MARINE RESEARCH TOPICS

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CLIMATE CHANGE

– its consequences for Norwegian aquaculture

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CLIMATE CHANGE

– *its consequences for Norwegian aquaculture*

Global warming will raise the temperature of Norwegian coastal waters and have significant effects on the aquaculture industry. In some places, fish farms will have to be relocated and farming technology modified in order to reduce the undesirable effects of higher temperatures. Unlike wild stocks, farmed organisms are quite literally locked into specific localities. Current sites will therefore be suitable for other species than those farmed today, and cultured species that at present are usual in Southern and Eastern Europe will gradually enjoy better conditions in Norway than further south. The distribution pattern of salmon lice and other pathological organisms will also change, partly as a consequence of more freshwater runoff and partly because of higher water temperatures. Certain diseases such as francisellosis in cod and vibriosis in several fish species will also become more common.

WHAT THE CLIMATE WILL BE LIKE

Studies of the future climate show that air temperatures in our region will rise by 2–4 °C in the course of this century. In the sea off the coast of Norway the temperature will rise by 1.5–2.0 °C, and in 50 to 100 years, the average temperatures that we currently enjoy in Western Norway will be common on the coast of North Norway. Climate studies also show that we will have more precipitation throughout the year, with the biggest increase occurring in the autumn. It is more uncertain whether winds will increase, but it is not inconceivable that there will be more storm activity, with higher maximum wind speeds. As far as tides are concerned, we can expected a moderate increase of about 80 cm.

DIFFERENT EFFECTS ON THE OPEN SEA AND THE COAST

The expected climate changes will affect coastal and fjord areas differently from the open sea. This is particularly true of summer temperatures in the surface layer. In coastal and fjord areas the temperatures in the uppermost few metres will rise more than out at sea, due to a combination of greater stratification (because of greater supplies of freshwater) and a greater contribution of heat from the atmosphere. Such conditions will also lead to greater temperature oscillations, because the difference in temperature between the surface layer and deep water will be greater.

The rise in temperature will probably no mean so much for the forces that move the water masses. The density of the water in our relatively cold region is only slightly determined by the temperature. On the other hand, salinity has a decisive effect on water density. Increasing rainfall on the coast, and thus higher levels of runoff from land, will be of great importance for stratification in the fjords. This process itself creates currents, in a thin brackish water layer at the surface. More freshwater also raises the buoyancy of the deeper water masses through the constant mixing caused by winds and tidal waters, which in turn may lead to horizontal pressure differences and thus currents and sub-surface waves. More frequent, stronger winds will also have direct effects on currents, distribution of water masses and dispersal (Figure 1).

Figure 1: Currents in the Hardanger Fjord in spring. The current is dramatically dependent on factors such as wind and freshwater runoff (snow-melt). Variations in these parameters can have major consequences for the aquaculture industry, for example because they affect the spread of salmon lice, bacteria and viruses.

DAMAGE TO FISH FARMS

More extreme weather will mean more strict demands being made of all structures in the sea. Most damage to fish farms is the result of bad weather, particularly in the autumn and winter. When farms are damaged, their fish escape. This is not only financially disastrous for the farmer but also damages the environment. The farmed fish breed with wild stocks, and the result is a different genetic composition of wild stocks than the natural one. The species is the same, and the differences that emerge as a result of breeding farmed fish and natural selection of wild fish are not particularly great. However, genetic influences may weaken the survival potential of stocks during critical periods.

More intense and more frequent storms will have to be met by stricter demands for escape-proof farms, which will naturally mean greater costs for the aquaculture industry in the shape of higher levels of investment in farming equipment.

FISH HEALTH IN A WARMER CLIMATE

Spread of salmon lice

Salmon lice have always been found on salmon, and there is nothing unnatural above them. But because farming by definition means an artificially high number of fish living together within a given volume, fish farms are a good place to multiply for salmon lice and other pathological parasites, and for bacteria and viruses. For farmed salmon, delousing is now so efficient that salmon lice are no longer a significant problem for farms. But even if each individual salmon produces only a small number of salmon louse eggs, the total amount present in many fjord systems will be so great that an unnaturally high number of salmon louse larvae will be capable of infesting wild salmon. The only way to save wild salmon will be by keeping numbers of salmon lice artificially low by taking extreme measures to delouse all farmed salmon. Systematic delousing and the development of a vaccine against salmon lice would be sensible measures.

How will a warmer climate affect the spread of salmon lice? Salmon louse reproduction and growth are temperature-dependent. The warmer it is, the more generations of lice can appear a year, thus increasing the reproductive potential of the lice. However, salmon louse larvae spread best at low temperatures, since they develop more slowly in colder water. The colder it is, the further can the larvae travel before they are fully grown. At the same time, we know that warmer weather can increase freshwater runoff into our fjords, which also changes the dispersal pattern of salmon lice (Figure 2). A number of factors are thus affected in different ways by a warmer climate, and it is not a given that the problem of salmon lice will increase. Nevertheless, there is much evidence that suggests that warmer winters – with salmon lice reproducing during the cold season – will take the lives of more wild salmon and sea trout. If this proves to be the case, the need for more effective measures to deal with salmon lice will increase.

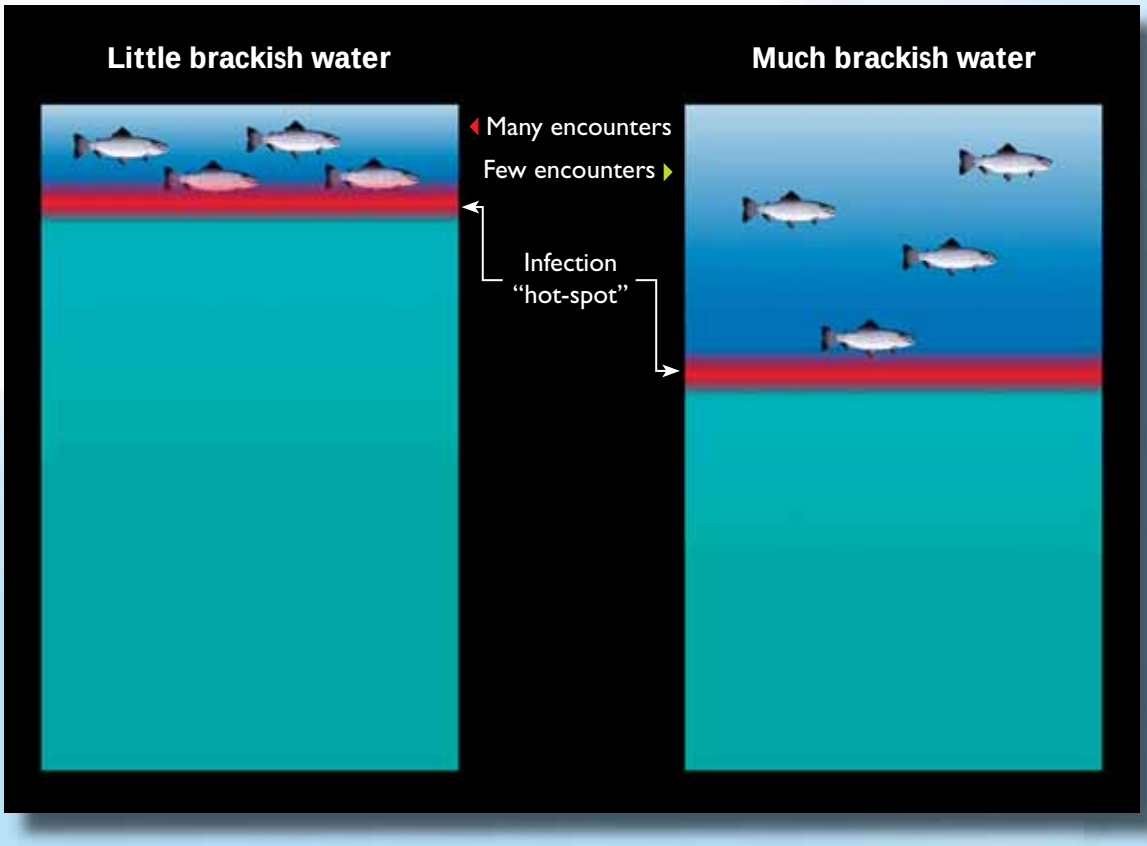
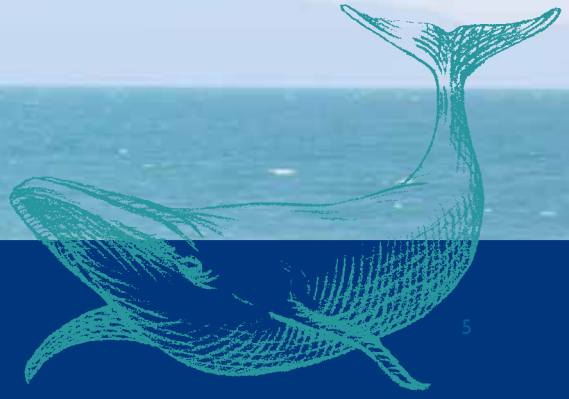


Figure 2: The amount of brackish water in a fjord has a significant influence on the number of encounters between salmon and lice. When there is little brackish water, due to little runoff, there will be more encounters between salmon and lice.

Figure: Frank Nilsen

There is good reason to believe that warm winters – with salmon lice breeding during the cold season – will kill more wild salmon and sea trout.



Heat-loving diseases

Parasitic organisms, including bacteria and viruses, live in what we might call “unstable equilibrium” with their hosts, which is to say that the relationship between parasite and host is continuously evolving. In processes of this sort, it is in the nature of things that some individuals will sicken and die. Sick fish in the open sea usually die quickly and tend not to be noticed. In aquaculture, on the other hand, the consequences of infectious disease very quickly become visible, a circumstance that has led to fish diseases usually being associated with aquaculture rather than with wild fish. Unlike wild fish, farmed fish are unable to evade climate change by changing their distribution pattern. Changes in hydrographic and temperature conditions therefore affect the likelihood of outbreaks of disease. If a site becomes less suitable for aquaculture, the chance of an outbreak will increase.

Higher temperatures often lead to reduced disease resistance. Most outbreaks of well-known diseases such as furunculosis and vibriosis have traditionally occurred during the summer months and early autumn. Stress may increase the likelihood of an outbreak, and it is typical for these to occur in connection with a sudden rise in water temperature. Vibriosis epidemics in wild fish, particularly saithe and cod, also occur most often when the sea is warm. Furunculosis occasionally occurs in wild salmon, typically in connection with high temperatures and low flow-rates in rivers.

It is not only temperature itself that causes stress. When the temperature is high, the oxygen concentration in the water falls, stressing the fish. Stress is not fatal in itself, but it can lead to outbreaks of disease.

Outbreaks often occur when temperatures are extremely high. It should be pointed out that the increase in mean temperature will not significantly affect the likelihood for disease. However, frequently occurring periods of high temperatures, and higher maximum temperatures, will significantly increase the likelihood out outbreaks. If we wish to study in more detail how much more disease we can expect with a warmer climate, it is the frequency and intensity of extreme situations that would be most important to study.

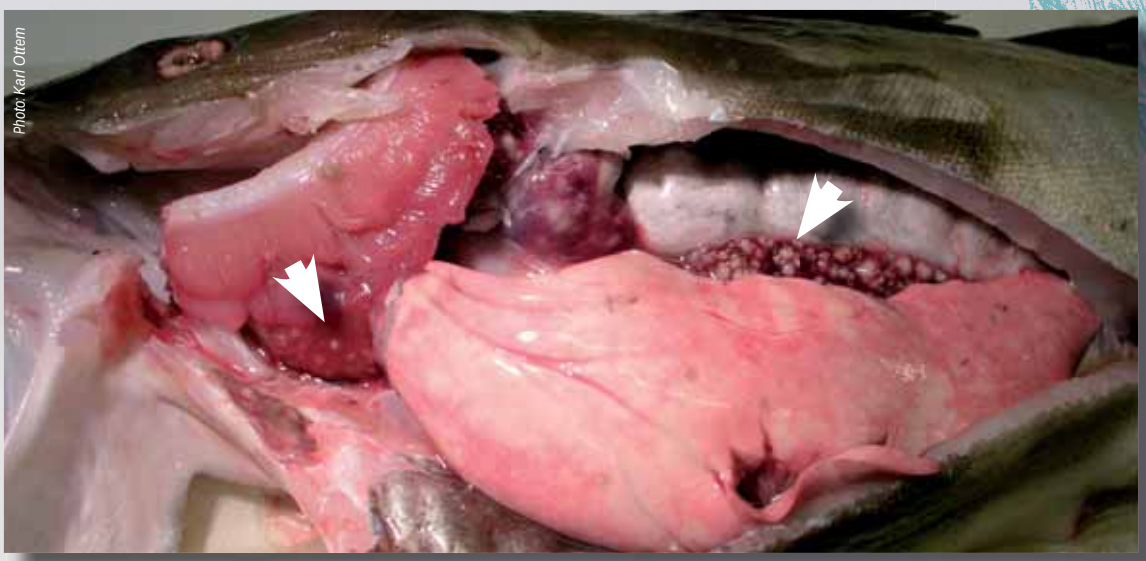


Figure 3: Cod with francisellosis. The characteristic white granulomas in the kidneys and spleen (arrowed) are typical signs of the disease, which is found in wild fish, but spreads throughout fish farms. The *Francisella piscicida* bacterium, which causes the disease, grows more rapidly at higher temperatures. So far, francisellosis has appeared most often in areas where the temperature has been high.

A heat-loving disease: francisellosis

Francisellosis has been widespread among wild fish for a long time, but in the course of the past few years it has been the cause of significant problems for Norwegian cod farming. The disease is due to a recently discovered bacterium that produces chronically inflamed granulomas, particularly in highly vascular organs such as the heart, kidney and spleen (Figure 3). In extreme cases, these can also be seen in the musculature and skin. Most cases of francisellosis have affected cod. The losses suffered by fish farmers are primarily the result of downgrading and reduced slaughter weight of the product, while stocks that include a high proportion of sick fish have to be destroyed. This disease develops more rapidly at high temperatures.

Wild cod with these symptoms from the southern Skagerrak/Kattegat were found at the same time as the first observations in Norwegian fish farms, but there is good reason to believe that the disease has been widespread in wild cod for a long time. To date, it has been observed in farmed cod as far north as the Nordland county , and in wild cod as far as Western Norway. It is possible that the finds from Nordland are related to transports of hatchery fish from the south, but this has not been proved. The most intense outbreaks of francisellosis in fish farms so far have been in areas with extremely high summer temperatures, particularly in the Counties of Rogaland and Hordaland. A combination of down-regulation of the fishes' immune system at high temperatures and the fact that the bacterium has a high optimal temperature for growth (around 20 °C) means that conditions have been right for an outbreak. If this is the case, we can expect there to be fewer outbreaks the further north we go, and that climate change will increase the incidence of this disease and gradually move the area in which it occurs further north.

Francisellosis is currently perhaps the most serious disease problem facing Norwegian cod farming. It is possible that reproduction of the bacteria in cod farms can increase infection pressure in wild fish, so that the incidence of the disease increases among them too. Higher water temperature itself offers better conditions for francisellosis in wild cod, but it is possible that wild fish will compensate by changing their distribution range. Experiments have shown that the bacterium is passed from infected to uninfected individuals in the same tank. This probably means that infected fish release bacteria to their surrounding, and that water-borne infection is likely. This is also the case with vibriosis and a number of other diseases that are common in both wild and farmed fish.

Vaccination at high temperatures

Excessively high temperatures damage the immune system in fish. Today, vaccination is essential in industrial fish farming as we know it in Norway. Without vaccines, diseases would have spread out of control from farmed to wild fish. Vaccines have also made it possible to reduce the consumption of antibiotics to a minimum level.

It is not a matter of indifference what the temperature is when we vaccinate fish. Experiments carried out at the Institute of Marine Research have shown that vaccinating salmon when temperatures are too high can raise the frequency of undesirable side-effects. Fusion of the abdominal wall with internal organs can be painful for fish, and black deposits of melanin caused by vaccination may reduce the quality of salmon fillets. Another type of injury that can be caused by vaccination is deformed vertebrae. All of these types of damage are affected by temperature, and vaccination at higher temperatures produces more of them.

WILL FISH GROW FASTER?

In 2006, the Norwegian aquaculture industry exported salmon worth NOK 16 billion, and it directly employs about 3000 people. This has been possible because our farmed species are well adapted to our current environment. All animals react to the environment they inhabit, and poikilotherms (cold-blooded animals) are particularly sensitive to temperature changes. Experiments have shown that fish growth rates are dependent on environmental factors such as sea temperature, oxygen saturation, salinity, currents and light. Without the natural ecological conditions that we have on the coast of Norway, it would have been impossible to farm salmon and to realise the important financial benefits that we do today.

A stable marine environment in equilibrium is characterised by repeated, highly similar seasonal changes from one year to the next. Global warming will gradually force the ecological system out of its natural equilibrium, for example by changing the average sea temperature.

Experiments have shown that changes in mean growth rates in salmon are greatest when the sea temperature rises by an average of less than seven degrees. The highest growth rates have been measured when the temperature is 15 °C, while cod grow fastest at 13.5 °C. Figure 4 shows how salmon grow at various temperatures.

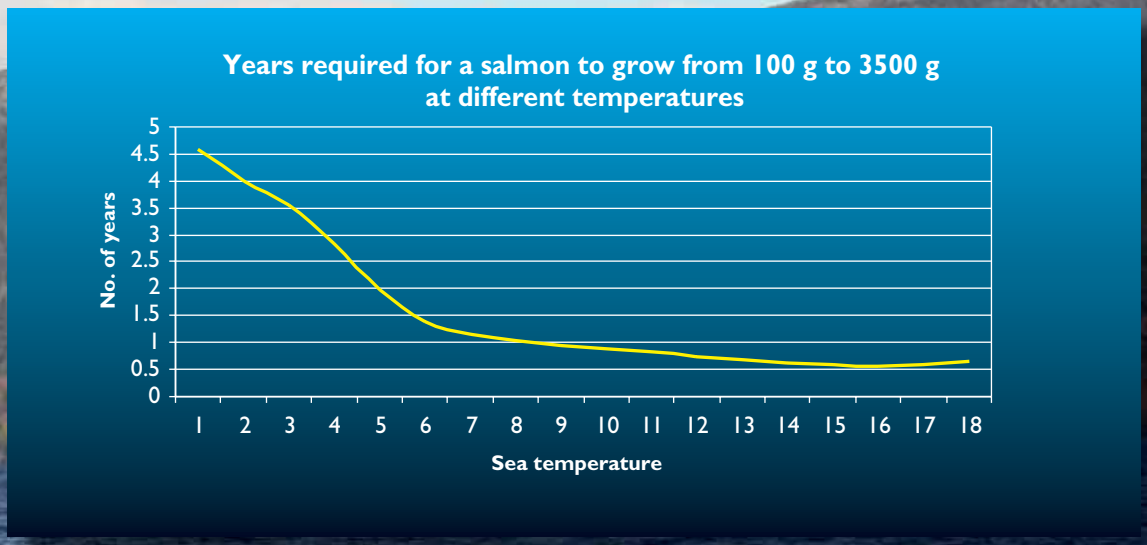
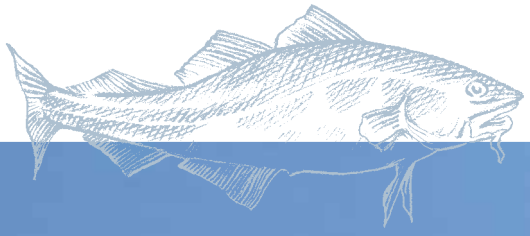


Figure 4: Salmon growth at different temperatures.
Source: Lorentzen, 2006



WILL SALMON AND COD HAVE TO MOVE NORTH?

Climate change alters the ecology and thus the financial risk for industries that are dependent on ecological conditions. In Norway's southern-most counties, fish farmers may find that the temperatures are so high that their fish do not grow. In the worst case, conditions could lead to outbreaks of disease and mass deaths. On the other hand, fish farmers in the north of the country may find that their fish grow faster, increasing their productivity.

The areas with optimal temperatures for salmon and cod will thus gradually move northwards.

However, this process will take place relatively slowly, and in the short run it will not be necessary to relocate fish farms further north. Figure 5 shows that mean and extreme temperatures between 2000 and 2070 will rise in such a way that the best conditions for salmon move from the Møre region to Helgeland. However, this model is based solely on optimal growth rates, while factors such as the spread of diseases and local hydrographic conditions in fjords have not been taken into account. It is likely that local effects in fjords in Western Norway will be greater than in outer regions.

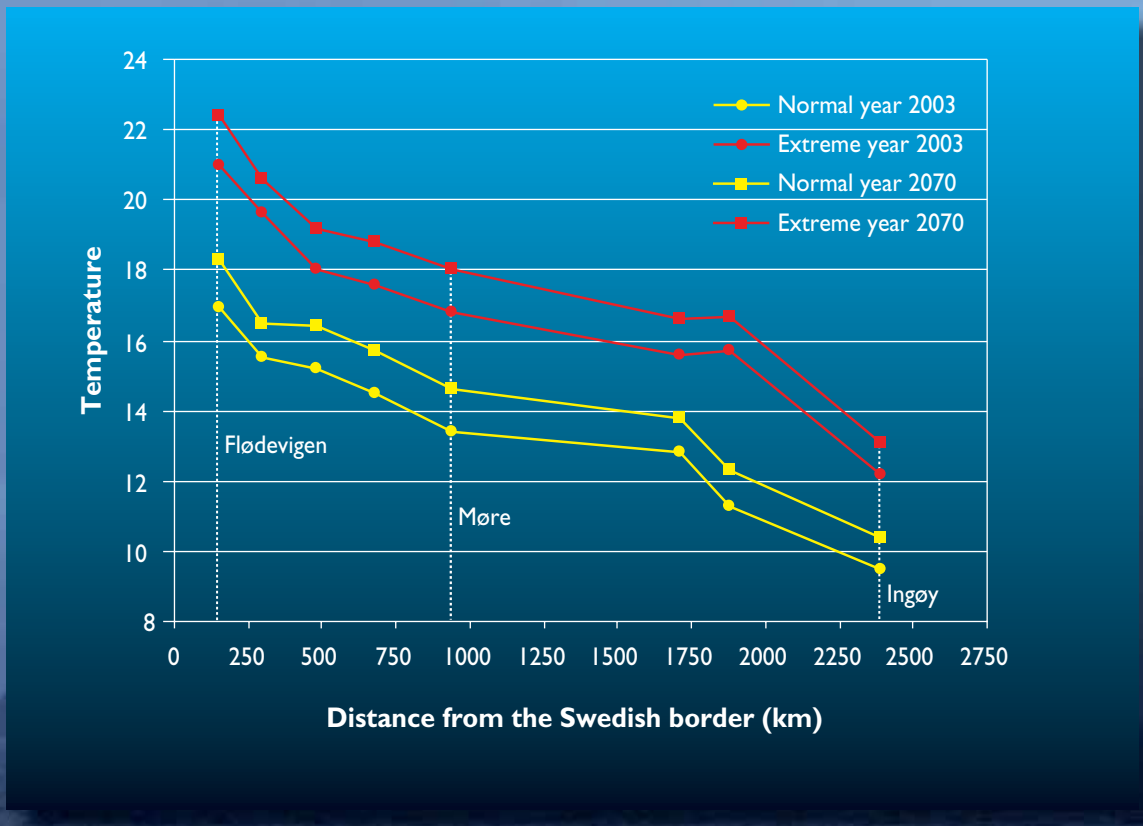
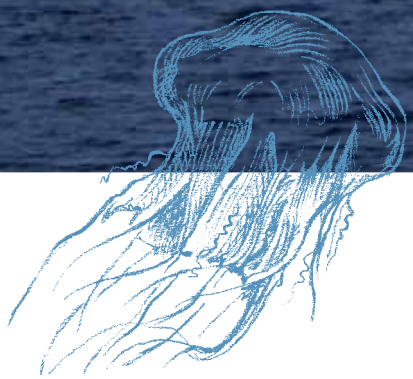


Figure 5: Maximum temperatures at the Institute of Marine Research's coastal stations (1 m depth) in 2003 and 2070 (estimated) in normal years (yellow lines) and extreme years (red lines). The x-axis represents the distance from the Swedish border at Svinesund (starts at 0 km) along the entire coast of Norway to the Russian border at Grense Jacobselv (approximately 2750 km from the border with Sweden).

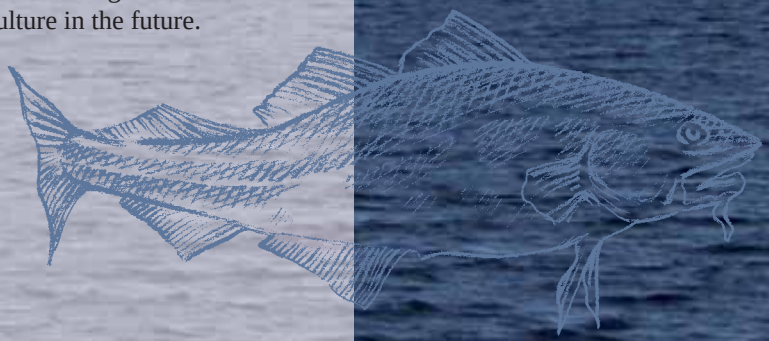


NEW AQUACULTURE SPECIES IN A WARMER CLIMATE?

Climate change is a global phenomenon. If "Norwegian" aquaculture species have to be moved northwards, the same thing will have to happen to species that are currently more common in southern and central Europe, such as sea bass and turbot, and shellfish such as scallops and oysters. Today, these are marginal industries in Norway, but are much more important in such countries as France and Spain. Climate change in Southern and Central Europe will thus have negative effects on the aquaculture industry in those countries, while conditions for farming these species will gradually improve here, particularly in Southern and Western Norway.

Turbot and sea bass are already being farmed on a small scale in Norway. Both species are part of our natural fauna, and it is likely that climate change will make them more common in our waters. Both aquaculture products are in demand and fetch high prices. Giant scallops are currently being farmed (sea ranching) as far north as the Trøndelag region, but are also found living "wild" as far north as Lofoten. Winter temperatures are the decisive factor here, and the distribution of these species will expand northwards. Today, oysters are traditionally farmed in enclosed sea-water pools in Western Norway, where local "greenhouse effects" produce extremely high temperatures during the summer months.

We can expect to experience major changes in the climate from the south to the north of Norway, while differences between local coastal and fjord climates in each part of the country will increase. This makes it likely that a larger number of farmed species and adaptations to the local effects of climate change will characterise Norwegian aquaculture in the future.



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