A General Framework for Measuring and Reporting Sustainability of the Aquaculture Industry

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Abstract. It has been a paradigm shift for the aquaculture industry in the current parallel era of circular economy, green shift, and Industry 4.0. As one of the world's largest industries with a long-lasting and significant influence on global prosperity, national economy, food safety, and public health, the importance of sustainability of the aquaculture industry cannot be underestimated. One of the challenges that dominate and hinder the industry's sustainable development is its lacking a common measurement structure and benchmarking tools. An in-depth analysis of existing measurement frameworks and/or standards, as well as accessible sustainability reports, is conducted, and the authors propose thereafter a general framework for measuring the sustainability in aquaculture in the context of an aquaculture supply chain.

Keywords: aquaculture, sustainability, supply chain, measurement and reporting framework

1 Introduction

The estimate that the world population will increase from today's seven billion to ten billion by 2050 triggers an emergent need to increase food production in the context of the current emphasis on human-centric development under sustainability[1]. This increased food production is also expected to meet more strengthened health and safety requirements for combating the growing challenges of malnutrition, obesity and fair distribution in a global perspective.

Seafood is one of the most important protein sources with well-recognized multi-beneficial health effects. Currently, according to World Wildlife Fund, approximately half of the current world population (three billion people) rely on wild-caught and farmed seafood as a primary source of protein. While growing demands for seafood have placed increasing pressure on wild fish populations, aquaculture provides an innovative substitution. In fact, aquaculture surpassed wild fish catch in volume already from 2013[2] and it is forecasted a more than doubling of marine aquaculture production from 30 million tonnes gross weight per year today to 74 million tonnes in 2050[3]. This envisaged growing production rate challenges the current aquaculture industry (AqIn) in many ways, from taking up cutting-edge technologies at all instances in a

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company and its extended activities in the whole supply chain, to a holistic measurement and benchmark of the company's and its supply chain's sustainability. The latter is particularly important in the sense of safeguarding the social and environmental sustainability of the AqIn is not at expense of a strong desire of rapidly increasing seafood production nor its accompanying economic wealth.

For AqIn, this holistic measurement of sustainability is of crucial importance for its global competitiveness, both in short- and long-term perspectives. A company needs the measurement to direct its business towards all three perspectives of sustainability, unbiased, and targeting customers with increasing awareness and consciousness of food safety, as well as reducing the industry's footprint on environment and societal commitments. The company is also obligated to comply with the increasingly stringent regulations from national and international authorities and needs often to respond to public query from environmentally and socially oriented NGOs.

This paper aims to provide a general framework for measuring sustainability of aquaculture industry. This purposes to offer a common, clear and easy-to-handle system to AqIn when sustainability needs to be measured and reported. The authors start with historical recursion of aquaculture industrial development in parallel with the development of concept of sustainability. This is followed by an exploration of aquaculture industry and its application of Industry 4.0 technologies aiming at conclusion of needs for measurement and reporting standards for directing AqIn towards sustainability. The authors have also explored the existing dominant certification standards in order to argue the needs and potential for improvement. A general framework to facilitate AqIn companies' sustainability measurement and reporting is suggested. The final part of the paper concludes the work in this study with suggestions for future work.

2 Aquaculture Industry: Sustainability and Technology Adoptation

It is said that the history of aquaculture can be traced back to the ancient China around 3000 BC with the ancient Rome as the follower in Europe[4]. The concept of aquaculture is very much expansive, with those reared as food for human consumption (i.e., finfish, shrimp, and mollusks), to those for ornamental purposes[5]. While the traditional AqIn normally concentrates on the same location of production as of consumption, the modern AqIn has a distinct geographical production and consumption pattern. Most of the production of the aquaculture species takes place in the developing nations whereas the consumption happens in the developed nations[6]. As the transportation distance between production and consumption has increased steadily due to increasing globalization, it is a great challenge to ensure product safety and quality in all processes and activities in the supply chain since "a supply chain is as weak as its weakest link".

The concept of sustainability is also central for AqIn. It was Brundtland Commission's report from 1987 that defined sustainable development is about taking care of the people living today and covering their needs without ruining opportunities for future generations[7]. To reach this, the United Nations (UN) developed sustainable development goals (SDGs) which must function as a common global direction for a country, industry, and civil society. The main pillars of sustainability are manifested in three

dimensions: economic, environmental, and societal. This definition of sustainability makes it clear that any economic growth should not come at the expense of environmental and social losses.

Many current researches have directed their attention to how AqIn's uptake of technological innovation, especially during Industry 4.0 – which can contribute to its performance improvement. Dupont, Cousin and Dupond [8] presented three European projects of water monitoring in aquaculture with the help of the Internet of Things (IoT) to reduce negative environmental consequence while increase user-friendliness and smartness. For AqIn, Industry 4.0 can be highly related with the knowledge from engineering and computer science coupled with multisensory schemes associated to online servers and/or workstations with the most appropriate software to manage and control the aquaculture system[9].

However, while Industry 4.0 technologies are proved to be highly applicable at AqIn, the connection between the technological implementation and the expected sustainable goals are not obvious. AqIn in general is struggling with different standards and certificate obligations and has difficulty in communication with general public regarding their sustainability performance. It is therefore of high relevance for the industry to develop a general framework that comply with current standards and certification requirements. This framework can then be applied to all companies in a supply chain to ensure performance compliance along the chain. The framework will also provide a common base that the sustainability of a supply chain can be measured and benchmarked with that of others.

3 Current Measurements and Benchmark Standards

With the production being spread out in the supply chain and the market elsewhere, not only for large corporates but also for small- and medium-sized enterprises (SMEs), are there a need for certification to ensure products meet sustainability requirement. The developed nations, such as the US and those in Europe, are markets that demand globally recognized certifications[10], [11]. These standard measurement criteria covers a wide range of factors such as product quality, production methods, sustainability, traceability and reporting methods[11], [12]. However, the focus of different standards varies based on multiple factors including their process of creation, stakeholders involved and etc.[13].

The most predominant aquaculture certification systems are Global Good Agricultural Practice (GLOBALG.A.P.) and Aquaculture Stewardship Council (ASC). While GLOBALG.A.P. is an Integrated Farm Assurance (IFA) standard for aquaculture covers finfish, crustaceans, mollusks, and seaweed for all types of farming systems, ASC standards are species-specific[14]. The GLOBALG.A.P. is also a voluntary international standard for food production, both in agriculture and aquaculture with a major focus on factors that comprises food safety, animal welfare, sustainability, employment and traceability[15]. ASC standards, however, set more requirements for processes and marginal values to minimize negative environmental and social effects from fish farming. Exploring into these certification systems, we identified following drawbacks:

- *Extensive work required*: the elaborate sections of control points to ensure sustainability as assessed by the standards are usually long, tedious and resource demanding and time consuming.
- *Resource dependence and exclusion of different groups*: because of the above-mentioned reason, only those resourceful companies can manage the process and therefore will exclude those who are less financially solid.
- *Third-party reliance questions dependence*: involvement of the third-party organizations to evaluate, inspect and measure control points set by the standards with less to no interference from the global standard organization, makes the evaluation less reliable.
- *Framed by stakeholders, mostly targeting the producers*: as the standards are framed as a result of discussions between stakeholders (with less produces/mostly corporate producers) and the dependence on the stakeholder's influence significantly varies, the results to form and update the standard is often targeted at the producers.

In short, both GLOBALG.A.P. and ASC standards provided a set of control points that are decided by the stakeholders in the standard setting committee. This is applied to benchmark best practices in the industry. However, at the present time, many SMEs' focuses of the standards depends on the stakeholders of the SME and not all stakeholders are conscious about the importance of the certificate. Moreover, the high cost of certification and certification process makes it less feasible for AqIn' SMEs.

Nevertheless, the need for standards in AqIn to promote sustainable supply chain is gaining exponentially increased importance. Although the existing certifications do not mean that the proposed methods are most sustainable, it is still important for these SMEs to equip themselves with measures and benchmarks so that such framework can direct their strategic and operational activities toward SDGs that associated to AqIn. This framework should also support stakeholders such as entrepreneurs, researchers and educational institutions with a quick and elaborate insights on the industry.

4 An Empirical Study on Current Sustainability Measurement and Reporting at Aquacuature Industry

This research explored and analyzed thirty-eight sustainability reports (see the detailed list in the appendix) stem from 29 companies, mainly from Norway, available in November 2021 – April 2022. A distribution of affiliations of these reports is as shown in Appendix 1.

What we observed from this empirical study is that companies were measuring and reporting sustainability with their understanding of the concept and focusing only on self-defined goals or core values. Moreover, not all companies publish sustainability report every year. There is lacking of the continuity and commitment to reporting due to reasons such as resource-shortage and lack of understanding of what to report. Poor performance in a particular year can also be the reason a company was reluctant to report in terms of sustainability. Therefore, the explored companies' sustainability report varied from contents and types of measurement and often exclude some important environmental and social factors.

The most predominant factors found from the study was related to the employee welfare, greenhouse gases emission and renewable energy adoption. In several fish feed manufacturing companies, most of the focus is on the supplier certifications such as sourcing from a certified producer producing fish oil, palm oil, fish species to manufacture fish feed for carnivorous fishes. They also shed some light on the resource utilization and emissions by the companies such as water utilization, wastes and disposal, GHG emissions etc.

Several companies these days have a method of reporting social sustainability as part of corporate social responsibility (CSR). In the recent times, there is an increased use of corporate sustainability (CS) reporting from the companies[16]. The CSR reporting is done as part of the corporate culture in several companies so as display the social responsibility the company holds. CSR is a framework that the company uses to report their behavior on the organizational, institutional and individual level[17]. Sometimes the corporates will also publish a sustainability report for the entire conglomerate where they own multiple actors in the supply chain.

At the moment, sustainability reporting is not a mandatory for AqIn SMEs. There are neither standard form for the reporting nor standard measurement framework. Different companies formulate therefore their sustainability reports (the appended list) differently. For instance, some companies have exclusive team inhouse for driving sustainable development and integrating this work with the company values creation and strategic development. Such companies usually publish a dedicated sustainability report. Other companies, however, publish their sustainability report as part of annual report.

Due to the lack of framework for sustainability reporting in the AqIn, benchmarking companies' sustainability is unattainable. And this motivates the work that presented in the following session.

5 A General Framework for Aquaculture Industry Sustainability Measurement and Reporting

For AqIn to meet the relevant SDGs and therefore ensuring its short- and long-term sustainability, it is of crucial importance to provide a sound, clear, and easy-to-handle framework for measuring and reporting its sustainability along supply chains, from breeding, ongrowing, processing and logistics and ensure that products are arrived at shelf in front of end-customers. This framework will include four categories of measures: environmental, social, economic, and administrative.

5.1 Environmental measures

Environmental aspect of the sustainability is a vital part of the sustainability reporting considered by most companies. In the proposed framework, we cover a wide range of aspects from ecosystem, resources management, biological and emissions. The purpose of this aspect is to develop the business without impacting the environment or utilizing as less resources as possible with best possible resource management. The

environmental factors that are covered are: (1) *Water* – water consumption, reuse and recycling, (2) *Land* – utilization of land and cover of plantations, (3) *Resources* – resources utilization and sustainable sourcing of the same, (4) *Disposal/ waste* – waste generates, reused and promotion of circular economy, (5) *Biological* – biological impact of the industry, (6) *Ecological* – ecological impact of the industry, (7) *Emissions* – GHG emissions by the industry and its supply chain.

5.2 Social measures

Social factor in a sustainable production means providing a quality life standards for the employees and the fishes. Several companies consider social factors as less significant or covers only the aspect of the employee's wellbeing. Moreover, the social factors are often considered with less traceable and qualitative information where the information is not as vital as it should be. In the proposed framework, the social sustainability factor is considered as vital as environmental and covers an extensive range of indicators to ensure wellbeing, diversity, safety and quality of life for not only the employees, but also the customers, humans involved and the fishes that are grown, maintained or processed. The social pillar of the sustainability covers the following aspects: (1) *Fish welfare* – quality of life for the farmed fishes and wild species during and after farming, (2) *Human welfare* – welfare of the general public to increase the standard of living, (3) *Workforce welfare* – employee's education, wellbeing, health and safety, diversity and inclusiveness, and monetary and other welfare benefits, (4) *Customer welfare* – customer health and safety.

5.3 Economical measures

The economical aspect of sustainability covers the factors that provide insights to the sustainability of the industry from a financial and longevity of the industry perspective. The major stakeholders that are interested in this set of factors are related directly or indirectly to the financial performance of the company or the value generation. However, this framework covers the interest of the industries that are involved with the AqIn directly or that can affect or affected by the industry. Moreover, this covers the factors that affects the financial performance of the industry that involves the product, quality etc. The predominant factors that are cover under this pillar are: (1) *Transportation* – transportation methods used to provide high level insights on the risk, cost, pollution etc. (2) *Conservation* of resources and products that affect the financial health, (3) *Impact* of the AqIn on other sectors, (4) *Operations* – industrial unit operations that affect the industry economically, (5) *Financial* health of the overall organization.

5.4 Administrative measures

We argue that it is important to add administrative dimension while measuring sustainability as it plays a decisive role in ensuring information transfer, transparency, and the availability of the resources such as human, technology and infrastructure. This part also ensures that the administration of the company has the basic requirements to

future-proof the developments in the industry. A fine method to ensure that the companies have the required technology to store database not only for reporting purposes but also for using the technology and data to make informed decisions. The administrative section was designed to ensure the aquaculture industry follows guidelines, rules and best practices within the following areas: (1) *Transparency* ensures transparency within the industry and the entire supply chain network, (2) *Traceability* maintains proper infrastructure and methods for tracing the sources of all products, funds and information in the entire supply chain network and includes reporting, (3) *Due diligence* steps taken to maintain an uncompromised, transparent reporting, (4) *Supplier and sourcing* – ability to identify, evaluate and utilize responsible sourcing, (5) *Governance* – compliance with local, national and international rules in sustainable production.

More detailed description of the proposed framework as well as method of sustainability index derivation is given in [18].

6 Conclusion and Future Works

The research presented in this paper analyzed two currently most established certification systems for measuring and reporting sustainability of AqIn. This analysis stated that GLOBALG.A.P. and ASC have their own focuses and strength in measurement, but both are complicated, extremely resource-demanding in practice. We suspect that smaller and resource-poor AqIn companies may not be able to utilize such systems. Our study on twenty-nine companies' practice in measuring and reporting their sustainability verified this suspicion and this leads to the needs of developing a clear, simplified and easy-to-handle framework for measuring and reporting sustainability of AqIn.

The suggested framework consists of four main categories of measurement and reporting. In addition to three categories of sustainability, a category 'administrative' is also suggested due to its importance in ensuring information transfer, transparency, and the availability of the resources such as human, technology and infrastructure. This is simply as it is said that 'what gets measured gets done'.

The future work to follow include to further develop measures in each category. Case studies at AqIn companies and its supply chains are also needed for the purpose of verify the soundness and applicability of the framework.

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Appendix. Sustainability reports and their industrial affiliation

S.no	Company	Year	Industry	Website/link to the report
1	Austevoll seafood	2020	AqIn	Sustainability report - Austevoll Seafood ASA (auss.no)
2	Avanti	2020	AqIn	Sustainability - Avanti Feeds
3	Bama	2021	FMCG	Sustainability - Bama
4	Biomar	2020	AqIn	Sustainability | BioMar
5	Cargill (2 reports)	2017, 2018	AqIn	Sustainability at Cargill | Cargill
6	Cermaq (3 reports)	2018,2019,2020	AqIn	Sustainablity - Cermaq Global
7	DNV	2019	Consulting	DNV Marine Aquaculture Forecast: Oceans' future to 2050 - DNV
8	EY Norwegian AQC analysis	2019	Consulting	The Norwegian Aquacultyre Analysis 2019 (ey.com)
9	Farmforce	2020	Edibles	Farmforce - Tackling Food's First Mile
10	Grathanglaks	2019	AqIn	Sustainability | Gratanglaks
11	Grieg seafood	2017	AqIn	How we work to improve (griegseafood.com)
12	Leroy (4 reports)	2015,2016, 2019,2020	AqIn	Sustainability report 2019 (leroyseafood.com)
13	Lisaqua	2021	AqIn	LISAQUA - Low-Impact & Sustainable Aquaculture
14	Mars	2019	FMCG	2019 EOY Review: Purpose, People Power, & Partnership | Mars, Incorporated
15	Måsøval	2020	AqIn	Reports and presentations (masoval.no)
16	matvett	2020	AqIn	Food-waste-reduction-in-Norway-2020.pdf (matvett.no)
17	Mowi (2 reports)	2019,2020	AqIn	Mowi's 2019 Annual Report - Mowi Company Website
18	Nireus	2016	AqIn	Nireus Aquaculture - ResponsibilityReports.com
19	Nordkalk (2 reports)	2019,2020	Manufacturing	Sustainability — Nordlaks
20	Norgesgruppen	2020	FMCG	ng-annual-sustainability-report-2020.pdf (norgesgruppen.no)
21	Nova sea	2019	AqIn	Sustainability report - Nova Sea
22	NRS	2020	AqIn	ASC-certified salmon from Norway (norwayroyalsalmon.com)
23	Nutreco roadmap for 2025	AqIn	RoadMap 2025 - Nutreco Corporate	RoadMap 2025 - Nutreco Corporate
24	Orkla	2019,2020	AqIn	Bærekraft – Orkla

25	Phillip morris	2018	Manufacturing	pmi-sustainability-report-2018.pdf
26	Rema 1000	2020	FMCG	CSR reports | REMA 1000
27	Salmo Arctica	2020	AqIn	Sustainability (salmofood.cl)
28	Skretting	2018	AqIn	Sustainability - Skretting
29	Unilever	2021	FMCG	Sustainability reporting centre | Unilever