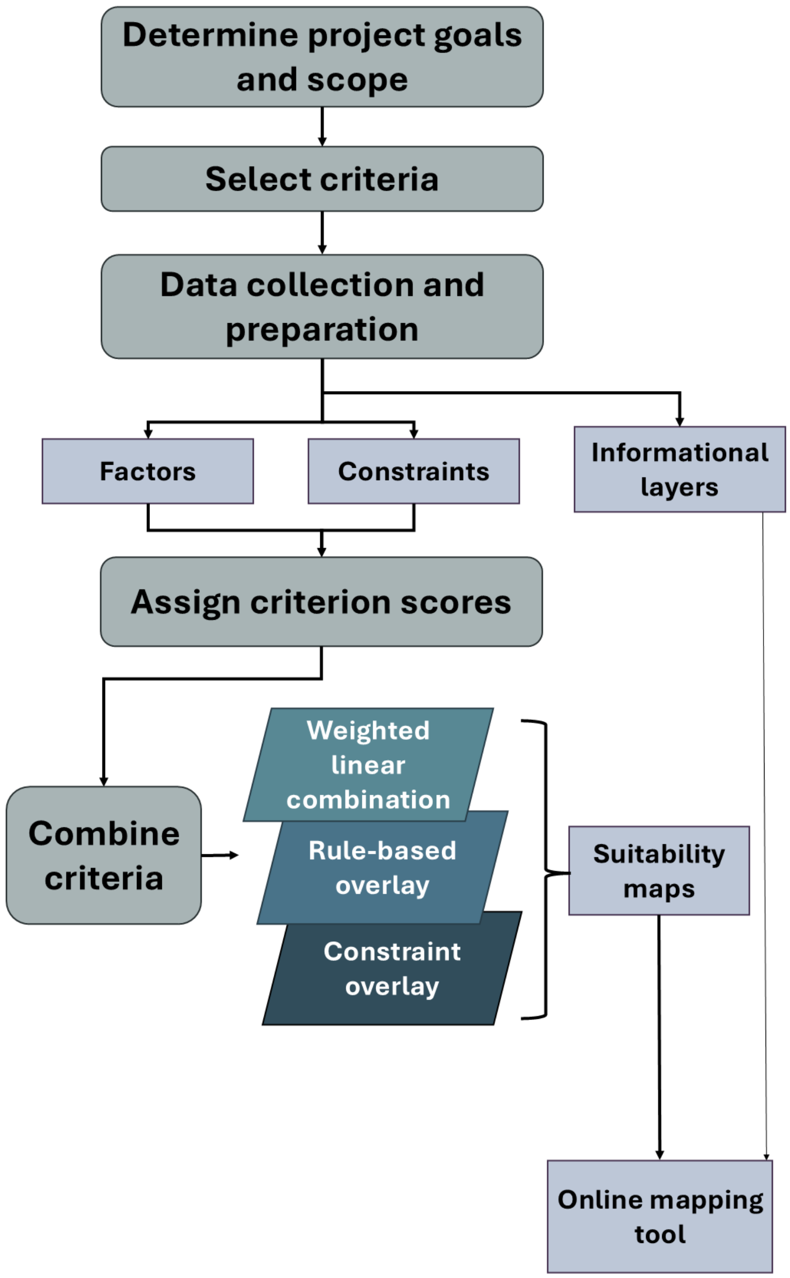

Figure 1. Process flowchart outlining key decisions, methods, and outputs involved in the suitability assessments in support of the aquaculture Coastal Classification System (CCS).

2.1 Assessment scope

2.1.1 Industry focus

The focus of this assessment is on year-round marine grow-out aquaculture for the most prominently cultured species in Nova Scotia, based on past aquaculture practices and anticipated future trends in the province. These include:

- Atlantic salmon
- Rainbow trout
- Blue mussel
- American oyster– suspended culture[1]

This assessment and results are applicable only in consideration of established technologies, management practices, and procedures that are presently used and widely adopted within Nova Scotia[2]. This assessment does not apply to experimental approaches, emerging technologies, and innovations, nor does it assume region-specific practices that have not been widely adopted[3].

2.1.2 A broad-scale assessment for decision-support

This assessment seeks to assess the potential for aquaculture development at a broad, province-wide scale. At this scale, assessments are designed to explore the suitability across a large geographic region, often consisting multiple bays or areas. At this level of analysis, this assessment aims to capture the key considerations that would either constrain and/or limit the culture of species or factors that producers would need to address or account for in placing or planning their aquaculture operations. The outputs are used to understand general patterns and trends across the province and could help identify potential areas of interest for further exploration. These are not site-level, or bay-level assessments. Therefore, the outputs of these assessments are designed to provide decision-support[4] to guide and inform potential producers and government agencies during early stages of aquaculture planning and policy development.

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[1] Only suspended culture is considered in this assessment. Bottom culture production is conducted within the province, but current trends show an increased interest in suspended production methods.

[2] Practices and operations in other jurisdictions are not considered, except to inform on generalized scientific justification on thresholds.

[3] For example, outputs are not applicable to Integrated Multi-Trophic aquaculture (IMTA) or closed containment. Emerging technologies like using genetically modified organisms (GMOs) and stocking triploid fish are also not considered.

[4] It is not designed as a decision-making tool to inform regulatory decisions around individual sites or proposals.

2.1.3 Area of assessment

The area of assessment (AOA) encompasses all marine waters from the coastline of Nova Scotia, up to three kilometres offshore, inclusive of the major jaws of land (**Figure 2**). This boundary was selected to include the present extent of current aquaculture in the province, and to exclude consideration for more offshore aquaculture operating in higher-energy areas beyond three kilometres (Howarth et al., 2022). Inland waters (e.g. rivers, lakes), land-based production, and brackish-water environments are not included in this assessment.

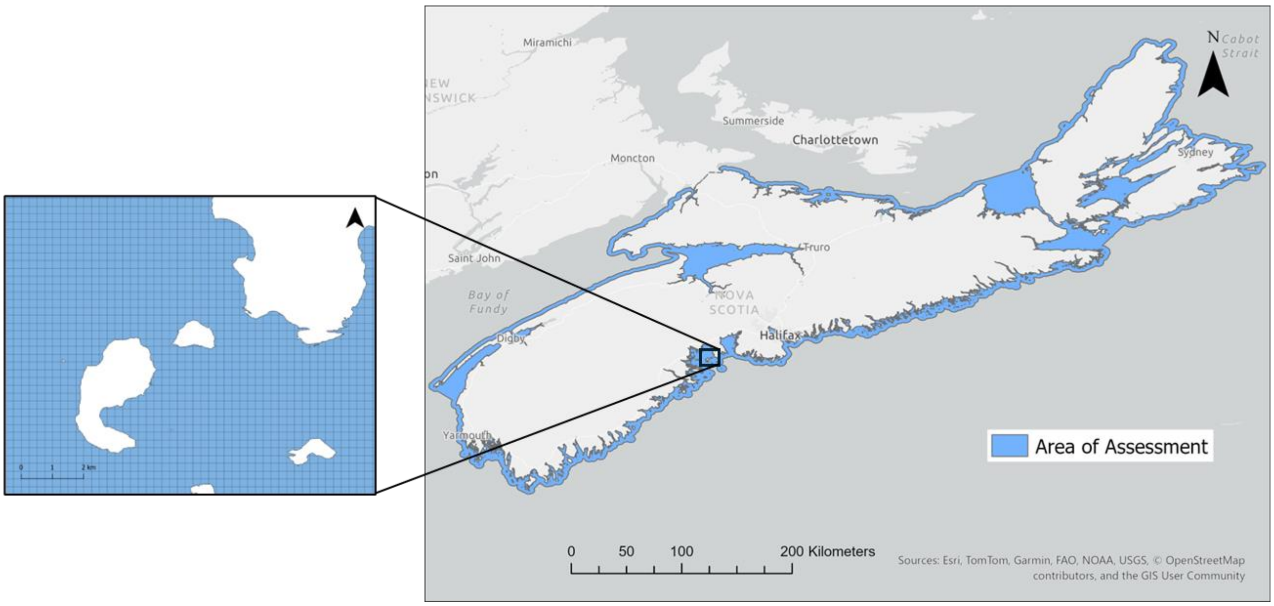

Figure 2. Area of assessment (AOA). For suitability analysis, AOA is gridded to show the units of assessment as an area defined by multiple equal-sized “cells” within a larger grid.

To calculate final ratings of aquaculture development potential, suitability analysis was conducted within a gridded overlay across the AOA. A grid represents the AOA as regular polygons ‘cells’ repeated over a surface with no gaps or overlaps. The grid cell size was determined to reflect both the spatial resolution of the underlying data and factors such as processing time and relevance to the analysis. As such, a spatial resolution of 100 metres was determined based on the datasets used and the goals of the assessment.

2.2 Criteria selection

The types of information (criteria) included in the assessments were reviewed to identify those relevant to the broad-scale assessment of aquaculture development potential in Nova Scotia, considering a range of factors that may make an area more or less suitable for aquaculture.

Criteria were selected to focus on restrictions and considerations related to the following objectives:

A. the **biophysical conditions** required for the health and well-being of the farmed species;
B. supporting **environmental protection and conservation** of significant habitats and species; and,
C. reducing potential **overlaps with other marine activities.**

To be included, the criteria had to be associated with at least one of the three objectives above and had to meet eight specific requirements to be used in the analysis (**Figure 3**)[5]. The criteria included reflect information that is measurable and fit for purpose for the specific goals of the assessment.

Figure 3. Inclusion of criteria was based on information that met eight selection properties.

[5] Definition of properties and further description of the process used to evaluate criteria against properties can be found in the earlier *Recommendations of Criteria* report (Colombo, 2024).

2.2.1 Types of criteria

To acknowledge limitations in assessing suitability and mapping complex considerations, criteria were categorized into three different criterion types. The final potential suitability ratings were determined using the factors and the constraints.

Factors can either enhance or detract from the potential for aquaculture development in an area. Each factor gets individually scored (lower to higher suitability) and then combined to calculate potential suitability ratings.

Constraints identify areas of exclusion for aquaculture development. To be considered a constraint, the criterion must identify a region or feature that would absolutely exclude aquaculture development, either due to direct spatial overlaps with infrastructure (e.g. submerged cables and pipelines), interference with designated activities or uses (e.g. anchorage areas), or areas considered legislatively restrictive (e.g. Marine Renewable Energy Areas).

Informational criteria provide important knowledge for understanding aquaculture development potential, but cannot be included within the suitability analysis due to data or knowledge limitations[6]. These criteria do not contribute to the final classification rating but are included as spatial layers in the final tool so that users can view additional information important to understanding suitability for aquaculture development.

2.2.2 Criteria included

The criteria included are outlined in **Table 1**. Assessed species require different criteria due to species-specific biophysical requirements, environmental interactions, and culture techniques. The criteria have been selected to reflect current marine conditions, sector needs, industry regulations, and aquaculture practices and technologies, as well as the existing state of knowledge and data availability at the time of the assessment.

Some relevant criteria were excluded from the assessment as they were not practical or appropriate to include in the assessment, based on an evaluation of the eight selection properties (**Figure 3**). Other criteria were beyond the scope of the assessment, such as those to measure optimal growing conditions or production needs. Production scale and site layout are more reflective of carrying capacity[7] and require a different data and modelling approach. These components are addressed in a separate initiative (Farming in Natural Systems-FINS).

[6] Determined if the criterion has either 1) insufficient data across the AOA; 2) limited reliability in the knowledge or information to score criteria, and/or 3) significant variability in what would make the criteria 'suitable' for aquaculture (e.g., highly dependent on local contexts).
[7] For example, a site might be suitable for 50,000 fish but not 500,000.

Table 1. Criteria included in assessments and their type / applicability to species assessed.

Criterion	Criterion Type	Finfish		Shellfish	
		Salmon	Trout	Mussels	Oysters
Extreme cold exposure	Factor	✓	✓		
Extreme heat exposure	Factor	✓	✓	✓	
Bathymetry	Factor	✓	✓	✓	✓
Drift Ice Risk	Factor	✓	✓	✓	✓
Wind and wave conditions	Factor	✓	✓	✓	✓
Critical habitat for species at risk	Factor	✓	✓	✓	✓
Marine protected and conserved areas	Factor	✓	✓	✓	✓
AIS vessel density patterns	Factor	✓	✓	✓	✓
VMS fishing vessel density patterns	Factor	✓	✓	✓	✓
Public coastal access	Factor	✓	✓	✓	✓
Anchorage areas	Constraint	✓	✓	✓	✓
Designated navigation features	Constraint	✓	✓	✓	✓
Marine Renewable Energy Areas	Constraint	✓	✓	✓	✓
Submerged cables and pipelines	Constraint	✓	✓	✓	✓
At-sea disposal sites	Constraint	✓	✓	✓	✓
CFIA disease restricted zones	Informational				✓
Shellfish Water Classification Program	Informational			✓	✓
Wild salmon rivers	Informational	✓			
Coastal wetlands	Informational	✓	✓	✓	✓
Terrestrial protected areas and parks	Informational	✓	✓	✓	✓
Important bird habitat	Informational	✓	✓	✓	✓
Existing aquaculture	Informational	✓	✓	✓	✓
Water lots	Informational	✓	✓	✓	✓
Crown leases and easements	Informational	✓	✓	✓	✓

2.3 Data acquisition and processing

For all criteria, data were selected that represent the most authoritative and highest resolution available. Spatial data layers were acquired from public sources (such as the Government of Canada Open Data Portal and the Nova Scotia Open Data Portal), developed through 'in-house' analysis[8], or provided through engagement with provincial and federal government agencies. Data was checked for completeness and quality, and the most up-to-date sources were used.

Many datasets required processing prior to use in the suitability analysis or inclusion in the final online platform. All data were projected and analysis performed using the Transverse Mercator projection based on the North American Datum of the Canadian Spatial Reference System (NAD 1983 CSRS UTM Zone 20N) for the Atlantic Canadian region. Methods applied for all datasets requiring some processing will be included in the final project reporting. Many datasets were provided in 'ready to use' formats, and notes on methods can be found within the data originator (see provided sources and data download locations in **Appendix i**).

2.4 Suitability analysis

A gridded suitability analysis was performed to calculate the suitability rating of all 'cells' within the AOA. The suitability analysis combines three methods commonly used in GIS-MCDA and the final ratings are based on the lowest rating across any of the three methods:

1. **Weighted Linear Combination (WLC)** combines factors through a weighted sum of scores, so that final ratings reflect the suitability of areas when considering multiple factors.
2. **Rule-based overlay** identifies areas that will be automatically assigned a "limited" or "moderate" rating due to the presence of critical conditions that would influence the suitability, regardless of the presence of any other factor.
3. **Constraints overlay** identifies areas that will be automatically assigned a "restricted" rating due to the presence of exclusionary restrictions that would preclude aquaculture.

Criteria are aggregated through different methods, depending on a) the criteria type, b) the presence of a limiting factor, and c) how the criterion was scored (**Figure 4**). Criteria can be included through multiple methods if they have both conditions that are limiting, and separate conditions that influence suitability and need to be incorporated (either through WLC or constraints). Together, these three MCDA methods ensure that the final classification of areas is determined by the combined effect of multiple variables, while acknowledging critical limiting factors and constraints to potential aquaculture development.

[8] Using data produced or contracted for, and by, CMAR for this project, such as through CMAR's Coastal Monitoring Program.

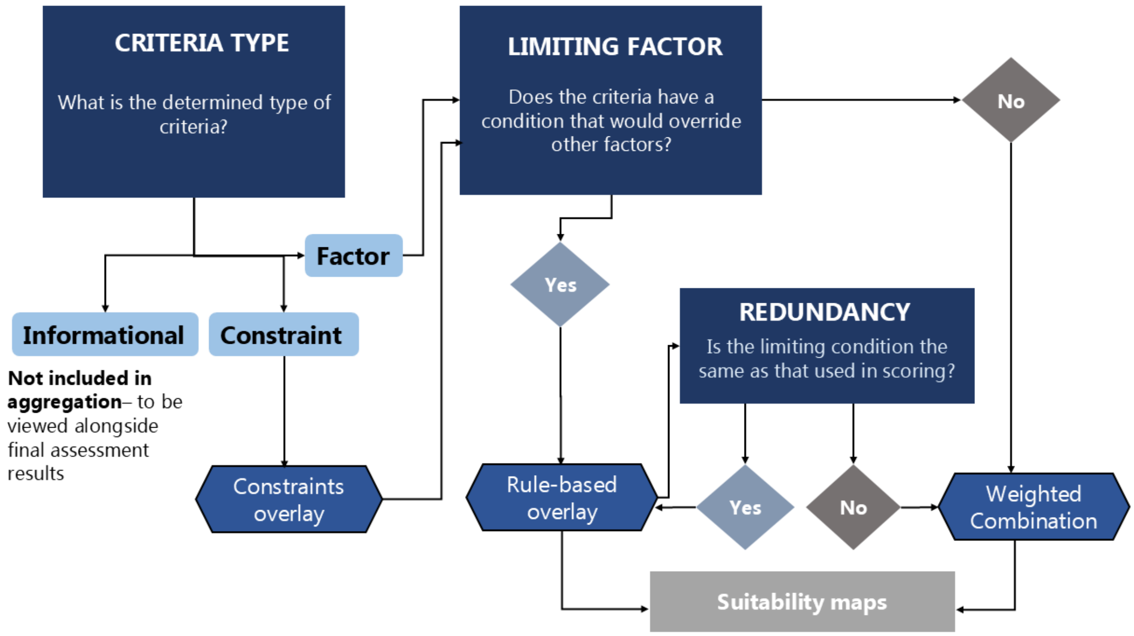

Figure 4. Decision flowchart describing considerations when determining the aggregation method(s) applicable to a given criterion.

Final suitability scores are presented in maps as one of four ratings:

Restricted: Unsuitable for aquaculture development.

Limited: Generally expected to have substantial challenges for aquaculture development and would require significant management or mitigation.

Moderate: Generally expected to be reasonable for aquaculture development, with further investigation needed to explore potential impacts or appropriate management and mitigation.

Good: Generally expected to be well suited for aquaculture development.

Presenting categorical ratings rather than numerical scores simplifies the interpretation of results. Within the final suitability maps, colours are used to represent the ratings.

2.4.1 Weighted combination

To aggregate criteria that combined alongside other factors, we apply weighted overlay procedures in GIS, following a general weighted linear combination (WLC) process:

$$S = \sum_{i=1}^{n} w_i \times c_i$$

S = Suitability index
w_i = Weight assigned to criterion i
c_i = Score of criterion i
n = Total number of criteria

To execute weighted overlay, each factor was first reclassified onto a common scale where 1 = limited, 2 = moderate, and 3 = good, based on the definitions of ratings outlined above. Factor scores were assigned by drawing on an established threshold and/or advice from scientific literature, as well as regulatory and legislative requirements, and industry practices / guidelines.

Before factors can be combined, weights are assigned to reflect the relative importance of each criterion[9]. For this assessment, each criterion was weighted equally. Equal weighting reduces subjective bias in assigning weights, which may differ based on priorities and local contexts[10].

The result of the weighted combination is a continuous suitability index ranging from 1-3, based on the weighted sum of several factor scores. An equal interval reclassification[11] is used to transform combined WLC scores into ratings (limited = 1 – 1.66, moderate = 1.67 – 2.33 good = 2.34 – 3).

2.4.2 Rule-based overlay

Within the suitability assessment, a rule-based overlay (Greco et al., 2016) is applied to certain criteria with conditions present that would influence the potential for aquaculture development independently of any other criteria (**Figure 4**). To apply this method, areas meeting specific conditions (decision rules) are automatically assigned a given rating based on how they influence aquaculture development potential. Decision rules ensure that critical thresholds are enforced, and essential limitations are not overlooked or diluted through WLC.

Eight factors and three constraints were identified to have conditions for rule-based overlay where areas would be automatically rated as either 'limited' or 'moderate'[12] (see **Appendix i** to see decision rules applied). Factors with decision-rules either have conditions that were considered

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[9] Weights are represented as a percentile number between 0 and 1, and across all criteria, must sum to 1 (or 100%).
[10] While criteria can influence aquaculture suitability differently, equal weighting was determined as the most appropriate given the goals of this assessment, guided by a sensitivity analysis supporting varying weighting approaches.
[11] The equal interval approach divides the range of possible continuous scores (1 through 3) into equal-sized subranges.
[12] No areas would be automatically rated as 'good' since there are no conditions considered in this assessment that would make an area automatically highly suitable for aquaculture development.

key determinants of suitability (e.g. high risk of extreme cold exposure that could lead to significant mortality risks for finfish aquaculture) or have regulatory implications that would be enforced regardless of the presence of any other criteria. For constraints, features represented on maps as either points or lines may not represent the full real-world spatial extent of features, and thus decision rules were proposed.

2.4.3 Constraint overlay

Constraints identify exclusionary areas, that when overlaid with ratings from WLC or rule-based overlay, the final rating would be assigned as 'restricted'. For those constraint features represented as point and line geometries, the spatial extent will be surrounding 100m^2 areas containing that feature[13].

2.4.3 Determining final suitability ratings

Final suitability ratings are determined by overlaying outputs from weighted combination with decision rules and constraints. As the different methods may produce different final ratings, the lowest score derived from any of the three methods will be used as the final suitability rating[14]. The resulting maps show a range of suitability ratings at each 100m^2 area within the wider AOA such that final ratings reflect either:

- A combination of factors that make an area have a specific overall rating for development potential, as determined through WLC; or
- The presence of a key condition (constraint or decision rule) that influences aquaculture development potential independent of any other criterion.

2.5 Assumptions, caveats, and future actions

This assessment provides broad-scale suitability assessments at a province-wide level. The suitability analysis produces findings at a 100m^2 resolution. However, not all datasets are resolved at that spatial granularity. Thus, it is inappropriate to use the assessment outputs for a site-level assessment of aquaculture suitability. Rather, the outputs are designed to offer sufficient resolution to assess regional patterns of suitability and identify broader areas that may or may not be suitable for aquaculture development.

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[13] This represents the spatial resolution of the assessment. We assign a 'one-cell' area for these features because point and line geometries in GIS are 'scalable' in that there is no defined "spatial extent" (i.e., width).

[14] If a criterion is rated as 'limited' from WLC but there is a decision rule which rates it as 'moderate', the WLC rating supersedes.

This assessment is not a fully comprehensive evaluation of all potential factors or data relevant to selecting optimal sites for aquaculture in Nova Scotia. The exclusion of some criteria does not mean that it is not important to aquaculture. Additional considerations would be evaluated during site application stages and are considered during aquaculture lease and licensing processes. This suitability assessment does not consider relevant infrastructural needs of producers. It also does not include societal preferences, or interactions on social capital, communities, or the viability of other industries. As such, this assessment is not designed to identify the most optimal sites for production, nor would they guarantee the successful development of potential operations. Other assessment tools and regulatory processes exist to capture relevant criteria not included in these assessments. As such, the results of this assessment and final suitability maps may not be appropriate for exploring the suitability of existing aquaculture sites.

This assessment applies the most recently available data, which may vary as a function of collection or publication time and does not necessarily reflect real-time conditions. The assessment does not predict long-term trends or project future changes beyond the project. It does not consider how potential environmental changes (such as climate change) will influence the criteria nor aquaculture practices and suitability. In addition, it does not consider short-term, seasonal/inter-annual variability, and anomalies (e.g. extreme weather events) which may affect the relevance of the results.

Not all relevant datasets could be used, as the assessment only includes data that is available across the entire AOA and at the resolution appropriate for a province-wide assessment. Therefore, the results of this assessment are directed by criteria that have available and measurable data. Some criteria are acknowledged as critical for aquaculture suitability (e.g. oxygen availability, current and flushing rate, primary productivity), yet were not included in these assessments due to insufficient data available. Potential data gaps are acknowledged, and uncertainties are reported for transparency.

2.5.2 Further development and review

This assessment was based on current practices, data, and policies at the time of the assessment. Thus, the results cannot be assumed to be appropriate for perpetuity. As criteria represent a broad array of considerations and data, different layers may require updating at different intervals. Thus, a multi-layered maintenance plan is recommended and will be outlined in the project's final technical reporting, to be released following the launch of the mapping platform.

Revision and maintenance of the tool so that assessments are up to date will improve the accuracy and usefulness of the assessments. This may include updating criteria layers with new or improved data on a regular basis. Furthermore, new datasets may become available that would improve measurement reliability of some of the criteria included as informational layers or some criteria excluded from the present assessment. The assessment process developed here permits the incorporation of new criteria and datasets. It is flexible in design so that the general process can be readily adapted to potential changes or additions.

There is opportunity for continued research, data collection, and contribution to this tool to improve its reliability and usefulness over time. Further opportunities for research, data collection, and analysis to support future iterations of this assessment will be discussed in the final technical reporting. In addition, opportunities for expanding the scope of these assessments to other spatial scales (e.g., bays of interest) and other species (e.g. marine plants) will likewise be discussed subsequently.

3. Results

Assessments resulted in a final suitability map[15] for salmon (**Figure 5**), trout (**Figure 6**), mussel (**Figure 7**), and oyster (**Figure 8**) aquaculture, depicting high-level potential suitability for aquaculture development.

In Nova Scotia marine waters, approximately 2% of the assessed area was considered 'restricted' for aquaculture development, based on a combination of constraint features (**Table 2**). Further exploration of results, including summaries by aquaculture development regions outlined in Stantec (2009), will be outlined in the final technical reporting.

Table 2. Percentage of area of assessment (AOA) assigned as either restricted, limited, moderate, or good for the potential for aquaculture development of each of the four species assessed.

	Species			
Rating	Salmon	Trout	Mussel	Oyster
Restricted	2.13%	2.13%	2.13%	2.13%
Limited	71.26%	71.25%	79.80%	77.15%
Moderate	1.36%	0.49%	4.59%	7.17%
Good	25.26%	26.13%	13.49%	13.54%

[15] The colours used to represent ratings in the referenced maps below are not final and may change based on feedback from accessibility audits and user testing.

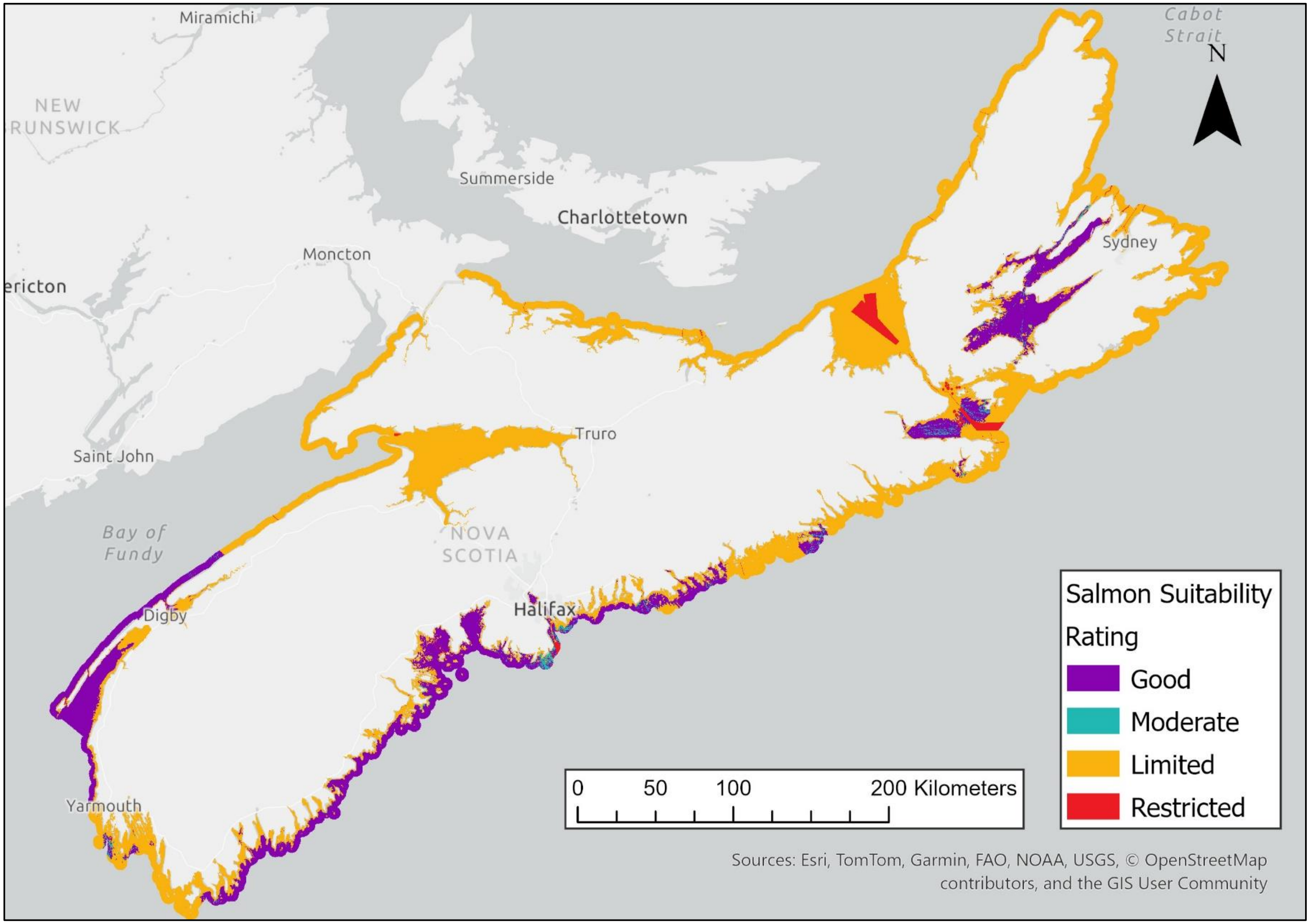

Figure 5. Aquaculture development potential ("suitability") ratings for Atlantic salmon (*Salmo salar*) across Nova Scotia's coastal waters.

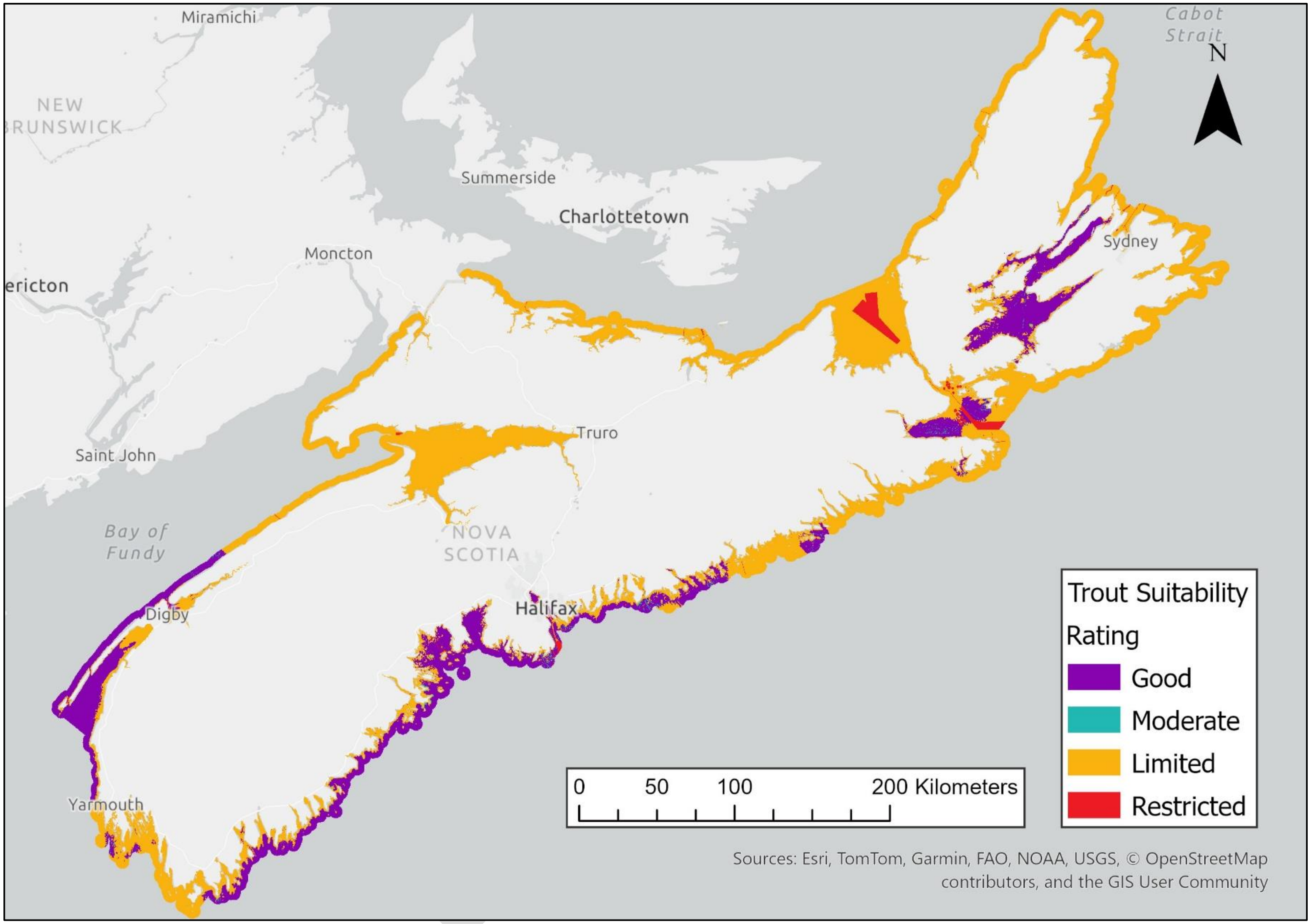

Figure 6. Aquaculture development potential ("suitability") ratings for Rainbow trout (*Oncorhynchus mykiss*) across Nova Scotia's coastal waters.

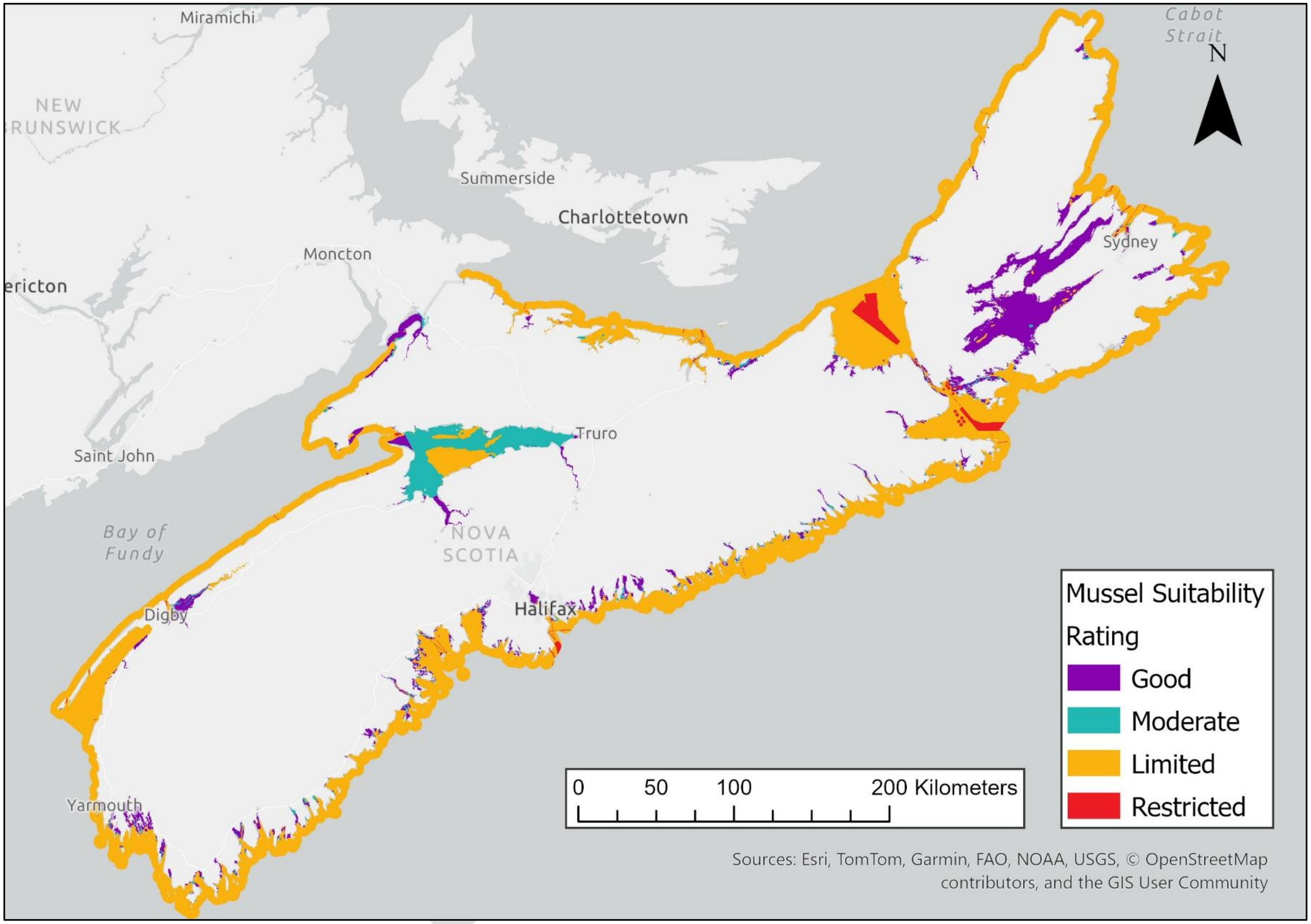

Figure 7. Aquaculture development potential ("suitability") ratings for Blue mussel (*Mytilus edulis*) across Nova Scotia's coastal waters.

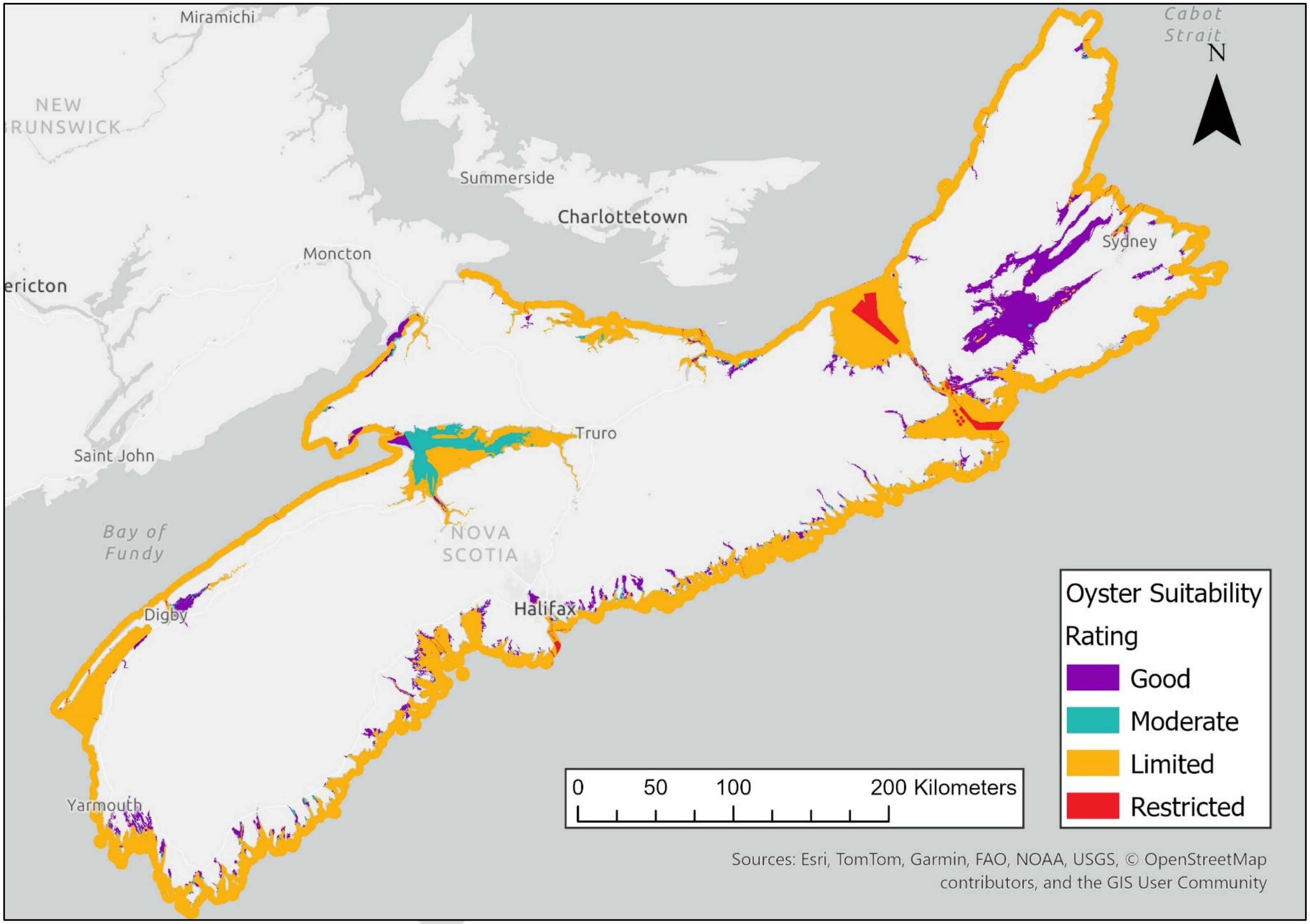

Figure 8. Aquaculture development potential ("suitability") ratings for American oyster (*Crassostrea virginica*) across Nova Scotia's coastal waters.

4. Development of the online mapping platform

4.1 Design and implementation

The results of the suitability assessments in support of the aquaculture Coastal Classification System will be publicly accessible through the Government of Nova Scotia website. The web-based platform consists of both an online mapping tool and an ArcGIS Story Map that will allow users to view the generated[16] suitability maps, as well as get more information about the criteria and information that was used during the assessment.

The online mapping tool was developed using ArcGIS Experience Builder platform. This 'out-of-the-box' platform is a sustainable system that is easy to use, adjust, and manipulate. The graphical user interface has several features, including a main map area and a series of tabs atop where users can navigate different portions of the tool. Various tabs can allow users to toggle between suitability outputs and other pertinent information, including criteria data layers and additional resources about the project. The tool will also include interactivity features, such as allowing users to zoom in and out of different spatial scales, or functions like measurement and drawing tools.

To provide users with additional, easily digestible information on the project inputs, data, and processes, the outputs will also be aggregated onto an ArcGIS StoryMap application that will share the outputs of the suitability analysis through a combination of background text, interactive maps, and other multimedia content.

The design of the mapping tool and Story Map were developed with functionality and accessibility in mind. We contracted Pisces RPM to conduct accessibility audits of the draft and final tools to ensure the main maps as well as all graphical and textual elements met accessibility standards.

The mapping platform will be housed and retrained on CMAR's internal server but hosted on the Government of Nova Scotia website. The mapping platform will be dynamic as it will be regularly updated on a defined schedule to maintain relevancy.

4.2 Integration of suitability assessment results

Multiple map layers were created to represent different aspects of the assessment, and include:

- **Suitability ratings** – maps showing areas classified into "restricted", "limited", "moderate", or "good" aquaculture development potential, for each assessed species
- **Data layers** – individual layers for each criterion used in the assessment

[16] The tool will allow users to explore the outputs of the analysis but not adjust the data or suitability model to generate different results.

- **Informational data** – individual layers showing informational criteria

These map layers are integrated into the online platform so that users can view both assessment results and the types of criteria and data that was used to inform final ratings. Appropriate links to original data sources are also available within the online mapping platform.

Additional information about the assessment methods, as well as the relevance and scoring of each criterion, will be integrated within the ArcGIS Story Map. The Story Map will also contain a tool guide that will provide users with more information on how to use the mapping tool.

4.3 User testing and feedback

The online mapping platform was developed through iterative improvements, based on recommendations and products developed by the creative services provider Rhyme & Reason Agency and through accessibility audits (see **Section 4.1**) and user testing conducted by Pisces RPM.

Useability testing on a 'mock'[17] draft platform was performed to gather potential user feedback on the functionality and design of the draft platform. This testing is not designed to gather public input on any data or criteria, or evaluate responses to the assessment outputs, but rather to understand user functionality. The final design of the platform, as well as the colours used to represent suitability ratings will be guided by results from user testing and accessibility audits. Further details on the user testing and accessibility audits will be provided in final technical reporting.

4.4 Deployment and Maintenance

The final maps and data layers will be deployed on a secure server maintained by CMAR. The online platform (mapping tool and Story Map) will be imbedded as an open accessible web-link on the Government of Nova Scotia website. A maintenance plan will be established and included in final technical reporting to ensure the platform stays up to date and provides necessary user support.

[17] The 'mock' platform does not include any real data, maps, or assessment outputs.

References

Aguilar-Manjarrez, J. et al. (2008). The potential of spatial planning tools to support the ecosystem approach to aquaculture. In *Expert Workshop* (Vol. 17, pp. 176). Rome, Italy: FAO.

Chentouf, S. et al. (2023). GIS-Based Multi-Criteria Evaluation (MCE) Methods for Aquaculture Site Selection: A Systematic Review and Meta-Analysis. *ISPRS International Journal of Geo-Information, 12*(10), 439. https://www.mdpi.com/2220-9964/12/10/439

Colombo, S. (2024). Nova Scotia Aquaculture Science Advisory Committee science advice on the recommended criteria for the aquaculture coastal classification system (NSASAC-2024-01). Dr. Stefanie Colombo, Chair, Nova Scotia Aquaculture Science Advisory Committee https://novascotia.ca/fish/aquaculture/research-development/NSASAC_2024-01_Science_Advice_Binder.pdf

Doelle, M., Lahey, W. (2014). A new regulatory framework for low-impact/high-value aquaculture in Nova Scotia: The final report of the independent aquaculture regulatory review for Nova Scotia. https://novascotia.ca/fish/documents/Aquaculture_Regulatory_Framework_Final_04Dec14.pdf

Falconer, L. et al. (2013). Using physical environmental parameters and cage engineering design within GIS-based site suitability models for marine aquaculture. *Aquaculture Environment Interactions, 4*(3), 223-237. http://www.int-res.com/abstracts/aei/v4/n3/p223-237/

Greco, S. et al. (2016). Decision Rule Approach. In *Multiple Criteria Decision Analysis: State of the Art Surveys* (pp. 497-552). New York, NY: Springer New York.

Honourable Tim Houston. (2021). Ministerial Mandate Letter to the Honourable Steve Craig. https://novascotia.ca/exec_council/letters-2021/ministerial-mandate-letter-2021-FA.pdf

Howarth, L. M. et al. (2022). Supporting the development of of offshore aquaculture in Nova Scotia. Centre for Marine Appplied Research (CMAR), COVE, Dartmouth, Nova Scotia. https://cmar.ca/supporting-the-development-of-offshore-aquaculture/

Malczewski, J., Rinner, C. (2015) Multicriteria Decision Analysis in Geographic Information Science. In, *Advances in Geographic Information Science*. New York: Springer.

Porporato, E. M. D. et al. (2020). Site Suitability for Finfish Marine Aquaculture in the Central Mediterranean Sea. *Frontiers in Marine Science, 6*(772). doi:10.3389/fmars.2019.00772

Stantec. (2009). Road map for aquaculture Investment in Nova Scotia. https://novascotia.ca/fish/documents/roadmapforaquaculture-rpt2010.pdf

Appendix i.

Table A1. Criteria included in suitability assessments for various species (S = salmon, T = trout, O = oysters, M = mussels), their associated data sources and processing, scoring, and rules used to determine suitability as well as associated comments and rationale. Scoring includes both a description of the decision rule if present (as automatically assigned a given rating), or the scores assigned for weighted combination (1 = limited, 2 = moderate, and 3 = good).

Criteria	Data source (s)	Data processing for source map	Species	Scoring	Comments/Rationale
Extreme cold exposure	Coastal Monitoring Program data - CMAR, supplemented by GHRSST Level 4 MUR Global Foundation Sea Surface Temperature	Risk ratings were determined by classifying the annual likelihood of extreme cold exposure, which was calculated by how often temperatures reached at or below -0.7 °C and interpolated across the area of assessment (AOA). Sea surface data points were added for complete coverage.	S, T	High-risk areas were automatically assigned a 'limited' rating. Medium risk areas were given a score of 2, and low risk a score of 3.	Extreme low water temperatures can pose significant mortality risks to finfish.
Extreme heat exposure	Coastal Monitoring Program data - CMAR, supplemented by GHRSST Level 4 MUR Global Foundation Sea Surface Temperature	Risk ratings were determined by classifying the likelihood of exposure to extreme heat, which was calculated by how often heat stress events occurred in an area, defined by the length of time water temperatures reached a critical temperature for species, and interpolated across the AOA. Sea surface data points were added for complete coverage.	S, T, M	Areas with high risk of extreme heat exposure were given a score of 1, medium risk a score of 2, and low risk a score of 3.	Exposure to prolonged elevated water temperatures can lead to heat stress, including impaired growth, reduced disease immunity and in some cases, mortality.
Bathymetry	General Bathymetric Chart of the Oceans (GEBCO); Canadian Hydrographic	Elevation data from NONNA bathymetry was extracted for marine areas to identify water depths below sea level. Data gaps were filled with GEBCO datasets.	S, T	Depths below 10 metres were automatically assigned a 'limited' rating.	Aquaculture operations must have sufficient water depth to accommodate infrastructure. Operations in shallow waters can have elevated welfare risks to cultured
			M	Depths below 5 metres were given a score of 1, and above 5 metres were given a score of 3.	

Criteria	Data source (s)	Data processing for source map	Species	Scoring	Comments/Rationale
	Service Non-Navigational (NONNA) Bathymetric Data		O	Depths below 2 metres were given a score of 1, and above 2 metres were given a score of 3.	species and increase risks of bio-deposition on seafloor environments.
Drift ice risk	Ice products produced by NSCC's Applied Geomatics Research Group for CMAR	Ice exposure risk was based on drift ice observations reported between 2014 – 2024, compiled through historical ice conditions across the AOA. In the case of shellfish aquaculture, risk was determined by considering drift ice frequency, as well as whether the bathymetry would be sufficient to avoid maximum drift ice thickness, or whether there is sheltering within the bay.	S, T	Areas with high risk of drift ice were given a score of 1, medium risk a score of 2, and low risk a score of 3.	High risk areas increase potential exposure to ice that can damage infrastructure or lead to accidental escape of farmed fish into the marine environment.
			M, O	Areas with a high risk of drift ice were automatically assigned a 'limited' rating. Areas with medium risk were given a score of 2, and low risk a score of 3.	In areas where gear can not be submerged, drift ice can scour equipment and lead to mechanical damage and mortality of shellfish.
Wind and wave conditions	Nova Scotia Wind-generated Wave Exposure Atlas - DSA Ocean for CMAR	Based on wind-derived wave exposure modelling that identifies maximum wave height (m) reported across a 10-year period (2014-2024).	S, T	Maximum significant wave heights above 5.5 metres were given a score of 1, between 4 and 5.5 metres were given a score of 2, and below 4 metres given a score of 3.	High wave exposure increases the risk of exposure-induced stress, physical injuries, and potential for infrastructure damage.
			M, O	Maximum significant wave heights above 2 metres were automatically assigned a 'limited' rating, with 1 to 2 metres given a score of 2, and under 1 metre a score of 3.	
Critical habitat for species at risk	Critical Habitat for Aquatic Species at Risk - Canada ; Critical Habitat for Species at Risk National Dataset - Canada	Critical habitat for species at risk in marine waters was identified.	All	Areas within a critical habitat for species at risk were automatically assigned a 'moderate' rating.	Critical habitats are protected under the Species at Risk Act and would require further investigation of potential interactions with relevant species and habitats.

Criteria	Data source (s)	Data processing for source map	Species	Scoring	Comments/Rationale
Marine protected and conserved areas	Canadian Protected and Conserved Areas Database (CPCAD)	The presence of a marine protected and conserved area was identified by extracting any 'marine' area within the datasets.	S, T	Marine protected and conserved areas were automatically assigned a 'limited' rating.	Protected areas have regulatory preclusions that may limit aquaculture operations and require significant attention to ensure no negative impacts to protected species and habitats.
			M, O	Marine protected and conserved areas were automatically assigned a 'moderate' rating.	
AIS vessel density patterns	Automatic Identification System (AIS) track line data from 2019, 2020, and 2021 provided by DFO	Classes of navigation channels were identified based on calculating the density of AIS track lines and applying spatial analysis to identify density clusters.	All	Areas identified as 'important vessel routes' were automatically assigned a 'limited' rating. Areas 'on-channel' of navigational routes were given a score of 1, 'near-channel' given a score of 2, and 'off-channel' a score of 3.	Areas of higher vessel traffic may introduce navigational hazards due to overlap with aquaculture infrastructure and activities.
VMS Fishing vessel density patterns	Vessel Monitoring System (VMS) data from 2019, 2020, and 2021 provided by DFO	Fishing vessel traffic density classes were identified by calculating the density of VMS data points. Data was reclassified based on quartile distribution into evidence-based density classes.	All	High traffic areas were given a score of 1, medium traffic areas were given a score of 2, and low traffic areas a score of 3.	Areas of higher vessel traffic may introduce navigational hazards due to overlap with aquaculture infrastructure and activities.
Public coastal access	Multiple	Locations of potential public coastal/ocean access points were compiled from multiple sources: • Coastal beaches (Ecological Land Classification, Protected beaches provided by Nova Scotia DNR) • Small craft harbours (DFO) • Public boat launch sites (NSDFA) • Marinas and yacht clubs (CMAR) The distance (m) of areas to the nearest public coastal access point was calculated for each public access point site.	All	Areas within 100 m of a public access point were automatically assigned a 'limited' rating.	Aquaculture within close proximity to areas used by the public to access the ocean may interfere with access to the ocean and coastal spaces for recreation, tourism, etc.

Criteria	Data source (s)	Data processing for source map	Species	Scoring	Comments/Rationale
Anchorage areas	Canadian Anchorages and Anchorage areas	Anchorage area points were extracted. No additional processing was required.	All	Areas associated with anchorage areas are 'restricted' for aquaculture. Areas within 200m of anchorage points are automatically assigned a 'limited' rating.	Specified anchorage areas have restricted access and are not suitable for co-location with aquaculture. Navigational hazards are possible within proximity to these areas, due to the drift of vessels and potential inaccuracy in mapped point data.
Designated navigation features	Vessel Traffic Routes	Multiple features designated for navigational safety were compiled and include: traffic separation zones, ferry routes, and recommended routes.	All	Areas associated with designated navigation features are 'restricted' for aquaculture. Areas within 200 m of ferry routes and recommended routes are automatically assigned a 'limited' rating.	It is important to avoid potential overlaps with existing areas designated for navigation. Navigational hazards are possible within proximity to these areas due to potential inaccuracy in the mapped geometries of line data.
Marine Renewable Energy Areas	Provided by Nova Scotia Department of Energy	Maps were brought into GIS. No additional processing was required.	All	Areas within Marine Renewable Energy Areas (MREAs) are 'restricted' for aquaculture.	As per the *Marine Renewable-energy Act*, MREAs can not be designated in areas permitted/leased for aquaculture.
Submerged cables and pipelines	Provided by DFO	Known active Subsea cables and pipelines were provided by network partners. No additional processing was required	All	Areas associated with submerged cables and pipelines are 'restricted' for aquaculture. Areas within 500m are automatically assigned a 'limited' rating.	Aquaculture should avoid areas where underwater cables and pipelines are present to prevent damage, avoid conflict with maintenance activities, and minimize potential safety hazards to operators.
At-sea disposal sites	Active and Inactive Disposal at Sea Sites in Canadian Waters	Active at-sea disposal sites were extracted. No additional processing was required.	All	Areas within at-sea disposal sites are 'restricted' for aquaculture.	Aquaculture should not interfere disposal, maintenance, and management of dumped materials.
CFIA Disease Regulated Areas	CFIA's online map for Multinucleate sphere unknown (MSX) and Perkinsus marinus (Dermo) Regulated Areas*	Declared infected areas and Primary Control Zones for both MSX and Dermo were extracted.	O	N/A	The health of cultured species may be impacted by potential exposure to diseases. Area-specific information on virulence and presence of these disease has not been mapped.

Criteria	Data source (s)	Data processing for source map	Species	Scoring	Comments/Rationale
Shellfish Water Classification Program	Canadian Shellfish Sanitation Program (CSSP)'s Shellfish Harvesting map (DFO)*	Layer extracted based on real-time map of openings and closures of Canadian harvesting areas for bivalve shellfish (mussels, oysters, clams and scallops).	M, O	N/A	Under the CSSP, shellfish harvest areas are classified as to their suitability for harvesting shellfish, according to water quality standards and sanitary conditions. How the area is classified, as well as existing prohibition orders can affect producer's ability to harvest or may imposing requirements for mitigation measures.
Wild salmon rivers	River significance levels from wild salmon river assessment - CMAR	River significance levels for wild Atlantic salmon plotted for rivers across Nova Scotia.	S	N/A	Significant rivers for wild Atlantic salmon may be sensitive to disturbance from marine activities. Aquaculture site decisions should consider the potential for interaction with wild Atlantic salmon and their habitat. However, the potential risks and impacts to salmon and their habitats would vary considerably based on proposed operations, and there is little evidence on appropriate distances from rivers.
Important bird habitat	Multiple	Bird habitat datasets within 100 m from the coast were extracted and combined into a single layer, including data from: • Significant Species and Habitat Database (NSDNR) • Important Bird Areas (IBA) BirdLife International • Critical Habitat for Species at Risk National Dataset (ECCC) • Migratory Bird Sanctuaries from the Canadian Protected and Conserved Areas Database	All	N/A	Important migratory and protected birds are sensitive to disturbance from marine activities. Aquaculture site decisions should consider the potential for interaction with birds and their habitats. Setback distances or required management and/or mitigation efforts would vary considerably depending on the area, species, and aquaculture operations.

Criteria	Data source (s)	Data processing for source map	Species	Scoring	Comments/Rationale
Coastal wetlands	Canadian National Wetlands Inventory	Wetlands within 100 m from the coast were extracted.	All	N/A	Wetlands play an important role in coastal ecosystems and have various government protections. Aquaculture site decisions should consider the potential for interaction with wetland ecosystems. Required management and/or mitigations is highly site-specific.
Terrestrial protected areas/parks	Multiple	Multiple layers showing protected areas and parks within the terrestrial environment were combined from: • The Nova Scotia Protected Areas System* • Protected beaches provided by DNR • Wildlife Management Areas, provided by DNR	All	N/A	Potential interactions or impacts with these areas from aquaculture may be highly variable and situation-specific depending on ecosystem type, resident species, and proposed adjacent activities
Existing aquaculture leases	Aquaculture lease mapping tool (Nova Scotia)*	Existing aquaculture leases, as well as existing rockweed leases.	All	N/A	New aquaculture developments cannot be sited in areas already leased to other marine aquaculture operators but may be possible in the case of site expansion.
Water lots	PID Data provided by GEONova	Extracted privately and government-owned parcels.	All	N/A	Water lots are parcels of marine space already owned or leased to specific entities.
Crown leases and easements	Crown Land	Extracted crown lease and easement data in the marine environment.	All	N/A	Within existing crown leases and easements, aquaculture development may not be permitted, although the restrictions would vary depending on the aquaculture operation and the type of crown lease or easement.

*Identifies data sources where maps on online tool are to be linked directly from an ArcGIS REST API

<table>
<tr><th rowspan="2">ITEM</th><th colspan="6">PROCESS</th><th rowspan="2">NOTES</th></tr>
<tr><th>Submit Request for Science Advice to Chair</th><th>Distribute Document(s) to Members for Review</th><th>Hold Meeting to Review / Compile Draft Science Advice</th><th>Distribute Draft Science Advice for Review</th><th>Complete Committee's Review of draft Science Advice</th><th>Send Science Advice to Minister</th></tr>
<tr><td>Criteria Scoring Overview Report</td><td>April 1, 2025</td><td>April 1, 2025</td><td rowspan="2">April 28, 2025</td><td rowspan="2">May 5, 2025</td><td rowspan="2">May 12, 2025</td><td></td><td>Overview of methods for processing and scoring the selected criteria.</td></tr>
<tr><td>Weighting and Aggregation Overview Report</td><td></td><td>April 14, 2025</td><td></td><td>Overview of methods for weighting and aggregating the criteria.</td></tr>
<tr><td>Final Summary Report</td><td></td><td>May 26, 2025</td><td>June 9, 2025</td><td>June 16, 2025</td><td>June 23, 2025</td><td>June 30, 2025</td><td>Overview of any changes made based on interim science advice received, as well as a summary of final products and recommendations for data updates, etc.</td></tr>
</table>

NOVA SCOTIA AQUACULTURE SCIENCE ADVISORY COMMITTEE
SCIENCE ADVICE

REQUEST ID#: NSASAC-2025-01

Title of Request:
Review and validation of the spatial suitability analysis completed for the aquaculture Coastal Classification System (CCS) project.

SCIENCE ADVICE

Issue Requiring Science Advice (to be posed as a question):
Do you agree with the process used to complete the spatial suitability analysis (including key development decisions and assumptions made during the structuring, scoring, weighting and aggregation phases) for the aquaculture coastal classification system project?

Summary of Committee Review:

The Nova Scotia Aquaculture Science Advisory Committee (the Committee) has reviewed the reports and supporting documentation presented in the corresponding Request for Science Advice. The reports included:

(1) *Recommendations on Scoring of Criteria. A report in support of the aquaculture coastal classification system project*, dated March 28, 2025;
(2) *Recommendations on Weighting and Aggregation of Criteria. A report in support of the aquaculture coastal classification system project*, dated April 14, 2025; and
(3) *Final Summary Report. A report in support of the aquaculture coastal classification system project*, dated May 26, 2025.

Supporting documentation included a Request for Science Advice Timeline Overview, which outlined the planned timelines for the Committee to receive reports associated with the request and deliver their science advice. According to the timeline, the Committee met on April 30, 2025, to discuss and provide science advice on the Recommendations on Scoring of Criteria report and Recommendations on Weighting and Aggregation report.

During the April 30, 2025 Nova Scotia Aquaculture Science Advisory Committee meeting, the Committee discussed major and minor comments related to the request and review of the Recommendations on Scoring of Criteria report and the Recommendations on Weighting and Aggregation of Criteria report. Major comments included requests for clarification on various questions and topics as described below. Minor comments included grammatical corrections or smaller revisions for consistency and/or clarity. Representatives of the Centre for Marine Applied Research (CMAR) and the Department of Fisheries and Aquaculture (the Department) were present to provide clarification to the Committee as required.

Specific to the **Recommendations on Scoring of Criteria** report, the Committee requested clarification on the interpretation of criteria values "high, medium and low" and how these qualitative assessments were translated into corresponding scoring ratings of "limited," moderate," and "good" (see Table 4 of the Recommendations on Scoring of Criteria report). CMAR explained that further detail on the criteria, such as the definition of value ranges and the rationale for scoring, is provided in Appendix i of the report. It was also noted that certain data layers were more complex and required extensive analysis and processing, which will be described in greater detail in the Final Technical Report.

The Committee asked what challenges for a public use situation have been considered in this document, noting that some have been included throughout the report and conclusion section, but elaboration may be required to support transparency and the usefulness of the tool in various sections of the document (*e.g.* the introductory paragraph). CMAR described challenges related to communication and the importance of translating technical information, including processing, analyzing and verifying large quantities of data, into plain language. There are nuances and limitations with the datasets, and the goal is to communicate to the public what has been included and excluded, as well as communicating the scale of the project (*i.e.* provincial scale). To support communications, the final tool will include a user-friendly online mapping platform and an ArcGIS Story Map. Further information about these outputs, including their purpose and how they were developed, will be included in the Final Summary Report and the Final Technical Report.

The Department added the challenge of communicating that the tool is a decision-support tool, not a decision-making tool. Clarification was provided on the licencing and leasing process, including the roles of the Nova Scotia Aquaculture Review Board (NSARB), the Administrator, and the Minister. It was noted that the NSARB and the Administrator are responsible for licencing and leasing decisions. The Minister does not make decisions on standard applications but makes decisions in the early stages of various licence and lease application processes. The factors to be considered in decisions related to aquaculture in Nova Scotia are outlined in the *Aquaculture Licence and Lease Regulations* made under Section 64 of the *Fisheries and Coastal Resources Act*. Decisions on site specific applications are also supported by input from provincial and federal government agencies, Consultations with the Mi'kmaq of Nova Scotia, public engagement, public comment, and intervenors, as applicable.

The Committee requested an overview on why temperature was not included in the criteria for American oysters (see Table 7 of the Recommendations on Scoring of Criteria report). CMAR clarified that temperature was not included for oysters because they are a robust organism, that are not susceptible to cold extremes and have high thermal tolerances for heat exposures as are currently experienced in Nova Scotian waters.

The Committee also asked for clarification on whether the Recommendations on Scoring of Criteria report and Recommendations on Weighting and Aggregation report will be public facing. The Department indicated that the intention is for these documents to be published on the Department's webpage dedicated to the CCS project and with the science advice submitted by the Committee. In addition, CMAR noted that the Recommendations on Scoring of Criteria report and Recommendations on Weighting and Aggregation of Criteria report attached to this request are interim documents and input from the Committee will be reflected in the Final Summary Report, which will be made available online.

A discussion was had regarding the specific inclusion of multinuclear sphere unknown (MSX) exposure and declaration zones as a criterion, but not other aquatic animal health related pathogens or diseases. The Department explained that MSX has been included as an informational layer rather than a suitability factor because the Canadian Food Inspection Agency (CFIA) has designated control zones in the province, which impact the ability to move product and requires permitting. There is insufficient information to evaluate the impact of diseases on the ability to grow this species, but there is a legislative restriction in place that is known and can be mapped. These restrictions, like the Canadian Shellfish Sanitation Program (CSSP) shellfish classification layer, will be updated in real time on the CCS mapping tool. The Committee noted it is possible that other CFIA disease restricted zones, not just MSX, may be designated in the future and the tool should be updated now to reflect this.

The Committee discussed that there are other criteria important to aquaculture that have not been included in this project due to lack of quality data available at this time. For example, the residence time (aka exchange turnover time) of water in different regions of coastal ocean directly and significantly influences water temperature, concentrations of oxygen, nutrients and organic matter as a result of the local hydrodynamic flushing. Such water renewal is crucial to fish health and mitigating benthic impacts of finfish aquaculture and is also important for shellfish aquaculture because it drives primary productivity. CMAR noted that the Final Technical Report will identify information gaps and future needs for the project. Additionally, there are other projects that may look at specific criteria at a higher resolution, such as the CMAR-led Farming in Natural Systems (FINS) project to develop an aquaculture ecological carrying capacity modelling platform for selected bays in Nova Scotia, as well as other academic aquaculture projects underway.

Specific to the Discussion on the **Recommendations on Weighting and Aggregation of Criteria** report, the Committee noted that a great deal of thought and analysis went into this report. Though challenging to communicate, its value in refining the decision-support tool has been adequately described. The Committee noted that in general, caution should be taken when applying weighting as there is subjectivity and outcomes could be changed by applying more or less weight to certain criteria. The Department explained that there will be full transparency about how conclusions were reached and how decisions on aquaculture are made (*i.e.* the licencing process will examine all criteria). CMAR explored a scenario in which certain groups of criteria, such as exposure and vessel traffic (as shown in Table 6), were assigned equal weighting. This approach tested how grouping and equally weighting related factors might influence overall outcomes. The Committee agreed with the approach taken to incorporate weighting capabilities into the design and start with equal weighting for the current version of the classification assessment. It is important to include it at this stage so that future weighting could be adjusted as credible information becomes available.

The Committee requested additional context on organizing criteria into flat or hierarchical structures (see Figure 4 and Table 6 in the Recommendations on Weighting and Aggregation of Criteria report). CMAR clarified that the discussion of structures refers to two separation options for the organization of criteria within the classification. Information on hierarchical structure was included to provide context on how it was decided to assume every criterion was equal (*i.e.* flat organization), and why this is a valid approach at this stage in the development of the CCS.

The Committee noted that the decision flowchart for considerations to determine the aggregation method(s) applicable to each criterion (see Figure 3 of the Recommendations on Weighting and Aggregation of Criteria report) was very useful in understanding this process. Clarification was requested on how some criteria were considered for both aggregation methods, namely weighted linear combination (WLC) and rule-based overlay (RBO) (see Table 1 of the Recommendations on Weighting and Aggregation of Criteria report). CMAR explained that Figure 3 provides more context to understand how this is applied. Criteria may be included in multiple aggregation methods depending on how they were scored, and whether there is the presence of a limiting condition. Some criteria are included only through RBO, in cases where the limiting condition is also the only threshold or value for consideration. For example, the presence of a marine protected and conserved area is limiting. In this case, any set-back buffers or any other variations to influence suitability are not considered, so this criterion is only incorporated through RBO. Criteria aggregated through RBO may also be included in the WLC or constraint overlay if other conditions existed that would influence overall suitability but may not be a limiting condition. For example, high exposure to extreme cold is a limiting condition for salmon and trout; however, in areas that are not high risk, it would also be important to capture the influence that medium risk or low risk areas might have within the combined WLC.

Discussion was held on the choice of colours selected to visualize final results (see Table 5 of the Recommendations on Weighting and Aggregation of Criteria report). The Committee asked why "good" has been classified by purple instead of green. CMAR indicated that user testing on the platform is taking place and options for colour schemes have been put forward. Accessibility audits are ongoing to determine usability (*e.g.* colour blindness), and a graphic design company has proposed various colour palettes. The 2014 Doelle-Lahey Panel Report noted a red, yellow and green colour scheme, but the colours of the final product will be informed by user-testing to ensure the platform is accessible. Red will be designated for truly restricted areas. The Committee agreed that ensuring colours are selected based on accessibility was a fair and valid approach.

The Committee requested comment on the mechanism for operation-specific details to be incorporated into the decision flowchart (see Figure 3 of the Recommendations on Weighting and Aggregation of Criteria report). For example, some aquaculture is seasonal and does not take place when ice or other extreme conditions are present. CMAR explained that this assessment assumed only year-round production and that specific mitigation practices were not presumed unless they are known to be common practice. This is something that would be considered at the site level and described in the aquaculture application.

Finally, the Committee asked for input on confidence levels that the documentation of the program will be useful and applicable into the future. The Department and CMAR explained that this is a living tool that may change in the future, therefore the documentation process, including geographic information system (GIS) flow charts and metadata, has been thorough. The tool and Story Map are on a sustainable system that allows anyone with GIS experience to work with it administratively with very little background information required. This kind of tool has been applied in other areas, but applying it to aquaculture in Nova Scotia is a new concept.

The Final Summary Report was updated and revised based on the feedback and advice provided by the Committee during the April 30, 2025 meeting. The report is intended to provide an overview of the final project methods and decisions, and to present overall findings reflective of the Committee's input. The Final Summary Report was provided to the Committee for review on May 26, 2025. The Committee met on June 13, 2025, to discuss the report and deliver final science advice on the question described above.

On June 13, 2025, the Committee convened to discuss their review of the Final Summary Report. Representatives of CMAR and the Department were present to provide clarification to the Committee as required. The Committee had no major or minor comments related to the Final Summary Report and noted that it succinctly outlined everything the Committee reviewed and commented on in the previous reports.

Advice of Committee:

Based on the review of the reports and supporting documentation, discussions with Committee members, and clarification provided by CMAR and the Department, the Committee concluded that the work done to date, including engagement, research and analysis, for this project is credible, and the reports are in excellent shape with no major concerns, or criticisms. The Committee is satisfied with the data collected and analyzed, and the work completed by the Department and CMAR on this project.

In response to the question posed in the Request for Science Advice, the Committee reached consensus that the process used to complete the spatial suitability analysis, including key development decisions and assumptions made during the structuring, scoring, weighting, and aggregation phases, was appropriate, robust, and credible. This assessment reflects the structured review process, which included timely access to relevant documentation and group meetings that enabled the Committee to share critiques and suggestions, with responses and clarifications provided by knowledgeable subject matter experts. There were no major concerns raised by Committee members regarding the process to complete the spatial suitability analysis for aquaculture.

In recognition of the importance of communication for this project, the Committee *recommends* the Department clearly define and communicate that the aquaculture coastal classification system is not meant to make decisions itself but rather is a tool that will provide information to support decisions related to aquaculture in the province. This definition should include specific descriptions, in plain words, with examples, of exactly how the tool will be used to inform and support specific types of decisions.

The Committee *recommends* the Department include in the report(s) a description of the licencing and leasing process, and the decision-making process for aquaculture applications in Nova Scotia. This could include links to resources on the Department's website where applicable. Additional information should be included on the role(s) of the decision maker(s) and how additional, higher-resolution data collection and feedback from other users, regulators and stakeholders is used at the site level to support decision-making as it pertains to aquaculture. Additionally, it should be clearly conveyed in the report(s) and resulting tool that the suitability map classification ratings of "limited", "moderate" or "good" inform the decision process but do not mean that aquaculture development will or will not occur in an area, and additional information and/or mitigations to barriers must be considered and described in an application for further assessment.

The Committee *recommends* that the Department review terminology used throughout the documents and update to appropriate terms as required. This includes updating the information layer of "MSX Declaration Areas" to "CFIA Disease Restricted Zones" to allow the addition of other disease restrictions if they become applicable.

The Committee *recommends* that the Department update existing documents, resources and/or webpages related to decisions on aquaculture to include reference to the coastal classification system tool as a support tool.

The Committee *recommends* that the coastal classification tool be maintained and updated on a regular basis as new information becomes available, including new datasets and models, and innovative farming technologies and methodologies. This is particularly important when considering future impacts of climate change (*e.g*. water temperature, hypoxia-anoxia) on the marine environment. There is opportunity for continued research, data collection and contribution to this tool to improve its reliability and usefulness over time.

The Committee *recommends* a commitment to continued funding for this project to ensure it remains up-to-date and valuable in supporting decisions related to aquaculture in Nova Scotia.

The Committee *advises* the Department to ensure public-facing final documents related to the CCS project include the following revisions to provide additional context and clarification:

1. An Executive Summary in plain language that provides a narrative of the CCS project and clarity on its scale and intended use.
2. A Limitations section to recognize limitations, uncertainties, assumptions and how these have been considered in the CCS project.
3. Additional clarification throughout the document(s) that the CCS is a decision-support tool and not a decision-making tool.
4. Additional context to the documentation of criteria weighting to clarify how weighting is or will be applied within the CCS.
5. Review and update terminology to ensure it is applicable and accurate (*e.g.* CSSP layer, CFIA Disease Restricted Zones).

The Committee also identified minor edits including grammatical corrections, which were provided to the Department.

APPROVAL

Approval Date	Name of Chair of Committee	Submission Date
June 24, 2025	Dr. Stefanie Colombo	June 24, 2025