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Testing the Waters of an Aquaculture Index of Well-Being

Craig Stephen [1,*] and Joy Wade [2]

[1] Canadian Wildlife Health Cooperative, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, SK S7N 5B4, Canada
[2] Fundy Aqua Services Inc., 1859 Delanice Way, Nanoose Bay, BC V9P 9B3, Canada; joywadefundyaqua@gmail.com
* Correspondence: cstephen@cwhc-rcsf.ca; Tel.: +1-306-371-7177

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Abstract: Social licence is rooted in perceptions of local rights holders and stakeholders. The disease focus of aquaculture health policy, practices, and research insufficiently reflects societal expectations for aquafarms to protect health of shared resources. Our case study of Atlantic salmon (*Salmo salar*) farming in British Columbia (BC), Canada, assessed the readiness of aquaculture to change from managing health as the absence of disease to a perspective of health as well-being to maintain social licence. We drafted an index of well-being based on agroecosystem health and socio-ecological health principles. We then reviewed publicly available industry and government information and undertook key informant interviews. The industry was well situated to develop and use a well-being index. Interviewees saw value in a well-being index and found it compatible with area-based management. Many elements of the index were being collected but there would be challenges to overcoming feelings of over-regulation; negotiating specific indicators for local situations; and securing the necessary expertise to integrate and assess the diversity of information. Health conflicts and disagreements facing salmon farming in BC are like those in other aquaculture sectors. Social licence may be improved if companies transparently report their state of the health by adapting this conceptual framework.

Keywords: Atlantic salmon; aquaculture; framework; fish health; social licence

1. Introduction

Social conflicts and disagreements over health issues have been one of the biggest impediments to aquafarm companies securing their social licence to operate [1–3]. Social licence to farm is gained when the private sector and government act to help develop strong and sustainable communities [4]. Social licence to operate is commonly understood to be the ongoing acceptance and approval of a project by local community members and other stakeholders that can affect its profitability [5]. The substance of a social licence to operate will vary with the nature of the project and the specific community needs. The assessment and application of social licence needs to be developed in conjunction with communities to ensure transparency and mutual benefit.

A lack of social licence negatively effects the commercial viability and reputation of aquaculture farms [6]. It is incumbent on farmers to provide the breadth and depth of information to shift from a "do no harm" approach to demonstrating positive benefits [2,7]. We argue that the focus on diseases in aquaculture health policy, practices and research is necessary but insufficient to reflect the expectations of society for aquafarms to promote and protect the health of the farmed animals and shared resources.

Health issues rightfully pre-occupy significant attention and investment in aquaculture. Losses due to diseases have been a major constraint to aquaculture production [8,9]. Infectious agents such as

norovirus and other environmental pathogens contaminate products, thus threatening markets and impacting public confidence (e.g., [10–12]). Ecosystem and environmental health concerns have arisen due to the prospect of transmission of infectious agents between cultured and wild stocks [13]. The effects on the ecological functions of drugs and chemicals used to treat disease (e.g., [14–16]), public health issues (e.g., [17–20]) or impacts on wild species genetic integrity (e.g., [21,22]) are other examples of health concerns. Community health equity issues arise when the benefits from aquaculture are not equitably shared or when marine and aquatic resources used for other economic, subsistence or cultural purposes are threatened by aquaculture operations [23]. At the base of these concerns is the need for healthy profits that are dependent on healthy, productive farmed animals and healthy environments.

Despite the multiple and interacting health concerns that span private and public domains, most aquaculture health policies and programs remain focussed on the detection, control and prevention of infectious and parasitic diseases, most often on those diseases that affect trade or commercial productivity. Globally; policy makers, industry, and industry critics have generally failed to evolve the way health is described and managed in accordance with recent thinking. In fields such as public health, wildlife health and livestock herd medicine, health is more than the absence of disease. It is a multi-dimensional attribute that provides the ability, or capacity, to realize full function, satisfy daily needs, and adapt to or cope with changing environments [24–27]. This conception of health is consistent with moves among regulatory agencies to implement integrated management models to ensure that aquaculture does not unduly harm the well-being of citizens, species and ecosystems [28]. It is also consistent with the concepts of ecological and sustainable aquaculture and cumulative effects management. As successful aquaculture systems must address the 'triple bottom line' of economic, social and environmental profits [29]; a modern health management system should support this need.

Social licence to operate [30] is rooted in perceptions and opinions of the local population and other rights holders and stakeholders. The concept of well-being provides a comprehensive understanding of the link between health and society. Well-being not only encompasses basic health needs such as adequate food, lack of disease and safety, but also considers how people think and feel about their life situation [31]. Neither social licence nor well-being have universally accepted definitions. We have adapted concepts of well-being from population and public health and of social licence from resource extraction industries in this framework. An aquaculture well-being index should provide succinct measures in multiple dimensions that help develop a shared perspective to explain, compare and improve a farm's health status. It should incorporate the perceptions of stakeholders into management processes to reduce conflict and increase compliance with policy changes, but this is often overlooked [32]. It should help support claims that practices are a valid and reliable means of meeting regulator, social, and production expectations. We recognize that a growing number of aquaculture producers have best management practices and sustainability plans that are used to enhance social licence, but we also recognize that often, social licence is lost when health is characterized only as the absence of disease because of prevailing scientific uncertainties and high public risk perceptions about disease. An index of well-being that could draw on existing information to communicate health as a positive construct that balances social and ecological impacts and benefits, as opposed to relying on weighing wealth generation against disease hazards generation, may be a more socially relevant way to support a social licence to farm [33–35].

We propose that aquaculture health should be defined as a multi-sector and multi-disciplinary collaborative endeavour that uses evidence-based strategies and other approaches to engage and work with communities, in a culturally appropriate manner, to optimize the social, economic, and ecological health of the farm ecosystem.

To determine if a well-being focused index would be useful in aquaculture management, we use a case study of Atlantic salmon (*Salmo salar*) farming in British Columbia (BC), Canada. The case study approach "allows in-depth, multi-faceted explorations of complex issues in their real-life settings" [36]. This approach is used to capture information on: how might a healthy aquaculture approach be received on the ground, what gaps exist in its delivery, or why an implementation strategy may or may

not be chosen over another approach. Two of the first steps in organizational change are to identify the level of satisfaction with the status quo and determine if there is a receptive context for change. We accomplished this by reviewing publicly available monitoring and reporting information for Atlantic salmon farms in BC and through key informant interviews. Prior to these steps, we developed a conceptual framework for a well-being index that could inform the other methods.

2. Results

2.1. Conceptual Model

In total, 247 papers met the criteria for inclusion. Information most relevant to assessing well-being was extracted from 45 papers that were largely concerned with emerging concepts of fish health; principles of agroecology and sustainable aquaculture; and approaches to incorporating socio-ecological concepts into health promotion programs.

Emerging models of fish health characterized health as a cumulative effect involving multiple factors including: (i) the biological endowment of the individual and population; (ii) the animal's social environment; (iii) the quality and abundance of the needs for daily living; (iv) their abiotic environment; (vi) sources of direct mortality; and (vii) changing human expectations [27,37,38]. In this perspective, health is a positive construct that focuses on the capacities and ability to thrive and meet goals rather than a deficits model defined by what is absent (ex. diseases). This health perspective is compatible with ecological approaches to aquaculture which require aquaculture to account for a full range of ecosystem functions and services, without threatening the sustained delivery of these services to society, while also improving human well-being and equity for all relevant stakeholders [29]. This health perspective also melds easily with criteria for certification for sustainable aquaculture, such as Best Aquaculture Practices (BAP), requiring industry to address diseases, biological and environmental standards. Principles shared across agroecosystem health, the socio-ecological model of health and, sustainable or ecological aquaculture that informed the development of the conceptual model are summarized in Table 1.

Table 1. Summary of the principles of agroecosystem management and health including a socio-ecological approach to human health informing a conceptual model of an aquaculture index of well-being.

Principles	Dimensions of Aquaculture Well-Being
Multi-dimensional	Health is the cumulative effect of social, economic, and ecological dimensions. Each dimension is to be healthy in a way that contributes to the health of the other dimensions. Multiple methods are needed to evaluate the health and multiple perspectives to assess farm health status. Intersectoral collaboration and interorganizational partnerships are needed at all levels.
Collaborative	Partnerships, cooperation and responsible governance, involving different actors at multiple scales are important. Policies influencing health span sectors and need to be collaboratively developed. Indicators of health need to be developed, reviewed and updated in collaboration with stakeholders and right holders to increase trust, relevance and utility. Community participation and engagement is essential for planning and decision-making. Collaborative governance is needed to steer the processes that influence decisions and actions through communication and collaboration amongst the private, public, and civic sector.
Efficient	Social, ecological, and economic capital should all be maintained. Production should minimize ecological footprint by reducing waste and losses. Business should be viable with good long-term prospects. Rural livelihoods, equity, and social well-being should be protected and improved.
Safe	Social needs should be satisfied while retaining ecological function, safe workplaces and safe products. Diversity strengthens ecological and socio-economic resilience.
Fair	Rights and opportunity of current and future generations to benefit from resources should be protected. Farms must be socially responsible and contribute to fair distribution of benefits. Management must be aware of the socio-environmental context of operation.
Adaptive	Systems should be able to absorb external social and ecological disturbance. Interventions employing multiple strategies and actions at multiple levels and sectors are most effective.
Transparent	Assessing health status requires values, knowledge, and context. Reports and communications must draw on multiple lines of information from social, biological and traditional knowledge that are all available for review and comment.

An agroecological perspective pursues the multiple social and ecological purposes of aquaculture by optimizing interactions between plants, animals, humans and the environment to support food production and security while protecting ecosystem services and biodiversity, strengthening the economic viability of rural areas and promoting a social justice in food production [39]. Agroecosystems are therefore, coupled social-ecological systems that generate ecosystem services that benefit human well-being [39,40]. Healthy agroecosystems need to manage and care for the biophysical, economic, and human conditions of the system [41]. The health status of any of these three conditions can promote, reduce or unravel the health of the farm [40].

Effective implementation of the socio-ecological model of health perspective requires the use of multiple strategies, operating at multiple levels in partnership across sectors and including a combination of integrated actions to support each strategy [42]. While experience has shown that broad based, well networked, partnerships are needed to successfully implement a socio-ecological approach to health, building partnerships requires critical reflection that balances the burden of being overly inclusive with the inattention to social concerns that comes from partnerships that are too exclusive [43].

The principles in Table 1 were combined with key references [44–48] to nominate goals and guidelines for a proposed aquaculture index of well-being (Table 2).

Table 2. Goals and guidelines informing the development of a conceptual model of an aquaculture well-being index.

Goal	Guidelines
Promote social licence	Participatory process tailored to local context to inform the index development and assessment processes.
	Reported changes are understandable to a diversity of community members and have end user relevance.
	Augments but does not override other reporting requirements.
Characterize progress in achieving and improving farm health	Assesses a suite of separate facets of health to assess current conditions, document trends and changes, anticipate emerging threats, identify causes of change and identify interdependencies.
	Produces longitudinal information on a balance of health determinants and outcomes to catalyze management actions or policies for continual improvement.
	Reflects what beneficiaries want to achieve for a healthy farm.
Well founded on biological and social knowledge	Based on a sound conceptual model.
	Are feasible, sensitive to change and measure what they proport to measure.
	Weighted based on strength of correlation of the indicator with the actual health status of the farm.

Figure 1 integrates concepts from Tables 1 and 2 with the population health model and with agroecosystem health concepts to develop a logic model for an aquaculture well-being index. Figure 2 nominates some farm level variables that can influence the inputs into the logic model, and which could guide selection of well-being indicators. Tables 1 and 2, and Figures 1 and 2 were used as a basis for discussion during key informant interviews.

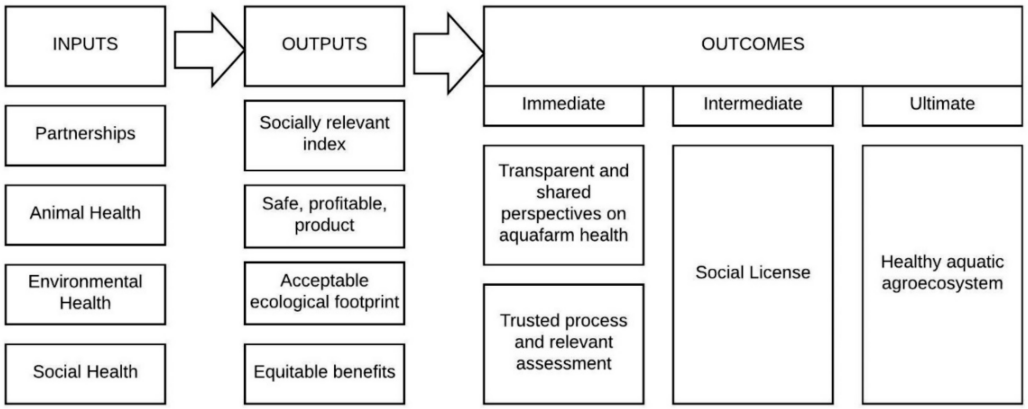

Figure 1. Logic model for an aquaculture well-being index.

AQUACULTURE FARM HEALTH INPUT ACTIVITIES		
ANIMAL HEALTH	SOCIAL HEALTH	ENVIRONMENTAL HEALTH
disease management	regulation	biological hazard control
disease prevention	worker safety programs	abiotic hazard control
animal welfare	community engagement	waste management
veterinary program	trusted communication	energy use
rearing environment management	resource use conflict management	habitat use and monitoring

Figure 2. Farm-level activities that can influence inputs in the logic model and provide data for to an aquaculture well-being index.

2.2. Case Study—Satisfaction with the Status Quo

News articles and blogs in 2017–2018 focussed on social conflict around four main themes of public discourse of aquaculture salmon health in BC: (i) diseases and parasites; (ii) contaminants; (iii) First Nations rights and title, and (iv) trustworthiness and transparency of information. Articles focussed on health were hazard focussed and no comprehensive assessment of health as a cumulative effect of social and environmental determinants could be found.

Conceptual saturation was achieved after interviewing eight informants. These included four representatives from the federal regulatory agency, three from the industry, and one from a provincial regulatory agency. Consistent replies were found in seven areas: (1) health issues were a major threat to social licence; (2) the absence of disease is emphasized as the defining feature of regulatory perspectives of healthy farms and fish, but economic health of the farm is implicit in the industry definitions of health; (3) a well-being index could support social licence, increase transparency and re-invigorate cooperative approaches to farm regulation and management but the lack of the necessary perspectives and people with skills to integrated social and environmental data were gaps to implementation; (4) all of the interviewees organizations collected information that could contribute to approximately 75% or more of the variables listed in Figure 2, but they all believed there could be challenges in nominating and negotiating thresholds of acceptable performance levels satisfactory to all stakeholders and right holders given the current level of social conflict about the industry; (5) the current approach to farm monitoring and reporting is inadequately synthesized across social, ecological, and abiotic perspectives and emphasized past performance rather than address future performance; (6) a healthy farm had to do no harm through the release of hazards, be a successful business and give back to the community

and society; and (7) it is currently no ones job to collect and integrate the diversity of information needed for a well-being index and it is not a regulatory requirement to do so.

Several respondents recommended that equitable benefits and profits be added under social health in Figure 2. Three respondents reflected that current health reporting requirements emphasize adverse outcomes (e.g., mortality) rather than reporting positive attributes (e.g., survival). The dynamic nature of the proposed well-being index and the need to tailor it to local expectations and conditions would require an adaptive approach to selecting the specific indicators and thresholds that would best meet needs.

2.3. Case Study—Readiness for Change

Aquaculture is regulated in BC both by Fisheries and Oceans Canada (DFO) and the province of BC. The province has authority over land and foreshore tenure. DFO is responsible for issuing aquaculture licences for marine finfish, shellfish and freshwater (or land-based) operations (https://www.pac.dfo-mpo.gc.ca/aquaculture/licence-permis/index-eng.html). Companies must operate in compliance with the Health of Animals Act, Food and Drugs Act and Species at Risk Act. As of 2018, DFO issued licences for up to 6 years for marine finish aquaculture operations. Licence conditions stipulate the operational and reporting requirements to operate legally and in compliance with the *Fisheries Act* and its regulations (https://www.pac.dfo-mpo.gc.ca/aquaculture/licence-permis/index-eng.html). Licence conditions include operational stipulations such as containment array requirements, reporting and administrative matters as well as reporting requirements such as sea lice counts and mortality reporting, escape prevention reporting and response (https://www.pac.dfo-mpo.gc.ca/aquaculture/licence-permis/docs/licence-cond-permis-mar/licence-cond-permis-mar-eng.pdf).

Many of the conditions are regularly checked or audited by DFO and self reported by the industry to the regulator. DFO reports to the public on many aspects of the operation of each active farm, particularly fish health. Data are available through the Open Government portal. Most public reporting is at the farm level including: fish transfer, carcass classification, fish health audit results, benthic monitoring results, marine mammal interactions, sea lice audit results, sea lice counts, antibiotic and pesticide use, escapees, incidental species, light intensity and a list of current valid farms including licencing numbers and location and site specific conditions. The number of audited farms and fish health samples collected is reported by quarter and the average monthly mortality rate is reported by fish health zone.

Although often difficult to navigate, the Government of Canada website does provide much information regarding the animal health pillar of Figure 2 except for animal welfare and their in-house veterinary program. They provide public access to farm-by-farm data on compliance measures related to animal disease. In terms of the social health pillar, they only provide information on the regulation of the industry and provide links to the various acts and other legislation related to the operation of an aquaculture facility in BC. Some environmental health elements are publicly reported such as benthic monitoring, pesticide use, and escapees. Weblinks to relevant acts and legislation related to environmental health are provided.

Two of the three-major Atlantic salmon producing companies operating in BC had some form of annual report or sustainability report, which was publicly available. The majority of sites operated by these companies had Best Aquaculture Practices Certification (BAP) and/or Aquaculture Stewardship Council (ASC) certification [49]. All three companies, therefore, have detailed information from all three pillars of Figure 2 available in documents posted on their websites. The level of detail available in the sustainability report varied. For example, Grieg Seafood is an international company and the annual sustainability report (2017) provided statistics such as mortality, antibiotic use and greenhouse gas emissions by area of operation whereas priorities and guiding principles were at a company wide scale. Marine Harvest Canada's integrated annual report (2017) was for the all aspects of operation including feed manufacturing, farming (six countries), sales, and marketing. The level of detail for BC operations was not as extensive as described for Grieg Seafood operations but, like the Grieg Seafood

sustainability report, significant effort was made to detail the social health initiatives specific to the province. Environmental health indices were largely reported for the whole of Marine Harvest not in detail for BC, the data however would be collected in order to be reported as a whole. Cermaq Canada did not have a sustainability or annual report readily available on their website but did post all data that they supply to DFO for public reporting and described many aspects of the animal, social and environmental health listed in Figure 2, many of which are outlined in company policies and guidelines. These sources of information demonstrate that all three companies value the collection, use, and dissemination of information to support their social licence to operate.

The BC salmon farming industry had multiple regulatory and voluntary reporting requirements and there were concerns expressed by key informants that, unless the proposed index synthesized or integrated multiple current requirements, this could become just one more element to report. There would be a need to tie the index to actions to make it useful; a concern given the stated opinions of some key informants that existing reporting requirements are insufficiently used to improve policies and practices. An industry representative expressed some concern that the current reactionary approach by government might not be conducive to a more proactive and well-being focussed approach outlined in the proposed index.

3. Discussion

Aquaculture health should be defined as a multi-sector and multi-disciplinary collaborative enterprise that uses evidence-based strategies and other approaches to engage and work with communities, in a culturally appropriate manner, to optimize the social, economic, and ecological health of the farm ecosystem. Despite this proclamation, there is little guidance on how to implement agroecosystem health and socio-ecological health management concepts into practical aquaculture advice. Stephen et al. (2008) [50] concluded that the regulatory and management focus on diseases as the paradigm for BC salmon farming health was an obstacle to creating a sustainability-based health management system. Howlett and Rayner (2004) [51] similarly proposed that the policy environment for the Canadian shellfish industry was based on an outdated, production-based model of earlier eras rather than developing policies that not only promote industrial activity, but also provide social legitimacy for the industry. A more integrated assessment of farm health as a socio-ecological entity is required to develop sustainable aquaculture and agriculture [52]. The proposed aquaculture well-being index could be a means to inspire dialogue on how to shift from health as hazards management to health as a collective and shared good that is collaboratively developed and protected.

This preliminary study suggests that the BC Atlantic salmon farming industry is primed to develop a well-being index. Our key informants all saw value in an index of well-being, and many viewed it as being compatible with emerging plans for area-based management of the industry. Although many of the elements to inform such an index are already being collected, there would be challenges to: overcome the industry's feeling of over-regulation; negotiate specific indicators that would address local contextual expectations; and secure the necessary skills and knowledge to reliably integrate and assess the diversity of information in a helpful and meaningful way. If successfully implemented, an aquaculture well-being index could be used to: (i) assess the capacity of a farm to perform its essential social, economic, and ecological services; (ii) identify and communicate critical gaps and accomplishment in performance, (iii) re-frame the dialogue on health away from disease risks to a balance of contributions to the community, ecosystem and society, and (iv) allow scrutiny thus driving a farm to continual improvement.

We began this process by recognizing the following principles for the implementation of a future aquaculture well-being index: (i) social licence is about perceptions and preferences, therefore the index must be people oriented; (ii) health is both an measurement of outcomes and capacities, therefore an index needs to assess current states and future capabilities; (iii) an index is used for comparisons, therefore, must be longitudinal and sustainable investment in its development and operation. Criteria

and indicators to assess farm health must, therefore account for the way companies, communities and governments expect the aquatic agroecosystem to perform [53].

A healthy farm can realize its profits and maintain functions desired by society while protecting the structure and resilience of its ecosystem over a long time. Such a perception of health requires an expansion of approaches used to document, manage, and improve health. Without a standard reporting framework, government, industry, and other interested parties cannot learn what initiatives work best, resources cannot be guided toward the most promising strategies, and there is little ability to promote accountability. A high-level perspective of health that spans socio-economic, disease and ecological domains may help set a foundation for a policy vision, but an operational definition needs to specify the process and properties that establish health status if it is to be used for measurement, management, research, and evaluating interventions [54]. Failing to specify how one recognizes health leaves one open to criticism for failing to reach achieved goals or ensures that goals are imposed rather than developed to meet the needs of sustainable aquaculture.

The issues facing the BC Atlantic salmon farming industry are not unlike other aquaculture sectors. For example, the assessment of sustainable development indices for Sri Lankan shrimp farming, which has struggled with a variety of health issues, found it necessary to integrate farm level social and environmental issues with disease information to identify best management practices [55]. Most attention on the positive contribution of aquaculture internationally has been directed toward its capacity to improve livelihoods, while most criticism has been directed toward conflict over shared resources and damage to common environments [23]. The lack of a shared set of evaluation criteria across countries and aquaculture sectors hampers attempts to find generalizable lessons on how to maximize social licence through integrated health management planning. However, the general principles presented in our conceptual model were applicable to the BC Atlantic salmon farming industry and may serve as a foundation for re-assessing the approach to health in other aquaculture production settings.

4. Materials and Methods

4.1. Developing a Conceptual Framework

A scoping literature review was conducted and summarized according to standard methods [56]. We searched for the terms "health, aquaculture, shrimp, salmon, shellfish, policy, agroecology, health promotion, socio-ecol* and sustainab*" alone or in combinations using Google, Google Scholar and the USearch search engine through the University of Saskatchewan's library. The USearch search engine has access to a variety of databases, including those commonly used in biology research including Web of Science, Ovid, and Scopus. We limited results to peer-reviewed journal articles published between 1990 and 2018 in English. Relevance screening was undertaken by only including papers that discussed aquaculture health programs or polices or papers that were relevant to establishing principles or practices for implementing socio-ecological health management or sustainable agriculture/aquaculture programs. Relevance screening was further guided by Wilburn and Wilburn (2011) [57]. Relevance screening was determined by reviewing abstracts.

4.2. Assessing Satisfaction with the Status Quo

To assess how fish health is perceived in BC, we undertook a Google search on "aquaculture salmon health British Columbia" to find news articles, blogs, and other popular grey literature to gain insight into the conversation in the media and general public perceptions on the topic. Key informant interviews were undertaken with aquaculture managers and leaders whose authority or responsibility included implementing, assessing and communicating salmon farm health information to government, industry and/or the public. As the goal of this study was to determine the usefulness of an index of wellbeing for aquaculture management, key informant selection was initiated by purposefully identifying people whose positions in the industry or government indicated these responsibilities.

Snowball sampling [58] was then used to identify other key informants. Interviews were continued until saturation was reached. Saturation is the point at which information from new participants provides no new insights and/or replicates or is redundant to ideas and information presented by earlier participants [59]. Thematic analysis was used to identify patterns and themes within and across interviews and we were guided by the methods of Clarke and Braun (2017) [60].

A consistent set of 10 guiding questions was used to direct open-ended interviews. The questions focussed on how the interviewee's organization defined and measured health at a fish and farm level, how health was integrated into sustainable development programs, how health affected social licence, if their existing programs and capacities could contribute to the proposed conceptual framework and if the framework, if implemented, could be helpful.

The BC salmon aquaculture industry is dominated by the production of Atlantic salmon (83.1 thousand tonnes in 2017) with some Pacific salmon culture (2.6 thousand tonnes in 2016) [61]. As of November 2017, there were 118 valid marine finfish licences in BC. Although many of these licences are permitted to produce multiple species, there are primarily three companies holding most licences (104/118 licences) and they routinely cultured Atlantic salmon (https://open.canada.ca/data/en/dataset/522d1b67-30d8-4a34-9b62-5da99b1035e6). As three companies are responsible for most of the salmon production in the province and, fish health was largely regulated by two government agencies, the sample size was by necessity small but reflective of the industry at the time of this study.

4.3. Examining Readiness for Change

The ability to re-purpose or re-apply existing information to address elements of the conceptual framework was assessed in part through key informant interviews and in part by examining what information Atlantic salmon farming companies are required to supply to meet regulatory requirements or what they voluntarily present in their sustainability or public reports.

5. Conclusions

In reviewing the literature, it is evident that there is a need to move toward a more comprehensive index of well-being for the management of aquaculture as has begun in terrestrial production systems. The case study demonstrated the desire of the BC Atlantic salmon farming community to adopt such an index although the details would need to be trialed in a study to determine feasibility, applicability, and cost of implementation. As a concept it was readily accepted and thought to be helpful for increasing social licence.

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