THE ROLE OF ECO-CERTIFICATION IN MARINE SALMON FARMING

by

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ABSTRACT

Eco-certification schemes are certifying an increasing volume of farmed seafood. These schemes promise to improve industry practices and sustainability by creating market incentives for producers to participate in eco-certification programs. However, the role and success of these schemes in contributing to ecosystem sustainability is unclear. This thesis explores the role of eco-certification in marine salmon farming, an aquaculture industry in which eco-certification has become especially relevant. It explores the current and potential role of salmon farming eco-certification in creating positive sustainability outcomes using the Food and Agriculture Organization (FAO)'s Ecosystem Approach to Aquaculture (EAA), a strategy for the development of sustainable aquaculture within the context of ecosystem services, as a guiding framework. Building on a literature review of the challenges and opportunities for aquaculture eco-certification to bring about sustainability (Chapter 2), this thesis identifies ecosystem services represented in salmon farming eco-certification schemes (Chapter 3). It then identifies themes related to the limitations of eco-certification schemes in addressing ecosystem-level sustainability that emerged from interviews with eco-certification scheme staff, auditors, and salmon farming industry members (Chapter 4). The relationship between stakeholders and eco-certification is explored using a public survey (Chapter 5) and analysis of salmon farming company sustainability reporting (Chapter 6). Results indicate that salmon aquaculture eco-certification addresses some ecosystem-level environmental sustainability issues, and that improvements can be made to better support EAA. Eco-certification appears to have a limited role in reputational risk management for farming companies but is important for indicating commitment to sustainability to shareholders. Finally, the efficacy of salmon farming eco-certification should be considered in concert with public regulation and corporate social responsibility (CSR) practices. The findings from this research contribute to an understanding of the success and effectiveness of aquaculture eco-certification, especially its relevance in supporting EAA, and provide practical insights for salmon farming companies and eco-certification schemes.

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CHAPTER 1: INTRODUCTION

1.1 ECO-CERTIFICATION

Sustainability certifications are a form of non-state market-driven governance that have been developed and advanced by private actors including industry and environmental non-governmental organizations (ENGOs) (Cashore, 2002). Transnational sustainability certification schemes challenge the traditional role of the state in managing resources by providing a market-based incentive for private resource users to comply with a set of sustainability standards provided by the eco-certification scheme (Bernstein & Cashore, 2008; Cashore, 2002; Vince & Haward, 2017). This incentive is often supported by an ecolabel that signals compliance with sustainability certification criteria. Therefore, producers that differentiate their products using sustainability certification and associated ecolabels may receive benefits including access to selective markets and price premiums where there is demand for sustainable products.

Sustainability certification has early roots in agriculture, beginning with the first organic certification in 1973, but it has since proliferated across many resource industries including agriculture, forestry, fisheries, and aquaculture (Auld, 2014) (Figure 1.1). These certifications include schemes that focus on specific environmental issues (e.g. organic production) and consumer interests such as food safety and quality, animal welfare, and social accountability (e.g. Fair Trade). Throughout this thesis, eco-certification refers to those sustainability schemes that broadly address sustainability issues, including social and environmental sustainability, but that are not used to certify compliance with a specific type of farming practice or trade relationship (e.g. organic, Fair Trade).

1.2 AQUACULTURE ECO-CERTIFICATION

Aquaculture, the cultivation of fish, shellfish, and seaweeds, has become an important source of animal-based protein. As fisheries resources continue to decline, the growth of farmed seafood production has outpaced fisheries, reaching a record high of 122.6 million tonnes in 2020 (FAO, 2022a). Aquaculture production is dominated by a few key species including Atlantic salmon (*Salmo salar*), which is now one of the most profitable and globally traded farmed species (FAO, 2022a). The growth of aquaculture and demand for farmed seafood has been met with concern about the social-ecological impacts of farming on coastal environments and communities, and the perception that public regulations have not sufficiently addressed those challenges has resulted in interest in other governance solutions including eco-certification (Jonell et al., 2013). Therefore, aquaculture governance is increasingly influenced by interactions between the market and communities, resulting in a hybrid governance arrangement that links the state, communities, and the market, challenging the traditionally dominant role of the state in regulating aquaculture (Vince & Haward, 2017).

Eco-certification schemes address the specific sustainability issues relevant to the sector they govern, e.g. overfishing in fisheries (Auld, 2014), logging of old-growth forests and clearcutting in forestry (Gulbrandsen, 2010), and use of pesticides and chemical fertilizers in agriculture (Conford & Holden, 2007). For example, fisheries eco-certification schemes rely on maximum sustainable yield to evaluate the sustainability of a fishery, amongst other criteria related to ecosystem impacts (Shelton, 2009). Aquaculture eco-certification schemes have evolved to address various sustainability issues relevant to marine farming including water use and pollution, benthic effects, effects on biodiversity, use of antibiotics and other chemical inputs, and impacts on workers and communities where farms are located (Boyd et al., 2005; Osmundsen et al., 2020). Therefore, although seafood eco-certification literature often considers aquaculture eco-certification under the larger umbrella of seafood eco-certification, given distinct production methods and sustainability challenges, it is worth considering aquaculture eco-certification and its role in industry and ecosystem sustainability separately from that of fisheries eco-certification.

1.2.1 Emergence of aquaculture eco-certification schemes

The early emergence of aquaculture eco-certification can be traced to both the sustainable seafood movement and to the continuance of agricultural sustainability and labelling initiatives. By the time the Marine Stewardship Council (MSC), the most prominent fisheries eco-certification scheme, was created in 1997, several examples of environmental certification had already become prominent within other resource sectors.

This included organic and agricultural certification schemes which were already beginning to introduce aquaculture-specific standards (Gulbrandsen, 2010). Later, the retailer program EurepGAP (now GlobalGAP) established its aquaculture standard in 2004 (Nilsen et al., 2018) which remains a prominent eco-certification that is important in European markets (Figure 1.1).

Aquaculture-specific eco-certification programs were borne out of pressure from environmental groups to address sustainability issues specific to the aquaculture industry (Auld, 2014; Nilsen et al., 2018). These schemes were developed to combat environmental degradation and legitimize aquaculture development where policy and regulation were perceived to be failing. First, the Global Aquaculture Alliance (GAA) was founded by industry members in 1997 in direct response to pressure from environmental groups, particularly over the removal of mangroves for shrimp aquaculture. The first project of GAA was the development of a Code of Practice for Responsible Shrimp Farming which would eventually be refined into the first of many species- and production system-specific standards that make up GAA's Best Aquaculture Practices (BAP) eco-certification program (Havice & Iles, 2015). Meanwhile, both World Wildlife Fund (WWF) and the Earth Island Institute began developing aquaculture-specific eco-certification programs. The Earth Island Institute had previously been involved in seafood sustainability through its dolphin-safe tuna labelling program and developed eco-certification standards for both wild fisheries and aquaculture, which are now part of the Friend of the Sea (FOS) program operated by the World Sustainability Organization (WSO). WWF, which had been instrumental in the development of both the Forest Stewardship Council (FSC) and MSC, established the Aquaculture Dialogues, a series of multi-stakeholder meetings with the goal of developing performance-based rules for the aquaculture industry in an open forum (Havice & Iles, 2015). These forums took place over a decade, and eventually the Aquaculture Stewardship Council (ASC) was formed to manage standards resulting from the Aquaculture Dialogues and administer a certification program (Figure 1.1). International aquaculture eco-certification programs including ASC, BAP, GlobalGAP, and FOS continue to certify an increasing volume of farmed seafood, yet the potential for eco-certification to improve aquaculture and ecosystem sustainability is uncertain (Bush et al., 2013a; Jonell et al., 2013).

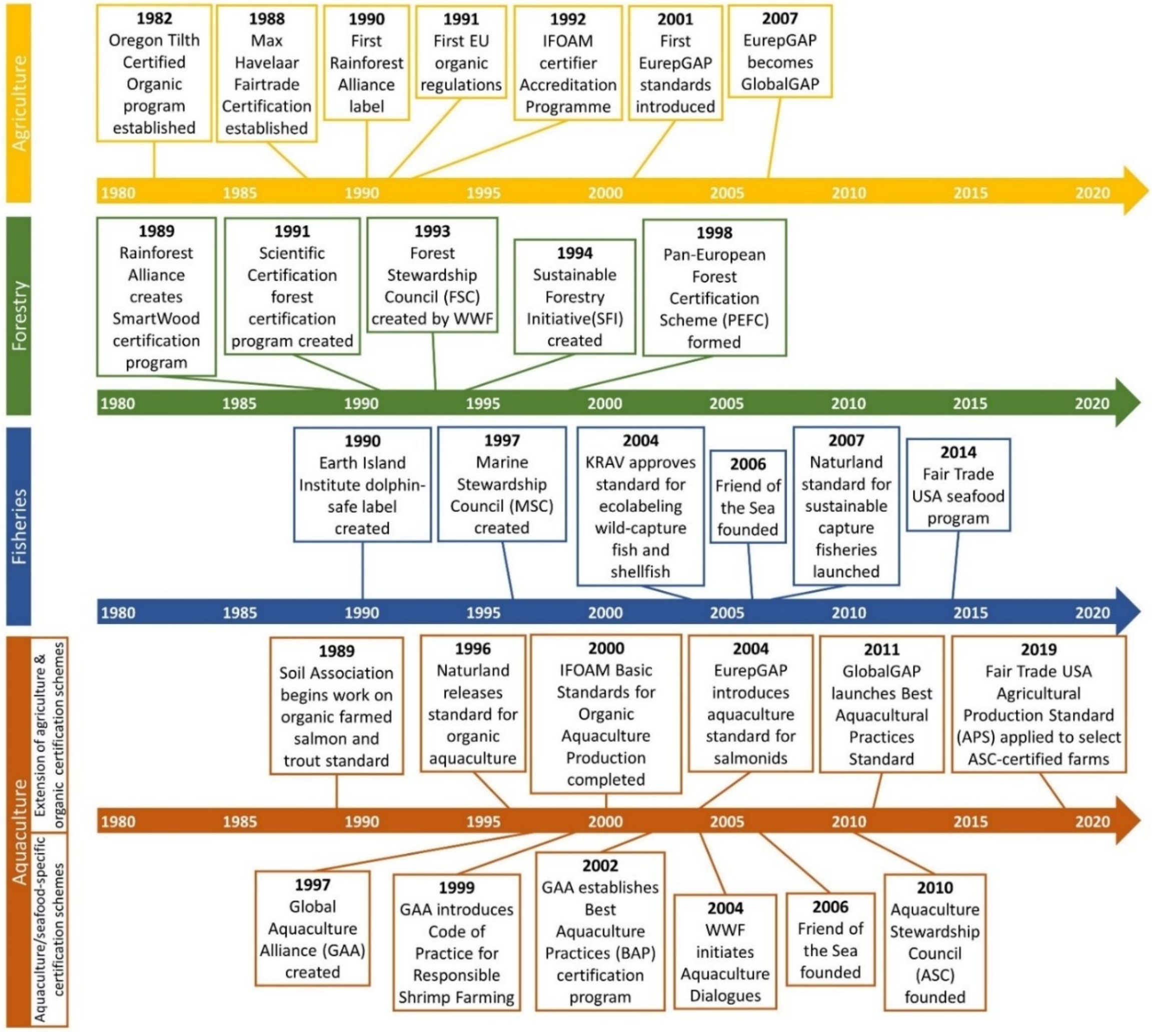

Figure 1.1 Timeline of the establishment of major ecolabels and environmental certifications in agriculture, forestry, fisheries, and aquaculture sectors. IFOAM = The International Federation of Organic Agriculture Movements.

1.2.3 Effectiveness of aquaculture eco-certification schemes

The success of eco-certification relies on four types of effectiveness outlined by Tröster & Hiete (2018): *problem-solving* effectiveness is the success of eco-certification in solving the sustainability challenges and issues it aims to address, *behavioural* effectiveness occurs when industry actors change their activities due to eco-certification, *constitutive* effectiveness is the acceptance of eco-certification amongst stakeholders, and *process* effectiveness is the uptake of eco-certification amongst companies within the industry. Together, *problem-solving* and *behavioural* effectiveness should produce positive sustainability outcomes, while *constitutive* and *process* effectiveness should support the legitimacy of eco-certification and create market incentives (Figure 1.2).

Within the salmon farming industry, the *problem-solving* and *behavioural* effectiveness of eco-certification might include addressing and mitigating social and environmental sustainability challenges which are associated with negative perceptions of the industry (Osmundsen & Olsen, 2017; Young & Matthews, 2011). Research suggests that aquaculture eco-certification criteria do not address all sustainability issues associated with aquaculture production (Alexander et al., 2020; Mussells & Stephenson, 2020; Osmundsen et al., 2020) and that eco-certification is lacking an ecosystem perspective (Bush et al., 2013a). Further, eco-certification may not provide incentive to continue making improvements once a product is eco-certified (Tlusty & Thorsen, 2017). These shortcomings both call the *problem-solving* effectiveness of eco-certification into question and may have implications for *constitutive* effectiveness if they affect stakeholder perceptions of aquaculture eco-certification.

The *constitutive* effectiveness of aquaculture eco-certification includes the credibility and legitimacy of eco-certification and eco-certification schemes amongst stakeholders. Research in this area has largely focused on consumer interactions with eco-certification including assessment of price premiums and willingness-to-pay for eco-certification (Asche et al., 2021; Carlucci et al., 2017; Danso et al., 2017; Ortega et al., 2014). However, these approaches do not address the broader legitimacy of eco-certification schemes which are perceived differently amongst different stakeholders (Weitzman & Bailey, 2018). Therefore, Barclay & Miller, (2018) call for sustainable seafood research that considers eco-certification audiences beyond consumers.

When it comes to *process* effectiveness, it is not clear that a sufficient proportion of aquaculture producers are participating in eco-certification to create significant change (Bush et al., 2013a). Approximately 6.3% of aquaculture production in metric tonnes was estimated to be certified in 2015. For comparison, 20.1% of wild-capture seafood was certified that same year (Potts et al., 2016). However, salmon farming is an especially important target of eco-certification programs; over 50% of global farmed salmon production is ASC-certified, and salmon accounts for over 60% of ASC-certified aquaculture and approximately 50% of BAP-certified aquaculture by volume (ASC, 2022a; GAA, 2020b). Despite generally weak consumer demand for eco-certified seafood, retailers continue to make commitments to sourcing sustainable seafood including eco-certified farmed seafood products (Alfnes, 2017) providing incentive for farming companies to participate in eco-certification schemes. Yet, other motivations including collective action, organizational support, and reputational benefits might also play a role in *process* effectiveness (Amundsen & Osmundsen, 2020; Vormedal & Gulbrandsen, 2020).

1.3 RESEARCH GOALS AND APPROACH

One of the challenges in considering the effectiveness of eco-certification schemes is determining what the ideal outcome of effective eco-certification is; that is, what is/are the issue(s) that *problem-solving* effectiveness must address. The emergence of aquaculture eco-certification schemes was motivated by specific sustainability challenges, and scheme criteria were developed to address some of those challenges; however, as the industry evolves, new practices, tools, technologies, and challenges emerge that require consideration. Further, the goals of sustainable development and the concept of sustainability are guided by new and emerging frameworks. In this thesis, the Food and Agriculture Organization (FAO) of the United Nation's Ecosystem Approach to Aquaculture (EAA) was adopted as a guiding framework in considering the effectiveness and role of eco-certification in salmon farming (Soto et al., 2008). EAA is guided by three principles: (1) development within the context of ecosystem functions and services without degradation of those services beyond their resilience capacity, (2) improvement of human well-being and equity for all, and (3) integration of aquaculture with other sectors. These principles demand an ecosystem perspective and management approach that considers the impacts of aquaculture at multiple scales including the farm, watershed, and globe (Soto et al., 2008).

The overall goal of this thesis was to understand the role of eco-certification in salmon farming. In particular, this research was motivated by questions arising from the potential for eco-certification to improve sustainability across scales, where sustainability is defined in accordance with EAA as the delivery of ecosystem services. The following research questions consider the role of eco-certification in salmon farming across types of effectiveness that contribute to both sustainability and market outcomes as both are necessary for the success of eco-certification:

1. How does salmon aquaculture eco-certification support EAA?
    a. How is the continued provision of ecosystem services supported by eco-certification?
    b. How are ecosystem-level impacts accounted for in salmon aquaculture eco-certification standards and processes?
2. How are stakeholders engaged in and affected by eco-certification?
    a. How does eco-certification affect public opinion of salmon farming?
    b. How is eco-certification integrated into salmon farming corporate social responsibility (CSR)?

These questions are approached from a pragmatic epistemological perspective to provide practical understanding of the role of eco-certification in the salmon farming industry. Thus, this research employs a mixed-methods approach oriented towards understanding the implications of the growth of aquaculture eco-certification for the salmon farming industry, eco-certification schemes, and society. Given the ubiquity of eco-certification within the salmon farming industry, this thesis does not address the question of if we should certify sustainable aquaculture, but rather how eco-certification can contribute to aquaculture sustainability as one influence within the hybrid governance of aquaculture.

1.4 THESIS STRUCTURE

This thesis includes five research chapters, each written as a standalone article (Chapters 2-6), and one concluding chapter (Chapter 7). Chapters 2-5 have been published in peer-reviewed scientific journals. Each chapter is oriented towards improving understanding of one of Tröster & Hiete's (2018) types of effectiveness associated with eco-certification (Figure 1.2). Chapters 2-4 focus on *problem-solving* and *behavioural* effectiveness, Chapter 5 has implications for both *constitutive* and *process* effectiveness, and Chapter 6 addresses *process* and *problem-solving* effectiveness while placing eco-certification within the larger context of industry self-regulation through CSR. Chapter 7 provides a summary and synthesis of the major findings from Chapters 2-6.

Chapter 2 presents a literature review of the sustainability outcomes of aquaculture eco-certification. It identifies key challenges for eco-certification schemes to improve aquaculture sustainability. This chapter also introduces EAA as a guiding framework for the evaluation and improvement of eco-certification schemes and provides potential pathways to address some of the challenges identified in the literature review.

Chapter 3 applies an ecosystem services framework to the assessment of salmon farming sustainability schemes as a tool for the operationalization of EAA. It provides an analysis of the categories of ecosystem services reflected in sustainability scheme criteria, and how those ecosystem services are enhanced or protected by different types of eco-certification criteria.

Chapter 4 provides a thematic analysis of interviews with eco-certification scheme staff, auditors, and members of the salmon farming industry to understand the limitations of farm-applied eco-certification schemes in addressing ecosystem-level sustainability challenges. It relies on first-hand knowledge and the experience of people involved in the process of eco-certification as well as documents that are central to compliance assessment to provide insight into the role of eco-certification criteria, auditors, and local regulations in the integration of ecosystem perspectives in eco-certification schemes.

Chapter 5 presents quantitative findings of a survey on public opinion of salmon farming and eco-certified salmon farming in communities with and without salmon farms. It provides insight into the role of eco-certification in community acceptance of aquaculture and reputational risk. Comparing communities with and without farms extended the spatial perspective required for the application of EAA from the environmental realm to the social realm through comparison of perspectives amongst people living in local communities where salmon farms are located with the perspectives of people living in communities geographically distant from farms.

Chapter 6 explores the use of eco-certification within salmon farming industry CSR practices. It provides an analysis of sustainability reporting from top salmon farming companies that focuses on the use of eco-certification in sustainability reporting, the potential impacts of CSR strategies on ecosystem services affected by salmon farming, and the overlap and integration of eco-certification with other CSR practices.

Chapter 7 provides a summary and synthesis of findings from Chapters 2-6.

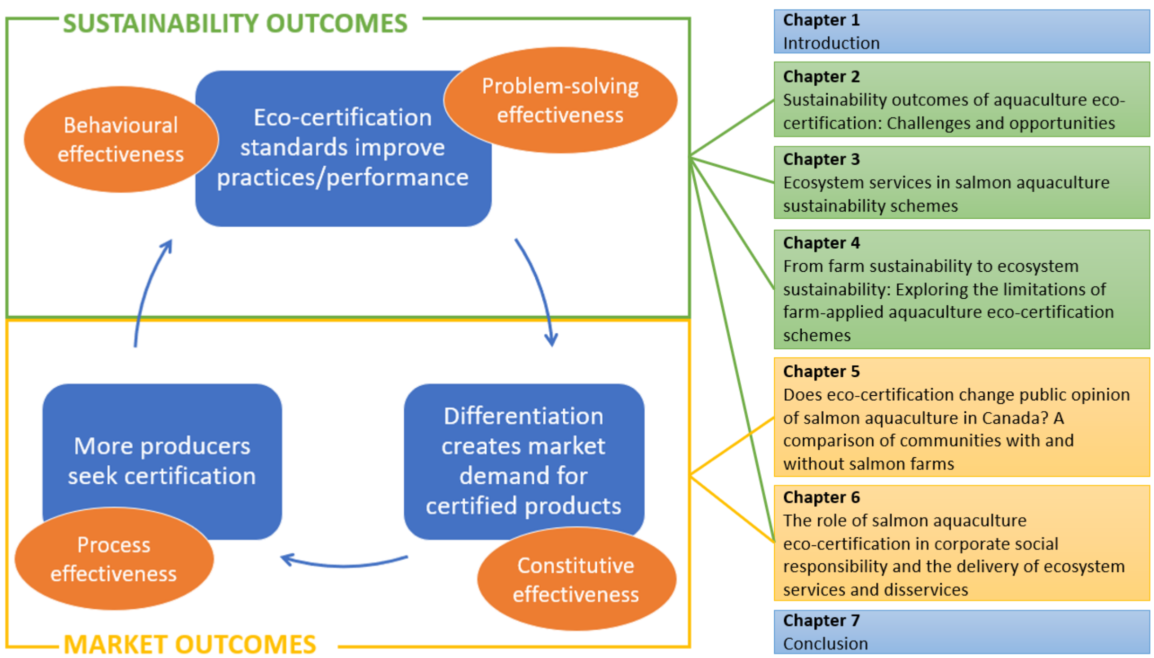

Figure 1.2 Summary of thesis structure and alignment with Tröster & Hiete's (2018) types of effectiveness associated with eco-certification.

1.5 STATEMENT OF CO-AUTHORSHIP

I developed the conceptualization of this thesis with guidance of my co-authors. Across all research chapters, I designed the research, conducted all data collection and analysis, and drafted the manuscripts. My co-authors provided input and feedback throughout the development of the research projects and manuscripts and supported the preparation and revision of manuscripts throughout the publication process. Published and co-authored chapters from this thesis are as follows:

Chapter 2:

Rector, M.E., Filgueira, R., Bailey, M., Walker, T.R., Grant, J. (2023). Sustainability outcomes of aquaculture eco-certification: challenges and opportunities. *Reviews in Aquaculture, 15*: 340-352. doi: 10.1111/raq.12763

Chapter 3:

Rector, M.E., Filgueira, R., Grant, J. (2021). Ecosystem services in salmon aquaculture sustainability schemes. *Ecosystem Services, 52*, 101379. doi.org/10.1016/j.ecoser.2021.101379

Chapter 4:

Rector, M.E., Filgueira, R., Grant, J. (2023) From farm sustainability to ecosystem sustainability: Exploring the limitations of farm-applied aquaculture eco-certification schemes. *Journal of Environmental Management, 339*: 117869. doi.org/10.1016/j.jenvman.2023.117869

Chapter 5:

Rector, M.E., Filgueira, R., Grant, J. (2023) Does eco-certification change public opinion of salmon aquaculture in Canada? A comparison of communities with and without salmon farms. *Aquaculture Economics & Management*. Advance online publication. doi.org/10.1080/13657305.2023.2196948

Chapter 6:

Rector, M.E., Filgueira, R., Grant, J. The role of salmon aquaculture eco-certification in corporate social responsibility and the delivery of ecosystem services and disservices.

CHAPTER 2: SUSTAINABILITY OUTCOMES OF AQUACULTURE ECO-CERTIFICATION: CHALLENGES AND OPPORTUNITIES

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Please note that this chapter appears as it did in the published article, with references and table, figure, and section numbers updated to match the format of this thesis document.

2.1 ABSTRACT

Both the aquaculture industry and eco-certification of aquaculture have grown significantly over the past 20 years, but the extent to which aquaculture eco-certification is effective in creating positive environmental and societal outcomes is uncertain. Therefore, a scoping review of research on the effectiveness of eco-certification in improving aquaculture sustainability outcomes, based on systematic search and inclusion criteria, was conducted. Challenges in producing sustainability outcomes through eco-certification were identified including: (1) choosing which components of sustainability to reflect in eco-certification criteria, (2) the risk of limiting improvements in sustainability by labeling a product 'sustainable', (3) accounting for different spatial scales of aquaculture effects, and (4) designing and applying sustainability criteria that work across different local environments. Potential approaches to these challenges include applying an ecosystem services framework to the identification of issues that could be addressed by eco-certification criteria, supporting continuous improvement of industry best practices, incorporating criteria related to the far-field effects of aquaculture, and recognizing and accounting for the impact of local conditions on farming and eco-certification. Although alternate governance approaches may be better suited to ensuring improved sustainability outcomes, potential improvements to eco-certification criteria and processes are presented as opportunities to match the effectiveness of eco-certification in creating positive sustainability outcomes to its success in creating a market for eco-certified farmed seafood. However, some of these improvements may require the addition of criteria or complexity within the eco-certification process, and their impact on market outcomes, particularly the participation of producers, should be considered.

2.2 INTRODUCTION

Over the past half-century, aquaculture production has grown rapidly in many parts of the world (Garlock et al., 2020) as have the number of aquaculture eco-certification schemes (International Trade Centre, 2022) and amount of aquaculture production that is eco-certified (Figure 2.1). At least 20 certification schemes for aquaculture products claim to address many sustainability issues in their criteria including social accountability, environmental performance, animal welfare, and workers' health and safety (Table 2.1) (International Trade Centre, 2022). Although eco-certification schemes vary in their specific objectives and governance structure, (Nilsen et al., 2018; Potts et al., 2016) in general they provide a set of sustainability criteria that a farm or group of farms is evaluated against. Those farms that meet criteria are granted eco-certified status which may also given them access to an ecolabel that can be displayed on eco-certified product (Bush et al., 2013a).

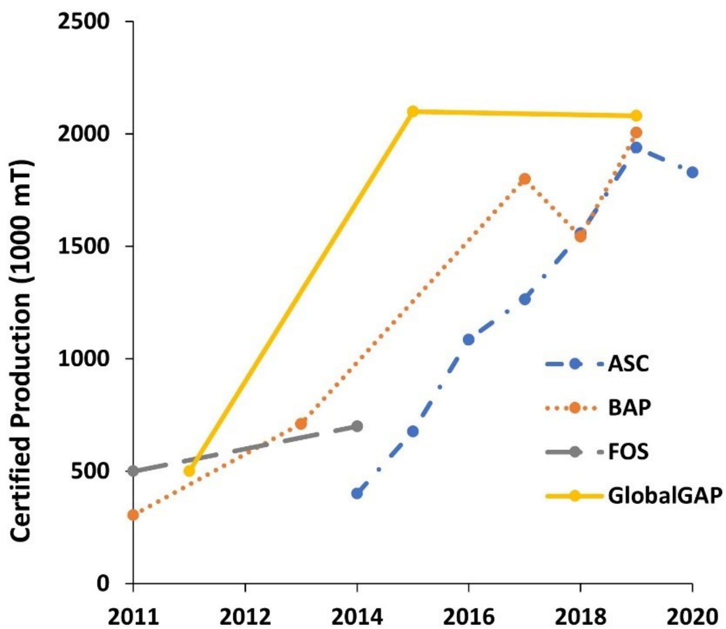

Figure 2.1. Volume of certified production for selected aquaculture eco-certifiers. ASC, Aquaculture Stewardship Council; BAP, Best Aquaculture Practices; FOS, Friend of the Sea. Data for ASC years 2015-2020 from ASC certification update reports (ASC, 2020b), for GlobalGAP 2019 from GlobalGAP annual report (GlobalGAP, 2020), for BAP 2018-2019 from GAA annual reports (GAA, 2019, 2020a), for BAP 2017 from Jonell et al. (2019), for BAP 2013, FOS 2014, and GlobalGAP 2015 from Potts et al. (2016), and for BAP, FOS and GlobalGAP 2011 from Boyd and McNevin (2012). Where certified volume in any given year differed between sources, data from annual reports were used where available.

Table 2.1. Examples of global aquaculture eco-certification schemes, the year they were introduced, their types of standards (coverage of species and farming systems), and types of issues addressed in their criteria. ASC = Aquaculture Stewardship Council, BAP = Best Aquaculture Practices, FOS = Friend of the Sea, WWF = World Wildlife Fund.

Program	Year	Origin	Farm Standards	Criteria Coverage
ASC	2010	WWF Aquaculture Dialogues	Abalone, bivalves, flatfish, freshwater trout, pangasius, salmon, seabass seabream and meagre, Seriola and cobia, shrimp, tilapia, tropical marine fish, seaweed*	Social improvements, environmental improvements, food safety and animal welfare
BAP	2002	Global Aquaculture Alliance	Salmon, finfish and crustaceans, mollusks	Food safety, social accountability, environmental responsibility, animal health and welfare
FOS	2006	Earth Island Institute Dolphin-Safe Project	Inland, marine, prawns, shellfish, seaweed and algae	No impact on critical habitat, compliance with water quality parameters, negligible escapes, no harmful antifouling or growth hormones, social accountability, reduced carbon footprint
GlobalGAP	2004	EurepGAP agriculture certification	General (applied to finfish, crustaceans, mollusks)	Legal compliance, food safety, workers' health and safety, social practices, animal welfare, environmental and ecological care

*joint standard with Marine Stewardship Council (MSC)

If the purpose of eco-certification is to create positive sustainability outcomes, then its success relies on there being a market for sustainable seafood that encourages industry participation, resulting in ecosystem sustainability which enables eco-certification and accompanying ecolabels to serve as honest signals of sustainability. Research has shown that consumers and producers both value eco-certification (Bronnmann & Asche, 2017; Chikudza et al., 2020; Olsen et al., 2021; Ortega et al., 2014; Soley et al., 2019) however, the potential of eco-certification to improve aquaculture practices and industry sustainability remains unclear (Bailey et al., 2018; Jonell et al., 2013, 2019). Evaluating eco-certification effectiveness in relation to sustainability outcomes is theoretically difficult in part due to the undefined concept of effectiveness and unclear expectations as to how sustainable aquaculture should be defined (Jonell et al., 2013). Evaluating outcomes of eco-certification is also practically difficult as the effects of eco-certification must be isolated from other factors and compared using rigorous research designs such as before-after-control-impact (BACI) which require the identification of appropriate controls or baseline data (Blackman & Rivera, 2011; Delmas, 2009).

Given uncertainty around the effectiveness of aquaculture eco-certification in creating positive sustainability outcomes, a lack of evaluation of actual sustainability outcomes of eco-certification (Blackman & Rivera, 2011) and the rapid growth of both the aquaculture industry (FAO, 2020) and amount of eco-certified farmed seafood (Figure 2.1), the goal of this scoping review is to identify key challenges and opportunities for aquaculture eco-certification to create positive sustainability outcomes.

2.3 APPROACH

2.3.1. Defining effectiveness

Eco-certification relies on the differentiation of products that meet sustainability criteria to create demand for those certified products, in turn enticing more producers to take part in eco-certification. This *theory of change* (*TOC*) relies on the differentiation of eco-certified products in the market, producer participation, and effective eco-certification criteria to create sustainability and market outcomes (Figure 2.2). The assumptions of the *TOC* can be mapped to Tröster & Hiete's (2018) four dimensions of effectiveness:

problem-solving effectiveness is the ability of eco-certification to address the problem it was developed to address, *behavioural effectiveness* is the change in activity of the industry, *process effectiveness* is the uptake of eco-certification within industry, and *constitutive effectiveness* is the acceptance of eco-certification by stakeholder groups, including consumers (Figure 2.2).

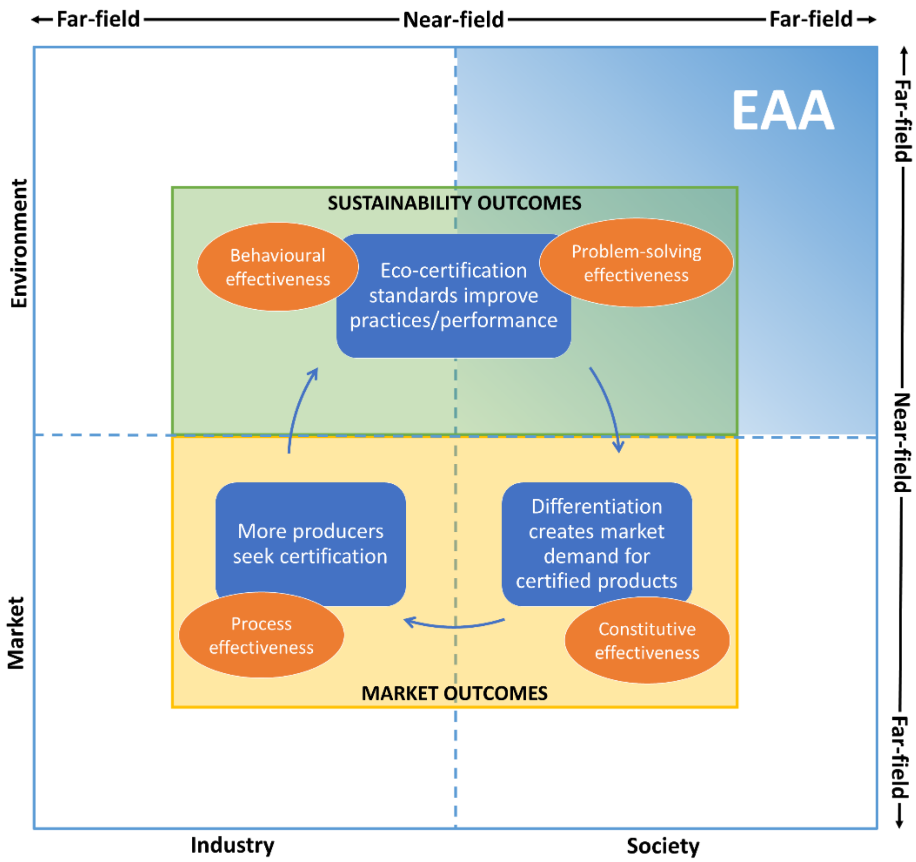

Figure 2.2. Integration of eco-certification theory of change, Tröster and Hiete's (2018) success-effectiveness dimensions, and the ecosystem approach to aquaculture (EAA). Quadrants represent components of the aquaculture assemblage affected by different types of eco-certification effectiveness. The scale of outcomes associated with eco-certification increases from local or near-field outcomes within the centre square of the diagram to far-field outcomes in the outer square.

Each type of effectiveness within the eco-certification *TOC* creates outcomes for a different set of actors or components within the aquaculture assemblage including society, producers, the environment, and the market. For example, *constitutive effectiveness* primarily creates change within society and the market as interest and trust in eco-certification amongst consumers and retailers increases, while *process effectiveness* primarily creates outcomes for producers and the market as participation becomes increasingly necessary for producers to remain competitive (Figure 2.2). While *constitutive* and *process effectiveness* help create a market for sustainable farmed seafood, *behavioural* and *problem-solving effectiveness* are necessary for improving aquaculture sustainability and creating positive sustainability outcomes. *Behavioural effectiveness* has a direct impact on the practices of producers and therefore the impact of individual farms on the environment while *problem-solving effectiveness* results in positive change for the environment and society. *Problem-solving effectiveness* therefore overlaps with the goals of Food and Agriculture Organization of the United Nations' (FAO) Ecosystem Approach to Aquaculture (EAA), a strategy for the integration of aquaculture within the wider social-ecological system in a way that improves human well-being and does not threaten ecosystem functions and services (Soto et al., 2008). Each type of effectiveness contributes to the overall success of eco-certification; however, if *constitutive* and *process effectiveness* are at work in the absence of *problem-solving* and *behavioural* effectiveness, eco-certification risks achieving market success without creating sustainability benefits (Ponte, 2012). Therefore, this review focuses on challenges and potential improvements in *problem-solving* and *behavioural effectiveness* that can support the development of aquaculture in ways that align with EAA by improving outcomes for the environment and society.

2.3.2. Scoping review

A scoping review of aquaculture eco-certification literature and subsequent snowballing was used to explore the role of eco-certification in improving aquaculture industry practices and sustainability outcomes. A title, abstract, and keyword search of the SCOPUS database using the search terms "(aquaculture) AND (certification OR eco-certification OR ecolabel)" was used to identify English language research and review articles published up to December 31, 2021. This search resulted in the identification of 254 articles after removing duplicates. A screening of titles and abstracts resulted in the removal of 113 articles including duplicates (4) and articles that did not provide analysis of aquaculture eco-certification (109). A second screening of abstracts and full articles resulted in removal of an additional 80 articles that primarily addressed market outcomes of eco-certification including *constitutive effectiveness* (44), *process effectiveness* (18), or a combination of both (5), as well as articles that primarily addressed the politics of eco-certification and its use as a form of transnational governance (12). Both review articles and research articles were included. An additional 9 articles, 1 book chapter, and 2 grey literature reports related to the sustainability outcomes of aquaculture eco-certification were identified through snowballing, resulting in a total of 74 articles included in the scoping review. The number of publications addressing the sustainability outcomes of aquaculture eco-certification increased over time beginning in 2003 (1) and peaking in 2020 (12). Research and review articles were published across 70 journals, with the largest number published in *Marine Policy* (9) followed by *Sustainability* (5). All other journals accounted for 3 or fewer articles.

2.4 CHALLENGES AND SOLUTIONS FOR AQUACULTURE ECO-CERTIFICATION

2.4.1 Evaluating the effectiveness of aquaculture eco-certification

Direct comparison of the sustainability outcomes associated with certified and non-certified production of goods is challenging due to the difficulty of isolating the effects of eco-certification from other factors (Boyd & McNevin, 2012). In the absence of experimental designs, other empirical methods including surveys, content analysis, and interviews have been applied to the study of eco-certification effectiveness (Tröster & Hiete, 2018). However, the majority of approaches have been theoretical and many empirical studies on eco-certification effectiveness lack the rigor necessary to detect and attribute positive sustainability outcomes to eco-certification (Blackman & Rivera, 2010, 2011). This was reflected in the review of selected literature. The majority of research on the sustainability outcomes associated with eco-certification of aquaculture relied on analysis of the qualities of scheme criteria, including types of issues addressed by eco-certification, (Alexander et al., 2020; Belton et al., 2009; Mussells & Stephenson, 2020; Osmundsen et al., 2020; Parkes et al., 2010; Tlusty et al., 2015) the stringency of criteria (Luthman et al., 2019; Tlusty et al., 2015), and the spatial scale at which the impacts of aquaculture are evaluated (Amundsen et al., 2019; Pelletier & Tyedmers, 2008; Tlusty et al., 2015). The actual practice of certifying farms including the auditing process (Amundsen & Osmundsen, 2019; Osmundsen et al., 2020; Tlusty & Tausig, 2015) as well as the specific fit of eco-certification schemes to the system, location, and species to which they are applied (context sensitivity) (Amundsen & Osmundsen, 2019; Belton et al., 2009; Osmundsen et al., 2020) have also been used to study both how eco-certification addresses sustainability issues (problem-solving effectiveness) and if producer practices change as a result of participation in eco-certification (behavioural effectiveness) of aquaculture eco-certification.

Relying on the analysis of criteria and processes that underly eco-certification to understand effectiveness is somewhat limited as it provides information about the potential effectiveness of eco-certification rather than actual effectiveness, which can only be demonstrated through the evaluation of outcomes. However, given the challenges in using experimental design to compare certified and non-certified farms, the evaluation of criteria and processes as well as theoretical approaches can be used to identify challenges and gaps related to the effectiveness of aquaculture eco-certification criteria. Based on a review of the selected literature, four major challenges in the effectiveness of aquaculture eco-certification in supporting positive sustainability outcomes were identified: (1) **defining sustainability** though choice of issues to include in eco-certification criteria, (2) **supporting continuous improvement** while engaging the poorest performers in improving practices, (3) **accounting for the scale of aquaculture effects** including the recognition and evaluation of far-field effects of aquaculture in eco-certification criteria, and (4) **recognizing local context** in the application of global eco-certification criteria (Table 2.2). The following sections provide an overview of the characteristics of aquaculture and the marine environment that contribute to these challenges, the ways in which they are currently addressed by eco-certification, and additional approaches that could improve the ways in which these challenges are addressed in support of EAA and the production of positive outcomes for the environment and society.

Table 2.2. Summary of major challenges in the design and application of aquaculture eco-certification criteria and potential approaches to these challenges.

Challenge	Aquaculture Qualities	Deficits	Potential Approaches
Defining sustainability	Many potential impacts, both positive and negative, across all dimensions of sustainability	Little representation of socioeconomic impacts	• apply ecosystem services framework to identify potential impacts and indicators • complement eco-certification with other tools suited to address social issues
Supporting continuous improvement	Aquaculture is a relatively new, rapidly changing industry with evolving practices and technologies that could be applied to environmental problems	Labelling a farm as 'sustainable' risks future improvements	• frequent updates to eco-certification criteria • differentiation between or within sustainability schemes • use of benchmarks/criteria that require demonstration of improvement over time
Accounting for the scale of aquaculture effects	Far-reaching environmental impacts are difficult to monitor, measure, and attribute to source; conflict between benefits experienced at different scales	Focus on farm-scale criteria	• increase the scale of unit of certification • include criteria based on LCA impact categories • include criteria related to the far-reaching impacts of aquaculture on ecosystem services • evaluate ecosystem-level sustainability outcomes
Recognizing local context	The local environment in which farms operate can vary significantly, and local conditions can affect aquaculture impacts and the suitability of eco-certification criteria	Incompatibility of eco-certification criteria in some farming scenarios	• use place-specific information to establish indicator thresholds for sustainability criteria • recognize/certify regional eco-certification schemes • build flexibility into criteria and/or auditing process

2.4.2 Defining sustainability

Marine aquaculture is a growing food resource sector with potential environmental impacts that vary by species and production system. Some common issues include water pollution (Wu, 1995), benthic effects (Hargrave, 2010; Kalantzi & Karakassis, 2006), interaction with wild species (Nash et al., 2000; Quick et al., 2004; Sepúlveda et al., 2013; Soto et al., 2001), the use of therapeutants (Boyd et al., 2005; Burridge et al., 2010; Macleod & Eriksen, 2011; McHenery et al., 1997; Méndez, 2006; Minchin et al., 1995), and the use of primary resources, especially for species and production systems that require the addition of feed (Boyd et al., 2005, 2007). Some social issues include potential conflict with other resource users, impacts of pollutants and accumulated toxins on public health, and working conditions (Boyd et al., 2005). More recent issues include the presence of microplastics in farmed fish and fish feed (Gündoğdu et al., 2021; Hanachi et al., 2019; Karbalaei et al., 2020). Certifiers are challenged with selecting which impacts to address and reducing them to auditable sustainability criteria. In doing so, eco-certification and the stakeholders who participate in setting eco-certification criteria are effectively defining sustainability for the aquaculture industry based on the type and scope of criteria they choose to include in eco-certification schemes (Osmundsen et al., 2020; Tlusty et al., 2012). This dynamic is further complicated by differences in both the type and scope of sustainability criteria between the many aquaculture eco-certification schemes that declare products sustainable (Parkes et al., 2010; Tlusty et al., 2015). These differences result in multiple levels or definitions of sustainability in the marketplace, which may confuse or be invisible to consumers who may assume that any ecolabeled product is equally sustainable (Tlusty et al., 2012), and most concerning for problem-solving effectiveness, may result in the labeling of an unsustainable product as sustainable (Bailey et al., 2018b).

The final criteria included in schemes perpetuates a definition of sustainability that has been examined by comparing scheme criteria against existing sustainability frameworks (Belton et al., 2009), aquaculture guidelines (Mussells & Stephenson, 2020; Parkes et al., 2010; Tlusty et al., 2015), and government regulations (Luthman et al., 2019). While these evaluations provide insight into what sustainability issues are included in eco-certification criteria and how those issues are addressed, by relying on an existing framework for evaluation or comparison of schemes, this deductive approach means evaluation is restricted to how well eco-certification addresses the problems included in those frameworks. Given that the types of sustainability issues addressed by eco-certification schemes may be influenced by membership in meta-governing organizations such as the Global Sustainable Seafood Initiative (GGSI) and the International Social and Environmental Accreditation and Labelling Alliance (ISEAL) which set standards for certifications based on their own goals (Samerwong et al., 2017), and by international guidelines for ecolabelling and certification (e.g. FAO Technical Guidelines on Aquaculture Certification) (Parkes et al., 2010), these comparisons may even be circular if they evaluate eco-certification criteria against a framework that informed the development and selection of criteria. Despite this limitation, some comparative evaluations (Belton et al., 2009; Mussells & Stephenson, 2020) as well as an inductive analysis of issues addressed in sustainability schemes (Alexander et al., 2020; Amundsen & Osmundsen, 2018; Osmundsen et al., 2020) provide empirical support for a common criticism of aquaculture eco-certification schemes, that eco-certification largely focuses on environmental issues and provides incomplete coverage of social sustainability issues. Major aquaculture sustainability schemes include social considerations in some form (Table 2.1), but additional criteria that ensure that local communities benefit directly from aquaculture activities could also prevent splintering of certification efforts and competition between schemes as seen in the emergence of Fair Trade certification in fisheries (Bailey et al., 2016; Borland & Bailey, 2019). Alternatively, eco-certifiers might work in collaboration with programs better positioned to address social issues; for example, ASC has piloted the application of Fair Trade USA's Agricultural Production Standard (APS) at ASC-certified farms (Fair Trade USA, 2019).

Given the range of both potential positive and negative social and environmental impacts of aquaculture paired with the currently narrow definition of sustainability advanced by eco-certification criteria (Rector et al., 2021), the EAA provides a potential framework for the identification of potential impacts and selection of eco-certification criteria. The future provision of ecosystem services, i.e. the benefits people receive from the environment, is central to EAA (Soto et al., 2008), and by calling for the development and management of aquaculture in a way that ensures the future provision of those benefits, EAA reflects the classic definition of sustainable development originating from the United Nations' World Commission on Environment and Development (Keeble, 1988). Therefore, a potential approach to the selection of eco-certification criteria that reflect a holistic sustainability is the use of an ecosystem services framework (Table 2.2). Aquaculture activities can both enhance and degrade ecosystem services, resulting in trade-offs and eventually an overall impact on human-wellbeing (Outeiro & Villasante, 2013). For example, when comparing the ecosystem services provided by shellfish, aquaculture shellfish systems enhance provisioning and cultural services in comparison to natural systems, but natural systems provide more regulating and habitat services (Alleway et al., 2018). At a time when seafood from wild fisheries is plateauing and aquaculture production is rising (FAO, 2020), including all ecosystem services impacted by aquaculture activities in criteria used to measure the sustainability of farms could help ensure that increasing reliance on provisioning services provided by aquaculture over those provided by fisheries does not result in unacceptable tradeoffs in the current or future availability of other ecosystem services.

Overall, analysis of eco-certification criteria suggests that aquaculture eco-certification may not be adequately addressing social sustainability. Using an EAA approach and identifying ecosystem services that may be impacted by aquaculture and therefore issues that should be addressed by eco-certification criteria could help eco-certification advance a more holistic vision of sustainability. However, alternative approaches to improving aquaculture sustainability should be considered, especially when it comes to social benefits (Stoll et al., 2019). Combining eco-certification with alternative approaches such as FairTrade certification could fill gaps where eco-certification is not a good fit, especially for social issues (Table 2.2). Further, including a broader range of issues in eco-certification schemes could impact the sustainability discourse within the sector, exposing the industry to a more holistic version of sustainability (Rametsteiner & Simula, 2003). Although an EAA approach can provide guidance for the selection of types of criteria that should be included in eco-certification schemes, this guidance does not address problems arising from differences between schemes in terms of the level of stringency or demand associated with criteria (Tlusty et al., 2012). While there may be opportunity to use these existing differences to encourage continuous improvement (Jonell et al., 2019), it seems unlikely that competing eco-certification schemes would voluntarily participate in a tiered between-schemes approach.

2.4.3 Supporting continuous improvement

A second criticism of the way in which seafood eco-certification defines sustainability is that by declaring a product sustainable, certifiers advance the idea of sustainability as an endpoint rather than a continuous process, providing no incentive for future improvement (Tlusty & Thorsen, 2017). Eco-certification may elevate underperforming farms to a level of sustainability, but substantial gains in sustainability in aquaculture are expected to be a result of technological innovation, which could be compromised when sustainability is defined as an endpoint rather than a process (Tlusty, 2012). Despite this criticism, there is some evidence that aquaculture eco-certification contributes directly to short-term producer improvements based on comparison of initial and final audits (Tlusty & Tausig, 2015). In addition, many salmon producers describe eco-certification as a constant process, requiring continual change (Amundsen & Osmundsen, 2020).

Jonell *et al*. (2019) outline three options for internalizing continuous improvement in aquaculture eco-certification: (1) updating eco-certification criteria to make it more stringent and comprehensive over time, (2) differentiation based on stringency between (horizonal differentiation) or within (vertical differentiation) eco-certification schemes, and (3) including criteria that require improvement in particular practice or performance indicators over time (Table 2.2). Some of these options are already practiced to some extent in aquaculture eco-certification.

First, aquaculture eco-certification schemes are updated periodically providing an opportunity to increase the stringency of requirements. Further, ISEAL and GSSI, two meta-governing agencies, both codify a review and revision (if necessary) of eco-certification criteria every five years (GSSI, 2021a; ISEAL, 2014). GSSI benchmark reports provide evidence that the aquaculture eco-certification schemes recognized by GSSI (ASC, BAP, and GlobalGAP) have a standard review schedule in place (GSSI, 2019, 2021c, 2021b). However, it is unclear how schemes ensure complete coverage of emerging issues and knowledge in review processes (Jonell et al., 2019). Further, overly ambitious eco-certification criteria may limit participation from producers that lack the resources to make improvements (Atyia & Simula, 2002; Gullison, 2003) or for which the resources required to meet criteria are higher than the perceived benefits (Tlusty, 2012).

Horizontal or between-schemes differences in the stringency and inclusion of different types of criteria between aquaculture eco-certification schemes has been observed (Mussells & Stephenson, 2020; Parkes et al., 2010; Tlusty et al., 2015); however, these differences must be recognized by consumers and retailers if they are to differentiate between levels of sustainability in a way that might support continuous improvement through market incentives. Vertical or within-scheme differentiation is also present in aquaculture eco-certification, though it is not directly related to level of compliance with sustainability criteria; BAP uses a 4-star system to differentiate between products that can be traced to BAP certified facilities along the supply chain, where each star corresponds to a hatchery, feed mill, farm, and processor (GAA, 2022b). Outside of within or between scheme differentiation, aquaculture schemes have addressed the need to recognize producers that are working towards improved sustainability but do not meet eco-certification criteria by supporting Aquaculture Improvement Projects (AIPs), e.g. the Southeast Asian Shrimp Aquaculture Improvement Protocol (SEASAIP) (Samerwong et al., 2020), a selva shrimp pubic-private AIP partnership in Vietnam, and an NGO-led Hainan Tilapia AIP (Bottema, 2019). Eco-certifiers have to balance recognizing producers that are actively taking steps towards meeting eco-certification with the risk of devaluing the credibility of their scheme (Bush, Toonen, et al., 2013).

Third, while some level of improvement over time may be required of farms seeking eco-certification renewal when new versions of eco-certification criteria are released, continual improvement is not commonly embedded within eco-certification criteria. The International Organization for Standardization's (ISO) 4001 Environmental Management System (EMS) standard provides a model in which continual improvement is central to the standard. Organizations seeking ISO 4001 certification are required to include planning and monitoring for continual improvement in their EMS, though the ways this requirement is implemented and audited varies between organizations (Brouwer & van Koppen, 2008).

Building on these existing approaches, including updating eco-certification criteria over time and allowing for differentiation between and within schemes could create positive social, environmental, and economic impacts if they are approached with the explicit goal of supporting continual improvement within the aquaculture industry. In addition, including criteria that rely on benchmarking and require farms to demonstrate improvement during eco-certification renewal audits could improve producer sustainability (Table 2.2).

2.4.4 Accounting for the scale of aquaculture effects

Aquaculture is a stationary, place-based activity, but social, environmental, and economic impacts may be both near and far-reaching (Krause et al., 2020; Weitzman et al., 2019). Near-field environmental effects include impacts on the benthos, water quality, and habitat, while far-field effects include the spread of disease, introduction of exotic species, coastal nutrient enrichment, impacts on food web dynamics, and marine litter (Weitzman et al., 2019). The use of simple physical, biological, and chemical indicators at the watershed scale have been proposed as a way to incorporate far-field environmental impacts into aquaculture management (Soto et al., 2008). However, the use of these indicators is complicated as aquaculture cannot be separated from the system in which it is embedded, and attributing specific environmental impacts to aquaculture activities as opposed to other anthropogenic activities or natural environmental processes (e.g. variation in benthic indicators under different hydrodynamic conditions (Cranford et al., 2010; Tomassetti et al., 2016), especially at the far-field scale, remains challenging despite progress in applying tools such as stable isotope analysis (Howarth et al., 2019, 2020; Y. Zhang et al., 2014) and chemical tracers (Sutherland et al., 2007).

The social and economic effects of aquaculture include impacts on income and employment, food security, and nutrition amongst others (Alleway et al., 2018; Krause et al., 2015). These impacts are experienced differently across spatial scales and are context and species-specific (Kluger et al., 2017; Krause et al., 2015, 2020). For example, broad health benefits stem from the nutrient density of farmed salmon including concentration of long-chain omega-3 fatty acids in salmon (Colombo & Mazal, 2020; Jensen et al., 2012; Tlusty, 2021). However, the influence of salmon farming on social dimensions of sustainability has also been shown to be greatest at the local scale in comparison to regional and national scales, while the influence of mussel farms on the same social dimensions is lesser overall and more variable across scales and regions (Krause et al., 2020). Locally, aquaculture can also impact social dimensions of sustainability where it competes with other coastal uses as well as aesthetic value (Outeiro & Villasante, 2013). These various scales of impact mean that local priorities may conflict with broader societal goals and vice versa (Kluger & Filgueira, 2021). Indeed, reconciling local and global needs and values is a management and governance challenge across resource sectors (e.g. Brinkman et al. (2020), Sincovich et al.(2018), Sayer & Collins (2012)). For example, when food security is prioritized globally, maximizing production to meet this demand puts pressure on local systems. Overall, complex social-ecological interactions and context specificity make the social and economic impacts of aquaculture difficult to predict (Krause et al., 2015), and adding to that difficulty, economic data on the effects of aquaculture is not available at the local scale in many regions (Mikkelsen et al., 2020).

The complex reality of the impact of aquaculture at multiple scales is not well reflected in eco-certification criteria. Although some criteria include far-field considerations directly (e.g. considering the effects of fish escapes) (Amundsen & Osmundsen, 2019; Chaplin-Kramer et al., 2015) and indirectly (e.g. promoting coordination among producers) (Amundsen & Osmundsen, 2019), aquaculture eco-certification largely focuses on farm-scale criteria and lacks ecosystem perspectives (Bridson et al., 2020; Bush et al., 2013a; Bush et al., 2019; Jonell et al., 2013). Some gaps in the recognition of far-field aquaculture impacts in eco-certification schemes include (1) a general lack of performance-based criteria (Rector et al., 2021), and specifically, a lack of limits or targeted reductions in greenhouse gas (GHG) emissions (Amundsen & Osmundsen, 2019; Madin & Macreadie, 2015), (2) under-emphasis of impacts on land-based resources, and (3) little consideration of externalities associated with product transport and distribution (Bush et al., 2013a; Tlusty & Lagueux, 2009), among others. Performance-based criteria that address the social and environmental impacts and outcomes of aquaculture beyond the farm-scale are necessary if problem-solving effectiveness is to be achieved in a way that supports the goals of EAA (Figure 2.2). Many of these impacts could be represented through the use of life cycle assessment (LCA) criteria in aquaculture eco-certification (Cao et al., 2013; Madin & Macreadie, 2015); however, some of the same general challenges in incorporating far-field impacts in eco-certification criteria are also relevant for LCA. Certifiers are still faced with the challenge of selecting impacts that should be included and are limited by those impacts that are already established in LCA databases (Pahri et al., 2015). Certifiers must also choose an appropriate system boundary for the calculation of each LCA impact (Bohnes & Laurent, 2018), and account for the effects of natural variation and interactions (Pahri et al., 2015). Including the far-reaching impacts of aquaculture in eco-certification criteria is necessary regardless of whether those criteria are drawn from existing LCA impact categories.

Additional criteria that reflect far-field impacts could improve the potential *problem-solving effectiveness* of eco-certification schemes, but demonstrating the actual effectiveness of eco-certification requires the evaluation of outcomes for the environment and society (Figure 2.2). This problem is not unique to aquaculture; there is also little evidence that eco-certification applied at the agricultural farm- fishery- or forest-level addresses broad ecosystem-level issues (Auld et al., 2008; Gulbrandsen, 2009; Jonell et al., 2013). For example, there is still little evidence that forestry eco-certification has been successful in achieving its initial goal of reducing tropical deforestation (Blackman et al., 2018; Marx & Cuypers, 2010), highlighting the incongruence between the “unit of certification” and the desired ecosystem-level outcome of eco-certification. In forestry, the unit of certification is typically a managed forest or forest plantation, and in agriculture, the unit of certification is the farm. For fisheries, the unit of certification is negotiated and determined by the eco-certification applicant; the Marine Stewardship Council’s (MSC) definition of the unit of certification is a combination of the fishery or stock and the fishing method, gear, or practice (Foley & McCay, 2014). Landscape or jurisdictional approaches to certification that expand the unit of certification to an entire seascape offer another approach to consider far-field effects and reflect an ecosystem approach to sustainability in eco-certification (Ghazoul et al., 2009; Kittinger et al., 2021). Although there are several unresolved barriers to this type of approach, it highlights an opportunity for larger units of certification to facilitate sustainability goals at a larger spatial scale.

While the unit of certification for aquaculture eco-certification schemes is typically an individual farm, consideration of the combined impact of multiple farms within a water body are reflected in criteria that require participation in zonal management schemes to control for disease and parasites (Amundsen et al., 2019) and evidence that farms are collectively operating within the carrying capacity of the water body (ASC, 2010; GAA, 2015). For example, ASC and BAP eco-certifications of bivalves require evidence that the total ecological carrying capacity of a water body is not exceeded, regardless of the impact of the individual farm seeking eco-certification (ASC, 2010; GAA, 2015). While this type of science-based technical criteria reflects beyond-the-farm impacts, it may also be difficult for producers to meet if they do not have the required equipment or expertise. This highlights the need for eco-certification to consider and support the capacity of producers to comply with criteria (Samerwong et al., 2020). Aquaculture eco-certification schemes have also begun offering group certifications that allow for multiple farms to be assessed as one unit of certification (ASC, 2019; GAA, 2018). Although improving accessibility to eco-certification for small scale producers appears to be the main motivation behind new group eco-certifications (ASC, 2019; GAA, 2018), adopting a group approach could facilitate the inclusion of performance-based far-field criteria that encourage cooperation between producers within a defined region associated with a spatially explicit unit of certification.

Including criteria related to both the near- and far-field impacts of aquaculture, adopting criteria from LCA, and increasing the scale of the unit of certification represent options to better reflect the ecosystem perspective, could help eco-certification create positive sustainability outcomes for the environment and society (Table 2.2). However, producer capabilities present major challenges to adopting a broader ecosystem perspective in aquaculture eco-certification criteria, and evaluation of sustainability outcomes at an ecosystem level are needed. Despite these challenges, aquaculture eco-certification must recognize far-reaching environmental and social impacts if it is to embrace the principles of EAA including development within the context of other sectors, continued delivery of ecosystem services, and contributions to human-wellbeing across scales (Soto et al., 2008).

2.4.5 Recognizing local context

The local environment in which aquaculture farms operate can vary significantly in terms of both the physical environment, and the social and institutional environment. These local conditions in turn affect the suitability of farm locations and potential impacts of farming. At a very broad scale, biophysical and governance conditions that can support different types of aquaculture vary across countries (Davies et al., 2019). At a smaller scale, biodiversity and community structure, hydrography, and water quality vary across aquaculture locations and have implications for the potential physical and ecological impacts of aquaculture (Ross et al., 2013). The social conditions in local communities, such as employment rates and community values, have implications for the potential social impacts of aquaculture (Ross et al., 2013). When it comes to eco-certification, the importance of local conditions alongside the need for auditable sustainability criteria that can be applied across different locations and contexts is a challenge. The need to be responsive to local conditions while maintaining the legitimacy of eco-certification requires balancing the real and perceived credibility of eco-certification, where the former must be responsive to local conditions and the latter relies on the consistent application of rigid eco-certification criteria. In some cases, species- and system-specific issues are addressed using different standards designed for those species or systems (Table 2.1), but the same criteria are generally applied across all farms regardless of location.

Eco-certification criteria that are irrelevant in specific locations or are redundant with local laws and regulations have the potential to create frustration for both certifiers and farmers. This is not only true for individual farms, but for entire regions where local practices and institutions may not be compatible with eco-certification requirements. For example, ASC generally focuses on large scale and intensive modes of production which is incompatible with regions where small scale and extensive operations make up a significant proportion of production (Havice & Iles, 2015; Marschke & Wilkings, 2014;

Vellema & Van Wijk, 2015). Eco-certification criteria may also be incompatible with cultural practices. For example, ASC criteria require formal contracts between producers and buyers to facilitate traceability, as well as formal labour contracts. These requirements are at odds with practices in rural areas where business interactions are based on trust and relationships, and requests for written contracts may be viewed as a violation of trust (Schouten et al., 2016; Vellema & Van Wijk, 2015). These types of issues may stem from the skewed representation of North American and European stakeholders in WWF's Aquaculture Dialogues (Havice & Iles, 2015).

Even in regions where eco-certification criteria are compatible with local practices, requirements to demonstrate compliance with criteria that overlap with local laws and regulations may be unnecessary and providing evidence of compliance viewed as a nuisance (Amundsen & Osmundsen, 2020). Further, where aquaculture eco-certification includes both best-practice criteria to limit the impacts of aquaculture on the environment as well as indicator criteria with specific limits on measurable inputs or impacts (Rector et al., 2021) the potential influence of upstream impacts and other location-specific factors on these measures are not always recognized in eco-certification criteria.

Location-specific information is currently incorporated in aquaculture eco-certification processes through (1) the use of criteria and compliance options that rely on local data and context, and (2) allowance for discretion on the part of auditors during assessments. First, the place-based nature of aquaculture and the development of marine spatial tools make it possible to include location-responsive criteria in aquaculture schemes (Chaplin-Kramer et al., 2015). For example, BAP requires maps of critical habitat within a 2km radius of the farm and consideration of assimilation capacity of the receiving water body in its certification process (Chaplin-Kramer et al., 2015). ASC bivalve criteria requires calculation of the total area of farms within the water body area where the farm seeking eco-certification is located (ASC, 2010). For salmon aquaculture, benthic criteria within the ASC salmon standard encourages the use of a site-specific allowable zone of effects (AZE) based on local depositional patterns (ASC, 2012). Many aquaculture schemes require a site-specific biodiversity-inclusive environmental impact assessment, though there is little direction on how auditors should evaluate those assessments (Chaplin-

Kramer et al., 2015). Options for compliance with water quality parameters include those outlined in BAP's standard for fish, crustaceans, and marine invertebrates raised in ponds, freshwater flow-though systems, and recirculating aquaculture systems (RAS). These farms can comply with water quality parameters by demonstrating that effluent meets BAP's limits for water quality parameters, by demonstrating that water quality does not deteriorate from nearby to downstream locations, or by demonstrating that water quality does not deteriorate between source and discharge in the case that farms use source water that exceed BAP's water quality parameter limits (GAA, 2022a). Additional local and contextual information could be used to establish site-specific indicator minima or maxima where eco-certification criteria currently rely on universal values, or to trigger use of additional criteria. For example, ecological carrying capacity criteria are only triggered in ASC's bivalve scheme when the area of farms within the water body where the farm applicant is located exceed 10% of the total area (ASC, 2010). Habitat and hydrographic information including flushing rate could also be used to inform site-specific effluent limits (Chaplin-Kramer et al., 2015).

Second, despite the apparent rigidity of eco-certification criteria, auditors have some latitude in the application of criteria in different contexts; third-party auditors maintain legitimacy by using predetermined criteria to assess farms, but they also interact with farm managers enabling some flexibility in how criteria are applied in specific locations or contexts (Amundsen & Osmundsen, 2019). Auditor experience plays a role in enabling this type of adaptiveness, where more experienced auditors may be able to understand how criteria are met in different ways whereas newer auditors may refuse to deviate from the way in which a scheme dictates criteria should be met, despite alternative routes being equally valid (Amundsen & Osmundsen, 2019). Alternatively, flexibility allowing for recognition of producer knowledge of local condition and impacts can be embedded within eco-certification criteria rather than relying on the discretion of auditors. Where the flexibility facilitated through the human element of the auditing process resolves conflict arising from the application of global aquaculture criteria to local conditions, embedding consideration of local conditions in eco-certification criteria might prevent that conflict from occurring in the first place. The impact of rigidity and flexibility of eco-certification criteria on the legitimacy of schemes is illustrated by the type of criticism received by schemes that adopt vague criteria versus those than adopt prescriptive criteria but allow for some variance in what and how criteria must be met: MSC's second principle, which is related to ecosystem protection, is not well defined and MSC receives criticism for inconsistency in the way this principle is interpreted and applied (Chaplin-Kramer et al., 2015). In comparison, ASC criteria is relatively prescriptive and ASC receives criticism for issuing variances on some criteria allowing farms with non-compliance issues to receive certified status (Roebuck & Wristen, 2018).

Regionally-specific eco-certification schemes can be tailored to local context and environmental conditions. Examples of this approach address issues identified in aquaculture where eco-certification criteria are either redundant or incompatible with local context. For example, a local eco-certification scheme for rooibos tea in South Africa recognizes the importance of local ownership of production, a priority for partners in the region who view local ownership as an important way to foster a shared commitment to conservation (Vellema & Van Wijk, 2015). Regionally-specific criteria have also been managed under international eco-certification schemes; the Forest Stewardship Council (FSC) provides general principles and criteria for eco-certification, but requires that those principles are used in conjunction with an approved set of regionally-specific indicators (FSC, 2015). Certification of regional schemes or mechanisms for establishing scheme equivalency could improve the representation of local conditions and priorities in aquaculture eco-certification. Further, recognition of regional schemes by global eco-certification programs could improve the representation of local stakeholders in the development of scheme criteria.

In summary, use of local data, context-specific compliance options, and application of regionally specific eco-certification criteria could improve the recognition of local conditions in aquaculture eco-certification (Table 2.2). However, while inconsistent interpretation and application of criteria can compromise the legitimacy of eco-certification schemes, a degree of flexibility is likely necessary if global scheme criteria are to be adapted to local conditions.

2.5. CONCLUSIONS

Although eco-certification has become ubiquitous in the aquaculture industry, there is still little known about its actual effectiveness in creating positive sustainability outcomes. Part of this knowledge gap is due to the difficulty of evaluating eco-certification outcomes; however, research that analyzes the implementation of eco-certification and its core criteria has provided insight into the potential effectiveness of eco-certification by identifying specific challenges. Addressing the gaps identified, including determining how sustainability should be defined by eco-certification, supporting continuous improvement, recognizing the multiple scales of effects of aquaculture in that are addressed eco-certification criteria, and accounting for local conditions in the application of eco-certification schemes is necessary if eco-certification is to create positive sustainability outcomes through *behavioural* and *problem-solving effectiveness*. Further, improving the *problem-solving effectiveness* of eco-certification can be both informed by and support the goals of EAA when criteria are designed to improve social and environmental sustainability at multiple scales. Specifically, adopting an EAA approach by using an ecosystem services framework could provide guidance for the identification of both near- and far-field impacts of aquaculture that should be reflected in eco-certification criteria. These should include criteria that reflect the full range of ecosystem services expected to be impacted by aquaculture, embracing a holistic definition of sustainability. Additional insights such as the need to incorporate local information and knowledge throughout the eco-certification process and adopt criteria that support continuous improvement in aquaculture practices and performance could also contribute to the role of eco-certification in advancing sustainable aquaculture (Table 2.2). While changes to aquaculture eco-certification structure, criteria, and auditing could help create more positive sustainability impacts, other market and non-market tools including state regulation will also be important for the sustainable development of aquaculture in ways that benefit both local and global communities.

The relationship between addressing sustainability issues (*problem-solving effectiveness)*, acceptance of eco-certification amongst stakeholders (*constitutive effectiveness)*, and producer participation in eco-certification (*process effectiveness*) should be considered whenever changes to eco-certification criteria are made. For example, there is an inverse relationship between the stringency of eco-certification scheme criteria and producer participation in eco-certification.(Kalfagianni & Pattberg, 2013) Therefore, increasing the complexity of eco-certification criteria to better address multiple dimensions of sustainability and scales of impact could potentially improve how eco-certification addresses sustainability issues (*problem-solving effectiveness*) and the credibility and acceptance of eco-certification amongst stakeholders (*constitutive effectiveness*) but could likely have a negative impact on the number of producers willing to participate (*process effectiveness*). Further, the capacity and capability of producers to comply with increasingly complex eco-certification criteria may be a limiting factor in the ability of eco-certification to support EAA. Still, complex systems require complex management approaches, and moving beyond easily auditable best practice criteria towards criteria that reflect the complexity of aquaculture as a social-ecological system is necessary for eco-certification to improve sustainability.

Finally, these potential approaches to addressing some of the key challenges in aquaculture eco-certification have the potential to improve sustainability outcomes that support EAA; however, changes should be paired with continued efforts to evaluate the outcomes of eco-certification which has been difficult due to a lack of baseline data and need to separate the effects of eco-certification from other factors. Shifting to a continuous improvement approach to eco-certification that requires collection, reporting, and comparison of performance metrics over time will improve evaluation capacity at the farm-scale, but the evaluation of ecosystem-level outcomes will likely require additional cooperation amongst eco-certification programs, scientists, and producers and a shift in the explicit goals of eco-certification programs from improving aquaculture sustainability to improving ecosystem sustainability.

CHAPTER 3: ECOSYSTEM SERVICES IN SALMON AQUACULTURE SUSTAINABILITY SCHEMES

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Please note that this chapter appears as it did in the published article, with references and table, figure, and section numbers updated to match the format of this thesis document.

3.1 ABSTRACT

The need to employ management strategies that recognize ecosystem services and their trade-offs is considered a cornerstone for the implementation of an Ecosystem Approach to Aquaculture (EAA), yet it is unclear how to operationalize these concepts. Here, the role of certification and sustainable seafood ranking programs (sustainability schemes) in maintaining ecosystem services and supporting an EAA was explored. The representation of ecosystem services within sustainability scheme criteria, as well as the attributes of those criteria, were assessed using marine salmon aquaculture as a case study. Criteria reflected a range of ecosystem services and support reducing pressure on those services. However, consideration of the resilience capacity of ecosystem services, recognition of enhancements to ecosystem services, and attributes that support cost-benefit analysis of salmon farming appear to be limited within sustainability scheme criteria. Overall, the farm-scale assessment approach of many sustainability schemes appears to be incongruent with the broader spatial perspective required to operationalize EAA.

3.2 INTRODUCTION

As global aquaculture production continues to grow, now surpassing wild capture fisheries (FAO, 2018), a number of programs and initiatives aimed at improving aquaculture sustainability have emerged. One such development is the use of certification and seafood ranking programs (hereafter, sustainability schemes) (Auld, 2014). These market-based programs rely on the assumption that improved market access for certified or recommended products will encourage the voluntary participation of producers (Tlusty, 2012). The capacity of third-party sustainability schemes to improve industry sustainability has received significant academic attention and criticism including the limitations of their ability to engage the industry as a whole (Jonell et al., 2013; Tlusty, 2012) and encourage innovation and efforts that go beyond standard compliance (Tlusty & Thorsen, 2017). Certification criteria have also been criticized, largely for focusing on farm-scale criteria and lacking ecosystem perspectives (Amundsen et al., 2019; Bush et al., 2013; Jonell et al., 2013). An ecosystem perspective is explicit in the Food and Agriculture Organization of the United Nations' strategy to develop aquaculture in an ecologically sustainable way that enhances socio-economic benefits. This strategy, called the Ecosystem Approach to Aquaculture (EAA), is based on three principles including (1) development within the context of ecosystem functions and services, (2) improvement of human-wellbeing, and (3) integration with other sectors (Soto et al., 2008).

While the natural environment provides ecosystem goods and services to people, including food provision, marine farming increases the amount of food provided through transformation of the natural environment. That transformation can include the use of sea cages, stocking of fish within those cages, and the addition of fish feed to the cage environment (Halwart et al., 2007). These alterations can result not only in an increase in food production, but also in potential changes to ecosystem structure, functions, and other services. EAA's first principle specifically calls for aquaculture development that does not degrade ecosystem functions and services beyond their resilience capacity (Soto et al., 2008); however, means to operationalize this principle are unclear. The ecosystem services framework could be used to assess tradeoffs and expected changes to ecosystem services based on the value of those services to people (Custódio et al., 2019; MEA, 2003). In the context of marine farming, this assessment might include the economic valuation of affected ecosystem services, including those not associated with existing markets (Ledoux & Turner, 2002). For example, the impact of fish feces and excess fish food on the waste processing service provided by the marine environment can be valuated based on the cost of treating the same amount of waste using an alternative method such as wastewater treatment technology (Folke et al., 1994; Mangi et al., 2011). The valuation of all services affected by different management scenarios could be used to guide decision making.

Despite the direction of the FAO provided by the EAA and the growing application of ecosystem services concepts in aquaculture, ecosystem services approaches are highly underrepresented in finfish aquaculture research, and in particular in marine finfish aquaculture (Weitzman, 2019). Previous work has identified some of the ecosystem services and functions that may be enhanced or degraded by finfish aquaculture including food provision (Alleway et al., 2018; Outeiro & Villasante, 2013), biological regulation (Outeiro & Villasante, 2013), water purification (Martinez-Espiñeira et al., 2016; Outeiro & Villasante, 2013), symbolic and aesthetic value (Alleway et al., 2018; Outeiro &

Villasante, 2013), and resilience and resistance via biodiversity (Alleway et al., 2018). Additional services that may be affected can be gleaned from research on aquaculture environment interactions. For example, the effects of salmon farming on the service 'climate regulation' through greenhouse gas emissions and energy consumption has been noted in Life Cycle Assessment studies (Nijdam et al., 2012; Pelletier & Tyedmers, 2008).

In addition to EAA, ecosystem services have been associated with the development of market-based instruments including certification (Froger et al., 2015). However, aquaculture certification schemes generally include few criteria based on beyond-the-farm indicators and monitoring, and lack ecosystem perspectives (Amundsen et al., 2019; Bush et al., 2013a; Jonell et al., 2013), both of which could support the protection and provision of ecosystem services. While certification has been criticized for its currently limited potential to improve aquaculture sustainability (Tlusty, 2012; Tlusty & Thorsen, 2017), it also has the advantage of being well-established and integrated within existing markets (Froger et al., 2015). Therefore, the purpose of this study is to assess the current representation of ecosystem services within seafood sustainability schemes for marine salmon aquaculture and provide insights on how the use of ecosystem services might advance the implementation of an EAA. Salmon was chosen as a model species given that Atlantic salmon aquaculture production has more than doubled in tonnage since the year 2000 (FAO, 2018). Where previous work provides broad context for the roles of certification in preserving ecosystem services (Froger et al., 2015) and the capacity of valuations to improve aquaculture sustainability (Alleway et al., 2018; Custódio et al., 2019), this study brings these ideas together in an analysis of the present state of sustainability schemes as tools for the optimal delivery of ecosystem services to people.

3.3 METHOD

A three-step process was developed and used to explore the representation of ecosystem services within sustainability schemes for farmed Atlantic salmon. It included gathering the criteria used in each scheme (Step 1), analysis of ecosystem services represented in criteria (Step 2), and analysis of the attributes of criteria (Step 3, Figure 3.1). Both inductive and deductive qualitative approaches based on existing ecosystem service classifications were used to develop and apply this three-step process.

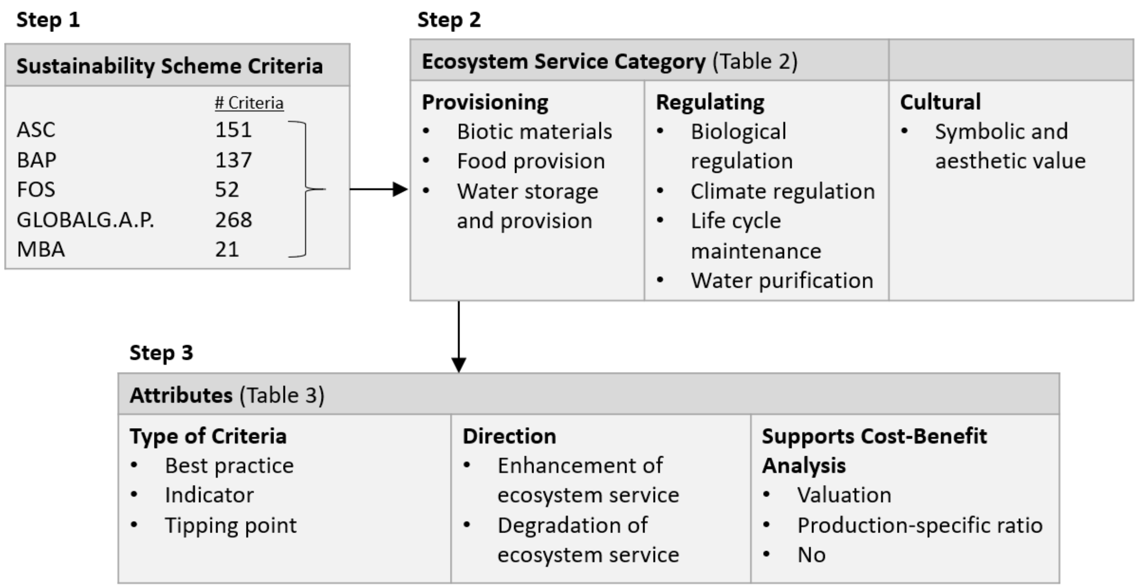

Figure 3.1. Three-step process developed and applied to sustainability schemes for farmed salmon.

3.3.1 Step 1: Scheme criteria gathering

Four certifications and one seafood ranking scheme were selected for analysis based on their prevalence and focus on environmental sustainability. Schemes specifically developed as animal welfare, organic, or food safety certifications were not included. Only those certifications active in at least three of the top five farmed salmon producing countries were included, namely, Aquaculture Stewardship Council (ASC), Best Aquaculture Practices (BAP), Friend of the Sea (FOS), and Global Good Agriculture Practice (GLOBALG.A.P.). Monterey Bay Aquarium's Seafood Watch (MBA), the most popular seafood ranking scheme which ranks marine farmed salmon as 'best choice', 'good alternative', or 'avoid' based on farming region, was included to provide a comparison with farm-certifying certification schemes. All four certification schemes address issues beyond the environmental impacts of salmon farming and are promoted as such; all four schemes address social accountability, and ASC, BAP, and GlobalGAP also address food safety and animal welfare. In contrast, MBA addresses only the environmental aspects of aquaculture. ASC and BAP use a certification scheme specific to marine salmon farming while FOS, GLOBALG.A.P., and MBA use a general aquaculture scheme for multiple aquaculture products (Table 3.1).

Table 3.1. Sustainability schemes included in analysis and scheme-specific language for criteria hierarchy.

Scheme	Organization	Document Title(s)	Version	Hierarchy of Criteria			# of Criteria
				Section	Sub-section	Criteria	
ASC	Aquaculture Stewardship Council	Salmon Standard	1.3	Principle	Criterion	Indicator	151
BAP	Global Aquaculture Alliance	Best Aquaculture Practices - Salmon Farm Standards	2.3	Unnamed	Unnamed	Standard	137
FOS	World Sustainability Organization	Friend of the Sea Sustainable Marine Aquaculture/ Aqua Marine	1.1	Criterion	NA	Requirement	52
GLOBALG.A.P.	Global Good Agriculture Practice	Integrated Farm Assurance + Aquaculture Module + Risk Assessment on Social Practice	5.2/1.3	Principle	Unnamed	Control point	268
MBA	Monterey Bay Aquarium	Seafood Watch Standard for Aquaculture	3.2	Criterion	NA	Factor	21

The sustainability schemes listed numbered criteria in sections grouped by topic, and sometimes sub-topics. For simplicity, the lowest hierarchical level of requirements is herein referred to as criterion/criteria regardless of scheme-specific language. For the four certification schemes included in analysis, criteria was collected from the SustainFish database (Amundsen & Osmundsen, 2018) and revised to reflect updates to certification schemes from ASC (Salmon Standard v.1.3) and GLOBALG.A.P. (Integrated Farm Assurance Aquaculture Module v.5.2) using updated documents found on the associated organization websites. Information for MBA was collected from scheme documents posted on the Seafood Watch website.

3.3.2 Step 2: Ecosystem Services Classification

The identification of ecosystem services represented in sustainability schemes were made through interpretation of services implicitly referenced in the criteria. The ecosystem services represented in each scheme criterion were identified following Liquete et al.'s (2013) integrated ecosystem service classification which harmonizes ecosystem service categories from four different classifications applied to coastal ecosystems (Table 3.2). Each criterion was assigned a pairing of an ecosystem service category and sub-category. Where criteria were interpreted to be related to more than one type of ecosystem service, the service category and sub-category of strongest association was selected. Where criteria did not correspond well to an ecosystem service, criteria were assigned a 'not applicable' status and an inductive abstraction of this data was used to develop sub-categories for these criteria.

Table 3.2. Integrated classification of ecosystem services used in this study. Adapted from Liquete et al. (2013).

ES Category	ES Sub-category	Description
Provisioning	Biotic materials	The provision of biomass for non-food purposes
	Food provision	The provision of biomass for human consumption
	Water storage and provision	The provision of water for human consumption
Regulating	Biological regulation	Biological control of pests that may affect commercial activities and human health
	Climate regulation	Regulation of greenhouse gases
	Life cycle maintenance	Biological and physical support to facilitate the healthy and diverse reproduction of species
	Water purification	Biochemical and physicochemical processes involved in the removal of wastes and pollutants from the aquatic environment
Cultural	Symbolic and aesthetic value	Exaltation of senses and emotions by landscapes, habitats, or species

3.3.3 Step 3: Criterion Attributes

Following assignment of ecosystem services to sustainability criteria, an inductive coding process was used to explore the attributes of criteria that corresponded to ecosystem services. Resulting codes corresponded to types of criteria (best practice, indicator, tipping point), the implied direction of effect of aquaculture activity on the associated ecosystem service (enhancement, degradation), and how criteria might support cost-benefit analysis of the impact on aquaculture on ecosystem services (valuation, unit of production ratio, no support) (Table 3.3). In the case of the MBA ranking scheme, which is based on a scoring system for each criterion as opposed to the compliance system used by certification schemes, the requirements to achieve the highest score for each criterion were used in analysis of criterion attributes.

Table 3.3. Criterion attributes applied in this analysis.

Attributes	Code	Description
Type of Criteria	Best practice	Efforts to reduce risks and pressure on the ecosystem services
	Indicator	A measure of impact on or state of the ecosystem service
	Tipping point	An indicator with a limit based on the resilience of the ecosystem service
Direction of Impact on Ecosystem Service	Enhancement	Criteria suggests potential enhancement of the ecosystem service
	Degradation	Criteria suggests potential degradation of the ecosystem service
Supports Cost-Benefit Analysis	Valuation	Requires or is based on a valuation of the ecosystem service
	Production-specific ratio	Uses a "per ton of fish produced" or other production-specific ratio of ecosystem degradation/enhancement
	No	Does not support cost-benefit analysis of the impacts of aquaculture on ecosystem services

3.4. RESULTS

Just over 58% (351) of criteria from the sustainability schemes were categorized under the hybrid ecosystem services classification. Those criteria were largely concentrated in the regulating category (85%) followed by provisioning (8%), and cultural (7%) service categories. The remaining 42% (278) criteria were classified as being not applicable to the provision of ecosystem services. Most criteria that were linked to the provision of ecosystem services (351) were best practice criteria (80%), followed by indicator (18%), and tipping point (2%). Key examples of best practice, indicator, and tipping point criteria for each ecosystem service category are provided in Appendix B.

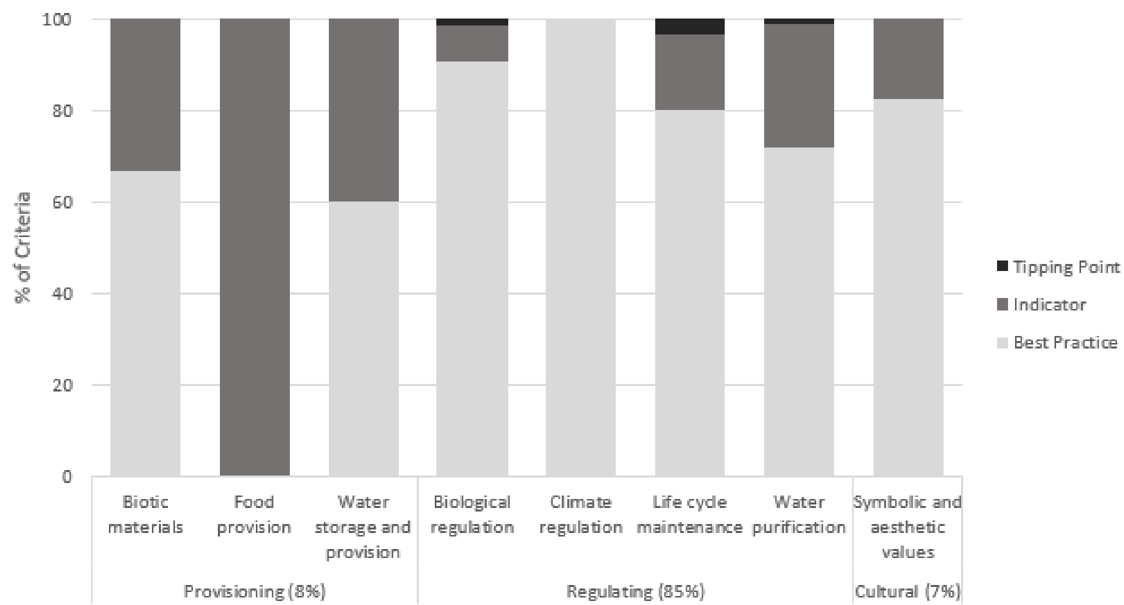

Figure 3.2. Type of criteria found within ecosystem services sub-categories.

Very few criteria (1%) pointed to potential enhancements to ecosystem services. Those that did were present in 'life cycle maintenance' and 'symbolic and aesthetic value', and examples include restoration activities, breeding programs for stock improvement, and social community benefits. The remaining criteria (99%) focused on preventing or measuring degradation associated with farming and were found across all ecosystem service sub-categories in the classification used here. No criteria referenced valuation techniques nor required the valuation of ecosystem services, though a small proportion of criteria (5%), all within regulating ('biological regulation', 'climate regulation', 'life cycle maintenance', and 'water purification') and provisioning services ('biotic materials'), included a production-specific ratio. For example, criteria based on feed efficiency ratios, waste production per ton of fish produced, and land appropriated for feed production per ton of fish produced, take trade-offs between various inputs and outputs into account. These types of production-specific ratio criteria reflect the trade-off approach inherent in cost-benefit analysis.

3.4.1 Provisioning Services

Provisioning services represented included 'biotic materials', 'food provision', and 'water storage and provision'. 'Biotic materials' criteria focused on the conservation of marine ingredients and broodstock, and included best practice (67%) and indicator (33%) criteria (Figure 3.2). 'Biotic materials' indicator criteria, including fish feed efficiency as well as fish oil and forage fish dependency ratios, represented the majority of criteria that included a production-specific ratio that could provide support for analysis of ecosystem service trade-offs in salmon farming. Within 'food provision', only indicator criteria (100%) were represented, which referred to maintaining community access to fishing grounds and other resources. Although farmed salmon contributes to 'food provision', this aspect was not represented. Criteria within 'water storage and provision' included best practice (60%) and indicator criteria (40%) criteria related to water use, salinization, and community access to freshwater resources (Appendix B).

3.4.2 Regulating Services

The greatest proportion of criteria (85%) fell within regulating services. This is also where the greatest diversity of ecosystem service sub-categories was found, including 'biological regulation', 'climate regulation', 'life cycle maintenance' and 'water purification'.

3.4.2.1 Biological Regulation

'Biological regulation' included largely best practice criteria (90%), followed by indicator (8%) and tipping point criteria (2%) (Figure 3.2). Criteria within 'biological regulation' can be divided into two subgroups: 'regulation of fish pests and diseases' and 'human disease regulation'. Many 'regulation of fish pests and diseases' criteria come from animal welfare sections of sustainability schemes; however, assuming that managing fish health on the farm will reduce the overall pest and disease load on the farm, and therefore limit risk of transfer to wild populations, precautionary criteria related to fish pest and disease management were assigned to this subgroup. 'Regulation of fish pests and diseases' criteria included those related to fish mortalities and reducing potential disease vectors. Two criteria in this subgroup were considered tipping point criteria. They were both ASC criteria requiring that maximum allowable sea lice load for the farm, and all farms within the area based management plan, be based on wild monitoring data. While no valuation of ecosystem services was present in this subgroup, criteria that internalized the concept of ecosystem service trade-offs by relying on a production-specific ratio were present in indicator and best practice criteria for unexplained mortalities, viral disease-related mortality, and therapeutant use. 'Human disease regulation' criteria included those requiring judicious use of antibiotics as well as those related to food safety (Appendix B).

3.4.2.2 Climate Regulation

All 'climate regulation' criteria were best practice criteria (100%) and were oriented towards monitoring pressure on 'climate regulation', including greenhouse gas emissions or energy consumption assessments and record keeping (Appendix B). GLOBALG.A.P. also included criteria that support planning for future improvements in energy efficiency, including reducing use of non-renewable energy. FOS criteria also supported reducing energy use over time, requiring certified farms to aim to achieve an annual reduction in energy consumption per unit of production implying a proportional trade-off between 'food provision' and impacts on 'climate regulation'.

3.4.2.3 Life Cycle Maintenance

'Life cycle maintenance' refers to the continuance of species reproduction and is not to be confused with the use of this term in Life Cycle Assessment (LCA). It is used here for continuity with existing ecosystem service classifications. 'Life cycle maintenance' criteria included mostly best practice criteria (80%), followed by indicator (17%) and tipping point criteria (3%) (Figure 3.2). These criteria can be further divided into two subgroups: 'biologically mediated habitat' and 'life cycle maintenance of wild salmon'. First, 'biologically mediated habitat' refers to habitat provided by living organisms and encompassed criteria related to impacts on biodiversity including benthic fauna and the broader ecosystem (Appendix B). Two 'biologically mediated habitat' criteria from MBA considered the continued provision of habitat services and were therefore classified as tipping point criteria. The first is a habitat conversion and function criterion that requires evidence that habitat is maintaining full functionality and no critical ecosystem services have been lost. The second is a criterion related to the content of habitat management measures which requires a cumulative management approach that is integrated with other industries and based on maintaining ecosystem functionality. Although both criteria rely on assessment of ecosystem functionality, they do not clearly describe functionality or the type of evidence that should be used to assess it. Second, 'life cycle maintenance of wild salmon' refers to the conservation and reproduction of wild salmon, and criteria in this subgroup included those related to fish escapes and the prohibition of transgenic salmon (Appendix B). This subgroup included one tipping point criteria (2%) from the ASC scheme requiring scientific research regarding the risk of the farmed non-native species becoming established in the area.

3.4.2.4 Water Purification

Criteria within 'water purification' included those concerning the use, disposal, and storage of potential contaminants, the application of feed, effluent parameters, and waste management. Most water purification criteria were best practice (72%) followed by indicator (27%) and tipping point (1%) criteria. The only 'water purification' tipping point criteria was MBA's "content of effluent management measures", which demanded use of an area-based, cumulative management system where water quality parameters are based on carrying capacity (Figure 3.2). This MBA criterion, as well as BAP's requirement that nutrient monitoring be coordinated with neighbouring farms or members of an Area Management Plan, are also noteworthy for their required integration of monitoring activities with other sectors, a principle of EAA.

3.4.3 Cultural Services

All cultural criteria corresponded to 'symbolic and aesthetic value' services and included best practice (83%) and indicator criteria (17%) (Figure 3.2). 'Symbolic and aesthetic value' criteria can be divided further into two subgroups: 'feel good or warm glow' and 'sense of place'. The 'feel good or warm glow' subgroup included criteria representing the non-use value received from knowing that biodiversity exists. These criteria included those related to the control and deterrence of farm-associated predators. It also included one service enhancement criterion from GLOBALG.A.P. regarding stock improvement through breeding. 'Sense of place' included a criterion stipulating that children of farm employees have access to education, and a second criterion that company contributions to the community be reported. Social benefits provided to the community through company contributions represents the potential enhancement of cultural ecosystem services.

3.4.4 Other Criteria

An additional 278 criteria were classified as not being associated with an ecosystem service. These included criteria related to operations (56%), animal welfare (20%), program integrity (10%), compliance with local laws and regulations (8%), and community engagement (5%). Operational criteria included record keeping requirements and human resource practices. Animal welfare criteria spanned the production life cycle and included criteria related to holding capacity, oxygen saturation, transportation conditions, and staff training. Program integrity criteria included those related to the tracking and management of certified products and any self-assessment or complaint management procedures related to certification. Finally, community engagement criteria included those requiring consultation with communities, public reporting, and responding to public requests for information.

3.4.5 Scheme Comparison

Although there was broad representation of ecosystem services across sustainability schemes, this representation was not always consistent between schemes (Table 4; Figure 3.3A). Regulating services were proportionally the most represented category across all sustainability schemes (ASC 86%, BAP 81%, FOS 84%, GLOBALG.A.P. 90%, MBA 70%), followed by provisioning services for ASC (9%) and FOS (11%), and by cultural services for BAP (12%) and GLOBALG.A.P. (5%) (Figure 3A). Within regulating services, ASC, BAP, and GLOBALG.AP. all skewed towards representation of 'biological regulation' criteria (45%, 26%, and 46% respectively) while FOS skewed towards representation of 'water purification' (50%) and MBA towards 'life cycle maintenance' (57%). 'Climate regulation' was also an area of difference with no representation in BAP or MBA, and a small proportion of regulating criteria in ASC (6%), FOS (6%), and GLOBALG.A.P. (3%) schemes (Figure 3.3B).

Table 3.4. Ecosystem service representation in sustainability schemes

Ecosystem Service		ASC	FOS	BAP	GLOBALG.A.P.	MBA
Provisioning	Biotic materials	✓	✓	✓	✓	✓
	Food provision	✓		✓	✓	
	Water storage and provision	✓			✓	
Regulating	Water purification	✓	✓	✓	✓	✓
	Climate regulation	✓	✓		✓	
	Life cycle maintenance	✓	✓	✓	✓	✓
	Biological regulation	✓	✓	✓	✓	✓
Cultural	Symbolic and aesthetic value	✓	✓	✓	✓	✓

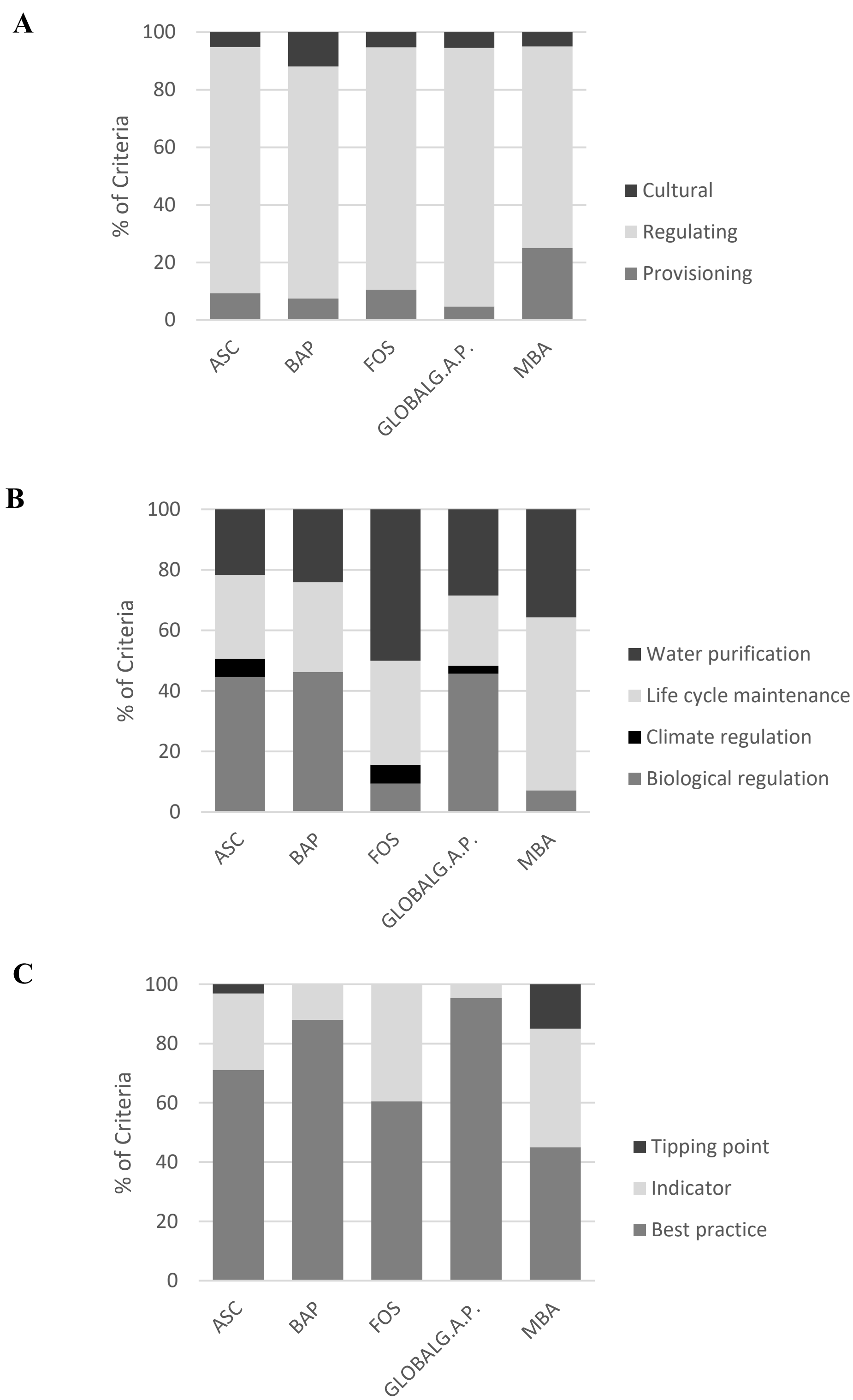

Figure 3.3. Proportion of (A) ecosystem service categories (B) regulating services sub-categories and (C) types of criteria found within sustainability scheme criteria.

Best practice criteria were the most represented criteria type across all sustainability schemes, followed by indicator, and tipping point; however, there was variation in the proportional breakdown of criteria types within sustainability schemes (Figure 3C). GLOBALG.A.P. contained the highest proportion of best practice criteria (95%), followed by BAP (88%), ASC (71%), FOS (61%), and MBA (45%). MBA contained the highest proportion of indicator criteria (40%), followed by FOS (39%), ASC (26%), BAP (12%), and GLOBALG.A.P. (5%). Tipping point type criteria were present in only two of the five sustainability schemes, MBA (15%), and ASC (3%) representing 'biological regulation' (ASC), 'life cycle maintenance' (ASC, MBA), and 'water purification' (MBA).

3.5. DISCUSSION

The purpose of this analysis was to explore the representation of ecosystem services within sustainability schemes for marine salmon aquaculture. In general, scheme criteria reflected a range of ecosystem services and were largely aimed at reducing potential pressure on those services with little consideration given to the resilience capacity of ecosystem services. There is also little consideration given to the enhancements to ecosystem services provided through salmon farming. Overall, these results indicate that the sustainability schemes analyzed do not currently reflect an ecosystem services tradeoff approach to decision-making that could support a cost-benefit assessment of current or future salmon farms in the context of an Ecosystem Approach to Aquaculture (EAA).

3.5.1 Representation of Ecosystem Services

Given the number of previous ecosystem service classifications applied to marine ecosystems (Liquete et al., 2013) and the many interpretations of those classifications (La Notte et al., 2017), some judgement was required in the categorization of individual scheme criteria. While the ecosystem service classification and categorization of criteria presented here relied on interpretation of both ecosystem service definitions and scheme criteria, it provided a useful structure for exploring the representation of ecosystem services in sustainability schemes. All ecosystem services categories from the Liquete et al. (2013) classification of services were represented in sustainability schemes and a broad range of sub-category services were also represented. While the number of criteria within ecosystem service categories does not necessarily speak to the quality of those criteria nor the degree of completeness in representing that service, proportionally high representation of regulating services within schemes does reflect the environmental sustainability focus of schemes. Low proportional representation of criteria related to cultural services echoes previous analysis of domains represented in farmed salmon certification scheme criteria (Osmundsen et al., 2020).

Several ecosystem services affected by salmon aquaculture were not represented in any of the sustainability schemes analyzed. For example, (Outeiro & Villasante, 2013) analyzed the impact of aquaculture infrastructure on the aesthetic value of coastal viewshed, an ecosystem service that was not included in the sustainability schemes analyzed here. Another service absent from sustainability schemes was the provision of artificial habitat for wild fish that congregate within and around farms (Gentry et al., 2020). Furthermore, some of the contributions of farmed fish to human health were not present. While precautions to reduce pressure on 'human disease regulation' were represented by criteria related to food safety practices, contributions to human health through the provision of food rich in omega-3 fatty acids (I. J. Jensen et al., 2012) and associated prevention of non-communicable diseases (Gormaz et al., 2014) were not included in any scheme. In fact, the production of food, a provisioning service provided through salmon aquaculture, was not reflected in sustainability schemes at all. Recognition of this contribution to an ecosystem service, as well as other potential contributions, is necessary for any tradeoff analysis approach to decision-making processes around new and continued aquaculture development.

3.5.2 Types of Sustainability Criteria

The types of criteria range in their embodiment of EAA's principle that ecosystem services should not be degraded beyond their resilience capacity. Best practice criteria provide basic safeguards against the potential degradation of ecosystem services. Indicator criteria prescribe measures and limits of the degree of pressure on or state of potentially degraded services. Finally, tipping point criteria, which also prescribe limits on pressures and states, are grounded in EAA's first principle by basing those limits on the amount of pressure a service can absorb before it is no longer able to recover. Classification of criteria was based on interpretation of information available within scheme documents only. It is possible that additional information, especially with regards to the rationale behind decisions to include certain criteria in schemes, could result in different classification of some criteria. However, overall, the use of tipping point criteria appears to be very limited. The high proportion of best practice criteria within certification schemes may be explained by the practical needs of certifiers, farmers, and auditors. Although some flexibility in applying criteria to local conditions is necessary (Amundsen & Osmundsen, 2019), schemes must rely on criteria that are unambiguous, allowing auditors to assess farms based on immediately observable farming practices, events, and metrics in order to maintain transparency and credibility. Further, the use indicator or tipping point criteria is complicated by the complexity of the marine ecosystem and the effects of aquaculture on the state of ecosystem services. For example, indicator values may be affected by interactions between the effects of aquaculture (Crain et al., 2008) or hydrographic conditions (Borja et al., 2009; Tomassetti et al., 2016).

Finally, incorporating EAA in certification through the use of tipping point criteria increases the complexity of certification. The technical and conceptual requirements necessary to include criteria based on carry capacities and ecosystem resilience may limit accessibility to certification, especially for small-scale producers with limited resources or expertise. The relationship between the credibility and accessibility of certification schemes based on the use of relevant criteria has been described as one side of a 'devil's triangle' that must be balanced if certification schemes are to remain credible while also being effective (Bush et al., 2013b). Schemes already rely heavily on human capital including producer skills and knowledge, but by including criteria that encourage investment in a variety of capitals they may be able to increase producer capacity to comply with increasingly complex criteria (Samerwong et al., 2020). For example, schemes that support data sharing, partnership with researchers and research institutions, and collaboration with other farms and industries may provide tools that allow farms to meet the technical requirements of tipping point criteria. Salmon aquaculture schemes already include some criteria related to sharing information and coordination between farms (Amundsen et al., 2019). Greater emphasis on these types of criteria may also contribute to the capacity to comply with new criteria based on the resilience capacity of ecosystem services that require a broader understanding of far-field ecological impacts.

3.5.3 Ecosystem Service Valuation and Tradeoffs

Sustainability schemes included some criteria that internalize a tradeoff approach by incorporating a production-specific ratio. However, in order to embrace a tradeoff approach grounded in the value of ecosystem services to people, the valuation of both the unit of production ('provision of food') and ecosystem service affected would be required to allow for assessment of the overall resulting value to human wellbeing. Overall, the limited recognition of ecosystem services enhanced through aquaculture and the absence of any criteria requiring the valuation of ecosystem services degraded or enhanced by salmon aquaculture suggests that schemes do not currently support cost-benefit analysis of farming activity.

Recognizing the enhancement of services through aquaculture is not only critical to tradeoff analysis but could serve to increase market recognition of those services. Where sustainability schemes currently take a precautionary approach that aims to minimize environmental impact, an approach that incorporates ecosystem service valuations could lead to more purposeful delivery of benefits to people by incentivizing the supply of ecosystem services through certification or seafood rankings (Alleway et al., 2018). Indeed, the future growth and supply of seafood from aquaculture is projected to be highest under policies that support the sustainable development of aquaculture and lowest under overly restrictive policies or policies that allow for the unsustainable development of aquaculture (Costello et al., 2020). Therefore, aquaculture certification criteria that support sustainable growth without being overly restrictive can be expected to help increase the provision of food. Furthermore, recognizing the benefits that people derive through aquaculture in sustainability schemes could encourage more consumers to participate in these programs, which is an essential component of the theory of change associated with certification and seafood ranking programs. Perceiving aquaculture as having benefits is strongly related to support for aquaculture (Rickard et al., 2020). Therefore, recognizing ecosystem service contributions in sustainability schemes could also have implications for the role of certification in the public perception of aquaculture more generally.

Many examples of valuations for ecosystem services affected by aquaculture are available that could be drawn on for the development of certification criteria that support cost-benefit analysis (Grealis et al., 2017; Outeiro & Villasante, 2013); however, incorporating valuation into sustainability schemes would also add complexity to the certification process, potentially limiting access to certification for many producers as is the case with including more indicator and tipping point criteria. Further, while examples might inform new certification criteria that incorporate a valuation approach, changes to ecosystem services are not experienced or valued by all people equally (Daw et al., 2011; Madin & Macreadie, 2015; Martín-López et al., 2009; Wieland et al., 2016). For example, aquaculture is expected to provide increased 'food provision' that may provide benefits in the form of increased employment rates, taxes, and food security, but access to those benefits, the degree of benefit received, and the value of that benefit, will depend on how the enhanced service is managed and where people are located. A region-specific approach (e.g. Forest Stewardship Council, (Madin & Macreadie, 2015) might weight criteria related to different ecosystem services based on the value of those services in the region of production. In addition to the value placed on benefits, access to benefits may also vary by region. Criteria that mediate or broaden the distribution of benefits might complement those that support cost-benefit analysis.

3.5.4 Variation Between Sustainability Schemes

Differences between schemes noted here do not suggest variation in the overall stringency or quality of these schemes but are an indication of differences in the representation of ecosystem services within them. Each scheme has a unique purpose, group of stakeholders, and process (Nilsen et al., 2018) which may explain these differences. For example, ASC included provisioning service criteria ensuring the maintenance of community access to food and water resources while MBA did not. This reflects MBA's focus on environmental impact and ASC's inclusion of both environmental and social responsibility in its mission. Some variation in the proportional representation of criteria within regulating service sub-categories can be explained by the organization of scheme criteria. For example, FOS led in representation of 'water purification' criteria; however, FOS lists each effluent parameter as a separate criterion whereas other schemes combine these parameters into one criterion.

Variation in the presence of both 'climate regulation' and 'biotic materials' criteria suggests that there are differences between schemes in coverage of the upstream and downstream effects of aquaculture. This result supports a previous finding that impacts beyond the farm are poorly represented in salmon aquaculture certification scheme criteria (Amundsen et al., 2019). Schemes could incorporate carbon footprint limits into criteria to recognize pressure on 'climate regulation'; however, certifications would need to be region-specific if differences in carbon emissions associated with shipping to various locations were to be recognized (Madin & Macreadie, 2015). Adopting a Life Cycle Assessment (LCA) approach to measure the impacts of aquaculture (Cao et al., 2013; Pelletier & Tyedmers, 2008), and including traceability and information transfer criteria in sustainability criteria (Amundsen et al., 2019) hold potential to address some of the spatially and temporally far-reaching environmental impacts of aquaculture.

Finally, variation in the proportional representation types of criteria amongst sustainability schemes showed that MBA and ASC were the only ones to incorporate tipping point criteria, and that MBA incorporated the highest proportion of those criteria. This difference may be due to the 'unit of certification' used in certification schemes, which is typically a single farm or production unit, compared to the recommendation approach of MBA which provides a ranking for species produced in different regions by specific methods. The broader ecosystem perspective required to set limits for tipping point type criteria is challenging to include in the single-farm 'unit of certification' approach. However, consideration of the combined impact of multiple farms within a water body are reflected in certification criteria that require participation in area-based management schemes (Amundsen et al., 2019) and in the case of bivalve farms, criteria that require evidence that farms are collectively operating within the carrying capacity of the water body (ASC, 2010; GAA, 2015). However, as stands, the farm-scale assessment approach of certifiers is not congruent with the broader ecosystem view required to ensure the future provision of ecosystem services and operationalize EAA. A regional approach to assessment may be better able to incorporate tipping point criteria based on an understanding of regional ecosystem resilience, and provide efficiencies in addressing technical components of tipping point criteria, for example, where the same ecosystem model is relevant to multiple farms within a region. Furthermore, a regional approach to assessment could support the use of region-specific valuations of ecosystem services.

3.6 CONCLUSIONS

While a broad range of ecosystem services are represented in sustainability scheme criteria for salmon aquaculture, those criteria do not currently support an ecosystem services approach to management based on the value of ecosystem services to people. However, EAA does not explicitly call for an accounting and valuation of ecosystem services, but rather for the development of aquaculture in a way that does not degrade services beyond their resilience capacity. Including all relevant ecosystem services, increasing the use of performance-based criteria based on the resilience capacity of those services, and internalizing a trade-off approach could all help certification operationalize EAA; however, there are several barriers to these proposed changes including the availability of data: complexity of the marine ecosystem, challenge of setting limits for tipping points based on ecosystem resilience, and overall understanding of trade-offs between services. Even given these challenges, changes to existing criteria or the development of new criteria may be able to address some of these requirements, but shifting to a regional assessment approach might be necessary to operationalize EAA through sustainability schemes. Overall, these recommended changes to criteria and structure of certification must balance the embracement of EAA principles without creating barriers to participation that could undermine the overall effectiveness of certification.

CHAPTER 4: FROM FARM SUSTAINABILITY TO ECOSYSTEM SUSTAINABILITY: EXPLORING THE LIMITATIONS OF FARM-APPLIED AQUACULTURE ECO-CERTIFICATION SCHEMES

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Please note that this chapter appears as it did in the published article, with references and table, figure, and section numbers updated to match the format of this thesis document.

4.1 ABSTRACT

Aquaculture eco-certification schemes provide standards against which individual farms are assessed, and those farms that comply with eco-certification criteria receive certified status. These schemes aim to improve aquaculture sustainability, but the site-by-site approach of eco-certification can be a barrier to the inclusion of ecosystem perspectives in the evaluation of farm sustainability. However, the ecosystem approach to aquaculture demands a management approach that considers broader scale ecosystem impacts. This study explored how eco-certification schemes and processes account for potential ecosystem impacts of salmon farms. Interviews with eco-certification auditors, salmon producers, and eco-certification staff were conducted. The experience of participants and information from eco-certification scheme criteria and other eco-certification scheme documents were used to identify thematic challenges associated with the consideration of ecosystem impacts including: assessing far-field impacts, managing cumulative effects, and anticipating ecosystem risks. Results indicate that eco-certification schemes work within the limitations of farm-scale application of global eco-certification standards to address potential ecosystem impacts by: (1) including eco-certification scheme criteria that address ecosystem impacts, (2) relying on the experience, expertise, and judgement of eco-certification auditors, and (3) referencing and deferring to local regulations. Results indicate that eco-certification schemes can address ecosystem impacts to some degree, despite their site-by-site approach. The integration of additional tools while supporting the capacity of farms to apply those tools, as well as increasing transparency during compliance assessment could help eco-certification schemes shift from providing assurance of farm sustainability to providing assurance of ecosystem sustainability.

4.2 INTRODUCTION

Salmon aquaculture is a growing industry that can have both positive and negative impacts on the environment. While salmon production is part of an overall increase in aquaculture production, which is expected to help feed a growing population (Boyd et al., 2022; Costello et al., 2020), it can also cause environmental change through the accumulation of fish feed and waste, fish escapes, and the use of chemicals and antibiotics, among other potential impacts (Klinger & Naylor, 2012; Weitzman et al., 2019). Global salmon production has tripled since the year 2000 (FAO, 2022b), and regulatory approaches that aim to limit potential negative impacts of salmon farming while maximizing contributions to human well-being are needed. Public governance mechanisms and tools for managing aquaculture development including international agreements, national and regional regulatory frameworks, and farm siting, licensing, and permitting have emerged and continue to evolve (Barton, 1997; Hersoug, 2015; McDaniels et al., 2005; Wiber et al., 2021). Further, the role of private governance and non-government actors in salmon aquaculture, including participation in voluntary eco-certification schemes, is growing (Rector et al., 2023a; Saha, 2022; Vince & Haward, 2019).

Aquaculture eco-certification schemes started by retailers, non-governmental organizations (NGOs), and producers first emerged in the mid-1990s in response to the perceived shortcomings of public governance practices in managing aquaculture growth and impacts (Auld, 2014; Saha, 2022). Eco-certification schemes like the Aquaculture Stewardship Council (ASC), Best Aquaculture Practices (BAP), and GlobalGAP provide standards consisting of sustainability criteria against which aquaculture farms and facilities can be assessed (Nilsen et al., 2018). Salmon producers report demand from buyers and retailers for eco-certified product (Olsen et al., 2021), and over 50% of global salmon production is certified by ASC alone (ASC, 2022a), indicating that a significant proportion of salmon aquaculture is being governed by private eco-certification schemes in addition to public governance practices. As the influence of eco-certification in the hybrid governance of aquaculture continues to grow (Vince & Haward, 2017), it is increasingly important to understand how its underlying criteria serve to limit negative environmental impacts and contribute to ecosystem sustainability.

National and regional regulation is broad in authority with the potential to address interconnected social-ecological challenges associated with aquaculture using multi-sector approaches as well through the control of individual farm leases and permits (Figure 4.1). However, public regulation of aquaculture is often fragmented and decentralized across institutional scales resulting in regulatory gaps (McDaniels et al., 2005; Sandersen & Kvalvik, 2014; Wiber et al., 2021). In contrast, eco-certification standardizes sustainability across national borders which makes it appealing for seafood buyers that can rely on a single credible international standard rather than vetting public regulation in multiple countries (Gutiérrez & Morgan, 2017). However, although eco-certification schemes govern aquaculture across geographic scales, the scale of application of eco-certification criteria or 'unit of certification' is typically an individual farm and eco-certification relies on standard criteria that can be assessed at that scale (Figure 4.1). This site-by-site approach and focus on indicators of sustainability that are observable at the farm may contribute to a perceived lack of ecosystem perspectives in eco-certification (Bush et al., 2013a; Jonell et al., 2013), though potential for eco-certification to address broader scale impacts has also been noted (Amundsen et al., 2019; Bridson et al., 2020).

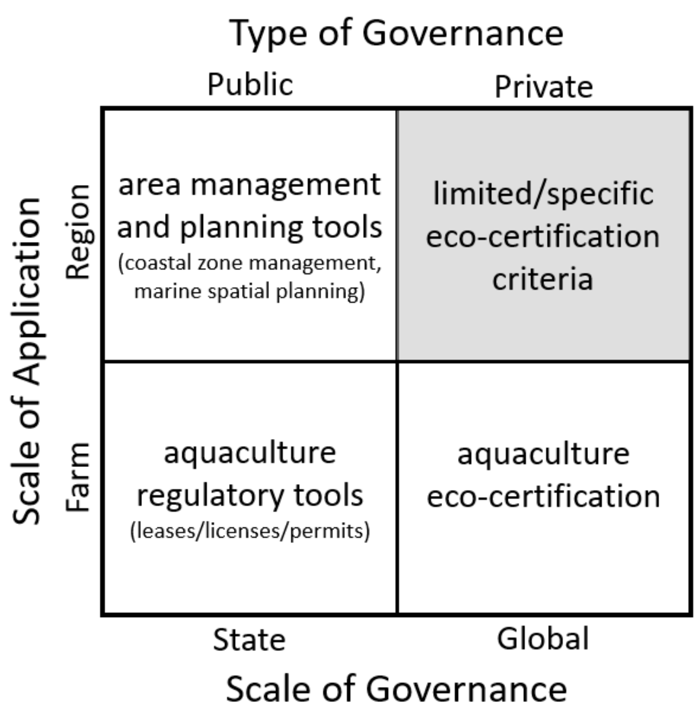

Figure 4.1. Scale of governance and application of public and private governance mechanisms including planning tools and processes, regulatory tools, and eco-certification. Aquaculture eco-certification is global in governance reach and applied at farms, but can be raised to the level of regional application through the use of specific eco-certification criteria (e.g., criteria that require participation in or formation of area management agreements).

The importance of an ecosystem perspective in aquaculture development is already explicit in FAO's Ecosystem Approach to Aquaculture (EAA), a framework for the sustainable development of aquaculture that demands a management approach that considers the impacts of aquaculture at multiple scales including the farm, watershed, and globe (Soto et al., 2008). Management at the farm-scale relies on understanding and measurement of physical processes while management at the watershed requires an understanding of ecosystem processes. Tools like carrying capacity models and marine spatial planning that embrace a broader spatial and ecological perspective than on-farm monitoring have contributed to the advancement of EAA (Brugère et al., 2018; Ross et al., 2013), and these tools have been embraced by public regulators (Lombard et al., 2019; Ross et al., 2013) and by private aquaculture eco-certification schemes in the case of bivalves and carrying capacity (Rector et al., 2023a). However, few indicators have been developed and validated for the assessment of watershed-scale impacts of salmon aquaculture in comparison to near-field and global impacts (Rector et al., 2022).

Combined, the farm-scale application of eco-certification schemes along with a required shift from focus on near-field physical processes to far-field ecosystem processes in aquaculture management and development presents a challenge for eco-certification if it is to serve as a guarantee of not only farm sustainability, but also ecosystem sustainability. Given the significant role of eco-certification in the transnational governance of salmon farming and the challenge of managing aquaculture development using the ecosystem perspective demanded by EAA, this study aims to understand how eco-certification accounts for ecosystem impacts by identifying challenges associated with addressing ecosystem impacts through eco-certification, and ways that eco-certification does or could address ecosystem impacts. This analysis builds on the understanding that though eco-certification is mediated by written standards and criteria, it is also an interactional process that relies on the experience, knowledge, and interaction between people involved in the process of eco-certification (Amundsen & Osmundsen, 2019). Therefore, this analysis relies on both the experiential knowledge of people engaged in the process of eco-certification and knowledge contained in guiding documents used in the assessment of salmon farms against eco-certification criteria.

4.3 METHODS

The consideration of ecosystem impacts in eco-certification was explored using information gathered from interviews with people involved in the process of eco-certification and from publicly available documents from global eco-certification schemes. This approach recognizes the value of insight from microlevel decision-makers (Sherren & Darnhofer, 2018) as well as the important function of institutional texts in the organizing of eco-certification.

4.3.1 Interviews

Participants with experience in the process of eco-certification were recruited using a purposeful sampling strategy employing both convenience and snowball sampling (Creswell & Poth, 2016). People with experience in the development and application of eco-certification criteria were recruited from certification bodies, eco-certification programs, and industry. Potential participants were identified by searching the websites of certification bodies, eco-certification programs, and salmon farming companies. In the case of farming companies, where an appropriate individual could not be identified, a general contact email was collected from the company's website. Additional potential participants were identified through the research team's network and through snowballing as participants identified additional contacts. Potential participants were contacted by email and invited to take part in a research interview over a video call, or by phone if they preferred. Video interviews provided a convenient way to conduct interviews given the various locations of participants. No geographic boundary was applied to recruitment, but only English-speaking participants were eligible to participate. Participant recruitment and interviews were conducted between May 1, 2021 and March 31, 2022 with ethics approval from Dalhousie University (REB#2021-5505).

Eight one-on-one interviews were conducted with auditors (3), eco-certification staff (2), and salmon producers (3). Following guidance from (Malterud et al., 2016), all five dimensions expected to impact information power, described as the information the sample holds relative to the study, point towards very high information power; therefore, a small sample size is expected to hold sufficient information. These dimensions include the narrow aim of the study, dense specificity of the experience of participants as people involved in the eco-certification of salmon farms, application of existing knowledge to the study design and analysis, strong quality of dialogue given the background knowledge of both the participants and researcher, and the case study approach which aimed to provide an in-depth analysis of how marine salmon farming eco-certification schemes consider ecosystem impacts (Malterud et al., 2016). Experience working in all top 4 salmon producing countries (Norway, Chile, Canada, and Scotland (FAO, 2022b)), which combined produce over 90% of salmon aquaculture volume, was reflected within the participant group. Each interview was conducted via a video call and lasted approximately one hour. Open-ended interview questions developed for each of the three roles from which participants were recruited were used to guide interviews, and probing questions were used to explicate and clarify meaning (Appendix C). All interviews were transcribed non verbatim, and thematic analysis was applied using inductive coding. NVivo Qualitative Data Analysis Software Version 12 PRO was used to conduct this analysis. Quotations were used, where authorized by participants, to illustrate findings, and are modified for length and to protect participant identity (Eldh et al., 2020).

4.3.2 Documents

Documents integral to the process of eco-certification were used to corroborate, clarify, and contextualize information provided by participants. These documents included eco-certification standards from ASC, BAP, and GlobalGAP, which represent the three eco-certification schemes most relevant to participants and are also internationally relevant global aquaculture eco-certification schemes recognized by the Global Seafood Sustainability Initiative (GSSI). This study builds on previous understanding and categorization of individual criteria within these eco-certification standards (see Rector et al., 2021). Throughout interviews, participants identified specific eco-certification criteria and types of criteria that address ecosystem impacts, and additional comparative analysis of the three eco-certification standards analyzed was applied to these criteria (Tables 4.1-4.3).

Participant interviews led to the identification of additional documents that are integral to the process of eco-certification and approaches to addressing ecosystem impacts. The additional documents consulted included the ASC Salmon Audit Manual, ASC Standards Related Variance Request Procedure, ASC Standards and CAR-Related Question for Interpretation Procedure, and ASC variance requests (VRs). VRs are documents prepared and submitted by a certification body to ASC for review when a farm wishes to request that an ASC criterion is adapted due to the local context in which the standard is being applied. VRs undergo a technical review by ASC, and ASC issues a decision on whether the VR is approved, not approved, or declined. VRs submitted to ASC after December 15, 2020, when the current VR process was implemented, and before November 30, 2022, were included in the analysis. Two VRs submitted during this timeframe remained under technical review at the time of analysis and were not included in analysis.

4.4 RESULTS

Three key thematic challenges associated with the consideration of ecosystem impacts were identified through thematic coding of interview transcripts: *assessing far-field impacts*, *managing cumulative effects*, and *anticipating ecosystem risks*. Analysis of interviews, eco-certification scheme criteria, and supporting documents resulted in the identification of three ways or approaches used to address these issues throughout the process of eco-certification: (1) including eco-certification scheme criteria that address ecosystem impacts within eco-certification standards; (2) relying on the judgement, expertise, and experience of the auditor in farm compliance assessment; and (3) referencing and deferring to local regulations (Table 4.1).

4.4.1 Assessing far-field impacts

Addressing ecosystem impacts of aquaculture requires a shift from monitoring farm-scale impacts to understanding and assessing impacts beyond the farm. Many eco-certification criteria directly target far-reaching impacts of salmon farming that can be assessed at the farm level. For example, ASC, BAP, and GlobalGAP all include specific eco-certification criteria that require planning and measures to limit effluent release, the potential spread of disease to other farms and wild fish populations, and the escape and impact of escaped salmon on the environment. As expressed by one participant: *"If you're reducing local impacts then you are by definition reducing broader impacts."*

Eco-certification schemes also rely on the use of an allowable zone of effect (AZE), a zone inside of which impacts are expected but outside of which there are set limits for chemical or biological indicators of benthic impacts, to ensure that expected local impacts do not reach beyond the immediate farm area (Table 4.2).

Table 4.1. Summary of sediment monitoring criteria from global salmon eco-certification schemes.

	ASC	BAP	GlobalGAP
Boundary of impact	Site-specific allowable zone of effect (AZE) based on a robust and credible multi-parameter modelling system (e.g., SEPA AUTODEPOMOD); monitoring must be used to ground truth the AZE	As defined in farm permits and/or local regulations, or 40m boundary that may be shifted to account for normally occurring uneven current patterns	Not defined
Threshold of impact	Redox potential > 0mV or sulphide ≤ 1500 µMol /L, AZTI Marine Biotic Index (AMBI) score ≤ 3.3 or Shannon-Wiener Index score > 3 or Benthic Quality Index (BQI) score ≥ 15 or Infaunal Trophic Index (ITI) ≥ 25, ≥ highly abundant taxa that are not pollution indicator species	Trigger level above which the farm would not be in full compliance with the local standard, its operating permit, or its own monitoring plan in countries where sediment monitoring is not required	Benthic biodiversity and chemical indicators monitored in accordance with a biodiversity-inclusive Environmental Impact Assessment (EIA) and legal compliance

Table 4.2. Summary of area-based agreement requirements from criteria of global salmon eco-certification schemes.

	ASC	BAP	GlobalGAP
Required coordination	Participation in an Area-Based Management (ABM) scheme where at least 80% of farmed production (by weight) within the defined area are participating in the ABM; farms in areas without an ABM must show leadership in working with neighbouring farms towards establishing an ABM.	Participation in Area Management Agreements (AMA) where they exist; farms in areas without AMA must be working towards participation in an AMA, provide a timeline for projected establishment of an agreement and cooperate with other neighbouring BAP-certified farms	If there is an area management plan, the farm must be actively participating
Definition of area/zone	As defined by regulatory requirement of the farm's jurisdiction; where the farm's jurisdiction does not require an ABM, the ABM must reflect a logical geographic scope such as a fjord or a collection of fjords that are ecologically connected taking into account water movement, where cumulative impacts on wild populations may occur, and other relevant aspects of ecosystem structure and function; at least 80% of farmed production (by weight) within the defined area must be participating in the ABM; all farms owned by the company applying for certification within the ABM must be participating	As defined by management area rules in countries where AMAs are established; improvement of AMA where they are not based on hydrographic characteristics is encouraged	Described as “producers, usually at the same water body”
Actions coordinated	Therapeutic treatments, stocking, fallowing, disease and pathogen monitoring, setting a maximum lice load	Production cycles, fallowing, nutrient monitoring, fish health management	Measures to prevent the introduction and spread of pathogens and diseases

Assessing far-field effects also requires an understanding of ecosystem processes and dispersion of waste. For example, eco-certification schemes might require the use of a site-specific carrying capacity model or determination of an AZE based on a multi-parameter modelling system (Table 4.1). Participants indicated that criteria that require the use of models can be a barrier to participation and equity in eco-certification, especially in countries with fewer resources to put towards satisfying voluntary eco-certification criteria: *"…if he is saying you need to have all these models in areas in which there isn't that expertise, that might be fine in Australia or the US or Northern Europe, but if you've got a salmon farm in Chile, which there's a lot, and I know there's a lot of expertise in Chile, but it's not as rich a country."* Some participants also expressed doubts about the accuracy of models to predict environmental impacts. Overall, the inclusion of criteria that account for the far-field impacts of aquaculture was perceived to be limited by scientific knowledge: *"…until there's really a stronger dataset in terms of determining exactly what are the impacts of salmon farming, it's going to be pretty hard to make any larger broad scale assessments of what needs to be in a standard."*

Participants pointed to the role of auditors in interpreting and applying criteria that target far-field impacts where those criteria are written ambiguously. As stated by one participant: *"When they're not defined well enough there's no way that you're being treated the same consistently from jurisdiction to jurisdiction or by different auditors within the same jurisdiction."* This can even be true of seemingly prescriptive criteria that rely on specific thresholds. For example, the ASC salmon standard includes a criterion that sets a limit of 300 escaped fish per production cycle, but auditors applying this criterion must choose to report either a major or minor non-conformity when the escape threshold is exceeded: *"So if you've got 301 fish, is that a major or is 10,000 fish major?"* Disagreement between an auditor and the technical reviewer for a particular audit, both of whom must be representatives of an accredited certification body, may lead to discussion and clarification, but as certification bodies must be independent from eco-certification schemes, there are limited opportunities for auditors to discuss the interpretation and application of specific criteria. For example, ASC provides a 'Question for Interpretation' procedure and platform that allows certification bodies to request interpretation of the language or intent of a specific criterion.

Finally, many eco-certification criteria refer or defer to local regulations, including criteria that address far-field impacts. For example, BAP defers to local regulations in the determination of AZE scale and benthic impact thresholds. In comparison, ASC demands that an AZE be set based on a robust and credible multi-parameter modelling system and sets global scheme-specific thresholds for benthic impacts beyond the AZE (Table 4.2).

4.4.2 Managing cumulative effects

Most eco-certification criteria are designed to assess the impact of an individual farm, and participants questioned the capacity of eco-certification criteria to address the cumulative effects of multiple farms in an area. For example, when talking about the number of fish escapes at individual farms in an area one participant noted that although individual farms may satisfy eco-certification criteria that set a limit on the number of fish escapes and/or unaccounted losses, the cumulative number of escaped fish combined with cumulative unaccounted losses in an area may still be of concern: *"Individually, I wouldn't raise an eyebrow, but it's still 10,000 fish lost in the same body of water, or unaccounted for."* However, eco-certification could play a unique role in understanding and managing bay-scale impacts of aquaculture as an aggregator of farm data, particularly when multiple farms dominate the seascape. When eco-certification schemes standardize, aggregate, and collate data from farms they build the potential to look ecosystem status and the impact of farming at a greater spatial scale. As one participant described: *"We're getting consistent data that we're better able to use going forward […] Maybe we can take that data and […] say in this region, this is what's going on […].*

Although the majority of eco-certification criteria focus on potential impacts of farming at individual farms, all eco-certification schemes analyzed also include criteria that require the use of area-based management agreements that address potential cumulative impacts (Table 4.3). Though each eco-certification scheme uses a different name for these agreements, they all emphasize planning and cooperation with other farms in the area. All three of the schemes analyzed require participation in an area-based management agreement if there is an active agreement where the farm is located. ASC and BAP also require that producers work towards the establishment of an area-based management agreement in areas where one is not already established (Table 4.3). Schemes also differ in their approach to defining the spatial scale of the area managed through these agreements. For example, both ASC and BAP refer producers to their local regulatory requirements for area-based management agreements to determine the scale of the area that should fall under the agreement, but BAP recommends improving those agreements where the size of the area is not determined based on hydrographic conditions. Therefore, farms eco-certified under the same scheme could have varying degrees of coordination between sites based on both the presence and differences in local regulatory requirements for area-based management agreements. As one participant noted: *"you can argue that those area management agreements occur at different scales. Some of them are very local and some of them are, you know, broader than just local."* Participants also pointed to the consolidation of the industry as a factor in coordination between farms, where in many cases a single company now operates all farms within a waterbody, effectively coordinating its own area-based management agreement. Finally, though schemes vary in the types of actions coordinated by area-based agreements, they are generally focused on fish health, especially controlling the potential spread of disease and pathogens. Apart from coordinated nutrient monitoring under the BAP standard, bay-scale benthic and nutrient impacts are not addressed by area-based agreements (Table 4.3).

Table 4.3. Summary of environmental assessments (including biodiversity, habitat, and risk assessment) requirements from criteria of global salmon eco-certification schemes.

	ASC	BAP	GlobalGAP
Criterion	Biodiversity-focused impact assessment	Wildlife interaction plan (WIP), environmental impact assessment where required by law	Biodiversity-inclusive environmental impact assessment (EIA); biodiversity-inclusive environmental risk assessment (ERA); biodiversity-inclusive environmental management plan (EMP)
Specific requirements	For any habitats or species that could be reasonably impacted by the farm, the assessment must incorporate: identification of proximity to those species and habitats, potential impacts on those species and habitats, strategies to eliminate or minimize those impacts, where damage to sensitive habitats has been caused by the farm, on-site or off-site restoration	A list of local laws and conditions of the farm’s operating permits that are relevant to wildlife management and protection, a map of "critical" or "sensitive" habitat within the region or proof of regulatory authorization of farm site and operation; a list of local species of concern, a wildlife interaction risk assessment that is prepared by an expert (if not considered as part of licensing); description of the farm's passive deterrence measures and inspection procedures	EIA that includes all impacts inherent to farming operations; ERA that includes all risks associated with farming operations and a biodiversity plan; EMP must incorporate regular environmental monitoring program based on risks identified in the EIA; demonstration of legal compliance on all issues included in EIA and ERA

4.4.3 Anticipating ecosystem risks

Eco-certification generally provides an assessment of a farm and its impact at a point in time. Therefore, eco-certification schemes are challenged with how to anticipate and account for potential ecosystem impacts in the time-bound assessment of individual farms. In comparison, regulators can employ a precautionary approach when siting farms as once a farm is established it becomes more difficult to prevent ecosystem risk due to the importance of where a farm is located in predicting the future sustainability of the receiving ecosystem: *"…from a regulatory point of view location is pretty highly scrutinized wherever you are in whatever jurisdiction so it may be something that the regulators focus more on than the certification programs do."* In contrast, eco-certification occurs after farms are already established or their location has been determined. However, assessment of the farm location and siting process can still be included as part of the compliance assessment. For example, eco-certification schemes include criteria that farms must not be in or close to sensitive habitat or high conservation value areas from being certified. This precautionary approach eliminates the potential of salmon farming to alter ecosystem structure and function within ecosystems that have these special designations.

Eco-certification schemes also address site-specific anticipated risks by including criteria that require farms to submit environmental assessments (Table 4.4), though in most regions some form of environmental assessment is already part of a regulatory regime. However, participants diverged in their depiction of how environmental assessment documents are considered by eco-certification auditors. For example, one participant indicated that *"[environmental assessment documents] are probably part of the paper documentation and there's probably not a lot of assessment"* while another noted that *"if there's any required or noted areas of concern, the company will have to show […] that they've considered this and what actions they have in place or will have in place to mitigate the situation"*.

Table 4.4. Summary of key challenges associated with the consideration of ecosystem impacts in eco-certification of salmon farms and approaches to addressing these challenges.

Challenges	Approaches		
	Criteria	Auditor	Local regulation
Assessing far-field impacts	• limit the potential for negative far-field impacts • require monitoring and applying impact thresholds outside of a boundary of impact (AZE)	• interpret criteria that address far-field impacts	• refer to existing farm permit or local regulation to determine AZE
Managing cumulative effects	• require coordination at bay scale (ABM, AMA, or AMP)		• refer to regulatory requirements for coordination at bay scale
Anticipating ecosystem-level risks	• require reflection on past incidents • require a precautionary approach to siting, including requiring environmental assessment(s)	• consider content of environmental assessment(s)	• refer to and overlap with regulatory requirements within requirements for environmental assessment(s)

Eco-certification schemes also look beyond the current impact of farms by including criteria that require reflection on past events and evidence that action has been taken to ensure that future risk of similar events has been reduced. For example, when interactions that result in the death of wildlife occur, ASC requires evidence that steps have been taken to reduce future risk of lethal incidents, and when escape events have occurred, BAP requires an investigation of the cause.

4.5 DISCUSSION

The purpose of this analysis was to understand how ecosystem impacts are addressed in global eco-certification schemes. The results support previous findings indicating that the farm-scale application of eco-certification criteria can be a barrier to including ecosystem perspectives in certification (Bridson et al., 2020; Bush et al., 2013a; Jonell et al., 2013). This conflict was reflected in the three thematic challenges associated with the inclusion of ecosystem perspectives in eco-certification that present challenges for eco-certification: assessing far-field impacts, managing cumulative effects, and anticipating ecosystem risks. However, these thematic issues were shown to be to some degree addressed by eco-certification criteria, auditor judgement, and reference to local regulations (Table 4.1). These opportunities to address ecosystem-level impacts are located throughout the process of eco-certification, from the selection of criteria to include in eco-certification, through to an auditor's assessment of farm compliance with those criteria (Figure 4.2). They also extend beyond the eco-certification process through reference and deference to regulations. Therefore, results also demonstrate that eco-certification schemes work within the limitations of farm-applied eco-certification schemes to address ecosystem impacts in the evaluation of farm sustainability.

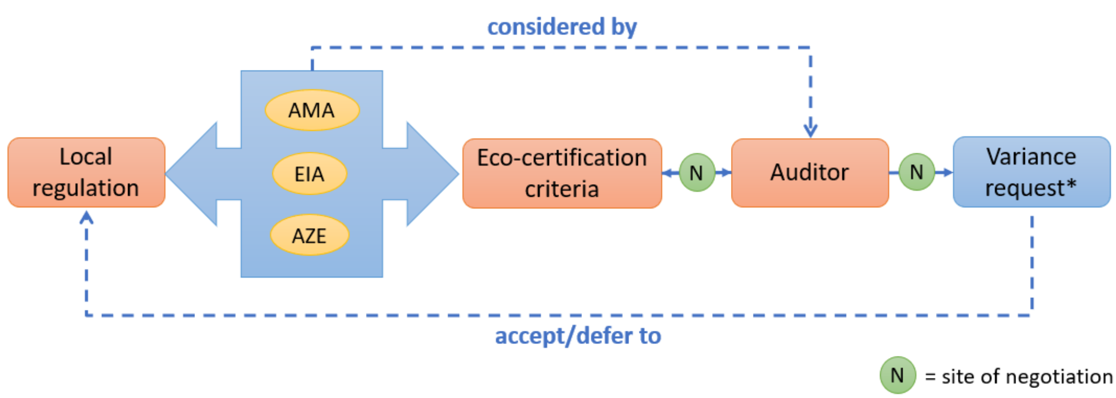

Figure 4 2. Sites where ecosystem impacts are considered in the eco-certification process. Orange squares represent the three tools used to address ecosystem impacts in eco-certification. Green circles represent sites of negotiation between the auditor or certification body and the eco-certification scheme. AMA = Area Management Agreement, EIA = Environmental Impact Assessment, AZE = Allowable Zone of Effects. Eco-certification schemes may use different names for these tools (see Tables 4.2-4.4). *The variance request process is only relevant to ASC.

4.5.1 Eco-certification scheme criteria

Potential far-field environmental impacts of salmon farming include the spread of disease, introduction of exotic species, coastal nutrient enrichment, impacts on food web dynamics, and marine litter (Weitzman et al., 2019). Eco-certification scheme criteria address many of these ecosystem impacts across all three thematic challenges identified in this analysis, either through criteria that require monitoring on and beyond the farm, or by requiring participation in and documentation of ecosystem-level management approaches like area management agreements and environmental assessment. However, where tools including ecological models have been developed to address ecosystem impacts, results suggest that not all farms will have the capacity to integrate these tools into their farming practices. Further, assessment of farm impact requires the attribution of impacts to the farm, but the use of chemical and biological indicators such as those used to measure impact outside of an AZE becomes more difficult at the far-field as the state of the environment may be a result of other anthropogenic activities, environmental conditions, or aquaculture (Borja et al., 2009; Tomassetti et al., 2016). New tools are being developed to disambiguate sources of impact (Howarth et al., 2019, 2020; Sutherland et al., 2007; Y. Zhang et al., 2014), which may provide options for eco-certification schemes that aim to assess sustainability based on the impact of individual farms rather than the state of the ecosystem in which a farm is embedded.

Farming can also have far-reaching impacts throughout the production and supply chain, including the use of land- and marine-based resources for the production of fish feed (Klinger & Naylor, 2012; Naylor et al., 2009). Eco-certification schemes address some of these far-reaching impacts through the inclusion of criteria that address resource use along the supply chain, especially criteria related to the use of marine ingredients and traceability (Amundsen et al., 2019), but they do not address others, including transport and distribution impacts (Bush et al., 2013a). Overall, some potential ecosystem impacts appear to be addressed by eco-certification criteria, while others are not well-represented (Alexander et al., 2020; Osmundsen et al., 2020; Rector et al., 2021), and choosing which potential impacts to include and prioritize in eco-certification remains a challenge (Rector et al., 2023a). Where fisheries sustainability is defined primarily based on maximum sustainable yield (MSY) (Shelton, 2009), there is no single measure that can serve as a reasonable proxy for aquaculture sustainability. Therefore, aquaculture eco-certification schemes must rely on a suite of criteria, and the selection of those criteria dictates which potential impacts are being addressed and the meaning of farm sustainability as indicated by certification (Osmundsen et al., 2020).

Beyond the impact of individual farms, an ecosystem approach to sustainability assessment also requires understanding of cumulative impacts and ecosystem risk. Although eco-certification schemes address cumulative effects by including criteria that require coordination and cooperation with other farms through participation or the development of area management agreements (Amundsen et al., 2019), this coordination is used to prevent the spread of disease but does not extend to other potential cumulative effects of salmon farming, other forms of aquaculture, or other sectors. Eco-certification may be able to incorporate tools like marine spatial planning and coastal zone management, which are being used by regulators to address ecosystem-level cumulative effects and user conflict (Brugère et al., 2018; Ross et al., 2013), but the limited sphere of influence of eco-certification beyond the aquaculture sector makes eco-certification an unlikely mechanism for the effective application of these tools. The way that eco-certification addresses ecosystem risk is also limited as where a farm is located is a critical factor in predicting the future state of the ecosystem in which it is embedded, but compliance assessment typically occurs once a farm is established. The use of environmental assessment has the potential to consider the effects of the environmental conditions where a farm is located as well as the cumulative impacts of other stressors in the environment; however, it is not clear how environmental assessments are considered in the eco-certification process. Further, eco-certification has failed to prevent future ecosystem degradation in at least one case; several participants referred to low oxygen events in Macquarie Harbour, Tasmania that were the result of environmental conditions including low flushing rates, high stratification, and nutrient inputs from agricultural and mining activity that eventually led to the loss of ASC-certified status for some farms in the area. These events led to a recommendation for ASC to improve eco-certification requirements for environmental assessments by adopting an "enhanced EIA with area approach". This enhanced EIA would incorporate more risk sensitive approaches, including but not restricted to assessing risk against a predetermined acceptable level of impact based on carrying capacity, improving monitoring of risks identified, and triggering management responses when thresholds are breached (Seafood Advisory Ltd., 2021).

Problems arising from the limited jurisdiction of aquaculture eco-certification, which has limited influence beyond the aquaculture industry, as well as the temporal mismatch between farm siting and compliance assessment, will likely remain a challenge to the potential of eco-certification to prevent ecosystem change and account for cumulative effects. Stoll et al. (2019) warns against blindly applying eco-certification to sustainability issues, such as accounting for ecosystem impacts, where other approaches may be better suited. For example, seascape labelling that uses a broader spatial and multi-sector approach to certification (Ghazoul et al., 2009; Kittinger et al., 2021) or multi-sector approaches enabled by the broad regulatory authority of government regulation may be better positioned to apply spatial management tools that include multiple sources of marine stressors.

4.5.2 Auditor experience, expertise, and judgement

Auditor interpretation of eco-certification criteria and compliance assessment of farms was an important factor in the role of eco-certification in the assessment far-field impacts and anticipating ecosystem risks. As noted by participants, despite auditor training and accreditation requirements, differences between auditors may impact the quality of compliance assessments or even eco-certification outcomes. Auditor knowledge and experience could be considered an asset to the credibility of eco-certification; however, since the credibility of eco-certification relies on the application of standardized criteria, the potential for differences between auditors in farm assessments may have implications for the credibility of eco-certification schemes. For example, less explicitly defined criteria can lead to inconsistency in the application of criteria and negative consequences for scheme credibility (Chaplin-Kramer et al., 2015).

Decreasing opportunities for human error or judgement within the compliance assessment phase could improve scheme credibility. For example, providing more explicit eco-certification criteria and improving auditor training could improve consistency in the application of scheme criteria. However, auditors are not detached from their own experience and expertise, and auditors must apply eco-certification criteria under different environmental conditions and contexts (Amundsen & Osmundsen, 2019); therefore, auditor training will not flatten auditor experience or expertise, and scheme criteria cannot account for every unique ecosystem in which eco-certification criteria are applied. Further, most eco-certification schemes rely on third-party assessment to bring legitimacy to the conformity assessment phase of eco-certification (Marx, 2014), and independent third-party assessment is also recommended in FAO's guidelines for aquaculture certification (FAO, 2011). The independence of eco-certification schemes, auditors, and farmers, necessarily limits opportunities to request clarification or advice in the application of eco-certification criteria in specific circumstances.

Where improving consistency in the application of eco-certification criteria is limited due to differences between auditors and farm context, increasing transparency in the application of eco-certification criteria may improve credibility (Amundsen & Osmundsen, 2019). Transparency within eco-certification schemes is already considered important for their success (Auld & Gulbrandsen, 2010; Parkes et al., 2010; Tröster & Hiete, 2018), and providing additional transparency in areas where auditor judgement is required is a potential pathway to improving eco-certification credibility. The ASC variance request process provides an example of increased transparency in the application of scheme criteria: In cases where a farm is not or can not be compliant with a criterion, a certification body can submit a variance request describing either why a criterion should not be applied to a farm or propose an alternate way in which the farm can show evidence of compliance (ASC, 2020a). VRs have been approved by ASC where criteria do not account for local environmental context (Appendix C). This example shows that increased transparency can be achieved in the compliance assessment phase of eco-certification in ways that also recognize the knowledge and experience of auditors while maintaining the independence of auditors and eco-certification schemes.

4.5.3 Reference and deference to local regulation

One of the key approaches to addressing ecosystem impacts in salmon aquaculture eco-certification was the use of tools already being used by regulators, and reference and deference to local regulations throughout the eco-certification process (Table 4.1; Figure 4.2). For example, many jurisdictions already require the use of an AZE, participation in an area-based management agreement, and environmental assessment. Deference to local regulations also occurs in ASC's variance request process: VRs have been approved where local regulations differ from ASC criteria; however, acceptance of local regulations appears to only occur where local regulations are deemed to meet the intention of criterion. For example, a VR to use the sea lice threshold set by regulatory authorities where that threshold was based on risk to wild populations in that specific region was granted, but VRs to use benthic sampling methods and thresholds from local regulations instead of those prescribed in ASC standards have not been approved where those methods and thresholds do not satisfy the intent of ASC criteria (Appendix C).

Reliance on local regulation to address ecosystem impacts through salmon aquaculture eco-certification may be an indication that the industry is already highly regulated, and that there are limited opportunities for eco-certification to provide additional environmental sustainability benefits beyond those provided through government regulation. The reliance of salmon eco-certification schemes on local environmental regulation has been noted previously (Seafood Advisory Ltd., 2021), as has significant overlap between salmon eco-certification and regulation on social issues (Alexander et al., 2020). The effectiveness of both eco-certification and government regulation in creating positive sustainability outcomes is limited by scientific knowledge, uncertainty, and capacity (Wiber et al., 2021), so as regulation improves, eco-certification may struggle to stay a step ahead in providing additional sustainability benefits. However, since eco-certification serves to standardize sustainability across jurisdictional boundaries, it will provide additional benefit in countries where regulations do not account for far-field, cumulative, or future ecosystem risk. For example, ASC salmon certification has been found to have the greatest additional sustainability benefit in Chile where eco-certification criteria related to some far-field impacts are more stringent than government regulation (Luthman et al., 2019). Eco-certification will also provide additional benefits in regions where use of an allowable zone of effects, participation in an area management agreement, and environmental assessment is not required.

Finally, eco-certification is challenging public governance of aquaculture, raising the question of who should oversee and evaluate industry sustainability (Vince & Haward, 2017, 2019). For example, the global reach of aquaculture eco-certification can serve to undermine local regulation, community priorities, and the sovereignty of nations in the management of aquaculture and coastal ecosystems (Foley & McCay, 2014; Vandergeest & Unno, 2012). As demonstrated by this analysis, addressing ecosystem impacts through eco-certification currently relies on many of the same tools used by regulators as well as deference to local regulation. At the same time, eco-certification emerged in response to the failure of public regulation to manage aquaculture development and impacts (Auld, 2014; Saha, 2022). Therefore, eco-certification appears to rely on local regulation as part of its approach to assessing farm sustainability while also relying on distrust in regulation for the market success of eco-certification. While eco-certification and public regulation may work in concert to improve sustainability (Shelton, 2009), the potential impact of aquaculture eco-certification on public trust and the legitimacy of public institutions should also be considered (Rector et al., 2023b).

4.6 CONCLUSION

Although the farm-scale application of eco-certification can be a barrier to the assessment of ecosystem impacts, eco-certification schemes partially consider ecosystem impacts by including criteria related to far-field impacts, cumulative effects, and ecosystem risks. They also rely on auditors to interpret and apply these criteria, as well as relying on reference and deference to local regulation. Dependence on auditors and local regulations suggests that there are limits to the eco-certification approach of applying global eco-certification criteria on a site-by-site basis. Embracing the role of these outside actors in the eco-certification process is necessary if eco-certification is to move from assessment based on near-field physical processes to far-field ecosystem processes. Eco-certification schemes that continue to adopt tools being implemented by regulators while supporting the capacity of farms to apply these tools can adopt an ecosystem perspective without negatively impacting participation in eco-certification. Finally, recognizing auditor expertise as an asset while increasing transparency in the compliance assessment phase of eco-certification will improve the potential for eco-certification to address ecosystem impacts without compromising eco-certification credibility.

CHAPTER 5: DOES ECO-CERTIFICATION CHANGE PUBLIC OPINION OF SALMON AQUACULTURE IN CANADA? A COMPARISON OF COMMUNITIES WITH AND WITHOUT SALMON FARMS

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Please note that this chapter appears as it did in the published article, with references and table, figure, and section numbers updated to match the format of this thesis document.

5.1 ABSTRACT

Aquaculture eco-certification is associated with some producer-level benefits including price premiums and market access; however, reputational benefits from eco-certification are unclear. A public survey was used to understand the effect of eco-certification on opinion of salmon farming in two Canadian provinces (British Columbia and Nova Scotia) and differences between communities where farms are located (communities of place) and communities geographically distant from farms (communities of interest). Eco-certification had an overall positive effect on opinion, especially amongst people with a negative opinion of salmon farming who value far-reaching social outcomes of farming. Communities of interest had a more negative opinion of salmon farming and eco-certified salmon farming and were more concerned about local environmental impacts than communities of place while communities of place valued economic outcomes more than communities of interest. The role of eco-certification in public acceptance of aquaculture is limited by a lack of trust in eco-certification and failure to address local issues including conflict amongst marine users.

5.2 INTRODUCTION

As aquaculture production has increased, so have the number of voluntary labels that producers may use to differentiate their product from others in the marketplace. These voluntary labels include organic, animal welfare, fair trade, food safety, and traceability labels, as well as sustainability ecolabels that address ecological and social sustainability (Alfnes et al., 2018; Bush et al., 2013a). Sustainability certification schemes, also referred to as eco-certifications, aim to improve social and environmental practices by certifying farms that comply with the scheme's sustainability standard, thereby offering buyers, retailers, and consumers assurance of the sustainability of certified farmed seafood (Bush et al., 2013a).

To be successful in creating positive sustainability outcomes, sustainability certification schemes must not only improve the sustainability performance of farms that become certified, but they must also create market incentives that encourage more producers to seek eco-certified status (Ponte, 2012; Rector et al., 2023a). These incentives typically include market access, price premiums, and consumer preference for eco-certified farmed seafood (Asche et al., 2021; Carlucci et al., 2017; Danso et al., 2017; Ortega et al., 2014), but given the growing importance of social acceptance for the future of aquaculture, improving social acceptance represents an additional potential motivation for industry participation in eco-certification (Olsen et al., 2021). Therefore, this paper explores the influence of eco-certification beyond the consumer and examines the role of eco-certification in public opinions about salmon aquaculture.

5.2.1 Salmon aquaculture eco-certification schemes

Salmon aquaculture is associated with potential environmental impacts such as changes in benthic community structure, water quality, marine habitat, and food web dynamics, as well as the potential spread of disease and pathogens, introduction of exotic species, coastal nutrient enrichment, and marine litter (Asche et al., 2022; Weitzman et al., 2019). Feeding efficiency and reliance on both marine and terrestrial ingredients remains a challenge in aquaculture, though this has also been an area of improvement with significantly lower fish-in-fish-out ratios across species (Naylor et al., 2021). It may also impact social dimensions of sustainability (Krause et al., 2020); for example, conflict between aquaculture production and other marine users (Grant et al., 2019), the provision of healthy food (I. J. Jensen et al., 2012), and the enjoyment and aesthetic value of coastal environments (Evans et al., 2017; McDaniels et al., 2005; Outeiro & Villasante, 2013). Criticism of salmon aquaculture related to these potential impacts has led to poor public perception of the industry and the perceived failure of public regulation of marine farming (Olsen & Osmundsen, 2017; Osmundsen & Olsen, 2017; Salgado et al., 2015; Weitzman et al., 2022; Weitzman & Bailey, 2019). These negative perceptions provide support for a sustainability movement that aims to improve global seafood sustainability, primarily through the use of market-based approaches such as eco-certification (Konefal, 2013; Roheim et al., 2018; Saha, 2022). Salmon accounts for a large proportion of eco-certified farmed seafood (approximately 60% and 50% of the volume of Aquaculture Stewardship Council (ASC) and Best Aquaculture Practices (BAP) eco-certified seafood respectively (ASC, 2022c; GAA, 2020b), and the total volume of eco-certified seafood continues to grow as producers look to address negative perceptions and retailers and consumers look for guarantees of sustainable production (Rector et al., 2023a).

Although eco-certification schemes have been successful in capturing a significant proportion of the salmon industry, the ability of these schemes to affect sustainability is not clear (Bush et al., 2013a; Rector et al., 2023a). Eco-certification standards are made up of a series of sustainability criteria selected by the certification program, therefore, eco-certification schemes are defining what sustainability means in the aquaculture industry (Osmundsen et al., 2020). Schemes differ in their inclusion of sustainability issues, but in general schemes provide a limited definition of sustainability, focusing on local environmental and technical aspects of farming while providing little assurance of social-cultural sustainability (Alexander et al., 2020; Amundsen & Osmundsen, 2018; Belton et al., 2009; Bridson et al., 2020; Jonell et al., 2013; Osmundsen et al., 2020; Rector et al., 2021; Rector et al., 2023a). Eco-certification schemes also differ in their inclusion of sustainability issues across the supply chain, which is an important consideration given the significant contribution of feed production and product distribution to the total environmental impact of aquaculture supply chain (Bosma et al., 2011; Mungkung et al., 2013, 2013; Naylor et al., 2009; Pelletier et al., 2009). Further, by relying on eco-certification criteria to evaluate and label a product as sustainable, eco-certification schemes treat sustainability as a technical outcome rather than a process, a depiction of sustainability that could limit future improvements (Amundsen, 2022; Jonell et al., 2019; Tlusty & Thorsen, 2017). While eco-certification and associated ecolabels simplify the communication of sustainability, it also makes the process and criteria behind eco-certification opaque to consumers, many of whom already have a limited understanding of seafood sustainability (Lawley et al., 2019; Winson et al., 2022).

Eco-certification simplifies sustainable purchasing decisions for seafood buyers, retailers, and consumers, but although eco-certification is considered necessary for entry into many international markets, evidence of producer-level benefits including price premiums have not been fully realized (Roheim et al., 2018). There is some indication of consumer preference, willingness-to-pay, and price premiums for eco-certified farmed seafood (Asche et al., 2021; Carlucci et al., 2017; Danso et al., 2017; Ortega et al., 2014), but preference for ecolabeled farmed seafood may be regionally-specific, may change over time, or may be sensitive to different survey approaches. For example, a 2012 in-person intercept study in Rhode Island showed consumer preference for wild over eco-certified seafood (Roheim et al., 2012), whereas a 2017 choice experiment in Germany showed that the ASC ecolabel made up for any negative association with farmed seafood. In general, ecolabels associated with aquaculture eco-certification schemes are still relatively new and not well recognized by consumers (Alfnes et al., 2018; Roheim et al., 2012).

5.2.2 Eco-certification and producer reputation

Eco-certification has been described as a form of non-state market-driven (NSMD) or private governance that relies on consumer demand to influence private producers (Auld et al., 2009; Cashore, 2002). However, eco-certification is also part of the larger hybrid governance of aquaculture wherein the state governs aquaculture through regulation, buyers and sellers influence aquaculture through markets, and communities exert power through the granting and withholding of social licence (Vince & Haward, 2017). While eco-certification works to improve aquaculture sustainability by providing a link between consumers and the market, governments and environmental groups have also been important to the success of eco-certification (Gulbrandsen, 2006) providing evidence that there is a wider audience for eco-certification than just consumers and retailers (Barclay & Miller, 2018). This audience includes local and wider communities that may challenge a producer's social licence to operate (SLO) (Boutilier, 2014; Vince & Haward, 2019).

Different types of communities are involved in granting social licence, and social licence may be independently present or absent across different segments of society (Dare et al., 2014; A. Zhang et al., 2015). These segments may include communities defined by geographic location (communities of place) as well as communities that hold similar values and interests (communities of interest) (Ford & Williams, 2016). In the case of aquaculture, acceptance is sometimes framed as a debate between local communities that may benefit from farming and distant communities of interest that are concerned about environmental impacts, even though opposition to aquaculture development has been observed from both local and distant communities (Mather & Fanning, 2019b).

By providing a link between communities and the market, eco-certification provides an additional mechanism for communities, especially distant communities of interest, including consumers with common values and interests related to sustainable aquaculture, to influence the aquaculture industry through demand for eco-certified farmed seafood (Vince & Haward, 2017). The opposite may also be true in that eco-certification may give the market power to influence communities, and therefore social licence, by creating reputational gains for aquaculture producers that are eco-certified. The potential severing of an individual company's social licence from its industry's social licence is an area of research in need of attention (Boutilier, 2014), and eco-certification provides a potential mechanism to do so. Therefore, in addition to market access and price premiums, aquaculture producers may seek eco-certification to manage reputational risk, both locally and globally, as members of a controversial industry. However, reputational gains associated with eco-certification appear to be limited to the organizations that operate eco-certification schemes and the retailers that make commitments to sourcing eco-certified seafood, and do not extend to producers (Olsen et al., 2021; Roheim et al., 2018; Vince & Haward, 2019).

5.2.3 Research objectives

Although eco-certification addresses sustainability at the farm-scale through the application of sustainability criteria on the farm, as a governance mechanism, eco-certification operates at a global scale giving power to physically distant communities of interest. Yet, eco-certification may also provide indirect market advantages including reputational gain which is important in both communities of place and interest. Therefore, the goal of this survey research was to explore the role of eco-certification in moderating opinions of salmon farming in communities with and without salmon farms. The survey and analysis were designed to address 3 key research questions:

1. Do communities of place and interest differ in their opinion of marine salmon farming, eco-certified marine salmon farming, and perception of eco-certification?

2. What potential impacts of salmon farming are relevant, and does the importance of different impacts or spatial scale of impact differ between communities of place and interest?
3. Does eco-certification influence opinion of salmon farming in communities of place and interest?

5.3 METHOD

5.3.1 Survey

A survey designed to elicit opinions about marine salmon farming and eco-certification was used to collect four types of information: (1) community characteristics, (2) opinion of salmon aquaculture and potential impacts of concern or importance, (3) opinion of aquaculture eco-certification, and (4) demographic information. Participants were prompted with the following description of aquaculture eco-certification prior to being asked to respond to questions about eco-certification: "Aquaculture eco-certification is a way for seafood farms to have an outside organization verify that the farm is operating in a sustainable way." They were also presented with the names and logos of three aquaculture eco-certification programs, Aquaculture Stewardship Council, Best Aquaculture Practices, and GlobalGAP. However, it is expected that participants brought their own knowledge and understanding of eco-certification to their responses. Results are therefore expected to reflect different understandings of eco-certification amongst participants.

The survey was shared exclusively through Facebook community groups associated with communities located in two Canadian provinces, British Columbia (BC) on the Pacific coast, and Nova Scotia (NS) on the Atlantic coast. This sampling approach allowed for targeting of communities with and without salmon farms, and for self-selection of people who were interested in the survey topic. This approach follows from previous explorations of social licence in aquaculture that consider the opinions and experiences of people who are engaged in and hold values related to aquaculture as they are the most likely to generate and shape discourse that might influence aquaculture policy (Billing, 2018; Sinner et al., 2020). Therefore, the segments of society compared in this analysis are defined by both their shared interest in aquaculture and eco-certification, and their proximity to a salmon farm. These segments include communities with farms (communities of place) and communities without farms (communities of interest). The survey was active over a three-month period from September 24 to December 31, 2021 and people over the age of 18 were invited to participate. All research involving human participants was carried out following procedures approved by Dalhousie's Research Ethics Board (REB 2021-5694).

5.3.2 Data analysis

Nonparametric tests were used to analyze differences between provinces and communities with and without farms on ordinal response variables including opinion of marine salmon farms, opinion of eco-certified marine salmon farms, familiarity of and trust in eco-certification, and change in opinion between marine salmon farming and eco-certified marine salmon farming. A nonparametric test was also used to compare change in opinion between marine salmon farming and eco-certified farming between participants who had a negative or positive opinion of salmon farming. Medians (*Mdn*) are reported where distributional shapes were similar; otherwise, mean ranks (*Mr*) are reported. Significance values of post-hoc tests were adjusted using the Bonferroni correction for multiple tests for variables with three categories.

A series of 21 4-point Likert scale questions about importance or concern related to potential impacts of salmon farming were condensed into impact categories based on two factors: dimension of sustainability and scale of impact. First, individual questions were assigned to one of three sustainability dimensions: environmental, social, or economic. Next, questions were assigned to a near- or far-field category based on the scale at which the impact is experienced or observable. Near-field social and economic impacts were considered those that are experienced in local communities, and near-field environmental impacts were considered those that are observable on farms. Far-field social and economic impacts were considered those that are experienced beyond communities where farms are located (though these impacts may also be experienced in local communities), and far-field environmental impacts included those that are observable beyond the farm. This resulted in the creation of 6 impact categories representing potential near-field and far-field environmental, social, and economic impacts of marine salmon farming.

Cronbach's alpha was used to ensure a high internal consistency ($\alpha > .75$) among questions combined within each category, and one Likert scale question about the importance of safe and equitable work conditions on salmon farms was not included in any of the impact categories as it had a significant impact on internal reliability. A score out of four was calculated for each participant based on their mean response to questions included in each impact category where 1 = not at all important/concerning to me and 5 = very important/concerning to me. Thirty-eight of 565 participants did not provide a response to one or more Likert scale questions that provided the basis for impact categories and a 25% tolerance rate for missing values was used in the calculation of scores for each category.

A series of ANOVAs were used to analyse differences between farm presence groups in the different impact category scores. Data were not normally distributed for all impact categories ($p > .05$) as determined by Shapiro-Wilk tests; however, groups were similarly skewed and non-normality is not expected to affect Type I error rate substantially (S. E. Maxwell & Delaney, 2004). Post-hoc Tukey tests were used to compare impact category scores between farm presence groups when homogeneity of variance was observed; Welch's ANOVA and pot-hoc Games-Howell tests were used when Levene's test of homogeneity of variances was violated.

A cumulative logit link ordinal regression model was constructed to explore how factors contributed to change in opinion of marine salmon farming triggered by eco-certification. As the goal of the analysis was to test the positive impact of eco-certification on opinion of salmon farming, participants who already had a "very positive" opinion of salmon farming were removed from the analysis as there was no opportunity for those participants to indicate an increase in opinion of marine salmon farming when it was eco-certified. The difference in response between survey questions about general opinion of marine salmon farming and general opinion of eco-certified marine salmon farming was reduced to three levels representing reduced, no change, and increased opinion, and was used as the response variable. General opinion of marine salmon farming was recoded to three levels, combining "very negative" and "somewhat negative" responses so that levels of the variable represent negative, neutral, and positive opinion of marine salmon farming. This recoding was required to meet the assumption of proportional odds. Trial models were explored, beginning with a full model including up 22 predictive variables, and removing variables that were not significant or did not have individual levels that were significant in predicting the response variable until only significant variables remained. In the case that one or more variables were not significant but included levels with significant odds ratios, each possible combination of these variables was explored, and the model of best fit was selected based on the maximum likelihood estimate of each iteration of each model as determined by Akaike information criterion (AIC). Additional details of model development are provided in Supplemental Material. All analyses were performed using IBM SPSS Statistics Version 27.

5.4 RESULTS

5.4.1 Population

A total of 565 people participated in the survey. Participants included 245 people from BC (43%) and 320 people from NS (57%), including 127 (22.5%) people with a salmon farm in their community, 338 (59.8%) people without a farm in their community, 99 people (17.5%) who were unsure about the presence of a farm in their community, and one person who did not respond to the question about the presence of a farm in their community (.2%). Participants included 205 (36%) people from urban and 360 (64%) people from rural communities, defined as communities of fewer than 10,000 residents.

Opinion of salmon farming did not differ between BC (*Mdn* = very negative) and NS (*Mdn* = very negative) ($U = 40441.500$, $p = .471$). Similarly, opinion of eco-certified salmon farming also did not differ between BC (*Mdn* = generally negative) and NS (*Mdn* = generally negative) ($U = 40187.500$, $p = .592$). Accordingly, these two populations were combined in all further analyses.

5.4.2 Do communities of place and interest differ in their opinion of marine salmon farming, eco-certified salmon farming, and perception of eco-certification?

Opinion of salmon farming was significantly different depending on the presence of a farm in communities (X^2 (2) = 19.488, p < .001) (Figure 5.1A) with a more positive distribution of opinion in communities with farms (Mr = 301.61) than without farms (Mr

= 261.53, p < .05), and a more positive distribution of opinion for the group of participants who were unsure about the presence of a farm in their community (Mr = 329.60) than communities without farms (p < .001). There was no difference in general opinion of salmon farms between communities with farms and the group of participants who were unsure about the presence of a farm in their community (p = .457). Opinion of eco-certified salmon farms followed the same pattern (X^2 (2) = 14.49, p <.001) (Figure 5.1B), i.e., opinion of eco-certified salmon farms skewed more positive in communities with (Mr = 303.60) than without farms (Mr = 262.35) (p < 0.05), and more positive in the group of participants who were unsure about the presence of a farm in their community (Mr = 324.24) than communities without farms (p < .01) (Figure 5.1).

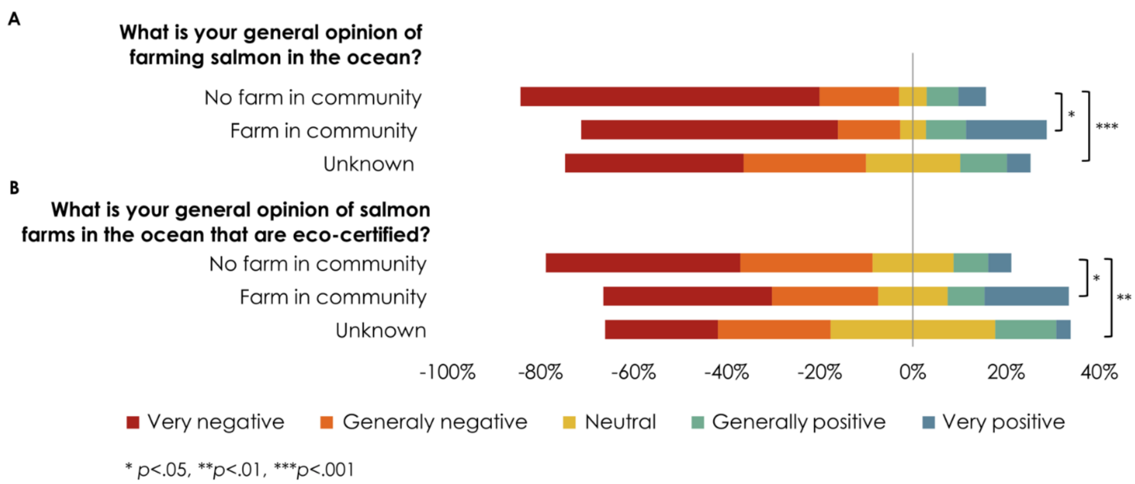

Figure 5.1. Distribution of responses to survey questions about opinion of salmon farming and eco-certified salmon farming for participants living in communities with farms (n=127), without farms (n=388) farms, and amongst participants who were unsure if there was a farm in their community (n=99).

Familiarity of aquaculture ecolabels differed significantly depending on the presence of a farm in the community (X^2 (2) = 19.103, $p < .001$) (Figure 5.2A). Familiarity of aquaculture ecolabels was higher in communities with farms (Mr = 325.84) than communities without farms (Mr = 279.31, $p < .05$), and in the group of participants who were unsure about the presence of a farm in their community (Mr = 235.38, $p < .001$). Familiarity was also higher in communities without farms than the group of participants who were unsure about the presence of a farm in their community ($p < .05$) (Figure 5.2A).

Trust in aquaculture eco-certification was similar across communities with farms (*Mdn* = slightly trustworthy), without farms (*Mdn* = slightly trustworthy), and the group of participants who were unsure about the presence of a farm in their community (*Mdn* = slightly trustworthy) (X^2 (2) = 2.544, $p = .280$) (Figure 5.2B).

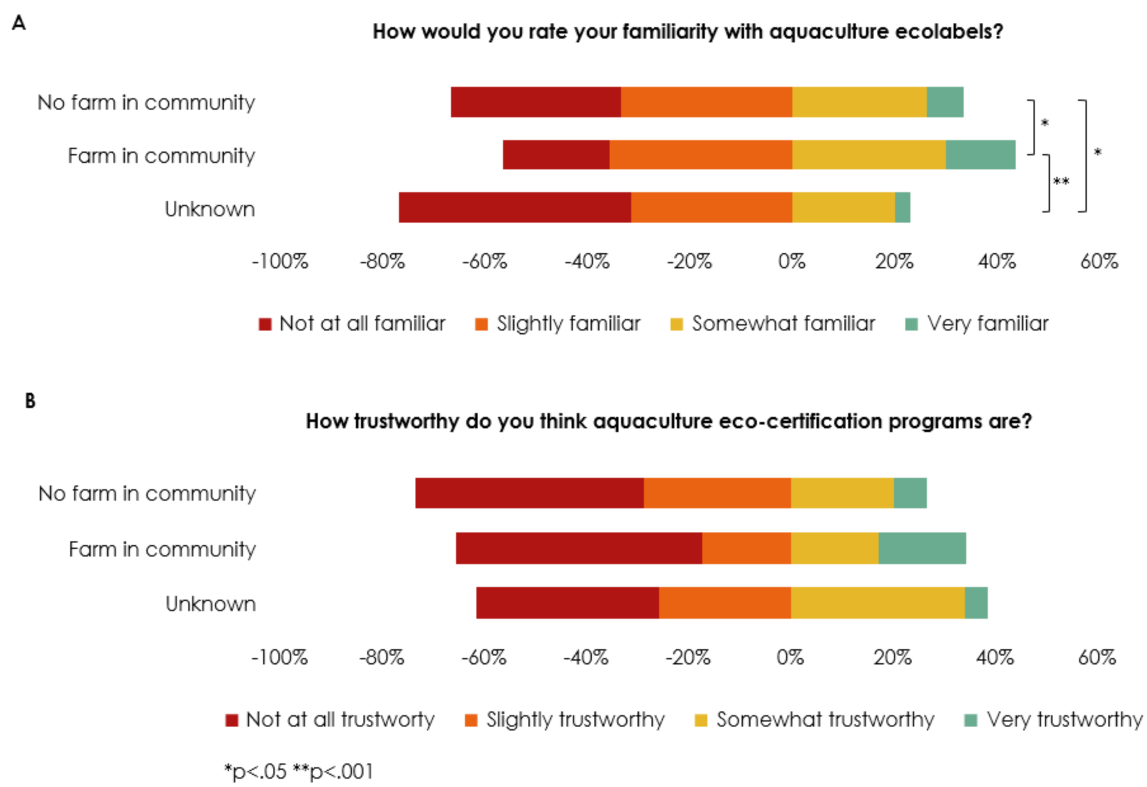

Figure 5.2. Distribution of responses to survey questions about familiarity and trust in aquaculture ecolabels and eco-certification.

5.4.3 What potential impacts of salmon farming are relevant, and does the importance of different impacts or spatial scale of impact differ between communities of place and interest?

There was a general pattern across questions about level of concern or importance of potential impacts of salmon farming, with environmental impacts being of greatest concern followed by social impacts and then economic impacts (Figure 5.3). The presence of a farm in a participant's community had a significant effect on all impact scores except for far-field environmental and far-field social impacts (Figure 5.4). Near-field environment impact scores were significantly higher for communities without farms than with farms. The opposite was true of economic impact scores where communities with farms had higher near-field economic impact scores than communities without farms, and higher far-field economic impact scores than communities without farms. Finally, near-field social impact scores were higher in communities without farms than amongst the group of participants who were unsure about the presence of a farm in their community (Figure 5.4).

Figure 5.3. Distribution of responses to 4-point Likert scale questions about level of importance or concern related to various potential impacts of marine salmon farming. Questions about importance are in italics.

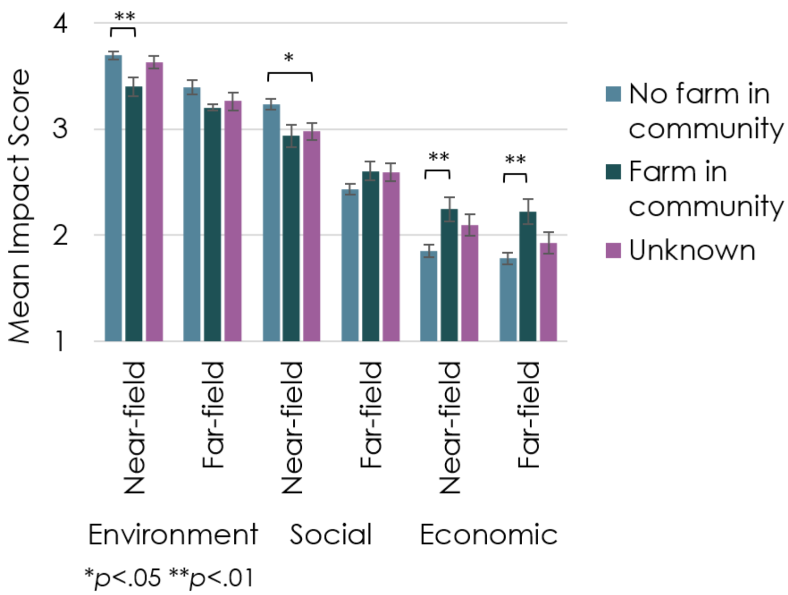

Figure 5.4. Mean score and standard error for impact categories, based on the average score of 4-point Likert scale questions included in the category where 1 = not at all important/concerning and 4 = very important/concerning.

5.4.4 Does eco-certification influence opinion of salmon farming in communities of place and interest?

Of 565 survey participants, 190 rated their opinion of eco-certified salmon farms higher than their opinion of salmon farms in general, whereas 326 did not change their rank in opinion based on eco-certified status, and 49 participants decreased their rank in opinion (Figure 5.5A). This overall increase in opinion from farmed salmon to eco-certified farmed salmon amongst participants was significant (z = 8.607, $p < .001$), but change in opinion between salmon farming and eco-certified farming did not differ based on the presence of a farm in communities ($Mdn = 0$, $X^2(2) = .313$, $p = .855$).

Results of an ordinal regression model indicated that four factors affected the influence of eco-certification on opinion of salmon farming: general opinion of marine salmon farming ($p <.001$), trust in eco-certification ($p <.001$), importance of near-field social impacts score ($p <.001$), and importance of far-field social impacts score ($p <.01$) (Table 5.1; Table SB.4.2.). Participants who had a negative or neutral opinion of marine salmon farming were 113.5 times and 7.0 times more likely to increase their opinion of marine salmon aquaculture when eco-certified than participants who already had a somewhat positive opinion of marine salmon farming. The odds that participants who did not trust, slightly trusted, or moderately trusted eco-certification increased their opinion of salmon aquaculture when it was eco-certified was 0.2%, 0.4%, and 0.8% of the odds that someone who was very trusting of eco-certification would increase their opinion of salmon farming when it was eco-certified. Impact scores were included in the model as continuous variables and odds ratios for impact scores can therefore be interpreted as the increase or decrease in odds associated with every increase of 1 in impact score. Each increase of 1 in near-field social impact (indicating greater concern about near-field social impacts) was associated with 59.0% lower odds of an increase in opinion from salmon farms to eco-certified salmon farms. Conversely, with each increase of 1 in importance of far-field social impact score (indicating greater importance of far-field social impacts), participants were 1.5 times more likely to have an increase in opinion associated with eco-certification of salmon farms.

Table 5.1. Ordinal regressions predicting change in opinion of marine salmon farming triggered by eco-certification based on the difference in response to questions "What is your general opinion of marine salmon farming?" and "What is your general opinion of salmon farms in the ocean that are eco-certified?" excluding participants who reported a "very positive" opinion of marine salmon farming.

		95% CI	
Variable/Levels	Odds Ratio	Lower	Upper
Opinion of salmon farms			
Negative	113.511***	36.526	352.414
Neutral	6.997**	2.143	22.844
Positive	1		
Trust in eco-certification			
Not at all trustworthy	0.002***	0.000	0.017
Slightly trustworthy	0.004***	0.000	0.039
Moderately trustworthy	0.008***	0.001	0.081
Very trustworthy	1		
Importance of near-field social impacts	0.590***	0.435	0.801
Importance of far-field social impacts	1.540**	1.165	2.038

**p<.01, ***p<.001

Due to the significance of opinion of salmon farming in predicting change in opinion when farming is eco-certified, this factor was also analyzed using a nonparametric test. Change in opinion from salmon farming to eco-certified farming differed amongst people who had positive, neutral, and negative opinions of salmon farming ($X^2(2) = 19.488$, $p < .001$) (Figure 5.5B). Distribution of change in opinion skewed more positive amongst participants with a negative opinion (*Mr* = 308.30) than participants with neutral (*Mr* = 243.46, $p < .01$) or positive (*Mr* = 184.71, $p < .001$) opinion suggesting that eco-certification may be especially relevant for reputational gain amongst people who have a negative opinion of salmon aquaculture. A decrease from opinion of salmon farming to eco-certified salmon farming was observed mostly amongst people who had a positive opinion of salmon farming (Figure 5.5B).

5.5 DISCUSSION

Responses to this survey were used to explore the impact of eco-certification on opinions of salmon farming, and factors that contribute to the role of eco-certification in moderating opinions of salmon farming. Although differences in opinion and impacts of importance between participants living in communities with and without farms were observed, these differences did not translate to a difference in the influence of eco-certification on opinion of marine salmon farming. Rather, factors including having a negative opinion of salmon farming, placing importance on far-field social impacts of farming, and trust in eco-certification were associated with increased odds of eco-certification triggering an increase in opinion of salmon farming.

5.5.1 Values and opinions differ between communities of place and interest

Although participants generally had negative opinions of both salmon farming and eco-certified salmon farming, there was an overall less negative opinion of both salmon farms and eco-certified salmon farms amongst people in communities with farms. This result is consistent with a phenomenon known as "environmental hyperopia" wherein people view distant environmental problems and those with which they have little involvement in as more serious than local problems that affect them directly (García-Mira et al., 2005; Uzzell, 2000). This phenomenon is also reflected in the perception that aquaculture is supported in local communities while opposition comes from geographically distant and vocal groups (Maxwell & Filgueira, 2020; RAIS Inc., 2014). Contrary to this perception and the findings of this study, proximity to proposed aquaculture development has also been associated with more negative perceptions of marine farming, sometimes referred to as NIMBYism (not in my backyard) (Froehlich et al., 2017; Murray & D'Anna, 2015; Shafer et al., 2010; Weitzman et al., 2022). However, perceptions may change as industries become established and people experience positive benefits (Ford & Williams, 2016; Williams et al., 2003); therefore, social acceptance may differ where farms are established in comparison to where aquaculture development is proposed.

In addition to opinion of salmon farming, differences in the level of concern or importance placed on different types of aquaculture impacts between communities of place and interest were identified. For example, comparison of impact category scores in communities with and without farms indicated that communities without farms were more concerned about near-field environmental impacts than communities with farms, and communities with farms placed more importance on both near- and far-field economic impacts than communities of interest. This result suggests that the scale at which a sustainability impact is experienced does not translate to greater importance for communities at that same level: communities of place are not more concerned about local impacts than communities of interest, nor are communities of interest more concerned about far-reaching impacts. Indeed, the opposite was true of environmental impacts where communities geographically removed from farms were more concerned about local environmental impacts than local communities. Greater concern about environmental impacts has previously been observed amongst people with less exposure to aquaculture (Freeman et al., 2012; Krøvel et al., 2019). Finally, greater importance placed on both near- and far-field economic impacts in communities of place supports findings that experience and perception of the economic impacts of aquaculture including the creation of jobs is a mediator of attitudes towards aquaculture in local communities (Krøvel et al., 2019; Lindland et al., 2019; Tiller et al., 2014; Vince & Haward, 2017; Whitmarsh & Palmieri, 2009).

Understanding differences in sustainability impacts of concern or importance between communities of various levels may be useful in identifying which impacts must be mitigated or enhanced for more socially acceptable aquaculture to be established in different segments of society, and which impacts must be addressed by eco-certification for it to enhance producer reputation in different segments of society. However, despite potential differences between individual communities, or segments of society as observed in this study, it appears that environmental impacts are overall top of mind in both communities with and without salmon farms.

5.5.2 The influence of eco-certification is relevant but limited in communities of place and interest

While communities where farms are located are most likely to experience the impacts of aquaculture, both positive and negative, they are also often left out of decision-making (Wiber et al., 2021). Eco-certification exacerbates this mismatch in direct experience of aquaculture expansion and decision-making by targeting consumers and retailers, shifting the governance of aquaculture and common pool coastal resources beyond local communities to global markets and private actors (Foley & Havice, 2016; Partelow et al., 2019). This makes geographically distant communities including consumer and retailers the targets of eco-certification schemes; however, people in this study who live in communities with salmon farms were both more familiar with eco-certification and were positively influenced by eco-certification indicating that eco-certification is also relevant in these non-target communities. Therefore, in the case of local communities, eco-certification works in the direction of producer influence on local communities through the reputational gain associated with eco-certification, but eco-certification does not provide an avenue for local communities to influence industry as it does for much larger and more distant consumer communities and retailers that are able to exert influence through market demand.

Although the realization of reputational gains for salmon farming from eco-certification has been questioned (Olsen et al., 2021), the small positive effect of eco-certification on opinion of salmon farming in this study suggests that the reputational gains associated with eco-certification extend beyond retailers and the organizations that operate eco-certification schemes to aquaculture producers, and that eco-certification provides a mechanism to differentiate an individual company's reputation from that of its industry. Therefore, producers may stand to benefit both locally through reputational benefits and globally through reputational and market benefits from participation in eco-certification schemes, though the small degree of change in opinion observed here may not be practically significant enough for producers to use in making decisions around seeking or maintaining eco-certified status.

While geographic factors including the presence of a farm were not associated with the influence of eco-certification on opinion of salmon farming, opinion of salmon farming, level of concern or importance of the potential social impacts of salmon farming, and trust in eco-certification were important factors in predicting change in opinion triggered by eco-certification. First, eco-certification was more likely to trigger an increase in opinion of salmon aquaculture amongst participants who had a negative opinion of salmon farming. In comparison, there appeared to be skepticism amongst participants who had a neutral or positive opinion of salmon farming with eco-certification even triggering a decrease in opinion amongst some of those participants. Eco-certification is costly and it requires time and expertise to become eco-certified (Atyia & Simula, 2002; Gullison, 2003; Tlusty, 2012), and these additional hurdles may be viewed as unnecessary by people who already have a neutral or positive opinion of salmon farming. Further, trust in government is an important predictor of opinion of salmon farming (Weitzman et al., 2022) and participants with neutral or positive opinions of salmon farming may already consider aquaculture to be a well-regulated industry without the addition of eco-certification.

Second, both near- and far-field social impacts were important factors in predicting the impact of eco-certification on opinion of salmon farming. Since salmon eco-certification criteria are largely focused on environmental impacts of farming (Amundsen et al., 2019; Rector et al., 2021), the association between higher concern about near-field social impacts of aquaculture and lower probability of eco-certification producing a positive change in opinion of eco-certification may indicate dissatisfaction with the limited inclusion of local social impacts in eco-certification criteria. People who live close to proposed farm sites have been found to use marine space more often and be concerned about restricting public use and maintaining place-based identity (Shafer et al., 2010). These opportunity costs are not well-represented in eco-certification, and eco-certification is not well-equipped to address trade-offs. For example, the benefits that producers receive from farming must be shared with local communities to account for costs including the use of marine space (Aanesen & Mikkelsen, 2020), yet eco-certification is based on producer compliance with criteria that are evaluated individually are not designed to enable trade-off or cost-benefit analysis (Rector et al., 2021). Sociocultural issues including user conflict and impacts on other marine industries may be better addressed by regulation and alternative approaches that address social sustainability at the local level (Bottema, 2019; Stoll et al., 2019). Conversely, the association between greater importance placed on the far-field social impacts of aquaculture and higher probability of eco-certification producing a positive change in opinion of eco-certification suggests that people who value the far-field social outcomes, including provisioning and cultural ecosystem services associated with farming (Krause et al., 2015, 2020; Outeiro & Villasante, 2013) are more positively influenced by eco-certification.

Third, trust in eco-certification was a significant factor in the prediction of the impact of eco-certification on opinion of salmon farming. Further, low trust in eco-certification and limited familiarity with aquaculture ecolabels observed in this survey suggests that credibility is a barrier to the success of eco-certification. Farmers have little control over what eco-certifiers communicate to consumers (Olsen et al., 2021), but eco-certifier efforts to improve trust in and knowledge of eco-certification, especially amongst the target audience of consumers with less exposure to salmon farming, can be expected to benefit the reputation of both eco-certifiers and eco-certified farms, improving the value proposition for seeking eco-certification. One source of distrust may originate from differences between regulation and eco-certification. For example, the endorsement of marine salmon farms by both ASC (ASC, 2022d) and BAP (BAP, 2022) in BC, a province represented in this survey, paired with government efforts to phase-out marine salmon farming in the province may contribute to confusion around which farms should be considered sustainable. The net-pen salmon farming phase-out in BC provides an example of how social licence, in its expanded definition that includes the use of social licence by local communities and groups to protest development and weak regulation (Mather & Fanning, 2019a), is reshaping regulation of aquaculture; however, it is unclear if or how social licence might influence eco-certification (Mather & Fanning, 2019b). Where local issues have been addressed through other private governance mechanisms including local partnerships between companies and First Nations (Young & Liston, 2010), eco-certification does not provide a clear pathway to address local social-cultural concerns or priorities.

5.6 CONCLUSION

This study examined the role of eco-certification in moderating opinion of marine salmon aquaculture in communities of place and interest and explored additional factors that contribute to the impact of eco-certification on opinion of salmon farming. Eco-certification was found to have a positive impact on opinion of salmon farming, although there was no difference in the impact of eco-certification between communities of place and interest. Eco-certification schemes focus on local environmental impacts but must find ways to address local social-cultural concerns and priorities such as use of marine space to continue providing reputational benefits; yet alternative governance approaches including government regulation of farm locations and interaction with other marine users are better suited to address these types of issues. Finally, while eco-certification provides reputational gains that may differentiate individual farms or companies from the reputation of the industry, especially amongst people with a poor opinion of salmon farming, improved understanding of what contributes to trust in eco-certification will benefit eco-certifiers and producers that seek eco-certification as a reputational risk management strategy.

CHAPTER 6: THE ROLE OF SALMON AQUACULTURE ECO-CERTIFICATION IN CORPORATE SOCIAL RESPONSIBILITY AND THE DELIVERY OF ECOSYSTEM SERVICES AND DISSERVICES

Rector, M.E., Filgueira, R., Grant, J.

6.1 ABSTRACT

Aquaculture eco-certification is especially relevant in salmon farming where it has emerged as a popular corporate social responsibility (CSR) strategy, providing global standards that can be applied to a globally traded commodity. However, eco-certification is just one of many CSR strategies used to address seafood sustainability at the corporate level. CSR is important for company image, but it is not clear whether or how these strategies contribute to sustainability outcomes. This paper applies an ecosystem services framework to an analysis of sustainability reporting from top salmon farming companies to identify links between eco-certification, other CSR strategies, and the delivery of ecosystem services. Although eco-certification was used to indicate commitment to sustainability practices across all companies, other CSR strategies, especially practices, power, and partnership, were more frequently and explicitly connected to the delivery of ecosystem services. Results show that individual CSR strategies including eco-certification are not isolated but interact and work in concert to manage the supply of ecosystem services.

6.2 INTRODUCTION

Marine aquaculture relies on the structure and function of both coastal and broader ecosystems to supply inputs and support the farming of fish, shellfish, and sea plants while also enhancing the provision of some ecosystem services and exerting pressure on others (Figure 6.1). For example, salmon aquaculture enhances provisioning services through the production of seafood, while putting pressure on regulating services such as life cycle maintenance and biological regulation through potential interactions between farmed and wild fish (Alleway et al., 2018; Outeiro & Villasante, 2013). Other ecosystem services enhanced or degraded by salmon farming may include additional regulating services such as water purification (Martinez-Espiñeira et al., 2016) and climate regulation (Nijdam et al., 2012; Pelletier et al., 2009), as well as cultural services such as symbolic and aesthetic value including supporting cultural identities and a sense of place though local employment (Alleway et al., 2018; Outeiro & Villasante, 2013). Potential impacts on ecosystem services are also found beyond the marine grow out phase of salmon farming including throughout feed production, smolt production, transportation, and processing (Ayer & Tyedmers, 2009; Madin & Macreadie, 2015; Pelletier et al., 2009). Therefore, aquaculture systems and supply chains are associated with both ecosystem services and disservices (Aubin et al., 2019). Reliance on common-pool resources and public goods including ecosystem functions and services to grow fish, combined with the delivery of ecosystem services and disservices, results in challenges for the governance of these shared resources (Partelow et al., 2022). For these reasons, the Food and Agriculture Organization of the United Nations' (FAO) provides guidance for the sustainable development of aquaculture in its Ecosystem Approach to Aquaculture (EAA), including the principle that aquaculture should be developed within the context of ecosystem functions and services, without degradation beyond the resilience capacity of those services (Soto et al., 2008). While is yet unclear how EAA should be implemented within the context of ecosystem functions and services, ecosystem services frameworks provide a useful tool for the development and evaluation of governance and management approaches (Alleway et al., 2018; Rector et al., 2021).

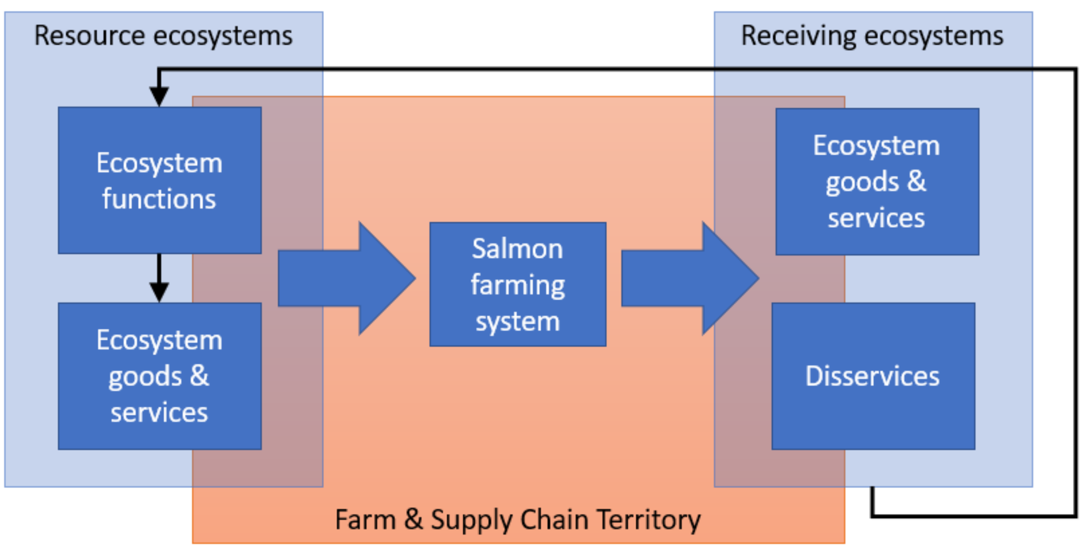

Figure 6.1. Salmon farming is embedded within ecosystems, relying on ecosystem functions, goods, and services while producing ecosystem goods, services, and disservices. Adapted from Aubin et al. (2019).

While seafood industries have traditionally been governed through public regulation, perceived failure of regulations to address environmental issues associated with seafood production has led to increasing involvement of non-state actors including the public, private businesses, and non-governmental organizations (NGOs). For example, major retailers are influencing seafood suppliers through purchasing policies designed to support their environmental, social, and governance (ESG) progress, and seafood companies have adopted corporate social responsibility (CSR) strategies to meet the demands of buyers and reduce reputational risks (Bailey et al., 2018; Packer et al., 2019). This means that the seafood industry is now regulated through a combination of public and private governance arrangements, including public regulation, private certification schemes, and self-regulation resulting in a complex governance arrangement involving many actors including the state, private businesses, and society (Bailey et al., 2018; Vince & Haward, 2017). This paper focuses on the governance of shared resources through eco-certification and self-governance, particularly on the role of eco-certification and CSR in the delivery of ecosystem services associated with marine salmon farming.

6.2.1 Eco-certification

Eco-certification schemes provide verification of the sustainability of aquaculture products based on a set of criteria used to evaluate sustainability; producers that meet a set of sustainability criteria receive eco-certified status (Bush et al., 2013a). Though eco-certified production still accounts for a small proportion of all aquaculture production by volume (Bush et al., 2013a; Rector et al., 2023a), a significant proportion of salmon farming is eco-certified including over 50% of global salmon production which is eco-certified by the Aquaculture Stewardship Council (ASC) alone (ASC, 2022a).

Eco-certification is increasingly considered necessary for market access as more retailers make commitments to sourcing sustainable seafood. For example, major retailers including Tesco, IKEA, Walmart, and Carrefour have made commitments to sourcing sustainable seafood by including targets for the proportion of seafood sold in stores that is eco-certified (Alfnes, 2017). Where public regulations may differ across regions or countries, eco-certification provides an international standard that retailers can rely on to support their ESG progress without the need to vet the sustainability practices of individual companies or the public regulatory regime where seafood is produced. This shifts the responsibility to demonstrate sustainability and associated risk to producers, benefiting buyers and retailers (Bush, 2017). Beyond meeting retailer requirements, producers may experience other direct and indirect benefits from eco-certification, including price premiums and consumer preference for eco-certified seafood (Asche et al., 2021; Carlucci et al., 2017; Danso et al., 2017; Ortega et al., 2014), as well as limited reputational benefits (Rector et al., 2023b). Additional motivations and benefits may include collective action to safeguard the marine environment on which the aquaculture industry relies for operation and expansion (Vormedal & Gulbrandsen, 2020) and improved internal procedures, systems, and documentation that are required to meet eco-certification standards that may improve operations and communication (Osmundsen et al., 2020).

Despite the market success of eco-certification, schemes may be limited in driving sustainability at meaningful spatial and temporal scales; eco-certification is largely lacking ecosystem perspectives, instead focusing on environmental sustainability at the farm (Bush et al., 2013a; Rector et al., 2023a), and once eco-certification is achieved there is no incentive for producers to make additional improvements (Tlusty, 2012; Tlusty & Thorsen, 2017). Further, although salmon aquaculture eco-certification works to prevent ecosystem disservices, it largely focuses on regulating services through criteria that call for the use of precautionary best practices with little regard for the provision of cultural and provisioning services (Rector et al., 2021).

6.2.2 Corporate social responsibility (CSR) strategies

Growth of the salmon farming industry is associated with improved environmental performance due to advances in technology and other solutions as more resources are put towards addressing industry-wide issues (Naylor et al., 2021; Tveterås, 2002). Yet, some environmental and social issues persist resulting in controversy impacting the legitimacy of the industry (Osmundsen & Olsen, 2017; Young & Liston, 2010; Young & Matthews, 2011). Without addressing sustainability issues, aquaculture companies face production, reputation, and market risks which have resulted in the adoption of corporate strategies to reduce these risks. These strategies can be described as proactive corporate strategies that go ‘beyond compliance’ with public regulations (Vormedal, 2017). Industry stakeholders recognize the concept of beyond compliance as both the exceedance of regulatory requirements and as activities that contribute to company sustainability, but that are not regulated (McGhee et al., 2019).

Going beyond compliance may include a range of activities that may be implemented by aquaculture companies, seafood buyers, or NGOs. For example, eco-certification promises to improve industry sustainability and provide assurance of the sustainability of eco-certified products, but it is only one of many voluntary CSR strategies employed by seafood companies (Bailey et al., 2018; Packer et al., 2019). Salmon farming companies have established sustainability principles (Huemer, 2010), engaged in public policy processes that influence aquaculture regulations (Vormedal, 2017), collaborated with other farming companies to address shared challenges (Osmundsen et al., 2021), supported local communities through engagement and donations (Huemer, 2010; Packer et al., 2019; Vince & Haward, 2017), and sponsored research on sustainable practices in collaboration with research institutes and universities. Where eco-certification is driven by market demand, other strategies may be associated with optimizing production or the need for social licence and acceptance. These strategies can be interpreted as environmental stewardship (Blasiak et al., 2021) and are of interest to shareholders as they reduce business risk associated with environmental performance and social licence. However, CSR strategies must also deliver sustainability improvements or risk being labeled as forms of bluewashing that prioritize company image and the business case for sustainability over sustainability outcomes (Bailey et al., 2018; Berliner & Prakash, 2015).

6.2.3 Research questions

Aquaculture is still a relatively new industry, but although there is a robust literature on regulation in the aquaculture industry (e.g. Barton, 1997; Henderson & Davies, 2000; Olaussen, 2018; Osmundsen et al., 2022), research on aquaculture-specific governance and management still lags behind research and literature on fisheries governance (Partelow et al., 2022). Private governance including eco-certification schemes and CSR could be relevant for the management of ecosystem goods and services impacted by salmon farming, especially given the rise of private and self-governance in the industry. However, eco-certification and other CSR strategies must be aligned with the provision of ecosystem services and prevention of disservices if they are to benefit society. Sustainability reporting has previously been used to explore the role of CSR in seafood suppliers (Packer et al., 2019). Here, sustainability reports are used to explore the role of eco-certification in the CSR strategy of salmon farming companies, and to identify which ecosystem services are supported by eco-certification and other CSR strategies. This document analysis approach was guided by the research questions:

1. How is eco-certification used to indicate commitment to sustainability?
2. What ecosystem services are associated with the use of eco-certification as a CSR strategy?
3. What other CSR practices are associated with the delivery of ecosystem services?

6.3 METHOD

A content analysis of sustainability and annual reports from top salmon farming companies, by production volume, was undertaken in an effort to understand the role of eco-certification in the CSR strategies of salmon farming companies and identify links between CSR strategies and the delivery of ecosystem services.

6.3.1 Identifying companies

A purposive sample of salmon farming companies was identified through aquaculture news sources IntraFish (B.-A. Jensen & Mutter, 2022) and Undercurrent News (Ramsden, 2020) as well as Mowi's Salmon Industry Handbook (Mowi, 2022) (Figure E1). The top 10 companies, by volume of salmon production, with publicly available sustainability or annual reports were included in the analysis (Table E1). Sustainability reports were downloaded from company websites where available. If no sustainability report was available, integrated or annual reports were downloaded (Table E1). Where neither sustainability nor annual reports were available, these companies were not included in analyses; thus, this analysis represents the CSR strategies of companies that have an interest in communicating CSR practices directly to shareholders through environmental, social, and governance (ESG) reporting. However, the 10 companies included in this analysis represent well over half of all global marine salmon farming production; therefore, this sample reflects the CSR strategies employed by companies producing the majority of global salmon production (Figure E1). All reports were uploaded and coded using NVivo Version 1.7.1. In a limited number of cases, the analyzed companies are active in multiple industries and reported on those value chains in addition to salmon farming within the same sustainability or annual report; notably, companies reported on activities related to animal-based agriculture and fisheries value chains. In these cases, activities associated with other industries were clearly identified within reports and only those activities related to salmon farming were included in the analysis.

Table 6.1. Themes emergent from inductive coding of the use of eco-certification in sustainability reporting, number of companies where theme was present in sustainability reporting, and total number of references to eco-certification themes across all sustainability reporting documents.

Use of eco-certification	Description	Number of Companies	Total Codes
Metric	Reporting number or percentage of farms and other supply chain components eco-certified	9	40
Supply chain	Requiring eco-certification compliance as part of supply chain control	8	35
Targets	Specific targets for number or percentage of farms and other supply chain components eco-certified	6	17
Comparison	First in milestones or percentage of eco-certified farms (ex. first company in country to have 100% of farms eco-certified)	4	4
Transparency	Public reporting on some environmental impacts as required by eco-certification scheme	3	8
Standard setting	Participation in the development of eco-certification standards	3	3

6.3.2 Coding documents

A combination of inductive and deductive coding was used to address the research questions. First, the presence of eco-certification including any reference to a specific eco-certification scheme within documents were coded, and additional inductive codes were applied related to how eco-certification was presented within sustainability reporting. These inductive codes were reduced to five common uses of eco-certification in sustainability reports: providing *targets* related to eco-certification, reporting *metrics* on number or percentage of production unites that are eco-certified, reporting eco-certification milestones or metrics in ways that provide a *comparison* to other companies, communicating that *supply chain* components are eco-certified and that chain of custody certification is used, providing *transparency* by reporting on eco-certification criteria, and indicating that the company has participated in eco-certification *standard setting* (Table 6.1).

Second, the presence of CSR strategies within documents were coded using a framework that was adapted from Packer et al. (2019) by separating eco-certification from other CSR practices to allow for comparison between eco-certification and other practices present in sustainability reporting. These strategies include eco-certification, power through supply chain control, internal practices, partnership with public and private actors, compliance and engagement with public policy and regulation, and philanthropy (Table 6.2).

Table 6.2. CSR strategies adapted from Packer et al. (2019) and applied to coding of salmon farming company sustainability reporting.

CSR Strategy	Description
Eco-certification	Participation in eco-certification schemes, either in general or with specific reference to ASC, BAP, GlobalGAP, or others
Power	Purchasing policies, supplier codes of conduct, and other practices that influence supply chain actors and/or support company sustainability
Practices	Internal codes of conduct, policies, management plans, technologies, reporting, and certifications
Partnership	Collaborations with other salmon companies, non-governmental organizations, scientists, other industry actors
Public policy	Participation in public policy and regulations, including compliance
Philanthropy	Donations, volunteering, and community events

Table 6.3. Integrated classification of ecosystem services adapted from Liquete et al. (2013) and applied to coding of salmon farming company sustainability reporting.

Ecosystem service category	Ecosystem service sub-category	Description
Cultural	Symbolic and aesthetic value	Exaltation of senses and emotions by landscapes, habitats, or species including cultural identity and a sense of place
	Recreation and tourism	Opportunities that the natural environment provides for relaxation and amusement
Provisioning	Biotic materials	The provision of biomass for non-food purposes
	Food provision	The provision of biomass for human consumption
	Water storage and provision	The provision of water for human consumption
Regulating	Biological regulation	Biological control of pests that may affect commercial activities and human health
	Climate regulation	Regulation of greenhouse gases
	Life cycle maintenance	Biological and physical support to facilitate the healthy and diverse reproduction of species
	Water purification	Biochemical and physiochemical processes involved in the removal of wastes and pollutants from the aquatic environment

Third, ecosystem services associated with CSR strategies were coded using the integrated ecosystem service classification system developed by Liquete et al. (2013) (Table 6.3). This classification integrates major ecosystem service typologies relevant to marine and coastal ecosystems. Each instance where maintenance of an ecosystem service was identified was assigned to an ecosystem service category and sub-category. The application of ecosystem service coding required a degree of interpretation as well as an assessment of the degree of association or direct linkage between farming activities and ecosystem services. For example, reports referred to a variety of strategies for improving social sustainability such as health and safety policies, community engagement efforts, and labour practices that could be interpreted as strategies that either indirectly enhance cultural services through the redistribution of benefits derived from the provision of food, or that mediate the equitable delivery of cultural ecosystem services. Although only ecosystem services directly linked to farming systems and supply chains were included in the coding of ecosystem services, these indirect services are also noted within the narrative description of results. The use of eco-certification and other CSR strategies to address ecosystem services was relevant across the supply chain, and results reflect the full scope of supply chain activities represented in sustainability reporting.

6.4 RESULTS

6.4.1 Use of eco-certification in sustainability reporting

Several aquaculture eco-certification and other certification schemes were referenced in sustainability reporting. The most common aquaculture eco-certification scheme referenced was ASC, followed by Best Aquaculture Practices (BAP), and GlobalGAP. Other certifications included environmental management system and organic certifications, marine and terrestrial feed ingredient eco-certifications, food safety and quality, occupational health and safety, and animal welfare certifications (Table 6.4).

Eco-certifications were used to indicate beyond compliance sustainability status across all companies, and both aquaculture and feed ingredient eco-certifications were used to communicate participation in these beyond compliance efforts in various ways (Table 6.1). First, most companies reported specific *metrics* related to the number of farms or facilities eco-certified under specific eco-certification schemes, or percentage of production that is eco-certified; e.g. Grieg reported "At the end of 2021, a total of 15 eligible sites were ASC certified (corresponding to 69% of net production)". Eco-certification of the *value chain* was indicated by referring to the eco-certification of upstream feed ingredients, or ensuring traceability and downstream chain of custody; e.g. Nova Sea stated that "We demand that all the feed we use be produced according to ASC criteria" and Lerøy stated that "Our product handling units (harvest and processing) also undergo audits to ensure traceability for certified products." Similar to the use of metrics, specific *targets* for the number of farms and production units or facilities eco-certified were used to indicate commitment to beyond compliance participation in eco-certification schemes; e.g. Blumar communicated a goal "to gradually increase the number of ASC-certified salmon farming centers, with the goal of reaching 60% certified centers between

2026 and 2027”. Some farms reported on their participation in eco-certification standard development or *standard setting*; e.g. “Lerøy Seafood Group has been involved in the development of the ASC-standard since 2004”. This participation appeared to be used to indicate leadership in sustainability. Some farms pointed to reporting of eco-certification criteria on company websites as a form of *transparency*; e.g. “Cermaq Chile provide information on e.g. sea lice, any escapes or wildlife interactions on its website for some farms to ensure easy access and to comply with requirements in the ASC standard.” Public reporting of eco-certification criteria was only reported in relation to ASC, which requires public reporting related to some eco-certification criteria including wildlife interactions and sea lice counts. Finally, companies reported on “firsts” in eco-certification, providing a *comparison* between companies; e.g. “At the end of 2021, Mowi accounted for 26% of all the ASC certified Atlantic salmon sites worldwide, reaffirming that we are the leading producer of ASC certified farm-raised salmon.” These comparisons suggest that eco-certification provides a way for companies to differentiate themselves from competitors and show leadership in progress towards improved sustainability.

6.4.2 Use of CSR strategies in the delivery of ecosystem services

CSR strategies presented in sustainability reporting impacted cultural, provisioning, and regulating ecosystem services (Figure 6.2). *Practices* was the most frequently represented CSR strategy and was used to address all three categories of ecosystem services, followed by *power*, *partnership*, and *public policy* which were also used to address all three categories of ecosystem services. The remaining CSR strategies, *philanthropy* and *eco-certification* were used to address provisioning and regulating services, but not cultural services. The use of these strategies to address ecosystem service categories is elaborated in the following sections.

Table 6.4. Sustainability certifications referenced in sustainability reporting. Risk management standards are not included in this list.

Certifications		Number of Reports
Aquaculture eco-certifications		
Aquaculture Stewardship Council	ASC	10
GlobalGAP	GlobalGAP	9
Best Aquaculture Practices	BAP	7
Environmental certifications		
ISO 14001 - Environmental Management System	ISO 14001	4
Debio (organic)		2
ISO 50001 - Energy management	ISO 50001	1
International Renewable Energy Certificates	I-REC	1
Feed ingredient certifications		
Marine Stewardship Council	MSC	7
ProTerra		6
Round Table for Responsible Soy	RTRS	6
MarinTrust		5
Global Standard for Responsible Supply	IFFO RS	3
European Soy		1
Food safety & quality certifications		
International Featured Standard	IFS	6
British Retail Consortium	BRC	6
Hazard analysis and critical control points	HACCP	5
ISO 9001 - Quality management	ISO 9001	3
Kosher		3
Brand Reputation through Compliance	BRCGS	2
Halal		2
Foundation Food Safety System Certification 22000	FSSC 22000	1
ISO 22000 - Food Safety Management	ISO 22000	1
Good Manufacturing Practices	GMP	1
Occupational health and safety certifications		
ISO 45001/OHSAS 18001 - OH&S Management Systems	ISO 45001/OHSAS 18001	4
Occupational Safety Standard of Excellence	OSSE	2
Animal welfare certifications		
Royal Society for the Prevention of Cruelty to Animals	RSPCA	1

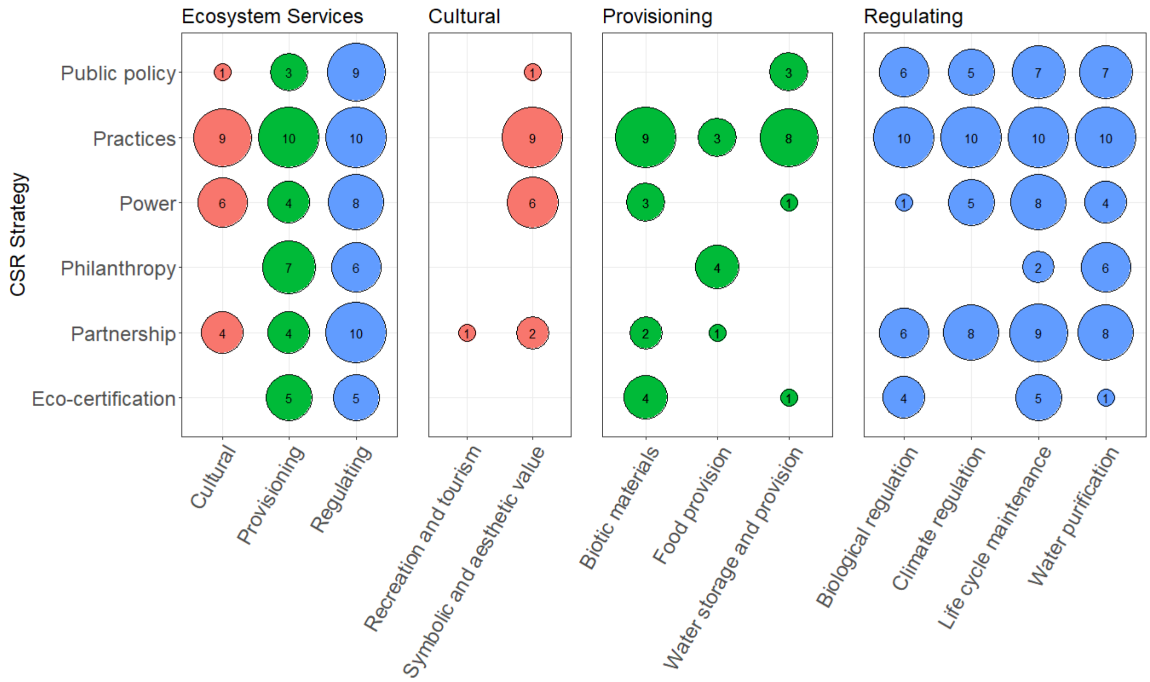

Figure 6.2. Ecosystem service categories and sub-categories impacted by CSR strategies. Numbers represent the number of companies with a combination of the corresponding ecosystem service category or sub-category and CSR strategy represented within sustainability reporting.

6.4.2.1 Cultural services

Cultural ecosystem services addressed in sustainability reporting included impacts on recreation and tourism, as well as symbolic and aesthetic value. *Practices*, *power*, *partnership*, and *public policy* were used to address cultural ecosystem services, in order of the number of companies where these strategies were applied (Figure 6.2).

Partnership was the only CSR strategy used to address recreation and tourism and included a partnership with a local community to include salmon farms as part of a tourism strategy, and work with local fishermen to secure a fishing concession.

The symbolic and aesthetic value sub-category included efforts to address odour and noise issues and create local jobs that contribute to cultural identities and a sense of place.

These *practices* included reducing low frequency sound emissions, investing in new technology to reduce odour emissions, and creating local jobs and training opportunities.

Companies employed their *power* to support local suppliers and contractors, contributing to the economy of local communities and creating a sense of place. Similarly, *partnership* strategies focused on working with local governments, communities, and education programs to develop and diversify local supply chains. One company referred to compliance with *public policy* as part of their noise and odour mitigation strategy.

Sustainability reporting included many other activities to support local communities; in particular, donations to local schools and education programs, sports teams, community events, and community groups were present. These philanthropic activities were not coded as part of this analysis as they were not considered direct cultural services enabled by farming activity; however, it is clear that these donations and community involvement are an important strategy for salmon farming companies, and they likely provide symbolic value. Additionally, animal welfare practices and compliance with third-party animal welfare certifications (Table 6.4) were present in sustainability reporting, but do not fit within the ecosystem services framework applied in this analysis.

6.4.2.2 Provisioning services

Provisioning services represented in sustainability reporting included the use of biotic materials, provision of food for human consumption, and water storage and provision. Each provisioning service sub-category was addressed by a variety of CSR strategies, with *practices* being the most prominent and the only strategy present across all sub-categories (Figure 6.2).

The use of biotic materials in salmon farming was addressed most prominently by *practices*, but also through *eco-certification*, *power*, and *partnership*. *Practices* in this sub-category largely included reference to the effective use and sustainable sourcing of terrestrial and marine feed ingredients. For example, the use of and improvement of metrics like the Fishmeal and Fish Oil Dependence Ratio (FFDRo), Forage Fish Dependency Ratio for Fishmeal (FFDRm), and Fish in Fish Out ratio (FIFO) were important practices in this category. In some cases, the specific targets or calculation for these metrics was informed by ASC criteria, which provides an example the role of *eco-certification* in guiding farm practices. In many cases, companies also required feed suppliers to have eco-certification status which provides a way for farms to shift responsibility for the protection of provisioning services, especially the use of biotic materials, to feed manufacturers using their purchasing *power*. Researching and sourcing alternative feed ingredients with the goal of reducing reliance on marine ingredients through *partnership* with researchers and suppliers, as well as using *power* to develop feed supply chains and accelerate a shift to alternative feed ingredients were also strategies related to the use of biotic materials.

Food provision was mainly enhanced through the *practices* that support food production, but was also supported through *partnerships* with local community groups and *philanthropy*, including donations of fish to community groups. Food provision was also supported through *practices* that limit food waste across the supply chain, including the efficient use of trimmings and the development of food packaging that extends shelf life.

The final provisioning ecosystem sub-category represented in sustainability reporting, water storage and provision, includes *practices* to limit the use of freshwater. Monitoring and metrics are used to track the use of freshwater and improvement in this area, and technology including investment in recirculating aquaculture system (RAS) technology was a common practice reported in sustainability reporting. These efforts extend to suppliers through risk assessments that demonstrate the use of *power* by farming companies. Compliance with *public policy* including meeting regulatory requirements for freshwater use and discharge, as well as compliance with *eco-certification* criteria related to the use of freshwater, were also referenced as ways that companies support the preservation of water storage and provision.

Many reports paid significant attention to food safety practices as well as compliance with third-party food safety certifications (Table 6.4). While food safety is an important mediator of provisioning services, it was not included as part of the ecosystem service coding scheme applied.

6.4.2.3 Regulating services

Regulating services were the most referenced ecosystem service type addressed using CSR strategies described in sustainability reporting. This category included the ecosystem service sub-categories biological regulation, climate regulation, life cycle maintenance, and water purification. Although *practices* was the most commonly applied CSR strategy within this category, all strategies were present across all sub-categories, with the exception of *philanthropy* which was not applied to biological or climate regulation services, and *eco-certification* which was not applied to climate regulation (Figure 6.2).

The biological regulation ecosystem service sub-category included preventing disease and pest regulation disservices associated with sea lice, fish disease, and the use of antibiotics. The *practices* used to prevent these disservices are also associated with efficient production, demonstrating significant overlap between production and environmental goals and strategies of salmon farming companies. This motivation is reflected in significant investment in research, development, and new technologies related to biological regulation; for example, companies reported investing in the development of vaccines, breeding and genetics, and non-medicinal sea lice control. Many of these research and development strategies included *partnership* with academic researchers or institutions. In some cases, these strategies are also passed down the supply chain to smolt and egg suppliers demonstrating the use of *power* as a CSR strategy. *Practices* that reduce the amount of time that fish spend in the sea during the grow out phase of production, which includes increasing growth rates and time spent in land-based smolt facilities, were also associated with preventing biological regulation disservices as biological risks are greatest during the grow out period. Other *practices* included the use of indicators, often associated with specific timebound goals, that require monitoring and reporting. This included monitoring and public reporting as required by ASC *eco-certification* in the case of sea lice counts and disease status. Compliance with *public policy* related to biological regulation services, especially maximum sea lice load, was also referenced in sustainability reporting.

Strategies to prevent climate regulation disservices included minimizing energy use and greenhouse gas emissions, primarily through *practices* related to measuring, reporting, and setting goals for energy use and carbon emissions. Many companies relied on or participated in established climate reporting protocols and initiatives such as the Science-Based Targets Initiative (SBTi), Greenhouse Gas Protocol Initiative (GHG Protocol), and the Carbon Disclosure Project (CDP) to support energy consumption and GHG emissions reporting. Some specific *practices* used to support reduction in energy use and GHG emissions included investment in variable supply air compressors and electric or hybrid boats, training employees to limit diesel-powered generators run-times, and shifting from the use of generators to grid electricity. Companies referenced participation in working groups or collaborations with other industry actors and NGOs to promote or pledge the reduction of greenhouse gas emissions within the seafood industry, though specific actions taken through these *partnerships* were not clear. Effort to reduce GHG emissions throughout the supply chain was evident within sustainability reporting, including reporting on scope 3 emissions (emissions from upstream and downstream activities not controlled by the company) associated with supply chain activities such as feed production, transportation, and processing. Some companies took actions in this sub-category through supply chain *power* by favoring the use of low-emission transportation methods or by ensuring that raw materials used in feed and feed production have a low carbon footprint. Companies also reported participation, alignment, and commitment to *public policy* and agreements including a Clean Production Agreement in Chile, the United Nations Framework Convention on Climate Change Paris Agreement, and United Nations Sustainable Development Goals.

Life cycle maintenance ecosystem services included preventing disservices through avoiding fish escapes, interaction with wildlife, and impacts on benthic fauna as well as other habitats. This sub-category addressed potential disservices resulting from the grow out stage of salmon farming as well as the production of fish feed. *Practices* used to address life cycle maintenance services included the use of indicators and monitoring those indicators, as well as best practices. For example, *practices* to avoid escapes focused on infrastructure and monitoring, including the use of specific nets and remotely operated vehicles (ROVs) to monitor farm sites, as well as specific employee training to prevent errors that may lead to escapes. *Practices* associated with preventing benthic impacts included choosing farming sites with good currents and water exchange rates to avoid benthic impacts, fallowing practices, and monitoring benthic impacts using grab samples. Techniques including using environmental modelling and developing eDNA monitoring tools were also reported. *Practices* used to prevent interaction with wildlife included choosing appropriate equipment and infrastructure. Some companies included public reporting of both escapes and interactions as part of the compliance requirements of the ASC *eco-certification* standard. *Partnerships* used to address life cycle maintenance services included cooperation with neighbouring farms through area management agreements (AMAs) on fallowing and sea lice management, disease control, and contingency plans in the case of escapes. Companies also reported on research *partnerships* related to the interbreeding potential of escaped salmon, eDNA monitoring tools, benthic recovery time, and other environmental monitoring programs. Finally, many companies reported compliance with *public policy* in relation to life cycle maintenance services. *Eco-certification* and *power* were employed as strategies for the delivery of habitat services; some companies relied on eco- and other certifications to ensure that feed ingredients do not contribute to habitat and biodiversity loss. For example, some companies relied on Marine Stewardship Council (MSC) or MarinTrust certification to ensure that marine ingredients did not contribute to overfishing or habitat loss, and some relied on ProTerra or Roundtable on Responsible Soy Association (RTRS) certifications to ensure that soy ingredients do not contribute to deforestation.

The final regulating service sub-category, water purification, included activities and strategies used to prevent disservices resulting from effluent, use of parasiticides, and waste associated with farming. While much of this sub-category addressed environmental impacts from the grow out stage of salmon farming, treating wastewater from smolt facilities also received significant attention and was largely addressed through *practices* including investment and use of technologies such as UV light treatment and biogas facilities. Additional *practices* used in this category include preference for non-medicinal treatment of sea lice overuse of parasiticides, monitoring for the effects of waste and parasiticide treatments on the environment, and recycling and waste management practices. Companies reported participating in industry *partnerships* and *philanthropic* and volunteer activities that included beach cleanups, education initiatives, and circular economy initiatives with the aim of reducing plastic pollution and other waste. Companies also used their *power* to engage supply chain actors in reducing waste and plastic pollution and companies reported working with suppliers to develop products that are more easily recyclable. *Public policy* strategies including compliance with discharge permits and environmental regulations related to effluent and waste management were also reported, as well as participation in the development of a plastic policy for the Norwegian aquaculture industry.

6.5 DISCUSSION

This paper explored the use of eco-certification in public sustainability reporting, and connections between CSR strategies and the delivery of ecosystem services associated with salmon farming. Sustainability reporting is typically targeted towards shareholders (Lindgren et al., 2021), and thus this analysis is limited by what companies chose to disclose and include for this audience. All companies included in this analysis referenced participation in eco-certification schemes as part of their CSR strategy (Table 6.4), with more than half of companies reporting on number or proportion of eco-certified farms and supply chain components and setting specific targets for eco-certified production (Table 6.1). Others cited early adoption of eco-certification or other milestones to demonstrate commitment to participation in eco-certification schemes, pointed to public reporting on environmental performance metrics on company websites as required by ASC, and indicated that they had or were participating in the development of eco-certification standards (Table 6.1). The presence and use of eco-certification in sustainability reporting suggests that eco-certification is important to companies as a tool to indicate commitment to sustainability to shareholders, despite the limited producer-level benefits of participating in eco-certification, beyond meeting buyer requirements (Blackman & Rivera, 2011; Olsen et al., 2021; Rector et al. 2023b), and the limited role of eco-certification in moderating public opinion of salmon farming (Rector et al., 2023b).

6.5.1 Eco-certification and the delivery of ecosystem services

The application of an ecosystem services framework revealed alignment between CSR strategies and the goals of EAA. It also helped delineate between CSR strategies that have meaningful sustainability impact versus those that serve company image, thereby enabling a focus on the sustainability case for CSR rather than the business case for CSR (Bailey et al., 2018), or a focus on 'doing' rather than 'being' (Huemer, 2010). At the same time, the ecosystem services framework did not capture some of the targeted outcomes of CSR strategies included in sustainability reporting as they were not directly connected to the delivery of ecosystem services; e.g. food safety, animal welfare, and community engagement. While EAA calls for the development of aquaculture without degradation of ecosystem services beyond their resilience capacity, the consistent and practical application of ecosystem services frameworks remains challenging, especially in the case of cultural ecosystem services, due to unclear links between perceived services and ecosystem elements (Blicharska et al., 2017).

The focus of aquaculture eco-certification criteria on environmental sustainability is well-established (Osmundsen et al., 2020; Rector et al., 2021); therefore, it is not surprising that eco-certification was presented in sustainability reports as a strategy for the prevention of regulating disservices, especially biological regulation and life cycle maintenance (Figure 6.2). Further, the limited spatial scope of aquaculture eco-certification, which is largely focused on farm-scale environmental sustainability (Amundsen et al., 2019; Bush et al., 2013a; Rector et al., 2023a), is congruent with a lack of connection between eco-certification and climate regulation in sustainability reporting (Figure 6.2). Aquaculture eco-certification schemes include criteria that require measuring and monitoring of energy consumption and emissions, but they have not yet incorporated limits on energy use of greenhouse gas emissions (Madin & Macreadie, 2015; Rector et al., 2021). However, climate regulation was highly represented in other CSR strategy categories, especially practices and partnerships, indicating that this ecosystem service requires attention outside of the requirements of eco-certification for companies to meet their sustainability goals.

Eco-certification was also presented as a strategy for the delivery of provisioning services. This connection mostly related to potential disservices associated with the use of marine and terrestrial feed ingredients. Reliance on wild fish to grow finfish is a prevalent sustainability concern (Naylor et al., 2009), and due to a shift away from marine ingredients, use of agricultural resources including land and freshwater use has also become more relevant (Froehlich et al., 2018; Naylor et al., 2021). Eco-certification schemes account for the efficient use of marine ingredients in salmon farming; for example, ASC criteria limit the use of fish meal and fish oil in feed by setting FFDRm and FFDRo requirements (ASC, 2022b). These criteria were reflected in the feed efficiency targets included in some sustainability reports, indicating that when eco-certification criteria include specific limits, those limits may be used to inform company sustainability performance targets. Influence between farming companies and eco-certification schemes was also present in the opposite direction, where some companies indicated that they participate in eco-certification standard development or standard setting, providing evidence of the dynamic participatory nature of rule-setting within eco-certification programs (Havice & Iles, 2015; Vellema & Van Wijk, 2015).

Though eco-certification was present in sustainability reporting and used to indicate commitment to social and environmental sustainability in general, other CSR strategies were more frequently explicitly connected to the delivery of ecosystem services. In particular, eco-certification was not associated with the provision of cultural ecosystem services, which is consistent with the relative underrepresentation of cultural services within salmon aquaculture eco-certification scheme criteria (Rector et al., 2021). Therefore, eco-certification appears to be just one of many CSR strategies that are associated with the delivery of ecosystem services, and other CSR strategies appear to both overlap with eco-certification and fill in gaps where eco-certification is not presented as a strategy associated with specific ecosystem services.

6.5.2 Certifying up the supply chain

A broad view of aquaculture sustainability requires a whole value chain perspective (Tlusty et al., 2019), and this perspective was reflected in sustainability reporting through the use of company power to improve sustainability performance throughout the supply chain. This was especially evident in overlap between power and eco-certification CSR strategies, where companies exerted power through requirements for suppliers to comply with eco-certification criteria or have achieved eco-certified status for their products.

Eco-certification supports buyers in shifting responsibility for sustainability onto producers (Bush, 2017), but the use of eco-certification in sustainability reports also indicates that it can be used by producers to shift responsibility for sustainability onto suppliers. This may be especially important where ecosystem disservices are most affected by activities outside of the grow out phase of salmon farming. For example, feed production affects both the use of biotic materials including marine and terrestrial ingredients (Froehlich et al., 2018; Naylor et al., 2021), as well as life cycle maintenance through reliance on wild fish (Naylor et al., 2009) and land use (Cottrell et al., 2018). Therefore, use of third-party eco-certification as a power strategy was largely applied to feed, as well as smolt supply (Table 6.4). This certifying up the supply chain may support the delivery of regulating ecosystem functions and services provided by habitat and biodiversity, but it also displaces responsibility to meet sustainability standards to suppliers.

In contrast to requiring suppliers to participate in eco-certification, supporting development and innovation in the supply chain extends responsibility to producers and is a strategy that was also observed within sustainability reporting. In some instances, companies also internalized climate regulation disservices by including scope 3 emissions in their GHG emission reporting. These examples of the use of power as a CSR strategy show how salmon farming companies are internalizing a value chain perspective that recognizes both upstream and downstream sustainability; however, the extent of producer power may not be sufficient to address downstream activities such as food waste, which has impacts across ecosystem services (Tlusty et al., 2019). The use of power through vertical integration, supplier policies, and supply chain eco-certification may improve sustainability performance across the supply chain; however, these strategies can be a burden to suppliers in low-income countries (Bailey et al., 2018; Roheim et al., 2018) and may disadvantage smallholders and suppliers (Trifković, 2014).

6.5.3 Other CSR strategies and incentives for the delivery of ecosystem services

CSR strategies identified in sustainability reporting that contribute to the delivery of ecosystem services also provide producer- and industry-level benefits including increasing production capacity and output, addressing bay-scale issues, and improving social acceptance. First, increasing production is supported by fish health management, the efficient use of inputs including feed, avoiding escapes, and advances in these practices through partnership with research institutions and the application of new technologies. These practices and partnerships are also linked to the delivery of ecosystem services and prevention of disservices. Indeed, rapid growth in salmon farming production is attributed to technological advancements and intensification (Afewerki et al., 2023; Kumar & Engle, 2016) which serve both sustainability and production goals. Second, bay-scale issues were addressed through collaboration amongst salmon farming companies within the same area, a strategy that has been used to address common problems such as disease management and water quality (Osmundsen et al., 2021). This type of collective action is also required by some eco-certification schemes (Amundsen et al., 2019; Rector et al., 2023b) and demonstrates the role of collective action in both managing common-pool resources (Osmundsen et al., 2021; Vormedal & Gulbrandsen, 2020) and protecting private assets, for instance, where the spread of disease and parasites is costly for producers (Abolofia et al., 2017; Aunsmo et al., 2010; Iversen et al., 2020). Finally, social acceptance of aquaculture is mediated by perceptions of the contribution of aquaculture to local economies including the creation of jobs (Krøvel et al., 2019; Lindland et al., 2019; Tiller et al., 2014; Vince & Haward, 2017; Whitmarsh & Palmieri, 2009); therefore, CSR strategies that prioritize the development of local supply chains and creation of local jobs address both social acceptance and cultural ecosystem services through the provision of symbolic value and a sense of place.

Sustainability reporting from salmon farming companies provided insight into the interactions and influence between various actors and institutions within the hybrid governance of aquaculture including eco-certification schemes, farming companies, public policy, and communities. Since salmon is a globally traded commodity, eco-certification and other CSR strategies may reflect the priorities of people distant from where farming and other supply chain activities take place as these strategies target shareholder, consumer and retailer audiences (Barclay & Miller, 2018). Local priorities may be better reflected in sustainability reporting where companies cited compliance with local regulations which are important for governing the use of shared resources and impacts on ecosystem services. The influence of public policy in sustainability reporting shows the persistent relevance and importance of public policy in aquaculture governance, despite the growing role of private governance within the industry. Further, public policy may be necessary to align company sustainability practices, especially where collaboration within the industry and amongst its partners is required (Osmundsen et al., 2021).

6.6 CONCLUSION

In this paper, sustainability reports were used to understand the role of eco-certification in the overall CSR strategy of salmon farming companies. Sustainability reports were used to explore how eco-certification is used to indicate commitment to sustainability, what ecosystem services are associated with the use of eco-certification, and what other CSR practices are associated with the delivery of ecosystem services. Although eco-certification was not strongly linked with the delivery of ecosystem services within sustainability reporting, it appears to be important to salmon farming companies and the shareholder audience of sustainability reports, providing a way to set sustainability goals and extend the reach of company CSR up the supply chain.

Private governance of aquaculture including eco-certification and CSR are increasingly necessary for salmon farming companies to remain competitive and must contribute to ecosystem sustainability to maintain credibility and legitimacy. However, while eco-certification does not address all potential ecosystem services affected by salmon farming, it is also not clear that it can or should. Instead, eco-certification and other CSR strategies appear to work in concert, contributing to the delivery of ecosystem services and preventing disservices where they are best positioned to do so. Eco-certification seems especially well situated to extend the reach of CSR across the value chain, though the implications of certifying up the supply chain for the equitable share of benefits derived from salmon farming should be considered. Just as the rise of private governance challenges the question of who should set and enforce the rules for sustainable salmon farming, the application eco-certification across the supply chain challenges who should be responsible for the sustainability of farmed salmon products.

Although the application of an ecosystem services framework in this study helped identify where CSR strategies are not just employed to improve company image or market access but meaningfully support the delivery of ecosystem services, it is clear that there are additional incentives for companies to go beyond compliance including increasing production and social acceptance. The alignment of these incentives with the delivery of ecosystem services is interesting in light of the emergence of payment for ecosystem services (PES) policies that aim to align the actions of private companies with public benefits. Additional market-based incentives linked to ecosystem services including both public (e.g. carbon tax) and private mechanisms (e.g. sustainability-linked financing, eco-certification) may support the development of CSR strategies that promote the delivery of ecosystem services. As observed here, many CSR strategies are linked to the management of shared resources, and the producer-level benefits associated with those strategies provide incentives for the provision of ecosystem services. CSR strategies, especially power, practices, and partnerships, may help companies achieve eco-certification by improving sustainability performance and managing ecosystem services and disservices in ways that align with eco-certification criteria.

CHAPTER 7: CONCLUSION

7.1 INTRODUCTION

The overall aim of this thesis was to understand the role of eco-certification in salmon farming. This included contributions to understanding both how aquaculture eco-certification supports sustainability (Chapters 2, 3, 4, 6), and how stakeholders including the industry and communities engage with eco-certification (Chapters 5 & 6). A mixed methods approach supported this goal and included the analysis of salmon aquaculture eco-certification standards and criteria, interviews, a public survey, and sustainability reporting from salmon farming companies. These sources of data reflect the perspectives and role of different stakeholders in salmon aquaculture eco-certification, explicating the relationship between aquaculture eco-certification and sustainability, and providing insight into different types of effectiveness (*problem-solving*, *behavioural*, *constitutive*, and *process*) that are necessary for the success of eco-certification. Results emphasize the role of eco-certification in creating positive sustainability outcomes and social acceptance of aquaculture across scales, guided by the ecosystem perspective necessary for the adoption of the ecosystem approach to aquaculture (EAA) in aquaculture management.

In Chapter 2, a literature review of the sustainability outcomes of aquaculture eco-certification identified key challenges for the success of eco-certification. This review brought forward themes that became important in subsequent chapters, especially how sustainability is defined by eco-certification and the role of eco-certification in ecosystem-level sustainability. Chapter 3 provided insight into how sustainability is defined by eco-certification and the potential for eco-certification to contribute to EAA by applying an ecosystem services framework to the analysis of salmon aquaculture eco-certification criteria. In Chapter 4, ecosystem-level sustainability was explored through thematic analysis of interviews with people involved in the process of eco-certification. This analysis identified specific eco-certification criteria that support an ecosystem perspective of sustainability, as well as the important role of auditors and public regulation in supporting ecosystem-level sustainability. Chapter 5 used survey data to understand the role of salmon aquaculture eco-certification in producer reputation and public opinion of salmon framing. Finally, Chapter 6 explored eco-certification within the larger context of corporate social responsibility (CSR) and its role in supplying ecosystem services.

In this concluding chapter, a summary of findings that address the research questions outlined in Chapter 1 is provided. Contributions including improved understanding of the effectiveness of eco-certification and practical implications for salmon farming companies and eco-certification schemes are outlined. Finally, study limitations and future directions for research are discussed.

7.2 OVERVIEW OF RESEARCH FINDINGS

The research questions posed in this thesis were motivated by the potential for eco-certification to support EAA through the delivery of ecosystem services across scales. As such, it addressed issues related to both sustainability and market outcomes as both are necessary for the success of eco-certification.

7.2.1 How does salmon aquaculture eco-certification support EAA?

EAA calls for the development of aquaculture without degradation of ecosystem services beyond their resilience capacity and requires consideration of the impacts of aquaculture across multiple scales (Soto et al., 2008). This strategy can provide guidance for the improvement and evaluation of aquaculture eco-certification schemes, especially in the selection of criteria to include in eco-certification schemes and the inclusion of ecosystem perspectives that account for the far-field impacts of aquaculture (Chapter 2).

Salmon aquaculture eco-certification schemes address regulating ecosystem services such as water purification, climate regulation, life cycle maintenance, and biological regulation using best practice criteria (Chapter 3). They also incorporate an ecosystem perspective using criteria that account for far-field impacts and rely on the judgement and expertise of auditors as well as local regulations to address ecosystem-level impacts (Chapter 4). However, this focus on regulating services does not follow through to cultural and provisioning services, which are less prominently addressed in eco-certification schemes (Chapter 3). Eco-certification schemes also take a largely precautionary approach to the management of ecosystem services using criteria that serve to prevent disservices rather than setting limits that take the resilience capacity of ecosystem services into account, or by supporting the provision of ecosystem services.

These results reflect previous research that point to a disproportionate focus on environmental impacts and incomplete coverage of sustainability issues in aquaculture eco-certification criteria (Alexander et al., 2020; Belton et al., 2009; Mussells & Stephenson, 2020; Osmundsen et al., 2020, 2020). However, although a lack of ecosystem perspectives has been a longstanding criticism of aquaculture eco-certification schemes (Bridson et al., 2020; Bush, Belton, et al., 2013; Jonell et al., 2013), interviews with people involved in the process of eco-certification showed that schemes are beginning to account for some ecosystem-level impacts, for example, through scheme criteria that call for collaboration amongst farms within the same region and overlap with tools already being employed by public regulators including environmental assessments (Chapter 4). Further, the role of auditors in evaluating materials including environmental assessments provided as part of the eco-certification process and reference and deference to local regulations supports the notion of eco-certification as a social process. Although eco-certification is grounded in a set of written rules and standards, it is also a socially mediated process involving multiple actors (Amundsen, 2022).

7.2.2 How are stakeholders engaged in and affected by eco-certification?

Salmon farming is a controversial industry (Osmundsen et al., 2017; Young & Matthews, 2011) which has received negative media attention in relation to potential environmental impact (Govaerts, 2021; Kluger et al., 2019; Olsen & Osmundsen, 2017; Weitzman & Bailey, 2019) and has been the target of national and international environmental campaigns (Young & Liston, 2010; Young & Matthews, 2011). Aquaculture eco-certification has also received negative media attention challenging the credibility or eco-certification schemes (Haas et al., 2020), yet eco-certification triggered an increase in opinion of salmon farming amongst survey participants (Chapter 5). This result was observed despite low levels of trust in eco-certification and familiarity of eco-certification labels and was observed in communities with and without salmon farms. Environmental impacts were the most concerning type of impact for the public, and eco-certification is largely focused on these types of impacts. However, eco-certification was less likely to trigger an increase in opinion of salmon farming amongst people for whom local social impacts were of importance. These results suggest that there is some alignment between what people value, what types of impacts eco-certification addresses, and whether eco-certification improves public opinion of salmon farming. Finally, eco-certification is more likely to trigger an increase in opinion of salmon farming amongst people with a negative opinion of salmon farming.

Eco-certification was also prevalent in sustainability reporting from salmon farming companies and was used by salmon farming companies to indicate commitment to sustainability practices, and to control upstream sustainability practices of suppliers (Chapter 6). However, when an ecosystem services framework was applied to the analysis of sustainability reporting, other CSR practices were more frequently aligned with specific ecosystem services and disservices. Criteria from eco-certification schemes may be used to set targets for indicators of the potential impacts of salmon farming, but it is the specific practices of salmon producers that contribute to the supply of ecosystem services – though these practices may enable companies to achieve or maintain eco-certified status. To expand on the metaphor of aquaculture governance as a concert (Barclay & Miller, 2018), eco-certification plays the role of the critic providing feedback based on established expectations (standards) that informs audiences (consumers, retailers, communities), and farming practices deliver the performance. Overlapping incentives including improved production and social acceptance are also involved in this recursive feedback loop.

7.3 CONTRIBUTIONS AND PRACTICAL IMPLICATIONS

This thesis aimed to improve understanding of the role of eco-certification in salmon farming, including its contribution to ecosystem sustainability and social acceptance. In doing so, it contributes both to a theoretical understanding of the effectiveness of aquaculture eco-certification and provides practical insight for eco-certification schemes and salmon farming companies.

7.3.1 The effectiveness of aquaculture eco-certification

When interpreted within the context of Tröster & Hiete's (2018) types of effectiveness associated with eco-certification, Chapters 2-3 suggest that the *problem-solving* effectiveness of eco-certification is a product of the types of criteria included in eco-certification schemes including what sustainability issues they address and how they address them. When these criteria are considered in the context of EAA, additional consideration of social and provisioning ecosystem services, the resilience capacity of ecosystem services, and bay-scale impacts are required to support the future supply of ecosystem services across scales. Chapter 4 challenges the assumption that eco-certification is an isolated arbiter of sustainability by showing the role of relationships and interactions between auditors, eco-certification schemes, and public regulation in the construction of eco-certification schemes and compliance assessment. These connections provide evidence for the reality of eco-certification as a social process, despite its basis in globally applied standards (Amundsen, 2022).

In addition to creating sustainability outcomes, aquaculture eco-certification must also create market incentives. However, understanding stakeholder engagement with eco-certification and the influence of eco-certification beyond potential market benefits is needed to explain the continued growth of aquaculture eco-certification despite limited producer-level benefits. Following from Barclay & Miller's (2018) call for research on engagement with eco-certification beyond the consumer audience, this thesis provides an understanding of the role of eco-certification in social acceptance (Chapter 5) and CSR (Chapter 6). *Constitutive* effectiveness may be weak amongst some stakeholders as observed in Chapter 5 as low trust in and recognition of eco-certification schemes, while still providing reputational benefits for producers and remaining strong amongst other audiences including shareholders and retailers, contributing to *process* effectiveness.

7.3.2 Implications for eco-certification schemes and salmon producers

Overall, the EAA-guided analysis of salmon aquaculture eco-certification criteria and processes in this thesis suggests that changes to both eco-certification criteria and processes could support *problem-solving* effectiveness. In many cases, the challenges for eco-certification schemes are not a result of scheme criteria and processes but are shared challenges across management and governance approaches. Aquaculture is a wicked problem and there are many uncertainties (Osmundsen et al., 2017), especially with respect to externalities including impacts on ecosystem services and the resilience capacity of ecosystems. Few environmental indicators have been developed or applied to bay-scale impacts (Rector et al., 2022), and social impacts differ across scale with trade-offs for local communities and global society (Kluger & Filgueira, 2021). However, recognition of cultural and provisioning ecosystem services within eco-certification criteria, and the inclusion of processes that recognize and make transparent the role of producers, auditors, and regulators in compliance evaluation could improve the role of salmon aquaculture eco-certification in supporting EAA. When it comes to *behavioural* effectiveness, the adoption of specific indicator limits outlined in eco-certification criteria by salmon farming companies in relation to specific environmental impacts such as effluent and sea lice load suggests that eco-certification schemes could improve *behavioural* effectiveness by including more indicator-driven criteria in their standards.

To improve *constitutive* effectiveness, eco-certification schemes will need to improve trust and find ways to address local social issues that are important to some community members. Of course, *constitutive* effectiveness is linked to *problem-solving* and *behavioural* effectiveness, and improvements or increased recognition of the impacts of eco-certification amongst stakeholders may contribute to increased *constitutive* effectiveness. If these improvements increasingly rely on auditor interpretation and experience, then eco-certification schemes will need to provide additional transparency related to the social process of compliance assessment to maintain credibility.

Eco-certification provides limited reputational benefits for salmon producers, and despite the positive effect of eco-certification on public opinion observed in Chapter 5, the practical significance of this small effect size is diminished further when the cost of participating in eco-certification is considered. Though eco-certification does not appear to be a powerful reputational risk management strategy, it does have potential to separate farm reputation from that of the industry, especially amongst people with a very negative opinion of salmon farming.

7.4 LIMITATIONS & FUTURE RESEARCH

This thesis provides an understanding of how aquaculture eco-certification supports and might support EAA. Though findings have relevance for other aquaculture systems and species, it will be important to understand how eco-certification addresses the potential impacts of different types of aquaculture on ecosystem services across spatial scales.

The perception of eco-certification and its effect on public opinion of farming is also likely to differ across aquaculture systems. Perceptions of aquaculture, values, and the relevance of different types of impacts are also likely to differ across communities. Results from the survey presented in Chapter 5 have general implications for the role of eco-certification in opinion of salmon farming, but these results do not account for community context beyond the presence of salmon farms. Community characteristics such as the degree or length of exposure to aquaculture activity, historical context in relation to coastal development and ocean-based employment, and shared community values are not reflected in these results. Community case studies and comparisons could help explicate the role of eco-certification in social acceptance of aquaculture.

Finally, this thesis provided increased understanding of individual types of effectiveness required for the success of eco-certification, but these types of effectiveness are linked and changes one will affect the others. Updates to eco-certification standards, events that might challenge the credibility or legitimacy of eco-certification schemes, and significant changes in the number of producers participating in eco-certification provide opportunities to improve empirical understanding of feedbacks between types of effectiveness.

7.5 CONCLUSION

This thesis explored the role of eco-certification in marine salmon farming to understand how eco-certification contributes or might better contribute to industry and ecosystem sustainability. The research was guided by two main questions: (1) How does salmon aquaculture eco-certification support EAA? and (2) How are stakeholders engaged in and affected by eco-certification. To answer these questions, analysis was guided by EAA and therefore reflects an ecosystem-level perspective of sustainability grounded in an ecosystem service framework that links natural ecosystems and human well-being. The thesis was structured around four types of eco-certification effectiveness: *problem-solving*, *behavioural*, *constitutive*, and *process* effectiveness, and each chapter contributes to understanding related to one of more of these types of effectiveness, all of which are necessary for the success of eco-certification.

Results indicate that salmon aquaculture eco-certification addresses some ecosystem-level sustainability issues, while improvements are needed to truly reflect EAA. Eco-certification is largely focused on preventing impacts on regulating ecosystem services, and while eco-certification addresses some sustainability issues that reach beyond the farm, it is also functionally constrained by the farm-scale application of eco-certification standards. Despite these limitations, eco-certification appears to be important as a tool to communicate commitment to sustainability and plays a limited role in reputational risk management. Improvements in aquaculture eco-certification may enhance its capacity to support EAA, and this includes continuing to draw on other tools including those employed by both regulatory authorities and private companies as they improve and adopt an ecosystem perspective of sustainability.

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APPENDIX A. CHAPTER 2 SUPPLEMENTARY MATERIALS

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Table A1. Key references associated with each challenge theme identified.

Challenge	Paper
Defining sustainability	Belton et al. (2009); Bush et al. (2013a); Luthman et al. (2019); Mussells & Stephenson (2020); Osmundsen et al. (2020); Parkes et al. (2010); Samerwong et al. (2017); Tlusty (2012); Tlusty et al. (2015)
Supporting continuous improvement	Amundsen & Osmundsen (2020); Jonell et al. (2019); Mussells & Stephenson (2020); Parkes et al. (2010); Tlusty et al. (2012); Tlusty (2012); Tlusty & Tausig (2015) Tlusty & Thorsen (2017)
Accounting for the scale of aquaculture effects	Amundsen et al. (2019; Amundsen & Osmundsen (2019); Bridson et al. (2020); Bush et al. (2013a); Bush et al. (2019); Cao et al. (2013); Chaplin-Kramer et al. (2015); Jonell et al. (2013); Madin & Macreadie (2015); Rector et al. (2021)
Recognizing local context	Amundsen & Osmundsen (2019); Chaplin-Kramer et al. (2015); Havice & Iles (2015); Marschke & Wilkings (2014); Roebuck & Wristen (2018); Schouten et al. (2016); Vellema & Van Wijk, (2015)

APPENDIX B. CHAPTER 3 SUPPLEMENTARYMATERIALS

Table B1. Summary of criteria related to provisioning services.

Criteria Type	Examples
Best practice	Measures implemented to collect water; recording feed-conversion ratios; use of broodstock from breeding programs only; feed ingredients from wild sources obtained from sustainable fisheries only
Indicator	Not blocking access to fishing areas and other resources; limits for feed fish efficiency ratio, fish oil forage fish dependency ratio, fishmeal forage fish dependency ratio; land and ocean area appropriated for feed; net protein gain or loss
Tipping point	None

Table B2. Summary of criteria related to regulating services.

ES Sub-category	Criteria Type	Examples
Water Purification	Best practice	Presence of a waste management/reduction plan; prohibition of growth hormones and specific chemical compounds; appropriate use, storage, labelling, and inventory of feed, chemicals, and therapeutants
	Indicator	Compliance with effluent and water quality parameters; biological waste per ton of fish
	Tipping point	Effluent management measures based on carrying capacity of receiving waterbody
Climate Regulation	Best practice	Assessments and monitoring of greenhouse gas emissions and energy consumption, improvements in energy efficiency
	Indicator	None
	Tipping point	None
Life Cycle Maintenance	Best practice	Presence of biodiversity policy and habitat rehabilitation planning; siting away from protected or critical habitat; monitoring infrastructure integrity
	Indicator	Faunal index score; downstream macro-invertebrate surveys; number of escapes
	Tipping point	Habitat maintaining full functionality; research regarding risk of establishment of non-native species being farmed
Biological Regulation	Best practice	Procedures for handling fish mortalities; treatment protocols; restrictions on antibiotic use
	Indicator	Sea lice levels; number/proportion of mortalities; number of antibiotic treatments
	Tipping point	Maximum sea lice load for area based on wild monitoring data

Table B3. Summary of criteria related to cultural services.

Criteria Type	Examples
Best practice	Avoiding lethal control of predators; limits on use of acoustic deterrent devices; presence of a breeding program aimed at stock improvement; access to education for children of employees; social benefits offered to employees and community
Indicator	Number of bird and marine mammal mortalities
Tipping point	None

APPENDIX C. CHAPTER 4 SUPPLEMENTARY MATERIALS

Interview Questions

Auditors

1. How does the location of a salmon farm affect the eco-certification process?
2. Are there any instances where local environmental conditions (i.e. hydrographic conditions or biodiversity) have impacted your evaluation of salmon farms, or application of sustainability criteria?
3. Are there instances where local social conditions (i.e. culture) have impacted your evaluation of salmon farms, or application of sustainability criteria?
4. Are there instances where local institutional conditions (i.e. local laws) have impacted your evaluation of salmon farms, or application of sustainability criteria?
5. Are there any instances where eco-certification criteria were irrelevant in a particular area? If so, how did you evaluate those criteria?
6. What role do you think local conditions should play in the evaluation of farm sustainability?
7. What types spatial information are used in the evaluation of salmon farm sustainability? How are they used?
8. How do you evaluate documents such as environmental assessments and habitat maps required by certification sustainability criteria? How do they factor into your evaluation of farms?
9. What impacts of aquaculture that reach beyond the farm are included in evaluation of farm sustainability?
10. What role do you think spatial information should play in the evaluation of farm sustainability?

Producers

1. How does the location of a salmon farm affect the eco-certification process?
2. Are there any instances where local environmental conditions (i.e. hydrographic conditions or biodiversity) have impacted the evaluation of one of your farms or the application of eco-certification sustainability criteria at one of your farms?
3. Are there instances where local social conditions (i.e. culture) have impacted the evaluation of one of your farms or the application of eco-certification sustainability criteria at one of your farms?
4. Are there instances where local institutional conditions (i.e. local laws) have impacted the evaluation of one of your farms or the application of eco-certification sustainability criteria at one of your farms?
5. Are there any instances where eco-certification criteria were irrelevant at a particular farm or for a region? If so, how were those criteria evaluated?
6. What role do you think local conditions should play in the evaluation of farm sustainability?
7. How do local conditions impact your farming and sustainability activities outside of the implementation of eco-certification?
8. What types spatial information have been used in the evaluation of your farms?

How have they been used?

9. Have you supplied documents such as environmental assessments and habitat maps during the implementation of eco-certification? How were these documents used in the evaluation of your farm?
10. What impacts of aquaculture that reach beyond the farm have been included in the evaluation of your farms?
11. What role do you think spatial information should play in the evaluation of farm sustainability?
12. How do you address the far-reaching impacts of farming activities in sustainability activities outside of the implementation of eco-certification?

Eco-certification scheme staff

1. How does the location of a salmon farm affect the eco-certification process?
2. How do certification criteria account for variation in local environmental conditions, including hydrographic conditions and local biodiversity?
3. How do certification criteria account for variation in local social conditions, including culture?
4. How do certification criteria account for variation in local institutional conditions such as local laws?
5. Are there any instances where eco-certification criteria are irrelevant in particular areas? If so, how are those criteria evaluated?
6. What role do you think local conditions should play in the evaluation of salmon farm sustainability?
7. What types spatial information are used throughout the implementation of eco-certification? How is it used?
8. Do you require submission of documents like environmental assessments and habitat maps? How do they factor into the evaluation of farm sustainability? How are auditors instructed to incorporate this material into their evaluation?
9. What impacts of aquaculture that reach beyond the farm are included in eco-certification criteria?
10. What prevents the inclusion of far-reaching impacts of aquaculture in eco-certification criteria? Are there ways in which more far-field impacts could be included?
11. What role do you think spatial information should play in the evaluation of farm sustainability?

Probing questions

1. What do you mean when you say X?
2. Can you provide an example of Y?
3. Can you tell me more about that?

ASC Variance Request Summary

Twenty-four variance requests (VRs) were submitted to ASC between December 15, 2020 and November 30, 2022. Two of these requests remained under technical review at the time of analysis and are not included in this summary.

VRs were requested for ASC criteria aimed at reducing impacts on ecosystem function (6), benthic biodiversity (4), marine mammals (4), disease and biosecurity (3), resource use (3), water quality (2), and wild salmon (2).

Table C1. Summary of ASC variance requests and associated impacts.

Impact	Number of VRs	Approved (%)	Not approved (%)
Benthic biodiversity	4	25	75
Disease & biosecurity	3	67	33
Ecosystem function	6	83	17
Marine mammals	4	50	50
Resource use	3	100	0
Water quality	2	0	100
Wild salmon	2	50	50
Total	24	58	42

The countries from which the largest number of VRs originated were Chile (6) and Australia (5); all other countries were associated with 3 or fewer variance requests.

Table C2. Summary of variance requests approved and not approved from different countries.

Country	Number of VRs	Approved (%)	Not Approved (%)
Australia	5	0	100
Canada	1	100	0
Chile	6	67	33
Denmark	2	100	0
Faroe Islands	2	0	100
Iceland	1	100	0
Japan	3	100	0
Norway	3	100	0
UK	1	0	100
Total	24	58	42

VRs that were related to environmental conditions or context were more likely to be approved (69%) than those that were not (38%). Of those VRs related to environmental conditions or context that were approved, justification for approval was often due to a criterion not accounting for the specific context under which the VR was requested (73%). For example, four separate VRs to allow for stocking of smolts produced in marine cage-culture in regions where indigenous salmonids are not present were approved as ASC criterion around smolt cage-culture production was developed with freshwater cage-culture in mind and not marine cage-culture.

VR related to environmental conditions/context	Number of VRs	Approved (%)	Not Approved (%)
yes	16	69	31
no	8	38	63
Total	24	58	42

The other main justifications for approval of VRs related to environmental conditions or context included that jurisdictional regulation was deemed to meet the intent of the criterion for which the VR was requested (18%). For example, a VR to change the sea lice limit from 0.1 during the sensitive period to 0.5 across the year was granted to a farm in Iceland as the 0.5 threshold set by authorities was based on risk to wild populations.

APPENDIX D. CHAPTER 5 SUPPLEMENTARY MATERIALS

Survey

Section 1: Residence

Q1 Please indicate the province where you live (British Columbia, Nova Scotia, other)

- British Columbia
- Nova Scotia
- Other

Q2 Which of the following best describes where you live:

- Rural area
- Small city or town (less than 10,000 people)
- Suburb near a large city
- Large city (more than 10,000 people)

Q3 Which city, town, or municipality do you live in:

- ____________________
- Prefer not to answer

Q4 Do you live in this city, town, or municipality year-round?

- Yes
- No

Q5 Is there currently a salmon farm in your community?

- Yes
- No
- Don't know

Q6 Has a salmon farm been proposed in your community in the last 5 years?

- Yes
- No
- Don't know

Q7 Approximately how far away is your house/dwelling from the coast?

- Waterfront
- Within 500 metres of the coast
- Between 500 metres and 1 kilometre from the coast
- Between 1 and 5 kilometres from the coast
- Over 5 kilometres from the coast

Section 2: Salmon farming

Q8 What is your general opinion of farming salmon in the ocean?

- Very positive
- Generally positive
- Neutral
- Generally negative
- Very negative

Q9 How knowledgeable do you feel about salmon farming?

- Very knowledgeable
- Knowledgeable
- Very little knowledge
- No prior knowledge

Q10 Please rate the importance of the following statements to you:

	Not at all important to me	Slightly important to me	Moderately important to me	Very important to me
Being able to buy farmed salmon at my grocery store is	○	○	○	○
The potential contribution of salmon farming to the provincial economy is	○	○	○	○

The potential contribution of salmon farming to the local economy where farms are located is	◌	◌	◌	◌
The potential creation of coastal and rural jobs created by salmon farming are	◌	◌	◌	◌
Safe and equitable working conditions at salmon farms are	◌	◌	◌	◌
The health benefits of eating farmed salmon are	◌	◌	◌	◌
The welfare of farmed salmon is	◌	◌	◌	◌
Knowing that farmed salmon is safe to eat is	◌	◌	◌	◌

Q11 Please rate your level of concern regarding the following potential effects of farming salmon in the ocean:

	Not at all concerning to me	Slightly concerning to me	Moderately concerning to me	Very concerning to me

The use of land to grow crops used in feed for farmed salmon is	◌	◌	◌	◌
The use of wild fish ingredients in feed for farmed salmon is	◌	◌	◌	◌
Potential coastal algal blooms caused by nutrient release from salmon farms is	◌	◌	◌	◌
The use of pesticides and herbicides in salmon farming is	◌	◌	◌	◌
The use of antibiotics on salmon farms is	◌	◌	◌	◌
The carbon footprint of farmed salmon is	◌	◌	◌	◌
The creation of “dead zones” on the ocean floor	◌	◌	◌	◌

under salmon farms is				
The transfer of disease from farmed to wild salmon is	◌	◌	◌	◌
The effects of escaped farmed salmon on wild salmon populations is	◌	◌	◌	◌
Birds and marine mammals being injured or killed near salmon farms is	◌	◌	◌	◌
The effects of salmon farming on local fisheries is	◌	◌	◌	◌
The effects of salmon farms on the beauty of coastal views is	◌	◌	◌	◌
The effects of fish farming on coastal recreation and tourism is	◌	◌	◌	◌

Section 3: Eco-certification & ecolabels

Q12 How would you rate your familiarity with ecolabels?

- ○ Not at all familiar
- ○ Slightly familiar
- ○ Somewhat familiar
- ○ Very familiar

Q13 How would you rate your familiarity with aquaculture ecolabels?

- ○ Not at all familiar
- ○ Slightly familiar
- ○ Somewhat familiar
- ○ Very familiar

Q14 The following are all aquaculture eco-certification programs. Listed beside each is the ecolabel associated with the program. Please rate your level of familiarity of each of these programs:

		Not at all familiar	Slightly familiar	Moderately familiar	Very familiar
Best Aquaculture Practices		○	○	○	○
Aquaculture Stewardship Council		○	○	○	○
GLOBALG.A.P.		○	○	○	○

Q15 Aquaculture eco-certification is a way for seafood farms to have an outside organization verify that the farm is operating in a sustainable way. How trustworthy do you think these eco-certification programs are?

- Not at all trustworthy
- Slightly trustworthy
- Moderately trustworthy
- Very trustworthy
- I don't know

Q16 How good do you think eco-certification programs are at addressing the following issues related to farming salmon in the ocean?:

	Not good at all	Slightly good	Moderately good	Very good	I don't know
Effects on the local environment where a farm is located	○	○	○	○	○
Effects on the environment beyond the area where a farm is located	○	○	○	○	○
Effects on the culture of communities where farms are located	○	○	○	○	○
Effects on the culture of the province	○	○	○	○	○

Effects on the economy of communities where farms are located	○	○	○	○	○
Effects on the provincial economy	○	○	○	○	○

Q17 What is your general opinion of salmon farms in the ocean that are eco-certified?

- Very positive
- Generally negative
- Neutral
- Generally negative
- Very negative

Section 4: Demographics

Q18 Please indicate in which age group you belong.

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 or older
- Prefer not to say

Q19 Please indicate the highest level of education you have attained.

- Less than high school
- High school
- Postsecondary certificate or diploma
- Bachelor’s degree
- Above bachelor’s degree and professional degrees (Masters, PhD, MD)
- Prefer not to say

Q20 Please indicate your average annual *household* income (in CAD)?

- Less than $19,999
- $20,000 – $39,999

- $40,000 – $59,999
- $60,000 – $79,999
- $80,000 – $99,999
- Above $100,000
- Prefer not to say

Q21 Are you, or anyone in your immediate family employed in any of the following marine-related occupations? Please choose all that apply.

- Fishing
- Aquaculture
- Coastal tourism
- Oil and gas
- Marine shipping
- Navy or Coast Guard
- Coastal construction
- Marine research
- Coastal or marine conservation
- None
- Other (Describe) __________________

Data Tables & Model Development

Data Summary

Table D1. Characteristics and perceptions of the study population including response rate per level of each variable.

	Persons (n = 565)	%
Location characteristics		
Province		
BC	245	43.4
NS	320	56.6
Urban or rural community		
Urban	205	36.3
Rural	360	63.7
Seasonal residency		
Yes	26	4.6
No	535	94.7
Missing	4	0.7
Salmon farm in community		
No	338	59.8
Do not know	99	17.5
Yes	127	22.5

	Persons (n = 565)	%
Missing	1	0.2
Salmon farm proposed in community in past 5 years		
No	207	36.6
Don't Know	196	34.7
Yes	159	28.1
Missing	3	0.5
Distance from coast		
Waterfront	57	10.1
Within 500m	134	23.7
500m - 1km	106	18.8
1-5km	141	25.0
>5km	125	22.1
Missing	2	0.4
Perceptions of marine salmon farming		
General opinion of marine salmon farming		
Very negative	326	57.7
Generally negative	101	17.9
Neutral	47	8.3
Generally positive	44	7.8
Very positive	47	8.3
Level of knowledge of marine salmon farming		
No prior knowledge	8	1.4
Little knowledge	122	21.6
Knowledgeable	286	50.6
Very knowledgeable	147	26.0
Missing	2	0.4
Perceptions of eco-certification		
Familiarity of ecolabels		
Not at all familiar	107	18.9
Slightly familiar	188	33.3
Somewhat familiar	199	35.2
Very familiar	69	12.2
Missing	2	0.4
Familiarity of aquaculture ecolabels		
Not at all familiar	184	32.6
Slightly familiar	189	33.5
Somewhat familiar	147	26.0
Very familiar	44	7.8
Missing	1	0.2
Familiarity of ASC label		

	Persons (n = 565)	%
Not at all familiar	256	45.3
Slightly familiar	141	25.0
Somewhat familiar	105	18.6
Very familiar	53	9.4
Missing	10	1.8
Familiarity of BAP label		
Not at all familiar	228	51.0
Slightly familiar	129	22.8
Somewhat familiar	92	16.3
Very familiar	46	8.1
Missing	10	1.8
Familiarity of GlobalGAP label		
Not at all familiar	365	64.6
Slightly familiar	110	19.5
Somewhat familiar	57	10.1
Very familiar	24	4.2
Missing	9	1.6
Trust in aquaculture eco-certification		
Not at all trustworthy	208	36.8
Slightly trustworthy	119	21.1
Moderately trustworthy	101	17.9
Very trustworthy	41	7.3
Missing	96	17.0
General opinion of eco-certified marine salmon farming		
Very negative	211	37.3
Generally negative	150	26.5
Neutral	113	20.0
Generally positive	48	8.5
Very positive	43	7.6
Demographics		
Age		
18-24	22	4.0
25-34	71	12.8
35-44	113	20.4
45-54	102	18.4
55-64	115	20.7
65 or older	132	23.8
Missing	10	1.8
Education		
High school	44	7.8

	Persons (n = 565)	%
Postsecondary certificate or diploma	183	32.4
Bachelor's degree	171	30.3
Graduate or professional degree	142	25.1
Missing	25	4.4
Household income		
Less than $19,999	9	1.6
$20-39K	56	9.9
$40-59K	70	12.4
$60-79K	85	15.0
$80-99K	67	11.9
Above $100K	178	31.5
Missing	100	17.7
Participant or immediate family member employed in marine-related occupation		
No	371	65.7
Yes	194	34.3

Table D2. Summary of responses to 4-point Likert-scale questions about the level of importance or concern about potential impacts of marine salmon aquaculture. Mean scores for condensed impact categories and Cronbach's alpha are presented in bold (M, Cronbach's α), followed by median response for individual 4-point Likert-scale questions included in the calculation of the associated construct. A 25% tolerance rate for missing values was used in the calculation of impact category scores. One Likert-series question about the importance of safe and equitable work conditions was not included in any of the constructs as it had a significant impact on internal reliability.

	Median	Persons (n = 565)	%	Missing (n = 565)	%
Near-field environmental impact score (3.62, .92)		565	100.0	0	0.0
"Dead zones" on the ocean floor	4	564	99.8	1	0.2
Birds and marine mammal injuries/fatalities	4	565	100.0	0	0.0
Use of pesticides	4	562	99.5	3	0.5
Use of antibiotics	4	564	99.8	1	0.2
Far-field environmental impact score (3.33, .86)		560	99.1	5	0.9
Disease transfer from farmed to wild salmon	4	565	100.0	0	0.0
Effects of escaped salmon on wild populations	4	565	100.0	0	0.0
Use of land to grow crops for salmon feed	3	558	98.8	7	1.2
Potential for coastal algal blooms	4	564	99.8	1	0.2
Carbon footprint of farmed salmon	4	564	99.8	1	0.2
Use of wild fish in salmon feed	4	559	98.9	6	1.1
Near-field social impact score (3.13, .88)		559	98.9	6	1.1
Effects on coastal recreation and tourism	3	564	99.8	1	0.2
Effects on local fisheries	4	562	99.5	3	0.5
Effects on coastal views	3	563	99.6	2	0.4
Far-field social impact score (2.50, .75)		562	99.5	3	0.5
Being able to buy farmed salmon	1	564	99.8	1	0.2
Health benefits of eating salmon	2	558	98.8	7	1.2
Food safety of farmed salmon	4	557	98.6	8	1.4
Welfare of farmed salmon	4	561	99.3	4	0.7

	Median	Persons (n = 565)	%	Missing (n = 565)	%
Near-field economic impact score (1.98, .96)		561	99.3	4	0.7
Creation of rural and coastal jobs	2	561	99.3	4	0.7
Contribution to local economy	2	562	99.5	3	0.5
Far-field economic impact score (1.91, NA)		562	99.5	3	0.5
Contribution to provincial economy	1	562	99.5	3	0.5

<u>One-way ANOVA results</u>

Table D3. One-way ANOVA results for differences in impact scores between farm presence groups.

	N	Levene Statistic	Sum of Squares	*df*	Mean Square	*F*	*p*
N-F Environment	564	<.001	8.054	2	4.027	5.105[a]	0.007[a]
F-F Environment	559	<.001	3.841	2	1.92	3.043[a]	0.05[a]
N-F Social	558	<.001	9.024	2	4.512	5.012[a]	.007[a]
F-F Social	561	<.001	3.583	2	1.791	2.175[a]	0.116[a]
N-F Economic	560	0.075	15.616	2	7.808	6.587	0.001
F-F Economic	561	<.001	17.966	2	8.983	6.084[a]	.003[a]

[a]based on Welch's F due to non-homogeneity of variance as determined using Levene's statistic

Ordinal Regression: Change in opinion of marine salmon farming triggered by eco-certification

Table D4. Recoding of response variables used in ordinal regression model.

Opinion of marine salmon farming		Impact of eco-certification on opinion of salmon farming	
Initial values	Final values	Initial values	Final values
Very negative Somewhat negative	Negative	Increased between 1 and 4 levels of survey options	Increase
Neutral	Neutral	No change	No change
Somewhat positive	Positive	Decreased between 1 and 3 levels of survey options	Decrease

Table D5. Predictive variables considered in the development of ordinal regression models.

Predictive variables considered
Location variables
Province
Urban or rural community
Seasonal residency
Salmon farm in community
Salmon farm proposed in community in past 5 years
Current or proposed salmon farm in community
Distance from coast
Perceptions of marine salmon faring
General opinion of marine salmon farming
Level of knowledge of marine salmon farming
Perceptions of eco-certification
Familiarity of ecolabels
Familiarity of aquaculture ecolabels
Trust in eco-certification
Demographic variables
Age
Level of education
Household income
Marine occupation
Importance of impacts scales
Near-field environmental
Far-field environmental
Near-field social
Far-field social
Near-field economic
Far-field economic

Testing for multicollinearity

The six "importance of impacts scales" that were considered as potential variables for were treated as continuous variables. The absence of multicollinearity was determined by creating dummy variables for each level of each categorical variable considered in the development of the model and using collinearity diagnostics. Collinearity statistics indicated multicollinearity amongst three indicator (dummy) variables representing levels of the categorical variable “trust in eco-certification”; the “not at all trustworthy” VIF was 16.417, the “slightly trustworthy” VIF was 13.007, and the “moderately trustworthy” VIF was 11.298. However, it was suspected that multicollinearity was due to the low proportion of people who rated trust in eco-certification as “very trustworthy” resulting a low proportion of responses in the reference category resulting in a more negative correlation between the non-reference indicators from the “trust in eco-certification” categorical variable. When the reference category used was changed to the “not at all trustworthy” level of the “trust in eco-certification” categorical variable, no collinearity amongst variables was detected.

Model selection

The model of best fit was selected following removal of non-significant variables and comparison of AIC as subsequent iterations of the model were considered and the final iteration was selected based on meaningful odds ratios and AIC value (Table S10). The assumption of proportional odds was met, as assessed by a full likelihood ratio test comparing the fit of the proportional odds model to a model with varying location parameters, $\chi^2(7) = 5.842$, $p = .558$. The deviance goodness-of-fit test indicated that the model was a good fit to the data $\chi^2(389) = 313.381$, $p = .998$, but many cells were sparse with zero frequencies in 59.6% of cells. The final model statistically significantly predicted the dependent variable better than the intercept-only model, $\chi^2(7) = 127.279$, $p < .001$ (Table S7). A total of 417 participant responses (80.5% of participants who did not rate their general opinion of marine salmon farming as “very positive”) were included in the model and 101 responses (19.5%) were excluded as these cases were missing data for one or more variables as participants did not respond to all survey questions.

Table D6. Comparison of full model and final model considered for predicting change in opinion.

	Intercept only -2 Log Likelihood	Final -2 Log Likelihood	Chi-Square	df	Sig	AIC
Full model	575.576	429.141	146.438	46	<.001	525.141
Final model	519.218	391.939	127.279	7	<.001	409.939

Table D7. Parameters from cumulative ordinal regression on change in general opinion of marine salmon aquaculture triggered by eco-certification.

Variable/Levels	*B*	SE	Odds Ratio	95% CI Lower	95% CI Upper	*p*-value
Opinion of salmon farming						
Negative	4.732	0.5780	113.511	36.562	352.414	<.001
Neutral	1.946	0.6037	6.997	2.143	22.844	0.001
Positive	0		1			
Trust in eco-certification						
Not at all trustworthy	-6.413	1.1879	0.002	0.000	0.017	<.001
Slightly trustworthy	-5.543	1.1700	0.004	0.000	0.039	<.001
Moderately trustworthy	-4.779	1.1577	0.008	0.001	0.081	<.001
Very trustworthy	0		1			
Importance of near-field social impacts	-0.527	0.1558	0.590	0.435	0.801	<.001
Importance of far-field social impacts	0.432	0.1422	1.540	1.165	2.035	0.002

APPENDIX E. CHAPTER 6 SUPPLEMENTARY MATERIALS

Table E1. Companies and sustainability or annual reports included in analysis.

Company	Report Type	
Mowi	Sustainability Strategy	https://mowi.com/wp-content/uploads/2021/04/Mowi-Sustainability-Strategy_A4_March-2021.pdf
Cermaq	Sustainability Report	https://www.cermaq.com/assets/Cermaq-GRI-Report-2021.pdf
Salmar	Integrated Annual Report	https://www.salmar.no/annual-reports-efes/SalMar_Annual_Report_2021_ESEF.html
Leroy	Sustainability Library	https://www.leroyseafood.com/en/sustainability/sustainability-library-2021/
Agrosuper (Aquachile)	Integrated Annual Report	https://www.agrosuper.cl/wp-content/uploads/2022/04/REPORTE-INTEGRADO-2021-INGLÉS.pdf
Multi X (Multiexport)	Sustainability Report	https://www.multi-xsalmon.com/wp-content/uploads/2022/06/Multi-X-Sustainability-Report-2021-1.pdf
Grieg Seafood	Integrated Annual Report	https://cdn.sanity.io/files/1gakia31/production/8699f764225f2b441044453452ada7923cca1994.pdf
Australis Seafood (Joyvio)	Sustainability Report	https://www.australis-seafoods.com/sostenibilidad_2022/pdf/Reporte_2021_en.pdf
Salmones Blumar	Integrated Annual Report	https://www.blumar.com/memorias/Blumars_Integrated_Report_2021.pdf
Nova Sea	Sustainability Report	https://novasea.no/en/baerekraftsrapport/

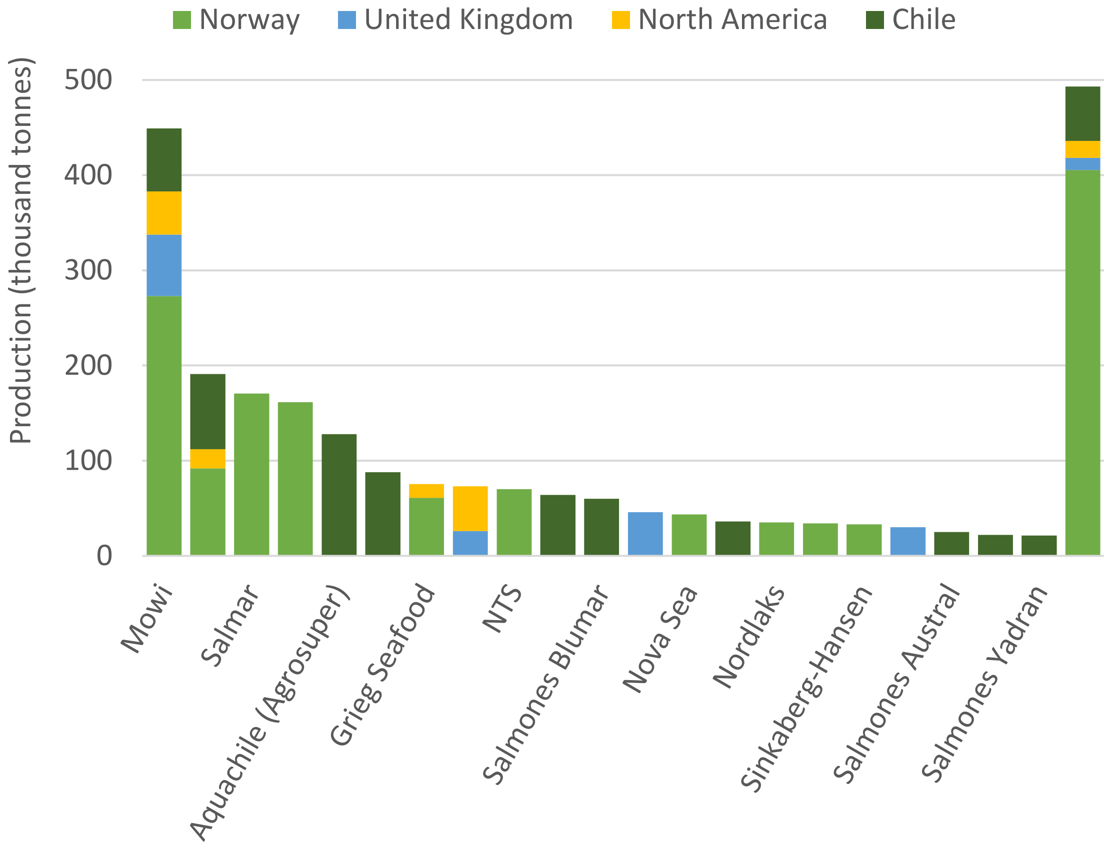

Figure E1. Salmon production across top producing companies in Norway, United Kingdom, North America, and Chile in 2021. Data includes the top 10 producers in Norway and Chile, and the top 4 producers in the UK and North America (company production figure does not include production where company is not within the top 10 or 4 producers; e.g. Cooke production in Chile is not included). The production figure for Cooke is a 2020 estimate. Production figures for NTS includes Norway Royal Salmon and production figures for Scottish Sea Farms includes GSF Shetland per Mowi's Salmon Farming Industry Handbook, to reflect acquisitions/mergers. Data used in this figure is from Mowi's Salmon Farming Industry Handbook (Mowi, 2022).