Evaluating the potential for seaweed aquaculture in Nova Scotia

By

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TABLE OF CONTENTS

List of Tables iii

List of Figures iv

Abstract v

Acknowledgements vi

Chapter 1. Introduction 1

1.1 Background 1

1.2 Management Problem 3

1.3 Research Aims and Objectives 4

Chapter 2. Methods 5

2.1 Study area: Nova Scotia, Canada 5

2.2 SWOT Analysis 6

2.3 Q-Methodology 6

2.3.1 Q-set and online survey 7

2.3.2 Participants 11

2.3.3 Statistical Analysis 12

Chapter 3. Results 13

3.1 SWOT Analysis 13

3.2 Q-Methodology 17

3.2.1 The Seaweed Skeptic 22

3.2.2 The Seaweed Solution 23

3.2.3 Areas of Consensus 23

Chapter 4. Discussion 24

4.1 Conflicting narratives 24

4.2 Undecided amidst uncertainty 25

4.3 The question of seaweed sovereignty 26
4.4 Seaweeds as economic sponsors 28
4.5 Bonus benefactors 29
Chapter 5. Conclusion 30
5.1 Moving forward 30
5.2 Recommendations 31
5.3 Conclusion 32
Bibliography 33
Appendices 46
Appendix i. 46
Appendix ii. 47
Appendix iii. 55

LIST OF TABLES

Table 1. Q-sort statements (n = 40) used in the Q methodology survey, organized by dimensional categories. 8
Table 2. Summary table of SWOT analysis. 14
Table 3. Factor scores for each idealized perspective organized by each category of Q-statements 18
Table 4. Overview of factor loadings for each participant, ranging from -1 (complete disagreement) to 1 (complete agreement). 21

LIST OF FIGURES

Figure 1. Q methodology survey setup. 11

Figure 2. Number of participants significantly associated with each perspective, organized by stakeholder group. 22

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ABSTRACT

Growing interest in the seaweed aquaculture industry has focused on the environmental, economic and social benefits it can offer. In Atlantic Canada, it is a small but emerging industry with the potential to grow and contribute to food security, climate change mitigation and coastal economic development. However, limited understanding of this potential has led to slow and fragmented development of the industry, without a clear direction of how to move the industry forward. This research uses Nova Scotia as a case study to understand the potential for the seaweed aquaculture industry by analyzing the perceptions of stakeholder groups (industry, academia, NGO/community and government). A SWOT analysis was completed to understand the main drivers and barriers impacting the industry and was used to develop a Q-methodology survey for identifying the important factors to consider in decision-making, management and planning of the industry. Results indicated that participants generally reflected one of two perspectives: the seaweed skeptic and the seaweed solution. Participant perceptions indicated areas where seaweed aquaculture can be a contributor in Nova Scotia, specifically in coastal community economic development and food sustainability. However, experiential knowledge gaps, uncertainties surrounding climate change impacts and lack of regulations appear to constrain individuals from fully supporting the industry. Further discourse is needed on the stewardship of and priorities for how this industry should be developed moving forwards. These findings illustrate possible enabling conditions for the future of this industry in Canada.

Keywords: seaweed aquaculture; Nova Scotia; SWOT analysis; Q-methodology

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CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

The escalating demand for seafood has led to increased industrial fishing pressures and the rise of illegal, unreported and unregulated fishing, resulting in the exploited state of wild-capture fisheries and destruction of critical ocean habitat (Jacquet & Pauly, 2007). Despite this destruction, global human consumption of seafood has more than doubled in the past 50 years (Guillen et al., 2019). The changes in marine ecosystems has led to fishing down the marine food web, and in response, aquaculture has been offered as a valuable alternative to meet growing global resource demands, without further degrading ecosystems (Costello et al., 2020; Eikeset et al., 2018; Jacquet & Pauly, 2007).

One form of aquaculture gaining popularity is that of seaweed aquaculture, which has become the fastest growing aquaculture sector due to its potential to contribute to some of the world's pressing societal challenges (National Oceanic and Atmospheric Administration Fisheries [NOAA], 2020). Specifically, seaweed farming has been promoted for its capacity to deliver benefits that support nations in achieving targets set by the United Nations Sustainable Development Goals (SDGs) (Mustafa et al., 2018). Seaweeds have been used for a variety of applications including food, domestic animals and fish feed products, fertilizers, peptides and pharmaceuticals (Skjermo et al., 2014). Conducted by nations around the globe for hundreds of years, today 35 million tonnes of seaweeds are produced, accounting for 51% of the total global mariculture production (Food and Agriculture Organization of the United Nations [FAO], 2020, 2022). This production has been dominated by Asia; however, within the last two decades, it has gained traction in western countries (Cottier-Cook et al., 2016; Kim et al., 2017).

In the last decade, seaweed production has undergone a significant global expansion driven by increasing recognition of its potential in two areas. Firstly, with the heightened human demand for food, seaweed cultivation has been acknowledged as a safe and healthy food source, capable of reducing food insecurities and deficiencies globally and as a low-carbon feed for agriculture and aquaculture alike (FAO, 2022; Grebe et al., 2019). Seaweed aquaculture can be advantageous when compared to some agriculture crops and aquaculture species as seaweeds can be fast-growing, grown year-round and do not require additional inputs to grow (Costello et al., 2020). It is therefore being promoted as a sustainable avenue for supplying the world's growing population and increasing consumption of seafoods (FAO, 2022).

Secondly, as the world learns to adapt to unpredictable weather events, degrading ecosystems and increasing biodiversity loss, seaweed aquaculture is also being considered for its potential to aid in climate change mitigation. Among the many ecosystem services that seaweed ecosystems provide, it is the potential for CO_2 removal that has garnered particular attention. Seaweeds consume carbon through photosynthesis, which is then exported to the deep sea or buried in coastal sediments to create long term carbon storage, or carbon sinks (Krause-Jensen & Duarte, 2016). However, the potential for seaweed production to absorb significant amounts of carbon is still debated as it has been observed that the majority of seaweed production decomposes in the ocean and therefore does not contribute to carbon sinks (Duarte et al., 2017). Considerable interest and development have also been directed at using seaweed aquaculture to create new biomass-based biofuels or for remediation of coastal pollution (Chen et al., 2015; Kraan, 2013). Given these attributes, seaweed aquaculture has been heralded as a possible solution to support climate action.

Seaweed aquaculture occupies a minimal portion of the coastal ocean – only 0.004% worldwide, as of 2013 (Duarte et al., 2013); however, expansion of the industry to meet climate and food security-related goals would require significant ocean area and a scaling up of commercial production (World Bank Group, 2016). Increasing seaweed production to meet the global needs and expectations for this industry are limited by the availability of increasingly limited suitable space and competition with other marine uses (Duarte et al., 2013). These areas will face further constraints imposed by the shifting temperatures of climate change, which could change the seasonal timing for growing seaweeds and for other ocean uses (Bricknell et al., 2021). These challenges are compounded by knowledge gaps surrounding the environmental impacts of inputting a seaweed farm, including increased susceptibility to diseases, alterations to the physiochemical environment and possible impacts on marine megafauna, among others (see appendix i for more information) (Campbell et al., 2019).

A small but emerging industry in Canada, access to ample seaweed resources and a good growing climate means there are opportunities for sustainable growth in Canadian waters. However, the industry is still in its early stages, and as a result, seaweed aquaculture has minimal commercial production. Various circumstances have contributed to a limited understanding of the potential for the seaweed aquaculture industry in Canada. Existing negative perceptions inherited from other forms of aquaculture has led to conflicting perspectives and perhaps poor social acceptability of new aquaculture (Spillias et al., 2022). These perceptions exert substantial influence on expanding and retaining access to production sites (Chu et al., 2010; Olsen & Osmundsen, 2017). This adversity is further complicated by lack of coordination among groups, resulting in a fragmented industry with growing conflicts (Spillias et al., 2022). Additionally, Canada lacks sufficient experience in the industry, so pathways for development have not been identified for industry members to move forward without experiencing significant pitfalls (Giercksky & Doumeizel, n.d.). This lack of experience also means the current regulatory framework in Canada is likely inadequate for supporting the seaweed aquaculture industry (Chopin, 2017). These circumstances have led to a poor understanding of the costs associated with seaweed aquaculture, stifling the ability of the industry to grow sustainably.

1.2 Management Problem

Seaweed aquaculture presents an opportunity, especially for Atlantic Canada, where much of the Maritime provinces' identity and livelihoods are connected to the ocean and the resource sectors that depend on it (Loucks et al., 2017). In this region, the ocean sector accounts for 55.8% of contribution to GDP, with employment led by jobs in the seafood industry (Statistics Canada, 2021). Aquaculture in particular has become an established industry that is increasingly becoming important for rural economic development (Flaherty et al., 2019).

Rural and coastal communities are challenged to plan and manage this aquaculture development in a sustainable manner, while also supporting societal needs and well-being (Soto et al., 2008). The ocean not only provides substantial economic benefit, but is also tied to food security and sovereignty, means of transportation, social networks and cultural and intergenerational connections for coastal communities (Armitage et al., 2017). Aquaculture developments also depend on the shared use of coastal spaces, which play a cultural role in the wellbeing of communities (Forster & Radulovich, 2015). Introducing seaweed aquaculture means maritime nations have to be willing to allocate space for seaweed farms, creating potential for conflict to arise (Campbell et al., 2021; Holden et al., 2019; Knapp & Rubino, 2016; Outeiro & Villasante, 2013). Thus, anticipating the emergence of the seaweed industry is important, as it could have great socioeconomic benefits and consequences in this region that will be particularly impactful for rural and coastal communities.

Various tools, such as marine spatial planning (MSP), have been identified as a way to plan for emerging ocean industries and support blue economy objectives within an increasingly busy ocean. These tools and the decisions they generate can profoundly impact coastal community development (Yet et al., 2022). Gaining perspectives from these communities and other rights holders that have a stake in the seaweed aquaculture industry will be needed to understand the major factors influencing its realization in Atlantic Canada. As these communities stand to be affected by the growth of aquaculture, it is important to understand where the industry is headed as it develops and to consider how industry growth and management should be planned to best manage ecological and socioeconomic outcomes.

This industry is still emerging, presenting an opportunity to plan its development in a way that balances the social and economic dimensions while protecting the ability of current and future generations to continue to benefit from goods and services provided by the ocean. Exploring various approaches and scenarios can guide Atlantic Canada to scope possibilities in making space for this emerging aquaculture industry, that take account of sociopolitical realities and ensure coastal community stability and well-being remain at the core of development.

1.3 Research Aims and Objectives

Rapid growth of the seaweed aquaculture industry could provide important environmental and socioeconomic opportunities, particularly for coastal communities. Nova Scotia, a province on the Atlantic coast of Canada, is an area populated by small coastal and rural communities, where development of aquaculture is a key priority (Province of Nova Scotia, 2009). This makes it an appropriate area to use as a case study for the emerging seaweed aquaculture industry.

This research includes two objectives, (1) to understand the major factors affecting the potential for seaweed aquaculture in Nova Scotia and (2) to explore how the seaweed aquaculture industry might be incorporated in ocean planning in Nova Scotia to ensure sustainable development. These objectives were driven by the following questions:

SubQ1: What are the barriers and opportunities of the seaweed aquaculture industry?

SubQ2: What are the major considerations affecting the potential for seaweed aquaculture in Nova Scotia?

SubQ3: What should be prioritized to guide development and planning of the industry in Nova Scotia?

Sub-questions 1 and 2 will be addressed through use of a SWOT analysis, while sub-questions 2 and 3 will be addressed through use of the Q-method. An understanding of the seaweed aquaculture industry can be used to inform the future of this industry in Nova Scotia, the Maritimes and potentially the rest of Canada as an ocean nation.

CHAPTER 2. METHODS

2.1 STUDY AREA: NOVA SCOTIA, CANADA

Nova Scotia (NS) is a unique coastal Atlantic province of Canada, being almost completely surrounded by water. With 7579 km of coastline, no place is further than 56 km from the ocean and has a population of approximately 1 million individuals (Nova Scotia Department of Finance, 2022; Nova Scotia Immobilien, n.d.). Seaweed aquaculture in NS and Canada remains small; it produced 12 655 tonnes in 2019 of both farmed and wild seaweeds, representing 0.04% of global production (Cai, 2021). Although the seaweed aquaculture industry is not yet established in the province, wild seaweed harvesting of dulse (*Palmaria palmata*) has been harvested and consumed by coastal communities along the Bay of Fundy for more than a century (Chopin & Ugarte, 2006). Wild harvest of two other species, rockweed (*Ascophyllum nodosum)* and irish moss (*Chondrus crispus*) did not begin until later in the 1900's (Chopin & Ugarte, 2006). In recent years, dulse has been undergoing research and development (R&D) for use as a crop in commercial cultivation in NS, but growing techniques are not yet refined, resulting in little development (Chopin, 2017b; Tremblay et al., 2017). Currently, irish moss is the only commercial species being cultivated in large scale land-based tank cultivation, for use in the food sector (Ross, 2017). However, these seaweeds have little promise for open ocean aquaculture as the growing environment is harsh, subjected to adverse conditions and susceptible to epiphyte growth (Hafting et al., 2012; Ross, 2017). For use in commercial mariculture, sugar kelp (*Saccharina latissima*) and winged kelp (*Alaria esculenta*) have become particular species of interest (Ross, 2017). Both of these 'brown' seaweeds are native to the region and have been successfully cultured in integrated multitrophic aquaculture (IMTA) trials in New Brunswick, a neighbouring maritime province (Chopin, 2017). A multi-year collaborative study that began in 2017 is finishing small-scale sugar kelp growth trials on shellfish farms in Cape Breton, NS to identify the structures and capacities already present in the province, and where current gaps are to move the industry forward (Tremblay et al., 2017).

2.2 SWOT ANALYSIS

A Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis was carried out to examine the strengths and weaknesses of the internal operating environment, and the potential opportunities and threats of the external operating environment that can impact the seaweed aquaculture sector (Rimmer et al., 2013). The SWOT analysis was conducted based on a scoping literature review (see appendix ii for more information). This review was not restricted to Nova Scotia due to limited information being available, as the industry is in the early stages of development. Scientific literature and case studies from other global regions where the seaweed industry has a longer history could provide insight into challenges and experiences that are not yet known in Nova Scotia or Canada. Reviewed literature included general information, regional case studies and SWOT analyses, all pertaining to seaweeds and aquaculture at large (i.e., not restricted solely to seaweed aquaculture). Literature searches were performed using academic databases and used general search terms to identify literature to include in the analysis. These terms were: “SWOT”, “seaweed”, “aquaculture”, “opportunities”, “challenges”, and “seaweed farming”.

2.3 Q-METHODOLOGY

Q-methodology (henceforth called “Q”) is a combination of qualitative and quantitative methods to investigate the subjectivity of its participants by asking them to rank statements according to their own point of view (Brown, 1993). Once completed, patterns are identified in the way the statements are sorted within and among participant groups, allowing a way for subjectivity to be understood. Since its inception in the 1930s, Q has been applied to a range of disciplines, including aquaculture (e.g. Carr, 2019; Rudell, 2012; Trueman et al., 2022), providing a “systematic method to reveal consensus and disagreement” among participants (Gao & Soranzo, 2020). This allows researchers to capture perspectives and attitudes on a topic through structured sorting, so smaller sample sizes can produce statistically significant results (Brown, 1993). As participants sort statements from their own point of view, Q provides an effective way to produce easily understandable outputs that may inform policy decisions and environmental management (Barry & Proops, 1999; Nikolaou & Evangelinos, 2010).

2.3.1 Q-SET AND ONLINE SURVEY

The Q-set are statements provided to participants that reflect common themes and factors in the literature that do or could influence the seaweed aquaculture industry in NS. Statements were developed based on the SWOT analysis conducted for this study (see appendix iii for more information). Statements were then revised for accessible language, and only the most relevant statements were retained for the survey. This is done to ensure a manageable number of statements for participants to consider, as well as to ensure the statements were balanced across potential positive, negative and neutral opinions on the topic. The final grouping of statements is the Q-set, which included 40 statements organized into five groups by topic: Economic, Environmental, Social, Technical and Regulatory (Table 8).

The statements were presented to participants in the same order, by topic. Participants would first sort statements into one of three categories: ‘agree’, ‘disagree’ or ‘neutral’ based on their perspectives. Once all statements were ‘presorted’ into these three categories, the participants would further sort the statements based on how strongly they felt about the issue in each statement. Q is designed to force a quasi-normal distribution, so only three statements were allowed in the category they felt most strongly about (+4/-4) and up to six statements for the neutral category (0) (Fig. 1). The participants were allowed to choose where each statement would go, allowing the final distribution among categories to be reflective of their perceptions. The survey was built using the online platform QSortware (qsortware.net) for participants to be able to complete the survey at their own discretion and on their own time. Once participants completed the survey, they could indicate whether they felt comfortable being contacted to discuss their choices. Follow-up interviews were carried out with participants with very distinct perspectives.

Table 1. Q-sort statements (n = 40) used in the Q methodology survey, organized by dimensional categories.

Category	Statement
Economic	Seaweed aquaculture is not an economically viable option for long-term income diversification.
	There is currently no demand for a domestic seaweed market in Nova Scotia/Canada.
	The upfront financial investment of seaweed aquaculture is not expensive.
	Seaweed aquaculture could contribute to coastal community economic development.
Environmental	Seaweed aquaculture ensures long-term storage of carbon.
	Due to the uncertainty associated with the profitability and environmental impacts of large-scale operations (e.g., possible marine mammal entanglement, competition with wild species), seaweed aquaculture should not be scaled-up from small scale operations.
	Seaweed cannot be considered as an environmentally sustainable, viable animal feed alternative.
	Seaweed can be considered as a viable fish oil replacement.
	Climate change does not present a risk to existing aquaculture infrastructure.
	Warming temperatures will make seaweeds more vulnerable to diseases and pathogens.
	Climate change will not affect seaweed marketability.
	Using hatchery seaweed for cultivation could impact the genetic diversity of wild populations.
	A seaweed farm will not have any negative environmental impacts.
	Habitat degradation from climate change will reduce the amount of suitable habitat for future seaweed aquaculture.
	Growing seaweeds could increase nutrient removal from coastal water eutrophication.
	Seaweed cannot feasibly be considered for use as a biofuel.
Social	Previous conflicting perceptions of existing aquaculture play a negative role in the success of the seaweed industry.

Category	Statement
	Community interests and needs are not currently considered in the decisions related to seaweed aquaculture planning.
	Seaweed offers a safe and healthy food source option.
	Clear communication from regulators won't help to increase social acceptability of the industry.
	Clear communication from industry managers will help to increase social acceptability of the industry.
	Including different knowledge systems will improve decision making regarding the seaweed aquaculture industry.
	Collaborative partnerships among farmers will be important for reducing industry financial barriers.
	Meaningful community engagement will increase public trust of seaweed aquaculture.
	Introducing seaweed aquaculture will increase spatial conflicts with other maritime ocean users.
	Public and consumer awareness of the benefits of seaweed is limited.
Technical	Current farming husbandry practices are not suitable for growing and harvesting seaweed.
	The current available processing technologies in Canada are inadequate for growing the industry.
	The seaweed supply chain and farming processes are energy intensive.
	Polyculture/Integrated Multi-Trophic Aquaculture (IMTA) practices that include seaweed cannot be scaled commercially to mitigate potential negative environmental impacts.
	Offshore seaweed aquaculture is not a viable option.
	Reliable seed sources for seaweed aquaculture are not available in Atlantic Canada.
	Seaweed aquaculture training opportunities are not available in Nova Scotia.
Regulatory	Federal and provincial governments should streamline the regulatory process for industry growth.
	Governments should not play a central role in the development of the seaweed aquaculture industry.
	Coastal communities should play a central role in the development of the seaweed aquaculture industry.

Category	Statement
	The current regulatory framework does not support growth of the seaweed aquaculture industry.
	The proposed Aquaculture Act will help provide a better framework to regulate the seaweed aquaculture industry.
	Marine spatial planning (MSP) is a viable tool for supporting coastal community interests.
	Marine spatial planning (MSP) can provide holistic planning for seaweed aquaculture.

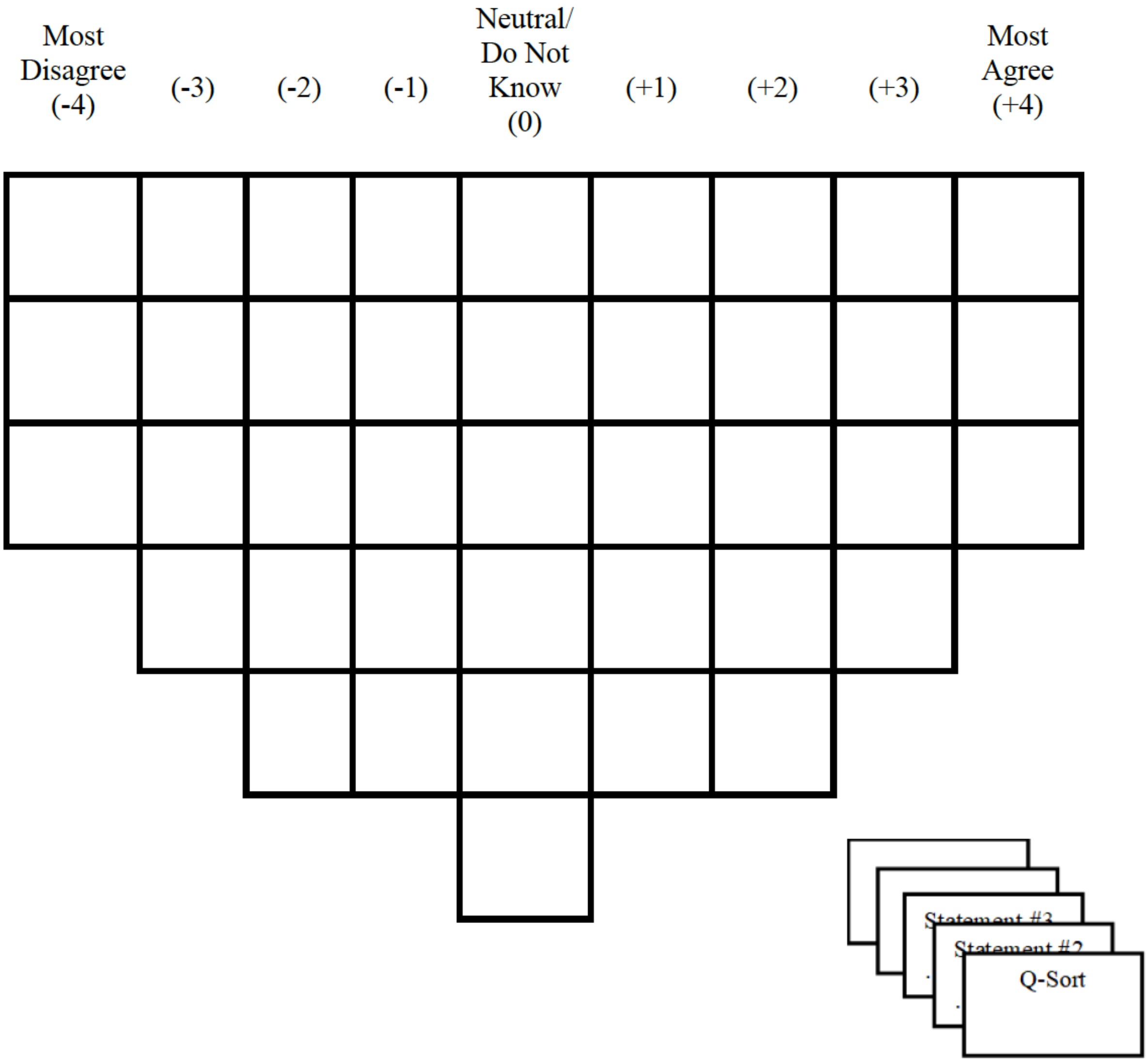

Figure 1. Q methodology survey setup. All 40 statements are placed on the matrix, according to the subjective ranking perceived by the participant. The number of statements allowed for each rank is illustrated by the number of rectangles below each column.

2.3.2 Participants

From August to September 2022, a survey questionnaire was distributed (under Marine Affairs Program Ethics Review Standing Committee #2022-07) to potential participants representing four stakeholder groups:

1) **Government (n = 5):** Representatives from federal, provincial and municipal governments were selected due to their expertise in seaweed aquaculture development, community planning, leasing and licensing processes or other regulations.

2) **Industry (n = 5):** Seaweed aquaculture license/leaseholders (new, existing, or former), industry employees and/or companies offering seaweed products or services and professional associations were selected due to their knowledge of seaweed farming operations and industry development.

3) **Community/Non-government organizations (NGOs) (n = 5):** Employees of NGOs, community organizations and/or associations as well as community members who are actively involved in seaweed aquaculture were selected due to their involvement in the current status of the seaweed aquaculture industry in Atlantic Canada.

4) **Academia (n = 5):** Researchers from social or natural science backgrounds were selected due to their expertise on topics such as rural and community development, seaweed aquaculture, marine ecology, oceanography, marine food systems sustainability and climate change.

These stakeholder groups were chosen to represent a wide range of perspectives from key groups involved in the seaweed aquaculture industry. Participants from these groups were chosen based on their expertise, knowledge and experience in relevant areas to be able to provide perspectives on the seaweed aquaculture industry in Nova Scotia and Atlantic Canada. Potential participants were identified by snowball sampling methods using staff directories, researcher's professional networks and industry search engines such as Linked In. Participants were then recruited by email with a detailed explanation of what the study entailed, study goals and how their involvement could contribute meaningfully towards understanding of the seaweed aquaculture industry. Overall, 54 participants were contacted, of which 20 responded.

2.3.3 Statistical Analysis

Distinguishing perspectives within and among stakeholder groups were identified using the 'qmethod' package in R 4.2.1 (Zabala, 2014), which is based on a quantitative factor analysis. Once the data was imported into R, a correlation matrix was first created for all 20 Q-sorts to see which are the most and least similar (a correlation of 1 represents two Q-sorts that are completely identical). Once this was completed, a principal component analysis (PCA) was conducted to explain the variance in the correlation matrix and find shared viewpoints from the sorts, known as 'factors' (Schulze, 2020). Q forces participants to decide what is most meaningful, therefore these factors (or "perspectives") represent individuals that share similar values and understanding surrounding the topic, in this case, seaweed aquaculture. To facilitate interpretation of PCA results, factor rotation was applied using varimax orthogonal rotation to maximize the amount of variance explained by the factors. The Pearson method was used for the correlation method.

To determine which perspectives explained the most variance, the number of relevant factors were selected based on the following criteria: a) eigenvalues > 2.00, meaning at least 2 significant Q-sorts were loaded onto a factor and b) explanatory variable > 10% (Watts & Stenner, 2012). The final factor analysis generated an idealized Q-sort, which represents the average of Q-sorts that were loaded significantly for each factor (Watts & Stenner, 2005). To determine the cut-off for identifying if a Q-sort was significantly linked to a perspective, the following equation was used:

$$s = 3.29 \times (\frac{1}{\sqrt{N}})$$

Where N = the number of statements (40), producing s = 0.520 at p = 0.001 level. This number means that a statistically significant loading must be equal to or greater than 0.520 to be included in a perspective. A p-value of 0.01 was then used to identify between distinguishing and consensus statements. The factor loadings, scores and statements were then subject to interpretation.

CHAPTER 3. RESULTS

3.1 SWOT ANALYSIS

Based on the SWOT analysis, five thematic areas were identified within the internal and external operating environments of the seaweed aquaculture industry (Table 2, see appendix ii for more information). The results of the analysis are outlined based on these five areas.

Table 2. Summary table of SWOT analysis.

Category	Strengths	Weaknesses
Economic	Affordable upfront investment High quality product output Focused on limited species	Minimal local market Lack of financing Lack of economic analyses
Environmental	Good growing environment Local seed sources available Sustainable crop and feed alternative	Limited grow-out space availability and identification Carbon footprint of supply chain Environmental knowledge gaps Vulnerability to diseases
Social	Increasing positive perceptions Delivery of ecosystem services	Lack of commercial experience Low consumer awareness Limited partnerships among organizations in the seaweed sector Limited personnel capacity
Technical	Good production cycle knowledge Capacity for research and development Established cultivation practices	Inadequate processing technologies available Need for standardization
Regulatory		Poor regulatory framework No regulated cultivation processes Lack of inclusive marine spatial plans
	Opportunities	**Threats**
Economic	Income diversification	Increasing capital investment Undeveloped market in Canada Market vulnerability to climate change
Environmental	Polyculture/IMTA/multi-use activities Potential for bioremediation Potential for use as a biofuel	Unknown environmental impacts of climate change Genetic diversity of seaweed strains Energy intensive supply chain
Social	Collaboration to reduce financial barriers	Potentially limited engagement with communities Conflicts with other marine users Lack of a social licence
Technical	Increased aquaculture support Education and training opportunities Social strategies to support industry resilience Increased research on seed sources	Slow move to seed banks Slow to embrace innovation Aquaculture infrastructure vulnerable to climate change effects
Regulatory	Inclusive public policies and regulations Regulated husbandry processes Development of new licenses A comprehensive Aquaculture Act	

Economic

The affordable upfront investment and the production of high-quality products were identified as strengths of seaweed aquaculture. Additionally, with production centered on a limited number of species, more research and development would be focused on a few species, allowing for in-depth knowledge to be gained. However, a limited local market, lack of financing and lack of economic analyses were identified as weaknesses to industry development. A threat identified that if operations scale up, increasing capital investment will be required. A related threat was then determined to be the market in Canada, which is currently undeveloped and susceptible to climate effects. Despite this, the analysis identified opportunities for income and employment diversification, specifically for rural and coastal communities.

Environmental

The growing environment of Atlantic Canada was regarded as a particular strength, as it provides optimal climate conditions and a readily available supply of local seed sources. Seaweed aquaculture was also recognized as a sustainable crop and feed alternative (i.e., for domestic animals and fish), as it requires no arable land, fertilizer or freshwater. Yet, limited availability of areas for grow-out and the carbon footprint of the supply chain were identified as weaknesses. Additionally, environmental knowledge gaps and vulnerability to physiological and pathological diseases were determined to be limitations of future development and management of seaweed aquaculture. Adverse environmental impacts associated with climate change and reduced strain diversity were identified as threats to the industry. The energy-intensive steps of seaweed farming and the resulting research and development to reduce energy consumption were also recognized as a threat to development of the industry. However, development of systems of polyculture/integrated multi-trophic aquaculture (IMTA), multi-use areas, bioremediation or bioenergy were identified as potential opportunities for reducing or offsetting ecological footprint.

Social

The rise of positive public perceptions associated with seaweed aquaculture throughout the western world and delivery of ecosystem services were identified as key strengths. However, lack of experience at commercial scales and low consumer awareness of the benefits of seaweed cultivation were identified as weaknesses. These weaknesses are paralleled by limited partnerships among organizations in the seaweed sector and the constraints (e.g., educational) that limit farmers in other industries to becoming seaweed farmers. However, this led to recognition of an opportunity for collaboration that could reduce financial and other barriers to industry development. Threats to this development included the potential for limited engagement among farmers and community members and increased conflicts with other ocean users, both contributing to lack of a social licence.

Technical

Good understanding of biological and production cycles in Atlantic Canada, capacity for research and development (R&D) and well-established cultivation techniques were identified as strengths. However, a weakness included processing and harvesting technologies that are currently inadequate for industry growth. The analysis also identified that there is a level of standardization and traceability required that has not been previously demanded in Canada. This led to identified opportunities of increased aquaculture support (e.g., subsidies) and enhanced education and training. The industry could be further supported through development of social strategies (i.e., aquaculture literacy and knowledge) or increased R&D on seedstock, which currently relies on wild seaweed strains. Identified threats included: a slow move to seed banks, a reluctance to embrace innovation and climate impacts on aquaculture engineering and infrastructure that could threaten the future of the industry.

Regulatory

No regulatory strengths were identified by the SWOT analysis, as a key weakness was the existing poor regulatory framework. This is illustrated by other identified constraints, including the absence of regulated cultivation processes and the lack of inclusion of seaweed aquaculture in marine spatial plans. However, this paucity left space for opportunities to create public policies that improve aquaculture and establish husbandry principles to enable consistent seaweed processing. Other opportunities included: possibilities for developing multi-species or multi-year licenses and an Aquaculture Act that considers an ecosystem-based management (EBM) approach. No regulatory threats were identified.

3.2 Q-METHODOLOGY

From the analysis of the Q-sorts (henceforth called ‘sorts’), two factors, or significant *perspectives*, emerged between and among participant groups, explaining 52% of the variance (26% each perspective). These two perspectives are defined by an idealized sort (Table 3), containing the factor scores of a participant that ideally represents that perspective. These perspectives grouped participants that share similar perceptions, indicated by the factor loading scores (Table 4). Based on both the idealized sort and factor loadings, *Perspective 1* was labelled as ‘The Seaweed Skeptic’ and *Perspective 2* as ‘The Seaweed Solution’. All surveyed participants (except for two) were grouped into one of these perspectives because of their perceptions and subjective attitudes towards the economic, environmental, social, technical and regulatory aspects of the seaweed aquaculture industry in Nova Scotia. There were 10 participants from all four stakeholder groups that aligned significantly with *Perspective 1* (Fig. 2), and eight participants, also from all stakeholder groups, that aligned significantly with *Perspective 2*, while two participants aligned significantly with neither (confounding sorts). The following sections describe the two perspectives and explore the areas of consensus and disagreement among the participants. Only salient statements (statements of extreme rank (-4, -3, +3, +4)) were further interpreted. The corresponding identifying number for each statement is indicated in brackets in the text that follows (i.e. (#)).

Table 3. Factor scores for each idealized perspective organized by each category of Q-statements. * Indicates significant difference between perspectives (* for $p < 0.01$ and ** for $p < 0.001$). Statements without significant differences are consensus statements, indicated by a 'C'.

Category	P1	P2	Significance
Economic			
1. Seaweed aquaculture is not an economically viable option for long-term income diversification.	1	4	**
2. There is currently no demand for a domestic seaweed market in Nova Scotia/Canada.	-1	-3	C
3. The upfront financial investment of seaweed aquaculture is not expensive.	0	0	C
4. Seaweed aquaculture could contribute to coastal community economic development.	4	4	C
5. Due to the uncertainty associated with the profitability and environmental impacts of large-scale operations (e.g., possible marine mammal entanglement, competition with wild species), seaweed aquaculture should not be scaled-up from small scale operations.	-1	-4	**
Environmental			
6. Seaweed aquaculture ensures long-term storage of carbon.	-4	1	**
7. Seaweed cannot be considered as an environmentally sustainable, viable animal feed alternative.	-2	-4	**
8. Seaweed can be considered as a viable fish oil replacement.	-2	0	**
9. Climate change does not present a risk to existing aquaculture infrastructure.	-4	-4	C
10. Warming temperatures will make seaweeds more vulnerable to diseases and pathogens.	4	1	**
11. Climate change will not affect seaweed marketability.	-4	-1	**
12. Using hatchery seaweed for cultivation could impact the genetic diversity of wild populations.	0	-2	**
13. A seaweed farm will not have any negative environmental impacts.	-2	0	**
14. Habitat degradation from climate change will reduce the amount of suitable habitat for future seaweed aquaculture.	2	-2	**
15. Growing seaweeds could increase nutrient removal from coastal water eutrophication.	0	3	**
16. Seaweed cannot feasibly be considered for use as a biofuel.	3	-2	**

Category	P1	P2	Significance
Social			
17. Previous conflicting perceptions of existing aquaculture play a negative role in the success of the seaweed industry.	2	2	C
18. Community interests and needs are not currently considered in the decisions related to seaweed aquaculture planning.	-1	-2	C
19. Seaweed offers a safe and healthy food source option.	4	4	C
20. Clear communication from regulators won't help to increase social acceptability of the industry.	-3	-1	**
21. Clear communication from industry managers will help to increase social acceptability of the industry.	0	2	*
22. Including different knowledge systems will improve decision making regarding the seaweed aquaculture industry.	3	3	C
23. Collaborative partnerships among farmers will be important for reducing industry financial barriers.	2	3	C
24. Meaningful community engagement will increase public trust of seaweed aquaculture.	3	2	C
25. Introducing seaweed aquaculture will increase spatial conflicts with other maritime ocean users.	0	0	C
26. Public and consumer awareness of the benefits of seaweed is limited.	2	1	C
Technical			
27. Current farming husbandry practices are not suitable for growing and harvesting seaweed.	-2	-3	C
28. The current available processing technologies in Canada are inadequate for growing the industry.	1	0	**
29. The seaweed supply chain and farming processes are energy intensive.	-3	-1	**
30. Polyculture/Integrated Multi-Trophic Aquaculture (IMTA) practices that include seaweed cannot be scaled commercially to mitigate potential negative environmental impacts.	-3	-3	C
31. Offshore seaweed aquaculture is not a viable option.	0	-3	**
32. Reliable seed sources for seaweed aquaculture are not available in Atlantic Canada.	-1	1	*
33. Seaweed aquaculture training opportunities are not available in Nova Scotia.	1	-2	**

Category	P1	P2	Significance
Regulatory			
34. Federal and provincial governments should streamline the regulatory process for industry growth.	-2	3	**
35. Governments should not play a central role in the development of the seaweed aquaculture industry.	-3	-1	**
36. Coastal communities should play a central role in the development of the seaweed aquaculture industry.	1	2	C
37. The current regulatory framework does not support growth of the seaweed aquaculture industry.	1	-1	**
38. The proposed Aquaculture Act will help provide a better framework to regulate the seaweed aquaculture industry.	-1	0	C
39. Marine spatial planning (MSP) is a viable tool for supporting coastal community interests.	3	2	*
40. Marine spatial planning (MSP) can provide holistic planning for seaweed aquaculture.	2	1	C

Table 4. Overview of factor loadings for each participant, ranging from -1 (complete disagreement) to 1 (complete agreement). Each score indicates how much each sort agrees with each factor or perspective. Bolded values represent participants with a significant load for that factor (values of coefficient > 0.520). Confounded sorts represent participants who did not score significantly for either factor.

Stakeholder	P1	P2
Perspective 1 (P1 – The 'Seaweed Skeptic')		
Government	**0.75**	0.12
Government	**0.74**	0.18
Government	**0.64**	0.12
NGO/Community	**0.67**	0.29
NGO/Community	**0.60**	0.38
NGO/Community	**0.63**	0.41
Academia	**0.62**	-0.01
Academia	**0.61**	-0.34
Academia	**0.55**	0.4
Industry	**0.60**	0.42
Perspective 2 (P2 – The 'Seaweed Solution')		
Government	0.34	**0.63**
Government	0.40	**0.61**
NGO/Community	0.52	**0.63**
Academia	0.30	**0.79**
Academia	0.12	**0.78**
Industry	-0.11	**0.82**
Industry	0.31	**0.79**
Industry	0.05	**0.65**
Confounded Sorts		
NGO/Community	0.25	0.16
Industry	0.48	0.16
Explained Variance (%)	26	26
Defining Q-sorts	10	8
Total Q-sorts	10	8

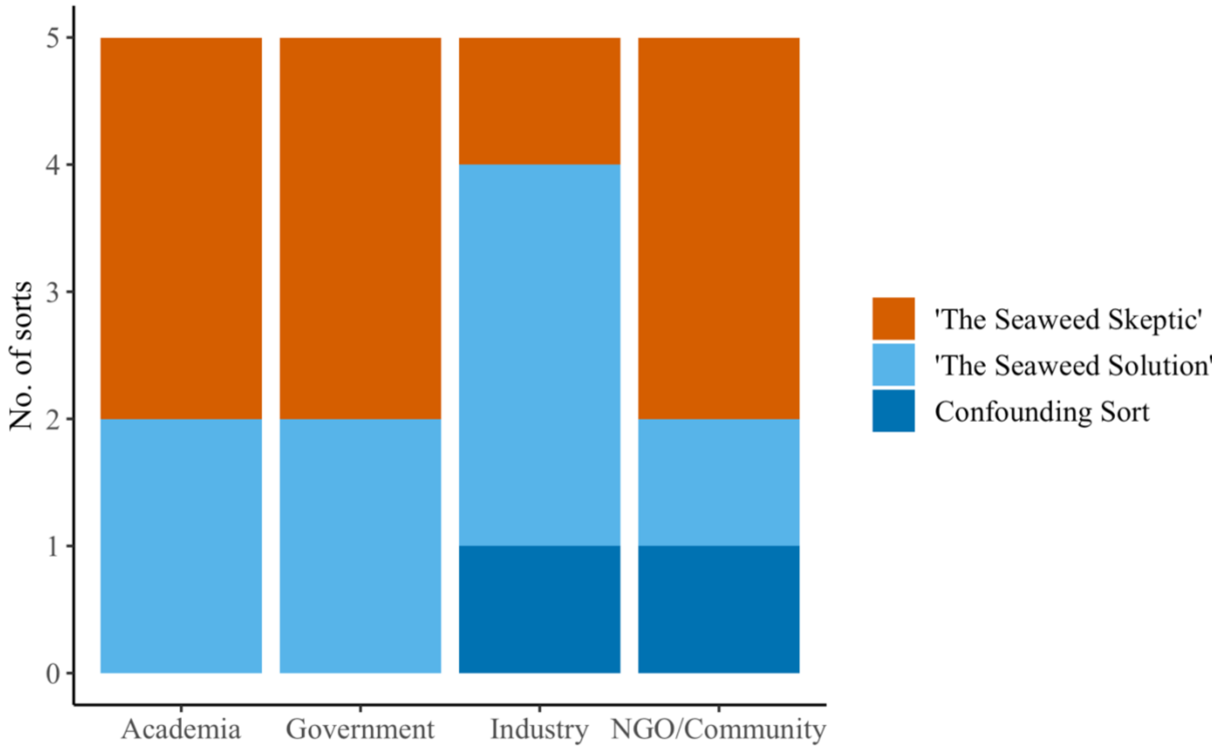

Figure 2. Number of participants significantly associated with each perspective, organized by stakeholder group. Confounded sorts represent participants who did not score significantly for either factor.

3.2.1 The Seaweed Skeptic

This perspective was characterized by the concerns associated with the seaweed aquaculture industry. Participants believed that seaweed aquaculture would not be able to deliver key environmental aims, specifically for use as a biofuel (16) or for long-term carbon storage (6). However, they recognized its potential as a sustainable, energy-efficient form of aquaculture, with the processes and supply chain of seaweed farming requiring little energy (29). This contradicted the findings of the SWOT analysis, which previously identified the supply chain as energy intensive.

Central to *Perspective 1* is its concern regarding the risks and uncertainties of this industry. They strongly believed that climate change presents a risk to the industry by affecting seaweed marketability (11), and seaweeds' susceptibility to diseases and pathogens (10). Participants in this perspective also focused on the social aspects of the seaweed farming industry. Participants sorted in this perspective shared the belief that governments should play a central role in developing the industry (35). If regulators could provide clear communication (20), it could help to increase public trust and thus social acceptability of the industry. Participants also indicated that MSP could be used as a tool to address these social dimensions, specifically to support coastal community interests (39).

3.2.2 The Seaweed Solution

This perspective was characterized by the recognition of multiple benefits to a range of stakeholders from growing seaweeds. The participants sorted in this perspective strongly believed in the opportunities for seaweed aquaculture as an animal feed alternative (7) and a strategy for mitigating coastal water eutrophication mitigation through nutrient removal (15). They also believed that there is promise for viable offshore seaweed aquaculture (31). As such, individuals who share this perspective believed the industry should be scaled up, despite environmental uncertainties and knowledge gaps (5). However, this perspective recognized drawbacks to seaweed aquaculture, indicating it may not be economically viable for diversifying long-term income (1). Similarly, participants perceived regulatory processes as a barrier to this industry being realized and that federal and provincial governments should streamline these processes to grow the industry (34).

3.2.3 Areas of consensus

Statements that were not ranked significantly differently between Perspectives 1 and 2 ($p > 0.01$) represent areas of consensus, meaning there is a general agreement in how participants in both perspectives chose to sort them. Overall, both perspectives strongly recognized (scored significantly for both factors [-4, -3, 3, or 4]) seaweed as a safe and healthy food source (19) and that seaweed aquaculture could contribute to coastal community economic development (4). Participants from both perspectives also strongly agreed that the following aspects to be important for advancing the industry: i) including different knowledge systems for decision-making (22), ii) developing commercially scaled practices that incorporate alternative culturing techniques (i.e., IMTA/polyculture) (30), and iii) acknowledging the risk climate change poses, specifically to existing aquaculture infrastructure (9). Other strong areas of agreement that scored strongly [-4, -3, 3, or 4] in at least one perspective included the need for meaningful community engagement to achieve public trust (24), the benefits of collaborative partnerships among farmers (23), and the current demand for a seaweed aquaculture market in Nova Scotia/Canada (2).

Both perspectives generated a neutral response [0] on whether the upfront financial investment was affordable (3), and that seaweed aquaculture will create spatial conflicts (25). Both perspectives also demonstrated a somewhat disinterested response [-2, -1, 1, and 2] towards public perceptions and the place of community needs, interests and role in the planning, decision-making and development of the seaweed aquaculture industry (18, 36, 26, 17). This apathy was also perceived towards managerial tools: MSP as a holistic planning approach (40) and the proposed Aquaculture Act as an improved regulatory framework (38).

CHAPTER 4. DISCUSSION

This research explored stakeholder perceptions of the outlook of seaweed aquaculture industry in Nova Scotia, revealing a clear divide between participants with contrasting views on the current and future state of the industry. These perspectives provide insight into the main factors affecting the industry and the considerations that should be taken into account when considering its potential to succeed in Nova Scotia. The discussion has been structured around the five most prominent themes identified in the findings. The following analysis allows for an exploration of the perceptions of and priorities for, sustainable seaweed aquaculture.

4.1 CONFLICTING NARRATIVES

The individuals included in the ‘seaweed skeptics’ perspective are characterized by doubts about seaweed aquaculture. In particular, this includes apprehension towards claims of climate mitigation opportunities, such as using seaweed to create a biofuel or for long-term carbon sequestration, as has been reported in the literature (Chen et al., 2015; Duarte et al., 2017). As a researcher participant remarked,

> “There’s a lot of really positive things here. However, I am skeptical of whether it's a form of carbon sequestration. I’m [also] a bit skeptical that people can be transformed to eat more seaweed, but I think that’s a cultural thing that needs to be developed.”

Although both perspectives included participants from each stakeholder group, the representation differed. The presence of NGO/community representatives in the skeptic perspective (n = 3) (Fig. 2) is perhaps due to a precursory climate of public skepticism and mistrust regarding aquaculture in Nova Scotia (Flaherty et al., 2019). Strong presence of the academic, NGO and government groups in the skeptic perspective may be due to the fact that establishment of the industry is predicated on policy, community engagement and science that is still developing and evolving (Cascadia Seaweed, n.d.). A patchwork of insufficient data and ambiguous evidence surrounding the relationship between carbon removal and seaweed cultivation clearly impacted participant outlooks.

This is contrasted by the views of participants in the ‘seaweed solution’ perspective, who recognized the opportunities and benefits of seaweed aquaculture, specifically as a feed alternative and tool for mitigating coastal eutrophication through bioremediation (see also Maia et al., 2016; Zheng et al., 2019). Among the skeptic perspective, only 10% of participants were industry members (n = 1), whereas among the solution perspective, approximately 40% of participants were industry members (n = 4) (Fig. 2). Given their direct relationship with aquaculture, industry members may be more likely to be seaweed solutionists. Where members of educational and political institutions might be constrained by bureaucratic, financial and temporal challenges, industry members may not be constrained by the same limitations. The feasibility of development occurring in certain areas might therefore seem more likely. The differences within and among the two perspectives could also be reflective of the history associated with seaweed aquaculture industry. As a government participant pointed out,

> “Lots of people have been looking at this since the 70’s. We’ve been trying since then to find some viable commercial application for seaweeds on a large scale and we haven’t been successful yet.”

4.2 UNDECIDED AMIDST UNCERTAINTY

Existing environmental and experiential knowledge gaps currently present an important challenge for the industry. Specifically, there was consensus that climate change posed a risk to the industry as it could have the potential to damage existing aquaculture infrastructure. Participants in the skeptic perspective strongly believed that climate change would also affect seaweed marketability. A changing climate could trigger changes in wave action and currents that have the potential to change the hydrodynamic forces acting on cultured seaweeds, which may impact quality and productivity and thus the market (Bricknell et al., 2021; García-Poza et al., 2020; Stévant et al., 2017). The industry is also constrained by the ecological carrying capacity of the environments in which seaweeds are grown, a limitation which is increasingly apparent under climate change (Costello et al., 2020). Therefore, the environmental knowledge gaps and uncertainties associated with climate change may present a barrier to the industry establishing itself.

Insufficient knowledge on critical aspects of seaweed biology, physiology and reproduction means high levels of uncertainty also surround the extent of the environmental impacts and risks of seaweed farms (Buschmann et al., 2017; Campbell et al., 2019). Interestingly, individuals in the solution perspective believed the industry should be scaled up, despite these gaps and uncertainties. Scaling up cultivation requires a more complete understanding of these uncertainties and the changes connected to a change in scale, compared to the 'low risk' of small-scale cultivation (Campbell et al., 2019). These gaps in knowledge likely stem from the province's lack of experience in seaweed farming, making it unfamiliar to coastal communities in the Maritimes (Flaherty et al., 2019).

In the absence of knowledge and experience in key areas, there is potential for economic and ecological risk, leading to new types of problems and impacts when establishing or scaling up a new industry (Giercksky & Doumeizel, n.d.; Grebe et al., 2019). This has already been seen in other regions of the world, such as Hawaii, India and East Africa, where introduction of non-native seaweed species have become invasive and caused significant environmental and economic damage (Conklin & Smith, 2005; Halling et al., 2013; Nelson et al., 2009; Pimentel et al., 2001). The recognized scattered data outside Asia (such as in Australia, see Spillias et al., 2022) and the absence of uniform protocols in evaluating the sustainability of cultivated seaweeds (Giercksky & Doumeizel, n.d.) demonstrate that more complete evidence will likely be required for stakeholders before it can move forwards.

4.3 The question of seaweed sovereignty

Participants who sorted in the skeptic perspective strongly believed that governments should play a central role in developing the industry. Both perspectives were characterized by a somewhat indifferent response [-2,-1,0,1 and 2] towards the place of community and public perceptions, needs and roles in the planning, decision-making and development of the seaweed aquaculture industry (18, 36, 26, 17). This suggests that the role of community and the public in developing the industry is not as big a priority for participants as other factors. This neutrality could be because of the nature of the Q-method, pushing individuals to determine their strongest priorities (Watts & Stenner, 2005). However, social acceptance by communities will likely have a major impact on how the industry develops, as has been seen by other aquaculture industries in Canada (Flaherty et al., 2019). Social acceptability is impacted by community perceptions of how aquaculture is regulated and managed (Wood & Filgueira, 2022). A lack of community and public involvement in planning and decision-making may lead to restrictions on communities that can negatively impact public trust and result in withdrawal from similar processes in the future (Flannery et al., 2018; Munro et al., 2017; Smith, 2018). Broad representation can lead to better decision-making, community support and social license for industry growth and projects, and promote engagement at a local level (Hallstrom et al., 2017; Pennino et al., 2021). As an academic participant indicated, it is important to have,

> "an.. infrastructure that would allow for people to survive in small and coastal communities, which are the heart and soul of Nova Scotia. [Community involvement] is one of the things that I see as a real benefit of the industry.. that local individuals can set up farms that are economically viable, without any major impediments."

While participants were generally neutral toward community and public involvement, they did strongly support including different knowledge systems in decision-making. This can include local, experiential knowledge, scientific, traditional or Indigenous systems of knowledge (Bennett et al., 2018). This is an important factor given that Nova Scotia is home to 15 Mi'kmaq nations, 13 of which reside in coastal areas (Province of Nova Scotia, 2019). Recognition of this by the majority of the participants' is indicative of what should be prioritized as this new industry is being developed. A seaweed aquaculture industry that integrates multiple ways of knowing can help to build a secure and equitable industry (Bennett et al., 2017; Kittinger et al., 2017). Inclusion of different knowledge systems can enrich planning and decision-making (Yet et al., 2022), leading to development of more informed policies. As put by an industry participant, on working with local fishermen,

> "They gave us that little bit of insight that we had no way to get. They know more than us [and] we don't want to undermine their knowledge, because they have been fishing there [for a long time]. Actually, the one we had the most difficulty with, was the one who helped us the most, in the end."

4.4 SEAWEEDS AS ECONOMIC SPONSORS

Generally, both perspectives shared that seaweeds present an opportunity both as a safe food source and an avenue for coastal community economic development; although only the solution perspective recognized seaweed aquaculture as an economically viable option for long-term income diversification. One of the ways it can do so is by supplementing or replacing income from existing marine resource production (Grebe et al., 2019). Factors that could help support new entrants to the industry could include a low initial financial investment and educational or training opportunities (Cleaver et al., 2018; Robledo et al., 2013). These can support individuals, often fishermen, in reducing barriers to adoption of aquaculture as a source of income (Cleaver et al., 2018). However, statements related to the financial investment and training opportunities were either neutral or not ranked strongly by either perspective, indicating that perhaps they are of less interest to industry growth.

Both perspectives believed there is demand for a seaweed aquaculture market in Nova Scotia. This is important as access and market competitiveness are needed to support an alternative or supplemental livelihood (Grebe et al., 2019). Compared to other forms of aquaculture, however, relatively little information is available on the economics of seaweed farming and the evaluation of monetary impacts of externalities related to cultivation (Neori et al., 2007; Troell et al., 2009; World Bank Group, 2016). It is likely that economic analyses will be needed for Nova Scotia to understand how the seaweed aquaculture may contribute to local community economic development, including and beyond income supplementation. Both perspectives also recognized that collaborative partnerships between researchers and industry can help to reduce industry financial barriers. This indicates that collaboration may be linked to the capacity of the industry to realize economic opportunities. As pointed out by an academic participant,

> "I like the idea of government and community partnerships. I presume that someone wanting to set up a farm on land would get some sort of substantial loan and infrastructure from the province and I don't see why that shouldn't also apply in the marine environment."

Consumer attitudes and acceptance have been identified as important in determining the direction of the European seaweed industry (van den Burg et al., 2021). Like Canada, Europe does not have the same tradition in food consumption habits compared to Asia, making market penetration limited (van den Burg et al., 2021). The successful large-scale production of seaweeds in countries such as China, Japan and Korea is due, in part, to the strong socio-cultural significance attached to seaweed (García-Poza et al., 2020; van den Burg et al., 2021). This is perhaps why there has only been development of pilot-scale and precommercial farming projects in Europe, Latin America and parts of Africa (Buschmann et al., 2014; Msuya, 2011; Peteiro et al., 2016; Stévant et al., 2017). Workshops, extension services and pilot-scale farms (Buschmann et al., 2017) seem to be a logical step for the industry to satisfy economic needs and sustainability requirements.

4.5 Bonus benefactors

Despite some skepticism regarding various aspects of seaweed aquaculture, the solution perspective strongly believed seaweeds could be used as an animal feed alternative. Although there is limited data on seaweed for feed purposes in the world outside Asia, seaweeds have been used as livestock feed for thousands of years (Giercksky & Doumeizel, n.d.; Makkar et al., 2016). A current constraint in major fed aquaculture is the high price, access and variability of fishmeal supply (World Bank Group, 2016). Since the nutritional value of algae oils in seaweeds are comparable to that of fish oils, seaweeds provide a cost-effective alternative that would reduce dependence on capture fisheries for feed (Costello et al., 2020; World Bank Group, 2016). Although these views were not shared by the skeptic perspective, the benefits and use of seaweeds as animal feeds is not a novel concept and merits further research.

The solution perspective also believed seaweed aquaculture could play a role in mitigating the effects of coastal water eutrophication through bioremediation. Bioremediation refers to seaweeds' ability to take up excess nutrients, such as nitrogen and phosphate (Zheng et al., 2019). These practices offer opportunities for waste management, eutrophication mitigation and minimizing the environmental risks and impacts associated with seaweed aquaculture. These environmental benefits have been readily demonstrated in China, where seaweed aquaculture is a large and developed economic activity (Yang et al., 2015a, 2015b; Zheng et al., 2019). One method of achieving this would be through means of alternative culturing techniques such as integrated multi-trophic aquaculture (IMTA) or polyculture, where seaweeds are used to extract nutrients released by other cultured species. Introducing IMTA systems that use seaweeds could also optimize lease spaces and diversify the harvesting income of farmers, providing another avenue for coastal community economic development (Chopin et al., 2001; Troell et al., 2003). Both perspectives strongly agreed that these types of alternative practices could be successful for seaweeds and could be scaled commercially.

CHAPTER 5. CONCLUSION

5.1 MOVING FORWARD

A primary concern for scaling up the industry is that it could lead to increased conflicts between and among industry stakeholders, coastal rightsholders and other ocean users (Flavin et al., 2013; Stévant et al., 2017). Spatial conflicts were perceived neutrally (0) by both groups, perhaps indicating that there is room for new industries in Nova Scotia's coastal waters. Yet, seaweed farming is still "a small, yet growing sector in Canada" (Fisheries and Oceans Canada, 2021), and increasing to large-scale or commercialization will require a compromise between sustainability, meeting regulatory requirements and making cultivation economically profitable (Flavin et al., 2013). To ensure long-term sustainability, industry development will require a framework, like the Ecosystem Approach to Aquaculture, that integrates aquaculture into the wider ecosystem to guide holistic practices that promote 'sustainable development, equity, and resilience of inter-linked social-ecological systems' (Soto et al. 2008).

Considering these challenges, many questions remain for how this industry should be planned and developed in the future. Both perspectives did somewhat agree that MSP could offer a holistic planning tool for the future of this industry and be a viable option for supporting coastal community interests. However, past MSP has been criticized for prioritizing economic interests, despite decisions directly impacting local livelihoods, lending to social and political opposition that limits its growth (Yet et al., 2022). Linking MSP with community-based processes would lead to outcomes that are in the best interest of the communities living there and gives local governments the opportunity to make decisions about its own coastal waters (Manuel & MacDonald, 2020). Governance of the aquaculture sector has been described as a wicked problem attributable to, in part, "opposing perspectives amongst community, industry and government stakeholders" (Flaherty et al., 2019). Sustainable management practices will depend on local communities who are connected, have access and have rights to participate in management of coastal areas (Armitage et al., 2017). However, as the statements of who should be involved in decision-making were not listed as a priority by participants, it could indicate that there are other issues that are more pressing at this stage of development. There was strong disagreement on who should play a central role in the development of seaweed aquaculture, clearly demonstrating the need for a framework to structure the evolution of this industry. Although many regulatory aspects were not prioritized by participants, interviewed participants brought up the leasing process, remarking on how slow and frustrating it is, with one academic participant remarking,

> "It just seems that this is exactly the kind of industry we need in Nova Scotia, but the regulations [entities] are required to work under are not working. [It would be good] to have seaweed aquaculture recognized in the same manner [as oyster and mussel aquaculture], that it's taking up nearshore space. There's no need to have whole new regulations, I would hope that all you have to do is tweak provincial regulations regarding lease areas to allow seaweeds in."

The development of a new industry requires new regulations that consider the other uses of the ocean. This reinforces the need for MSP or a planning tool to help manage the use of Nova Scotia's shared coastal spaces.

5.2 Recommendations

To achieve full-spectrum sustainability that balances the social, environmental, economic and governance dimensions of the seaweed aquaculture industry, holistic approaches such as MSP, ecosystem-based management and adaptive management that are focused on proactive, community-based participation and involvement are recommended. Using such management models along with collaborative governance arrangements can help to build decentralized decision-making processes. A combination of these approaches can help to build an industry that is equitable and ensures protection of community access to marine resources. The industry will also require the development of regulations and policies to provide a robust framework for implementation, management and monitoring of the industry. Given these anticipated needs, forward thinking tools and strategies should be used to guide the development of seaweed regulations and policies. Other countries' successful frameworks can be used as examples to inform Canadian policies and move forward in a new industry amidst considerable uncertainty. Management and planning will likely also require fostering immense interdepartmental coordination and collaboration. There is a paucity in research and analyses on the economics of seaweed aquaculture and education of individuals looking to learn seaweed farming methods. These areas, including developing market mapping and farming training programs should be focused on to develop capacity for the future seaweed workforce. This may mean building the foundation for a large-scale industry by first creating capacity for small-scale farms that center community benefits and well-being.

5.3 CONCLUSION

Stakeholders from four groups provided insight into the factors affecting the potential for seaweed aquaculture in Nova Scotia. Two main perspectives were found that defined most participants: the ‘Seaweed Skeptic’ and the ‘Seaweed as a Solution’. While the skeptic perspective was defined by its apprehension involving the uncertainties of the industry, the solution perspective was characterized by its belief in the environmental benefits of seaweed aquaculture. Participant perceptions showed there is interest and pathways for seaweeds to contribute to coastal community economic development and food sustainability. Although participants from both perspectives identified potential environmental, economic and social opportunities, key experiential knowledge gaps persist that amplify existing uncertainties and act as barriers for industry growth. The conflicting discourses on who should be involved in the decision-making, development, management and planning indicate that the industry is strongly tied to social and regulatory components that are currently underdeveloped. These findings can help to illustrate what may be needed to advance the seaweed aquaculture industry in Nova Scotia and to envision its future in Canada at a time when collaboration, food security and climate action are critical to humanity.

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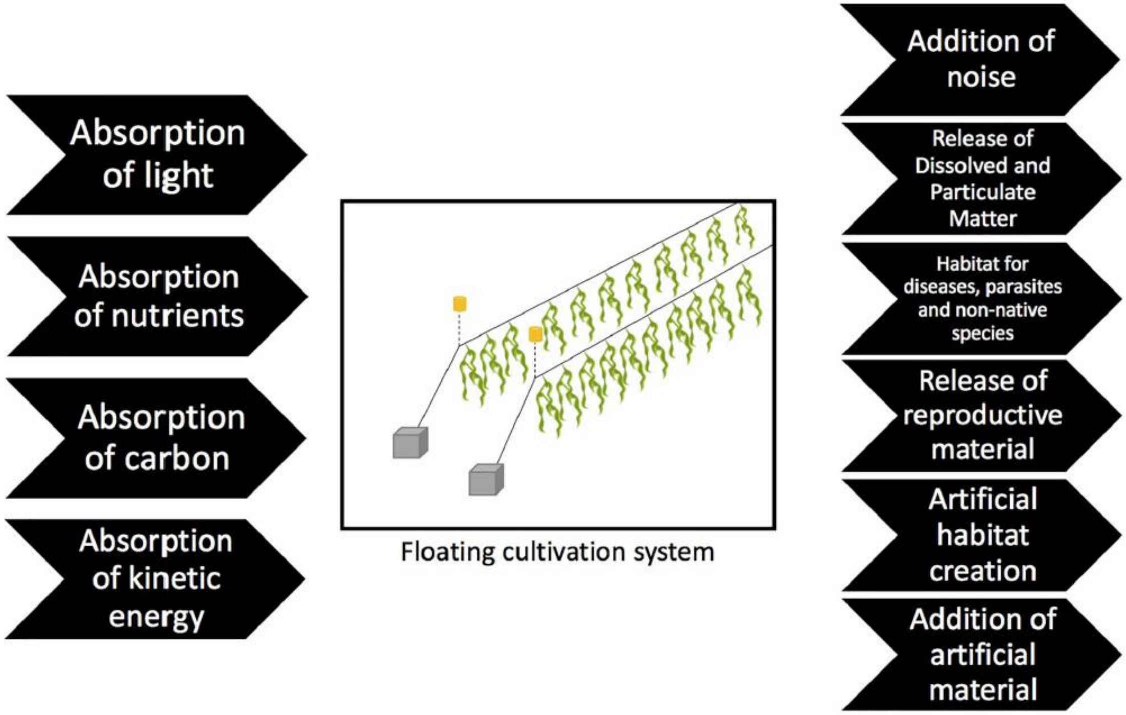
APPENDICES

APPENDIX I. Drivers of environmental change associated with the input of a seaweed farm. Taken from Campbell et al., 2019.



APPENDIX II. SWOT analysis factors and their relevant source material.

Analysis	Factors	Source
Strengths	Affordable upfront investment	Henríquez-Antipa, L. A., & Cárcamo, F. (2019). Stakeholder's multidimensional perceptions on policy implementation gaps regarding the current status of Chilean small-scale seaweed aquaculture. *Marine Policy*, *103*, 138-147.
	Cultivated biomass provides better quality products because each step of the process can be monitored	Henríquez-Antipa, L. A., & Cárcamo, F. (2019). Stakeholder's multidimensional perceptions on policy implementation gaps regarding the current status of Chilean small-scale seaweed aquaculture. *Marine Policy*, *103*, 138-147.
	Limited diversity of species in production means that more R&D effort can be focused on a few species. This can result on greater knowledge of few species.	Rimmer, M. A., Sugama, K., Rakhmawati, D., Rofiq, R., & Habgood, R. H. (2013). A review and SWOT analysis of aquaculture development in Indonesia. *Reviews in Aquaculture, 5*(4), 255-279.
	Good growing environment and climate conditions in Atlantic Canada	Chopin, T., & Ugarte, R. A. U. L. (1998). The seaweed resources of eastern Canada. *Seaweed Resources of the World. Japan International Cooperation Agency, Yokosuka, Japan*, 289-291.
	Seedstock can be sourced locally	Chopin, T. (2017). *Part 1: The Good The Bad The Ugly: Developing Seaweed Cultivation in Canada- From Growing Biomass to Commercializing/Marketing it & Dealing with Regulations -or their absence.*
	Sustainable aquaculture crop and feed as it requires no arable land, fertilizer or water	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture, 13*(1), 460-503.

	Continued delivery of ecosystem services	Henríquez-Antipa, L. A., & Cárcamo, F. (2019). Stakeholder's multidimensional perceptions on policy implementation gaps regarding the current status of Chilean small-scale seaweed aquaculture. *Marine Policy*, *103*, 138-147.
	A rise in popularity and positive public perception throughout the western world	Widrig, T. (n.d.). *Exploring edible sea vegetables today and moving forward in Atlantic Canada.* Mermaidfare.com
	Good understanding of both the biological and production cycles	Chopin, T. (2017). *Part 1: The Good The Bad The Ugly: Developing Seaweed Cultivation in Canada- From Growing Biomass to Commercializing/Marketing it & Dealing with Regulations -or their absence.*
	Good research and development capability and capacity	Rimmer, M. A., Sugama, K., Rakhmawati, D., Rofiq, R., & Habgood, R. H. (2013). A review and SWOT analysis of aquaculture development in Indonesia. *Reviews in Aquaculture*, *5*(4), 255-279.
	Uncomplicated and well-established cultivation techniques, making it easier for the industry to grow	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.
Weaknesses	Limited consumption of seaweed currently in Canadian food culture	Sewuster, J. (2017). *Maximizing raw material utility and return on investment.* Canada and Sea Farmers 2017 - Seaweed Symposium. Aquaculture Association of Nova Scotia.
	Lack of inclusion in marine spatial plans and appropriate financing	World Bank Group. (2016). *Seaweed Aquaculture for Food Security, Income Generation and Environmental Health in Tropical Developing Countries*. World Bank, Washington, DC.

Deficit of economic analyses to determine the actual potential	Henríquez-Antipa, L. A., & Cárcamo, F. (2019). Stakeholder's multidimensional perceptions on policy implementation gaps regarding the current status of Chilean small-scale seaweed aquaculture. *Marine Policy*, *103*, 138-147.
Lack of clear identification of cultivation sites	Henríquez-Antipa, L. A., & Cárcamo, F. (2019). Stakeholder's multidimensional perceptions on policy implementation gaps regarding the current status of Chilean small-scale seaweed aquaculture. *Marine Policy*, *103*, 138-147.
Knowledge gaps: environmental impacts, long-term carbon storage	The Pacific Seaweed Industry Association. (2022). *Seaweed carbon.* Seaweed Around the Clock Conference.
Carbon footprint of processing operations (i.e., fossil fuel-based dryers)	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.
Subject to physiological and pathological diseases	Rimmer, M. A., Sugama, K., Rakhmawati, D., Rofiq, R., & Habgood, R. H. (2013). A review and SWOT analysis of aquaculture development in Indonesia. *Reviews in Aquaculture*, *5*(4), 255-279.
Lack of experience in cultivation at commercial scales in most of the species	Henríquez-Antipa, L. A., & Cárcamo, F. (2019). Stakeholder's multidimensional perceptions on policy implementation gaps regarding the current status of Chilean small-scale seaweed aquaculture. *Marine Policy*, *103*, 138-147.
Limited collaboration or partnerships among organizations	Henríquez-Antipa, L. A., & Cárcamo, F. (2019). Stakeholder's multidimensional perceptions on policy implementation gaps regarding the current status of Chilean small-scale seaweed aquaculture. *Marine Policy*, *103*, 138-147.
Limited capacity of farmers (in other industries) to adopt to new technologies and approaches due to educational,	Rimmer, M. A., Sugama, K., Rakhmawati, D., Rofiq, R., & Habgood, R. H. (2013). A review and SWOT analysis of aquaculture development in Indonesia. *Reviews in Aquaculture*, *5*(4), 255-279.

	attitudinal and resource constraints	
	Low consumer awareness of benefits	Giercksky, E., & Doumeizel, V. (n.d.). *Seaweed revolution: A manifesto for a sustainable future* (p. 16).
	Processing and harvesting technologies - inadequate drying and processing methodology for crops	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.
	Requires a level of traceability, standardization and efficacy that has not been previously demanded	Hafting, J. (2017). *The cultivation of seaweeds for high value products: prospects and challenges.* Bulletin of the Aquaculture Association of Canada 2017-1 Aquaculture Canada and Sea Farmers 2017 - Seaweed Symposium. Aquaculture Association of Nova Scotia.
	Poor regulatory framework currently hampering diversification ~ doesn't consider an ecosystem-based management approach	Chopin, T. (2017). *Part 3: The Good The Bad The Ugly: Developing Seaweed Cultivation in Canada- From Growing Biomass to Commercializing/Marketing it & Dealing with Regulations -or their absence.*
	No legislated cultivation techniques/regulations	Chopin, T. (2017). *Part 3: The Good The Bad The Ugly: Developing Seaweed Cultivation in Canada- From Growing Biomass to Commercializing/Marketing it & Dealing with Regulations -or their absence.*
Opportunities	Diversification of employment and income opportunities for rural/coastal communities/fishermen	Cleaver, C., Johnson, T.R., Hanes, S.P., and Pianka, K. (2018). From fishers to farmers: Assessing the aquaculture adoption in a training program for commercial fishers. Bulletin of Marine Science. 94: 1215-1222.

Development of polyculture/IMTA/co-cultivated activities, infrastructure and regulations	Chopin, T. (2017). *Part 2: The Good The Bad The Ugly: Developing Seaweed Cultivation in Canada- From Growing Biomass to Commercializing/Marketing it & Dealing with Regulations -or their absence.*
Development of multi-use/co-location systems	Buck, B. H., & Buchholz, C. M. (2004). The offshore-ring: a new system design for the open ocean aquaculture of macroalgae. *Journal of Applied Phycology*, *16*(5), 355-368.
Potential for bioremediation of excess nitrogen and phosphorus	Zheng, Y., Jin, R., Zhang, X., Wang, Q., & Wu, J. (2019). The considerable environmental benefits of seaweed aquaculture in China. *Stochastic Environmental Research and Risk Assessment, 33*(4), 1203-1221.
Potential for use as a biofuel	World Bank Group. (2016). *Seaweed Aquaculture for Food Security, Income Generation and Environmental Health in Tropical Developing Countries*. World Bank, Washington, DC.
Cooperative collaboration that could reduce barriers to equipment investment	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.
Can increase aquaculture support (i.e., subsidies, R & D, infrastructure) not just for seaweed, but other aquaculture forms	Rimmer, M. A., Sugama, K., Rakhmawati, D., Rofiq, R., & Habgood, R. H. (2013). A review and SWOT analysis of aquaculture development in Indonesia. *Reviews in Aquaculture*, *5*(4), 255-279.
Industry's resilience depends on social strategies (i.e., knowledge and related discourse)	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.

Enhanced training opportunities and consumer education	Tremblay, I. (2017). *Seaweed cultivation in Northeast Atlantic: what we learned at NACE.* Aquaculture Association of Nova Scotia – Seaweed Cultivation Workshop.
R&D and commercialization of reliable seed sources	Tremblay, I. (2017). *Seaweed cultivation in Northeast Atlantic: what we learned at NACE.* Aquaculture Association of Nova Scotia – Seaweed Cultivation Workshop.
Development of public policies that improve aquaculture	Henríquez-Antipa, L. A., & Cárcamo, F. (2019). Stakeholder's multidimensional perceptions on policy implementation gaps regarding the current status of Chilean small-scale seaweed aquaculture. *Marine Policy*, *103*, 138-147.
Development of multi-species and multi-year licenses	Chopin, T. (2017). *Part 3: The Good The Bad The Ugly: Developing Seaweed Cultivation in Canada- From Growing Biomass to Commercializing/Marketing it & Dealing with Regulations -or their absence.*
An Aquaculture Act that considers the ecosystem-based management approach to aquaculture	Chopin, T. (2017). *Part 3: The Good The Bad The Ugly: Developing Seaweed Cultivation in Canada- From Growing Biomass to Commercializing/Marketing it & Dealing with Regulations -or their absence.*
Inclusion of seaweeds in a variety of amendments to federal and provincial regulatory frameworks, policies and programs	Tremblay, I. (2017). *Seaweed cultivation in Northeast Atlantic: what we learned at NACE.* Aquaculture Association of Nova Scotia – Seaweed Cultivation Workshop.
Establishing husbandry principles for seaweed that can consistently be used	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.

Threats	Increasing harvest volume increases capital investment	Rimmer, M. A., Sugama, K., Rakhmawati, D., Rofiq, R., & Habgood, R. H. (2013). A review and SWOT analysis of aquaculture development in Indonesia. *Reviews in Aquaculture*, *5*(4), 255-279.
	Undeveloped market outside of Asia	Giercksky, E., & Doumeizel, V. (n.d.). *Seaweed revolution: A manifesto for a sustainable future* (p. 16).
	Decreased marketability due to climate change and changing morphology/retention	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.
	Energy-intensive steps in seaweed farming and processing: work to reduce energy consumption	The Pacific Seaweed Industry Association. (2022). *Seaweed carbon.* Seaweed Around the Clock Conference.
	Genetic diversity of aquaculture crops/strains	Provan, J, Maggs CA. (2012). Unique genetic variation at a species rear edge is under threat from global climate change. *Proceedings of the Royal Society B: Biological Sciences* 279: 39-47.
	Dependence on wild species for seedstock for supplying larger retailers	Widrig, T. (n.d.). *Exploring edible sea vegetables today and moving forward in Atlantic Canada.* Mermaidfare.com
	Unknown environmental impacts	Campbell, I., Macleod, A., Sahlmann, C., Neves, L., Funderud, J., Øverland, M., ... & Stanley, M. (2019). The environmental risks associated with the development of seaweed farming in Europe-prioritizing key knowledge gaps. *Frontiers in Marine Science*, *6*, 107.

Level of engagement among farmers and community members	Yet, M., Manuel, P., DeVidi, M., & MacDonald, B. H. (2022). Learning from experience: Lessons from community-based engagement for improving participatory marine spatial planning. *Planning Practice & Research*, *37*(2), 189-212.
Lack of a social license	Giercksky, E., & Doumeizel, V. (n.d.). *Seaweed revolution: A manifesto for a sustainable future* (p. 16).
Conflicts with the changing activities of other ocean users (i.e., earlier seasons will change seasonal timing of other ocean users)	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.
Climate change will impact aquaculture engineering and infrastructure	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.
Slow to embrace innovation	Henríquez-Antipa, L. A., & Cárcamo, F. (2019). Stakeholder's multidimensional perceptions on policy implementation gaps regarding the current status of Chilean small-scale seaweed aquaculture. *Marine Policy*, *103*, 138-147.
Slow move to seed banks for natural genetic diversity for future breeding	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.

APPENDIX III. Survey statements, their identifying number and their relevant source material.

(#)	Statement	Source
1	Seaweed aquaculture is not an economically viable option for long-term income diversification.	World Bank Group. (2016). *Seaweed Aquaculture for Food Security, Income Generation and Environmental Health in Tropical Developing Countries*. World Bank, Washington, DC.
2	There is currently no demand for a domestic seaweed market in Nova Scotia/Canada.	Giercksky, E., & Doumeizel, V. (n.d.). *Seaweed revolution: A manifesto for a sustainable future* (p. 16).
3	The upfront financial investment of seaweed aquaculture is not expensive.	Robledo, D., Fraga, J., & Gasca-Leyva, E. (2013). Social and economic dimensions of carrageenan seaweed farming in Mexico. *Fisheries and Aquaculture*, *Technical Paper: FAO, Rome*, *580*, 185–204.
4	Seaweed aquaculture could contribute to coastal community economic development.	Rebours, C., Marinho-Soriano, E., Zertuche-González, J. A., Hayashi, L., Vásquez, J. A., Kradolfer, P., ... & Robledo, D. (2014). Seaweeds: an opportunity for wealth and sustainable livelihood for coastal communities. *Journal of Applied Phycology*, *26*(5), 1939-1951.
5	Due to the uncertainty associated with the profitability and environmental impacts of large-scale operations (e.g., possible marine mammal entanglement, competition with wild species), seaweed aquaculture should not be	Grebe, G. S., Byron, C. J., Gelais, A. S., Kotowicz, D. M., & Olson, T. K. (2019). An ecosystem approach to kelp aquaculture in the Americas and Europe. *Aquaculture Reports*, *15*, 100215.

	scaled-up from small scale operations.	
6	Seaweed aquaculture ensures long-term storage of carbon.	Krause-Jensen, D., and Duarte, C. M. (2016). Substantial role of macroalgae in marine carbon sequestration. *Nature Geoscience, 9*(10), 737–742. d
7	Seaweed cannot be considered as an environmentally sustainable, viable animal feed alternative.	Maia, M. R. G., Fonseca, A. J. M., Oliveira, H. M., Mendonca, C., and Cabrita, A. R. J. (2016). The potential role of seaweeds in the natural manipulation of rumen fermentation and methane production. Sci. Rep. 6:32321.
8	Seaweed can be considered as a viable fish oil replacement.	World Bank Group. (2016). *Seaweed Aquaculture for Food Security, Income Generation and Environmental Health in Tropical Developing Countries*. World Bank, Washington, DC.
9	Climate change does not present a risk to existing aquaculture infrastructure.	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.
10	Warming temperatures will make seaweeds more vulnerable to diseases and pathogens.	Campbell, I., Macleod, A., Sahlmann, C., Neves, L., Funderud, J., Øverland, M., ... & Stanley, M. (2019). The environmental risks associated with the development of seaweed farming in Europe-prioritizing key knowledge gaps. *Frontiers in Marine Science*, *6*, 107.
11	Climate change will not affect seaweed marketability.	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.
12	Using hatchery seaweed for cultivation could impact the	Kim, J. K., Yarish, C., Hwang, E. K., Park, M., & Kim, Y. (2017). Seaweed aquaculture: cultivation technologies, challenges and its ecosystem services. *Algae*, *32*(1), 1-13.

	genetic diversity of wild populations.	
13	A seaweed farm will not have any negative environmental impacts.	Campbell, I., Macleod, A., Sahlmann, C., Neves, L., Funderud, J., Øverland, M., ... & Stanley, M. (2019). The environmental risks associated with the development of seaweed farming in Europe-prioritizing key knowledge gaps. *Frontiers in Marine Science*, *6*, 107.
14	Habitat degradation from climate change will reduce the amount of suitable habitat for future seaweed aquaculture.	Grebe, G. S., Byron, C. J., Gelais, A. S., Kotowicz, D. M., & Olson, T. K. (2019). An ecosystem approach to kelp aquaculture in the Americas and Europe. *Aquaculture Reports*, *15*, 100215.
15	Growing seaweeds could increase nutrient removal from coastal water eutrophication.	Zheng, Y., Jin, R., Zhang, X., Wang, Q., & Wu, J. (2019). The considerable environmental benefits of seaweed aquaculture in China. *Stochastic Environmental Research and Risk Assessment*, *33*(4), 1203-1221.
16	Seaweed cannot feasibly be considered for use as a biofuel.	Kraan, S. (2013). Mass-cultivation of carbohydrate rich macroalgae, a possible solution for sustainable biofuel production. *Mitigation and Adaptation Strategies for Global Change*, *18*(1), 27–46.
17	Previous conflicting perceptions of existing aquaculture play a negative role in the success of the seaweed industry.	Cottier-Cook, E. J., Nagabhatla, N., Badis, Y., Campbell, M., Chopin, T., Dai, W., ... & Gachon, C. M. M. (2016). Safeguarding the future of the global seaweed aquaculture industry. *United Nations University and Scottish Association for Marine Science Policy Brief*. 12.
18	Community interests and needs are not currently considered in the decisions	Yet, M., Manuel, P., DeVidi, M., & MacDonald, B. H. (2022). Learning from experience: Lessons from community-based engagement for improving participatory marine spatial planning. *Planning Practice & Research*, *37*(2), 189-212.

	related to seaweed aquaculture planning.	
19	Seaweed offers a safe and healthy food source option.	World Bank Group. (2016). *Seaweed Aquaculture for Food Security, Income Generation and Environmental Health in Tropical Developing Countries*. World Bank, Washington, DC.
20	Clear communication from regulators won't help to increase social acceptability of the industry.	Yet, M., Manuel, P., DeVidi, M., & MacDonald, B. H. (2022). Learning from experience: Lessons from community-based engagement for improving participatory marine spatial planning. *Planning Practice & Research*, *37*(2), 189-212.
21	Clear communication from industry managers will help to increase social acceptability of the industry.	Yet, M., Manuel, P., DeVidi, M., & MacDonald, B. H. (2022). Learning from experience: Lessons from community-based engagement for improving participatory marine spatial planning. *Planning Practice & Research*, *37*(2), 189-212.
22	Including different knowledge systems will improve decision making regarding the seaweed aquaculture industry.	Bennett, N. J., Kaplan-Hallam, M., Augustine, G., Ban, N., Belhabib, D., Brueckner-Irwin, I., ... & Bailey, M. (2018). Coastal and Indigenous community access to marine resources and the ocean: A policy imperative for Canada. *Marine Policy*, *87*, 186-193.
23	Collaborative partnerships among farmers will be important for reducing industry financial barriers.	Henríquez-Antipa, L. A., & Cárcamo, F. (2019). Stakeholder's multidimensional perceptions on policy implementation gaps regarding the current status of Chilean small-scale seaweed aquaculture. *Marine Policy*, *103*, 138-147.
24	Meaningful community engagement will increase public trust of seaweed aquaculture.	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.

25	Introducing seaweed aquaculture will increase spatial conflicts with other maritime ocean users.	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.
26	Public and consumer awareness of the benefits of seaweed is limited.	Giercksky, E., & Doumeizel, V. (n.d.). *Seaweed revolution: A manifesto for a sustainable future* (p. 16).
27	Current farming husbandry practices are not suitable for growing and harvesting seaweed.	Henríquez-Antipa, L. A., & Cárcamo, F. (2019). Stakeholder's multidimensional perceptions on policy implementation gaps regarding the current status of Chilean small-scale seaweed aquaculture. *Marine Policy*, *103*, 138-147.
28	The current available processing technologies in Canada are inadequate for growing the industry.	Costello, C., Cao, L., Gelcich, S., Cisneros-Mata, M. Á., Free, C. M., Froehlich, H. E., ... & Lubchenco, J. (2020). The future of food from the sea. *Nature*, *588*(7836), 95-100.
29	The seaweed supply chain and farming processes are energy intensive.	Duarte, C. M., Wu, J., Xiao, X., Bruhn, A., & Krause-Jensen, D. (2017). Can seaweed farming play a role in climate change mitigation and adaptation? *Frontiers in Marine Science*, *4*.
30	Polyculture/Integrated Multi-Trophic Aquaculture (IMTA) practices that include seaweed cannot be scaled commercially to mitigate potential negative environmental impacts.	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.

31	Offshore seaweed aquaculture is not a viable option.	Bak, U. G., Gregersen, Ó., & Infante, J. (2020). Technical challenges for offshore cultivation of kelp species: lessons learned and future directions. *Botanica marina*, *63*(4), 341-353. Fernand, F., Israel, A., Skjermo, J., Wichard, T., Timmermans, K. R., & Golberg, A. (2017). Offshore macroalgae biomass for bioenergy production: Environmental aspects, technological achievements and challenges. *Renewable and Sustainable Energy Reviews*, *75*, 35-45.
32	Reliable seed sources for seaweed aquaculture are not available in Atlantic Canada.	Ross, N. (2017, January 26). *Seaweed Cultivation Workshop*.
33	Seaweed aquaculture training opportunities are not available in Nova Scotia.	Bricknell, I. R., Birkel, S. D., Brawley, S. H., Van Kirk, T., Hamlin, H. J., Capistrant-Fossa, K., ... & Moeykens, S. (2021). Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Reviews in Aquaculture*, *13*(1), 460-503.
34	Federal and provincial governments should streamline the regulatory process for industry growth.	Chopin, T. (2017). *Part 3: The Good The Bad The Ugly: Developing Seaweed Cultivation in Canada- From Growing Biomass to Commercializing/Marketing it & Dealing with Regulations -or their absence.*
35	Governments should not play a central role in the development of the seaweed aquaculture industry.	Yet, M., Manuel, P., DeVidi, M., & MacDonald, B. H. (2022). Learning from experience: Lessons from community-based engagement for improving participatory marine spatial planning. *Planning Practice & Research*, *37*(2), 189-212.
36	Coastal communities should play a central role in the development of the seaweed aquaculture industry.	Rebours, C., Marinho-Soriano, E., Zertuche-González, J. A., Hayashi, L., Vásquez, J. A., Kradolfer, P., ... & Robledo, D. (2014). Seaweeds: An opportunity for wealth and sustainable livelihood for coastal communities. *Journal of Applied Phycology*, *26*(5), 1939-1951.

37	The current regulatory framework does not support growth of the seaweed aquaculture industry.	Chopin, T. (2017). *Part 3: The Good The Bad The Ugly: Developing Seaweed Cultivation in Canada- From Growing Biomass to Commercializing/Marketing it & Dealing with Regulations -or their absence.*
38	The proposed Aquaculture Act will help provide a better framework to regulate the seaweed aquaculture industry.	Cascadia Seaweed. (n.d.) *Integrating Seaweed Aquaculture into Canada's Blue Economy Strategy: A Call to Action*.
39	Marine spatial planning (MSP) is a viable tool for supporting coastal community interests.	Yet, M., Manuel, P., DeVidi, M., & MacDonald, B. H. (2022). Learning from experience: Lessons from community-based engagement for improving participatory marine spatial planning. *Planning Practice & Research*, *37*(2), 189-212.
40	Marine spatial planning (MSP) can provide holistic planning for seaweed aquaculture.	Lester, S. E., Stevens, J. M., Gentry, R. R., Kappel, C. V., Bell, T. W., Costello, C. J., ... & White, C. (2018). Marine spatial planning makes room for offshore aquaculture in crowded coastal waters. *Nature communications*, *9*(1), 1-13.