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What's the clue; better planning, new technology or just more money? - The area challenge in Norwegian salmon farming

Bjørn Hersoug [a,*], Eirik Mikkelsen [a], Tonje C. Osmundsen [b]

[a] Nofima, Tromsø, Norway
[b] NTNU Samfunnsforskning, Norway

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ABSTRACT

Norwegian salmon farming has grown tremendously over the last 50 years, and it now constitutes around 75% of the country's total seafood export value. The grow-out phase typically takes place in coastal waters. There are ambitions for continued strong growth. Five years ago, a survey revealed that the fish farmers saw the lack of available sea area as the industry's greatest challenge for continued growth. This paper examines the current and future situation for area use, needs and availability, for salmon farming in Norway. The paper considers several possible changes that can influence this, including the coastal zone planning system, new technologies for offshore, land-based and closed salmon farming, and new tax-schemes that affect the distribution of burdens and benefits from salmon farming. The main finding is that central government has several options available, if it would like to prioritise aquaculture in terms of access to coastal waters.

However, this would imply a full-scale overhaul of the present allocation system, as well as a dramatic change of the current planning system, which in turn means challenging local democracy – not a very likely development under the current political circumstances. This leaves the industry with two options; to reduce salmon lice, emissions and escapes and to increase legitimacy on all levels, and by granting the local municipalities a larger share of the enormous value creation seen in the salmon sector.

While the ambitious plans of doubling production by 2030 and increase it five times by 2050 certainly will require more and better coastal aquaculture localities, the actual extent of area shortage will to a large degree depend on the development of new production models; land-based, offshore, contained net pens and the production of large smolt. Success in these endeavours, could also have an impact on global production of salmon, by opening the market for new actors, thus reducing the Norwegian share and the profitability of the industry.

1. Introduction

Within 50 years, Norwegian salmon farming has become an outstanding success. From a total production of less than 1000 tons in 1970, the current production is 1350,000 tons, of which 97% is for export. While Norway is only responsible for 2.5% of the global aquaculture production in volume, the share of total value is 11% (Garlock et al., 2020). At present, salmon farming constitutes 74% of total seafood export value from Norway, thus by far surpassing the traditional fisheries. On top of that, salmon farming takes place mainly in remote coastal communities, offering valuable employment in municipalities hard hit by the rationalization of the traditional fisheries and processing industry (Johnsen 2020). By 2020, aquaculture seems destined to be one of the few industries that can offer an alternative, when the important petroleum industry will have to wind down some time in the future. The ambitions are high; the government has indicated a possible doubling of total production by 2030 and increasing the current production five times by 2050 (Meld. St.16, 2014-15). Taking into consideration that Norway has a coastline of 103,000 km (including inlets and islands) and an Exclusive Economic Zone (EEZ) of nearly one million km, it may seem like a paradox that *lack of coastal space for aquaculture is a major problem.* However, lack of space was highlighted by a government appointed public commission already in 2011 (FKD 2011) and later reiterated in several white papers. When asked in 2014 about the greatest challenges in the industry, the large majority of salmon farmers maintained that lack of available space was the biggest problem (Hersoug et al., 2014). In fact, despite high prices and much political goodwill, the actual production has not increased significantly over the last seven years (Isaksen

* Corresponding author.
E-mail addresses: bjorn.hersoug@nofima.no (B. Hersoug), eirik.mikkelsen@nofima.no (E. Mikkelsen), tonjeo@ntnu.no (T.C. Osmundsen).

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and Mikkelsen, 2012). In this article, we will try to explain the paradox, and consider possible solutions. It should be added that lack of appropriate space for aquaculture is not a particular Norwegian challenge. The same applies to a number of countries where food requirements for an increasing population are met by turning food production from land to sea (Froehlich et al., 2018).

The article has two main research questions. 1) How is the aquaculture industry's access to suitable production areas today? 2) How can access to sea areas develop in the future? To answer the first question, we consider data on currently approved aquaculture localities, their use and expressed needs for more suitable areas. To answer the second question, we start by analysing how the demand for sea areas might change, particularly due to new types of aquaculture production technology that is being developed and tested. Then we consider how the aquaculture industry's access to areas could be affected by changes in the governance system, and by the incentives authorities at different levels have for allocating areas to aquaculture. This is seen against how the policy agenda for aquaculture might develop – which impacts of aquaculture will be deemed most important and pressing in the future?

The materials and method are dealt with in section 2, while the theoretical underpinnings of our study are described in section 3. The administrative aquaculture system is described in section 4, while the research questions regarding status and factors that may affect future supply and demand for areas are subsequently dealt with in separate sections (5, 6 and 7). The incentives are described in section 8. In the final section (9), we discuss how the different management interventions and overall development traits may affect the aquaculture industry's access to inshore sea areas, acknowledging that aquaculture is just one of several important stakeholders operating in the coastal zone.

2. Materials and methods

This article is a mix of an original research article and a review article. The authors have studied the management of Norwegian salmon farming for more than ten years. Throughout this period, the area challenge has become ever more important. If the industry is to expand as projected in various policy documents, it needs access to more (and better) areas. What are the challenges for this, and how can it be achieved? The article is based on social science research written on this subject over the last ten years. Since the theme is *Norwegian* salmon farming, several of the articles and reports referred, especially the more recent ones, are written in Norwegian. Wherever possible, however, the authors have tried to use scientific papers, published in English in international journals.

Many of the papers have been written with a narrower approach, concentrating on specific issues connected to the area question. The idea behind this article is to bring these aspects together, illustrating the many facets connected to the seemingly simple question of getting access to space for a successful but disputed industry. The review is combined with assessments of three types of changes that may influence the demand and supply of suitable areas for aquaculture, namely changes in the governance of sea areas, new aquaculture production concepts, and changes to the incentives for allocating areas to aquaculture. Only qualitative assessments have been done.

The exploration of how possible changes to sea area governance can affect area access for aquaculture is based on Mikkelsen et al. (2019). The report considers many possible changes across six different categories (see Table 2). The categorisation came out of an analysis of how area planning has developed in Norway, planning theory, and today's legislation for governing aquaculture. How the changes can affect area access for aquaculture is based on a written draft expert judgement, assessed in a workshop of researchers with relevant competence.

The analysis of incentives to the municipalities for prioritising aquaculture is also based on Mikkelsen et al. (2019) and NOU 2019.18. It includes a systematic assessment of the costs and benefits from aquaculture to municipalities, counties, and Norway as nation. It is partly quantitative and partly qualitative, and includes jobs from aquaculture, value added and its distribution, environmental impacts, and electoral incentives for politicians. Here we focus on the *incentives for municipalities*, which in today's system is pivotal for area planning making room for salmon farming.

3. Framing the area challenge; theoretical and historical starting points

Salmon farming in Norway started its tremendous growth when the first open net pens were constructed and placed in coastal waters around 1970. This is still the dominant form of salmon production in Norway. Alternative technologies are being developed and have started to be used, in both Norway and elsewhere. They include land-based farming, offshore farming and semi-closed or closed pens in coastal waters as well as production of large postsmolt. They may all affect the future availability and need for sea-areas for salmon farming in the coastal zone in Norway. It is, however, not the sea area as such that is most interesting for the fish farmers, but the water body beneath. It must have suitable temperature and salinity, currents that remove faeces and spilled feed and supply water with oxygen - but not with so strong currents that the fish get exhausted from swimming. The net pens must also be sheltered from extreme waves and weather, both for the welfare of the fish, and for securing safety of gear and operators.

To make the sea area into a governable object it must be represented in a way that reflect all these qualities, so that it can be a foundation for management (Johnsen et al., 2009; Johnsen 2014). This happens when components and processes in the ecosystem, including what humans do in it and to it, are translated and assembled with techniques to measure, quantify and model them so they can be represented symbolically (Osmundsen et al., 2020a). For salmon farming in Norway, this includes defining maximum allowable biomass (MAB) and limits for salmon lice infestation for the salmon in the pens. This is also the type of rationale behind marine spatial planning, where the areas managed are governance objects representing abiotic and biotic conditions as well as patterns of use and stakeholder interests. Different measures and governance instruments are created to handle different aspects of the governance object (Johnsen et al., 2014). As concerns and contexts evolve, it may be necessary to adjust or invent new measures and instruments. What has been the main concerns in salmon farming governance in Norway has varied over the years, but they have all related to the different dimensions of sustainability (Osmundsen et al., 2020b).

In the early 1970s, when salmon farming in marine waters started, there were three main reasons for regulating it (Hersoug et al., 2019). The first was the economic profitability of the industry itself, and thus related to economic sustainability. Production was limited in order to secure high prices, and to avoid that the demand for fingerlings/smolt grew faster than the supply. The second reason was that the authorities wanted to use aquaculture to increase employment in rural coastal areas, which were facing severe problems as the traditional fisheries and processing industry were contracting. Therefore, the right to farm fish was granted to certain groups and regions. This was about social sustainability. The third reason was to limit environmental impacts. Fish farming in coastal waters will influence the natural environment, at least to some degree. The third reason was thus about environmental sustainability. Environmental changes also may affect fish farmers and other sectors and industries in the same area, so this was also about social and economic sustainability. The different dimensions of sustainability are often intertwined. Even today, the concerns for regulating aquaculture are about all three dimensions of sustainability (Osmundsen et al., 2020b).

The physical impacts of each individual farm are local or regional, but the interests affected can be both local, regional, national and even international. An example of the latter is the risk salmon farming poses to biodiversity, particularly of wild salmon stocks, where Norway has national as well as international obligations. The governing of salmon

aquaculture must thus be geographically integrated across individual fish farms and across the spatial jurisdictions of various regional and local authorities. Similarly, different policy areas and their responsible authorities must also be integrated and coordinated. Integration is achieved through the hierarchy of government, through the market, and in governance networks, where independent actors from state, economy and civil society have sustained interaction (Torfing 2012). For most public authorities involved in aquaculture governance, it is mandatory to involve civil society and market actors through different forms of hearing processes. This is the case both for municipal area planning according to the Planning and Building Act, and the general management of aquaculture according to the Aquaculture Act.

In these cases, governance is seen as a mechanism, with institutional procedures of formal decision making within and among public institutions (Levi-Faur 2012). The term *governance* is however, used in at least three other meanings as well. The structure of formal and informal institutions; the process and steering functions for policy making; and the strategic efforts of actors to change institutions and the mechanisms that shape choices and preferences (op cit.). All of these meanings of governance are relevant when analyzing the practices within the system and the development of the governance system for aquaculture areas.

The governance system, with its procedures and roles, and power of different actors, have been designed and have evolved over time to try to ensure that central concerns can be balanced and prioritized in accordance with societal interests. Over time, there may be limits to what is considered possible to change, even if concerns and context have changed substantially. The governance system is a social construct, but as soon as it is established and fortified by institutions, laws, science, stakeholders and lobby groups, it may be difficult to change. The network created by various types of actors seems stabilized and may be taken as a fact, or as *the (only) solution*. The limitations on possible changes may be political – attempts to make major changes will come at high political costs, financial – actors have been granted rights that will be very costly to revoke, or practical – it will be very complex and costly to make changes. There can thus be *path dependency* in the governance system, as well as institutional inertia and policy layering (Hersoug 2005; Kelly et al., 2019). To establish a new regulatory system implies the creation of new institutions (or the modification of old), laws, networks of stakeholders and material artefacts. In our case, creating a new regulatory regime is critically dependent on the production of knowledge, that is, on science, which in turn can be made operational for management interventions. However, scientific results often come with considerable uncertainty. Consequently, between a policy based on *knowledge* (i.e. science) and the recommended use of a *precautionary approach*, there may be ample room for negotiations, lobbying and power play.

For obvious reasons, the salmon farming companies also play an important part in governing the industry. The scale of production is essential, thus driving the concentration process, although also small companies may demonstrate excellent economic results. Even more important is the constant drive towards innovations, particularly in terms of technology (Bergesen and Tveterås 2019), which now also has started moving salmon farming offshore and on land.

Over the years, the weighting of concerns has varied in aquaculture governance (Hersoug et al., 2019). Over the last ten years, the environmental impacts have been in focus, in particular the salmon lice situation (Olsen and Osmundsen 2017). This culminated when salmon lice impacts on wild fish in 2017 became the (only) indicator to determine if the production volume in different regions could be increased, had to be reduced, or remain constant. The distribution of economic benefits from aquaculture has always been an important issue but has over the last few years been raised even higher on the political agenda. A municipal area-fee for aquaculture was high on the agenda ten years ago, but it only resulted in a property tax on fish pens, which gave very little income to the municipalities (Isaksen and Mikkelsen 2012; Misund et al., 2019). Political agenda setting can be affected by focusing events that happen by chance (Birkland and DeYoung 2012), or by deliberate political work to expand or confine an issue to certain political arenas (Baumgartner and Jones 2010). Because of the changed political agenda, new instruments for distribution of wealth from the aquaculture industry to others have been established, particularly benefitting the coastal municipalities. This shows how multiple objectives in the management of aquaculture require multiple instruments, and that new concerns and objectives may require new management instruments, and a new policy mix.

In summary, regulating aquaculture is done for different reasons, but they all depend on being legitimate, i.e. accepted as necessary and valid by most stakeholders (Jentoft 2004; Suchman 1995). However, particularly in wealthy democratic counties, there are disagreements with respect to social and ecological impacts of aquaculture that impose limitations to further growth of aquaculture production (Young et al., 2019). In Norway, part of the opposition towards aquaculture can be explained as resulting from mistrust towards the authorities' perceived ability to control the industry (Olsen and Osmundsen 2017; Osmundsen and Olsen 2017). Currently, also elements of the regulatory framework are questioned in public debate, e.g. how the regulatory framework fails to regulate dumping of delicing medications, and the use of ethoxyquin in fish feed. Achieving public regulations that are perceived as legitimate in controlling the aquaculture industry also has a bearing on how supportive the public is towards the industry and its future expansion.

4. Governing area access to aquaculture

In order to perform aquaculture in Norway you need a license consisting of two types of individual licenses. First, a production license. These licenses were first allocated for free, object to strict regulations pertaining to ownership (one license per owner) and volume of net pens, later to be sold at fixed prices and finally partly allocated by auction. Previously, licenses were allocated through irregular license rounds, based on certain political criteria (Hersoug et al., 2019). From 2017, the industry is regulated by the so-called "traffic light system", where the coast is divided in 13 production zones, and where further growth is determined bi-annually by its environmental status, as measured by one single indicator; the frequency of salmon lice (Osmundsen et al., 2020a). In green zones, total production can increase by 6%, in yellow zones production must be stable, while in red zones production has to be reduced by 6%, all measured by maximum allowable biomass (MAB). The zones were created to reduce the amount of sea lice, but most importantly; to make the farmers themselves responsible for the environmental situation in their respective zones.

A standard license used to be 780 tons MAB, which is the maximum tonnage a company can hold at any time, while licenses in the extreme north were higher (945 tons MAB), due to lower temperatures and hence, slower growth rates. With the new traffic light system, licenses no longer have a standard size. At present (March 2020) there are altogether 950 commercial licenses. In addition, there are specific licenses for brood stock production, for research, educational and exhibition purposes, most often operated together with the commercial licenses.

In addition to the production license, all operators need a locality license. These are allocated according to a complicated and intricate system, as illustrated in Fig. 1. The industry is regulated according to eight sector laws, of which the Aquaculture Act (*akvakulturloven*) is the most important. The counties coordinate and grant the locality permit and the full aquaculture license. However, a locality can only be allocated if permissions are granted according to different sector laws. This gives some sector directorates a de facto veto right to block an application for aquaculture space.

Localities must also be in accordance with municipal area plans after the Plan and Building Act (*plan-og bygningsloven*). The municipalities plan their sea areas out to one nautical mile beyond the base lines. So far, no localities are outside this limit, where the state is responsible, but offshore aquaculture is foreseen. A recent inter-ministerial report has

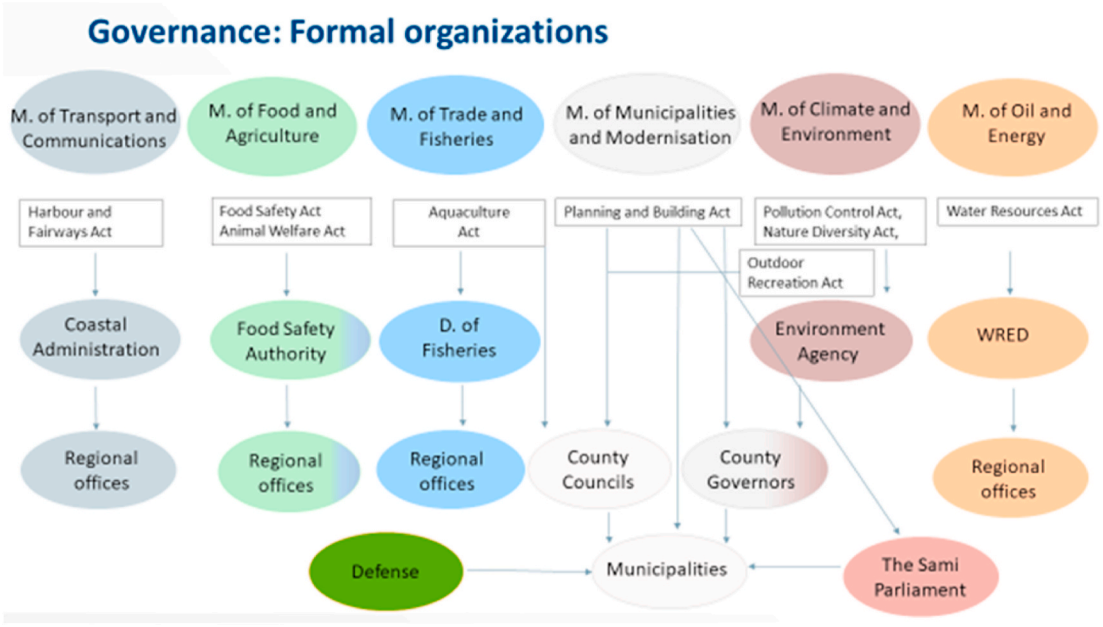

Fig. 1. The governance of aquaculture space (localities). From Solås (2019).

assessed the challenges and options for governing offshore aquaculture (NFD 2018).

With the over-arching Plan and Building Act, the municipalities are guaranteed a heavy hand on the steering wheel and hence a democratic influence on area allocation. There are, however, also here several authorities that have a veto right. If conflicts cannot be resolved through negotiations, the Ministry of Local Government and Modernisation will decide. A shortcoming with municipal area planning is that 225 municipal coastal areas planned by 225 individual municipalities is not the best starting point for increased ecosystem-based management, which is the declared goal in marine spatial planning.

Furthermore, most municipalities lack both capacity and competence to do integrated coastal management plans (Hersoug 2013; Hersoug and Johnsen 2012). Many municipalities have realized this situation and opted for inter-municipal area planning, often supported by their county. This has improved quality and efficiency of the planning processes, and given coastal plans for much larger areas, while still being open to a great degree of stakeholder input (Kvalvik and Robertsen 2017).

5. What is the area challenge?

Even if most salmon farmers claim there is a shortage of coastal space available for aquaculture, it seems worthwhile to investigate this. A starting point could be the physical occupation of space. There are (at least) four different ways of calculating the actual area occupation. The first is the shear physical space occupied by the net pens and the platforms. In earlier days, the farmers claimed that the total area occupation would just about cover the two runways at Oslo's airport (Gardermoen), in other words, a marginal area occupation of approximately 59 km^2 for the 900 licenses (in 2010). However, in practical terms the area occupation is larger. First, there is a limitation on sea transport, which should keep a distance of at least 25 m to any aquaculture installation. Furthermore, it is prohibited to fish closer than 100 m from a farm. This increases the actual area occupation to around 184 km^2, but still a marginal part of the Norwegian coastal zone. Even more important is the anchoring area. Every net pen, placed in a system of 6–10 net pens, needs anchoring to the seabed, often stretching up to 1000 m from the farm. If we use the anchoring area as de facto area occupation, the total equals around 420 km^2 or less than 0.5% of the total coastal area available along the coast (Andreassen et al., 2010).[1]

So why this claim of area shortage? First, because not all sea space is equally valuable. In modern aquaculture the companies look for "super localities", that is, sheltered waters, with suitable depth (minimum 30 m), good currents and proximity to modern infrastructure (roads, electricity, and communities). Then the potential areas are considerably reduced. Second, aquaculture is only one out of many legitimate users of coastal sea space. In Norway we have significant coastal fisheries, taking place all along the coast, with a history stretching hundreds of years back. Even if the total number of fishers have been reduced from 120,000 in 1946 to around 10,000 in 2020, the coastal fisheries still play an important role for many coastal communities, and they have a strong legal backing through the Ocean Resource Law (*havressursloven*). All fishing and spawning areas are ranked according to their importance (national, regional, or local), and aquaculture farms can normally not be placed in such areas.

Furthermore, sea transport is important in the coastal areas, carrying nearly as much cargo as the roads on land (SSB 2020a). A system of main and side transport lanes has been established, where the state is responsible for keeping these corridors free from interventions. The Norwegian Coastal Administration (*Kystverket*) is authorised to review and if necessary, veto new coastal installations. This also applies to aquaculture installations. More recent, tourism and recreation have expanded and become more important. Tourism employs more than 150,000 man-years or 6% of total Norwegian employment, and a large part is connected to the coast. As an example, in Lofoten where we find the largest cod fisheries in the world, the income of tourism surpassed the total income from fisheries in 2009 (Arbo and Hersoug 2011). Although tourists have different demands, many come to see unspoilt areas, free from man-made installations, including aquaculture. Marine tourist fishing is a segment of particular interest. In 2010 more than 430 dedicated fishing tourism establishments were identified (Borch et al., 2011), while now more than 1100 companies have registered as a fishing tourism company (Fiskeridirektoratet 2020b). Fishing tourists use the inshore areas along the coast intensively most of the year, and

[1] A more recent update shows that the area occupation as per 2020 seems to be around 520 km^2. (Robertsen pers. comm.), or slightly more than 0.5% of the coastal inshore area.

report to view the salmon farms as a nuisance, as they limit the available areas for fishing (Borch 2009).

Regarding recreational use, a total of 437,833 recreational houses and cabins are registered, of which many are on the coast (SSB 2020b). Most people have got more spare time over the years, and they spend more time at their cabins and second homes. Although they are poorly organised, they may in many places operate as an important pressure group, often in opposition both to industrial user groups (such as aquaculture) and to conservation interests (Aanesen and Mikkelsen 2020). Marine conservation is still a marginal stakeholder, as only 3% of the coastal zone is protected as compared to 14.3% on land, but the ambition is to increase this to 7% of the total coastal area (NOU 2004.28). For this, it is not decided to what extent aquaculture can be combined with the different administrative conservation categories. In addition to the marine conservation plan, the Norwegian Parliament decided in 2007 to declare 53 national salmon rivers and 27 national salmon fjords, where no new salmon farms could be established, while existing farms were subject to stronger regulations pertaining to escapes, salmon lice and fish diseases (Hersoug and Johnsen 2012). Recreational fishing for salmon is by far the best organized pressure group, and they have over the years been able to influence the regulations of salmon farming to an important degree (Liu et al., 2011).

The energy sector is also an emerging stakeholder in the coastal areas. While all production of oil and gas takes place offshore, pipelines occupy large tracts of sea bottom, especially on the west coast. So far, there is only one marine windmill in Norway, an offshore demo project (NVE 2019). Marine wind power will certainly expand in Norway in the near future. The land-based windmill industry has been met with stern resistance in most municipalities, and most people concerned (with the important exception of the fishers) have pointed at offshore windmill farms as the most evident candidate for producing more sustainable energy (Heidenreich 2016). The Norwegian government has proposed to open two offshore areas for it (OED 2019), and Equinor have concrete plans to use wind energy for oil platforms in the North Sea (Equinor 2020) which the authorities have committed to support with 2.3 billion Norwegian kroner (Enova 2019). However, fishermen have protested strongly against the plans.

Finally, we should mention the Norwegian military, claiming large areas for training and exercises. In the important aquaculture county of Troms in the north, the Navy have exclusive rights to ca. 30% of the inshore coastal area, limiting further the areas available for aquaculture (Rånes 2017). In sum, all the other stakeholders in the coastal zone have legitimate claims, most often, strong legal backing and in three important cases (the Norwegian Food Safety Authority, the Directorate of Fisheries and the Norwegian Coastal Administration) also effective veto powers. Thus, the areas available for further expansion of aquaculture are strongly circumscribed.

However, the most serious limitation to further access comes from the industry itself. This is due to the need to protect neighboring fish farms, as well as wild fish populations from being affected by salmon lice and diseases (based on a production model with open sea cages). The Norwegian Food Safety Authority has decided that each farm should have at least 2.5 km to the next farm and minimum 5 km distance to a processing plant. Local conditions do vary, regarding both land formations and water currents, the size of farms and local wild fish populations. Distance restrictions could be eased some places if there were more knowledge about the actual local conditions, and how they affect the spread of diseases and parasites, but until a more detailed system is in place, the same regulations generally apply to the entire coast. For illustrative purposes, Andreassen et al. (2010) made a map where all 900 localities were shown with a sanitary 5 km zone. This implies an area occupation of 20% of the waters in the coastal zone, and this is, in other words, *the most important restriction on further growth.*

So, what has been the response by the salmon farmers? First, to intensify production. In 1999, total production was 474,000 tons based on 1866 localities. In 2019, total production was 1350,000 tons, spread over 966 localities, of which 862 were in active use during the year. The industry had increased production threefold, while halving the number of localities. Hence, each locality is considerably larger, measured by Maximum Allowable Biomass (MAB). However, the intensification was not evenly spread out along the coast. Due to historical reasons, salmon farming started in earnest on the west coast, gradually moving north, where limitations on license allocation for a long time stunted growth (Hallenstvedt et al., 1985). This partly explains why the potential for future expansion is largest in the north.

Simple statistics can illustrate the situation in the regions of Norway (Table 1). The number of approved sea-localities for grow-out of salmon and trout varies across the Norwegian counties (Fiskeridirektoratet 2020c), depending on several factors, including the size of their coastal zones and the historical development of fish farming. In all counties, the average number of localities used (per month) and the number of unique localities used per year is less than the total number of approved localities. However, the shares they make up differ considerably between regions.[2] Hordaland was top of the list, with 99% of approved localities used over the year, and Finnmark at the bottom, with 73%. This means that the county of Hordaland has very limited flexibility and few localities available if special circumstances, such as diseases or harmful algal blooms, should occur. The density of localities in the coastal waters of the counties also spans a large range, from more than four per 100 km^2 in Hordaland, to 0.5 per 100 km^2 in Finnmark. This indicates that it is much harder to find more areas for new localities in Hordaland than in Finnmark.

Even though the average MAB per locality and production per pen is smaller in Hordaland than in other counties, the national production could have increased 3.3, times if the production across the country was as area-intensive as in Hordaland. Further strengthening the future possibilities for expansion of salmon farming in the north, is the effect of global warming, which seems likely to affect the southernmost regions the most (Falconer et al., 2019).

To what extent can the optimistic prognosis of doubling production by 2030 or increase it fivefold by 2050 be fulfilled? The simple answer is that doubling within ten years is impossible with the present regime.[3] The number of licenses limits growth within this system, and the growth allocated to each of the existing farmers. While licensed capacity is approximately 850,000 tons MAB, the 900 localities are restricted to a total production of ca. 3 million tons MAB. In other words, there is ample room for expansion within the areas already allocated to salmon farming. However, around 1/3 of the present localities must lay fallow at any given time, which means that the actual production potential is around 2 million tons MAB, which in theory makes room for more than a doubling of the existing production. Hence, at present the limitations are mainly on *production license capacity, not on locality license capacity,* although there are large geographical variations. However, if existing localities are not permitted to expand further (a cap on MAB due to environmental constraints), this means that further expansion towards 2050 must take place within larger (and better) areas for aquaculture, *given the existing production model.*

6. Solutions "inside the box"

In today's governance system new aquaculture localities in the

[2] Here we use the names of the old counties as they appeared before 1.1.2020, when 19 old counties were merged into 11 new.

[3] According to Tveteråas et al. (2019:110) a doubling of production by 2030 and a fivefold increase by 2050 implies a growth rate of 5% per year. As a comparison, the growth rate during the period 1990–2017 was ca. 8% per year. However, measured as tonnage, it looks different; during the period 1990–2017 the annual average increase was 43,000 tons per year, while a 5% increase from 2020 onwards would imply 163,000 tons per year. In 2020, the net growth granted in the new traffic light system will be 24,000 tons or ca. 2%.

Table 1
Salmon aquaculture data per county, 2017[a].

County	Number of approved Localities	Average number of localities in use	Number of unique localities used	Slaughtered (tonnes)	Coastal zone area km2	Locality MAB per approved locality (tonnes)	Number of approved localities per 100 km2 coastal area	Locality MAB (tonnes) per 100 km2 coastal area	Pens per 100 km2 coastal area
Finnmark	78	42	57	96082	15671	3724	0,50	18,3	1,9
Troms	117	62	91	197643	10985	4255	1,07	43,4	4,2
Nordland	209	109	161	242633	31236	3169	0,67	19,2	2,5
Trøndelag	154	78	120	190962	12430	4095	1,24	48,1	4,0
Møre og Romsdal	87	62	79	174013	6875	3626	1,27	39,6	5,4
Sogn og Fjordane	86	57	77	111278	4973	3094	1,73	50,4	5,8
Hordaland	176	121	175	191857	4162	2711	4,23	108,8	15,1
Rogaland & others	79	46	68	94436	7414	3198	1,07	28,9	3,8
Norway	**986**	**578**	**828**	**1298904**	**93745**	**3446**	**1,05**	**33,6**	**3,8**

[a] Coastal zone area as of February 2018, locality MAB data as of 29 October 2018. Data sources. Norwegian Fisheries Directorate, and Norwegian Mapping Authority (area-data).

Table 2
Possible changes to six major aspects of coastal zone planning in Norway.

#	Plan area	Plan authority	Participation in planning	Knowledge base	Trade-off method	Plan design
1	Administratively or functionally defined size	Single municipality	Authorities, industry, other civil society actors	Expert knowledge	Minimum standards, prohibition, injunction, formal objections	Zoning alternatives
2	Sea areas alone, or sea and land	Several municipalities together	Formal right to object («veto»)	From sector authorities	Centrally set criteria	Single use or multi use areas with aquaculture
3	Single municipality	County council	Central government planning guidelines	From stakeholders	Integrated. Impact assessment, cost-benefit, multi-criteria analysis	"Stampsize" or larger aquaculture areas
4	Several municipalities	State authority. County Governor	Regional plans	Expertverified stakeholder knowledge	Professional final decision	Dispensation possibilities
5	County	State sector authority	Meetings and hearings	Central databases	Political decision	Time limited zonation
6	One or several production areas defined by the state	A new central state directorate	Participation in working groups, with early plan phase input	Centrally decided methods	Political decision rules/ procedures or individual cases	Planning provision, use requirements
7	One or several production zones (the traffic light system)	Separate institution, with users and authorities	Stakeholders coresponsible for designing the plan	Produced independent of planning process	Auction of «area blocks»	3D planning
8			Advisory council with users and others	Rules on how to handle knowledge gaps, uncertainty, & precautionarity	Area fee, user fee	"Industrial zone" in the sea

coastal zone must be placed in accordance with municipal area plans. Many aspects with coastal zone planning in Norway could however, be changed, as *Table* 2 indicates.[4] Is it likely that some of the changes could increase the chances for salmon farming to get better access to sea areas than today? Many of the changes listed in the table will affect basic qualities of the planning system, including the degree of coordination, harmonisation and equality between different types of stakeholders, interests and geographic areas. Furthermore, the legitimacy of the planning process and the final plans can be affected, as well as how resource-demanding and complex the planning process will be, and the degree of predictability and flexibility in the plans. Nevertheless, only three of the possible changes are likely to increase the areas set aside for aquaculture (Mikkelsen et al., 2019).

If the typical planning area is made larger in geographical terms, it will be possible to find space for more types of interests than when the planning area is small (Table 2, Plan area *#1*). Norway has 225 coastal municipalities, of which 159 has localities designated for salmon and trout aquaculture. In a plan for a relatively small sea area, it might only be possible to find space for what is considered the two or three most important interests. If two or more such small areas next to each other are considered together, it might be possible to find space for several of the most important interests. Through larger planning areas, it might be possible to fit in both more areas for aquaculture as well as other interests than at present, provided that trade-off mechanisms can be worked out. This is a key argument for more inter-municipal planning, in addition to the reasons mentioned earlier.

Another possible change could be to use the counties and their adjoining sea areas as planning unit. This has partly been tried (in Hordaland) with a rather mixed success (Hersoug et al., 2019). Planning from above has not been received positively by the municipalities most involved in aquaculture, and they feel planning at this level could limit their possibilities for aquaculture development in the future. At present, most counties, especially after the merging process, do not have neither the competence nor the capacity to do such planning. This could be changed in the future, but the government has recently strengthened the self-determination of the municipalities through legislation and national guidelines. Hence, this alternative is not seen as very realistic in the short term, even if it would have been beneficial from an ecosystem planning perspective.

[4] Each cell in the table is a possible individual change, in principle independent of the changes in other cells in the same row or columns or elsewhere. Some changes in one dimension (=cell in a column) will however necessarily require some changes in other dimensions.

The same applies to the water regions, established in order to conform to EU's water directive. These water regions, cutting across most other administrative borders, may make sense from an ecological perspective, but they do not have any administrative measures, which make them utterly ineffective in a management perspective (Hovik and Hanssen 2016). The 13 *production areas* in the new "traffic light system", developed to regulate growth of salmon and trout production, have also been suggested as possible area planning units. This raises the challenge of mixed jurisdiction, as the production areas encompass sea areas under municipality jurisdiction as well as sea areas outside the base lines (+1 nautical mile), which is the jurisdiction of the state. In addition, this is a system developed exclusively for aquaculture, with no institutional role for other stakeholder interests.

Two other alternatives are discussed more in detail by Mikkelsen et al. (2019). The first suggests to set aside some coastal sea areas for certain types of predefined activities, and then auction off the right to use those areas (blocks) (Table 2, Trade-off method *#7*), a system similar to what has been indicated for an aquaculture *offshore regime* (NFD 2018). With the current profitability, salmon farmers would likely win many of those auctions. The area blocks would have to be assessed beforehand in terms of possible activities and regulatory conditions. If most of the income from the auctions went to the planning authorities, it would also give them an incentive to set aside many such area blocks, which in turn would reinforce the aquaculture industry's access to coastal sea areas. This is an idea that also has been suggested by the think-tank Triton, working exclusively with aquaculture issues (Seniortanken/Triton 2014).

The last change that might offer more space for aquaculture could be the establishment of "marine industrial parks" (Table 2, Plan design #8). This concept has some resemblance to the area blocks just described, but in the marine industrial parks commercial actors would themselves be allowed to coordinate, find and make space for as much value adding activities as possible. Through the coordination they would internalise what would otherwise be external effects and balance the impacts the activities might have on each other with measures and side payments to maximise the overall net benefits. What kind of activities that would be acceptable in such an industrial park, would have to be decided by public authorities. Within the park, the density of commercial activities would likely be higher than if public authorities should plan and coordinate the commercial actors. This would likely reduce the area-pressure elsewhere and allow for more industrial activities. In conclusion, many aspects of coastal zone planning may change in the future, but in relation to the aquaculture industry's area challenge, only three options seem likely to contribute to solve it.

In addition to these possibilities for more areas to aquaculture with today's dominating open cage production technology, new production concepts can also affect the possibilities for increased salmon production. We now turn our attention to these.

7. Solutions "outside the box"

While open cage culture in coastal waters is the predominant production model in Norwegian salmon farming, there are a number of developments that could modify the need for more inshore space. The first applies to land-based production. Even if land-based production has been shown to be far more costly than the present sea-based cage culture, there are several new projects in the process of being realized (Bjørndahl and Tusvik 2019). In Norway, there is currently (2020) only one small facility put in operation, in Fredrikstad, south of Oslo. However, several projects are being planned, and the first ones already have got the required technical approvals. More important, Norwegian interests are also behind large-scale developments in the US (Maine and Florida), where the company Atlantic Sapphire plans to produce up to 220,000 tons per year (iLaks 2019). If they are successful, this could, within a few years, change the dominant position of Norwegian salmon farming, and hence, contribute to stronger competition and lower prices. In Norway, the attraction of land-based farming is that licenses are in principle free of charge, which is a major inducement, noting that the present price for a standard license (780 MAB) is around 150–200 million NOK or 15–20 million USD.

A second factor, that could modify the present scarcity of space, is the move to establish offshore salmon farming. These projects have been established by a separate development scheme, called *Development licenses*, established in 2015 with the goal of promoting new technology, leading to more sustainable farming and reducing the need for coastal space. The projects have to be based on new technology and involve heavy investments (Osland 2019). So far, 100 standard licenses have been granted to 18 projects, while two projects are still in the pipeline (Fiskeridirektoratet 2020a). The incentive behind the scheme is that these licenses are given for free, and can be converted to ordinary commercial licenses as soon as the projects have reached their stated goals and have been reported to the Directorate of Fisheries (and made available to the public). It should, however, be noticed that the two most typical offshore projects, the Ocean rig by Salmar and the Ocean ship by Nordlaks, both are being placed in coastal waters, inside the base lines. If or when they will enter offshore areas is still not decided. Nevertheless, the government has taken the signals and already prepared a draft for how these areas (outside the coastal waters) can be managed (NFD 2018). Even if the first results from Salmar are positive (good growth, less salmon lice and diseases, easy management), more conclusive results will not be available before 2025-30. If successful, not only in technical terms, but also economically, offshore development could lead to less pressure for coastal space in the future. At the same time, it will reduce the current comparative advantages of Norwegian salmon farming, based on sheltered waters with strong currents and close to modern infrastructure.

A third option is a new production model based on large post-smolt. While the current production model is based on smolt weighing 80–120 gr, an increasing number of farms have started to produce large smolt on land (200 gr up to 1 kg), thus reducing the time spent at sea, and hence reducing the salmon lice problem, while at the same time using their production limit (their licenses' MAB capacity) more effectively. Production of large smolt on land is largely based on Recirculating Aquaculture Systems (RAS) technology and requires both more space and higher capital investment. With current prices and salmon lice problems, it has proved financially worthwhile, and many new post-smolt facilities are now in the process of planning and construction (Bjørndal and Tusvik 2020). This will, other factors constant, reduce the demand for more space at sea in the future, while the new facilities will require considerable areas on land.

Finally, the use of closed sea pens, which received an important boost by the allocation of green licenses in 2015, could open for a re-entry of many localities in the fjords, previously abandoned, due to shallow waters and low interchanges of water (Hersoug and Robertsen 2020). While there were 1866 localities declared by 1999, the number has been reduced to 966 by 2019. A number of the abandoned localities could be re-established, if the residues from farming (remains of feed and faeces) could be collected and reused for other purposes. However, economic analyses indicate that the investments in closed pens will not pay off, at least with today's most likely technical solutions. If the disease and salmon lice problems become very severe, this could change the picture (Bjørndal et al., 2018).

Shortly summarised, while more and better space no doubt is required if Norwegian salmon farming is to expand as projected, the exact demand is difficult to prognosticate due to the dynamic character of the sector. Depending on the extent (and speed) of land-based farming, offshore farming, the use of large post-smolt and the development of contained sea pens, the demand for further inshore areas will vary. The supply side of available sites is also closely linked to the perceived standing the aquaculture industry has in society, mainly in terms of how useful the industry is perceived to be for coastal communities, to which we now turn.

8. Changing incentives to expand aquaculture

When the Norwegian aquaculture industry started in earnest by the early 1970s, the only incentive for the coastal municipalities was increased employment. As the industry developed, employment increased, both in the actual farming as well as in the processing facilities. For many communities, the multiplier effects were even more important, as the industry bought products and services over a large range, both locally and nationally (Johansen et al., 2019). However, the organization comprising nearly all the largest salmon producers; the network of coastal municipalities (*NFKK*) were adamant that they did not receive their fair share of the values created in the sector. Their demand was an annual area or production fee, in order to compensate for costs involved in preparing the ground for the aquaculture industry. Costs involved both the actual costs involved in planning and implementation, but also the political costs involved in meeting the objections from competing stakeholders, such as fishers, the tourist industry, the recreational sector as well as the conservationists. This was even more pressing, as the industry had changed considerably over the years, from being a small-scale owner-operator industry to larger companies, of which several are multinationals (Nøstbakken and Selle 2019).

After years of haggling, the Norwegian parliament finally approved of a new scheme for compensation, offering the municipalities and counties 80% of the income generated by selling new licenses and increased capacity to existing farmers. From 2017, this brought considerable income to the aquaculture municipalities, but the income was highly variable and more important, it comprised only payment for *new licenses and increased capacity*, while no payment was offered for the already established farms.[5] A recent study indicated that even with the transfers from the Aquaculture Fund, some local ownership that brings home profits may be needed for the net local/regional benefits to outweigh the local population's valuation of negative environmental impacts (Aanesen and Mikkelsen et al., 2019).

The political parties then (in 2018) decided to get a public commission to look into the general issue of taxation of the aquaculture industry. When the report (NOU 2019.18) was published in November 2019, three of the political parties in government had already decided that they were against a resource tax, as suggested by the report. While the report suggested a tax regime similar to that, which had been established in hydroelectric energy production as well as in petroleum, with a 40% tax on profit above the normal, the salmon farmers were against any new tax regime. Their intense lobby campaign was rather successful, claiming that taxes of this order would drive the industry abroad. The solution was also refuted by the most important aquaculture municipalities and their allies in the labour union (*LO*) as well as the Norwegian employer organisation (*NHO*). The municipalities and their allies claim that a resource rent tax would only end up in the central system, whereby redistribution to the municipalities would be coordinated with already established redistribution schemes, thus giving little extra for the municipalities offering coastal space for the industry.

In the end, the government decided to offer the municipalities a production fee of NOK 0.40 per kg of salmon. However, the distribution key for the Aquaculture Fund (*Havbruksfondet*) was changed, to the effect that the municipalities now shall receive only 40% of the income paid for new licenses and new capacity, while the state retain 60%. While the industry has been very content with this solution, many municipalities still consider the payment for use of public property too meagre, thus affecting the legitimacy of the demand for larger areas to the aquaculture industry.

[5] As described in NOU 2019.18, the Aquaculture Fund is not a real fund, like the Norwegian Petroleum Fund, as all proceeds are redistributed immediately. This implies that the entire resource rent is spent on this generation, not leaving any proceeds for future generations. Hence, the Resource Rent Committee (NOU 2019.18) has suggested turning the Aquaculture Fund into a real fund, or alternatively, to merge it with the Petroleum Fund, thus securing that only the annual interest is paid as compensation to the municipalities.

9. Discussion: legitimacy as the key to greater access?

The paradox raised in the introduction, of having area scarcity when the aquaculture industry is occupying only 0.5% of the coastal areas, can largely be explained by three factors. First, the strict sanitary regulations (minimum distance between farms), secondly by the fact that the industry is primarily interested in "super localities", and finally by the fact that the coastal areas encompass a large number of competing interests, which may have exclusive rights to their sea areas.

Consequently, only a part of the coastal areas within the base lines +1 nautical mile is available for aquaculture. Nevertheless, the answer to the first research question is mixed; the aquaculture farmers claim there is a scarcity of available sea areas, while our analysis strongly indicates that it is possible to produce considerably more than today within the Norwegian coastal zone, but some regions are clearly full. The current limitation is primarily on the number of production licenses and the strict regime established by the traffic light system, not on the available sea space as such. A doubling of production by 2030 is theoretically possible within the areas already allocated to aquaculture, while the current growth rate most likely will result in a total production of ca. 2 million tons in 2030. However, after 2030, plans of increasing the present production fivefold towards 2050 will depend on getting access to larger sea areas, *given the predominance of the current production model, based on open net pens.*

In order to get access to larger and better areas, the benefits of increased aquaculture production have to outweigh the costs, where a number of factors have to be integrated into the calculations. However, the *distribution* of costs and benefits is equally important. Only a fair distribution of costs and benefits can secure increased legitimacy for the industry. Legitimacy seems to be the key to greater access. This applies to all three political and administrative levels in the Norwegian system; the national (state), the regional (counties) and the local (municipalities).

At present, the industry does not enjoy such widespread legitimacy. While the most important objectives in the early years of the Norwegian aquaculture management system were to control total production and secure rural development, environmental concerns have become increasingly more important. This applies to animal health within the net pens as well as the effects on the wider environment from harmful emissions, the spread of diseases and salmon lice, and not least escaped farmed salmon. That the industry hardly has been able to increase production volume since 2012 is largely due to lack of environmental sustainability.

While economic sustainability for the industry has been extremely successful in this period, generating a resource rent (over and above ordinary profitability) of ca. 20 billion NOK per year over the last few years (NOU 2019.18), the social sustainability has been more questionable. Although the industry has created employment both in the actual farming, in the processing industry and in many related industries, there is a widespread feeling that there has been a mismatch in the distribution of costs and benefits. This applies in particular to municipalities, which have only grow-out operations. Hence, over the last ten years there has been a strong demand for stable municipal tax income from the aquaculture industry's area-use or production.

For the industry to be allowed to grow and get access to larger and better areas, it must increase its legitimacy. Then both the environmental and social sustainability of the industry must be improved. The environmental problems mentioned above must be reduced, including improved conditions for the cleaner fish (Grefsrud et al., 2019). Furthermore, the demands from the municipalities about a better deal regarding the sharing of benefits must be met. The recent major reform of the aquaculture management system, introducing the traffic light system and the Aquaculture Fund was an attempt to improve both

environmental and social sustainability. However, in the traffic light system salmon lice is the *only* indicator to determine industry growth, and it seems unlikely that more environmental indicators will be added soon. (This was considered when the system was established and dismissed as being too uncertain and leading to disputes). Environmentally based legitimacy must thus be improved by other means.

For years, Seafood Norway, organizing the majority of salmon producers, countered all attempts of establishing an annual area or production fee to the municipalities. When threatened with a resource tax of 40%, they gave in and accepted the moderate fee. Whether this and the changed allocation key for the Aquaculture Fund will be sufficient to secure more space for the industry, remains to be seen. While it seems that the resource rent commission's proposal will not be realized, at least for now, it has worked as a focusing event, setting municipal benefits of aquaculture high up on the agenda, and changed the bargaining range between the seafood industry and the municipalities. Summing up, within the existing management system, more sustainable operations and better incentives to the local municipalities could improve the aquaculture industry's access to larger (and better) areas.

There are also more dramatic solutions. As indicated in Table 2, the Norwegian planning system could change in several dimensions in the future. At present, planning at sea follows the tradition established on land, by zoning the various activities, some for exclusive use, others, for joint use. So far, the concept of ecosystem-based planning is only in its infancy. However, only a few of these changes are due to grant greater access for aquaculture. This article has pointed out three alternatives, of which increased inter-municipal planning seems the most promising. This approach could also be combined with greater use of (central) state guidelines, and support from the counties. A separate *aquaculture directorate* has also been suggested (Robertsen et al., 2016), in response to complaints that the authorities with a veto-right quite often are unable to see the overall cost-benefit picture, focusing too narrowly on their respective sector responsibilities. Other alternatives encompassing larger planning areas, where ecosystem concerns can be better integrated and trade-offs be made, are difficult to foresee, as they are institutionally weak and lack management measures. This applies to proposals of using counties, production areas or water regions as new planning entities.

It is expected that more and more stakeholders will require participation in the planning processes. This will not simplify decisions. The knowledge base in coastal zone planning will increasingly be central, digital databases. This will offer greater degree of equal treatment and predictability, while increased use of an ecosystem approach to planning could lead to more variation, especially if more attention is paid to cultural ecosystem services, where local values and preferences dominate (Sundsvold and Armstrong, 2019). In the end, political processes will still determine the prioritization of which coastal areas should be used for what. Even with access to a larger and better factual basis, it will largely be up to local politicians to assess both risks and benefits (Solås et al., 2015).

Finally, we have pointed to solutions "outside the box", i.e. technical solutions that can reduce aquaculture's demand for coastal inshore areas and reduce the environmental problems of operating there. Offshore or land-based aquaculture, if commercially successful, will definitely influence the need for coastal inshore areas, although the total production volume from these concepts will probably be rather limited for many years.[6] The downside of these concepts becoming successful would be that they also allow production much closer to the major markets. Especially for Asia and the US, for which the transport costs from Norway are large, this will increase competition and lead to lower prices and profits. Norwegian producers' traditional comparative advantages, such as sheltered fjords with right temperature, closeness to modern infrastructure, and advanced research institutions, would be weakened. The wider social and economic effects of offshore aquaculture are not well understood (Krause and Mikkelsen 2017), but Norwegian technology and expertise on offshore and land-based aquaculture could possibly be developed into a significant export sector, similar to Norway's offshore petroleum technology sector.

Currently, there are two solutions that may reduce the need for new areas, also in the short run. The first refers to the production of large post-smolt, which is due to reduce the time at sea to reach market size and hence, reduce the problems with salmon lice. The second is the production based on closed containments, which will reduce environmental problems and facilitate the use of localities formerly abandoned due to local contamination. However, business economics is uncertain, especially for the last concept (Bjørndal and Tusvik 2019).

In conclusion, there is no quick fix to get access to larger areas for aquaculture purposes. While the aquaculture industry tries to frame the challenge as a question of *national interest*, where the best paying activity (measured as value added) should receive priority, other stakeholders support a planning system, whereby different issues have to be *negotiated* and a political compromise made in the end. As demonstrated above, new production models may solve some sustainability challenges, while leaving others undecided. In the end, it is also a political compromise how much each of the sustainability dimensions should weigh in. Fulfilling all three at the same time seems difficult, necessitating trade-offs and compromises. At present, *economic sustainability* is not a problem, but if land-based salmon farming becomes a success, producers closer to the market could lead to increased competition and falling prices. Currently, focus is on *environmental sustainability,* where the industry is struggling with several issues (salmon lice, escapes and discharges). So far, *social sustainability* has been partly neglected as an explicit concern but grown in importance during the latter years to a point where it can no longer be neglected. Reducing the environmental challenges and achieving social legitimacy is necessary for further growth of the Norwegian salmon aquaculture industry. As demonstrated, both the industry and public authorities have key roles to play in achieving that.

Ethical statement

Bjørn Hersoug: Conceptualization, Methodology, Investigation, Writing - original draft,

Eirik Mikkelsen: Conceptualization, Methodology, Investigation, Writing - original draft, Funding acquisition.

Tonje C. Osmundsen: Conceptualization, Methodology, Investigation, Writing - original draft, Funding acquisition.

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Declaration of competing interest

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[6] By the end of 2020, several land-based salmon farming projects are being built in Norway as well as in China, the US, Poland, France. In Denmark, a small-scale operation has been running for several years, but so far, without earning money. The same applies to Norway, where a small-scale farm has been established in Fredrikstad, although several much larger projects are now in the construction phase. The most ambitious project is being realized in Miami (the US), where Atlantic Sapphire plans to produce 200,000 tons on land by 2030.

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