Environmental Innovation and Societal Transitions 48 (2023) 100753

Contents lists available at ScienceDirect

Environmental Innovation and Societal Transitions

journal homepage: www.elsevier.com/locate/eist

Law and sustainable transitions: An analysis of aquaculture regulation

Lena Schøning[a,*], Vera Helene Hausner[b], Mathilde Morel[a]

[a] Centre for the Law of the Sea, Faculty of Law, UiT The Arctic University of Norway, Postboks 6050, Langnes N-9037, Norway
[b] Arctic Sustainability Lab, Faculty of Bioscience, Fisheries and Economics, UiT The Arctic University of Norway, Norway

ARTICLE INFO

Keywords:
Sustainability
Law
Transition
Trajectories
EU taxonomy
Aquaculture

ABSTRACT

The global demand for aquaculture products is rising, driven by declining wild fisheries, food security, and blue economy policies and initiatives, suggesting that aquaculture is significant for a sustainable future, despite its negative environmental impacts. Here we investigate the role of law in accelerating the transition towards sustainable aquaculture activities. We use the EU taxonomy for environmentally sustainable activities to define transitional criteria and examine the use of regulations to accelerate the transition in Norway. Even though both the Norwegian government and industrial actors promote transition toward sustainability, we find few regulations in place that accelerate the transition, and we find that sustainability ambitions are likely to be unmet in a business-and-regulation-as-usual scenario. Additional to discussing the role of law in sustainability transitions, we offer a method which can be employed to analyze regulation of different sectors or geographical areas and to devise policy recommendations for sustainable transitions.

1. Introduction

Global consumption of food from the sea is steadily increasing and perceived as a key element of sustainable food production for the future, given emissions from, and a lack of land and water for, agriculture (Costello et al., 2020; European Commission, 2020; Bartley, 2018, FAO, 2022). In recent decades, the aquaculture sector has increasingly been recognized for its essential contribution to global food security and nutrition (FAO, 2022). Yet, aquaculture production is already known to have negative environmental impacts, such as high CO_2 emissions and nutrient discharges (Bohnes et al., 2019; Jiang et al., 2022; Kim et al., 2020; Winther et al., 2020). Further expansion of aquaculture production requires a sustainable transition, meaning systemic changes necessary for human activities to reduce their overall environmental impacts and to transition from unsustainable to more sustainable activities (Johnstone and Newell, 2018; Kivimaa and Kern, 2016). To achieve systemic changes, law has a role to play, although a transition to sustainability depends on multiple preconditions (such as management, innovation, and capital) that goes beyond law. This study analyzes the role of law in accelerating sustainability transitions, using salmon aquaculture in Norway as a case study.

Understanding the role of law in sustainability transitions demands plural research perspectives at different levels of analysis—micro as well as macro (Köhler et al., 2019). This study perceives law as the collective body of binding rules, in which national law and regulations is a part, which is specific to and applicable in each (nation) state. Soininen et al. argue that law plays an important role in sustainable transitions but has been subject to research in transition literature to only a limited extent (Alomari and Heffron,

* Corresponding author.
E-mail address: lena.schoning@uit.no (L. Schøning).

https://doi.org/10.1016/j.eist.2023.100753
Received 8 February 2023; Received in revised form 30 May 2023; Accepted 13 July 2023
Available online 25 July 2023

2021; Heffron and McCauley, 2018; Huhta, 2022; Kivimaa et al., 2021; Lähteenmäki-Uutela et al., 2021; Soininen et al., 2021). Huhta frames the roles of law as facilitative, restrictive, and steering (Huhta, 2022). Soininen et al. conceptualize the role of law in governing sustainability transition as the controls of a vehicle—the steering wheel reflecting goals, the brake pedal reflecting slowing down transitions, and the accelerator describing how law could speed up transitions (Soininen et al., 2021). Our study explores this conceptualization by examining whether Norwegian regulations are accelerating, or if an untapped capacity for accelerating the transition (Garmestani et al., 2019; MacLean, 2020) of aquaculture activities exists. Further, our study discusses the steering wheel that reflect the (sustainable) direction.

We could add to this controls-of-a-vehicle conceptualization that sitting in the front seat is most often the (nation) state (Johnstone and Newell, 2018), the "Archimedean point or scale of reference in law" (Langlet, 2018). Law is inherently state-centric, as the state is a key subject of international law and the maker of national law. This study will demonstrate how national law and regulations, and the states defining them, have a powerful role in determining conditions for access to resources and space and conditions for how activities should be conducted, which defines the environmental impacts of an activity. These conditions are set out in complicated legislation, 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 2022). The conditions are defined by nation states as policymakers or regulators, which in turn adhere to international and regional law, such as European Union (EU) law.

Norway is not technically a part of the EU but implements most regulations and initiatives concerning trade and the environment as defined by the EEA Agreement (EEA Agreement, 1994). The many policies and legislative initiatives framed as the European Green Deal therefore impact the sustainable transition of activities in Norway. The EU Taxonomy Regulation is a finance mechanism incentivizing investments in environmentally sustainable activities (Taxonomy Regulation/852). This regulation will have consequences for investments in the aquaculture industry, depending on whether aquaculture activities will be assessed as environmentally sustainable for investment purposes.

The approach of the EU Taxonomy Regulation is arguably novel by providing a legal definition of, and a standard for, "environmentally sustainable activities," as defined by six environmental objectives. This study is inspired by the EU Taxonomy Regulation yet uses it for a different purpose. We use the six environmental objectives as transition criteria. Thus, we question whether Norway uses regulations to accelerate a transition of aquaculture activities to meet these criteria, i.e., to become environmentally sustainable.

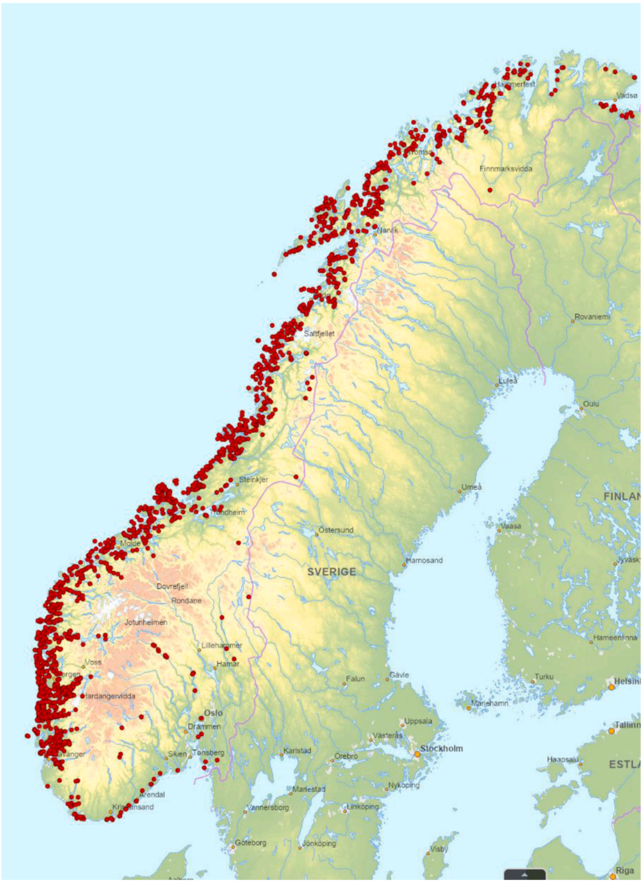

Fig. 1. Yggdrasil mapping solution, Norwegian Fisheries Directorate.

We assume that the development of activities to become environmentally sustainable, will demand three parallel and complementary transitional paths or trajectories: (1) Some existing activities would need to improve to meet these objectives; (2) some existing activities that would never meet the objectives would need to be phased out ("the flip-side of transitions" (Köhler et al., 2019)); and (3) some new activities meeting the objectives would need to be phased in. The latter two trajectories resemble the "creative destruction" policy mixes of Kivimaa and Kern (Kivimaa and Kern, 2016) and the three transition phases of Ludwig (Ludwig, 2019), yet they are supplemented by the first trajectory. In combining the trajectories, we examine whether Norwegian regulations are accelerating the transition of aquaculture activities along one or more of the trajectories.

While we illustrate our approach by regulation of Norwegian salmon aquaculture, the methodology, including transition criteria and trajectories, could be employed to other sectors or activities, or a different geographical scope. Further, this study demonstrates how the standard of environmentally sustainable activities of the EU Taxonomy Regulation could be used to interpret, specify, or clarify environmental legal obligations or political ambitions for transitions to be (environmentally) sustainable, in Norway and beyond. The following Section 2 introduces the methodology, Section 3 analyzes the three transitional trajectories, Section 4 discusses the findings, and finally, Section 5 concludes the study.

2. Methodology

2.1. The case of Norway

In addition to being the world's leading producer of Atlantic salmon, Norway is the largest aquaculture producer in Europe and the eight largest aquaculture producer in the world (FAO, 2022; Rocha et al., 2022). In 2022, Norway exported 1.3 million tons of fish from aquaculture worth NOK 111.3 billion (~EUR 10.4 billion), to Europe, the USA, China, and Japan (Norwegian Seafood Council, 2023). The size of this Norwegian industry implies that the environmental impacts are correspondingly high. Thus, the laws and regulations that define the environmental impacts of these activities make an interesting case for examining trajectories for sustainability transition.

Production of salmon dominates the Norwegian aquaculture industry (Winther et al., 2020). In 2021, along the long and fjord-rich coastline of Norway, 1243 salmon farming licenses were in operation (Norwegian Fisheries Directorate, 2022a), as indicated by red dots in Fig. 1.

Salmon aquaculture activities exert pressures and have impacts upon ecosystems, as any food production does, whether land or sea based. Salmon farming consists of multiple phases involving different inputs, outputs, and services, including breeder fish production (to make eggs); hatchery fish production (production of fry, i.e., young salmon in fresh water); food fish production (feeding of salmon at sea) (Misund, 2022); slaughtering, processing, and packaging; and transport to secondary processing facilities or onward to different markets via road, rail, or air transport (Falconer et al., 2022). The different inputs, outputs, services, and production phases induce a range of environmental pressures, some locally, others globally (e.g., CO_2-emissions), some measurable, others not.

An underlying assumption of this study is that salmon aquaculture in Norway could transition to become environmentally sustainable as per the transition criteria that Section 2.2 will unpack. This assumption is not necessarily shared by all. Other sustainability perspectives on, and criticism of, the sustainability of salmon aquaculture not captured by our perspective exist (Osmundsen et al., 2020). We will give a brief recap of some of these perspectives, as they show the range of sustainability issues salmon aquaculture gives rise to, and illustrate how sustainability could and should be approached in multiple ways, while this study only captures one. We do not analyze whether salmon aquaculture should be replaced by aquaculture of a more diverse set of marine species, by protein sources with fewer environmental effects (e.g. wild-caught white fish (Ziegler et al., 2021) or plant-based protein) nor whether aquaculture should replace other sources of protein with higher environmental effects (e.g., red meat) (Kanemoto et al., 2019; Kim et al., 2020; Winther et al., 2020). We do not question whether making human food of the feed provided to the salmon (which in 2020 consisted of 73.1% vegetable ingredients such as soy protein and 22.4% marine ingredients from fish meal or fish oil (Aas et al., 2022)) would be a more efficient use of resources (in 2020, a total of 1976,709 tons of feed ingredients were used to produce 1467,655 tons of salmon (Aas et al., 2022)), as well as providing improved food security for the poor (Metian, 2009; Seto and Fiorella, 2017).

Some other sustainability perspectives that this study does not discuss involve certain negative impacts associated with salmon aquaculture (compared with using the feed for food), such as: the breeding and feeding of salmon is technology heavy and accordingly expensive; it raises salmon welfare issues (Olaussen, 2018; Sommerset et al., 2022); and it occupies marine areas, which leads to competition and conflicts over marine areas (negatively impacting on, for example, coastal fisheries) (Sætre and Østli, 2021; Winther et al., 2020). Neither do we discuss positive impacts of salmon aquaculture, including the creation of jobs at the coast, profit opportunities for investors, and tax income. If one assumes that salmon aquaculture is non-sustainable, only the trajectory based on the phasing-out of aquaculture activities would be valid. This study, however, assumes that salmon aquaculture could be environmentally sustainable by meeting the six environmental objectives of the EU Taxonomy Regulation. The implied sustainability transition is therefore simplified to make an analysis possible.

2.2. Transitional criteria and sustainability ambitions

The six environmental objectives used as transitional criteria are climate change mitigation; climate change adaptation; the sustainable use and protection of water and marine resources; the transition to a circular economy; pollution prevention and control; and the protection and restoration of biodiversity and ecosystems. Thus, we question whether existing aquaculture regulations in Norway support a transition of these activities to meet these criteria as per the three trajectories and to become environmentally sustainable.

The Aquaculture Act of Norway sets out a standard for the acceptable pressures and impacts of these activities (Aquaculture Act, 2005). The act imposes that aquaculture shall be established, conducted, and winded up in an “environmentally sound way” (Aquaculture Act, 2005), a phrase referred to as the environmental norm. This study argues that the environmental sustainability standard of the EU Taxonomy Regulation is *one* way of interpreting the environmental norm. Thus, first, the present case hinges the environmental sustainability standard of the EU Taxonomy Regulation on the environmental norm of the Aquaculture Act.

Second, the environmental sustainability standard of the EU Taxonomy Regulation could be considered as an interpretation, specification, or clarification of legal or political ambitions that aquaculture activities should transition to be (environmentally) sustainable. The purpose of the Aquaculture Act includes promotion of the profitability and competitiveness of the aquaculture industry “within the frames of sustainable development” (Aquaculture Act, 2005).

Additionally, the ambition that the aquaculture industry in Norway should be sustainable enjoys broad support. The Norwegian aquaculture industry has declared ambitions to become sustainable by 2030, (Seafood Norway, 2018). Political consensus exists on the ambition that the aquaculture industry in Norway should be sustainable by 2030 (Solberg, 2021; Støre, 2021). This political ambition is even included in an international policy statement adopted by Norway and 13 other coastal states as the High-Level Panel for a Sustainable Ocean Economy (High Level Panel, 2020). The High-Level Panel defines as an outcome in 2030 that “aquaculture is sustainably grown to meet global needs, and waste is minimised and managed throughout the value chain” and as a priority action to this end to put “in place policies and management frameworks to minimize the environmental impacts of aquaculture” (High Level Panel, 2020).

2.3. The three transitional trajectories

The first transitional trajectory investigates whether Norway uses regulation to accelerate improvement for existing aquaculture activities for each of the transitional criteria or environmental objectives. This investigation asks two questions. The first is whether the regulations demand any positive (meaning beyond-zero) *contribution* to any of the environmental objectives. The second question is whether they demand any *improvement* of negative impact relevant to the environmental objectives. For example, a positive contribution to climate change mitigation means reducing CO2 in the atmosphere, unlike improving the carbon footprint by reducing CO2 emissions, which the second question target.

In comparison, the approach of the EU Taxonomy Regulation, which concerns screening activities for investment purposes, is that activities to be regarded as environmentally sustainable should significantly contribute to one of the six environmental objectives and do no significant harm to any of the other five objectives. This study rather combines contribution with improvement, reflecting that we investigate transitioning as a process over time, rather than a one-off decision of harm significance to qualify for future green investments. Nonetheless, the investigation of improvement will shed light on regulatory potential for reducing harm for all six objectives.

The second trajectory analyzes whether the regulatory framework for aquaculture activities provides for a phase-out of activities that are not environmentally sustainable. Köhler et al. refer to the phasing-out of systems and regimes (unlike activities) as the “the flip-side of transitions” (Köhler et al., 2019). The underlying assumption is that the systems and regimes are not necessary or eligible alternatives exist. Several drivers of a phase-out could be imagined: replacement by new innovations, lack of demand for un-sustainable alternatives, or different kinds of disincentives (Rinscheid et al., 2021). This study focuses on the use of regulation as a phase-out tool.

The study of the third transitional trajectory examines whether the phase-in of new activities, which are environmentally sustainable at the outset, is provided for in the conditions for issuing concessions and access to localities. The second and third trajectories resemble the “creative destruction” policy mixes of Kivimaa and Kern (Kivimaa and Kern, 2016). By combining them with the first trajectory, this study accounts for the assumption that some existing aquaculture activities and actors could become environmentally sustainable, unlike a need for total replacement. The next section analyzes whether Norwegian aquaculture regulations are accelerating transitions of activities along one or more of the trajectories.

3. Analysis

3.1. First trajectory: Improvement of existing activities

3.1.1. Climate change mitigation

The CO_2 emissions of aquaculture production in Norway have been examined in different assessments (Bohnes et al., 2019; Jiang et al., 2022; Winther et al., 2020). A 2022 study by SINTEF and partners conducts a life cycle assessment of the climate footprint of different Norwegian salmon products (Johansen et al., 2022). This study alongside other studies identifies two main drivers of climate change emissions: feed (Bohnes et al., 2019) and transport (specifically air freight, in which the salmon is flown to Asian and US markets) (Johansen et al., 2022; Winther et al., 2020). Winther et al. state:

> The fish feed is the single factor that contributes most to the carbon footprint of farmed fish [1,7]. In the last ten years, there has been a shift in the fish diets towards a more crop-based diet and currently salmon feed typically consists of about 70% of crop-based raw materials [20]. Fresh Norwegian fish has become a success in many markets, including Asia and the US, especially as regards salmon used in sushi and sashimi. This has led to a large increase in airfreight of fresh seafood from Norway in recent years [21] (Winther et al., 2020).

Additionally, drivers of climate change that are relatively minor yet not unimportant include emissions resulting from different product inputs, related services, and product phases including energy use in the food production phase (ABB and Bellona, 2021), processing, packaging, smolt production, and the use of biproducts (Johansen et al., 2022). Nonetheless, for the supply chains using air-freight, the air-freight accounts for 68–82% of the carbon footprint. When emissions from transport to market is excluded, 75% of the carbon footprint is attributed to production of feed (Johansen et al., 2022).

The feed and the air freight are goods and services provided for the production of farmed salmon. The environmental norm of the Aquaculture Act and the sustainability ambitions for the aquaculture activities equally apply to providers of goods and services to the aquaculture industry (Aquaculture Act, 2005; Støre, 2021). The High-level Panel for Sustainable Ocean Economy emphasizes a management framework to minimize the environmental impact of feed (High Level Panel, 2020). The sustainability vision document of the seafood industry includes statements involving the reduction of fossil fuels and the selection of feed to reduce the carbon footprint (Seafood Norway, 2018). These initiatives show how reducing CO_2 emissions throughout the value chain of salmon production enjoys broad support.

Currently, no regulations relevant to aquaculture activities demand a positive (beyond zero) contribution to climate change mitigation. Neither do regulations demand that CO_2 emissions from feed shall or should be improved, nor do they incentivize or require a de-escalation of emissions to meet the 2030 target. However, the SINTEF study calculated an emission reduction of around 10% since 2017, due to changed feed composition (Johansen et al., 2022), which therefore results from voluntary contributions. The nonetheless high CO_2 emissions resulting from the use of feed have been known about for decades, without triggering any regulatory measures so far. The governmental strategy of both the previous and current governments has so far been to facilitate or stimulate to improve the climate footprint of feed (Solberg, 2021; Støre, 2021). These strategies did not discuss the scalability of these innovations, risks associated with these efforts, or any projections or monitoring of whether they will be sufficient to meet the 2030 goals and under which conditions. The SINTEF study concludes that "there are plenty of improvement opportunities in salmon supply chains that could reduce greenhouse gas emissions as well as production costs further" (Johansen et al., 2022). He et al. suggest that climate change mitigation efforts for the aquaculture industry include reduced use of energy-intensive feedstuff, improved feed management, and reduced fuel use (He et al., 2018). None of these mitigation efforts are demanded by regulation today.

In response to the second driver, transport, studies suggest to find alternatives to air-freight, and if not feasible for fresh products, to shift towards products with longer shelf-life (e.g., frozen) (Iversen et al., 2022; Johansen et al., 2022; Tveiterås et al., 2022; Winther et al., 2020). Further, a report on Ocean Solutions to Climate Change, published by the High-Level Panel on Sustainable Ocean Economy, recommends avoiding the transport of fish by air (Hoegh-Guldberg et al., 2019). Any measures to improve the climate gas emissions of the transport sector in general (e.g., mode of transport and source of power) could potentially benefit the transport that results from demand from the aquaculture industry. Yet, in addition, a sector-specific perspective is useful. To reduce transport emissions from aquaculture activities, the regulator could consider disincentivizing the air-freight of salmon. In contrast, the current national transport plan for 2022–2033 is paving the way for increased export of seafood from Norwegian airports (Solberg, 2020).

Climate gas emission reduction plans and policies (unlike regulation) focus on reducing emissions from aquaculture production facilities and service vessels (Norwegian Environmental Directorate, 2020a; Norwegian Government, 2020-Norwegian Government, 2021). The focus on electrification is not explained, yet it is clearly relevant (ABB and Bellona, 2021) despite not being the main driver. The case may be that, implicitly, an approach that combines the aquaculture sector with the fisheries sector limits to the commonalities between these two sectors (such as ports and marine transport), thus excluding feed, air-freight and other drivers of climate gas emissions specific to aquaculture (and those specific to fisheries). Contrastingly, an approach based on main drivers from specific sectors or activity types could reveal more potential.

To improve the carbon footprint, the government could, for example, demand that the quantity of non-carbon friendly feed and transport should decrease to meet the 2030 vision. Further, the government could adopt reporting requirements such as yearly plans and risk analysis from each actor to be compiled into an overview of the industry that the regulator could use as a decision-basis for any further measures (or relief of measures as the case may be).

3.1.2. *Climate change adaptation*

Adapting to climate change means adapting to many different climate-related hazards that could be expected because of climate change, such as a warming ocean, runoff of toxins, or landslides (First Delegated Act of the EU Taxonomy, 2021). These hazards would have a biological impact and socioeconomic consequences. Some examples of impacts and consequences of climate change for the aquaculture industry are decreased productivity due to changing biological conditions, loss of production facilities or infrastructure, limited access to feeds from marine and terrestrial resources, and limited access to fresh water (Dabbadie et al., 2018).

In 2010, the 16th Conference of the Parties (COP 16) of the United Nations Framework Convention on Climate Change agreed to formulate and implement national adaptation plans as per the Cancun Adaptation Framework (UNFCCC, 2010). Currently, Norway has developed adaptation plans and measures for some sectors and risks, such as the energy and transport sector (Norwegian Environmental Directorate, 2020b). Further, some general guidelines that highlight the role of municipalities in climate change adaptation have been issued (Norwegian Government, 2018). Currently, no plan for climate change adaptation for aquaculture has been adopted. Guidelines for creating climate adaptation plans for aquaculture exist, which provide good practice recommendations for making such plans, including how adaptation plans should identify risks and opportunities, relevant measures and their operationalization (Pham et al., 2021), and suggested adaptation responses relevant to salmon aquaculture (Falconer et al., 2022).

The lack of a plan makes it hard to identify the extent to which adaptation measures are implemented in the Norwegian regulations. For example, recently, new technical regulations and standards for floating aquaculture installation have been adopted with the explicit purpose to reduce escaped salmon (Technical Regulation for Aquaculture Installations, 2022). The regulations require such installations to be designed and used in accordance with best practices and best knowledge (Technical Regulation for Aquaculture Installations, 2022). Such practices and knowledge would include those related to climate change adaptation. Yet, whether climate-related hazards have been considered in the wake of the regulations and whether impacts and consequences beyond escapees have been considered is unclear. In any case, no existing regulation explicitly demands a positive contribution to climate change adaptation or improvement measures.

3.1.3. Sustainable use and protection of water and marine resources

Aquaculture activities use water resources in different ways throughout the value chain. In Norway, the food fish production phase mainly takes place as open net pen production (in a sea cage) in the fjords and near-shore coastal waters. Thus, nutrients such as uneaten feed and feces affect these waters. The food fish production phase is a key driver of eutrophication (Bohnes et al., 2019), yet the Norwegian Institute of Marine Research considers that the risk of regional effects in Norway is low (Grefsrud et al., 2022).

The Norwegian regulations on the use and protection of water quality, concerning all kinds of activities, aquaculture included, are set out in the Water Resources Act and the Water Regulation (Water Regulation, 2006; Water Resources Act, 2000). The Water Regulation includes the obligation that coastal waters (and beyond) shall have at least good ecological and chemical status, reflecting the implementation by Norway of the EU Water Framework Directive (Water Framework Directive, 2000/60/EC). The regulations ban deterioration of coastal waters caused by any kind of activities, including aquaculture (Water Regulation, 2006). However, the directive does not demand any activities to positively contribute to sustainable use and protection of water and marine resources.

Most of the coastal waters of Norway have good or high environmental status. Where coastal waters have less than good status, which is the case for a few areas in Norway, the Water Regulation demand that the status shall be improved and restored (Water Regulation, 2006). Therefore, these regulations include improvement measures relevant to aquaculture activities, where these are the source of negative impact. Accordingly, as required by the EU Water Framework Directive, Norway has regulations requiring the improvement of the environmental status of coastal waters where the coastal waters have less than good status.

3.1.4. Transition to a circular economy

As per the EU Taxonomy Regulation, circular economy refers to "an economic system whereby the value of products, materials and other resources in the economy is maintained for as long as possible" (Taxonomy Regulation/852). In aquaculture, this objective could relate to the aquaculture actors' roles as producers of food, byproducts, sludge, packaging, and waste; consumers of feed, equipment, plastics, vessels, and facilities; and recipients of residual raw materials and other recirculated products (Solberg, 2021).

A circular economic system may require circular value chains, reflected in regulation that transcends established value chains, traditional sectors, and borders, such as products and materials law, patents and trademark law, competition law, procurement law, and consumer law (Nogueira López, 2022). Nonetheless, aquaculture in Norway produces, consumes, and receives distinct products, materials, and resources, as per the examples in the previous paragraph, which supports the appropriateness of considering supplementary sectoral regulations. Some of these products, materials, or resources, such as production facilities and vessels, are already subject to safety and environmental regulations, to which conditions of reuse, repairability, waste reduction, and recirculation could be added. For example, the recently adopted regulations on a technical standard for aquaculture production facilities that only have one explicit purpose–to avoid escape of farmed salmon (Technical Regulation for Aquaculture Installations, 2022)–could further have included the purpose of transitioning to a circular economy. Furthermore, the handling of the remaining products, materials, and resources could be eligible for regulatory conditions, incentives, or restrictions promoting circular economic principles.

Nevertheless, no regulations for aquaculture activities have been identified that require contribution to, or improvement of, the transition of circular economy. Nonetheless, the purpose of the Pollution Act may reflect certain circular economic principles: to reduce existing pollution, to reduce waste, and to advance waste management (Pollution Act, 1981). This act will be discussed in the next section.

3.1.5. Pollution prevention and control

Pollution and waste from aquaculture production facilities possibly includes, aside uneaten feed and feces, copper from impregnated nets and other chemicals (for cleaning, disinfection, maintenance, etc.); foreign substances including veterinary medicinal products and plastics from feed hoses, net cage rings, and ropes; oil and diesel spills; noise; and waste from discarded production facilities (European Commission, 2016; Institute of Marine Research, 2016; Norwegian Environmental Directorate, 2017; Solberg, 2021). Further, pollution emerges from the preceding fish hatchery and smolt production and the subsequent production stages, including lice removal, slaughter, and transport.

The Pollution Act includes an overall obligation to avoid pollution, however, aquaculture facilities have obtained permission to pollute and are thus exempted (Pollution Act, 1981). Production at sea by open net pens (sea cages) involves no system for filtering or removing pollutants; thus this technology and the regulations permitting it, as the regulator explains, assume that the solution to pollution is dilution (Norwegian Environmental Directorate, 2017). Regulations exist on the cleansing of nets and restricting available locations (Aquaculture Act, 2005; Salmon Allocation Regulation, 2004). Moreover, restrictions exist on the quantity of fish per facility, which, individually and combined, provides a local and national ceiling of total pollution (Aquaculture Operation Regulation, 2008). However, since, nationally, there has been a continuous increase of aquaculture over the recent decades (Norwegian Fisheries Directorate, 2022a), unless pollution per facility is continuously diminishing, the national total pollution ceiling is continuously expanding. In any event, Norway does not require of aquaculture to contribute-beyond-zero to pollution prevention and control.

Currently, an individual pollution permit is nonetheless required. Recently, a change to the pollution permit system has been proposed. In this relation, the authorities describe the pollution permits in the following manner:

> Since it is not possible to clean emissions from open net pen production facilities at sea, the pollution permits include no pollution limits. Instead, the permits impose an upper limit of how much fish the owner at any time may have at the locality, assessed as maximum permitted biomass. Further, the pollution permits normally includes conditions that the owner shall monitor the organic influence on the seafloor around the facility (Norwegian Government, 2020), author's translation).

Thus, the pollution permits focus on the maximum mass of fish per locality and the influence on the seafloor underneath the at-sea production facilities. In addition to these types of requirements, procedures for the handling of waste, including dangerous waste exist (Pollution Act, 1981), disposal of waste in harbors (Pollution Regulation, 2004), and a requirement to be particularly cautious to avoid unacceptable effects on the near environment when emitting medications and other chemicals (Aquaculture Operation Regulation, 2008; Product Control Act, 1976). Yet, none of these regulations require an improvement by a reduction of emissions.

Finally, the internal control regulations request each aquaculture actor to have an internal control system (Internal Control Regulation, 1996). The internal control system demands the actors set environmental goals and make environmental risk assessments. Nonetheless, these regulations and guidelines leave the impression that they focus on preventing pollution that is visible or monitorable in the food fish production phase at sea, as they discuss the "recipient" or the near environment of production facilities (Internal Control Regulation, 1996; Norwegian Environmental Directorate, 2017). Certainly, it is important that pollution from production facilities directly affecting the local environment is in focus. Nevertheless, there is the potential to target, through regulation, pollution prevention throughout the stages of salmon production that demand continuous improvement, independent of where the pollutants end up or whether they are measurable. In any event, the current regulations leave the aquaculture actor to set the environmental goals.

3.1.6. Protection and restoration of biodiversity and ecosystems

In principle, aquaculture could contribute to the protection and restoration of biodiversity and ecosystem if, for example, contributing to flood control and protection of biodiversity as when providing habitats for amphibians or birds (European Commission, 2016). Yet, no regulations exist requiring aquaculture activities in Norway to contribute positively to the protection and restoration of biodiversity and ecosystems. The Biodiversity Act demands that public decision-making considers environmental effects (Biodiversity Act, 2009). However, conceptually, taking something into consideration does not include a duty to prioritize that consideration or improve the outcome of the decision on behalf of the environment (Schøning, 2019). This type of regulation may therefore not lead to the prioritization of biodiversity and ecosystems.

Beyond climate gas emissions (Section 3.1.1), impacts on water quality (Section 3.1.3), and pollution (Section 3.1.5), aquaculture could impact biological quality elements by the interbreeding of salmon with wild stocks, pathogen infections (e.g., sea lice), escapees, and the introduction of non-native species (European Commission, 2016) that may, for example, displace native species and disturb existing ecosystems. Given the range of impacts that could be subject to improvement, this section will first discuss ways of selecting impacts and then which impacts the regulations cover.

Strategic and individual environmental impact assessments are ways to assess impacts relevant to the protection and restoration of biodiversity and ecosystems. Strategic assessments are relevant to the authorities for strategic decisions, for example, considering impacts of the total load or increased load of all activities. However, Fauchald demonstrates how many strategic decisions concerning the regulatory system for aquaculture in Norway do not rely on impact assessments (Fauchald, 2020). Within the total load of acceptable impacts, individual environmental impact assessments are relevant for individual activities that differ with respect to location and production methods. However, the aquaculture regulations leave it to the aquaculture actors to decide whether impact assessments are necessary (Aquaculture Operation Regulation, 2008; Fauchald, 2020). For the granting of access to production sites, Norway has only exceptionally demanded aquaculture actors to provide environmental impact assessments (Fauchald, 2020). However, once production sites are in use, environmental monitoring is demanded, limited to the seabed underneath and near the production facility (Aquaculture Operation Regulation, 2008).

In addition to the limited monitoring requirements, Norway has adopted regulations that target two well-known risks to the protection and restoration of biodiversity and ecosystems. The first risk is farmed salmon escapees, which, by being genetically modified through breeding to accommodate for being farmed and consumed, pose a threat to the wild salmon stock by interbreeding (Grefsrud et al., 2022). The annual number of reported escapees over the last decade has ranged from an all-time high of 286,662 in 2019 to an all-time low of 17,187 in 2017 (Norwegian Fisheries Directorate, 2022b). The escapees pose a further threat by displacing other species and disturbing existing ecosystems. Regulation (and strategies) to avoid escapees could be envisioned in multiple ways, such as by: reducing the total number of aquaculture activities; using land-based or closed facilities; regulating the genetic modifications allowed; regulating facility design, including barriers; regulating lice removal, reloading, and transport; regulating preparedness; and regulating escapee targets, triggering stricter requirements if the target is not met (or relief of requirements if targets are met).

Norway has a zero-escapees' vision and strategy that involves knowledge gathering, experience sharing, safety systems, and preparedness (Strategy Against Escapees, 2017). The strategy mentions regulation only in one aspect: technical requirements for floating aquaculture facilities. This strategy involves "review of the regulations to safeguard necessary requirements to barrier steering of actors" (Strategy Against Escapees, 2017). The zero-escapees' vision is not reflected in regulations requiring a decrease of escapees over time.

The second of the two well-known risks to protection and restoration of biodiversity and ecosystems targeted by aquaculture regulation is sea lice.

> The proliferation of sea lice—a parasite that thrives in dense, fish-farming sites—has been shown to be an important part of the explanation for the decline in wild salmon that return to Norwegian rivers (…) When salmon smolt migrate from their natal rivers during spring, passing a "belt" of salmon farms on their way towards the open sea, they often become heavily infested with sea lice. If such an infestation reaches between 0.04 and 0.15 mature lice per gram smolt weight, it may cause high stress levels and reduce the smolt's swimming ability, heightening the risk of mortality at sea (…) (Larsen and Vormedal, 2021)

Sea lice threaten not only wild salmon and trout but also the welfare and mortality of farmed salmon. The current sea lice regulations provide for a decrease in production volumes if the Ministry of Trade, Industry, and Fisheries deems the effect of sea lice in each of 13 production areas unacceptable (Production Area Regulation, 2017). Sea lice proliferation therefore becomes key to growth for the aquaculture industry (Olaussen, 2018), providing strong incentives to reduce the occurrence of sea lice. Therefore, Norway has regulations requiring improvement related to this specific risk. In addition, regulations exist on a quality norm for wild salmon, including a goal for its quality (Quality Norm for Salmon Regulation, 2013).

Strong incentives to combat sea lice may lead to other challenges (Olaussen, 2018), which the regulation system does not account for. Further, Larsen and Vormedal find that "successful compliance with lice thresholds has no observable, positive effect on the infestation pressure on wild salmon" and that the "environmental effectiveness of stricter thresholds is limited, and should be accompanied by complementary measures" (Larsen and Vormedal, 2021). Seemingly, the regulatory improvement requirements have not led to a reduced risk.

3.2. Second trajectory: The phasing-out of un-sustainable activities

As per the Aquaculture Act the ministry may change or revoke aquaculture permits "if this is necessary out of consideration for the environment" (Aquaculture Act, 2005). It could be argued that transition to environmentally sustainable activities is necessary for the environment. Based on this interpretation, the ministry may revoke individual aquaculture licenses. Further, on the same condition of necessity for the environment, the ministry may adopt regulations targeting the revocation of multiple licenses (Aquaculture Act, 2005). The activities to be phased-out could be, for example, those actors that does not improve against the transition criteria within a set deadline, or those volumes, feed compositions, production methods, transportation means, or species that are not compatible with meeting these criteria.

A legislative basis for Norway to revoke licenses exist, thus this trajectory may immediately seem straight forward. However, while aquaculture actors are aware of the risk of revocation, their expectations of predictability and protection of property and entitlements may make such regulations challenging to implement. In parallel with providing for revocation, the Aquaculture Act provides for how licenses can be mortgaged, thus facilitating for investments relying on these licenses. While revocation of licenses overrides any mortgages as per the Aquaculture Act, in practice such revocation becomes complicated. To accommodate such complications, a revocation of licenses in 2030 could, for example, be announced some years prior to revocation that provides some predictability for actors and investors.

3.3. Third trajectory: The phasing-in of new sustainable activities

Licenses are required for aquaculture activities in two ways, to become a licensed actor and to obtain a licensed location (Aquaculture Act, 2005). A general condition for the allocation of both kind of aquaculture licenses is that "it is environmentally sound" (Aquaculture Act, 2005). "Environmentally sound" could be interpreted to capture soundness considering environmental effects of a set of environmental objectives (Biodiversity Act, 2009), such as those discussed in this study and reflected in the EU Taxonomy Regulation. Thus, the potential exists to phase-in only those actors that conduct environmentally sustainable activities (Myklebust, 2021) or to prioritize environmentally sustainable aquaculture production in the granting of localization licenses.

How Norway has approached these environmental provisions in the granting of licenses is reflected in the detailed licensing regulations. Briefly, issuing of new licenses to actors depend on the highest monetary bid. Issuing of new licenses to localities depends on individual decisions considering area plans or area restrictions (Planning and Building Act, 2008) and permissions under multiple acts including the Pollution Act (Aquaculture Act, 2005; Auction Regulation, 2022; Salmon Allocation Regulation, 2004; Sund et al., 2021). Thus, the potential to phase-in environmentally sustainable activities as per the Aquaculture Act is not reflected in the detailed regulations on the granting of licenses, such as explicating the environmental standards the companies must meet to qualify for a license. Rather, the granting of licenses depends on monetary auctions and individual decisions considering multiple different interests, certainly including environmental interests (Biodiversity Act, 2009; Pollution Act, 1981). However, individual decisions considering multiple interests may not lead to the prioritization of environmentally sustainable actors.

In addition to the aforementioned conventional licenses, special licenses have previously been granted to develop new technology and to reduce the negative impacts of escapees and sea lice on farmed salmon and the environment (Norwegian Fisheries Directorate, 2022c). Currently, a proposal is at hearing for special licenses for a limited amount of fish for production facilities that have zero emissions of swimming sea lice and sea lice eggs or that collects a minimum of 60% of sludge (Ministry of Trade, Industries, and Fisheries, 2022). While these special licenses may phase-in activities that in one of these two respects are more environmentally sound than others, the proposal does not provide for a phase-in of activities that are environmentally sound in respect of the six environmental goals as per the definition of environmentally sustainable activities. Phase-in could include, for example, aquaculture using different production methods; local resources as feed; increased local consumption and climate neutral transportation methods; and a combination of different species and methods that offers ecosystem services and synergic effects. One example of salmon aquaculture activities that might lead to improvements or contributions relevant to the environmental objectives, is co-production between salmon and kelp, where nutrient emissions from salmon farming are used as nutrients for kelp production, and at the same time binds carbon (Ellis and Tiller, 2019).

4. Discussion

For the first transitional trajectory, we found that the regulations do not require of aquaculture activities to reduce CO_2 emissions; implement climate change adaptation measures; or improve their contribution to a transition to a circular economy (such as through regulation of reuse, repairability, waste reduction, and recirculation). Improvement related to these environmental objectives depends on the voluntary contribution of the aquaculture industry. Regulation of the environmental objective "sustainable use and protection of water" involves the improvement schemes of the Norwegian Water Regulations, implementing the EU Water Framework Directive's requirement of a good environmental status of coastal waters. Regulation demanding improvement of negative impacts to some extent exist for pollution prevention and control and for two selected impacts (farmed salmon escapees and sea lice) relevant to the objective on the protection and restoration of biodiversity and ecosystems. For none of the six environmental objectives do the Norwegian authorities demand an escalation of improvement to meet the 2030 sustainability ambitions. Regulations do not require positive contribution of aquaculture activities to any of the six environmental objectives.

For the second transitional trajectory, we found that the regulatory framework provides a legislative basis for a phasing-out of non-environmentally sustainable aquaculture activities. Nevertheless, as investments are based on the licenses, any decision on a phase-out, such as in 2030, should be announced soon providing for some predictability for those investors, companies, and employees relying on the to-be phased out activities.

For the third transitional trajectory, we found that the potential for the phase-in of new activities, which are environmentally sustainable at the outset, is provided for in the conditions for the issuing of concessions and access to localities. Thus, Norwegian authorities may issue new concessions and access to localities to those conducting environmentally sustainable aquaculture. However, the availability of localities is limited, therefore phasing-in new activities depends on the phase-out of activities under the second trajectory.

We can conclude that Norway to a limited degree uses regulation as a tool to steer and accelerate aquaculture activities towards environmental sustainability by 2030 and that an untapped capacity to speed up transitions (Garmestani et al., 2019) exist for aquaculture activities. Except from the improvement demanded by the EU Water Framework Directive, Norway has the regulatory power to improve and accelerate aquaculture to sustainability. Thus, the state of Norway is the reluctant driver, sitting in the front seat, not yet using the accelerator. The current government has stated that it will review the regulatory framework of the aquaculture industry, to improve sustainability (Støre, 2021). It remains to be seen if Norway will push the accelerator in the future.

The Norwegian authorities are responsible for the total environmental impacts of aquaculture activities in Norway. As per the Norwegian Constitution, they are obliged to take necessary action to ensure the protection of nature and biodiversity (Norwegian Constitution, 1814). Whether regulation is a necessary tool in this regard is to some extent a matter of (political) imagination or vision combined with empirical data. If politicians envision that desired and demanded improvements in the aquaculture industry, phase-ins of new sustainable aquaculture actors, and phase-outs of un-sustainable aquaculture activities would result from alternative strategies, then the powerful instrument of regulation may not be necessary. To meet the sustainability ambitions of 2030, only seven years ahead, the vision should be supported by data. To what extent have improvements, phase-ins, and phase-outs taken place as of today? Monitoring progress, related risks, estimated effects, and scalability is key to meeting objectives independent of strategies. Yet, the authors are unaware of any such overviews that may indicate the progress and scenarios and which sustainability standard will be met by the aquaculture industry by 2030.

Whether regulation is a necessary tool to transition further depends on the willingness of industries. Sustainability transitions research explains how such transitions may threaten the economic positions and business models of large and powerful industries, with the result that such industries may contest the need to accelerate transitions to protect their interests (Köhler et al., 2019). If the sustainability standard desired by the aquaculture industry in Norway is less strict compared with that the regulator desires, the potential for voluntary adjustments by the industry is limited, which supports the use of regulation. Relevant to our case, a study by Aarset et al. found a trend of passive adaptation to external requirements, in the sustainability practices among some representatives of the Norwegian salmon-farming industry (Aarset et al., 2020), further supporting the need to use regulation as a tool. On this basis, meeting sustainability ambitions by 2030 seems unlikely in a business-and-regulation-as-usual scenario.

Our approach to analyze sustainable transitions in aquaculture production by defining trajectories with criteria set by the EU Taxonomy Regulation for sustainable activities, provides a promising method for evaluating regulation as a transitional tool to meet legal demands and political ambitions of sustainability. As demonstrated, to take a value-chain and activity-specific focus, aligned with a general standard of environmental objectives, is one way to identify the environmental impacts or sustainability of a given sector. Moreover, it has shown how the environmental impacts are defined in a complicated legislation including activity-specific regulations, regulations targeting particular environmental impacts (such as pollution), regulations targeting particular resources (such as water), and planning laws and regulations. While aquaculture companies may voluntarily limit their environmental impacts beyond these regulations, they nonetheless define the maximum allowed impacts. The legislation defining the environmental impacts of an activity attest to nuance the use of categories such as environmental policies or environmental laws, as neither of these categories would normally include sector-specific regulation. Further, a focus on sector-specific regulation could enrich the discussion on industrial strategies (Busch et al., 2018) if the desired outcome is a change to the legally defined environmental impacts. Finally, the sector-specific approach has resulted in findings that could assist in the provision of policy-relevant advice, as each of the criteria and trajectories have resulted in suggestions of alternative regulations.

Section 2.1 has identified several sustainability perspectives relevant to aquaculture, while this study only captures one. Actors in the aquaculture industry in Norway have been requesting for one single sustainability standard for over a decade (forskning.no, 2011; Intrafish.no, 2022). The approach of this study deviates somewhat from the EU Taxonomy Regulation in questioning improvement unlike doing no significant harm. The EU Taxonomy's technical drawing of a line between environmentally sustainable and un-sustainable activities for investment purposes may not align with either the purpose of regulators (such as Norway) in accelerating sustainability transition for aquaculture or the private certification schemes need for documentation and market shares. Multiple sustainability standards may therefore be a necessary reality. The legal standard and definition of environmentally sustainable activities of the EU Taxonomy Regulation is nonetheless a welcomed initiative facilitating discussion and refinement of the content of (environmental) sustainability for aquaculture (Aarset et al., 2020; Mikkelsen et al., 2021; Osmundsen et al., 2020) from a regulator perspective. Any such definition should capture all impacts throughout the value chain of the activities (Tveiterås et al., 2022), including associated inputs, services, and output. In contrast, a focus only on environmental impacts on the near-by marine environment of the production facility only captures selected negative environmental impacts.

To the conceptualization of the role of law as the controls of a vehicle (Soininen et al., 2021), this study supports and nuances the role of law as an accelerator that could speed up transitions but that could further be unused, reflecting an untapped capacity for transitions in law (Garmestani et al., 2019). The study further supports the conceptualization of law as a steering wheel of any given (sustainable) direction and demonstrates how it could or should be interpreted and specified by states as regulators. Sustainability transitions research demonstrates how the notion of sustainability is highly contested (Köhler et al., 2019). Without clear sustainability or environmental standards or end goals, there is no direction for how the aquaculture actors should adapt, the evaluation of any adaptation, and the monitoring of progress. Lack of direction in regulations therefore remains risky for the aquaculture actors (Aarset et al., 2020). Further, when no environmental sustainability standard is explicated, there is no baseline for discussion, critique, or revision.

5. Conclusion

This study brings to the attention the role of national laws in defining conditions for access to resources and space and conditions for how activities should be conducted. These conditions define the environmental impacts of activities yet have little focus in environmental and sustainability scholarship and debates. The responsibility of states to define and refine these impacts will be crucial to (environmental) sustainability transitions. Ultimately, defining and refining environmental impacts by law to accelerate transitions is not just a matter of how to regulate, but of political prioritization, courage, and power to make and operationalize such laws.

CRediT authorship contribution statement

Lena Schøning: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Vera Helene Hausner:** Conceptualization, Writing – review & editing, Funding acquisition. **Mathilde Morel:** Validation, Writing – review & editing.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Lena Schøning and Vera Helene Hausner report financial support was provided by Norwegian Government Ministry of Climate and Environment. Lena Schøning holds shares in a company investing in funds that may from time to time invest in aquaculture companies.

Data availability

The data or regulations analyzed in this study is freely available at www.lovdata.no. Further details of each regulation is provided in the list of references.

Acknowledgments

The authors thanks all our friendly colleagues and peers for discussions following presentations of the study. A special thanks to Eirik Mikkelsen for comments on an early draft. The responsibility for errors of fact or judgement remains with the authors.

References

Aarset, B., Carson, S.G., Wiig, H., Måren, I.E., Marks, J., 2020. Lost in translation? Multiple discursive strategies and the interpretation of sustainability in the norwegian salmon farming industry. Food Ethics 5, 11.

Aas, T.S., Åsgård, T., Ytrestøyl, T., 2022. Utilization of feed resources in the production of Atlantic salmon (Salmo salar) in Norway: an update for 2020. Aquac. Rep. 26, 101316.

ABB, Bellona, 2021. Helelektrisk havbruk: Hvordan oppnå nullutslipp innen 2030? ABB/Bellona, Oslo. https://indd.adobe.com/view/552951eb-423a-4887-9be1-1c81abb92548.
Alomari, M.A., Heffron, R.J., 2021. Utilising law in the transition of the Kingdom of Saudi Arabia to a low-carbon economy. Environ. Innov. Soc. Transit. 39, 107–118.
Aquaculture Act, 2005. Lov om akvakultur (akvakulturloven). LOV-2005-06-17-79. Lovdata, Lovdata.no.
Aquaculture Operation Regulation, 2008. Akvakulturdriftsforskriften FOR-2008-06-17-822. Lovdata, Lovdata.no.
Auction Regulation, 2022. Auksjonsforskriften 2022 FOR-2022-07-22-1386. Lovdata, Lovdata.no.
Bartley, D. et al., 2018. The FAO Blue Growth Initiative: Strategy For The Development Of Fisheries And Aquaculture In Eastern Africa. FAO Fisheries and Aquaculture Circular 1161.
Biodiversity Act, 2009. Lov om forvaltning av naturens mangfold (naturmangfoldloven) LOV-2009-06-19-100. Lovdata, Lovdata.no.
Bohnes, F.A., Hauschild, M.Z., Schlundt, J., Laurent, A., 2019. Life cycle assessments of aquaculture systems: a critical review of reported findings with recommendations for policy and system development. Rev. Aquac. 11, 1061–1079.
Busch, J., Foxon, T.J., Taylor, P.G., 2018. Designing industrial strategy for a low carbon transformation. Environ. Innov. Soc. Transit. 29, 114–125.
Costello, C., Cao, L., Gelcich, S., Cisneros-Mata, M.Á., Free, C.M., Froehlich, H.E., Golden, C.D., Ishimura, G., Maier, J., Macadam-Somer, I., Mangin, T., Melnychuk, M. C., Miyahara, M., de Moor, C.L., Naylor, R., Nøstbakken, L., Ojea, E., O'Reilly, E., Parma, A.M., Plantinga, A.J., Thilsted, S.H., Lubchenco, J., 2020. The future of food from the sea. Nature 588, 95–100.
Dabbadie, L., Aguilar-Manjarrez, J., Beveridge, M.C.M., B, B.P., Ross, L.G., Soto, D., 2018. Effects of Climate Change On aquaculture: drivers, Impacts and policies, Impacts of Climate Change On Fisheries and aquaculture: Synthesis of Current knowledge, Adaptation and Mitigation Options. FAO Fisheries and Aquaculture Technical Paper, Rome.
EEA Agreement, 1994. Agreement On The European Economic Area. OJ No L 1, 3.1.1994, p. 3.
Ellis, J.H., Tiller, R., 2019. Conceptualizing future scenarios of integrated multi-trophic aquaculture (IMTA) in the Norwegian salmon industry. Mar. Policy 104, 198–209.
European Commission, 2016. On the Application of the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) in Relation to aquaculture, COMMISSION STAFF WORKING DOCUMENT. European Commission, Brussels.
European Commission, 2020. The EU Blue Economy Report. 2020. Luxembourg.
Falconer, L., Telfer, T.C., Garrett, A., Hermansen, Ø., Mikkelsen, E.I., Hjøllo, S.S., McAdam, B.J., Ytteborg, E., 2022. Insight into real-world complexities is required to enable effective response from the aquaculture sector to climate change. PLOS Climate 1 (3), e0000017.
FAO, 2022. The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. FAO, Rome.
Fauchald, O.K., 2020. Miljøprinsipper og strategiske beslutninger – reform av norsk lakseoppdrett. Tidsskr. Rettsvitensk. 133, 264–305.
First Delegated Act of the EU Taxonomy, 2021. First delegated act on sustainable activities for climate change mitigation and adaptation objectives of the EU taxonomy. EU. OJ L 442, 9.12.2021, Brussels, pp. 1–349.
forskning.no, 2011. A Norwegian research dissemination platform. https://forskning.no/miljoovervakning-oppdrett-havforskning/kritisk-til-miljorapport-om-oppdrett/750096 (accessed 21 July 2023).
Garmestani, A., Ruhl, J.B., Chaffin, B.C., Craig, R.K., van Rijswick, H.F.M.W., Angeler, D.G., Folke, C., Gunderson, L., Twidwell, D., Allen, C.R., 2019. Untapped capacity for resilience in environmental law. In: Proceedings of the National Academy of Sciences, 116, pp. 19899–19904.
Grefsrud, E.S., Berg Andersen, L., Bjørn, P.A., Grøsvik, B.E., Hansen, P.K., Husa, V., Karlsen, Ø., Kvamme, B.O., Samuelsen, O., Sandlund, N., Solberg, M.F., Stien, L.H., 2022. Risikorapport Norsk Fiskeoppdrett 2022 - risikovurdering. Rapport fra havforskningen, Bergen.
He, P., Davy, D., Sciortino, J.B., Malcolm, C.M., Arnason, R., Gudmundsson, A., 2018. Countering Climate change: Measures and Tools to Reduce Energy Use and Greenhouse Gas Emission in Fisheries and aquaculture, Impacts of Climate Change On Fisheries and aquaculture: Synthesis of Current knowledge, Adaptation and Mitigation Options. FAO Fisheries and Aquaculture Technical Paper, Rome.
Heffron, R.J., McCauley, D., 2018. What is the 'Just Transition'? Geoforum 88, 74–77.
High Level Panel, 2020. High Level Panel for a Sustainable Ocean Economy. Transformations For a Sustainable Ocean Economy: A Vision For Protection, Production and Prosperity. World Resources Institute, Washington DC.
Hoegh-Guldberg, O., Caldeira, K., Chopin, T., Gaines, S., Haugan, P., Hemer, M., Howard, J., Konar, M., Krause-Jensen, D., Lindstad, E., Lovelock, C., Michelin, M., Nielsen, F., Northrop, E., Parker, R., Roy, J., Smith, T., Some, S., Tyedmers, P., 2019. The ocean as a solution to climate change: five opportunities for action. World Resources Institute, Washington, DC.
Huhta, K., 2022. The contribution of energy law to the energy transition and energy research. Glob. Environ. Chang. 73, 102454.
Institute of Marine Research, 2016. Effekter av utslipp fra akvakultur på spesielle marine naturtyper, rødlista habitat og arter M-504/2016. Miljødirektoratet, Oslo.
Internal Control Regulation, 1996. Internkontrollforskriften FOR-1996-12-06-1127. Lovdata, Lovdata.no.
Intrafish.no, 2022. Norwegian fisheries newspaper. https://www.intrafish.no/samfunn/salgssjef-i-masoval-vi-ma-gjore-barekraft-til-noe-vi-kan-males-pa/2-1-1143809 (accessed 21 July 2023).
Iversen, A., Ziegler, F., Rotabakk, B.T., 2022. Økonomiske og miljømessige effekter av superkjøling av laks. Nofimas rapportserie, 21.
Jiang, Q., Bhattarai, N., Pahlow, M., Xu, Z., 2022. Environmental sustainability and footprints of global aquaculture. Resour. Conserv. Recycl. 180, 106183.
Johansen, U., Nistad, A.A., Ziegler, F., Mehta, S., Langeland, M., Wocken, Y., Hognes, E.S., 2022. Greenhouse Gas Emissions of Norwegian Salmon Products. SINTEF Ocean AS, Trondheim, Norway.
Johnstone, P., Newell, P., 2018. Sustainability transitions and the state. Environ. Innov. Soc. Transit. 27, 72–82.
Köhler, J., Geels, F.W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M.S., Nykvist, B., Pel, B., Raven, R., Rohracher, H., Sandén, B., Schot, J., Sovacool, B., Turnheim, B., Welch, D., Wells, P., 2019. An agenda for sustainability transitions research: state of the art and future directions. Environ. Innov. Soc. Transit. 31, 1–32.
Kanemoto, K., Moran, D., Shigetomi, Y., Reynolds, C., Kondo, Y., 2019. Meat consumption does not explain differences in household food carbon footprints in Japan. One Earth 1, 464–471. Cambridge, Mass.
Kim, B.F., Santo, R.E., Scatterday, A.P., Fry, J.P., Synk, C.M., Cebron, S.R., Mekonnen, M.M., Hoekstra, A.Y., de Pee, S., Bloem, M.W., Neff, R.A., Nachman, K.E., 2020. Country-specific dietary shifts to mitigate climate and water crises. Glob. Environ. Chang. 62, 101926.
Kivimaa, P., Kern, F., 2016. Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. Res. Policy 45, 205–217.
Kivimaa, P., Laakso, S., Lonkila, A., Kaljonen, M., 2021. Moving beyond disruptive innovation: a review of disruption in sustainability transitions. Environ. Innov. Soc. Transit. 38, 110–126.
Lähteenmäki-Uutela, A., Lonkila, A., Huttunen, S., Grmelová, N., 2021. Legal rights of private property owners vs. sustainability transitions? J. Clean. Prod. 323, 129179.
Langlet, D., 2018. Scale, space and delimitation in marine legal governance – perspectives from the Baltic Sea. Mar Policy 98, 278–285.
Larsen, M.L., Vormedal, I., 2021. The environmental effectiveness of sea lice regulation: compliance and consequences for farmed and wild salmon. Aquaculture 532, 736000.
Ludwig, G., 2019. The role of law in transformative environmental policies—a case study of "timber in buildings construction in Germany. Sustainability 11 (3), 842.
MacLean, J., 2020. Learning to overcome political opposition to transformative environmental law. Proc. Natl. Acad. Sci. 117, 8243–8244.
Metian, A.G.J.T.M., 2009. Fishing for feed or fishing for food: increasing global competition for small pelagic forage fish. Ambio 38, 294–302.
Mikkelsen, E.I., Myhre, M.S., Robertsen, R., Winther, U., 2021. Making a web-portal with aquaculture sustainability indicators for the general public. Front. Sustain. Food Syst. 644314.
Ministry of Trade, Industries, and Fisheries, 2022. Høring - forslag om etablering av en ny ordning for tildeling av tillatelser til miljøteknologiformål. Government of Norway. https://www.regjeringen.no/no/dokumenter/horing-forslag-om-etablering-av-en-ny-ordning-for-tildeling-av-tillatelser-til-miljoteknologiformal/id2875765/?expand=horingsnotater.

Misund, B., 2022. Fiskeoppdrett. Store Norske Leksikon. https://snl.no/fiskeoppdrett . (accessed 23 July 2023).
Myklebust, I.E., 2021. Rettslege rammer for oppgåvefordeling mellom planstyresmakter og akvakulturstyresmakter. In: Hauge, K.B., Stokke, K.B. (Eds.), Integrert Kystsoneforvaltning, pp. 313–339.
Nogueira López, A., 2022. Circular o en bucle? La insuficiente transformación de la legislación de residuos. Revista aragonesa de administración pública, pp. 11–27.
Norwegian Constitution, 1814. Grunnloven LOV-1814-05-17. Lovdata.
Norwegian Environmental Directorate, 2017. Forurensningsmyndighetenes forventninger til oppdrettsanlegg i sjø M-735/2017. Norwegian Environmental Directorate, Oslo.
Norwegian Environmental Directorate, 2020a. Klimakur 2030: Tiltak og virkemidler mot 2030. Miljødirektoratet, Oslo.
Norwegian Environmental Directorate, 2020b. Klimatilpasning i sektorer. Norwegian Environmental Directorate, Oslo.
Norwegian Fisheries Directorate, 2022a. Aquaculture statistics of Norway. Akvakulturstatistikk: Matfiskproduksjon av laks, regnbueørret og ørret. https://www.fiskeridir.no/Akvakultur/Tall-og-analyse/Akvakulturstatistikk-tidsserier/Laks-regnbueoerret-og-oerret/Matfiskproduksjon. (accessed 23 July 2023).
Norwegian Fisheries Directorate, 2022b. Statistics of escaped farmed salmon in Norway. Rømmingsstatistikk. https://www.fiskeridir.no/Akvakultur/Tall-og-analyse/Roemmingsstatistikk. (accessed 23 July 2023).
Norwegian Fisheries Directorate, 2022c. Overview of the granting of aquaculture licences in Norway. Tildeling og tillatelser. https://www.fiskeridir.no/Akvakultur/Tildeling-og-tillatelser/Tildelingsprosessen. (accessed 23 July 2023).
Norwegian Government, 2018. Statlige planretningslinjer for klima- og energiplanlegging og klimatilpasning. FOR-2018-09-28-1469. Lovdata, Oslo.
Norwegian Government, 2020. Public consultation letter on changes to the pollution regulation of Norwegian aquaculture. Revidering av forurensningsregelverket for akvakultur i sjø. Norwegian Environmental Directorate, Oslo.
Norwegian Government, 2021. Norwegian climate plan for 2021-2030.Meld. St. 13 (2020–2021) - Klimaplan for 2021–2030. https://www.regjeringen.no/no/dokumenter/meld.-st.-13-20202021/id2827405/ . (accessed 23 July 2023).
Norwegian Seafood Council, 2023. Norway's Seafood Exports Worth NOK 151.4 Billion in 2022. Seafood.no, Tromsø.
Olaussen, J.O., 2018. Environmental problems and regulation in the aquaculture industry. Insights from Norway 158–163.
Osmundsen, T.C, Amundsen, V.S., Alexander, K.A., Asche, F., Bailey, J.L., Finstad, B., Olsen, M.S., Hernandez, K., Salgado, H., 2020. The operationalisation of sustainability: sustainable aquaculture production as defined by certification schemes. Glob. Environ. Chang 60, 102025.
Pham, T.T.T., Friðriksdóttir, R., Weber, C.T., Viðarsson, J.R., Papandroulakis, N., Baudron, A.R., Olsen, P., Hansen, J.A., Laksá, U., Fernandes, P.G., Bahri, T., Ragnarsson, S.Ö., Aschan, M., 2021. Guidelines for co-creating climate adaptation plans for fisheries and aquaculture. Clim Change 164, 62.
Planning and Building Act, 2008. Lov om planlegging og byggesaksbehandling (plan- og bygningsloven) LOV-2008-06-27-71. Lovdata, Lovdata.no.
Pollution Act, 1981. Lov om vern mot forurensninger og om avfall (forurensningsloven) - LOV-1981-03-13-6. Lovdata, Lovdata.no.
Pollution Regulation, 2004. Forskrift om begrensning av forurensning (forurensningsforskriften). Lovdata, Lovdata.no.
Product Control Act, 1976. Produktkontrolloven LOV-1976-06-11-79. Lovdata, Lovdata.no.
Production Area Regulation, 2017. Produksjonsområdeforskriften FOR-2017-01-16-61. Lovdata, Lovdata.no.
Quality Norm for Salmon Regulation, 2013. Kvalitetsnorm for ville bestander av atlantisk laks (Salmo salar) - FOR-2013-09-20-1109. Lovdata, Lovdata.no.
Rinscheid, A., Rosenbloom, D., Markard, J., Turnheim, B., 2021. From terminating to transforming: the role of phase-out in sustainability transitions. Environ. Innov. Soc. Transit. 41, 27–31.
Rocha, C.P., Cabral, H.N., Marques, J.C., Gonçalves, A.M.M., 2022. A global overview of aquaculture food production with a focus on the activity's development in transitional systems–the case study of a South European Country (Portugal). J. Mar. Sci. Eng. 10, 417.
Sætre, S., Østli, K.S., 2021. Den nye fisken: Om temmingen av laksen og alt det forunderlige som fulgte. Spartacus, Oslo.
Salmon Allocation Regulation, 2004. Laksetildelingsforskriften FOR-2004-12-22-1798. Lovdata, lovdata.no.
Schøning, L., 2019. More or less integrated ocean management: multiple integrated approaches and two norms. Ocean Dev. Int. Law 51, 95–115.
Seafood Norway, 2018. Sjømat 2030 Et blått taktskifte. Sjømat Norge, Oslo.
Seto, K., Fiorella, K.J., 2017. From sea to plate: the role of fish in a sustainable diet. Front. Mar. Sci. 4, 00074.
Soininen, N., Romppanen, S., Huhta, K., Belinskij, A., 2021. A brake or an accelerator? The role of law in sustainability transitions. Environ. Innov. Soc. Transit. 41, 71–73.
Solberg, 2020. National plan of transport for Norway 2022-2033. Nasjonal transportplan 2022-2033. Meld. St. 20, 2020–2021. https://www.vegvesen.no/fag/fokusomrader/nasjonal-transportplan/nasjonal-transportplan-2022-2033/. (accessed 23 July 2023).
Solberg, E. 2021. Havbruksstrategien: Et hav av muligheter. https://www.regjeringen.no/contentassets/e430ad7a314e4039a90829fcd84c012a/no/pdfs/et-hav-av-muligheter.pdf. (accessed 23 July 2023).
Sommerset, I., Walde, C.S., Bang Jensen, B., Wiik-Nielsen, J., Bornø, G., Oliveira, V., Haukaas, A., Brun, E., 2022. Fiskehelserapporten 2021, Veterinærinstituttets rapportserie. Veterinærinstituttet, Oslo.
Støre, J.G, 2021. Hurdalsplattformen. The Hurdal platform for a government formed by the labour party and center party 2021–2025. https://www.regjeringen.no/no/dokumenter/hurdalsplattformen/id2877252/. (accessed 23 July 2023).
Strategy Against Escapees, 2017. Norwegian strategy against escaped farmed salmon. Strategi mot rømming avnærings- og fiskeridepartementet. https://www.regjeringen.no/no/dokumenter/strategi-mot-rommingfra-akvakultur/id2547105/ (accessed 23 July 2023).
Sund, E.W., Mestad, O., Sjørettsfondet, 2021. Framtidens havbruksforvaltning: Utredning fra en arbeidsgruppe ved Nordisk institutt for sjørett. Sjørettsfondet, Nordisk institutt for sjørett. Universitetet i Oslo, Oslo.
Taxonomy Regulation, 2020/852. Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088 (Text with EEA relevance) 198, 13–43.
Technical Regulation for Aquaculture Installations, 2022. Forskrift om krav til teknisk standard for akvakulturanlegg for fisk i sjø, innsjø og vassdrag FOR-2022-08-22-1484. Lovdata, Lovdata.no.
Tveiterås, K., Sperre, I.M., Arhaug, J., Pedersen, M., Jensen, N., Gregussen, O., Rist, S., Nergaard, Ø., 2022. Report on green value creation and processing of seafood. Grønn verdiskaping og økt bearbeiding i sjømatindustrien. Nærings- og fiskeridepartementet, Oslo. https://www.regjeringen.no/no/dokumenter/rapport-8-mars-2022/id2898776/?ch=1 (accessed 23 July 2023).
UNFCCC, 2010. Cancun Adaptation Framework under the United Nations Framework Convention on Climate Change. FCCC/CP/2010/7/Add.1.
Water Framework Directive, 2000. Directive 2000/60/EC of the European Parliament and of the Council establishing a Framework For the Community Action in the Field of Water Policy. /60/EC. OJ L 327, 22.12.2000, pp. 1–73.
Water Regulation, 2006. Forskrift om rammer for vannforvaltningen (vannforskriften) - FOR-2006-12-15-1446. Lovdata, Lovdata.no.
Water Resources Act, 2000. Vannressursloven LOV-2000-11-24-82. Lovdata, Lovdata.no.
Winther, U., Hognes, E.S., Jafarzadeh, S., Ziegler, F., 2020. Greenhouse Gas Emissions of Norwegian Seafood Products in 2017. SINTEF Ocean AS, Trondheim, Norway.
Ziegler, F., Jafarzadeh, S., Skontorp Hognes, E., Winther, U., 2021. Greenhouse gas emissions of Norwegian seafoods: from comprehensive to simplified assessment. J. Ind. Ecol. 1908–1918.