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CERES storyline - salmon in the NE Atlantic

What do we expect under climate change?

As Atlantic salmon are anadromous (adult fish live in the sea and migrate into fresh water to spawn), the production cycle has both fresh water (hatchery and nursery) and marine phases (on-growing to harvest). Salmon aquaculture production in Europe (including Norway, Iceland and the Faroe Islands) represents ~48% of total aquaculture production (1,331,955 tonnes in 2013). Therefore, in terms of quantity it is by far the most important aquaculture product in Europe. Within the EU-28, salmon aquaculture production has increased only marginally since 2010 while it has massively expanded in Norway.

One of the objectives of CERES is to determine the potential impact of climate change on the salmon aquaculture production and how the industry can adapt to and benefit from future change. This will particularly focus on the grow-out phase in marine systems.

Direct effects:

- Increased sea temperatures may lead to faster growth rates in certain areas. However, prolonged periods of warmer summer temperatures may cause thermal stress which reduces growth potential, and may make fish more susceptible to disease.
- Increased sea temperatures may open up new areas for salmon aquaculture production further north (e.g. in Norway, Iceland), but equally may reduce production in more southern areas that are already on the temperature limits for this species. Thus, overall there may be a shift from current production areas to areas further north, and may drive production further offshore.
- Changes in the frequency and strength of storms may pose a risk to industry infrastructure, e.g. salmon pens may be dislodged from seabed.
- Adverse weather events may also temporarily limit production (e.g. by reduced feeding) and health management practices (i.e. removal of mortalities, health treatments). In addition, increased strength of storms can lead to physical skin damage to the fish, which can then be prone to secondary bacterial infections.
- With climate change it is predicted that winds will increase in intensity and storminess, so harmful jellyfish species such as *Pelagia noctiluca* or *Muggiaea atlantica* may be swept into coastal waters of the North East Atlantic more frequently, which can cause fish health issues.

Indirect effects:

- Outbreaks of diseases may increase or decrease depending on changing conditions.
- Increased temperatures may increase the geographic range of some diseases (northern spread) and increase the occurrence of as yet unknown or emerging diseases.
- Sea lice and amoebic gill disease (AGD) are some of the main challenges for the industry in sea water. The life cycle of these parasites is directly related to sea water temperatures and therefore it is possible that the impact of sea lice and AGD will increases with warming seas .
- White spot (caused by the protozoan parasite *Ichthyophthirius multifiliis*) is an important disease for freshwater Atlantic salmon stages, and the parasite life cycle is also directly associated with water temperature, which may increase as temperatures increase.
- Increased incidence of AGD and sea lice may lead to an increase in the number of disease treatments. Bath treatments used for AGD, and sea lice, include enclosing cages in tarpaulins (baths) and adding freshwater or hydrogen peroxide. Higher water temperatures may increase risk of fish losses during bath treatments due the higher oxygen requirements during treatment, fish stress and increased toxicity (i.e. hydrogen peroxide). Hydrogen peroxide treatment is not recommended above 13.5°C and higher sea temperature may limit this treatment as an

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option. Periods of low rainfall may also limit access to freshwater.

- Lumpfish are used as a biological control for sea lice in Atlantic salmon aquaculture. These fish eat sea lice to lower the concentrations. However, Lumpfish are cold water species and increasing sea temperatures may lead to thermal stress, which may reduce efficacy and result in lower efficiency for this treatment option.
- Jellyfish fish kills may become more prevalent in some areas. For example, if the prevalence and widespread occurrence of Pelagia noctiluca increases it will have a detrimental impact on the aquaculture industry. Currently there is anecdotal evidence that they are increasing but limited scientific evidence.
- Even if jellyfish do not increase, an increase in the salmon aquaculture footprint will increase the likelihood of future fish kills.
- Gill health is one of the main health challenges for the industry, and gill disease can be caused by infectious and non-infectious agents. Increasing temperatures, leading to increased pathogen load, and increasing phyto and zooplankton blooms may increase impact and prevalence of complex gill disease cases.
- The biofouling hydroid Ectopleura larynx is the predominant fouling organism on salmon nets in the North Atlantic. Increased abundances of this species (either through increased growth rates, or a prolonged season for growth) will result in added production costs due to increased frequency of cleaning or changing of nets. The costs associated with such biofouling are substantial and the blasting of such hydroids into the water can directly sting and injury the salmon.
- Some other potential impacts, not be related to climate change specifically but relevant in the overall context, relate to management of the industry. The current inflexibility to implement adaptive changes to sites, technology and management practices, without the need long and complex license changes, hinders adaptive change. Also, if certain locations can no longer support salmon production due to climate change, scaling up production in other areas to offset the loss of business and reduced supply is not a simple or short task, and thus food security may become an issue.

What are the challenges?

There is a large uncertainty surrounding many of the above potential impacts on salmon aquaculture. This is largely a result of limited long term datasets to examine trends or limited data on new and emerging diseases. For example, there are few jellyfish time series to examine whether Pelagia noctiluca is increasing in the North Atlantic and limited research to show the effectiveness of proposed mitigation measures (e.tg. bubble curtains).

Amoebic gill disease (AGD) has emerged to become one of the most significant health challenges in marine salmon in Northern Europe and despite the identification of risk factors such as high water temperature and high salinity with AGD

here remains a dearth of knowledge on the factors that have led to this dramatic increase in prevalence and impact. There are also very limited studies on the interaction of changing biofouling cleaning methods, parasites, environment (in particular temperature and salinity) with marine aquaculture finfish species and these gaps in our knowledge require to be addressed.

What is the working program in CERES?

As part of CERES, we will examine the effectiveness of a bubble curtain to keep harmful jellyfish out of salmon aquaculture cages. We will aim to conduct some experiment challenge trials on salmon to examine whether a fish feed supplement could protect salmon from the toxic effects of jellyfish venom.

We will use a salmon growth model and the Farm Aquaculture Resource Model (FARM) to assess individual and site level population changes to fish production in sea cages. Taking predictions of climatic conditions produced by climate modellers we will evaluate changes in species growth and time for growth, and environmental loads for salmon aquaculture, resulting from climate impacts. This will be conducted for various sites around the North Atlantic region including Ireland, Scotland and Norway.

We will also further develop a new product called WATER, a model that predicts, based on environmental conditions, locations where "Aquaculture can Thrive in EuRope" which will enable users to look at the physical locations where salmon aquaculture will and will not be possible under a changed climate. This will assist policy makers, investors and other stakeholders to improve spatial planning for salmon aquaculture depending on how the climate changes in the future.

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