



The effects of climate change upon aquaculture

by Maurine Toussaint, Gergő Gyalog, Courtney Hough, Elizabeth Ytteborg, ClimeFish, Norway



Following the summer temperatures in Europe 2018, it becomes clear that European aquaculture needs specific adaptation plans in case of extreme climate change. High mortalities have been reported due to elevated temperatures, water evaporation and algae blooms.

ClimeFish is a four-year European project funded by the Horizon 2020 research and innovation programme that aims to create a decision support framework (DSF) to ensure sustainable fish production in Europe under climate change. The project focuses on three different fish supply sectors: marine aquaculture, marine fisheries and lakes and ponds, which are divided into 16 case studies that involve more than 25 species across the continent.

The main objective of the ClimeFish project is to ensure that future growth in seafood production occurs in areas and for species with a potential for sustainable growth. The project has been running for more than two years now.

The marine aquaculture sector includes six specific case studies describing different aquacultured species and systems. Three fish species includes the most popular marine farmed fish species in Europe, Sea bass (*Dicentrarchus labrax*) in Greece and Atlantic salmon (*Salmo salar*) in Scotland and Norway, as well as common carp (*Cyprinus carpio*) pond farming in Hungary, in addition to shellfish farming in Italy, Spain and Scotland.

The ClimeFish climate scenarios used to forecast growth in the seafood production were initially based on the three specific climate scenarios from the International Panel of Climate Change, IPCC. These scenarios have already been outdated, bringing new scenarios in the picture.

In addition, the local aquaculture farms that ClimeFish is addressing are not covered by the global scale temperature models available. The consequence is that multiple models and temperature data are needed to correct the existing sea water temperatures so that they follow the overlapping timeframes

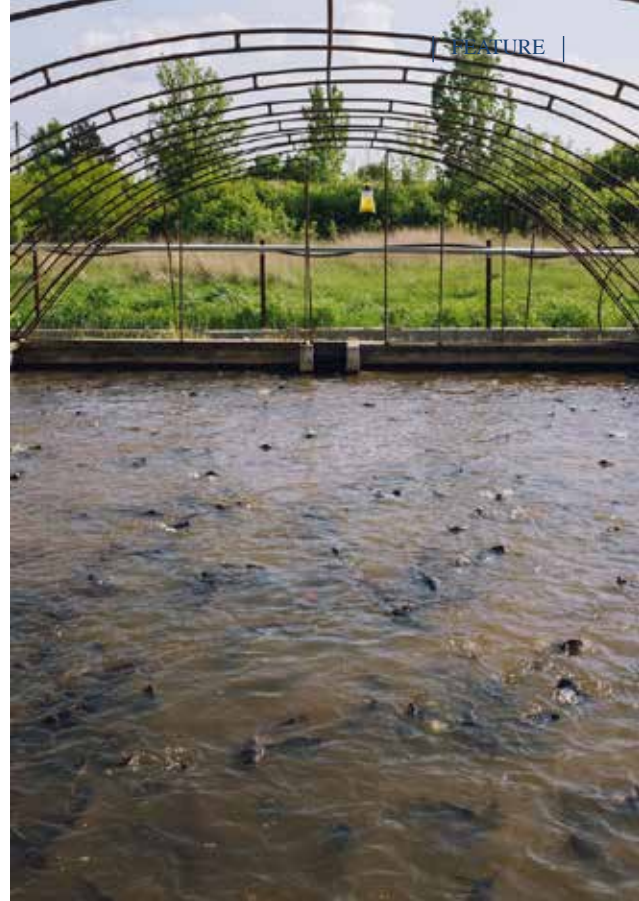
available and predict the correct temperatures 30 years from now. The climate predictions are used in species specific growth models developed in the project to forecast future growth until 2050.

The impacts of climate change on marine aquaculture

Climate change affecting aquaculture is reflected by temperature changes in both water and air, particularly surface temperatures in marine conditions and other alterations in oceanographic conditions, including currents, wind speed and waves.

Feed intake and growth in marine fish are dependent on temperature. Therefore, extreme weather conditions, creating abnormally high temperatures that persists for weeks, will put fish and shellfish under stress that can affect their growth and development. Severe heatwaves may create temperatures above





the thermal window for the farmed species. For example, it has been shown for Atlantic salmon that four weeks with sea water temperatures above 22 degrees may result in an increase of 20 percent in mortality.

For temperatures above 16 degrees, feed intake is reduced and stagnation in growth occur. ClimeFish are currently looking into the highest highs and the lowest lows of the future temperatures and what these will mean for the species concerned.

ClimeFish will be able to answer questions such as, how many days will be within the optimal temperature range for growth in 2022? As an example, will the temperature be beyond feeding optima for Atlantic salmon during summer times in South of Norway 2020?

These questions are extremely relevant for farmers and farm management, but the data may also be used more politically.

The DSS tools developed for the aquacultured species in ClimeFish will simulate and visualise expected changes such as the biological implications of different climate change scenarios, feed and stocking practices, management scenarios and spatial settings.

Extreme weather conditions becoming more intense and more frequent, fall of oxygen levels and changes in salinity are important effects gathered from climate change. Changed hydrodynamics and storms causing material damage and flooding of freshwater farms put pressure on the farmed species.

Increased stress may reduce fish and shellfish robustness, lowering the susceptibility to diseases and infections. One major concern is related to new and emerging diseases

and parasitic infections, as well as increased occurrence of well-known parasites and pathogens, following temperatures rise and altered hydrodynamics. For shellfish farmers, occurrence of red tides is an example of one of the many threats increasing with



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climate change. New conditions may affect the way farms are managed, how treatment procedures are carried out, and even the spacial planning of farm locations.

Another huge issue that the aquaculture sector is facing is the access to proteins, minerals and omega-3 fatty acids, essential nutriment in fish feeds. Climate change could potentially decrease the production of crucial ingredients in the fish feed such as corn and soy. Other sustainable resources and innovative solutions are now needed to support the industry. FAO has indicated that corn and soy production may decrease by 70 percent by 2050 under climate change and the impact may be severe.

With growing production and increased feed consumption, ClimeFish results can be used to calculate the future need for protein ingredients in the seafood production sector, thereby helping to evaluate future needs and resource allocation.

Climate change effects on pond farming in central Europe

The ClimeFish project also brings a focus on pond farming through its Hungarian case study. Carp is the number one farmed fish in Hungary and Hungary is the third biggest carp producer in Europe, with more than 10 000 tons per year.

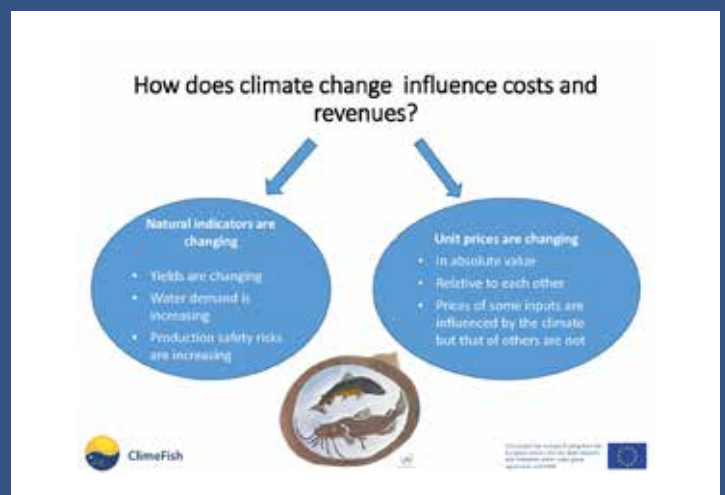
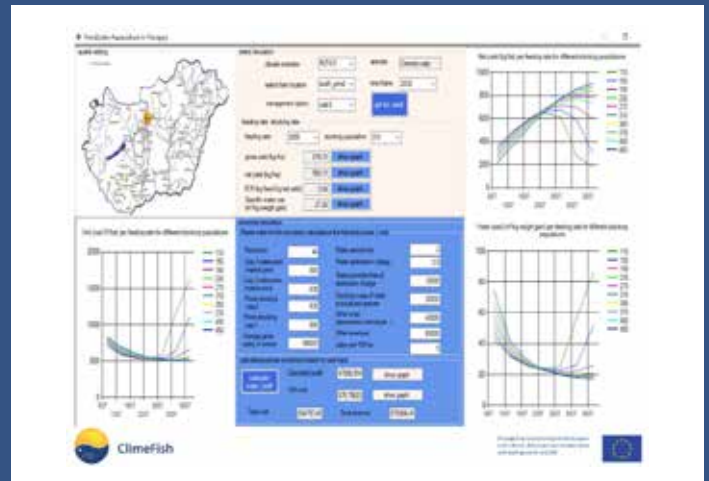
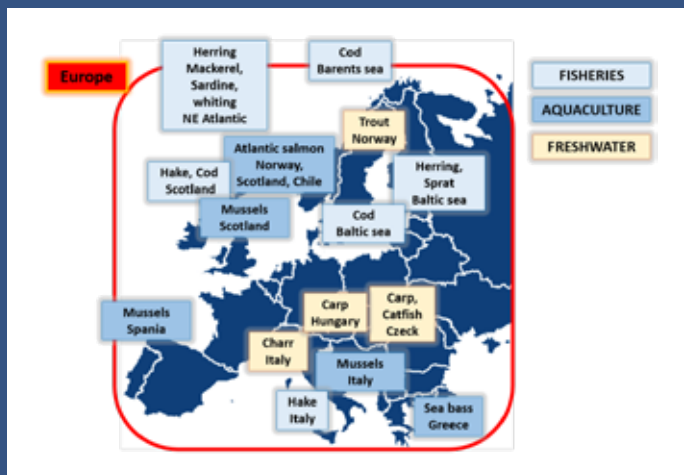
Obviously, the extremes of flooding and drought are especially important for freshwater farms. As in the marine system, climate change impacts both the fish and the production system in ponds: altered metabolic activity changes the appetite of carps on the one hand and impacts on the pond food web changes the availability of naturally-produced food on the other hand.

Initial model-runs in the project show that carp yields can be somewhat higher with increased temperatures; however, there



is still much to understand regarding climate change impacts on welfare and health parameters. For example, it is likely that higher evaporation rates will increase the water costs and, in addition, negatively affect water quality. These effects may increase the production costs in ponds, the price of the marketed product and profitability.

One of the goals in the ClimeFish Hungarian case study is to develop a DSS where the farmers may be able to predict the upcoming yield and costs, thereby plan their production accordingly. The DSS developed for Hungary will, for example, let farmers chose between different management options, like different pre-computed stocking and feeding regimes (stocking density and feed capacity), production cycle and harvesting possibilities for each of the climate scenarios and spatial settings (short-term (2020), middle-term (2030) and long-term (2050) forecasts).





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Adaptation strategies

More than a billion people worldwide rely on food from the ocean as their primary source of protein. Understanding and anticipating the effects of gradual change as opposed to extreme events is the core challenge of the aquaculture industry. The progress made in innovation and technology can already prevent some effects of climate change such as selective breeding for more robust species, the introduction of insect meal and other sustainable sources in place of fish meal in feeds, improvement of marine farms infrastructure like development of offshore facilities, closed systems and IMTA farming.

The DSS tools developed in ClimeFish will simulate and visualize expected changes like biological implications of

different climate change scenarios, feed and stocking practices, management scenarios and spatial settings. Results are obtained from using intricate food web models for growth, socio-economic evaluations and risk assessment, all in co-creation with stakeholders' interest.

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Development work on climate adaptation strategies, guiding investments, providing guidelines for adaptation and help to decide best management plans is urgent.



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