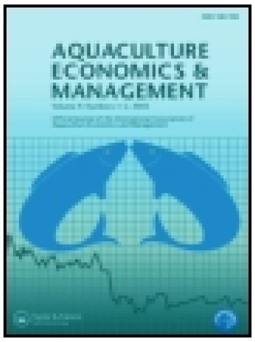

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Level up or game over: the implications of levels of impact in certification schemes for salmon aquaculture

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ABSTRACT

Certification schemes are becoming increasingly important within aquaculture management, but the indicators that are used by these schemes are subject to considerable debate. Many have questioned their actual impact on improving the industry, and whether they effectively address the many externalities of aquaculture production. In this paper, we study the choice of indicators in eight major certification scheme standards for salmon aquaculture and examine to what degree they manage to address impacts beyond individual production sites. We find that, in accordance with the criticism, the majority of indicators pertain only to the site-level. However, indicators related to traceability, and to coordination and sharing of information among producers can elevate local concerns to a higher level of impact. We, therefore, argue that among all the certification scheme standards considered here, these types of indicators should be emphasized to a larger extent.

KEYWORDS
Aquaculture; sustainability; certification; levels of impact

Introduction

Global aquaculture production has increased rapidly in recent decades due to the immense technological and scientific advances in a short period of time (Asche, 2008; Kumar & Engle, 2016). Because of the rapid growth and strong potential for further growth, aquaculture is often considered a vital piece of the puzzle in fighting the pending world food shortage (Kobayashi et al., 2015). Aquaculture may also contribute to increased income and food security (Belton, Bush, & Little, 2018), generate positive socio-economic effects (Ceballos, Dresdner-Cid, & Quiroga-Suazo, 2018), and there is increasing evidence that it is a more sustainable production technology

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compared to the production of other animal proteins (Froehlich, Runge, Gentry, Gaines, & Halpern, 2018).

Aquaculture is, however, an industry characterized by complexity and much controversy. It is the environmental risks associated with aquaculture that tend to dominate the media debate (Olsen & Osmundsen, 2017). These can include emission of untreated effluents, the spread of disease, and potentially unsustainable fishing for raw materials for feed (Jonell, Phillips, Rönnbäck, & Troell, 2013). Studies show that there is a preference for wild fish relatively to farmed, presumably due to the environmental impact of aquaculture (Roheim, Sudhakaran, & Durham, 2012; Uchida, Onozaka, Morita, & Managi, 2014). The industry is also associated with damaging socio-economic impacts such as conflicting interests concerning marine space and resources, inadequate food safety, and social disruption (Hai, Visvanathan, & Boopathy, 2018). While there is much debate concerning how to deal with the challenges, the aquaculture industry is constantly evolving through the discovery of new potential solutions (Klinger & Naylor, 2012). Despite clear evidence that government mandated regulations do work in some cases (Tveteras, 2002), the rapid development of the industry has left regulatory authorities largely lagging behind, being reactive rather than proactive (Peel & Lloyd, 2008).

As a response to the challenges associated with aquaculture and to promote the more sustainable practices, there has been a rise in private governance as part of the "sustainable seafood movement" (Bush & Roheim, 2018). This entails different local and global actors, such as NGOs and retailers, developing sustainability standards intended to ensure a safe product that has been produced in an environmentally and socially responsible manner. Such standards are made up of indicators with corresponding requirements, with which the aquaculture companies need to comply in order to obtain and maintain the certification. The standards vary in focus, depending on its scheme's purpose, process of development, and proprietorship (Nilsen, Amundsen, & Olsen, 2018). It has been shown that standards such as these can, for instance, overcome consumer preference of wild fish over farmed (Bronnmann & Asche, 2017). Fish farmers also try to provide more credible ecolabels using organic labeling (Asche, Larsen, Smith, Sogn-Grundvag, & Young, 2015; Ankamah-Yeboah, Nielsen, & Nielsen, 2016).

These certification schemes frequently act as more stringent regulatory agents than national authorities (Washington & Ababouch, 2011). However, Bush et al. (2013, p. 1067–1068), among others, argue that aquaculture certification "takes an enterprise-level approach" with the result that important environmental externalities are "rarely effectively considered." They also argue that the social externalities of aquaculture, which are believed by many to be extensive and significant, are seldom included. Certification schemes, for example, may disadvantage small producers of the global south and undermine the sovereignty of governments of the global south by moving the locus of decision-making beyond their shores (Busch, 2017).

This paper explores whether certification schemes for salmon aquaculture, with their focus on site and firm-level criteria and compliance, actually can make the industry more sustainable on a wider scale. To assess this, we draw upon a thorough examination of over 1900 sustainability indicators from eight salmon certification scheme standards commonly used by producers in Norway, Chile and Scotland. Our findings show that indicators in these schemes do primarily pertain to individual production sites, predominantly addressing issues concerning the site and the company operating there. However, it is necessary to differentiate between the level of *criteria* with which the companies need to comply and the level of the targeted *impact* of these criteria. Taking this distinction into account, we find that a majority of the indicators address broader scale impacts, including many of the indicators with site-level criteria. We will here discuss how site-level indicators manage to target a wider level of impact through additional requirements that seek to include externalities of the production.

Theoretical background

The intention of certification is to use the communication between buyers and sellers as a means to move the aquaculture industry in a more sustainable direction. Within the literature on ecolabel economics, certification is treated as a signaling game, a tradition that can be traced back at least to the seminal contributions to information economics by Akerlof (1970) and Spence (1973). This literature views consumers as facing a type of adverse selection problem, where the true properties of the goods they wish to buy are hidden from them. A key function of certification is then to provide consumers with better information, enabling them to make better-informed choices. The signaling effect of certification does not only involve end-consumers, however, as many certification schemes operate only at the business-to-business level, without consumer-facing labels. Thus, certification involves the industry itself, buyers, retailers, researchers, government and the general public, underlining the importance of the reliability of the information provided by these schemes.

Efforts to reduce the footprint of aquaculture production necessitate that negative externalities associated with aquaculture production are addressed. This is the general purpose of the various indicators and certification schemes considered here. In the present context, we understand negative externalities as undesirable effects of aquaculture production that are not fully accounted for by the market. Externalities take various forms, and some have more widespread consequences than others. Salmon aquaculture, when practiced as open cages in marine waters, potentially directly affects its surroundings in several ways, which can include impacts on habitats, wild species, water quality, chemical emissions, and the spread of resistance to antibiotics (Osmundsen, Almklov, & Tveteras, 2017; Tlusty, 2012). Which of these challenges are most pertinent can vary across countries, regions and even fjords. Other more global impacts of salmon farming include energy use, biotic resource use, greenhouse gases, acidifying and eutrophying emissions (Pelletier et al., 2009). The magnitudes of these externalities are often both difficult to measure and highly controversial. It is perhaps even harder to understand the social and economic externalities generated by any given fish farm or enterprise, such as the potential negative impacts on indigenous peoples, as aquaculture production may hinder traditional livelihoods (Gerwing & McDaniels, 2006). As Raynolds (2004, p. 728) puts it, commodities are enmeshed in a "complex web of material and nonmaterial relationships connecting […] social, political and economic actors."

Some externalities can be confined to the specific production site, such as fish welfare, which may not be adequately addressed by the producer if the market is not willing to pay for it. Frequently, however, externalities range over several levels, such as sea lice which are troublesome both for the producers themselves, nearby producers, and society as a whole as it may pose a threat to the wild salmon stock. One can argue that this is not an externality at the site-level if the producer fully acknowledges the effect of sea lice on his own profitability and thus acts accordingly. To avoid discussions as to whether a certain undesirable side-effect is to be considered an externality or not in the strict sense, we generally refer to these phenomena as "impacts." The scale at which these concerns are mainly felt is referred to as an "impact level," and our intention is to evaluate whether or not local indicators, as measured at site or firm-level, are adequate correctors of impacts that extend beyond a given production facility or firm.

According to Bush et al. (2013), only local effects of aquaculture production are taken into account by the various certification schemes, as it is often individual production sites that are certified. This entails that compliance with the standard indicators occurs on each aquaculture site (or processing facility), which necessarily prompts indicators that can be measured and met on a site-level. Similarly, Belton, Murray, Young, Telfer, and Little (2010) argue that certification schemes are neglecting vital issues such as unsustainable resource use further upstream in the value chain because they only focus on the localized impacts at the farm-level. Furthermore, because private production units are certified, there is no guarantee that the cumulative environmental effects of several farms in one production area are addressed (Boyd & McNevin, 2012).

With requirement compliance being at the site or firm-level, individual decisions on actions such as de-lousing and fallowing can have a limited effect if not coordinated with a larger area. The same goes for the handling of viruses and emergency slaughtering following disease outbreaks (Pettersen, Osmundsen, Aunsmo, Mardones, & Rich, 2015). Furthermore, by focusing on issues pertaining to the specific farms, externalities that are not directly associated with the farm activities, such as the use of unsustainably produced feed, transport, and processing further down the production chain, may not be adequately accounted for (Bosma, Anh, & Potting, 2011). Also, according to Bush et al. (2013), the environmental impact on surrounding agriculture or natural ecosystems are less then perfectly addressed by certification schemes, thus confirming that these schemes take a too particularistic approach. Similarly, Bruce and Laroiya (2007) argue that increasing returns to scale in environmental protection often implies that the sum of site-level impacts is not equal to the impact on society as a whole.

All these contributions point to the same issue, namely that certification schemes and the set of indicators included in these, take a narrow approach to sustainability, and that site-level criteria are not adequate in addressing broader scale impacts. This, in turn, speaks to the reliability, or lack thereof, of the information provided by these standards, as they claim to promote a more sustainable aquaculture industry by certifying responsible production.

Materials and methods

In exploring the reliability of the information provided by certification through assessing the degree to which aquaculture schemes capture externalities, we examined the content of selected certification scheme standards for salmon aquaculture. While a part of the criticism of aquaculture certification points to criteria and compliance being on site-level and thus limiting its ability to address broader scale impacts, a standard that applies to specific sites may still have indicators that target impacts beyond the site-level. In order to explore whether certification is indeed making the industry more sustainable, we, therefore, examined the specific indicators that make up different standards.

There exists a myriad of labels that salmon farmers can choose from (Alfnes, Chen, & Rickertsen, 2018), of which we have selected eight of the major certification schemes and their standards for salmon aquaculture in

Table 1. Chosen certification schemes and standards.

Certification scheme	Standard	Version	Intent/ambition
Aquaculture Stewardship Council (ASC)	Salmon	v1.0	Minimize or eliminate the key negative environmental and social impacts of salmon farming, while permitting the industry to remain economically viable
GLOBALG.A.P.	Aquaculture/GRASP	v5.0/v1.3	Economically, ecologically, socially and culturally responsible agriculture (and aquaculture)
Friend of the Sea (FOS)	Marine Aquaculture	v1.1	Conserve the marine environment while ensuring sustainable fish stocks for generations to come
International Featured Standards (IFS)	Food	v6.0	Quality assurance and food safety
BRC Global Standards (BRC)	Food Safety	v7.0	Food safety, quality and operational criteria in food manufacturing
Royal Society for the Prevention of Cruelty to Animals (RSPCA)	Farmed Atlantic Salmon	*09/2015*	Animal welfare, sustainability, traceability, biosecurity
Global Aquaculture Alliance (GAA)	BAP Salmon	v2.3	Food safety, social welfare, environmental, animal health and welfare
Scottish Salmon Producers' Organization (SSPO)	Code of Good Practice - Seawater Lochs	*02/2015*	Balance between industry activities and regulatory detail or bureaucracy, assurance of quality, high minimum standard and continuous improvement

Norway, Chile and Scotland as our data material (see Table 1 for summary). The Aquaculture Stewardship Council (ASC) proclaims to certify environmentally and socially responsible seafood in general. For the ASC Salmon Standard, the certificate is valid for 3 years, with farms audited annually. Global Good Agriculture Practice (GLOBALG.A.P.) is similarly an "all-around" scheme that claims to cover food safety and traceability, environment, workers' health, safety and welfare, and animal welfare. GLOBALG.A.P. certifies companies, with a select number of farms being audited annually. Friend of the Sea (FOS) stresses the safeguarding of the marine environment and its resources. Their certificates are valid for 3 years, with on-site audits every 18 months. The International Featured Standards' (IFS) Food Standard emphasizes food safety and quality assurance. The certificate applies to processing facilities and is valid for 1 year. BRC Global Standards (BRC) is a brand and consumer protection organization, with a standard emphasizing food safety and quality issues, similar to IFS. Audits are performed at processing facilities, with the frequency depending on performance. Royal Society for the Prevention of Cruelty to Animals (RSPCA) emphasizes animal welfare, with members being subject to annual assessments, in addition to annual unannounced audits. The Global Aquaculture Alliance (GAA) standard, Best Aquaculture Practices (BAP), claims to address four pillars of responsible aquaculture: food safety, social welfare, environmental, animal health and welfare. Salmon farms are audited annually, when possible. The Scottish Salmon Producers Organization's (SSPO) standard, Code of Good Practice, is a national standard that claims to provide general good practice across all aspects of fish production. On-site audits are performed annually.

A total of 1916 indicators were coded according to both "level of *criteria*" and "level of targeted *impact*." "Criteria" refers here to the specific requirement set for each indicator, while "targeted impact" represents the issues that are addressed through these requirements. For "level of criteria," the indicators were coded as either "site-level," "beyond site-level" or both. "Site-level" signifies compliance at the site and immediate surrounding area only, "beyond site-level" concerns company senior management or external parties such as feed producers and suppliers, and "both site-level and beyond" requires compliance both on and outside the site, as with various collaborations with neighboring sites.

For "level of targeted impact", the indicators were coded as either "site-level," "beyond site-level" or both. "Site-level" has a targeted impact on the site only (e.g., fish welfare), "beyond site-level" addresses external issues only (e.g., food safety), and "both site-level and beyond" has a targeted impact both on and outside the specific site (e.g., disease control).

All indicators that were coded as having a targeted impact beyond site-level were further categorized according to a more specific level, as either "impact surrounding site," "broader impact" or both. "Impact surrounding site" includes impacts on the surrounding environment and the local community. "Broader impacts" goes beyond the surrounding area, including national and global issues.

Additionally, we utilized the codification of these 1916 indicators according to 28 different topics relevant for making the aquaculture industry sustainable, as provided by Amundsen and Osmundsen (2018). Based on this work, we were able to identify which groups of indicators pertain to issues directly affecting the site and the company, and which address broader scale impacts of aquaculture production. To explore the relationship between these different levels, we focused on groups of indicators addressing multiple levels, i.e., indicators with potentially both a lower site-level impact and a wider level of impact. Through the examination of these indicators, we identified several common characteristics among them, providing valuable insight into how the level of impact can be elevated, even with site-specific standards and indicators.

Findings

By studying the specific indicators of the eight sustainability standards, we can investigate the reliability of the information provided by the

Table 2. Indicators coded according to level of criteria and targeted impact.

	ASC	GLOBAL G.A.P.	FOS	IFS	BRC	RSPCA	GAA	SSPO	Total
Total number of indicators	152	267	52	278	255	468	137	307	1916
Site-level criteria	96	198	43	190	203	263	104	228	1325
Site-level impact	26	91	7	0	0	212	51	125	512
Impact beyond site-level	38	56	28	190	203	22	29	33	599
Both site-level and beyond	32	51	8	0	0	29	24	70	214
Beyond site-level criteria	41	2	7	26	4	108	1	35	224
Site-level impact	1	0	0	3	0	99	0	16	119
Impact beyond site-level	35	2	5	19	4	2	1	0	68
Both site-level and beyond	5	0	2	4	0	7	0	19	37
Both site-level and beyond criteria	15	67	2	62	48	97	32	44	367
Site-level impact	0	13	0	0	0	90	6	2	111
Impact beyond site-level	6	32	2	62	48	3	14	3	170
Both site-level and beyond	9	22	0	0	0	4	12	39	86

certification schemes. As argued in much of the literature above, we indeed find that the various indicators to a large degree cover issues pertaining to the activities of each individual aquaculture site or processing facility. However, this mainly concerns the level of criteria, i.e., the level where compliance is required. As seen in Tables 2 and 3, a clear majority of the indicators, 1325 of 1916 in total, have criteria on site-level only, but most of these indicators nevertheless have a targeted impact that goes beyond site-level (1174 when including the ones that target wider impacts only, and the ones that target both site-level and wider impacts, see Table 3). We also find that most of these indicators have a targeted impact that goes beyond the area surrounding the site, to include national and global challenges. Among the indicators targeting the conditions at the production site, these involve issues such as fish welfare and local sampling water and sediment quality. Concrete examples include SSPO's #5.2 "*Each farm should have access to a veterinary surgeon experienced in fish health to advise on fish health matters and medicine usage, and who is available to attend at short notice*" and RSPCA's #E3.6 "*Biofouling must not be allowed to build up on enclosure nets.*"

Of the 1174 indicators with a targeted impact going beyond site-level, many address issues pertaining to the area surrounding the site, both the surrounding environment and the local community. For example, all six of the schemes that audit fish farms (all except the IFS and BRC standards) include indicators related to escapees, which can cause harm to local wild salmon stocks. These indicators include minimizing escapees, dealing with them, training staff to prevent them, and reporting them. Other indicators with targeted impact level surrounding the site concern the potential spread of disease, coordination with neighboring sites and conflict resolution with the local community. Concrete examples include FOS' #3.1 "*The average yearly percentage of fish escape assessed is not higher than 0.5% of the total of bred fish*" and GAA's #4.9 "*Production cycles, fallowing and nutrient*

Table 3. Summary of coding.

Level of criteria	1916
Criteria site-level only	1325
Criteria beyond site-level	224
Criteria both site-level and beyond	367
Level of targeted impact	1916
Impact site-level only	742
Impact beyond site-level	837
Impact both site-level and beyond	337

monitoring shall be coordinated with the other neighboring BAP applicants or certified farms, or with members of an established AMA [Area Management Agreement]."

Among the indicators that target impacts beyond the site level, we also find that many of them operate on a broader level than just the surrounding area, and are directed towards suppliers and other actors along the value chain, global consumers and the global environment. From Table 4 we find that 791 indicators at least partly address issues beyond both the site and surrounding areas. These typically relate to issues concerning food safety, traceability and record-keeping of activities, and general transparency. Concrete examples include IFS' #4.18.1 "*A traceability system shall be in place which enables the identification of product lots and their relation to batches of raw materials, packaging in direct contact with food, packaging intended or expected to be in direct contact with food. The traceability system shall incorporate all relevant receiving processing and distribution records. Traceability shall be ensured and documented until delivery to the customer*" and ASC's #4.4.1 "*Presence and evidence of a responsible sourcing policy for the feed manufacturer for feed ingredients that comply with recognized crop moratoriums and local laws.*" It is important to note that the great majority of these indicators are found in the two food safety standards, BRC and IFS. If these standards had not been included, the number of indicators under this category would go from 791 to 261.

While our findings indicate that these sustainability standards do in fact address more impacts of a broader scale than much of the criticism suggests, they still have pronounced limitations in this regard. For instance, a deficiency observed in our analysis is that certification schemes almost exclusively pay attention to environmental and resource impacts in the sea and not land-based resources. Due to the controversy surrounding the use of wild pelagic fish as a raw material in fish feed, there has been an increase in the use of non-marine ingredients, such as soy protein. Despite its potential severity, the environmental impacts of this rising demand, e.g., deforestation, are only addressed in the ASC standard. Similarly, emissions from transport services related to both feed and fish are not easily accounted for. Indeed, as noted by Bush et al. (2013), none of the major aquaculture sustainability schemes consider the environmental cost of

Table 4. Of those indicators with targeted impact beyond site-level.

Total	1174
Impact surrounding site	383
Impact broader than surrounding site	654
Impact both surrounding site and broader	137

transportation and distribution. Of the eight, the ASC standard is the only one that has indicators on GHG emissions, but these do, at this time, only request records of annual GHG assessments, with no set limit on emission. The idea is that by acquiring assessment data, ASC can later add a requirement related to the maximum amount of GHG emissions allowed.

By examining the groups of indicators that target multiple levels, we see that many indicators with site-level compliance are "lifted up" to a higher level of impact by some form of governance, such as traceability, transparency, sharing of information, and coordination between other aquaculture sites or other marine resource users. For example, indicators related to introduced or amplified parasites and pathogens in the ASC standard focus on participation in an Area-Based Management (ABM) scheme. Similar arrangements can be found in other standards, under names such as Area Management Agreements (GAA and RSPCA), Area Management Plan (GLOBALG.A.P.) and Farm Management Area (SSPO). Another example is feed indicators that not only involve the safety of the feed for the fish (fish health and welfare) but also traceability concerning food safety for consumers and source of marine raw materials to ensure responsible environmental management of small pelagic fisheries. Looking at the commonalities between these multi-level indicators, we have identified two key characteristics that allow a higher level of targeted impact: *traceability* and *coordination and sharing of information*:

Traceability

In the present context, we define "traceability" as the ability to track the history of any substance through all its stages of production, processing and distribution, i.e., a new form of informational governance (Bailey, Bush, Miller, & Kochen, 2016). Traceability is thus important in order to assess the environmental and social footprint of aquaculture products from cradle to plate. In addition, traceability is central to ensuring that the end product is a safe and healthy food commodity. The potentially excess use of marine products further down the food chain is also addressed by the traceability criterion. Traceability indicators operate across the whole value chain, across sectors, regions and countries, and can thus be said to answer some of the criticism to sustainability indicators considered here. We also find that traceability is prevalent within all certification schemes that we have examined.

As regards to indicators related to food safety, traceability is a key requirement. For instance, three of the standards (BRC, IFS and GLOBALG.A.P.) have strict indicator requirements concerning product withdrawals and recall procedures, necessitating extensive documentation and searchable records that ensure an effective response in the event of safety issues or product defects. Traceability for food safety also involves indicators related to dangerous toxins in fish feed or medicinal residues from treatment of the fish, which can be found in ASC, GAA, GLOBALG.A.P. and SSPO.

Coordination and sharing of information

A popular objection to sustainability indicators on a firm or site-level is that they do not address the issue of firms making individual decisions without coordinating with other agents operating in the same area. Many interdependencies exist between producers that operate in the same area, and area-based management is thus central to the sustainability of the aquaculture industry. Highly suboptimal outcomes have been demonstrated in situations where agents fail to cooperate. Coordination and information sharing is important not only among producers in the same area, but also for the industry as a whole, and for increased trust and transparency between the industry and other central stakeholders such as regulating authorities and the general public.

Our findings show that the ASC, GAA, RSPCA, GLOBALG.A.P. and SSPO standards all have indicators related to coordination and collaboration. These indicators include, among others, coordination of production cycles, stocking, fallowing, nutrient monitoring, and fish health management activities, and information-sharing in the event of discharge, unexplained increased mortality or diseases that must be notified to the OIE (World Organization for Animal Health). The IFS and BRC standards do not have any indicators on coordination and collaboration, as they pertain to processing facilities, leaving just the FOS standard without any across-site coordination or collaboration indicators.

Discussion

As argued in much of the certification literature, it is challenging to capture broader scale impacts when operating with site and enterprise-level standards. Our findings indicate, however, that this can to some extent be accomplished in many cases by "lifting up" site-level criteria using some form of governance characteristic. We have identified *traceability* and *coordination and sharing of information* as prevalent requirements in the certification schemes examined here, enabling site-level certification to have a more far-reaching impact. These indicators have the potential to counteract much of the criticism that has been posed towards certification schemes and sustainability standards for being too near-sighted.

Traceability is emphasized in all of the standards considered here, in many different forms. A substantial share of the indicators with broader targeted impacts relates to various facets of food safety, a key aspect of responsible aquaculture. These include proper species identification, prevention of harmful residue from chemical treatment of the fish, identification of allergens, and hindering of product contamination or tampering. In addition to helping ensure a safe product, traceability is crucial to perform corrective measures in case of unsafe food leaving the plant and to provide the consumer with the correct product information.

When attempting to address the broader scale impacts of aquaculture, it is important to consider improvement across the entire value chain. This includes, for example, using traceability to ensure responsible sourcing of raw materials for feed, considering the controversies surrounding both the use of wild pelagic fish and the use of soy protein as main ingredients. As this example illustrates, however, assessment of the many environmental externalities of aquaculture is characterized by much complexity. Achieving full traceability of the environmental impact of aquaculture is a difficult task, particularly due to the immense data requirements involved in identifying these global effects. Conducting comprehensive life cycle assessments of the whole production process is neither viable by existing methods, nor required by any certification scheme. Bosma et al. (2011), in a partial life cycle analysis of catfish farming, found that environmental effects from feed are given some attention by existing certification standards, but not the impact of processing and distribution. This corresponds to our findings.

Coordination and sharing of information are crucial in addressing the negative impacts of aquaculture that go beyond site-level. The type of strategic dynamic that frequently occurs among individual agents may lead to particularly adverse effects. Prisoner's dilemma types of situations arise when actors do not cooperate and view sustainability as a zero-sum game. If not all firms in the same area adhere to the same certification scheme, more responsible behavior by some agents may induce less responsible behavior by others. Area-based management is a strategy for achieving coordination and sharing of information, as it obligates different sites and companies to engage in, e.g., limiting disease outbreaks and ensuring biosecurity through a collaborative effort. Coordination and transparency among neighboring sites do have their limitations due to proprietary issues, as companies will seek to safeguard the information that might give them a competitive advantage. However, its many advantages suggest that coordinated efforts should be emphasized to a larger extent.

Sharing of information as an approach to minimize externalities of aquaculture does not only apply between neighboring sites but also in regards to general transparency, which is demanded both by regulatory authorities and the general public. Sharing of information can be in the form of publicly available information, such as sea lice levels in the ASC standard, or information that is available on request. These requirements help ensure complete and thorough documentation and record-keeping, while also promoting increased accountability of the aquaculture companies. This can in turn help expose larger disease outbreaks, keep the public safe from potential safety hazards and facilitate better dialog with stakeholders and the local community. Transparency is also important in regards to food safety, due to the necessity of proper labeling of ingredients and allergens.

Traceability and coordination/sharing of information are both contingent on a key feature of standardization: documentation. The proliferation of certification has, therefore, led to increased emphasis on reporting and record-keeping. The question as to whether it is worth the extra financial costs and manpower is difficult to answer. Nevertheless, as these two characteristics exemplify, site and enterprise-level standards can target broader scale impacts by "lifting up" site-level criteria and compliance.

Concluding remarks

Sustainability certification has the potential to provide benefits at all levels in the supply chain. For consumers, more information about the sustainability properties of various commodities allows better-informed choices. For producers, the reputational benefit that comes with certification may have a substantial financial value. For retailers, certification schemes offer an opportunity to outsource reputational risk. Whether such schemes actually do help to make the industry more sustainable is, however, a more difficult question to answer (Roheim, Bush, Asche, Sanchirico, & Uchida, 2018).

In this paper, we explored the content of eight prominent certification scheme standards for salmon aquaculture, with particular focus on the level of impact that the standard indicators target. By doing so, we intend to add some analytical clarity hitherto missing in the debate about aquaculture, and provide insight into the reliability of the information that is given to consumers, retailers, government, etc., through certification.

In certain cases, the individual efforts of different sites can efficiently address externalities from production, e.g., preventing fish from escaping the cages will necessarily lead to an overall reduction in escapees. For certification to have a substantial impact on the industry, however, broader scale impacts need to be addressed. Our findings indeed suggest that many of the indicators are directed toward specific sites and production facilities, thus being local in nature. However, by applying a distinction between the level of criteria and level of targeted impact, we see that certain broader scale impacts of aquaculture are indeed addressed. We also find that indicators related to traceability and coordination/sharing of information are promising in elevating local concerns to a wider scale.

When discussing sustainability, it is important to keep in mind the obscurity that characterizes this concept. Despite its prevalence, there lacks a common consensus as to what it actually means and how it can be accomplished. Further complicating the matter, the complexity of the aquaculture industry and the ecological systems within which the industry finds itself is the cause of much disagreement as to what a "sustainable aquaculture industry" might actually look like. There is no blueprint to follow due to contradicting findings within the scientific community, in addition to the many contradicting needs and interests of the various stakeholders affected by the industry.

Some of the standards recommend practices that diverge, and occasionally are even contradictory. An example is the use of acoustic deterrent devices (ADD), which are used to scare away predators. The ASC standard forbids the use of these, while the SSPO standard states that they "*should be used where and as permitted*," and the RSPCA standard requests them at "*[a]ny site that is recognized as having a high risk of attack or has suffered an attack in the past.*" This represents one of many difficult value questions that have no clear answer, or rather an answer that depends on what one wishes to safeguard – the fish or surrounding marine mammals. As exemplified here, the lacking consensus as to which activities are more "sustainable" makes it difficult to say for certain which measures have the biggest impact. With the many different considerations present, tradeoffs are essential in the process towards a "sustainable aquaculture industry."

Despite its many benefits, we need to acknowledge and fully understand the limitations of certification. These standards are not likely to fully transform a sector that struggles with fundamental environmental, economic and social problems. Many of the externalities of aquaculture seem to go beyond the reach of certification, such as those that require international cooperation and problems that cross different production sectors, such as transport. It is, however, important to keep in mind that certification is only a part of a global governance regime, and it needs to be regarded as such. Regulating such a complex industry is necessarily a concerted effort, meaning that certification must function as a complement to government regulations. Furthermore, the industry itself has a responsibility as a contributory actor in this governance regime. When we can acknowledge both strengths and limitations of the different regulation efforts, both private and public, this can potentially enable better collaboration between them in making the aquaculture industry more sustainable, whatever that may entail.

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