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Balancing sustainability and growth: How effective is the governance of the Norwegian salmon farming?

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Abstract

This thesis evaluates the governance effectiveness of the Norwegian salmon farming industry, analyzing how regulatory frameworks, stakeholder dynamics, and technological innovation address sustainability and growth challenges. Combining documentary analysis and stakeholder interviews, it assesses current mechanisms and the Aquaculture White Paper (Meld. St. 24 (2024-2025))'s potential to ensure long-term industry viability. Section 2 examines Norway's licensing regime and traffic light system, which aim to promote sustainable growth but face enforcement inconsistencies and adaptation challenges. Section 3 explores stakeholder perceptions of the White Paper. While it offers environmental and welfare improvements, its predictability for growth is debated. An unclear socio-economic model and divergent views highlight the need for inclusive governance and better knowledge-sharing. Finally, section 4 investigates BiOceanOr's oxygen monitoring system, demonstrating how real-time data and predictive analytics can enhance environmental management. However, supportive policies are critical for widespread adoption. Key findings are that (1) simpler and coordinated regulations are essential for effective governance, (2) the White Paper's success depends on clear implementation to balance growth and sustainability, and (3) BiOceanOr's technology could bridge governance gaps by enabling proactive compliance, improving fish welfare, and fostering evidence-based decisions.

Key Words: Sustainability, Growth, Governance effectiveness, Norwegian salmon farming, Aquaculture White Paper (Meld. St. 24 (2024-2025)), Stakeholder perceptions

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List of abbreviations

Abbreviations	Definition
ACS	Grouping of concessions for salmon aquaculture [*Agrupacion de Concesiones para la Salmonicultura*] in Chile
ASC	Aquaculture Stewardship Council
BW	BarentsWatch
BtoB	Business-to-business
BtoG	Business-to-government
DO	Dissolved oxygen (in water), expressed in concentration (mg/L) or percentage of air saturation (%)
DoF	Directorate of Fisheries [*Fiskeridirektoratet*], agency of the Norwegian Ministry of Trade, Industry and Fisheries
ENGO	Environmental non-governmental organization
FAO	Food and Agriculture Organization of the United Nations
FHF	Norwegian Seafood Research Fund [*Fiskeri- og havbruksnæringens forskningsfinansiering*]
GS	Governing system
HAB	Harmful Algal Bloom
IMR	Institute of Marine Research [*Havforskningsinstituttet*]
MAF	Ministry of Agriculture and Food [*Landbruks- og matdepartementet*], Norwegian ministry with chief responsibility for food policy and agricultural policy
MAB	Maximum Allowable Biomass
MCE	Ministry of Climate and Environment [*Klima- og miljødepartementet*], Norwegian ministry responsible for carrying out the environmental policies of the government
MLGRD	Ministry of Local Government and Regional Development [*Kommunal- og distriktsdepartementet*], Norwegian ministry responsible for the Planning and Building Act, local government finances and local administration, rural and regional policy, and other related responsibilities
MTIF	Ministry of Trade, Industry and Fisheries [*Nærings- og fiskeridepartementet*], Norwegian ministry responsible for the trade, industry, and ocean policy
NASF	North Atlantic Seafood Forum
NEA	Norwegian Environment Agency [*Miljødirektoratet*], agency of the Norwegian Ministry of Climate and Environment
NFSA	Norwegian Food Safety Authority [*Mattilsynet*], joint agency of the Norwegian Ministry of Agriculture and Food, the Ministry of Health and Care Services, and the Ministry of Trade, Industry and Fisheries
NOBF	Nice Ocean Business Forum
NSC	Norwegian Seafood Council [*Norges sjømatråd*]
PO	Production zone or area [*produksjonsområde*], refers to the 13 production zones defined in the TLS
SaaS	Software-as-a-Service

SDGs	Sustainable Development Goals (United Nations)
SG	System-to-be-governed
SLO	Social license to operate
SMA	[*Superintendencia del Medio-Ambiente*], agency of the Chilean Ministry of the Environment
SMEs	Small and medium-sized enterprises
TLS	Traffic Light System, refers to the regulatory system currently regulating growth of the Norwegian salmon aquaculture
UNOC3	3rd United Nations Ocean Conference
VI	Norwegian Veterinary Institute [*Veterinærinstituttet*]
WP	Aquaculture White Paper "The Future of Aquaculture – Sustainable Growth and Food for the World" [*Meld. St. 24 (2024-2025) "Fremtidens havbruk – Bærekraftig vekst og mat til verden*"]. *NB*: "WP" specifically refers to this particular Aquaculture White Paper.

1. Introduction

1.1. Context and definitions

The importance of the Norwegian salmon farming industry

The Norwegian salmon farming industry has experienced rapid growth since its beginning in the 1960s (Hersoug, 2021), establishing Norway as a **global leader** in aquaculture. Norway produces over half of the world's Atlantic salmon, *Salmo salar* (hereafter: salmon), yielding approximately 1.5 million tonnes of salmon annually since 2021 (MTIF, 2025a; **Appendix 1**). The industry is characterized by its industrialized and capital-intensive nature (Liu, Chuenpagdee, & Sumaila, 2013), dominated by multinational companies such as Mowi, SalMar, Lerøy Seafood, and Cermaq, which collectively control the majority of the production capacity (MTIF, 2025a).

Moreover, the industry strongly supports the Norwegian economy. In 2023, Norway set a new record for salmon exports, valued at NOK 122.5 billion. It is the **second-largest export sector** after oil and gas. The record was driven by a weak krone, but it still highlights the strength of Norwegian seafood abroad (NSC, 2024).

Sustainability and growth goals

Sustainability and growth are pivotal goals for the Norwegian salmon farming industry. However, the industry faces significant environmental challenges, including **sea lice** (*Lepeophtheirus salmonis*) and **fish escapes** from open net-pens, which pose threats to wild fish stocks (Grefsrud *et al.*, 2025; Thorstad & Forseth, 2025; MTIF, 2025a). Sea lice are parasitic copepods that attach to salmonids, causing wounds and increasing susceptibility to infections. The increasing production in open net-pens has exacerbated the spread of sea lice, impacting both farmed and wild salmon populations (IMR, 2018). Treatments for sea lice, while necessary, can compromise the welfare of farmed fish, further complicating sustainability efforts. **Fish welfare** is a growing concern for stakeholders. The national fish mortality rate has risen, reaching 16.7% in 2023, which translates to 62.8 million dead farmed salmon during the sea phase (**Appendix 2**; Sommerset *et al.*, 2024). These challenges have contributed to a negative public perception of the industry, affecting its social acceptance and highlighting the need for improved sustainability practices (Eriksen & Mikkelsen, 2024).

The Norwegian government has set ambitious targets for the industry, aiming for **sustainable aquaculture by 2030** and aligning with the 2030 Sustainable Development Goals (SDGs) (FAO, 2024). Efforts to achieve these goals include reinforcing environmental regulations and reducing fish mortality rates. The Aquaculture Act stresses that aquaculture must be “operated in an environmentally sound manner” (Aquaculture Act, 2005), and the Norwegian government aims at **reducing the fish mortality rate dramatically down to 5%** for all fish species in aquaculture. However, the timeline and methods for achieving this remain uncertain (MAF, 2024; MTIF, 2025a).

Additionally, the industry and government share ambitious growth targets, **envisioning a fivefold increase in the value of the seafood sector by 2050** compared to 2010 (Misund & Tveterås, 2019). Growth should contribute to providing sustainable food to a growing global population and supporting Norway's transition to a "post-oil" economy (Misund & Tveterås, 2019; Johansen *et al.*, 2019). Aquaculture is also expected to stimulate coastal development and employment (Aquaculture Act, 2005; MTIF, 2025a). However, since 2012, the production of salmon and rainbow trout has slowed down (**Appendix 1**). Achieving the fivefold increase in production seems impossible with the classic open net-pens technology, making innovation and new production methods essential for industry growth (Larsen, Jakobsen, & Steinmo, 2025).

Governance and the Aquaculture White Paper (Meld. St. 24 (2024-2025))

Effective governance is essential for balancing sustainability and growth in the salmon farming industry (Hersoug, 2021). The current regulatory framework includes tools such as the Maximum Allowable Biomass (MAB) at firm and site levels, production and locality licenses, and the Traffic Light System (TLS) for regulating growth based on the impact of sea lice on wild salmon stocks (Aquaculture Operation Regulations, 2008; Jensen, Tveterås, & Nielsen, 2024; Aquaculture Act, 2005; Trafikklyssystemet, 2025). It is debated for its effectiveness in creating a good environment for sustainability and growth. The framework is seen as **complex**, with a lack of environmental sustainability, which in turn makes the industry less socially acceptable (Hersoug, 2022).

To address these challenges, the Norwegian government (hereafter: "government") published an **Aquaculture White Paper** (WP) in April 2025, proposing radical changes to the regulatory framework (MTIF, 2025a). The WP includes a new sea lice regulation system and a different licensing regime, aiming to improve sustainability and growth. However, the WP's ability to achieve these goals is questioned by several stakeholders, reflecting the complexities of governing a rapidly evolving industry. The Norwegian parliament (hereafter: "parliament" or "Storting") has called for further assessment of the WP's consequences and the introduction of a technology-neutral "Environmental Technology Scheme" (*miljøteknologiordning*) (author's transl.) by autumn 2025 (Stortinget, 2025).

Key concepts and definitions:

Sustainability, in the context of this study, is defined broadly, encompassing environmental, social, and economic dimensions. It aligns with the Brundtland Report's definition of sustainable development (Brundtland, 1987), meaning that the industry and its activities as a whole should be understood as interlocked with the surrounding social and political, natural, and economic environment (Christiansen & Jakobsen, 2017). In particular, **environmental sustainability** is discussed as the level of overall environmental impacts of aquaculture, as well as the extent to which the production cycle eliminates waste and pollution (Schøning, Hausner, & Morel, 2023; Ellen MacArthur Foundation, 2013). This holistic approach to sustainability is crucial for understanding the interconnected challenges and opportunities facing the Norwegian salmon farming industry.

Governance refers to the act or process of governing or overseeing the control and direction of an entity, in this case, the aquaculture industry (Merriam-Webster, n.d.). Governability, the overall quality for governance, includes the processes, institutions, instruments, actions, and resources that together contribute to making the coastal space and actors governable (Jensen, Sønvisen, & Johnsen, 2025). Governability consists of three main components:

- a **governing system (GS)**, in this case, the institutions and regulatory tools and mechanisms;
- a **system-to-be-governed (SG)**, in this case, the aquaculture industry, other users, and stakeholders of the marine environment and nature itself (Osmundsen *et al.*, 2022);
- and the interactions between these two (Kooiman, 2008).

Finally, **innovation** refers to the introduction of new ideas, methods, or technologies that create value. **Business innovation activities** include all developmental, financial, and commercial activities undertaken by a firm that are intended to result in an innovation for the firm (OECD/Eurostat, 2018). **Innovation ambitions** relate to how firms approach short- and long-term perspectives of innovations influenced by present and future regulations (Larsen, Jakobsen, & Steinmo, 2025). While the grow-out phase primarily occurs in open net-pens (inshore), innovative production technologies such as offshore farming, closed-containment systems, and land-based recycling aquaculture systems are increasingly being adopted (Afewerki *et al.*, 2022; Jensen, Sønvisen, & Johnsen, 2025; Føre *et al.*, 2022).

1.2. Problematic and objectives of the study

This master's thesis explores **the governability of the regulatory framework of the Norwegian salmon farming industry from the perspective of various stakeholders**. The research aims to address the following questions:

- How can the governance of the Norwegian salmon farming industry enable predictable and sustainable growth, according to the stakeholders?
- How do stakeholders perceive the future governance of the industry, particularly in light of the recently published WP?
- In this global context, how can a firm like BiOceanOr deliver value to the industry?

The study seeks to understand stakeholder reactions to regulatory changes and the differing interests among participants. It provides insights into the strategies required to govern the salmon farming industry effectively, particularly within the framework of the WP process.

Companies like **BiOceanOr**, operating in this dynamic context, must integrate regulatory changes into their strategic planning to effectively target and capitalize on emerging opportunities. BiOceanOr is a technology company that leverages the Internet of Things and machine learning, combined with oceanography and biology, to offer "bio-guided services" and support decision-making, particularly in the aquaculture sector. The company has developed a Software-as-a-Service (SaaS) suite named AquaREAL, which delivers real-time and predictive analytics for water quality (BiOceanOr, n.d.).

Currently, BiOceanOr focuses primarily on predicting dissolved oxygen (DO) levels in the water column at aquaculture sites. In Chile, the company has initiated a project called PREDIMAR in collaboration with the Chilean Environmental Agency (SMA). This project aims to offer a data-driven solution for salmon farmers by forecasting dissolved oxygen variations up to 48 hours in advance on a regional scale (SMA, 2025). BiOceanOr aims to expand its presence in the Norwegian salmon farming industry. To achieve this, the company needs a deeper understanding of the industry's evolution and governance.

1.3. Methodology and structure of the work

The study employs a mixed-methods approach, combining literature review and **semi-structured interviews**. The literature review encompasses scientific and grey literature, news articles, websites, to provide a comprehensive understanding of the governance history, current regulatory framework, stakeholder relationships, and recent changes, including the WP. The interviews, detailed in **Appendices 3 and 4**, involve stakeholders from the GS and the SG of the Norwegian salmon farming industry. Anonymized interviews enable to create a relationship of trust thus collect views on sensitive subjects, and to establish contact between the interviewee and BiOceanOr for potential future partnerships. Interviews particularly allow the interviewee to develop its argument on relevant subjects. **Thematic analysis** is used to identify recurring themes and patterns in the qualitative data collected through interviews.

In addition, I participated in two business fairs with BiOceanOr to aid their business development: the North Atlantic Seafood Forum (NASF) 2025 and the Nice Ocean Business Forum (NOBF) as part of UN Ocean Conference 3 (UNOC3). By managing the booth alongside my colleagues at NASF, the world's largest seafood business conference (NASF, n.d.), I gained insights into the aquaculture sector's challenges, which helped contextualize my study and establish valuable contacts. I also visited three fish farming sites post-event, further grounding my research in real-world contexts. At NOBF, a significant event for the blue economy (Métropole Nice Côte d'Azur, 2025), I pitched BiOceanOr and engaged with various stakeholders. Overall, these experiences deepened my understanding of BiOceanOr's strategic vision and market opportunities within the Norwegian salmon farming industry.

The study is structured as follows:

- **Section 2** examines the current regulatory framework, its tools, and stakeholder interactions to understand the challenges and needs for governance changes.
- **Section 3** presents stakeholders' perceptions of the proposed future governance, focusing on environmental sustainability, fish health and welfare, industry growth, and the socio-economic model promoted in the WP.
- **Section 4** offers business and strategy-related propositions on how BiOceanOr can deliver value to the aquaculture industry in Norway.

This structure aims to address the research questions and provide a comprehensive analysis of the governability of the Norwegian salmon farming industry.

2. The current governance of the Norwegian salmon farming industry produces limited governability and requires changes

2.1. Licenses, MAB, taxes, and spatial planning are the main regulatory tools

Historical context and regulatory framework

The Norwegian salmon farming industry began in the late 1960s as a complementary activity for the fishermen (Afewerki *et al.*, 2022). Initially, the production volumes were very modest, around 500 tonnes of salmon and trout in 1970 (SSB, 1991). The first successful **net-pen**, introduced in 1970, represented a critical radical innovation that remains the most popular production method today (Afewerki *et al.*, 2022). This innovation sparked significant interest (Hersoug, 2021).

From the beginning, the authorities intend to use the new industry as a lever to support rural development as the rural coastal areas are facing severe challenges (Hersoug *et al.*, 2021). **Ownership** is thus an essential concept in the regulatory framework. To regulate the emerging sector, a temporary fish farming act, introduced in 1973, dealt with the issuing of **fish farming licenses** for salmon and trout (Hersoug, 2022). The licensing system was designed to create a small-scale industry, keeping large-scale industrial capital outside the new development, with the declared policy of "**one man, one license**" (Hersoug, 2021). The policy was to ensure regional development and secure local ownership (Liu, Chuenpagdee, & Sumaila, 2013). The industry continued to evolve, and in 1985, a new aquaculture act liberalized ownership regulations. This act removed the "owner-operator" principle, although maintaining that the owners must be "local" and must not control majority interests in more than one farm. In 1991, the ownership requirements are further liberalized, towards an "as far as possible" local ownership and permitting owners to have majority interests in several farms thus facilitating the growth of larger, more professionalized salmon farming companies (Hersoug, 2022).

The current **Aquaculture Act** [*akvakulturloven*] of 2005 aims to promote the profitability of the aquaculture industry while ensuring sustainable development. It sets out the conditions for obtaining a license to operate and stipulates that **aquaculture must be operated in an "environmentally sound manner"**. This act regulates aquaculture overall, including both aquatic animals and plants, and is designed to balance economic growth with environmental protection (Aquaculture Act, 2005).

The **Aquaculture Operation Regulations** [*akvakulturdriftsforskriften*] of 2008 further emphasize the importance of creating value on the coast, ensuring good fish health and welfare, and preventing and limiting pollution and waste problems from aquaculture operations (Aquaculture Operation Regulations, 2008). The interviewees highlight several key principles of the regulations, including it being "***knowledge-based***" (Regulator 5; Regulator 6; Market player 1) and "***technology-neutral***" (Regulator 5; Regulator 1; Regulator 6). The principle of technology neutrality is particularly important, as it allows for innovation and flexibility in the industry, but **Section 3** of this study shows that this principle is questioned by the interviewees.

Licenses

Aquaculture licenses have been a cornerstone of the regulatory framework since 1973 and are solidly entrenched in the governance of the industry. These licenses are twofold: **production licenses**, which give the opportunity to have a certain production volume stated as tonnes of MAB at any time, and **site (locality) licenses**, which give the opportunity to produce in a given area according to the coastal zoning plan of the given municipality (Hersoug, 2022). Both types of licenses are required to farm fish. As environmental concerns rose in the 2000s due to sea lice and escape events, the regulation adapted to better manage these environmental challenges. To promote the development of new technology to alleviate the negative environmental impact of fish farming, **special purpose licenses** have been introduced gradually since 2013 (Osmundsen *et al.*, 2022). These include licenses for research, exhibition, and education (DoF, n.d. a). Furthermore, **"green" licenses** were introduced in 2013 as ordinary licenses, while **"development" licenses** were introduced in 2015 as special purpose licenses, both with focus on environmental risks and technological innovation in fish farming (Osmundsen *et al.*, 2022; Larsen, Jakobsen, & Steinmo, 2025). Examples of innovations include lice skirts, traps, filters, laser technology, and vaccinations (Afewerki *et al.*, 2022).

However, with many types of licenses that differ in terms of purpose, management, and restrictions, Hersoug argues that the licensing regime has increased significantly in the period 1973-2021, thus making the system overall very complex and difficult to control (Hersoug, 2022). The licensing regime is seen as an administrative burden with long-lasting award processes that lack transparency and predictability (Osmundsen *et al.*, 2022). Jensen, Sønvisen, and Johnsen also underscore the complexity of the coastal governance system thus the complexity of introducing innovative technology (Jensen, Sønvisen, & Johnsen, 2025).

Maximum Allowable Biomass

The MAB is a key regulatory tool in place since 2004. It is defined as the maximum biomass of live fish that can be kept at any given time on one locality (Aquaculture Operation Regulations, 2008). The introduction of MAB was supported by science, administration, and farmers' organizations, with the main arguments in favor being improved fish welfare and biological sustainability, relative ease of control, increased flexibility, and robustness regarding political and market conditions (Hersoug, 2021).

The MAB is restricted at both firm and farm site levels as described in **Appendix 5**. Each firm owns a number of licenses with a specified MAB, which detail the farm site and production area where the license can be used. Usually, firms own a higher total MAB at farm site level than at firm-level. In fact, this is necessary to achieve sufficient MAB capacity utilization at firm-level since firms must have fallowing periods with no production at a farm site (Jensen, Tveterås, & Nielsen, 2024). Historically, local differences in Norway have been considered with the MAB by setting the standard license to different tonnages based on regional water temperatures and growth rates. For example, the standard license is set to 945 tonnes in Troms and Finnmark due to lower water temperatures and slower growth, and to 780 tonnes everywhere else (DoF, n.d. b; Hersoug, 2021).

The MAB system is designed to ensure that fish farming operations do not exceed the carrying capacity of the environment. It provides a mechanism for controlling the density of fish in net-pens, thus contributing to improving fish welfare and biological sustainability. The MAB also allows for flexibility in response to changing market and environmental conditions, making it a robust regulatory tool (Hersoug, 2021).

Spatial planning and coastal development

Coastal municipalities and county municipalities play a key role in the GS of the Norwegian salmon farming industry. The **Planning and Building Act** of 2008 gives these municipalities the responsibility for managing coastal space through coordinated water and coastal zone planning (Planning and Building Act, 2008; Jensen, Sønvisen, & Johnsen, 2025). They decide to what extent they want to allocate space for aquaculture and where, ensuring that the industry is integrated into the broader coastal management framework. Planning becomes an essential activity in the Norwegian aquaculture governance system (Jensen, Sønvisen, & Johnsen, 2025). This planning process is essential for balancing the needs of the aquaculture industry with other coastal activities, such as tourism, shipping, and conservation. It involves a range of stakeholders, including local communities, environmental organizations, and governmental agencies, who work together to develop comprehensive coastal zone plans.

To ensure that municipalities and county municipalities benefit economically from welcoming salmon aquaculture in their coastal waters, an **Aquaculture Fund** (*Havbruksfondet*) was established, with its first payments made in 2017 (DoF, n.d. c; Misund *et al.*, 2023). The fund is financed through a fee on the production of salmon, trout, and rainbow trout, and it distributes a share of these fees to the municipalities based on their shares of the site production capacity. The municipalities receive 80% of the fund, while the county municipalities receive the remaining 20% (DoF, n.d. c). This extra income should encourage municipalities to allocate more areas to salmon farming (Eriksen & Mikkelsen, 2024), supporting the growth and sustainability of the industry.

The ”salmon tax”

The salmon farming industry contributes to society through various taxes, including the controversial "**salmon tax**" introduced in January 2023. This ground rent tax is designed as a cash flow-based tax, where investments in the sea phase of the value chain are deducted immediately from the gross income (Norwegian Tax Administration, 2025). As for the Aquaculture Fund, the salmon tax should ensure that the society benefits economically from salmon aquaculture by receiving a part of the yield created by the exploitation of common natural resources.

The salmon tax has been extremely **controversial** (iLaks, 2024a; IntraFish, 2025). An industry actor argues that it creates unpredictability and has dramatic consequences for fish farmers, such as freezing projects and investments due to high uncertainty linked to the tax (Producer 1; iLaks, 2024a). Moreover, the actual benefits of the salmon tax have not been as high as expected, which has contributed to its perceived failure (Guttormsen, 2025). In 2024, the government collected approximately 868 million NOK from the tax, instead of the 5 billion NOK expected (IntraFish, 2025). This shortfall is largely due to the reorganization of fish farming companies, which have adapted to the tax by creating separate entities to minimize their taxable income (MTIF, 2025a; Producer 1; Guttormsen, 2025). As the Aquaculture Fund and the salmon tax are not questioned in the future governance, these aspects are not further discussed in this study.

The regulatory framework of the Norwegian salmon farming industry, comprising licenses, MAB, spatial planning, and taxes, aims to balance growth and environmental sustainability. However, the complexity and administrative burden of these regulations pose significant challenges. The interplay between these regulatory tools and their impact on the industry will be further explored in the context of stakeholder dynamics and the TLS in the following sections.

2.2. The play between the stakeholders is complex: The locality license application process (case study)

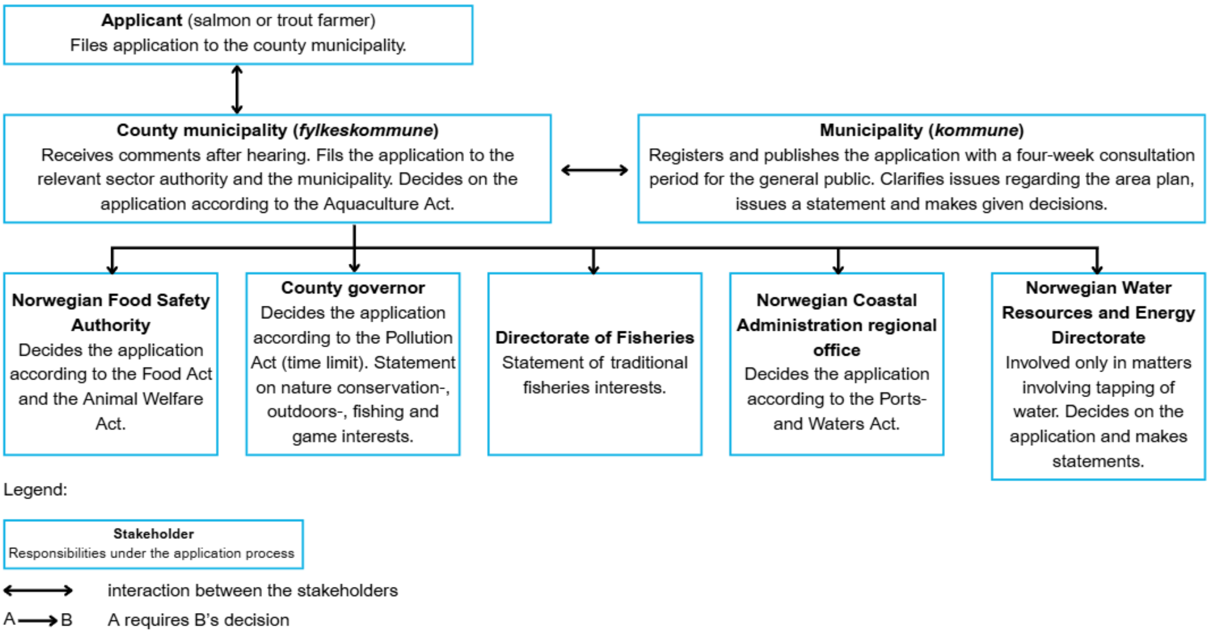

Figure 1. Stakeholder roles and interactions under the aquaculture locality license application process (Source: NEA, 2025; KPMG Law Norway, 2023).

Roles of the actors and the locality license application process

The governance of the Norwegian salmon farming industry involves numerous stakeholders, each with distinct roles and responsibilities. These stakeholders include industry actors such as fish farmers, suppliers, and market entities, as well as political authorities, governmental agencies, research institutes, and environmental non-governmental organizations (ENGOs). The government sets the overarching policies and goals, organized into several ministries. For instance, the Directorate of Fisheries (DoF) and the Norwegian Food Safety Authority (NFSA) fall under the Ministry of Trade, Industry, and Fisheries (MTIF), while the Norwegian Environment Agency (NEA) is under the Ministry of Climate and Environment (MCE).

The process of applying for a locality license is a complex interaction among these stakeholders, as illustrated in **Figure 1**. When a salmon farmer applies for a new locality license, the county municipality (*fylkeskommune*) coordinates the process, ensuring the quality of the application while the municipality makes it public. The municipality then sends the application to the relevant authorities, including NFSA, the county governor (indirectly to NEA), DoF, the Norwegian National Coastal Administration (*Kystverket*), and, if necessary, the Norwegian Water Resources and Energy Directorate (NVE). Each of these authorities assesses the application based on their specific scope and priorities, defined by regulations such as the law on food production and food safety (*matloven*) for NFSA. The county municipality plays a crucial role in clarifying whether the locality fits the coastal zone planning. Furthermore, NFSA, Kystverket, and the county governor possess a "veto right" on the awarding of a locality license. This means that if any of these authorities respond negatively to the application, the locality license will not be issued (Regulator 2). The final decision rests with the county municipality, which must weigh the various inputs and advice from the different authorities (County official 1).

Other stakeholders interact in the governance of the Norwegian salmon farming industry. Research institutes play a crucial role in producing background information on aquaculture, climate change, water quality, and many other subjects, working closely with management and regulatory bodies (Researcher 4; Regulator 4). Two major research institutes interact with the stakeholders of the salmon farming industry: the Veterinary Institute (VI) and the Institute of Marine Research (IMR) (MTIF, 2016). VI interacts indirectly with the governance system by working on how regulations affect disease situations, providing input to NFSA, and producing the yearly fish health report, which is a valuable document for many stakeholders (Researcher 5; Researcher 1). IMR is the main knowledge provider and institutional cooperation partner of DoF, providing expertise and knowledge on the impacts of aquaculture (Regulator 4; Regulator 6; Regulator 1).

Fish farmers have several roles in the governance system. They are dependent on each other, especially regarding sea lice management, and collaborate with researchers and ENGOs (Producer 1). However, the relationship between fish farmers and regulators is often seen as insufficient, with a lack of dialogue and understanding of each other's needs and constraints (Researcher 2; Researcher 3).

Political organizations and ENGOs play roles in political activities like lobbying and campaign advertising. They either decide on actions or try to influence decisions. ENGOs are typically more political than governmental agencies and research institutes, representing and advocating for opinions and visions. They inform stakeholders, communicate with political parties, and serve as alternative sources of information, especially for international media (ENGO 1).

Complexity and critiques of the governance system

The governance system, especially the locality license application process, faces several critiques from the stakeholders. One of the main criticisms is the **complexity** and **lack of coordination** among the different actors. A regulator highlights the "*poor coordination between the actors' actions*," questioning, "*when should what concern be prioritized?*" (Regulator 3). This lack of clear hierarchy and the conglomerate of actors can create conflictual situations, particularly regarding the power of the municipalities (Regulator 2; Expert 2).

Another critique is the **inefficiency** and **lack of transparency** in the licensing process. Some actors argue that the process takes too long and that the requirements for a successful application are not clearly communicated, leading to inefficiencies and frustrations (Researcher 2; Researcher 3). A state agent agrees that the cooperation and dialogue with the fish farmers is of great value for the agencies, especially DoF, because the fish farmers have a practical approach and may provide useful background information as a good introduction to the issues to be dealt with (Regulator 4). However, the relations may be skewed by power imbalances as the farmers hold (or believe they hold) more knowledge than the regulators (Researcher 3; Expert 2). A state agent further explains that although "*there is a general established truth that everything is difficult to do and takes time,*" this is normal and should be understood. In fact, they remind that salmon farming in Norway is "*living animals produced industrially with many evolving technologies which requires enormous expertise*," in addition to the huge responsibilities given to the governmental agencies (Regulator 5).

The GS tries to handle the complexity of the governance system. Recent reorganizations and modifications in the regulatory framework have paved the way for the WP and more globally a new management. For instance, NFSA underwent a reorganization in September 2024, creating an "aquaculture supervision division" to shift from a regional approach to a national organization with specialized supervision divisions. This reorganization aims to improve governability and efficiency (NFSA, 2025; Regulator 3). Similarly, DoF was reorganized at the end of 2022, transitioning from an organization based on tasks to one based on functions to enhance governability (Regulator 4).

Regarding the right to pollute, if an economic activity pollutes, it must obtain a particular right to do so (Regulator 5). Before 2024, the county governor had to give individual emission permits according to the Pollution Control Act (*forurensningsloven*) (Producer 2; Regulator 6; County governor of Trøndelag, 2024). However, a new pollution regulation for aquaculture was implemented in February 2024 to simplify the process (Regulator 6). Conditions in permits under the Pollution Control Act to prevent and reduce pollution and waste from aquaculture are replaced by standard requirements in the aquaculture operation regulations (Producer 2; Regulator 6; County governor of Trøndelag, 2024). The new requirements aim to ensure that the industry receives standardized requirements that are updated and adapted to current knowledge about the environmental impact of aquaculture in the sea (County governor of Trøndelag, 2024).

Furthermore, to support the fish farmers in transitioning from traditional open net-pens to zero and low emission technologies the "**NOU 2023:23**" report proposes a "**Flexible Environmental Scheme**" (*miljøfleksordning*) (author's transl.) (MTIF, 2023; Regulator 4). Although this scheme is still not implemented, it paved the way for further changes in the regulatory framework, as proposed in the recently published WP (Regulator 5; ENGO 1; Regulator 4).

The interactions among stakeholders in the governance of the Norwegian salmon farming industry are complex, particularly during the locality license application process. The roles of the main stakeholders are detailed, and the complexity and critiques of their relationships are highlighted. Recent reorganizations and new regulations aim to improve governability, but challenges remain, particularly in terms of coordination and efficiency. The next section will investigate the TLS and its criticisms to understand the radical proposals in the WP and their possible consequences.

2.3. Most actors perceive the Traffic Light System to be ineffective in allowing predictable and sustainable growth

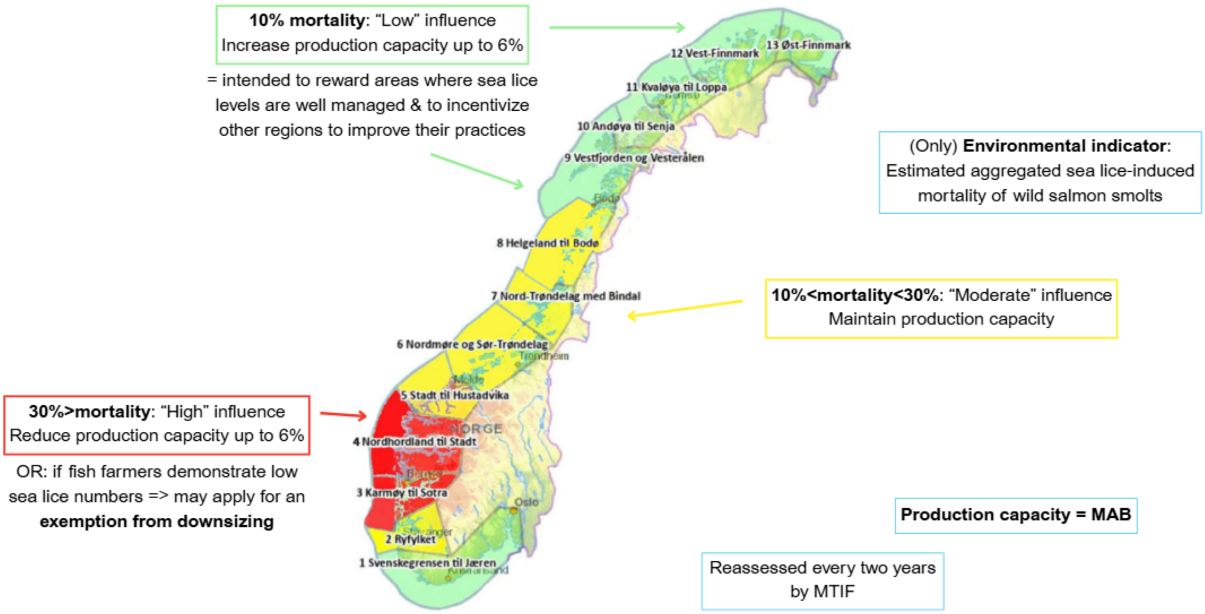

Figure 2. The map of the PO for salmon, trout and rainbow trout and their coloring according to the TLS for the period 2024-2025 (Source: MTIF, 2024; DoF, n.d. d).

What is the Traffic Light System?

The salmon farming industry in Norway is regulated by a management system called the **Traffic Light System** (TLS). The goal of the TLS is to tackle the problem of sea lice in the salmon farms specifically, and it should allow predictable and sustainable growth for the aquaculture industry (Trafikklyssystemet, 2025). As illustrated in **Figure 2**, it uses a color-coded scheme—green, yellow, and red—to indicate the potential for growth in the different production areas (PO). The colors are determined according to an environmental indicator which is the estimated aggregated sea lice-induced mortality of wild salmon smolts (DoF, n.d. d; Jensen, Tveterås, & Nielsen, 2024). Each color corresponds to specific regulatory measures affecting the MAB as described in **Appendix 6**. The coloring is reassessed every two years by MTIF (MTIF, 2024).

Critiques of the Traffic Light System:
Ineffectiveness in controlling sea lice

Although the TLS is only a few years old, most stakeholders question its efficiency in allowing predictable and sustainable growth for the aquaculture industry. Sea lice and escapes are still major environmental challenges not solved yet. The fish mortality rate is still too high and has not improved either (MTIF, 2025a; **Appendix 2**). This is a shared view amongst the interviewees (Regulator 5; Regulator 2; ENGO 1; Regulator 1). The TLS regulates the growth of the industry according to one single indicator, sea lice levels in the PO, which shows how impactful sea lice is for the industry.

The fundamental problem with sea lice is that it threatens the fish welfare of both the farmed and wild salmon. Studies show that one of the major threats to the wild salmon and trout is the sea lice from the farmed fish (Thorstad & Forseth, 2025; **Appendix 7**). Several industry actors thus feel like the fish welfare of the wild salmon and trout populations is considered more of a problem than that of the farmed salmon because, to improve the wild salmon stocks, "*the farmed salmon must suffer*" (Regulator 2; Industry representative 1; Producer 1; Expert 2). On the other hand, an ENGO finds that the threshold values are "*still too high to ensure good survival of the wild smolt*", and thus that the protection of the wild salmon is not successful either (ENGO 1).

Lack of flexibility and adaptability

The TLS is also criticized regarding the socio-economic issues it leads to. The regulation at PO-level is highly controversial. For many actors, this level of management is "*too global*" not enabling to differentiate and reward the "*good fish farmers*" as they should (Researcher 4; Expert 1; County official 1; Expert 2). A regulator adds that the TLS is hence "*counterproductive in regards of fish welfare*" as it does not contribute to "*punish the bad players*" (Regulator 2). It even escalates to the point of the TLS being judged "***unconstitutional***" by some actors, putting forward that the reduction of MAB imposed by the TLS to all fish farmers in a red PO, is a form of **collective punishment** based on individual actions (Expert 2; Producer 1; Industry representative 1).

Schøning, Hausner, and Morel show that the legislation is complicated, "including sectoral regulations (specific to the activity in question), regulations targeting particular environmental impacts (such as pollution), regulations targeting particular resources (such as water), and planning laws and regulations" (Schøning, Hausner, & Morel, 2023). Some authors and stakeholders find the current regulatory framework complex and layered (Hersoug, 2022; Osmundsen *et al.*, 2022; O17; Expert 2; Regulator 3). The regulations and management tools add up. To some extent, the regulators agree with the farmers that the current regulation is "***overlapping***" (Regulator 5), "***patched***" (Regulator 6), and "***fragmented***" (Producer 1; Expert 2). According to a regulator, this is due to the different authorities coping with regulations that do not necessarily have the same goals (Regulator 1).

Economic and operational challenges

The TLS should allow sustainable growth for the salmon farming industry, but projections of the current system show that all PO are likely to steer towards yellow light in the long-term meaning no growth (MTIF, 2025a). A state agent provides an interesting explanation, saying that the TLS neither regulates the size of the localities nor how the MAB at firm-level is distributed between the multiple localities in the different PO (Regulator 1). A fish farmer adds that growth is difficult because of the high price of the locality licenses at auction and the limited production licenses which push towards buying out other farmers for one company to grow (Producer 1).

Moreover, the TLS is applicable to adjust ordinary production licenses only (DoF, n.d. d). In an industry with high profitability and strong barriers to further growth, Hersoug *et al*. warn against the use of special licenses as they may undermine the ordinary regulatory system if they are not "limited, closely circumscribed, and controlled" (Hersoug *et al.*, 2021). In fact, as of February 10, 2025, about 20% of the total production of salmon, trout, and rainbow trout comes from such licenses (MTIF, 2025a), not subject to the TLS, which is considered significant or too much (ENGO 1; Regulator 1; Regulator 4; Regulator 2).

Social license to operate and environmental sustainability

Environmental and fish welfare concerns are prominent critiques of the TLS, which can impact the industry's social license to operate (SLO) (Eriksen & Mikkelsen, 2024). SLO is thus a critical concept in the governance of the salmon farming industry. It refers to the level of acceptance or approval of a given social unit like the local communities and the public regarding industry operations.

Although sustainability and social acceptance are important challenges faced by the industry, these are not always sufficiently considered in the regulation as such. Schøning, Hausner, and Morel investigate the role of law in accelerating the transition towards (environmentally) sustainable aquaculture activities in Norway, finding quite few regulations in place that accelerate the transition even though both the government and the industrials promote it. The authors find no regulation that requires positive contributions to any of the six environmental objectives used as transition criteria (Schøning, Hausner, & Morel, 2023). Some stakeholders further argue that the system does not go far enough in addressing the broader environmental impacts of salmon farming, such as sludge and feed waste (Regulator 5; Expert 2). The need for a "***paradigm shift***" in the industry is often discussed, emphasizing the importance of moving towards new aquaculture practices (Expert 2; Regulator 2; Researcher 1).

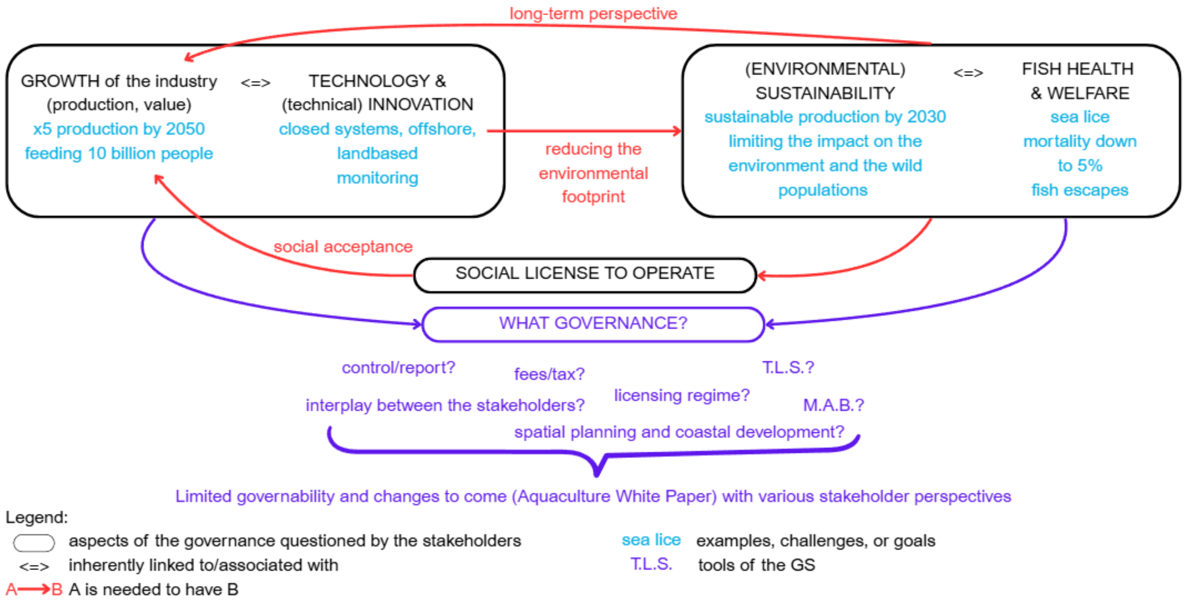

Figure 3. Key aspects and challenges of the governance of the Norwegian salmon farming industry.

Summary of Section 2

The governance of the Norwegian salmon farming industry is a complex interplay of various stakeholders and regulations. **Figure 3** shows key aspects and challenges of the current governance. The TLS is a key component of this governance, aimed at controlling sea lice contamination. However, the TLS faces significant critiques regarding its effectiveness, flexibility, economic impact, and environmental considerations. The interactions among stakeholders, as detailed in the previous section, highlight the challenges and complexity of the GS. Recent reorganizations and new regulations aim to improve governability, but challenges remain.

The WP proposes changes to the governance and regulatory framework, aiming to balance growth, technological innovation, environmental sustainability, and fish health and welfare. The expectations and reactions to it vary among stakeholders, with differing views on the future of the industry. The next section will delve into the broader implications of these governance and regulatory changes, exploring the potential impacts on the industry's growth and sustainability.

3. The stakeholders question the future governance, and hold different views on whether the WP could improve governability

The Aquaculture White Paper (Meld. St. 24 (2024-2025)) is titled "**The Future of Aquaculture – Sustainable Growth and Food for the World**" (MTIF, 2025a). In the WP, the government formally presents several changes in the regulatory framework and hence initiates a rather long process before its implementation in about 3 years from now (Bryde Martin H., 2025). The sea lice regulation is to be based on **sea lice quotas**, with a fee on exceeding emissions. The regulatory basis would be the estimated total emission of sea lice larvae. The threshold value should be determined according to the environment's carrying capacity. Furthermore, the WP changes the licensing regime by suggesting **removing the MAB at firm-level**. The government wants to establish a "one license, one locality" policy meaning there would be only one production license attached to each locality. The WP proposes a fee to handle the issues with **"lost fish**", meaning dead and escaped fish. Finally, a **more comprehensive area planning** should be allowed through stronger knowledge and central government planning guidelines for the planning of coastal areas (MTIF, 2025a). The government reminds that this new management system should make it more profitable to operate with low environmental impact and good animal welfare (MTIF, 2025b).

Most actors are very surprised by the WP and how radical the proposals are though. This section investigates the reasons why, and what the stakeholders suggest to improve the governability. In this way, this work provides additional information on strategies required to govern the salmon farming industry, also within the frame of the WP process.

3.1. The WP has potential for improved sustainability and fish welfare, but a lack of knowledge and common understanding creates disagreement

A strong focus on sea lice

The WP's strong focus on sea lice is well-received by the stakeholders who recognize sea lice as the "***biggest challenge***" in the industry (Regulator 2; ENGO 1). This focus is seen as crucial for improving the environmental sustainability of salmon farming and ensuring the health and welfare of both farmed and wild fish populations. The regulator further explains that sea lice should remain a regulating factor "*as long as there is no vaccine, no efficient medicines, or until the production systems physically separate the fish from the sea lice*" (Regulator 2). Regarding the indicator proposed in the WP, the total amount of sea lice larvae emitted from a farm, it is "*decisive*" for determining the impact on the wild salmon according to a researcher. In that sense, the WP is more **impact-based** than the TLS (Researcher 5). This perspective is shared by several other stakeholders, including an ENGO and researchers, who believe that the WP's focus on sea lice will incentivize better management practices and ultimately lead to improved fish health and welfare (ENGO 1; Researcher 5).

Removing the MAB is another significant change proposed in the WP. This change is viewed positively by many stakeholders, as it is expected to provide more flexibility for fish farmers and encourage production strategies that are more aligned with the **environment's carrying capacity** (ENGO 1; Producer 2). The fish farmer employee explains that removing the MAB could lead to a shift in mentality, where fish farmers focus on producing more in areas with a better capacity to sustain pollution instead of polluting where the company has "*more rights to pollute*" as it is most often the case today. This change is seen as a way to give fish farmers more responsibility to "*better work with nature*" (Producer 2).

Environmental and fish welfare considerations

The WP's emphasis on sea lice is also seen as a step towards achieving the **quality standard for wild salmon stocks** (*kvalitetsnorm for villaks*), which is a priority for many stakeholders, including ENGOs and research institutes (Thorstad & Forseth, 2025). The urgency of improving wild salmon stocks is underscored by recent events, such as the closure of 33 “salmon rivers” in June 2024 due to low wild salmon populations (NEA, 2024). Additionally, the Atlantic salmon's status was changed from Least Concern to Near Threatened on the IUCN Red List in 2023, further highlighting the need for immediate action for an ENGO (IUCN, 2023; ENGO 1). However, there are also concerns that the focus on sea lice may overshadow other environmental issues that also need to be addressed, such as emissions of nutritional salts, feed waste, and sludge (Researcher 1; Regulator 6; Expert 2).

There is also ongoing debate about the **link between sea lice in farms and their impact on wild fish populations**. Some industry actors question the scientific basis of this relationship and argue that the research is not thorough enough to justify the focus so strongly on sea lice (Industry representative 1; Expert 2). They point to independent research projects, such as Salmon Tracking 2030, which aim to provide a more comprehensive understanding of the factors affecting wild salmon populations (Salmon Tracking 2030, n.d.). An industry representative finds that the public research is a bit misinforming for the politicians and authorities because Salmon Tracking 2030 shows that there is most often enough wild fish in the rivers to enable their reproduction, but not always enough fish to fish. They question the economic importance of the fishing activity compared to the aquaculture industry. For them, putting the fishing activity forward leads to nonsense (Industry representative 1). However, other stakeholders, including a state agent and an ENGO, argue that the link between sea lice and wild fish populations is well-established and that the focus on sea lice is justified (Regulator 2; ENGO 1).

Questions on operational challenges

While the WP aims to improve environmental sustainability, there are concerns about its economic and operational implications. Some stakeholders worry that the proposed changes could lead to even greater costs to monitor the environment (Producer 3; Producer 2). There are questions about how the sea lice emission quotas will be monitored and enforced, and whether the fees for exceeding these quotas will be sufficient to incentivize good practices (Regulator 2; Researcher 5). The regulator further argues that as much as the quota for sea lice emissions must be set at a low enough level to incentivize good practices, the fee for exceeding the quota must be high enough to discourage non-compliance. They explain that the goal is to ensure that fish farmers do not simply "*pay themselves out of the sea lice problem*" (Regulator 2).

Similarly, there are concerns about the proposed fee on "lost fish" which includes both dead and escaped fish. A researcher highlights the ambiguity in defining a "lost fish", particularly in cases where fish are intentionally killed to prevent the spread of disease. They point to a recent example where millions of fish were killed to prevent the spread of pancreas disease in PO8, raising questions about how such cases would be handled under the new regulations (Researcher 5; iLaks, 2024b).

Defining sustainability

The WP's proposals have sparked discussions about what constitutes **sustainable aquaculture**. Schøning, Hausner, and Morel highlight the importance of clear sustainability standards and end goals, stating that "without clear sustainability or environmental standards or end goals, there is no direction for how the aquaculture actors should adapt". This sentiment is echoed by several stakeholders, who emphasize the need for a shared definition of sustainability that can guide the industry towards more sustainable practices. In fact, if what sustainability means is either not defined or does not cover the same meaning and goals for all the stakeholders, then the latter cannot work efficiently together towards sustainability (Schøning, Hausner, & Morel, 2023).

Some stakeholders define sustainability in terms of **environmental impact**, emphasizing the need for zero emissions and minimal impact on the environment (ENGO 1; Regulator 2). Others highlight the importance of fish health and welfare, arguing that sustainable aquaculture should prioritize the well-being of both farmed and wild fish populations (Regulator 2; Researcher 5; Researcher 1). While environmental sustainability is a key focus, there is also recognition of the need to consider the economic and social aspects of sustainability, with some stakeholders arguing that a **strong economy** is essential for enabling positive environmental actions (Producer 1; Industry representative 1; Producer 3).

Furthermore, sustainable production is also defined in regard to how important the salmon farming industry is for **the politicians** particularly as they are the ones to decide what an "*acceptable level of pollution*" is (Regulator 5). Furthermore, a fish farmer employee underscores the power of **the consumers** in acknowledging what sustainable production is (Producer 1). In fact, the latter "*have never had as much knowledge as today*" (Producer 1). The ideal is to find a balance between environmental sustainability and growth of the industry (Regulator 5; Producer 2), but finding such an equilibrium is the biggest challenge for both fish farmers and policymakers (Liu, Chuenpagdee, & Sumaila, 2013).

The role of certification schemes in defining and operationalizing sustainability is also discussed. Some authors argue that certification schemes, such as ASC and GLOBALG.A.P., have taken on the role of defining sustainability standards and operationalizing them within the industry. However, there are concerns that these schemes may not address sustainability as a whole, focusing primarily on environmental and governance indicators while neglecting cultural and economic issues (Osmundsen *et al.*, 2020). For two label representatives, this is explained by two reasons. Firstly, the label they work for "*tackle[s] the biggest impacts first, [namely] the environmental and the social impacts [of the industry]*". Also, the economic aspects are more difficult to assess, although they actively work on this (Market player 2; Market player 3). In this way, the certification schemes acquire a high degree of structural power "by devising the standards and operationalizations, and granting or withholding certification of compliance", thus becoming "the arbitrators of what sustainability means". This challenges the governability (Osmundsen *et al.*, 2020).

The WP's proposals are seen as a step towards improving the environmental sustainability of the Norwegian salmon farming industry. However, there are concerns about the need to address other environmental issues and define sustainability more broadly. The lack of knowledge and common understanding among stakeholders creates disagreement and highlights the need for further assessment and scientific consensus.

The next section will further investigate the possibilities for growth under the WP, exploring how the proposed changes could impact the industry's ability to expand while maintaining a focus on environmental sustainability and fish health and welfare.

3.2. Debate on the WP's growth and predictability potential

Removing the MAB: A radical change with mixed perceptions

The WP proposes significant regulatory changes, notably the removal of MAB at firm-level. This change is viewed as a radical shift that could potentially boost production by removing what is seen as a cap on production and allowing salmon farmers to increase their net biomass. The government's rationale is that the MAB becomes unnecessary with the new sea lice management system in place (MTIF, 2025b; MTIF, 2025a). Some stakeholders see this as an opportunity to enhance production efficiency and fairness in regulation. For instance, a fish farmer employee and an ENGO note that this change could theoretically allow for unlimited biomass for "*good farmers*" who maintain low sea lice levels, independent of their neighbors' performance (Producer 1; ENGO 1). This **individual approach** is perceived as more just and could lead to **more efficient production** and industry growth by enabling fish farmers to fully exploit their localities' carrying capacity (Producer 3).

However, the optimism surrounding the removal of MAB is tempered by several practical limitations. Stakeholders highlight significant biological constraints, including environmental limits, spatial restrictions, and the current reliance on open net-pen technology. Concerns about a "***biological collapse***" in certain coastal areas suggest that ecological limits have already been exceeded, making unrestricted growth unsustainable (Regulator 2; Researcher 1). Additionally, challenges such as **feed sourcing** and **smolt production** pose substantial barriers to sustainable growth. An industry actor points out that the current feed sources are insufficient to support a fivefold increase in salmon and trout production, and the environmental impact of feed production is a significant concern (Expert 1). Furthermore, the production of smolt in hatcheries is already under pressure according to a researcher, and increased demand could exacerbate these issues (Researcher 3).

Despite the removal of MAB, other regulatory measures, such as those tied to the localities' carrying capacity, may act as ***de facto* limits on production growth**. A fish farmer employee believes that these regulations could effectively replace the MAB, thereby limiting the potential for unlimited growth (Producer 3). Thus, while the removal of MAB is seen as a step towards greater flexibility and efficiency, the actual impact on industry growth may be constrained by these underlying biological and regulatory factors.

Valuation and financial implications of removing the MAB

The removal of MAB at firm-level represents a radical change with significant financial implications for the salmon aquaculture industry. Production licenses are a major asset for aquaculture firms. In fact, the auction in 2024 priced a regular license of 780 tonnes at 273 million NOK (Santi, 2025). These licenses serve as critical security for banks and investors, as they are owned and can be pledged and mortgaged, facilitating financing and investment in the industry (KPMG Law Norway, 2023). The potential removal of this regulatory cap raises important questions about **how firms will be valued** in the future and what assets will serve as collateral for financing. This uncertainty could destabilize the market and stock exchange, creating significant challenges for industry stakeholders (Producer 3; Industry representative 1).

Industry representatives further argue that politicians may not fully understand the connection between regulatory changes and their economic and financial consequences. The removal of MAB could eliminate a significant revenue stream for the state, although this might be offset by fees associated with sea lice quotas and locality licenses (Producer 3). However, the overall impact on industry growth remains uncertain, and stakeholders are skeptical about whether this change will genuinely stimulate growth. A thorough **assessment** of the financial and operational consequences of removing the MAB is seen as essential to understanding its potential benefits and drawbacks (Producer 3; Industry representative 1).

Predictability: A crucial factor for industry growth

Predictability is a crucial factor for the salmon farming industry, influencing investment decisions and risk management. A stable and predictable regulatory environment enhances stakeholders' confidence and willingness to invest in new projects and technologies (Producer 1; Industry representative 1; Producer 3). Documents such as the Animal Welfare White Paper (Meld. St. 8 (2024-2025)) and the WP provide a **common direction** for the industry, improving governability and fostering a sense of stability (Producer 1; Regulator 2). For example, the Animal Welfare White Paper's goal of achieving a 5% mortality rate is seen as a clear target that can guide industry practices (Producer 1).

However, the aquaculture industry faces significant **unpredictability** due to delayed implementations and frequent regulatory changes. The Flexible Environmental Scheme (*miljøfleksordning*), a temporary arrangement aimed at reducing the industry's environmental impact, has been long awaited by the stakeholders but has yet to be implemented. This delay, along with the introduction of new regulatory frameworks such as the MAB in 2005 and the TLS in 2017-2018, highlights a "**10-years regulatory cycle**" that offers neither predictability nor continuity according to some stakeholders (Hareide Henrik, 2025). This unpredictability is seen as **harmful to the industry**, as it creates uncertainty and deters investment (Industry representative 1). For instance, the salmon tax introduced in 2023 caused significant disruptions and led to the freezing of investments due to high uncertainty (Producer 1; iLaks, 2024a).

The WP's proposals, including the introduction of sea lice emission quotas and fees for "lost fish" add further layers of regulatory complexity and uncertainty. Stakeholders question how these new regulations will be monitored and enforced, and whether the fees will be sufficient to incentivize good practices (Researcher 5; Regulator 2). The ambiguity surrounding these issues adds to the overall unpredictability and could deter investment in the industry. Thus, while predictability is essential for industry growth, the current regulatory environment is seen as unstable and harmful to investment by most industry actors and some other stakeholders.

Technological innovation and technology neutrality

Technological innovation is crucial for addressing the aquaculture industry's challenges, particularly in reducing environmental impacts and improving fish health and welfare. Stakeholders agree on the **necessity of investing in new technologies**, such as land-based, offshore, and closed containment systems, to achieve zero or low emissions. These technologies are seen as essential for maintaining or increasing production volumes while diminishing the industry's environmental footprint (ENGO 1; Expert 1; Researcher 1).

However, investing in new technologies is expensive and risky, especially in an unpredictable regulatory environment. The **high costs** and **technical risks** associated with new technologies, coupled with the need for regulatory approval, pose significant challenges for industry stakeholders (Producer 3). For example, this fish farmer employee highlights the case of a semi-closed post-smolt facility that was never approved by the authorities, resulting in a significant financial loss for the company. Moreover, they argue that "*the political sphere has not shown interest in stimulating technology development until now*", but that "*the government [now] wants [the fish farmers] to transition quickly*" (Producer 3). The **biological risk** (the risk of losing fish) is also a burden for the fish farmers when testing new technologies as they can cause lower production and higher mortality (Producer 3). In addition, the risks are often dependent on the local environment, meaning that more testing and more risks are always needed in each locality (Producer 1). This underscores the risks associated with investing in new technologies and the need for a more supportive regulatory framework (Expert 1; Producer 3). Finally, although new technologies are part of the solutions, they pose significant challenges, for example in regard to the fish health and welfare (Researcher 5; Expert 1) and the equipment and energy required to function (Producer 3; Regulator 2).

The principle of **technology neutrality** is also debated among stakeholders. While some support the push for low-emission technologies, especially closed-containment systems (ENGO 1; Expert 1), others argue that the current regulatory framework does not provide genuine technological neutrality, as it favors certain production methods over others (Industry representative 1; Producer 3). This raises concerns about the financial and operational feasibility of adopting new technologies and the potential impact on the industry's competitiveness (Industry representative 1). Thus, while technological innovation is necessary for addressing the industry's challenges, a more gradual and supportive approach to implementation is seen as essential to facilitate this transition.

Stakeholders' perceptions of the WP's ability to enable growth in the Norwegian salmon farming industry are mixed, reflecting the complex and multifaceted nature of the challenges involved. While the removal of MAB is seen as a potential opportunity for greater flexibility and efficiency, practical limitations and regulatory uncertainties temper this optimism. Predictability is crucial for industry growth, and the current regulatory environment is seen as unstable and harmful to investment by most industry actors. Technological innovation is necessary but requires significant financial support and a more gradual approach to implementation. This reminds of Asche and Smith's idea that innovations in the GS are as important as technological innovations for an environmentally and economically sustainable seafood industry (Asche & Smith, 2018). Jensen, Sønvisen, and Johnsen draw a similar conclusion by highlighting the need for technological and institutional innovations happening in concert with each other (Jensen, Sønvisen, & Johnsen, 2025). In that sense, the "**Environmental Technology Scheme**" pushed by parliament, should help support the transition (Stortinget, 2025).

Overall, stakeholders emphasize the need for a balanced approach that addresses both environmental sustainability and economic growth, ensuring the long-term viability of the aquaculture industry. Further assessment and scientific consensus are needed to develop a regulatory framework that can support the industry's growth while ensuring its long-term sustainability. By incorporating stakeholder perceptions and addressing the underlying challenges, the WP can provide a more robust and effective foundation for the future of the aquaculture industry.

3.3. An unclear socio-economic model promoted in the WP and expected company strategy shifts

The WP challenges various aspects of the Norwegian salmon farming industry, including environmental sustainability, technology and innovation, growth, predictability of governance, and the roles of stakeholders in the regulatory framework. These changes are expected to lead to shifts in the socio-economic model of the industry. However, the socio-economic model promoted in the WP remains unclear to many stakeholders.

Comprehensive area planning and locality licensing

A more comprehensive area planning is presented as a priority in the WP, with many stakeholders agreeing on its essential nature (Regulator 3; Regulator 1; County official 1; Regulator 5; Regulator 2; Producer 3). A state agent emphasizes the need for clear political decisions regarding the **prioritization of coastal activities**, such as aquaculture, tourism, and infrastructure, particularly in terms of area use (Regulator 3). Although technology is expected to aid further growth and environmental sustainability, aquaculture requires more space and better exploitation of the given space (County official 1; Regulator 1; Regulator 5). The current locality structure tends to shift from several smaller localities to fewer but larger ones, which may not be an optimal use of space (County official 1; Producer 2). The Hardanger fjord is often cited as an example of an aquaculture "*hotspot*" with "*too many sites*" and increasing environmental problems, necessitating a rethinking of its area use (Regulator 5; County official 1). The **locality structure** as a whole needs revision, especially considering new technologies that require different spaces, such as offshore or land-based areas (Regulator 1).

In the future system, **company strategies** regarding area use may change. With the potential removal of MAB at the firm-level and a "one license, one locality" policy, having several smaller localities could give fish farmers more flexibility, particularly in terms of the local carrying capacity of the environment (Producer 2). Conversely, a state agent suggests that localities may become larger to optimize economies of scale, but with greater distances between them (Regulator 3). A veterinarian researcher agrees with this trend but expresses uncertainty about its wisdom from a disease dispersal perspective, given the likely high density in these localities (Researcher 5). Two technology researchers perceive that the use of localities without the firm MAB could lead to many more localities being utilized, and they question whether the GS expects the balance between localities to create itself without sufficient regulation (Researcher 2; Researcher 3).

The **value of locality licenses** in the future system is a topic of debate. For a state agent and a fish farmer, the carrying capacity of localities will be crucial in determining which technology to implement, with healthier environments sustaining more open technologies and others requiring zero-emission technologies (Regulator 6; Producer 3). If the firm MAB, the current "currency" for growth and exchanges, is removed, the value of aquaculture will increasingly lie in locality licenses. This shift could lead to two risks: the **privatization of coastal areas** if locality licenses are auctioned as suggested in the WP, and the **cementing of the locality structure** (Bryde, 2025; Producer 3). The fish farmer employee explains that responding to the unpredictability of governance by keeping localities "*as long as possible*" could create even greater pressure for space and be counterproductive (Producer 3).

SMEs vs. big companies: Advantages and challenges

The innovation effort required to "survive" in the future system raises questions about the socio-economic model favored by the regulations. The model is partly based on the size of salmon farming companies, with larger companies like Mowi, Salmar, and Lerøy Seafood being multinational and listed on the stock exchange, controlling a significant portion of the industry's production capacity (MTIF, 2025a). Although the WP regulations are designed to be neutral, some stakeholders believe they favor larger companies in practice. SMEs often struggle to meet the increasing requirements and higher investments needed to maintain or increase production, leading to periodic buyouts (County official 1). Additionally, several large fish farmers have holdings of just under 50% in other fish farming companies (MTIF, 2025a), and smaller companies are seen as more "*vulnerable*" (Expert 1; Producer 1). Research by Larsen, Jakobsen, and Steinmo found that SMEs are less capable of developing innovations and face distinct regulatory challenges compared to their larger counterparts. If environmental regulations are uniformly imposed, smaller firms bear “a disproportionate burden” (Larsen, Jakobsen, & Steinmo, 2025).

However, stakeholders also see possible advantages for SMEs compared to larger companies in the WP. Larsen, Jakobsen, and Steinmo found that SMEs pursue radical innovations, contrasting with earlier studies that suggested larger firms were the ones pursuing radical innovation in response to regulations (Larsen, Jakobsen, & Steinmo, 2025). A researcher notes that some medium-sized companies are ahead in technology (Researcher 5). Eide Fjordbruk is an example of SME leading in closed-containment technology development with its closed unit called Watermoon (Wilcox, 2024). SMEs may also have better control of their localities if they have fewer of them (Producer 1; Producer 2). As costs rise, the new regulations will require more investment per fish, meaning that larger companies producing more biomass will be more affected than SMEs (Producer 3). In reality, the size of the company does not determine everything; the geographic area will likely determine the investments and level of production more than the company size (Producer 3; Industry representative 1; Producer 2).

Some stakeholders argue for the importance of **maintaining diversity** in the industry, particularly in supporting SMEs due to their local investments. **Locally-owned** companies, often SMEs, tend to invest more locally, supporting coastal development and the rural economy (County official 1). A fish farmer employee in a multinational company acknowledges the importance of "*buying local services as a larger company*" to maintain territorial anchoring and increase the SLO through better relationships with the local economy (Producer 1). Therefore, an interesting question is whether the regulations following the WP should allow for a diversified salmon farming industry and emphasize social aspects to help SMEs sustain their competitiveness and the wider sustainability impact of the industry nationally and globally in the long run (Larsen, Jakobsen, & Steinmo, 2025).

Roles and stakeholders in the WP: Importance of local governance

The WP raises questions about the interplay between stakeholders and governance, although some stakeholders believe it does not address this sufficiently (Industry representative 1; Regulator 2). The WP was expected to investigate the responsibilities of governmental agencies and other stakeholders but does so to a limited extent (County official 1; Regulator 3). No actor possesses a "*sheriff star*", meaning superior decisive responsibility for making decisions, such as awarding locality licenses (Industry representative 1). There have been discussions about creating an independent governmental agency, the "**Fisheries and Aquaculture Directorate**" (*Fiskeri- og Havbruksdirektorat*), to consolidate the responsibilities of different regulatory bodies, assess and award localities, and simplify regulations. However, this idea is not addressed in the WP, which is a disappointment for some actors (Industry representative 1; Regulator 2). The parliament seems to have identified this regret and asks the government to investigate this idea further (Stortinget, 2025).

Other stakeholders argue that while the structure of the GS is important, the design of new regulations is even more crucial (County official 1; Regulator 3). A state agent questions the extent to which authorities should be grouped, highlighting that stakeholders, particularly politicians, only consider the reduction of coordination effort between agencies but underestimate the other consequences of merging agencies (Regulator 3). For example, the state agent emphasizes the role of NFSA in market access and sales, with food safety and product quality being "*top criteria in the market*", along with taste and healthiness according to a market actor (Market player 1). NFSA contributes to creating trust, especially in international markets, and this could be altered if NFSA is grouped with other agencies. If a Fisheries and Aquaculture Directorate were to be created, the state agent argues that it should only group responsibilities for area management and keep NFSA separate for these reasons (Regulator 3).

A political organization representative and a fish farmer employee underscore the importance of **local governance** and relationships in increasing the level of SLO (County official 1; Producer 1). The political representative specifically questions the central government planning guidelines proposed in the WP and their implications for local and municipal governance. They emphasize the importance of governance at the municipal level, particularly in conflict resolution (County official 1). The fish farmer employee further highlights that SLO operates on two levels, local and global, and that creating and nurturing relationships with local stakeholders helps on both levels. **Early, open, and honest communication** is key, with the employee stating that "*nothing is worse than having information first released on [a Norwegian tabloid]'s front page*" (Producer 1).

Political debate and priorities for the industry

The questions and debates surrounding the WP fuel the political discourse on the salmon farming industry and its priority. State agents tend to remind that the WP is a "*political matter*" independent of their work (Regulator 1; Regulator 6; Regulator 4; Regulator 2). Although the government clearly states its support for the development of the industry, many stakeholders question this commitment, citing a lack of concrete follow-up and a **mismatch** between announcements and measures taken (County official 1; Industry representative 1; Producer 1; Producer 3). The industry representative finds a mismatch between regulations and what is practically feasible, as well as between the priorities of governmental agencies (Industry representative 1). Two fish farmer employees even question, "*Maybe it is impossible to do aquaculture?*" and "*To be or not to be? [Is the aquaculture sector in Norway] the future industry of the younger generation?*" (Producer 3; Producer 1). They express **anger and disappointment** towards national politics and wish for a true focus on the salmon farming industry, stating that "*the [government and the central politicians in Oslo] need a wake-up call*" (Producer 1).

In conclusion, the socio-economic model promoted in the WP is unclear to the stakeholders, with numerous questions regarding localities, technology choice, company size, governance level, and the priority given to the aquaculture sector. The WP's lack of clarity and concrete follow-up fuels political debate and disappointment among industry stakeholders, highlighting the need for a more robust and effective foundation for the future of the aquaculture industry.

3.4. Conclusions and discussion

Aspect	Summary	Stakeholder perceptions
Environmental sustainability, fish health and welfare	The WP proposes new methods for protecting the environment and ensuring fish health and welfare.	Most stakeholders believe the proposals may improve environmental sustainability, but there is disagreement on the impacts of aquaculture on the environment and wild fish.
Growth and predictability	The WP aims to boost industry growth and provide predictability in governance.	Most stakeholders disagree that the WP will boost growth, raising concerns about the predictability of growth and regulations.
Technology and innovation	Technology and innovation are seen as key solutions for achieving sustainable growth.	Stakeholders agree on the necessity of investing in new technologies but face challenges in implementation and risk management.
Area planning and locality licensing	Comprehensive area planning is highlighted in the WP.	Stakeholders agree on the need for better area planning but have mixed views on the future structure of localities and the value of locality licenses.
Local governance and SLO	The importance of local governance and maintaining a SLO is highlighted.	Stakeholders emphasize the need for local engagement and communication to build trust and improve SLO.
Socio-economic model	The WP may introduce changes to the socio-economic model of the industry.	The socio-economic model promoted in the WP is unclear to many stakeholders, leading to uncertainty about how companies will adapt.
Roles and stakeholders in governance	The WP raises few questions about the responsibilities of different stakeholders.	There is a need for improved cooperation among stakeholders.
Political debate and priorities	The WP fuels political debate on the priority and future of the salmon farming industry.	Some stakeholders express disappointment and call for a clearer focus on the industry's development and support.

Table 1. Key aspects of the governance and stakeholder perceptions in Norwegian salmon farming.

Summary

The WP introduces significant proposals across various aspects of the Norwegian salmon farming industry, grouped in **Table 1**. Stakeholders have mixed perceptions regarding the WP's potential to improve environmental sustainability, boost growth, and implement technology and innovation. The lack of a unified definition of "sustainable production" or "sustainable growth" among stakeholders complicates predictions about the future regulatory framework's performance. Concerns about predictability and the socio-economic model promoted also arise, leaving uncertainty about how companies will adapt to future governance and highlighting the need for further dialogue and cooperation among stakeholders.

While there is consensus that the TLS has not been successful, stakeholders are cautiously optimistic about the WP. There is considerable uncertainty about its ability to improve governability, with many details yet to be defined. The intentions behind the WP are generally perceived as supportive of sustainable industry growth, but the translation of these intentions into effective regulations and management systems will be crucial.

Suggestions to improve the governability based on the needs of the stakeholders

To enhance governability, several needs and suggestions have emerged from stakeholder perceptions. There is a clear **need for more information and knowledge** on various themes. The impact of sea lice on wild salmon populations remains debated, with stakeholders using different information sources and having varying priorities. For instance, DoF required more time to assess sea lice quota models, but the government opted for "*the most radical alternative*" (Berge, 2025; Producer 3), highlighting uncertainties even within regulatory bodies (Producer 3). Therefore, establishing a **consensus on the knowledge base** is essential before implementing new systems like those proposed in the WP (Hareide, 2025). **Defining sustainability** should be a collaborative effort, focusing on environmental and governance aspects while also considering financial and socio-economic factors.

Other environmental issues, such as climate change and its impacts on aquaculture, ocean dynamics, and feed-related issues, need further exploration and understanding. Documenting and gaining more knowledge about **new technologies** and their environmental and economic efficiency is also crucial, as stakeholders agree that production methods must evolve. However, industry actors feel that they bear all the risks—technological, financial, and biological—and that this pressure is not fully understood by the GS. Improving **cooperation** among stakeholders is essential for several reasons. Industry actors regret that other stakeholders, particularly politicians, do not fully grasp the realities of operating an aquaculture farm (Hareide, 2025). They recognize the need to inform and educate others (Producer 3). Improved cooperation could help define concrete, precise, and useful common goals. Enhanced **communication**, **dialogue**, and **openness** between governmental agencies and fish farmers are key to improving cooperation.

Discussion

This study, based on semi-structured interviews, reveals the complexity and diversity of stakeholder perceptions regarding the current and future governance of the Norwegian salmon farming industry. While the methodology may introduce biases due to a non-representative sample, it successfully highlights the varied perspectives and aims to reach data saturation.

Several improvements could enhance this work. Interviewing a more diverse range of fish farming companies, including those using different technologies (land-based, offshore, closed, and submerged cages), could provide a more quantitative understanding of industry sentiments toward the WP. Additionally, interviewing different hierarchical levels within companies (from field operators to strategic management) might reveal further insights. Geographical diversity in interviews could also provide a more comprehensive view, as perceptions may vary by region. For example, fish farmers in PO with different statuses under the TLS may have varying views on the WP (Producer 3).

The WP is part of a longer process, with final implementation expected around autumn 2028 (Bryde, 2025). Several political parties agreed in June 2025 to introduce a new Aquaculture strategy but with certain amendments to the original proposal (Stortinget, 2025). This ongoing process underscores the dynamic nature of governance in the salmon farming industry and the need for continuous dialogue and adaptation among all stakeholders.

4. In this context, BiOceanOr can help making DO an operational parameter for decision making and supporting governability

4.1. BiOceanOr leverages the DO data into actionable analytics and forecasts

Dissolved oxygen as a factor of growth, appetite, digestion, and stressors

The governance of the Norwegian salmon farming industry aims to enable more growth and environmental sustainability (MTIF, 2025a). The WP highlights the need for knowledge on several aspects and better cooperation among stakeholders, particularly in data sharing (County official 1; Regulator 1). BiOceanOr's expertise fits into this context as the company focuses on the **impact of the environment on aquaculture**, enabling fish farmers to improve fish health and welfare and increase production.

BiOceanOr specializes in analyzing and predicting water quality parameters, particularly dissolved oxygen (DO), at site-level. DO is a crucial factor for the growth of Atlantic Salmon. Research by Mette Remen has shown that **oxygen reductions negatively influence the production performance and welfare of salmon** (Remen, 2012). To maximize the growth potential of Atlantic salmon in the on-growing phase in open sea cages, the DO level must exceed the minimum DO required for maximal feed intake (DOmaxFI). Studies demonstrate sustained appetite with decreasing DO until a threshold level (DOmaxFI) is reached, at which point appetite gradually decreases. Both the maximal level of feed intake (DFImax) and the DOmaxFI are highly dependent on temperature (Remen *et al.*, 2016).

Furthermore, research on the effects of hypoxic periods on the feeding behavior and physiology of Atlantic salmon post-smolts suggests that 70% O2 may represent a threshold for reduced growth and that 60% O2 represents a minimum O2 saturation for the welfare of Atlantic salmon post-smolts subjected to cyclic hypoxia at 16°C. Acute reductions in oxygen to levels below 60% O2 induce oxygen shortage and a generalized stress response in fed fish (Remen *et al.*, 2012). Hypoxia thus acts as a stressor for Atlantic Salmon, severely impeding digestion and growth (Nuic *et al.*, 2024).

Adjusting feeding according to DO levels and other stressors, such as delousing operations, is essential in the salmon farming industry. Optimizing feed usage is not only **economically beneficial** for fish farmers but also crucial for **limiting biological risks**, such as mass mortality events due to low DO levels (Salmon Business, 2024). Feed is the single largest cost for Norwegian salmon farmers, accounting for approximately 50% of the industry's unit production costs (Asche & Oglend, 2016). Efficient utilization of feed is important both economically and from a sustainability perspective, as it reduces environmental pollution through feed waste (Newton & Little, 2018).

BiOceanOr: Helping adjust feed according to predicted DO levels

BiOceanOr offers a SaaS solution that leverages DO data into actionable analytics and forecasts for fish farmers, making this parameter a **decision-making tool**. The predictive model provides fish farmers with predictions over the next hours on DO levels, including early warnings for levels under a defined threshold, as illustrated in **Figure 4**. This forecasting tool enables fish farmers to guarantee good DO levels for salmon in a commercial environment and decide when to turn on oxygenators, for example. BiOceanOr also works on designing "best feeding windows", indicating optimal periods for feeding during the day based on DO levels and planned operations that could cause stress to the fish.

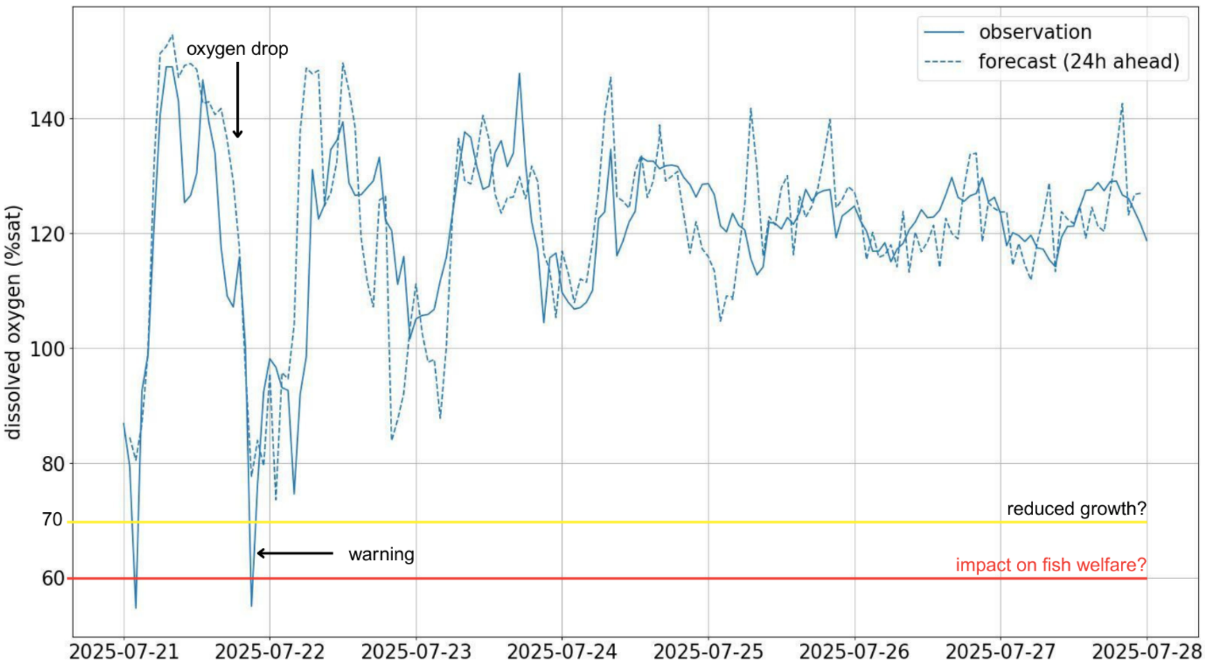

Figure 4. Example of a DO forecast time-series by BiOceanOr at a salmon farming site in Norway.

By helping fish farmers feed salmon in the best possible conditions for feed intake and digestion, BiOceanOr contributes to improving **fish health and welfare**. The company enables optimal use of resources, whether energetic, economic, or environmental, by reducing feed waste. The installation of the service requires minimal effort from fish farmers, as measuring DO in net-pens is mandatory in Norway (Aquaculture Operation Regulations, 2008), and most sensor systems capture multiple environmental parameters, including DO saturation, temperature, current speed, salinity, and turbidity (Berntsson *et al.*, 2024). Via an API, BiOceanOr leverages this data to optimize production efficiency.

BiOceanOr is actively working on several improvements to its services, including enhancing the predictive model to incorporate more key factors and increase the precision of outputs. The company is also developing a data consistency tool to improve the quality of data collected, making its analysis and predictions more accurate.

Growing interest in DO analysis and forecasts in Norwegian salmon farming

Adjusting feeding according to DO is essential in the salmon farming industry, particularly in the context of the WP and climate change. The DO dynamics inside net-pens are often unknown (Regulator 3), especially with new production methods expected in the future. The complexity of DO dynamics, influenced by factors such as sea water temperature, current, density stratification, fish size, health and metabolism, biomass density and distribution, topography, production routines, and farm configuration, underscores the need for better understanding and monitoring. With growing data collection and complex phenomena, there is increasing interest in implementing digital technologies and utilizing big data analyses in aquaculture operations (Berntsson *et al.*, 2024). Several interviewees expressed a desire to better understand **DO dynamics in commercial environments**, supporting BiOceanOr's efforts. While water quality, particularly DO, is not currently considered a limiting factor in Norwegian salmon aquaculture, stakeholders recognize the importance of controlling and monitoring as many factors as possible, including DO, to ensure optimal conditions for fish health and welfare (Expert 1; Researcher 1; Expert 2).

Climate change and new dynamics observed and expected in the natural environment further emphasize the need for growing interest in water quality. A researcher in oceanography finds that three evolutions of the marine ecosystems are expected in the future, namely more nutrient salts in the water, less light coming through the water, and higher sea water temperatures (Researcher 4). IMR expects marine heatwaves to likely occur more frequently with climate change (Grefsrud *et al.*, 2025). Regulators and researchers regret the lack of discussion about water quality in Norwegian salmon farming, with concerns about deteriorating water quality inside net-pens and the potential impacts of climate change on DO levels (Regulator 3; Regulator 2; Researcher 4; Researcher 1). Warmer water temperatures, associated with high densities in net-pens, could lead to more problems with DO in the future, affecting not only DO levels but also sea lice pressure, bacterial diseases, and string jellyfish pressure (Grefsrud *et al.*, 2025; Researcher 5; Producer 1; Producer 2).

In the context of climate change, new production methods, and a growing need to improve SLO, stakeholders expect requirements and regulations to evolve towards **more monitoring of the water environment**, with DO being one of the indicators to be monitored (Regulator 3). Certification schemes already ask fish farmers for more demanding monitoring than regulations, and the evolution of standards is in line with the increasing expectations for sustainability and environmental responsibility in the industry (Market player 2; Market player 3).

In conclusion, as Atlantic salmon depend on DO to survive and grow, managing DO is essential for welfare and growth (Berntsson *et al.*, 2024). BiOceanOr contributes to creating knowledge about water quality and DO dynamics in commercial environments, emphasizing the importance of these aspects in the context of the WP and climate change. By using DO as an indicator of good water quality and fish welfare, BiOceanOr helps fish farmers optimize feed utilization, improve production efficiency, and align with the spirit of regulations that aim to minimize unnecessary suffering for fish (Expert 2). Anticipating risks linked to water quality can be more efficient than reacting to “incidents”, and stakeholders suggest exploring other aspects of water quality, such as the forecast of harmful algal blooms (HABs), diseases like infectious salmon anemia, and string jellyfish pressure, for further improvements in the industry (Expert 1; Producer 2).

4.2. Enhancing environmental knowledge with BiOceanOr

Dissolved oxygen as an indicator of carrying capacity

The WP states that it is the effective capacity of the environment to sustain pollution locally that should drive how much aquaculture, thus pollution, is "acceptable" in each locality (MTIF, 2025a). However, the WP doesn’t clearly establish what indicators should be used and how the carrying capacity is to be determined. Some scholars argue that DO levels should be “the critical parameter for determining **carrying capacity estimations** within a fjord” as reviewed by Quiñones *et al.* (Quiñones *et al.*, 2019).

DO is an important indicator of water quality, directly reflecting an **aquatic resource's ability to support aquatic life**. While each organism has its own DO tolerance range, generally, DO levels less than 5 mg/L are considered stressful for fish, and levels less than 3 mg/L are too low to support fish. DO levels below 1 mg/L are considered hypoxic and usually devoid of life (US EPA, 2025). Moreover, if the DO levels are already low in a locality without aquaculture, the additional life brought into the local system, especially in open net-pens, could further weaken the ecosystem.

In Chile, a significant environmental impact of salmon farms is the increase in organic matter load to the seafloor, which can decrease DO in the water column and the oxidation-reduction potential of the sediments. High flows of organic matter can create hypoxic or anoxic conditions in surface sediments, preventing survival of oxygen-dependent macrofauna. Decomposition of excessive organic matter increases microbial oxygen consumption in bottom waters, ultimately forming toxic hydrogen sulfide under anaerobic conditions (Quiñones *et al*., 2019).

Oxygen is thus essential for proper mineralization and degradation of organic matter, facilitated by mineralizing bacteria at optimal temperatures. Poor DO levels negatively influence the nitrogen cycle, rendering an environment less capable of sustaining aquaculture pollution. Many stakeholders note decreasing oxygen levels on the seabed in areas like the Hardanger fjord, where aquaculture localities are densely located (County official 1; Regulator 5). The county governor has even halted the review of new locality applications due to oxygen problems at the bottom (County official 1). Stakeholders recognize that this trend implies the environment may soon be less able to sustain aquaculture pollution (Regulator 1; Regulator 5; County official 1). Thus, DO could serve as an indicator of the **environment's ability to sustain aquaculture pollution**, such as feces and feed waste.

Growing interest in science and knowledge among industry stakeholders

Furthermore, there is a growing interest in science and knowledge in the industry. With climate change and marine heatwaves to be expected more frequently, some industry actors are aware that there could be drops of oxygen more frequently (Producer 2). They question their knowledge on the phenomena linked to climate change: "*[The stakeholders] could know more about [climate change] even though [they] might not be able to do anything about it*" (Producer 3), and "*there is a lot [the stakeholders] do not understand [of the underwater environment and the relationship between the intensity of the production activity and the water environment]*" (Producer 2). For them, this should change, and they wish to understand why and how the environment behaves also outside the net-pens, and why and how the environmental problems occur (Producer 2; Producer 3).

The interest of the industry actors as well as other stakeholders is also linked to the new production methods and particularly those that explore new spaces like offshore and submerged (open or closed) systems. The industry is expected to use new spaces for salmon farming, where the water quality, especially the DO dynamics, is not well known. The carrying capacities and risk factors along the coast are different (County official 1; Producer 1; Producer 2). A state agent questions these aspects: "*What is water quality at sea? How to ensure good water flow through the offshore facilities?*" (Regulator 3). These developing technologies boost the interest in science in the industry. According to researchers in aquaculture technologies, it is "*a myth, a rumor, that the fish farmers do not use science*", and they do even more especially because of the new technologies (Researcher 2). They further explain that "*it is exciting [as researchers] to participate in projects with fish farmers [because] they are very interested*" (Researcher 3). The researchers nuance their opinion explaining that the interest of the fish farmers highly depend on the subject. As an example, the researchers mention projects on water chemistry as projects that particularly interest the fish farmers. However, if the project requires too much effort, handles very sensitive issues, or if the fish farmers can already buy an existing technology to solve the issue directly, the interest in the research project is much lower (Researcher 2; Researcher 3).

The external environmental is linked to the dynamics inside the net-pens, especially for open systems, which also explains the interest of the industry actors. It's high time the stakeholders stopped talking about "*incidents*" when a rare but not unknown event occurs like a drop of oxygen or an algae bloom (Expert 2; Producer 2; Regulator 3). Such events often explain much of what is happening in the open net-pens, and they can also explain the dynamics in semi-closed, closed, and submerged systems. In this way, BiOceanOr can help the fish farmers and other stakeholders "*gain situational awareness*" and understand the phenomena and why they are happening (Expert 2; Producer 2).

The role of BiOceanOr

With the expertise of BiOceanOr on the analysis and modeling of DO dynamics in commercial environments, the company could help **building environmental knowledge** with and without aquaculture. This would primarily be of interest for the GS in order to determine typical carrying capacity of the environment based on DO. With its expertise in forecasting and predictive modeling, BiOceanOr could also contribute to the discussions on the impact of climate change on aquaculture and to considering multiple temporal scales of the capacity of the environment to sustain aquaculture as emphasized by Weitzman, Filgueira, and Grant for a holistic carrying capacity process (Weitzman, Filgueira, & Grant, 2021). By building knowledge on these aspects, BiOceanOr could help the fish farmers and other stakeholders to work on climate change adaptation on the one hand, and understanding new spaces and the risks linked to them on the other.

Other indicators are surely important like those assessed in the B and C-surveys to monitor the impact of aquaculture on the seabed conditions (DoF, n.d. e). Further investigating the correlation between the seabed conditions and the water quality in the water column could be of interest for the GS to assess whether DO is actually an important factor to determine the carrying capacity of the environment.

4.3. BiOceanOr can help support governability and accompany the paradigm shift: The PREDIMAR project in Chile (case study)

What is PREDIMAR?

BiOceanOr primarily operates in the salmon farming sector. **Chile**, the second largest producer after Norway, produced about 703,000 tonnes in 2024 (FAO, n.d.; SUBPESCA, 2024). Salmon production concentrates in the regions of Los Lagos and Aysén, representing about 85% of salmon production in 2024 (SUBPESCA, 2024). The Chilean salmon farming industry frequently faces mortality events due to low DO levels. Linford *et al.* reveal the mechanisms leading to hypoxic conditions in various fjords of Patagonia, driven by the advection of low-oxygen waters, organic matter degradation from freshwater inputs, and phytoplankton blooms (Linford *et al.*, 2024). This context and stakeholder awareness of these issues explain why BiOceanOr has been able to easily penetrate the Chilean market.

BiOceanOr is further exploring its market opportunities by developing a business-to-government (BtoG) model between the company and the public sector. The **PREDIMAR** project aims to develop a tool for predicting the evolution of water quality for salmon aquaculture in Chile, with a focus on predicting DO variations in water. The project will enable authorities and fish farmers to anticipate environmental situations that put at risk the health, survival, and growth of salmon.

BiOceanOr should develop a tool able to predict the variations of DO in sea water in aquaculture facilities up to 48 hours in advance, and the forecasts will be delivered at the ACS level (regional level) (SMA, 2025). The beneficiary of the project is the SMA, an agency of the Chilean Ministry of the Environment responsible for environmental monitoring and inspection of environmental instruments (SMA, n.d.). Financial support for the project was obtained through the FASEP program, running from February 2025 to September 2026 (SMA, 2025).

Enhancing governability and accompanying the paradigm shift through a PREDIMAR-like project:

The PREDIMAR project is interesting for several reasons, and BiOceanOr wishes to highlight how this project can bring value to other salmon-producing countries such as Norway.

Useful

A project like PREDIMAR requires comprehensive **structuring of water quality data**, which is essential for extracting valuable information. As a researcher points out, "*The better the measurements [of environmental parameters] today, the better the results of the predictive models*" (Researcher 4). This improved data structuring could enhance the quality of annual reports on salmon aquaculture, such as the risk report by IMR. PREDIMAR's real-time data complements such long-term analysis, enabling short-term risk anticipation. Fish farmers could also find significant value in this approach for their monitoring activities. Additionally, such structuring is valuable for the fish farming companies facing issues with data quality.

Easy to implement

Implementing a project like PREDIMAR in Norway is feasible due to the existing infrastructure, where fish farmers already use real-time sensor networks to measure environmental parameters like DO levels (Berntsson *et al.*, 2024). This setup allows for immediate data collection, forming a strong foundation for the project.

The project would require enhanced **data sharing** and standardization though, aligning with the industry's digitalization goals and contributing to the objectives outlined in the WP (MTIF, 2025a). **Standardization** is crucial for effective data sharing and must accompany the digitalization of the industry (Expert 2). Fish farmers are increasingly open to sharing data, which can improve cooperation and predictive accuracy without compromising sensitive information (Researcher 3; Researcher 2; Researcher 4).

PREDIMAR represents a "digital regulation innovation", requiring minimal new infrastructure. **BarentsWatch** (BW) could serve as a potential platform for integrating this data. BW is a public common solution where data from several governmental agencies are collected and are accessible to the user. Its goals are precisely to establish and develop digital services for data sharing and cooperation that contributes to using and managing the Norwegian ocean and coast in an efficient, sustainable, and well-coordinated manner (Røeggen, n.d. a). BW is a facilitator for growing collaboration, between public agencies as well as between the public and private sectors (Røeggen, n.d. b). Integrating a service for water quality and DO measurements into BW could further enhance its utility and support the goals of PREDIMAR.

BtoG beneficial for both parties

BiOceanOr argues that a BtoG project like PREDIMAR is beneficial for both the GS and the SG, mainly the industry actors. For the GS, the project could help define water quality standards, especially for DO. Berntsson *et al.* emphasize the importance of high-quality environmental data for animal welfare and production optimization (Berntsson *et al.*, 2024). DO forecasts at a regional level could provide fish farmers with **real-time water quality information**, aiding operational decisions like feeding. For more precision (at site-level), BiOceanOr still offers its BtoB services. This project could foster **new ways of cooperation** and relationships between fish farmers and regulators.

Good timing due to the WP

The situation in Norway seems ideal for implementing such a project, aligning with the government's ambitions in the WP for digitalization and environmental sustainability (MTIF, 2025a). The PREDIMAR project is possible in Chile due to SMA's specific regulations requiring detailed DO measurements and data sharing (Chile, 1989; SMA, 2020). A new data-sharing routine in Norway could enable similar benefits of a PREDIMAR-like project.

In summary, the PREDIMAR project is useful for stakeholders and easy to implement in Norway, where digitalization is advanced. This BtoG project benefits both the GS and the industry actors, inspiring new ways of cooperation. BiOceanOr aims to leverage Norway's governance changes, although social acceptance of private-public collaborations may pose challenges. Engaging platforms like AquaCloud into the project could facilitate easier entry.

5. Conclusion and discussion

Summary of the findings

The master's thesis has explored the governability of the regulatory framework of the Norwegian salmon farming industry, focusing on the perspectives of various stakeholders. The findings reveal that the current governance system, characterized by tools such as the MAB, licenses, and the Traffic Light management system, faces significant challenges in balancing sustainability and growth. The industry, while being a crucial economic sector for Norway, struggles with environmental issues like sea lice infestations and fish welfare concerns, which have led to a negative public perception and calls for improved sustainability practices. The introduction of an Aquaculture White Paper in April 2025 proposes radical changes to the regulatory framework, aiming to enhance environmental sustainability and fish welfare. However, the WP's effectiveness is debated among stakeholders, with concerns about its potential to achieve the intended goals of sustainable growth and predictability. The study highlights the complexity of stakeholder interactions and the need for a more cohesive and transparent regulatory approach.

The research questions guiding this study were:

1. **How can the governance of the Norwegian salmon farming industry enable predictable and sustainable growth, according to stakeholders?**

Stakeholders perceive that effective governance requires a balance between environmental sustainability and industry growth. The current regulatory framework is seen as complex and layered, with a need for simplification and better coordination among regulatory bodies. The WP's proposals, such as the removal of MAB and the introduction of sea lice emission quotas, are steps towards this balance but require careful implementation and stakeholder engagement to ensure success.

2. **How do stakeholders perceive the future governance of the industry, particularly in light of the recently published WP?**

Stakeholders have mixed perceptions of the WP's potential to improve governability. While some view the WP's focus on sea lice and environmental sustainability as positive, others express concerns about the lack of clarity and the potential economic and operational impacts. There is a consensus that the WP's success will depend on its ability to address the broader environmental impacts of salmon farming and to provide a clear and predictable regulatory environment.

3. **In this global context, how can a firm like BiOceanOr deliver value to the industry?**

BiOceanOr, with its expertise in real-time and predictive analytics for water quality, especially DO, can contribute to supporting the industry's transition towards more sustainable practices. By providing actionable insights and forecasts, BiOceanOr can help fish farmers optimize production efficiency, improve fish welfare, and align with regulatory requirements.

The company's involvement in projects like PREDIMAR in Chile demonstrates its potential to enhance governability and accompany the paradigm shift in the industry. By leveraging its expertise in data analytics and forecasting, BiOceanOr can help the industry adapt to regulatory changes, improve environmental sustainability, and achieve predictable growth.

The company's role in building knowledge on the environment and its carrying capacity can further support the industry's efforts to address environmental challenges and comply with regulatory requirements. BiOceanOr's predictive models and data consistency tools can provide valuable insights for stakeholders, fostering a more collaborative and informed approach to governance.

Limitations and future research

This study has several limitations that should be acknowledged. The research is based on a mixed-methods approach, combining literature review and semi-structured interviews. While this approach provides a comprehensive understanding of the governance challenges and stakeholder perceptions, it may introduce biases due to the non-representative sample and the subjective nature of qualitative data. Future research could benefit from a more diverse and representative sample of stakeholders, including fish farming companies using different technologies and operating in various regions. Additionally, interviewing different hierarchical levels within companies could provide a more nuanced understanding of the industry's challenges and opportunities.

In conclusion, this study highlights the complex interplay between regulatory frameworks, stakeholder perceptions, and industry practices in the Norwegian salmon farming industry. By addressing the governance challenges and leveraging the expertise of companies like BiOceanOr, the industry can move towards a more sustainable and predictable future. The findings underscore the need for continuous dialogue, collaboration, and innovation among stakeholders to achieve the shared goals of environmental sustainability and industry growth.

Other aquaculture producing countries are currently reviewing their regulatory framework. For instance, Chile has recently proposed a “traffic light” system for its salmon industry, similar to Norway's approach, which categorizes production areas based on environmental impact levels to manage and mitigate risks (Appel, 2025). This raises questions about the global relevance and adaptability of governance models in aquaculture, demonstrating how different countries are addressing similar challenges.

Furthermore, sustainability of salmon farming should be understood in a broader manner. The WP mainly focuses on the production phase of salmon and trouts, but other aspects of the governance could be discussed. Sustainability is not just for the grow-out phase, but also the smolt production, slaughtering, transport, and distribution. Aquaculture involves the production of aquatic organisms, yet discussions rarely encompass other aquaculture productions. Interviewing stakeholders and considering their suggestions for improved governability of the entire value chain could provide valuable insights for enhancing sustainability across the sector.

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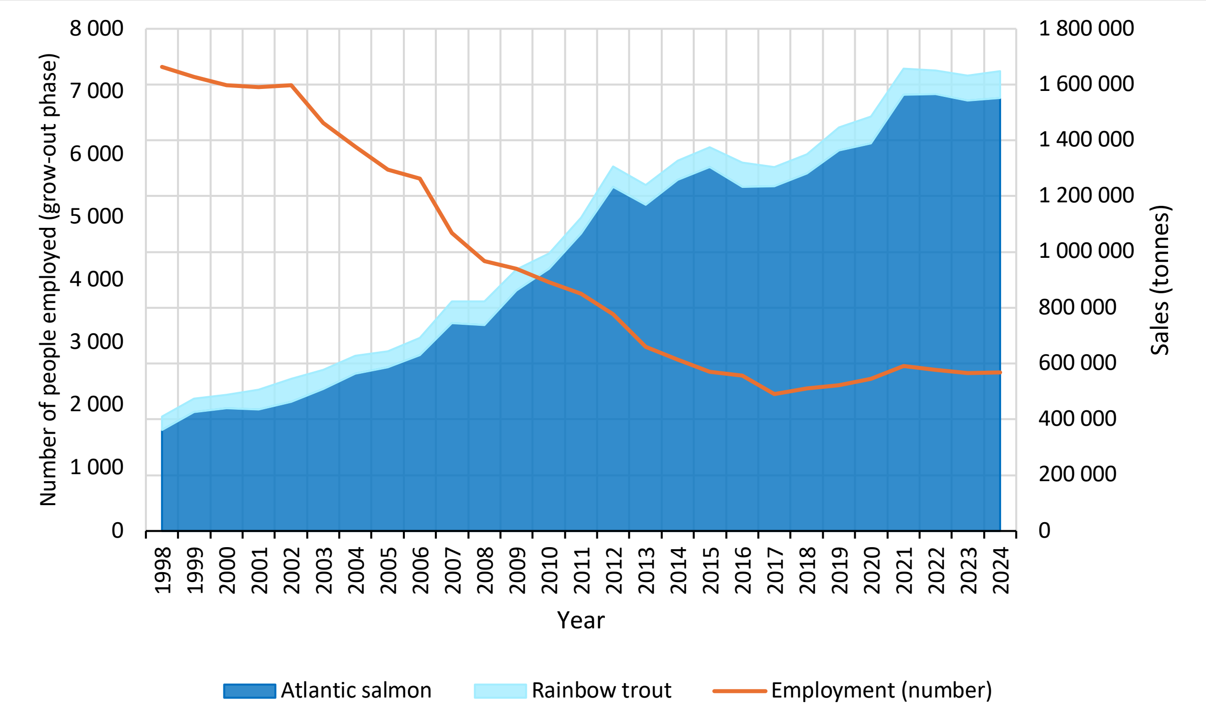
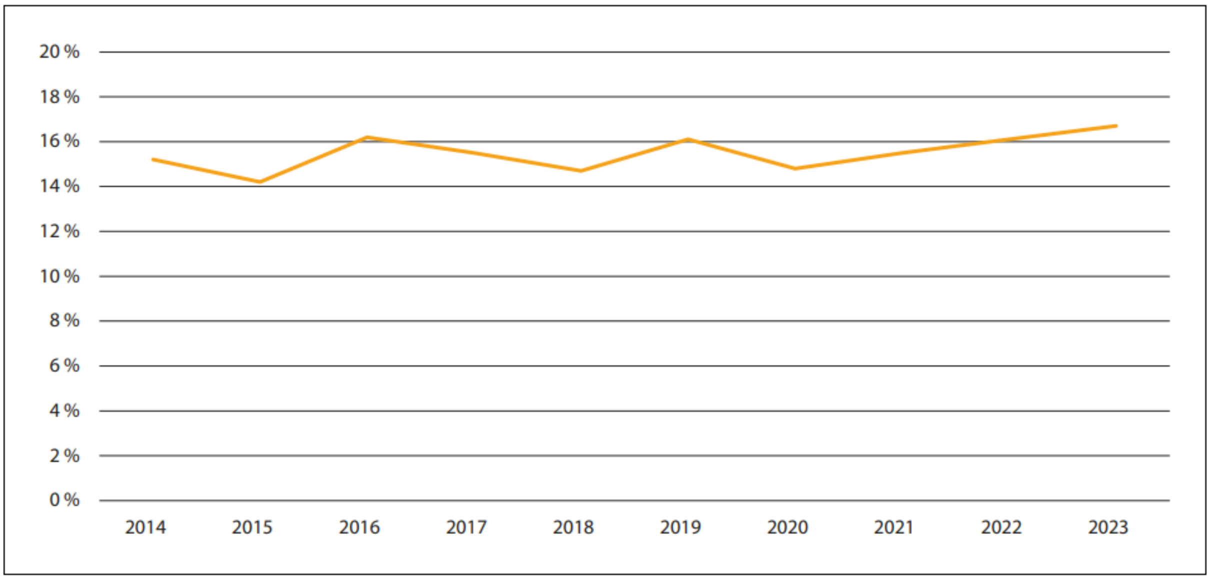
Appendices

Appendix 1. Sales of Atlantic salmon (*Salmo* salar) and rainbow trout (*Oncorhynchus mykiss*), and employment, from 1998 to 2024 (Source: DoF, 2025, https://www.fiskeridir.no/statistikk-tall-og-analyse/data-og-statistikk-om-akvakultur/akvakulturstatistikk-laks-regnbueorret-og-orret-offisiell-statistikk).



Appendix 2. Annual fish mortality rate (percent) in the sea-phase for salmon production, from 2014 to 2023 (Source: MTIF, 2025a).



Appendix 3. Example of an interview guide used to collect data on stakeholder perceptions.

<table>
<tr><td colspan="3">Interview guide for: <u>Governmental authorities</u>
Initial instruction: How should the Norwegian salmon farming industry <u>be governed</u> to reach its goals of sustainability and growth? What is the role of the <u>institutional actors</u>, and to what extent do they provide support for governability? To what extent are the environment and water quality included in your work?</td></tr>
<tr><th>Thematic focus</th><th>Questions</th><th>Aim</th></tr>
<tr><td>The play between the stakeholders</td><td>Relationship with industry actors (fish farmers, suppliers)
- What are the industry actors expecting from you?
Relationship with regulators
- Do you have a (in)direct connection with the other authorities?
- If not, what are the legal/administrative and strategic hurdles which prevent such a collaboration? Would you have wanted more collaboration?
- Did you engage in the WP (& how)?
Relationship with other interest groups
- Do you work with ENGOs, research institutes, other organizations (& how)?
- What is (or should be) their role in the regulation?
- What do <u>they</u> expect from you? What do <u>you</u> expect from them?
PREDIMAR: Would such a program improve the relationship between the farmers and the authorities? What would you expect from such a program in Norway?</td><td>Understand the role of the governmental authorities in the governance.

Understand to what extent governmental authorities are important for the other stakeholders.</td></tr>
<tr><td>Changes in the regulatory framework: the Aquaculture White Paper (WP)</td><td>Expectations vs. reality
- To what extent are your expectations met with the WP?
- To what extent would such new regulations affect your work?
Efficiency of the measures announced
- Will it be more efficient to reach the goals of sustainability and growth (& why)?
- Do you think it will solve the problem of a complex and layered regulation? More efficient?
- Is it too radical? Quick enough?
- Do you think it will make the governance more adaptable, and more efficient to anticipate changes?</td><td>Understand their reaction to the WP (globally positive, negative, or neutral).</td></tr>
<tr><td>(Environ-mental) sustainability and fish welfare</td><td>Defining sustainability in the governance
- What is ‘sustainability’ for you? Do you think it’s the same for the other stakeholders?
- To what extent should (environmental) sustainability be integrated into the global governance? Is that its place in today’s regulation?
- In the WP, do you find the concept more or less central in the governance (& why)?
From volume to impact-based regulation:
- The government wants to incentivize low environmental impact production systems. Is it actually enabled with this regulation?
- Is the definition of “low impact” too focused on some issues (sea lice, escapes, and not the whole ecosystem)?
- Is there an overwhelming focus on sea lice and escapes? What other environmental issues are not dealt with (& why)? Is it problematic?
Fish welfare (mortality): Is a fee for ‘lost’ fish as announced by the government the most efficient way of reaching 5% mortality (& why)? What risks?
Water quality</td><td>Understand their vision of sustainability and how they operationalize it.

Understand their reaction to the impact-based regulation announced by the government.</td></tr>
</table>

	- To what extent is it important to monitor/predict DO in Norway (& why)? - To what extent do you acknowledge the relationship between good DO levels, feeding, and fish welfare? - Do you think BiOceanOr, providing DO forecasts, can add value to optimize the feeding/production?	
Growth and technologies challenging the governance	Do you agree that technology is the (only) way to both improve (environmental) sustainability and stimulate growth? **Technologies challenging the current governance** - To what extent do new technologies and innovation challenge <u>the governability</u>? - Do you think suppliers (like BiOceanOr) can improve governability? **A new framework for growth and innovation** - "*The TLS doesn't give the industry strong enough incentives to develop, invest in, or implement more environmentally friendly production methods*." (Minister of Fisheries and Ocean Policy) => Do you agree? - Are removing the MAB, selling new licenses, and creating a more global spatial planning the solutions to stimulate growth? - The government says it "*openly supports the development of the industry and creating as much total value as possible*" (Minister of Fisheries and Ocean Policy) => To what extent does the WP create a good framework for new technologies and innovation? - How does the current or future regulation help with risk management? **Data utilization and sharing** - Is data sharing more/less important in this new context? - Most farmers collect data on water quality/DO => To what extent do they use it? Would BiOceanOr provide valuable help by leveraging this data?	Understand whether the governance actually enables growth and innovation.
Social license to grow and industry image	**Challenges with SLO** - Does the industry lack social license to grow? - Do the fish farmers expect you to improve SLO? - Do suppliers (like BiOceanOr) have a role in improving SLO (& how)? - Benefit sharing to encourage the municipalities to give space to aquaculture; Is the resource rent tax still controversial? - With the WP, will the resource rent tax make more/less sense? **Socio-economic model favored by the WP** - To what extent does the WP consider socio-economic aspects? - Arguing that the government lets the farmers "choose their production methods", what types of production are actually possible in this context? - Big vs. small companies: Does the regulation favor a certain socio-economic model? Is the regulation as 'neutral' as announced by the government?	Are the socio-economic aspects considered? Although a certain socio-economic system isn't directly supported, is it true in practice?

Appendix 4. Stakeholder interview details and corresponding text references.

Interviewed stakeholders	In-text citation	Interview before or after the WP, and virtual or in-person (by default)
Industry actors (producer & industry organization)	Producer 1 Producer 2 Producer 3 Industry representative 1	After * After (virtual) After (virtual) * After *
Industry actors (experts)	Expert 1 Expert 2	Before (virtual) Before (virtual) *
Industry actors (market)	Market player 1 Market player 2 Market player 3	After * Before (virtual) Before (virtual)
Governmental authorities (regulators): DoF, NEA, NFSA	Regulator 1 Regulator 2 Regulator 3 Regulator 4 Regulator 5 Regulator 6	After (virtual) After (virtual) before (virtual) * After After After
Political authority: county municipality	County official 1	After *
Researchers: IMR, SINTEF, VI	Researcher 1 Researcher 2 Researcher 3 Researcher 4 Researcher 5	After After (virtual) After (virtual) After * After *
ENGO	ENGO 1	After *

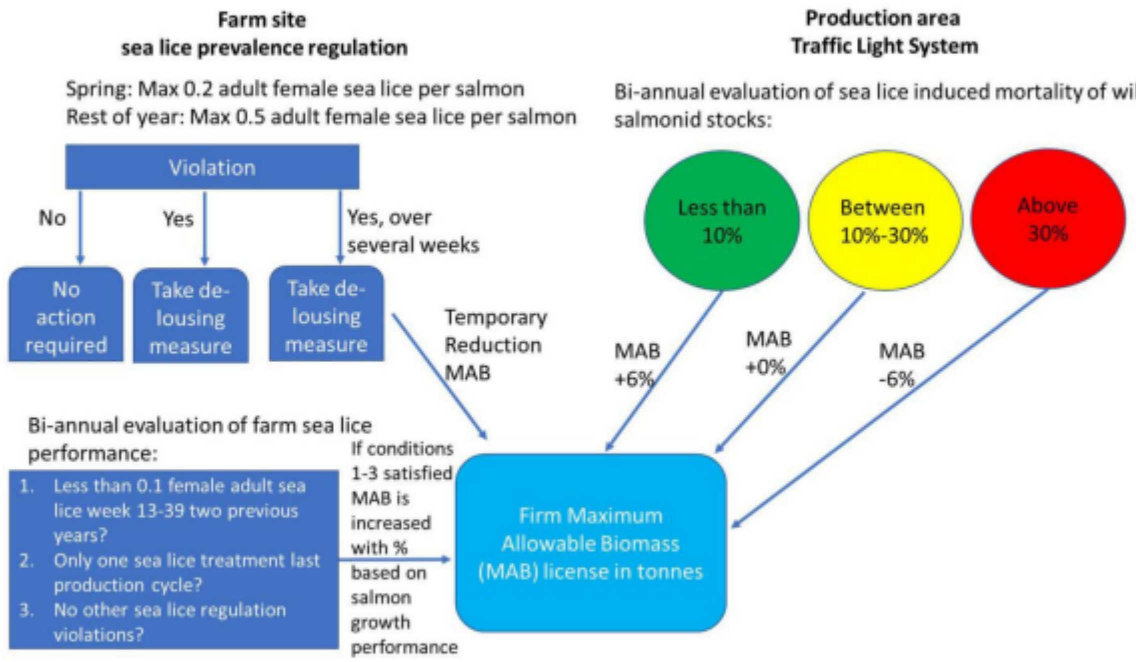
Explanation:

- **Anonymity and limited data**: Industry actors, the county municipality, and the ENGO interviewed are not specified.
- **A total of 22 people were interviewed**, with 16 interviewed individually and 2 pairs for technical reasons (Market players 2 and 3; Researchers 2 and 3).
- **Interviews conducted before the publishing of the WP** took place between March 17, 2025, and April 10, 2025. These interviews aimed to complete the readings and refine the study's focus (involving Expert 1, Expert 2, Regulator 2, and Market players 2 and 3).
- **In-person interviews after the WP** took place between April 23, 2025, and April 29, 2025), primarily in Bergen and Oslo.
- **Virtual interviews after the WP** occurred between April 24, 2025, and May 15, 2025.
- **10 "second interviews"** were conducted between June 5, 2025, and June 17, 2025, all of which were virtual and are noted with an asterisk (*).
- **Interviews were conducted in Norwegian** (native language) and translated into English (native language) by the author, except for that with Market players 2 and 3, which was conducted in English.

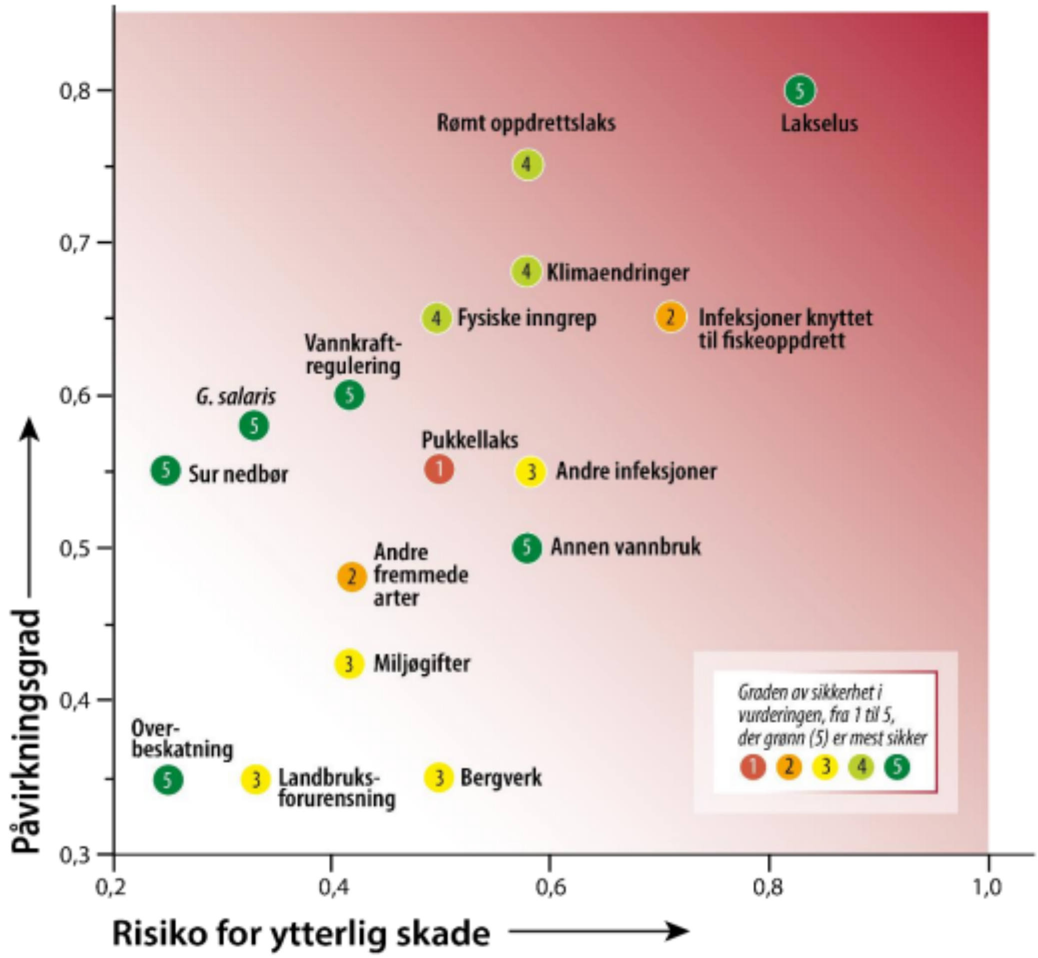
Appendix 5. Maximum Allowable Biomass (MAB) for firms, farm sites and production areas (Source: Tveterås, R., Misund, B., Roche Aponte, F., & Pincinato, R. B. (2020). Regulation of salmon aquaculture towards 2030: Incentives, economic performance and sustainability. Stavanger: NORCE Norwegian Research Centre AS. 82 p. https://hdl.handle.net/11250/3050414).

Level	Comment
Firm	Each firm owns a number of licenses with a MAB, which specify the farm site and PO where the license can be used.
Farm site	The MAB at the farm site level is restricted.
Production area (PO)	Since MAB licenses owned by firms specifies the PO where they can be used, the total MAB at the PO level is also restricted.

Appendix 6. Overview of the salmon lice regulation in Norway (Source: Jensen, Tveterås, & Nielsen, 2024).



Appendix 7. Various human-induced risk factors to wild salmon in an impact and risk diagram (Source: Thorstad & Forseth, 2025).



Explanation:

The diagram shows human-induced risk factors to the wild salmon stocks. Horizontal axis: Risk of further damage. Vertical axis: Level of impact. The background color indicates the severity (dark color being the most severe). The colors of the points symbolize the degree of certainty in the assessment, based on how well-documented the effect is, and how consistent the documentation and experts are in the assessment, using a five-point scale (5 being the most certain). For more details, please refer to: Thorstad & Forseth, 2025.