Why and how to regulate Norwegian salmon production? – The history of Maximum Allowable Biomass (MAB)

1. Introduction

Salmon farming has been hailed as one of the great success stories in modern Norway. The industry started in the late 1960s and within 50 years became the most important export industry next to oil and gas, producing 1.3 million tons per year of salmon and trout, making Norway the largest salmon producer in the world, responsible for more than half the total production. Prospects for the future are even more optimistic, leading researchers claiming that Norway could possibly double its salmon production by 2030 and increase fivefold within 2050 (DKNVS and NTVA 2012), making salmon production one of the industries to help cover the gaps as petroleum production will have to wind down over the next decades (Bang & Lahn 2020; Lahn 2019).

However, these expectations are not shared by everyone. Salmon farming is, in spite of its success, a highly controversial industry. By 2020, the Norwegian producers have not been able to increase the production, measured in tons, substantially above the 2012 level. While sales prices have increased, providing new export records every year, the volume remains nearly the same for the eight consecutive year. This is mainly due to two factors. First, the problems created by salmon lice and escapes from the salmon farms (Liu et al. 2011; Torrissen et al. 2013). This is by recreational fishers and the Institute of Marine Research (IMR), the leading scientific adviser to the government, considered the largest threat to the many wild salmon stocks along the Norwegian coast (IMR 2019). Traditional fishers have also voiced serious concerns regarding the effects of salmon farming on wild stocks, like cod, saithe, crabs and shrimp. This applies in particular to the use of harmful chemicals when delicing the salmon and cleaning the nets. Second, many of the municipalities, which through coastal zone planning are responsible for allocating space for the industry, are impatient (NFKK 2018). For years, they have been promised a larger share of the profits. If they do not get more economic benefits from the aquaculture activities, they are reluctant to offer more space for the industry. “No pay, no cure!” If the industry is to expand as projected, this will require both more and better space[1], and per 2020, the municipalities have the key to provide more space for aquaculture (Hersoug et al. 2019).

The salmon lice problems kept the authorities from issuing ordinary aquaculture licenses between 2009 and 2013, despite the government’s high ambitions for growth in the aquaculture industry. Since then, a number of new and creative management measures have been introduced. They

[1] “Better space” refers to the fact that all salmon farming companies are looking for the so-called *super localities* (sites), i.e. sites with moderate waves, good water exchange, the right temperatures and access to modern infrastructure. Many of the sites originally granted to salmon farming did not contain these qualities.

have been successful in terms of allowing new technological innovations, while the environmental problems largely remain the same. The challenge over the entire period 1970-2020 has been; how to regulate the industry most effectively, allowing growth and innovation while at the same time secure environmental sustainability.

Figure 1: Norwegian production of salmon and trout 1970-2019 (Source: FAO and DoF)

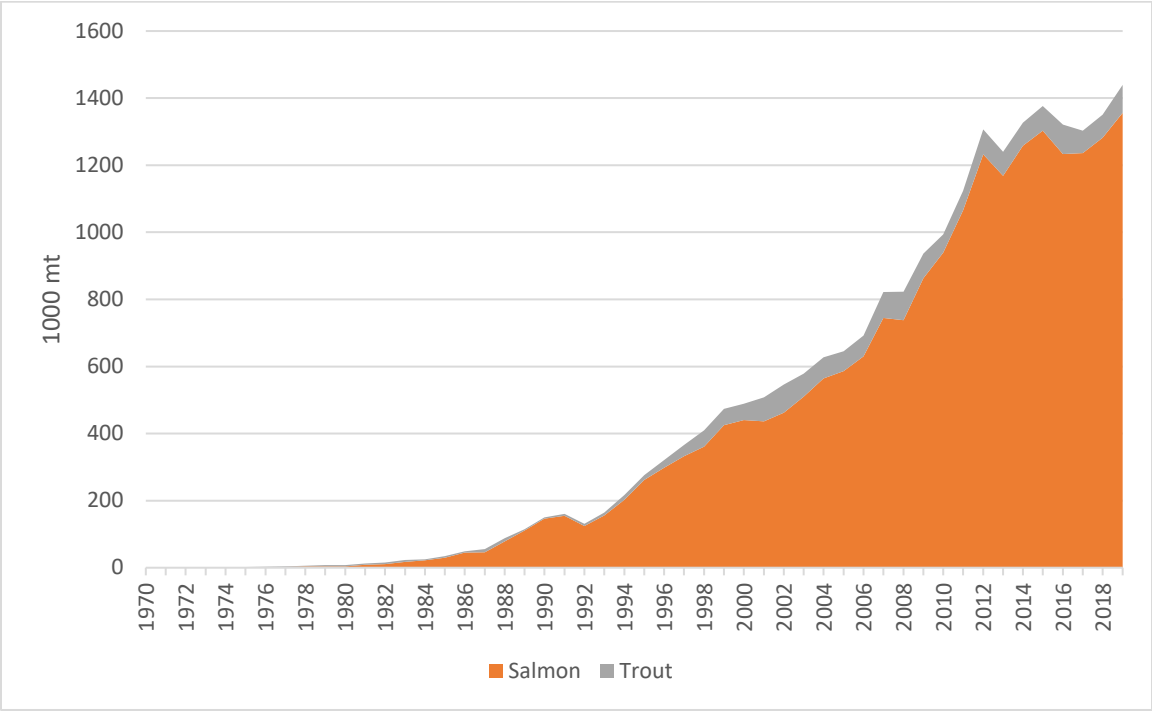
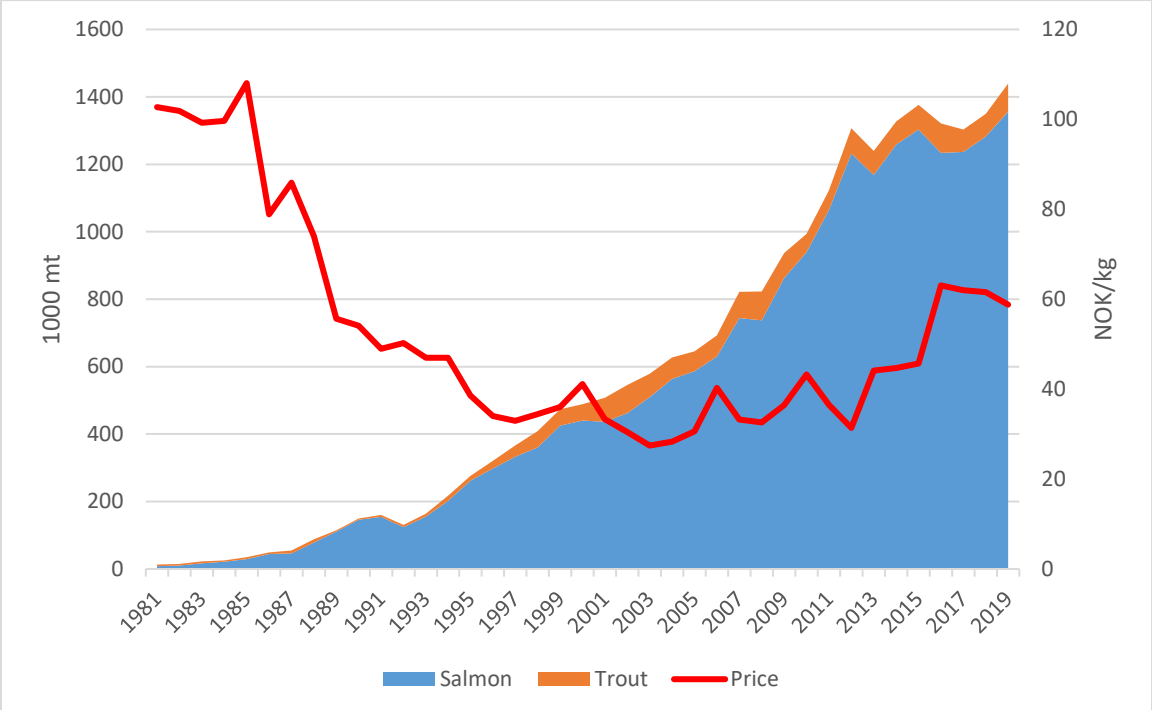


Figure 2: Prices and total production 1981-2019, corrected for inflation. (Source: FAO and DoF)



In that respect, the Norwegian regime represents a peculiar case, regulating the *total output*. Why regulate salmon production in terms of *output*? It is common knowledge that marine aquaculture involves externalities, i.e. what one farmer does may have consequences not only for the environment, but also for other farmers in the same area. However, that does not necessarily imply that production as such has to be regulated in terms of total output. All the important salmon producing countries have environmental regulations, some strict, others more lenient, but Norway is the only country regulating total output, although indirectly, through control of the production volume.[2] In order to understand the system of regulation based on Maximum Allowable Biomass (MAB), we have to look back to the start of Norwegian salmon production. This article will trace the history back to 1970, when commercial salmon farming started in earnest, following the regulatory history right up to the present (2020). Three questions have been central to answer through this article:

- Why has Norway chosen to regulate total production?
- How has the regulatory tools changed over time?
- Why has Norway maintained the use of MAB, even when it was accepted that this was an inefficient tool in terms of regulating total production?

The article is based on historical materials, research articles, books, official White Papers, reports and reviews. In order to cover also the most recent developments, more specific reports (in Norwegian) as well as press clippings from two of the most active press agencies following the salmon sector; Intrafish and iLaks, have also been included.

Following this introductory section, the regulatory history over 50 years is presented in sections 2-10, while section 11 presents a discussion and finally section 12, the conclusions.

2. Volume or weight? - the initial choice

Production of trout has a long history in Norway (Hovland et al. 2014). However, it was first when the aquaculture farmers turned from fresh water to marine waters, from dams on land to net pens in the sea and from trout to salmon, that the Norwegian aquaculture industry became a success in terms of increased production. In 1970, production was very modest, ca. 500 tons of trout and 100 tons of salmon (SSB 1991). However, the potential of the new technologies led to great interest, and in 1971, the government decided to establish an official commission to look into how the new industry could be developed and regulated. The Lysø commission established what should be the dominating regulatory regime for the industry for the next 50 years. While their final recommendation did not appear before 1977, the commission recommended already in 1973 that all salmon and trout farms should be

[2] Chile as well as Canada and Scotland have a MAB restriction on *locality* level. In 2018 Chile also imposed a total production cap on company level, for the farmers to choose as one out of two options (NOU 2019:18).

registered and a license system be introduced. The commission argued that a license system was urgently needed in order to adjust production capacity to market possibilities, and secondly, in order to keep the industry as an important element to support rural development, based on the idea that the owner should be the operator (Hovland et al. 2014). In 1978, the producer owned sales organization (FOS) was created, largely based on similar cooperative organizations in the fisheries and in agriculture, primarily to ensure fair treatment of producers and to prevent buyers from exploiting market power (Hersoug 2005).

While environmental concerns were also mentioned in the first regulations in 1973, the basic idea behind the license system was to create a small-scale industry, keeping large-scale industrial capital outside the new development, with the declared policy of "one man, one license". The urgent challenge was; how to limit production. In the 1960s both public banks and private owners had lost considerable sums due to overproduction of trout. According to the commission, they had three options; regulate the individual production through a cap (measured in tons), regulate the sea area available for the individual farm (measured in m^2) or the individual production volume (measured in m^3). The Lysø commission recommended a cap on production, claiming that 50 tons of salmon or 100 tons of rainbow trout would be sufficient to make a decent living for the prospective farmers. However, the already established farmers disagreed, being afraid of strict limits to further development, and the government decided to use an indirect measure of production, namely, net pen volume. Hence, when the first licenses were allocated, the pen volume was fixed to 8,000 m^3, while the applicants from 1975-78 received only 5,000 m^3. In 1981 the pen volume was further reduced to 3,000m^3, then adjusted to 5,000 m^3, in 1985 to 8,000 m^3 and finally, in 1988, to 12,000 m^3 (Hersoug 2005; NOU 2019:18). The upward adjustments in the size of each farm as well as the new licences awarded meant that the limitation on production was not limiting the development of the industry to any extent, and the industry grew rapidly as salmon farming became a highly profitable activity.

As salmon farming increasingly was seen as a golden opportunity, the licenses became valuable. However, they could not be traded, as the license was closely connected to the owner/ operator. If a farmer went broke, the licence reverted to the state, which in turn could allocate it to a new farmer, and a farmer needed permission from the government to sell the license to a third party. The economic prospects were bright, and in the 1980s, there was no shortage of investment capital. The original idea, of regulating total production through production capacity, soon turned out to be imperfect, to say the least. First, there was a tremendous pressure for accepting new operators because of the profitability of the industry. Second, the official way of measuring volume was rather imperfect. According to the Directorate of Fisheries (DoF), the farm register should contain 85% the area of the net pens times 6 m depth, thus giving the official production volume. In reality, many farmers had already found out they could use deeper net pens (30-50 m), thus increasing the production volume.

Consequently, total production increased, from 600 tons in 1970 to 8000 tons in 1980. Unfortunately, the market did not expand with the same speed. This is a good example of what economists refer to as *distortions* incentivized by regulations, as farmers try to avoid the intent of the regulations by adjusting their production practices when it is profitable to do so (Asche et al. 2007).

3. Return to sender – an unsuccessful attempt of tonnage regulation

By the end of 1988, the Fisheries Director was asked to evaluate an alternative to the current volume limitation. According to the Ministry of Fisheries, the volume limitation was rather dysfunctional regarding fish health issues as well as environmental regulations. The commission worked for two years, ending up with a unanimous recommendation of changing the system to a *fixed tonnage* for a standard license (DoF 1990). After reviewing the production profiles of active salmon farmers, the commission decided that 350 tons should be the limit. Again, many salmon farmers were rather sceptical of fixing a production limit. In the end, the Ministry decided to put the recommendation on hold, maintaining the established volume limitation of 12,000 m^3.

However, one important element was added to the volume criterion, namely a *density regulation*, limiting the biomass to no more than 25 kg per m^3, which in effect meant that the maximum allowable biomass at any time would be equivalent of 300 tons. Even though the density regulation was introduced for reasons of animal welfare and in order to reduce the risk for diseases, it had, in combination with the volume restrictions, a certain effect on the total production. However, during the next ten years, it was trade conflicts with the USA and the EU, which should act as the most important regulator of production volume in Norwegian salmon farming (Asche 1997, Berge 2001).

4. EU the ultimate regulator; introduction of feed quotas

For years, the sales union (FOS), that was established in 1978, was reasonably successful in regulating production according to market demands, but in 1990 overproduction became a serious problem (Hovland 2014). In 1991, FOS went bankrupt after an ill-conceived market intervention. The sales union calculated that by buying large quantities of salmon, placing the fish in freezing storehouses, they could somehow overcome the overproduction crisis. The sales union continued buying (at guaranteed minimum prices), financed by large loans from private banks. When the government no longer would guarantee the loans, the sales union went bankrupt. As a result, a large number of salmon farmers also went bankrupt, which in turn opened for a restructuring of the industry. This was acknowledged by the authorities, giving up the policy of “one farmer, one license”, changing the

Aquaculture Act in 1991. During the period 1992-2002, the total production increased from 147,800 tons to 546,000 tons (see figure 1). In the same period, no new licenses were allocated, and there were no changes to the volume restrictions. Hence, *the increase was the result of a tremendous increase in productivity.* In 1992, each employee was responsible for 79.5 tons of production, while in 2002 the figure had increased to 342.4 tons per employee, an increase of 330% over ten years. Another measure could be the production cost. In 1992, it was 36 NOK per kg, while in 2002 it had been reduced to 17 NOK (values adjusted for inflation) (Asche and Bjørndal 2011).

However, the production success and rapid reduction in production cost and prices would create new problems. Two thirds of the total production were exported to the EU market, and in the salmon producing countries within the EU, i.e. Ireland and Scotland, the farmers were rather unhappy with the dramatic increase in supply and lower prices. The same applied to American farmers who argued that Norwegian producers were subsidized. US authorities acted swiftly and in 1991 imposed anti-dumping duties on frozen and fresh salmon from Norway, leading to near extinction of Norwegian salmon export to the US. The Norwegian share of the US market was reduced from 60% to 5% from 1989 to 1991 (Asche 2001; Kinnucan and Myrland 2002). In the meantime, Scottish and Irish salmon farmers had complained to the EU Commission, recommending dumping duties for Norwegian salmon export. During the next few years, the EU established quotas and minimum prices for Norwegian salmon production six times, but each time with mixed success. In 1997 the EU and Norway finally agreed to a new salmon agreement limiting Norwegian growth in exports to the EU to 11% the first year and 10% thereafter and a minimum price of 3,25 Euro (Sørheim Nielsen 2007).

In order to control growth, the Norwegian authorities realized that production volume, even when combined with density regulations, was a rather imprecise measure. In 1996, *feed quotas* were introduced, after an extended discussion between the authorities and the salmon producers, in order to control the growth of the industry. The amount of feed that each fish farmer could purchase annually, was set by the Ministry of Fisheries. The aim of the feed quotas was to limit the growth in export to EU, and to maintain a floor price. In 2002, a standard license (12,000m^3) had a feed quota of 840 tons of dry feed, a quota that had been increased by 5-10% per year since the introduction. As a means to reduce production, the feed quotas were quite effective, since fish feed is not easily substituted, although more expensive higher energy per unit feed was introduced. However, fish quality deteriorated, and the system was complicated as the actual production was limited by volume, density regulations, a restriction on biomass (65 kg per m^3), while on locality level, the license was restricted in terms of area. In addition, regulating feed was considered *unethical* from a fish health perspective. The Director of Fisheries was therefore, in 2001, asked to come up with a better and more coherent regulatory system, based on the (continued) use of licenses, feed quotas and the carrying capacity of each locality (DoF 2002).

5. The change to MAB

A new committee, consisting of experts from various fields, supported by representatives from the industry association, delivered its report in 2002, suggesting a system based on Maximum Allowable Biomass (MAB). The committee discussed three alternatives; Maximum Allowable Area, Maximum Allowable Feed (measured by energy content in Joule) and MAB. The unanimous recommendation was to base the system on MAB, which could be combined with feed quotas, if this was deemed necessary in order to limit production. Nevertheless, the Director of Fisheries continued the work on Maximum Allowable Area, presenting a number of objections to the MAB solution (Aarset et al. 2005). In the end, the industry association (FHL) won the day, recommending a simplification.

The arguments in favour of MAB were shortly summarised that the system would improve fish welfare and biological sustainability, it would be relatively easy to control, it would increase flexibility and not least, be more robust regarding political and market conditions. Economists would also argue that the distortions of output regulations are smaller than the distortions caused by input regulations (Asche and Bjørndal, 2011). The downside was that MAB would increase differences in production potential at various sites due to different natural conditions. Furthermore, that MAB would be less flexible in a situation where sales had to be reduced due to market conditions (and hence require an increase in standing biomass) (DoF 2002). In 2005, the proposal was implemented with some minor modifications. The feed quotas were abandoned, while the density requirement was maintained. The local differences in production potentials were partly alluded to by setting the standard license to 780 tons MAB, but where it was 900 tons (later extended to 945 tons) in the two northernmost counties (Troms and Finnmark) due to lower water temperatures and slower growth.

The great advantage of using MAB was that both production and locality could be measured by the same currency, tons of biomass. Indirectly, the MAB restriction on biomass would indicate the maximum total production, while the MAB on locality level would indicate the carrying capacity of each site. Compared to the previous system, the MAB system would increase the incentives towards using local advantages, while at the same time improve fish health and environmental sustainability. While there was some disagreement within the industry organization regarding the use of MAB, most farmers realized the potential for increased production by the regulatory change, and resistance disappeared over time. Overnight the production potential increased by nearly 30%, because the MAB limitation was considerably higher than the previous feed quotas. However, it took considerable time to utilize fully the potential of increased production caused by the regulatory change.

Shortly summarised, the introduction of MAB was supported by science (by the institute of Marine Research (IMR)), by the administration (the Directorate of Fisheries) and by the farmers' organization (NFF, later Seafood Norway). In the following years, the system was strengthened and

refined, by introducing minor adjustments. Nevertheless, it turned out to be difficult to control total production, as the physical control had to be based on the farmers' own reports. No automatic device was available to measure the weight of fish in each net pen, and as a result, few farmers were actually convicted for having too large biomass (Bjelland et al. 2012). Finally, after a few years, it became clear that environmental sustainability had not improved as much as wanted. The license system, built on MAB as the common currency, was due to new changes, or to be more precise, to new *amendments*, as the basic structure was maintained.

6. Regulating the environment through MAB

When the MAB regime was implemented in 2005, the *location MAB* was computed according to the same formula, i.e. per each m^3 volume, the locality could hold 65 kg fish. However, this conversion did not imply any assessment of recipient capacity. This was institutionalized by the introduction of a specific Norwegian standard 9410 in 2000. In this standard it was specified how the bottom conditions should be investigated, although there is no formula that can be used to calculate the carrying capacity of a specific locality based on these investigations. According to the environmental authorities, the sustainability of a fish farming site will depend, among other things, on the natural state of the water body, organic load, chemical conditions in the sediment, use of chemical agents, benthic composition, current conditions, water exchange cycles and finally aquaculture biomass and production in the fish farm (IMR 2019). This means that the carrying capacity of a specific site is the result of a number of factors, which can be expressed by numbers, while the *weighting* of the various conditions is largely based on the discretion of the environmental authorities.

The emissions from Norwegian aquaculture are by no means negligible. In the Risk Report Norwegian Fish Farming (IMR 2018), the total estimated emissions in the form of faeces and feed waste are estimated to be between 540,000 and 670,000 tons organic material. While this is a contentious issue, in particular for the critics of Norwegian aquaculture, the authorities have so far assured that the emissions pose a minor challenge to the water quality in coastal waters, with some notable exceptions (IMR 2019). However, the important point here is that by moving from feed quotas to a MAB regime, the environmental authorities "lost" the direct connection between production capacity and emissions. The MAB restriction, as it is applied on locality level, is at best, one out of several indicators of the environmental situation. The challenge of measuring environmental conditions connected to aquaculture can be illustrated by the split of responsibilities; the Directorate of Fisheries is responsible for parts of investigations while the environmental authorities, headed by the County Governor, is responsible for following up on other parts of the investigations. However, both are bound to use MAB as the ultimate indicator of carrying capacity.

7. Fine-tuning the MAB-tool

In 2012, Norwegian salmon production reached 1.2 million tons, which implied a doubling of production over the ten years since 2002, just before the MAB was introduced. The development was described as "a fairy-tale" (FKD 2012). Nevertheless, the MAB-regime was not perfect. When the regime was introduced in 2005, the MAB limits were set generously, allowing a rapid increase in production volume. However, after a few years, many salmon farmers were approaching the MAB ceiling and were looking for ways of increasing production further (Dahl and Idsø 2017). Prices were high, the market expanded, and a disease crisis in Chile limited competition from other producers (Iversen et al. 2020). Hence, in 2009 the industry association FHL was investigating the possibility of fine-tuning of the MAB regime primarily to allow for increased production. Salmon has a seasonal growth cycle, and most farmers approached their MAB limit in the fall, while the MAB could not be fully utilized at any other time of the year. If the fixed MAB that could not exceed 780 tons at any point in time could be transformed into a rolling 12 months average MAB, this would increase flexibility as MAB that was not utilized in winter, spring and summer could be transferred to make the peak higher in the fall. Furthermore, it was argued that this would strengthen the position of smaller producers and improve the situation of salmon processors alluding to regional policy objectives.

A new committee presented two models, noting that a rolling MAB would allow the producers to select their production and slaughter profile over a 12 months period, but still limited to the given MAB limit. This was the proposal recommended by the committee, noting that a rolling MAB would give the producers maximum flexibility (FKD 2012). However, due to environmental considerations, the new minister decided to discard the proposal, while the other alternative known as the Bremnes model after its originator, based on *average* MAB during the year, was offered as a three-year trial, subject to strict conditions and a fee of 1.5 million NOK per license. In the end, this offer attracted very little interest, as only six farmers (21 licenses) applied to try it out (Intrafish 2016).

Nevertheless, flexibility regarding MAB could be useful under special circumstances. In August 2014, all Norwegian seafood was blocked from the Russian market, representing 11% of salmon exports and 50% of trout exports. In order to meet this market shock, the authorities decided (at the request of the salmon farmers) to give a temporary increase of 6% of MAB for salmon and 20% for trout, lasting to April 2015. The same mechanism was utilized to meet a toxic algae bloom in the northern regions in 2019, when the affected farmers were allowed to exceed their MAB limits for a period, which would cover approximately 60% of their losses (Hersoug and Robertsen 2020).[3] While a

[3] The flexibility of MAB was also useful when processors were granted the right to combine their MAB capacities in different regions under the system of *an interregional MAB*. This allowed them to move production to the most convenient localities, still keeping the companies' total MAB restrictions. This system was maintained also in the new traffic light system (see section 9).

flexible MAB could be used to meet extraordinary circumstances, whether caused by the market or by nature, the main principle was squarely established in the government's White Paper from 2015: "Market regulation should not usually be a government task, and the government believes adaptation of production to the market in the main should be the industry's own responsibility" (Meld.St.16. (2014-2015): 40, author's transl.).

On the other hand, securing the environment was definitely a task for the authorities. There was only one problem; further growth and securing the environment could hardly be combined under the present production regime, based on open net pens. A new approach would be to combine the existing MAB regime with stronger environmental restrictions.

8. Diversifying the MAB-system: Green and super-green licenses

In 2011–2012, it was obvious that a further expansion of aquaculture was not on the political agenda. The Ministry of Fisheries and Coastal Affairs had received strong criticism from the National Audit Office (Riksrevisjonen 2012) regarding the management of the Norwegian aquaculture industry, and a proposal to increase the MAB by 5% for all farmers had to be cancelled. Only farmers in Troms and Finnmark (where the main environmental concern, salmon lice, was not very prevalent) got the opportunity to increase production. Meanwhile, the farmers expressed a strong desire to increase production; they had the capacity and skills, there were few problems on the market, with some exceptions for restrictions in China, and prices and profits were high. A solution was the introduction of so-called *green licenses*, where farmers were given the opportunity to expand production if they adopted new technologies that could lead to a reduction of salmon lice and escapes.

The scheme was eventually relatively complicated, in that the Ministry simultaneously wanted to embed both regional priorities and maintain a diverse farming structure in terms of company size. Furthermore, the Ministry wanted to use both public auction and allocation by fixed price. Finally, the environmental criteria were differentiated, as 35 of the allocated licenses should have an upper limit of 0.25 adult female sea lice per salmon, while ten licenses had to commit themselves to maximum of 0.10 sea lice per salmon (Klausen 2016, Hersoug 2016, Osmundsen et al. 2020). The assignment process was organized so that a small group of professionals, headed by a lawyer, accounted for the selection, based on criteria that were prepared in advance. They chose to concentrate on measures that would reduce the incidence of salmon lice and the risk of escapes. In practice, this implied a variety of louse defeating devices, which ranged from the use of skirts (outside the net pens) to the use of laser cannons to shoot salmon lice. Furthermore, the use of large smolt (up to one kilo, produced in land-based facilities) and triploid salmon was prioritized. Interest was great and 255 applications were received in all.

Evaluated five years later, the scheme had a mixed success (Hersoug and Robertsen 2020). While there had been a number of incremental innovations, the scheme was administratively extremely complicated. The politicians said: “Green licenses, never again!” The most dramatic downside was that the criteria (reducing salmon lice and escapes) were not written directly into the licenses, and were thus only perceived as *indicative*, not as mandatory requirements. Furthermore, operating with three different limits on salmon lice (0.1, 0.25 and 0.5) made the control rather demanding. Both industry and authorities were looking for a new approach.

9. Fortifying the MAB-system: the traffic light system

While the outgoing Labour/centre/left government tried to get around the political limitations on further growth by introducing green licenses in 2013, the new conservative/right government proposed a completely new approach to regulating (or facilitating) growth. The new government was concerned with a perceived lack of clarity regarding future growth in the salmon sector, and tried to suggest a predictable growth path, thus reducing the uncertainty for salmon farmers. Right from the beginning, the authorities stressed that the future growth of the sector had to take place within a sustainable framework. This meant that further growth would be determined by biological sustainability, as indicated by various parameters yet to be defined. A White Paper contained three alternatives for further growth: 1) a continuation of allocation rounds based on objective criteria, 2) a fixed annual growth rate, or 3) a system with a decision rule, based on production areas and environmental indicators. The government clearly preferred the third alternative, which was implemented in 2017.

The new production management regime is based on 13 production zones where future growth is determined by the colour of a traffic light. Growth will depend on the environmental situation as measured by the number of adult female sea lice per fish and assessments of lice-induced mortality for wild fish stocks, made by an appointed scientific committee (Misund 2019). The basic idea of the new regime is that the farmers will know in advance, when and where further expansion is possible. They will also know how much growth can be anticipated, and how often the situation will be evaluated. Furthermore, they will be collectively responsible for the environmental standard in their zone(s) and, hence, for expansion, stagnation, or reduction of their licensed MAB. The idea behind the system was to regulate growth on an objective basis, with criteria determined beforehand, thus presenting a system with a greater degree of predictability.

In spite of the good intentions, the traffic light system was not received with enthusiasm by the salmon farmers (Osmundsen et al. 2020). They were particularly concerned with the lack of scientific rigour (the connection between amount of salmon lice and reduction of wild salmon) and the element of collective punishment, whereby also farmers with few salmon lice would be punished together with

farmers with more significant lice problems, if they were located in red areas.[4] The main reasons while the system still was accepted were the pressure from environmental interests, combined with a lack of plausible alternatives. In our context, it is worth noticing that no one questioned the use of licensing and MAB as the basic building blocks of the new system.

10. Keeping MAB but side-lining the traffic light system: development licenses, land-based production and post-smolt production

While the green licenses managed to kick-start many improvements in terms of technology, including closed containments and triploid salmon, they were basically, incremental in nature. They did not solve the area challenge, nor the environmental challenges connected to salmon lice and escapes (Hersoug and Robertsen 2020). Hence, the government came up with a new scheme in 2015, called *Development licenses*, 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 large investments (Osland 2019). If a committee deemed a project sufficiently innovative, the applicant would be awarded license to try out the concept. As per the end of 2020, 103 standard licenses have been granted to 20 projects, while two projects are still in the pipeline (DoF 2020a). The incentive behind the scheme is that these licenses are given for free, and can be converted to ordinary commercial licenses at a fixed price of 10 million NOK (1 million USD). This can be done 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. In the Norwegian setting, there has been an intense debate whether this should be termed *subsidies* or just *incentives* (Vormedal et al. 2019). The fact of the matter is that standard licenses (780 MAB) are currently selling at a price of 150-200 million NOK, thus the scheme involves an incentive worth up to 15 billion NOK in total. It should, however, be noticed that these projects involve heavy investments, where the two largest projects cost in the order of 800-1000 million NOK each. Hence, there is a risk that the scheme rewards the projects with the highest investment costs, instead of solving the most pressing problems within the existing production model, based on open net pens (PwC 2017, Hersoug et al. 2021).

Even if the first results from the first of these projects that has been realized, the company Salmar's "Ocean Rig", are positive, 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 (NFD 2018). At the same time, it will reduce the current comparative advantages of Norwegian salmon farming, based on sheltered waters with strong currents

[4] This was later solved by the introduction of an exemption rule, §12, whereby farmers in red and yellow zones could apply for increase if they for several years had a minimum of sea lice (0.1 in the preceding production cycle and maximum one treatment).

and close to modern infrastructure. In our context, it is worth noting that the entire scheme is only kept partly inside the traffic light system, which was supposed to be *the main regulatory system* for Norwegian salmon farming. Development licenses may be awarded growth in green production areas, but they are not subject to reduction (of 6% of MAB) if located in red areas. On the other hand, the authorities have maintained the same "currency", namely MAB. The capacity for each of the development projects is calculated in tons of MAB, and when converted, they will have to be placed where the companies have available locality MAB. Hence, both the green licenses and the development licenses indirectly contributed to the strengthening of the MAB system.

The same applies to two other emerging production systems, which do not fit into the traffic light system, but conform to the MAB-based mould, namely land-based production and the production of postsmolt.[5] In 2015, the Ministry published new regulations for land-based production as well as production of postsmolt. Both production systems had been analysed by a committee of experts, recommending that land-based production should not have to pay a levy to the state, as the operators would have to secure land areas, either by buying or by leasing, thus paying the private owners of land. The government decided that it would be in the Norwegian interest to be involved in this technology, and hence, encourage land-based developments, although the economy of these operations was still rather uncertain. Bjørndal and Tusvik (2019) show that they have significantly higher production costs than net pens. Even if the extent of land-based production in Norway was considered modest, the argument in favour of maintaining the MAB system is worth noticing: "The Ministry considers it important that the permits for land-based aquaculture with food fish is limited by production capacity, and the Ministry proposes maximum allowable biomass (MAB) as a production restriction to harmonize with the other regulation of production of salmon, trout and rainbow trout." (NFD 2015:5) (author's transl.).

The same applied to production of post-smolt, which previously had been limited to 250 gr, and production licenses had been granted in number of smolt per year. By 2016 there was a growing interest of producing large post-smolt on land, thus reducing the time spent at sea to one year and hence utilizing the MAB limit more effectively. The Ministry decided that licenses for increased post-smolt should be granted free of charge and without any limitation as to the number of licenses or the size of the operations. As always, the Ministry held the backdoor open. In the White Paper outlining the new policy, the Ministry maintained that if production (from land-based farming) should be so great that it would pose problems (for the sea-based farmers), production limits could be imposed *later* (Meld. St. 16 (20014-2015)). Limiting total production was definitely down, but not (completely) out!

[5] Postsmolt fish are kept in land-based tanks after the smoltification process that normally occurs when the fish is about 100g, so that it is transferred to the sea pen at larger sizes reducing the time the fish spend in the sea and hence the salmon lice problems.

Figure 1: Flowchart diagram: license arrangements in Norwegian salmon farming.

1973: License regime introduced
Proposal of fixed tonnage per license
Net pen volume per license implemented (3-12,000m^3)
1978: Mandatory sales union (FOS) introduced
1991: FOS bankrupt, end of mandatory sales union
1996: Feed quotas introduced (after trade conflicts with the EU and the US)
1998: Unsuccessful proposal of tonnage regulation
2005: MAB introduced. A standard license = 780 tons of MAB
2012: Proposal of rolling MAB refuted, average MAB introduced on a limited scale
2013: Green licenses introduced (45 + 35 ordinary licenses on green terms)
2015: Temporary MAB increase (compensating loss of Russian market)
New regime for land-based aquaculture (based on MAB)
New regime for post-smolt production (based on MAB)
2017: The traffic light system for growth introduced (based on MAB)
Development licenses introduced (based on MAB)
2018: First proposal for an offshore aquaculture regime
2019: Temporary MAB increase (compensating loss from algae bloom in the north)
2020: First development licenses converted to ordinary commercial licenses

11. Discussion: MAB forever?

The Norwegian aquaculture license consists of two licenses: *the production license*, offering the right to farm fish according to a certain cap on production indicated by MAB, and *the locality license*, offering the right to farm at a certain place (a locality), where the maximum load also is indicated by MAB. You cannot perform salmon farming without having both. There is no doubt about the need for environmental regulations, although it can be discussed whether using MAB is the best way to do it. The production license however, has been more disputed. In 2013, before the Conservative party (*Høyre*) entered into government, political leaders proclaimed that production licenses should be abolished, regulating the industry only through locality measures. After entering government, this idea has vanished, and consecutive governments have signalled that the production license should remain.

With a few notable exceptions, this is supported by the majority of salmon farmers, including the large companies noted on the stock exchange. These licenses are currently traded for 150-200 million NOK, serving as important collateral for bank loans and constituting an important part of the companies' equity. Hence, the chances of doing away with these licenses are slim, although many, also within the industry, admit that the system blocks newcomers and to some extent may limit innovation (Vormedal et al. 2019). The most important reason why the system has survived is that the limited number of licenses has implied a limited production and hence, high prices and profitability (Asche et al., 2018; Misund and Nygård, 2018). Among economists there is an extensive debate whether the extra profit is due to *resource rent* or *regulatory rent* (NOU 2019:18; Tveterås et al. 2019). The fact of the matter is that the government's active regulation of producers has secured a sizeable extra profit, over and above all other industries in Norway over the last eight years.

At the same time it is important to notice that licensing never succeeded in controlling *total production.* The attempts of introducing a fixed tonnage per license failed twice, because the existing farmers strongly resisted the idea of a production ceiling. The net pen volume, introduced in 1973 was also rather imperfect, as the real net pen volume could be much larger than the official regulation. Describing the situation by the end of the 1980s, the editor of the history of Norwegian aquaculture, claimed that: "Nothing indicated that the authorities made a real attempt of adjusting the production capacity to the market, as they were enabled to do according to the Aquaculture Act" (Hovland (2014: 216), author's transl.).

During the next decade, the EU actually forced Norwegian producers to implement a new system, namely feed quotas to limit production. The feed quotas were more efficient than the net pen volume in controlling total production, but the use of feed quotas had other unwanted consequences. Hence, when MAB was introduced in 2005, after considerable research regarding the best measure to constrain production, it was a compromise. The compromise worked because most farmers realized that the MAB limitation was so generous that they could expect further growth. Nevertheless, by 2010 several farmers were nearly approaching the MAB ceiling and started to look for ways of further expanding production. Introduction of interregional biomass restrictions[6] and the attempts of introducing annual average MAB, may be seen as refinements of the MAB system. However, by that time the government had given up the idea of controlling total production. Still, the MAB was maintained as a measure for the individual licenses, that is, useful for all sorts of book-keeping.

Regarding the locality license, there is unanimity that environmental regulations are needed, but that they can be improved. As can be seen, the new traffic light system has provided an attempt of

[6] Companies with licenses in several regions (later Production Areas) were allowed to merge their licenses and connected MAB, to produce in the region (now area) where it was most convenient and efficient. Originally this was an arrangement specifically designed for salmon farmers involved in further processing.

improving the system, whereby environmental considerations have become more important. However, also the traffic light system builds on MAB as a constitutive element. Growth (and reduction) is regulated with basis in production MAB per license, while the environmental status is decided on the basis of carrying capacity (measured by MAB), supported by the counting the number of salmon lice per fish in the production areas, as the only indicator. Together, the use of MAB in both types of licenses implies a strengthening of MAB as *the currency* in salmon regulations, just like maximum sustainable yield (MSY) and individual transferable quotas (ITQs) have become the basic units in fisheries management (Holm and Nielsen 2007). Here it is worthwhile to note that neither is given by nature, these entities are socially constructed and they could be changed, if better and more reliable measures become available.

Over the years, the license system, based on MAB, has been strengthened and fortified. It proved easy to administrate and was therefore solidly entrenched in the administration (the Ministry of Fisheries and in the Directorate of Fisheries). Furthermore, it has been backed by science, and this applies in particular to the extension of the MAB system, namely the traffic light system. Osmundsen et al. (2020) have described the construction of salmon lice as the crucial indicator, demonstrating the essential role of science in the opinion process. The same applies to the MAB-system, where scientists have participated all along, not only in choosing the measure, but also in supporting it at critical junctures. The same applies to lobby groups, headed by the industry associations. They have supported the system, although hesitantly, through close dialogue with the authorities. Even the critical opinion has accepted the idea that capacity, both in terms of production and in terms of environmental protection, is based on defined levels of MAB, although they have not always understood the difference between production MAB and locality MAB (FKD 2012).

In fisheries management Holm and Nielsen (2007) show that *fishing effort* in many ways was a better indicator than MSY and the accompanying ITQs, but much more difficult to apply across fisheries in different countries, with different fleets and different fishing efficiency. Hence, MSY and ITQs became the golden standard in fisheries management. In aquaculture, the diffusion process has been different. In spite of Norway being the leading salmon producer, responsible for more than half the global production, with Norwegian owned companies represented in all major producing countries, no other nation has copied the Norwegian idea of controlling the *total production* through MAB. However, they all use licensing and some form of MAB to control the production of each *individual* license or site (Hishamunda et al. 2014).

What about the political will and the possibilities for pursuing various concerns through the licensing system using MAB as measure? During the entire period considered for this study, licensing has been viewed as a central regulatory instrument, even if the goals were changed during the period. Originally, licenses were seen as a standard method when certain persons, areas, and technologies

were to be prioritized, a method well known from the traditional catch fisheries. The challenges in the early days (1970–2002) were threefold: to use aquaculture to strengthen remote coastal areas, control production, and secure the economy of operation. Throughout the 2000s, the idea of strengthening the coastal communities was maintained, but the ownership regulations were gradually reduced. The government has now given up most of the original goals. It accepts that modern salmon farming is a technologically advanced industry with high capital demands where larger companies can deliver better results,[7] although it maintains the goal of having a "diversified industrial structure." The concentration process has led to 10 aquaculture companies being responsible for nearly 70% of the production, while 89 companies take care of the remaining 30% (Marine Harvest 2019). For obvious reasons, large companies demand different policies than did the entrepreneurs starting up the industry in the 1970s and 1980s. Most of all, they demand a stable administrative framework. They never asked for the abolishment of the licensing regime. While the production of smolt was liberalized in the 1980s, the licensing system was maintained for commercial grow-out farms by successive governments, through new aquaculture laws and regulations. A pure technical assessment, where farmers were competing for available space and had to abide by environmental impact measures could have been an alternative, as originally suggested by a think tank (Triton 2015). Instead, the licensing system has been thoroughly institutionalized, strengthened, and fortified to the extent that as of 2020, none of the political parties has any suggestions of changes (Peters 1999). In the language of actor-network theory, the licensing regime has been *stabilized* (Latour 1987). This is indeed remarkable, as the wider regime has changed considerably over the last 50 years, from a corporatist regime, emphasizing rural development, redistribution of resources, and a national level of governance, to a technocratic regime with focus on profitability and international standards, largely based on directives from the EU (Aarset and Jakobsen 2009).

However, the *content* of the licensing regime has changed over time with greater emphasis on environmental concerns, especially from 2010 onwards. So, will license regulation combined with MAB restrictions be required in the future, when the goal is to double production by 2030 and increase it fivefold by 2050? While an ambitious goal such as a doubling the production by 2030 would require an annual growth rate of 5%, the current regime is based on less than 3% per year. Hence, high production goals will be "very difficult to achieve" (Tveterås et al. 2019: 111), if dependent on traditional production technology. Nevertheless, even the critics maintain the idea of regulating capacity by the use of licenses and MAB. So far, no other alternative has gained any traction.

[7] In pure economic terms, small and medium-sized companies are quite competitive with the larger ones. It should be noticed though, that even "small" companies may have a turnover of 250-300 million NOK.

12. Conclusions

The use of MAB in regulating the volume of production and the environmental concerns in Norwegian aquaculture is the provisional end of a long regulatory story, starting with the idea of fixing a certain tonnage per license, followed by the use of volume of net pens, then turning to feed quotas, ending up with MAB per license. MAB is, however, not the end of regulatory history. In the future, it is possible to consider more precise regulatory tools, whether applied to production volume or to measure the carrying capacity of a production site (a locality). When MAB as per 2020 still dominates as a regulatory tool, the short explanation is that it has proved *useful*, in spite of many deficiencies. It was definitely not able to control total production, and in 2015, the authorities officially declared that this goal (of adjusting production to market demands) was not a task for the government. However, MAB was still useful for bookkeeping and a back-up in case of new trade conflicts. Furthermore, the salmon farmers saw the value of keeping the production license, as it makes up a considerable part of the companies' equity and hence their possibilities of obtaining credit. As per 2020, the production license measured by MAB, seems to be solidly established, but in administrative terms more as a type of "currency", valuable for bookkeeping, than for regulating total production. Every new type of licensing scheme, whether green, development or land-based, have relied on MAB, which is also the backbone of the traffic light system, created to regulate future growth of Norwegian salmon farming.

Regarding the use of MAB for environmental regulations, the arguments seem stronger. All stakeholders agree that aquaculture farming with open net pens in marine waters have externalities, which have to be controlled and preferably, reduced. Up to 2005, this was done through control of the environmental situation at the different localities and their immediate surroundings. With the introduction of MAB, the results of these investigations were transformed to *carrying capacity*. Although MAB is a rather imperfect measure for the carrying capacity of a locality, it proved easy, in technical terms, to turn emission quotas into MAB, indicating the maximum tonnage (of fish) that could be kept on one locality. Even if other environmental indicators may be added, MAB is again convenient for bookkeeping, as a production license may be split, operating on several localities, while several production licenses, also from different companies, may operate on the same locality

Whether this coupling of production and environmental concerns will be accepted in the future, remains to be seen. So far, the use of MAB in both spheres has strengthened the "currency". MAB has turned out to be practical in a number of ways, both for management as well as for market transactions. As previously indicated, no country has so far found an ideal system of regulating salmon farming according to multiple sustainability goals (Osmundsen et al. 2017). The systems are socially constructed, very much based on historical conditions, and gradually modified and strengthened, depending on experiences and political pressures from various stakeholder groups. On top of that, we also find an element of path dependency (Hersoug 2005; Kelly et al. 2019). A license system was

originally chosen to regulate the new industry, because the fisheries administration had long time experience with such systems in the traditional fisheries. However, a license has somehow to be connected to production capacity, just like a fishing vessel will be allocated a specific quota. Here we see that the salmon farmers and the authorities have struggled to find the right measure, which at the same time should guarantee a sustainable development, be fair and easily administrated. The introduction of MAB in 2005 was the result of a compromise, the "least bad option". 15 years later, it has become thoroughly institutionalized. It is used to control the individual licenses, to keep track of carrying capacity on site and area level, and it has been applied for all new license systems introduced since the 1980s (Hersoug et al. 2021). Furthermore, the use of MAB has been strengthened by the establishment of an aquaculture register, which is very similar to a cadastre, used on land to keep track of ownership for more than 350 years (NOU 1999:1).

Since 2005 MAB has been subject to fine-tuning, but maintaining the same logic, measuring both production volume at the level of each license (or company) and the carrying capacity of each locality. MAB has become what in actor network theory is called a "transportable immutable", i.e. a measurement that can be transported across companies, localities and regions, covering a variety of different types of licenses, convenient for market transactions as well as management (Latour 1987, 1993; Johnsen 2013). Therefore, while a number of objections have been raised against the use of MAB, the measure has been strengthened over time, supported by science, the administration and the salmon farmers themselves. Churchill famously claimed that "No one pretends that democracy is perfect or all-wise. Indeed it has been said that democracy is the worst form of Government except for all those other forms that have been tried from time to time.…" (Langworth 2020).The same can be said of MAB, it is certainly not perfect, but better than most of the other systems that (so far) have been used in order to control both production and environment.

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