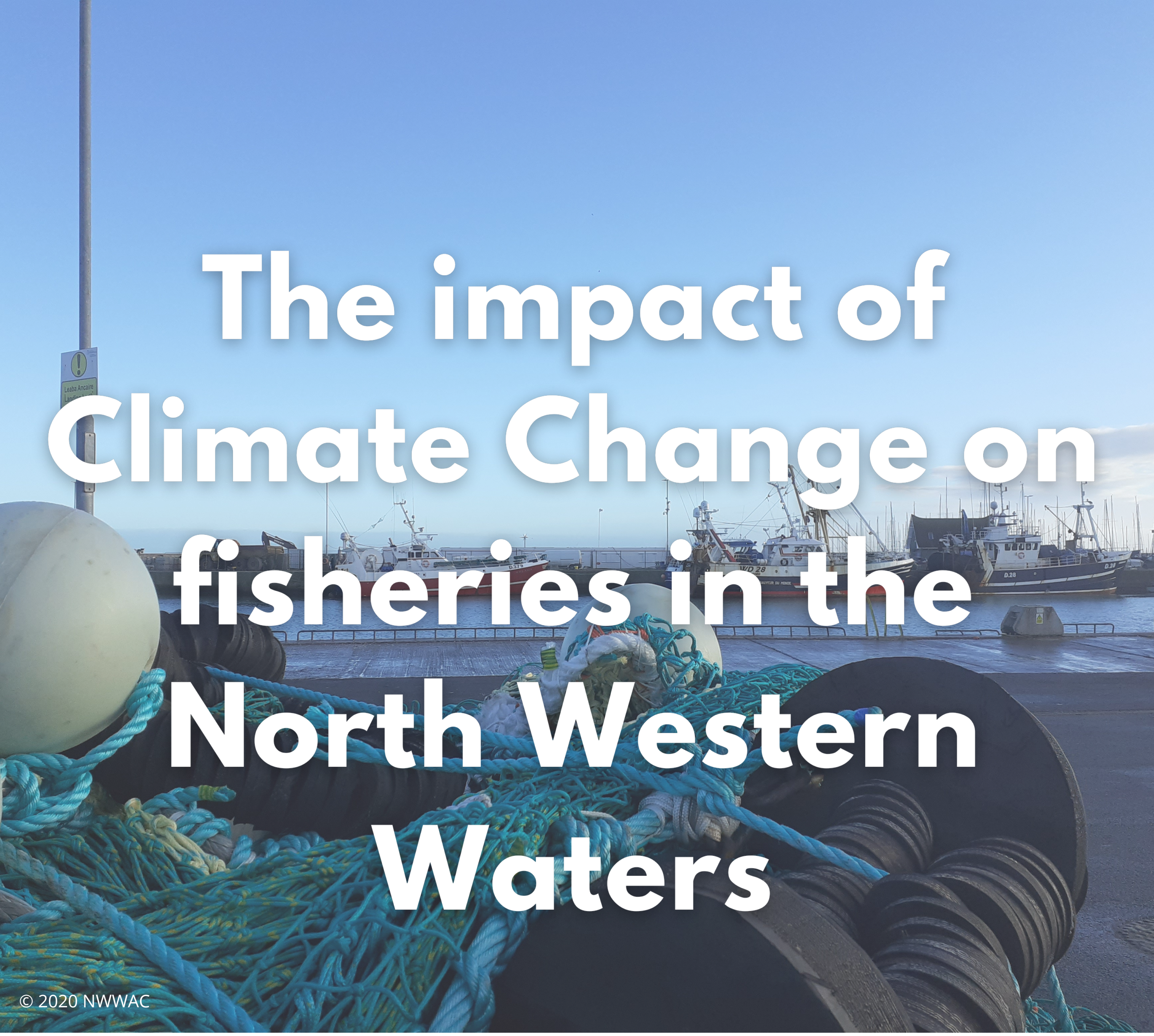
The impact of Climate Change on fisheries in the North Western Waters



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EXAMINING POLICY, RESEARCH, AND POTENTIAL MITIGATION AND ADAPTATION STRATEGIES

Report from the virtual workshop organised by the
North Western Waters Advisory Council
Focus Group Climate & Environment

INTRODUCTION

Emiel Brouckaert
Chairman of the NWWAC Executive Committee

This workshop was initiated by the North Western Waters Advisory Council (NWWAC) Focus Group Climate & Environment and it presented an opportunity to learn from the experts on how fisheries in the North Western Waters (NWW) are impacted by Climate Change. It is now commonly expected that the sea water temperature will increase over the coming decades, already impacting the ecosystems and fish stocks distribution and abundance in the English Channel, the Irish Sea, the Celtic Sea and the West of Scotland. This workshop assessed what this will mean in terms of sustainable fisheries management. The fishing industry is facing many challenges and to address the climate one it is important to assess the mitigation and adaptation strategies available. Learning about Climate Change at this workshop demonstrated that the fishing sector can also contribute actively to address its own impact on climate.

The European Union adopted a Green Deal, putting climate and environmental action as one of its key priorities. In this context, several EU initiatives fostering Climate Change mitigation, adaptation and environmental protection have been implemented and need attention and involvement of the NWWAC. The members felt that this topic was of such particular importance to the NWWAC, that a standing Focus Group Climate & Environment was set up in July this year to identify and examine the NWWAC needs in developing related advice to the Commission.

To aid the members of the NWWAC in this task as well as to inform the work of its Working Groups, the workshop provided an overview of the challenges related to climate change and fisheries in the North Western Waters and examine potential mitigation and adaptation strategies.

Stephanie Schmidt,
International Relations Officer, DG MARE

The European Commission international governance agenda has identified Climate Change as a priority area for action. In principle, Climate Change, oceans and fisheries interact in three main ways:

- Climate Change has a big impact on the ocean in terms of warming and acidification, which in turn affect ecosystems and fish stocks productivity and distribution. Climate Change also increases storms' frequency, which challenges the security of maritime activities.
- The ocean has an important role to play when it comes to Climate Change adaptation and mitigation strategies, acting like a carbon sink but also providing space and dynamics for renewable energy production.
- Maritime activities also produce emissions of carbon dioxide and other greenhouse gasses. It is important to decarbonize the maritime industries, including the fisheries sector.

One of the priorities of the European Commission is the EU Green Deal, which has the overall objective to make Europe climate neutral by 2050, through a just transition to a sustainable economy, decarbonizing industries, tackling pollution and restoring biodiversity. In this regard, the oceans are recognized in the Green Deal and in the initiatives stemming from it. For example, the European Biodiversity Strategy has the objective to reach 30% of maritime protected areas coverage by 2030. The recently adopted the Offshore Renewable Energy Strategy, aiming at upscaling the production of offshore energy (mainly through windfarms), will also have an impact on the use of maritime space, making Maritime Spatial Planning even more important. The Strategy recognises that it is fundamental to find and maintain a balance between the different sectors using ocean space. To ensure all relevant stakeholders are properly involved, the Strategy establishes a community of practice to facilitate dialogue between the interest groups (including the Advisory Councils).

There will soon be an assessment of the Common Fisheries Policy (CFP), which the Commission has to deliver by the end of 2022, and particular attention will be paid to Climate Change. The Commission is now preparing a study on the relation between Climate Change and the CFP based on the following concerns: is our management and governance system climate proof for the long ward trends and changes Climate Change will produce, but also for the ad hoc shocks that can happen? What can be done to climate proofing the sector? The Advisory Councils will be involved and informed as this study proceeds and continues to be developed.

THE IMPACT OF CLIMATE CHANGE ON THE OCEANS

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THE INTERNATIONAL POLICY DIMENSION IN RELATION TO CLIMATE CHANGE AND FISHERIES

Ernesto Peñas Lado, IUCN Fisheries Expert Group

According to the objectives of the Green Deal, the European economy needs to be decarbonized by 2050. The contribution of the maritime sector to the total CO2 emission is less than 3%, with the fisheries sector's footprint being very small. It has been argued that derogations could be put in place that exempt the fishing sector to participate in the effort of decarbonization. However, **the sector needs to be part of the solution and not of the problem, embracing the cost of decarbonization from day one.** Currently, certain fishing modalities have a rather unimpressive level of energy efficiency and the public scrutiny will increase in the future, as the landing sectors tend to decarbonize.

Technology that would support the decarbonization of the sector is developing and improving. Options include improvements in engines functioning and the use of different energy sources (solar, wind and hydrogen).

The hydrogen fuel-cell seems to be the most promising alternative. Quite a lot of activity is taking place worldwide in this regard. There is a particularly interesting case in Japan, where national research institution in cooperation with the Toyota corporation is developing a 19 tonnes fishing vessel running on hydrogen produced entirely by an offshore wind park. Such projects are good examples for the European sector to consider for future perspectives. In this regard, the European Commission has been investing in research in the hydrogen technology: the Horizon 2020 programme has funded 108 projects. However, only a few were related to the maritime sector and even fewer to the fishing sector.

It is important that the fisheries sector ensures that it receives enough attention in the 2021-2027 funding programme to secure that its needs are considered in the developments of these new technologies.

THE IMPACT OF CLIMATE CHANGE ON THE OCEANS

Several studies compare the carbon footprint of various food sources. When comparing animal protein sources, there is a general trend identifying the highest carbon footprint in relation to certain land-based animal proteins, while **seafood production presents lower carbon footprints**. This fact will certainly have relevance in future policy debates. The fishing sector should be very aware that it has a comparative advantage in this particular regard. Our best efforts are still needed to ensure fisheries sustainability. At the same time, if seafood is strategically a more climate friendly source of animal protein, future policies should focus not only on sustainability but also on efficiency in turning marine productivity into proteins for consumers. If we are to increase our efficiency and sustainability in exploiting fisheries, a change of paradigm might be needed: from fishing what the market wants to selling what the nets catch.

In a report from 2016, ICES has highlighted how the effects of global warming are already altering the traditional fisheries management areas, which inevitably means changes in the way the fishing sector can exert its fishing rights. **The displacement of fish biomass as a consequence of Climate Change requires an adjustment of management areas and relative stability.** Having an efficient system to allocate fishing rights is a precondition for good management. It is important to develop a system which is fixed in terms of allocation of fishing rights and at the same time adaptive to the movement of fish stocks.

Climate Change contributes to marine biodiversity loss and to lower levels of ecosystems resilience. Healthy and resilient marine ecosystems are fundamental to sustain a florid fisheries sector. Many initiatives have been implemented to protect biodiversity in a context were more and more activities are occupying the maritime space. The space available to the fishing sector is shrinking. One of the most important initiatives for protecting biodiversity worldwide is the Convention on Biological Diversity, aiming at covering 30% of the ocean with marine protected areas by 2030. The EU is highly supportive of this objective. **The fishing industry will have to be very involved and proactive in the design and implementation of protected areas, but also in proposing alternative measures which will be equivalent in the delivery of the objective.**

THE IMPACT OF CLIMATE CHANGE ON THE OCEANS

CLIMATE CHANGE EFFECTS ON EUROPEAN FISHERIES: FROM PHYSICS TO FISH PRICES

Dr. Myron Peck, Royal Netherlands Institute for Sea Research

ICES and PICES are working together to look at the effects of Climate Change on fisheries through the Strategic Initiative on Climate Change Impacts on Marine Ecosystems. The Initiative is fed by regional research programmes around the world including CERES. By focusing on both bottom-up solutions and top-down policies opportunities, CERES integrates the different scientific knowledge (ecology, economics and social sciences) to produce future climate impacts scenarios and robust scientific advice.

CERES considered the IPCC Representative Concentration Pathways (RCPs) 4.5 and 8.5 climate scenarios to 2070 or 2100. As highlighted in the CERES Synthesis Report, the projected change of sea surface temperature in 50 years is expected to be much worse for RCP8.5 than RCP4.5. Thus, **while we need to act to cut our emissions, we also need to plan for the case in which we are failing.** The model outputs also report an alarming decrease in primary productivity in certain basins such as the North Sea. Projections of future storminess are very uncertain, but generally more frequent, larger storms are expected in the North Sea.

When considering the ecology aspect, CERES examined more than 20,000 studies and concluded that freshwater fish and aquaculture species are the most studied, while there is still a lot of uncertainty about the marine species. **Looking at the work done on marine fisheries, results show that studies are mostly focused on the effects of temperature changes on growth development, while the impacts of important interacting parameters (pH, temperature, salinity and dissolved O2) on key fish stocks are still largely understudied.**

THE IMPACT OF CLIMATE CHANGE ON THE OCEANS

Projections suggest changes in the fish stocks distribution, especially shifting towards the poles, producing consequences on the food web. Projections of shifts are consistent across different types of models for the same species in the same region, showing markedly stronger effects for RCP8.5 compared to RCP4.5. Northern European countries might benefit from this shift, depending on responsiveness of management to new opportunities and trans-boundary agreements.

Recognising the importance of the social aspects when considering Climate Change impacts, a lot of effort was spent to engage stakeholders, through workshops, interviews, advisory meetings and focus groups. CERES developed four contrasting future scenarios (i.e. linked to environmental, economic, legal, technological and political changes) out of these consultations. Profitability was tested under these four scenarios and results show that changes in policy (e.g. access rights, discard ban) and economics (future changes in fuel / fish price) are more important than the direct, biological effects of climate change by 2050. However, climate is going to have a much stronger effect by 2100.
Long-term climate adaptation planning is needed to ensure the sustainability of the fisheries sector.

Finally, a Climate Change risk analysis was performed under the CERES programme, taking into account both the types of species being captured by local communities and the way these fishing communities were structured:

- Regions in SE Europe and UK have highest risk to both fleets and communities (low GDP, few targeted species)
- In other regions, risk is greatest at fleet or community level but considerable differences exist, even within a country
- Smallest vessels (less than 6m) had much higher risk than other size classes (Mediterranean Croatia, Bulgaria, France, Malta and Greece)
- In some regions(e.g. SE Baltic) increasing resilience is needed (e.g. creating alternative employment opportunities in community)
- In regions where fleet risks dominate, it is important to prioritize increasing fleet efficiency / diversity

QUESTIONS & ANSWERS

When calculating the carbon footprint of seafood, the impacts of fisheries on carbon rich ecosystems like seagrass meadows are not taken into account. Don't you think that when considering fish as a good source of protein in light of climate change, the impact of destructive fisheries practices on carbon rich ecosystems should be factored in?

Ernesto Penas: I am not sure we can say that the effects of seagrass beds are not taken into account. The research I referred to was done through meta-analysis, considering various parameters. If you consider the carbon footprint of the fishing activity in Europe, the estimation has to take into account that in EU trawling on seagrass beds is prohibited. Seagrass beds are now protected under fisheries law so that is considered in the evaluations.

Is It correct to assume that the perception or definition of a MPA is a ban for all types of fishing activity?

Stephanie Schmidt: No, this is not the definition of a MPA as such. The aim of an MPA is to deliver certain conservation objectives according to which management measures can be implemented regarding maritime activities, including fishing. This could mean that in some areas some fishing activity may be prohibited, but this is established on a case-by-case basis, depending on the specific objective of a MPA, on the area considered or on the national provisions in place. In any case, these measures should be discussed and developed in consultation with the stakeholders and sectors concerned.

Is the Commission planning an assessment for offshore energy to be biodiversity proof like the CFP is has to be climate proof?

Stephanie Schmidt: Yes, there needs to be an environmental impact assessment. There is also a lot of support towards low impact offshore wind farming, for example floating wind farms, less impacting to the seabed.

CLIMATE CHANGE & FISHERIES IN THE NWW

CLIMATE CHANGE & FISHERIES IN THE NWW

CLIMATE IMPACTS ON PRODUCTIVITY OF NWW FISH STOCKS AND HOW FISHERIES MANAGEMENT CAN ADAPT

Dr Tara Marshall, University of Aberdeen

The productivity of commercial fish stocks depends on five vital rates: natural mortality, recruitment, fishing mortality, individual growth. Fish are ectotherms and some of the vital rates are temperature dependent: metabolic rates can double with ten degrees increase in water temperature. This has consequence on any type of development rate that is the expression of the metabolism. A study by Alan Baudron in the North Sea in 2014 using the DATRAS database for eight commercial species in the North Sea as well as some long-term data from the Netherlands market sampling programme for flatfish. The model is based on a cohort from 1970 to 2006 and studies the impact of temperature increase on individual growth rates. Results show a common trend, with **the maximum adult body size decreasing as the temperature of the North Sea warmed**. This had consequence on the yield per recruit and with an average decline of 23%.

Spawning times are also temperature dependent. This was detected for cod in both the North Sea and in the Irish Sea, as reported in a study published in 2017, where there was a shift to early spawning times. Earlier spawning has the potential to create a mismatch with larval prey, and as the mismatch index increases, the recruitment rates will decrease through food limitation impacting survival. The features of this correlation were consistent in the two areas analysed in the study. Thus, **temperature dependency of growth rates and spawning times have the potential for decreasing productivity as waters warm.**

Given the temperature-dependency of fish vital rates, **current reference points in stock assessment**, i.e. BMSY and FMSY, which are based on historical levels of productivity, **will need to be adjusted for expected future levels of productivity.** In order to accommodate the awareness of climate impacts on fisheries resources management, appropriate policy responses are needed that focus on supporting planned adaptation and mitigation solutions:

- Vulnerability assessments, which are a form of risk analysis, on a species-by-species basis. The species identified as most vulnerable should be prioritised in adaptation planning.
- Develop responsive harvest control rules for the most vulnerable species.
- Performing carbon-footprint calculations to ensure a climate-smart food production. Sustainably produced fish are a climate smart protein source, but industry and science need to work together to estimate how smart. Improving fuel efficiency will have the greatest impact on the sector carbon footprint.

CLIMATE CHANGE & FISHERIES IN THE NWW

EVERYTHING YOU WANTED TO KNOW ABOUT CLIMATE CHANGE, BUT WERE AFRAID TO ASK

David Reid, Glenn Nolan and Caroline Cusack,
Marine Institute

Dramatic changes in sea surface temperature have been recorded in the Atlantic, linked to water circulation. The general trend shows an increase in temperature. The subpolar gyre has not warmed as rapidly as the rest of the world. This may be the signature of the Atlantic Overturning Circulation in decline. In 2015, the coldest ever sea surface temperatures were recorded south of Iceland. Since 2015, the freshest ever values were recorded in the Faroe Channel.

Future climate projections for South West of Ireland under the two emission scenarios, RCP4.5 and 8.5, **show higher warming especially closer to the coast, in the areas that are critical for fisheries.** Salinity changes are also occurring though most of them are minor in Irish waters. Dramatic changes are predicted in the deeper waters. By 2035 there will be warmer and fresher waters as a general conclusion. Changes in temperature affects the availability of food for fish, as plankton spatial distributional is driven by temperature changes.

To summarise the effects of Climate Change on fish and fisheries:

- Changes in distribution: northern species reduce as the ocean warms, while southern species increase as they find it easier to grow at higher latitudes.
- As the water gets warmer, changes in phenology (timing of spawning and maturing) and body size occur: fish tend to mature earlier and at smaller sizes in warm water.
- Fish use more energy to live in warm water, with less energy to allocate to growth and reproduction; acidification may also increase energy use.

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Fifteen stocks in the Celtic Sea can be expected to reduce in the expected MSY, which will have an impact on the management of these species. Haddock is currently below its temperature preference. Cod and herring as well are basically outside their temperature range in the Celtic Sea. There are also species that will probably do better with increasing temperature, such as hake, sole and Nephrops.

Looking at cod recruitment in the Celtic Sea, there is a lot of variability over the years. **Peaks in cod recruitment occurred in years when the water temperature dropped below 10 degrees.** Cold water in the Celtic Sea and Irish Sea is driven by the North Atlantic Multidecadal Oscillation, which is currently in a down phase, but can be expected to start warming in the coming years with Climate Change. This means that 2014 might be the last good recruitment year for cod.

As demonstrated in a study by Mark Payne, oceanography and climate change models can help predicting blue whiting spawning distribution and amount. The ocean is not predictable everywhere, but the North East Atlantic, i.e. the European sector, is the most predictable on the planet on Decadal Timescales.

Two projects of interest are being carried on by the Marine Institute:

The ClimFish project, looking at impacts of Climate Change on commercial fish stocks and marine ecosystems in Irish Waters. A specific focus is given to dispersal and delivery to nursery areas for herring. The project is also investigating the effects of climatic drivers on selected adult fish distribution and migration and on recruitment productivity of key species.

The Mission Atlantic project, mapping and assessing present and future status of Atlantic marine ecosystems under influence of Climate Change and exploitation. The research will look at state drivers and tipping points, i.e. the resilience of fish stocks. The aim is to model dynamics of the Atlantic Ocean ecology, resulting in future projections on climate and resource exploitation, considering ecosystems risks and vulnerabilities.

CLIMATE CHANGE & FISHERIES IN THE NWW

USING PROJECTIONS AND PERCEPTIONS TO EXPLORE CLIMATE CHANGE IMPACTS IN SOUTH-WEST UK FISHERIES

Dr Katherine Maltby, Gulf of Maine Research Institute

As a consequence of Climate Change, the South West UK seas (Celtic Sea, Channel and Southern North Sea) are rapidly warming, with projections seeing temperature increases of 2 to 4 degrees by the end of this century. With these waters getting warmer, the boundary between cooler northern waters and warmer southern waters in this area is getting more blurred and ecological impacts on fish species (e.g., spawning times, altered community compositions) have already been experienced.

The presented research focused on impacts on abundances and distributions that can be expected in the future. Eight species of commercial importance were considered and a range of 13 climate scenarios were used to produce future projections through to 2098. **Results from this work suggested a quite consistent decline in relative abundance for cold adapted species, such as anglerfish, Atlantic cod and megrim. Relative abundance trends increase for john dory, lemon sole and red mullet, while there is a marginal increase for Dover sole. There seems to be relative stability for plaice.**

Looking at spatial abundance trends, results suggest region-wide increases in abundance of John dory and red mullet. Dover sole is projected to increase in most parts of the study area. Anglerfish and megrim are projected to decline across their range, with some localised increases for megrim to the West. Lemon sole is projected to decline in the Northern extent but increase towards the South, while plaice showed increases to the East of the region but decreases to the West.

The mentioned abundance expansions may provide new or further fishing opportunities (e.g. red mullet, john dory, Dover sole) but that depends on fisheries access, markets and adaptability. Future declines in anglerfish, Atlantic cod and megrim are likely to occur: hence, further management measures to reduce the vulnerability of these stocks to further warming may be required, by reducing other pressures such as fishing.

CLIMATE CHANGE & FISHERIES IN THE NWW

Overall, most projected responses were comparable among climate projections, but uncertainty in the rate and magnitude of changes often increased substantially beyond 2040.

Other climate impacts that can affect fisheries are storminess and extreme weather events. Studies highlight that weather extremes and storminess have fundamental roles in shaping fishers' behaviour. They also increase levels of physical risk, discomfort and trip profitability, and ultimately whether fishers can fish or not. In light of this, storminess should be increasingly incorporated in fisheries climate vulnerability assessments.

When thinking about managing and adapting to Climate Change, it is important to understand people's willingness and support for initiatives, their behavioural intentions and the constraints and barriers they see to adaptation. The research focused on the Brixham (UK) fishing community with 31 structured interviews conducted (~55% of fleet, including vessels below and above 10 meters length, whose activities range from beam and bottom trawling to scallop dredging). Fishers were able to describe a number of physical changes to the marine environment, including warming seas, rising sea levels and change in storminess. They also recognised the ecological impacts such as shifting stocks, changes in breeding seasons and altered abundances. However, most fishers do not think that their fishing practices would be impacted, except for maybe the need to change target species.

Awareness of impacts may not necessarily translate into perceived need or willingness to prepare for and adapt to future impacts: fishers identify numerous non-climate risks for the future, while Climate Change is regarded by the majority of interviewees as a low risk. These low-risk perceptions are influenced by scepticism and perceived ability to adapt. Fisher's ability to adapt is not only depending on personal preferences and historical perceptions ("I won't change"), but also on management, financial and current fishing practices constraints ("I can't change").

Low risk perceptions and scepticism suggest potential issues regarding the perceived legitimacy of future climate-orientated fisheries management measures. Fishers' future responses depend on both their perceptions of change and their capacity to change. Incentivising adaptation through awareness raising will likely be insufficient; fisheries adaptation planning should also tackle wider constraints and future non-climate risks. Further work is needed to understand perceptions of multiple stakeholders.

QUESTIONS & ANSWERS

What kind of research and which types of collaboration are needed to engage the fisheries stakeholders in the discussions about Climate Change impacts and adaptation?

Tara Marshall: The salience of Climate Change needs to be increased so that the industry can appreciate its importance. Scientists need to very effectively communicate both uncertainties
and certainties around climate change impacts and package it in the right forward. Also, there is a lot happening at the policy level, for example Climate Change is being embedded in the CFP. As scientists, we need to figure out what messages need to be developed.

Katherine Maltby: There is very limited research available on understanding stakeholders' perception on Climate Change, but also the factors both hampering and facilitating adaptation. Fishermen are naturally adaptive and responsive, but we need to identify what the barriers are as well as what can support them in the process. The salience issue is surprising and there seems to be a lot of scepticism about what is happening within the industry. It is important to improve the dialogue and include them in decision making and scientific processes.

David Reid: The Marine Institute did an exercise in the Irish sea on ecosystem modelling on why stocks have not recovered despite the massive reduction of effort. Work included fisheries stakeholders and their involvement was very productive. The fishers were asking to try various approaches to the modelling. The high level of engagement allowed the fishers to understand what was going on and also to use that information to dialogue with decision makers. Fishers need to be engaged throughout the entire process and the Advisory Council has been very useful in sponsoring this.

Ernesto Penas: More research on the change of species available is needed, as the fishing industry will have to adapt to catching different species and marketing same. It is also necessary to refocus fisheries management into an ecosystem approach to maximise the productivity of the system. This will need a change in certain research priorities away from individual stocks and towards the evaluation of the ocean systems productivity. This may mean a slightly higher level of risk regarding some individual species. To improve the efficiency of sustainable exploitation of marine resources it is important to investigate much further how to assess the ecosystem surplus that can be exploited and what are the effects of taking a little bit more chances on the protection of some individual species.

MITIGATION AND ADAPTATION STRATEGIES FOR FISHING FLEETS IN THE NWW

MITIGATION AND ADAPTATION STRATEGIES FOR FISHING FLEETS IN THE NWW

HOW CAN FISHERIES LOWER THEIR CARBON FOOTPRINT AND EMISSIONS?

Dr. Michel Kaiser, IUCN Fisheries Expert Group

The main carbon emission challenge for fishing is represented by the fossil fuel consumption to catch fish. However, some fisheries also have a direct impact on carbon reservoirs on the seabed and on the ability of the marine ecosystem to store carbon.

Data show that by reducing the overall time spent at sea, the amount of the marine environment that is affected is reduced and carbon emissions are reduced as well. If stocks would be rebuilt, then less time would be needed to catch the quota and fishing would have a much smaller footprint on the marine environment.

There is currently a huge effort to consider alternative sources of fuel: hydrogen looks very promising and trials are happening across Europe. Hydrogen can be injected into diesel engines with relatively small modifications, increasing the combustion temperature and reducing the emission of toxic substances while improving fuel efficiency. This technology could be a steppingstone towards a carbon free economy. Electric power might be feasible for certain fleet segments, for example coastal, small scale fleets.

There is also a continue need to improve vessel design and gear design in relation to energy efficiency. A considerable focus to date has been on reducing bycatch and secondary effects on the seafloor. At the moment, fishing gears produce a considerable amount of drag. **Technology that alleviates the issue of physical contact between the gear and the seabed is certainly going to reduce fuel consumption (for example, the electric pulse trawl).**

One of the other advantages of reducing physical contact with the seabed is the reduction in the secondary negative impact on the biological system. As we reduce gear weight and penetration of the seafloor, this decreases the amount of marine organisms killed in the sediment. These organisms are important in processing carbon which is then stored in the sediment. Similarly, **by reducing gears penetration of the seabed, we also reduce the interaction with carbon stores**, which should not be liberated and mineralised in the water column.

MITIGATION AND ADAPTATION STRATEGIES FOR FISHING FLEETS IN THE NWW

To enable more careful management decisions, it is fundamental to have detailed information on where the most important carbon stores are located and consider which of those are more prone to be penetrated by fishing gears (because of the soft nature of the sediment).

Another key aspect is to understand the fuel efficiency and the food production efficiency of our fisheries. For wild capture fisheries, especially pelagic and white fish, the actual food production efficiency in terms of tonnes of landings per unit of fuel consumed to catch that food, compares very favourably to other forms of food production. However, this is not a uniform picture and depends on the type of fishery. **Having more detailed information about the efficiency across the different metiers in the fleet would really help governments to target financial incentives and investments to improve particularly problematic sectors of the fleet to help them meet the zero-carbon agenda.**

The following case study from the Ramsay Bay Marine Nature Reserve and Territorial User Right Fishery in the Isle of Man demonstrates how different approaches to management can help reducing fishing footprint at sea. The main fishery in this territorial sea area is a scallop dredge fishery, which is considered to be one of the most disruptive types of fisheries to seabed systems. The Isle of Man government created a fisheries management system that integrated a fishery zone surrounded by mandated conservation zones for seagrass beds, mussels reefs and mud beds (all of them are carbon stores). The fishermen were given ownership and responsibility on how to manage the fishery zone. In turn, they were asked to participate in the science and in the management decision-making process. To make this arrangement work, it was vital to have detailed information on where the target species were distributed across the seafloor. The strategy was then to target the fishing only to those areas where the highest density of scallop occurred and to leave those areas with low density closed to fishing. A quota was also jointly set on the fishery.

The outcome was a very reduced area of fishing, but it was so efficient that the quota was removed from that area within three days, with a very limited portion of the seabed being impacted by the activity (~3% of possible fishing ground). When comparing this fishery to the open access fishery in the surrounding waters, the higher performance in terms of profitability and landings efficiency in the territorial user right fishery greatly minimized fuel consumption and thus its carbon emissions. It was also noted that edible protein Energy Return On Investment (EROI) ratio of scallops from the Ramsey Bay fishery outperforms other proteins, such as pig, meat and egg production. Thus, **even a fishery that is usually considered highly disruptive, if managed well, provides really good incentives for the industry to reduce its carbon footprint.**

MITIGATION AND ADAPTATION STRATEGIES FOR FISHING FLEETS IN THE NWW

REGULATORY AND TECHNOLOGICAL CHALLENGES FOR FISHING VESSELS ENERGY TRANSITION

Jérome Jourdain, Union des Armateurs à la Pêche de France

Global emissions from the international shipping sector have globally increased since 1990, hence the IMO's objectives of reducing them by at least 50% by 2050 compared to 2008. Where does the European fishing fleet, whose international character of is less marked than that shipping, fit in all of this? And **how can the EU fishing fleet succeed in its energy transition and reduce GHG emissions?**

The Union of Fishing Vessels Owners of France (UAPF) initiated in 2019 a study, Gespeche, on the analysis of reports sent to the Climate Change convention (UNFCCC) on the evolution of GHG emissions from fishing vessels since 1990 (reference year for the objectives of the Paris Agreement). The study took into account two methods:

- a top-down approach, looking at consumption of vessels regardless of their nationality, from purchases on French territory, as used by the French administration;
- a bottom-up method, considering the consumption of French vessels based on their level of activity, regardless of where they are refuelling.

Results of the two methods confirm sharp reductions in the overall levels of GHG emissions from the French fleet, which will enable the reduction targets set by the IMO for 2030 to be reached from 2017. Indeed, because of EU rules for managing the capacity of the fishing fleet, in 27 years the French fishing fleet has lost 41% of its engine power, so that in 2017, engine power was only 59% of the engine power recorded in 1990. Moreover, the number of EU vessels decreased of 22.000 units in 20 years, with only 65.000 remaining operational (75% under 12 metres). Finally, it is undeniable that technological progress has improved the performance of fishing vessels since 1990 and that the increase in exploited stocks biomass in EU waters visible since 2010 likely supported the improvement of ships energy efficiency.

Thus, as a consequence of improving the energy efficiency of fishing vessels, the ratio of quantity of CO2 emitted / quantity of catches obtained by the French fishing fleet has decreased significantly since 1990. This statement is generally applicable to the EU fleet level, even though it is important to consider the different segments in more detail.

MITIGATION AND ADAPTATION STRATEGIES FOR FISHING FLEETS IN THE NWW

Another study from the UAPF, Jauge Skil Faut, provides a summary of regulatory changes applicable to fishing vessels within the EU over the past 25 years.

The 1992 reform of the CFP imposes limitations on the tonnage and propulsive power of EU vessels. While this has not changed in the past 25 years, the study highlights that it is a shared opinion among fishing professionals that vessel tonnage is poorly suited to the economic and technical challenges that arise for the construction of today's vessels (including purposes of seeking better profitability, better crew comfort and installation of technologies that minimise the sector environmental footprint).

The study identifies that the changes in the analysed regulations generally have a very different influence depending on the length classes of the vessels, with the strongest impact having been identified for vessels of less than 12 meters in length and for those larger than 25 meters.

These results indicate that **the origin of the need for additional tonnage faced by fishing companies is probably due to the fact that the current framework does not anticipate the implementation of new technologies (LNG, hydrogen, etc.) and does not consider the search for better energy efficiency beyond the current mandatory standard.**

Overall, there are both regulatory and technological constraints to the energy transition of EU fishing vessels. The limitations on the tonnage and propulsive power at European level were not originally designed to regulate the emission of GHG. It is not possible to replace a vessel with a larger one with the same hold capacity, which prevents any attempt to move to other fuels/propulsion engines.
The future evaluation of the CFP can play a very important role in the development and evolution of this framework and thus **in the energy transition of the EU fishing sector.**

EU fishing companies are continuously devising and implementing creative solutions to save energy. However, the current technologies are still not a direct alternative to fossil fuels and while the industry is trying to reduce its environmental impact by improving engine efficiency, more knowledge is needed on technological possibilities. In the case of a shift towards alternative fuels, several logistic issues need to be considered in relation to marketing, ports equipment (charging stations, LNG storage, etc.), maintenance and crew training.

MITIGATION AND ADAPTATION STRATEGIES FOR FISHING FLEETS IN THE NWW

HOW RESTORING FISH POPULATIONS HELPS MITIGATE CLIMATE CHANGE

Rebecca Hubbard, OurFish

The ocean is a life giver supporting all life on earth, providing almost half of the oxygen we breathe. Besides supporting industries such as fisheries and tourism, it is critical to climate functioning and regulation: it has absorbed over 93% of the excess heat created as the result of GHG emissions and stored around 30% of carbon from these emissions. Finally, it provides other important services such as food, medicine and wellbeing. Fish can be considered as the lifeblood of the ocean: we need healthy, diverse fish populations, which contribute to functioning marine food webs and help to keep marine habitats healthy and intact.

The understanding of the role of fish in blue carbon has been developing recently, in terms of how **fish influence carbon absorption and sequestration in the ocean by contributing to the biological pump of marine life that moves carbon through the ocean cycle.** First of all, fish play a key role especially as biomass, as fish live in the sea and absorb carbon. When fish die, deadfall carbon falls to the seafloor where it is stored. When fish eat, they absorb the carbon which then reaches the floor as fish poo and gets stored. Research also mentions the Twilight zone, which is a mesopelagic mixing, with the fish moving up and down the water column helping to move the carbon through the system.

Finally, the example of the whale pump is very relevant: whales absorb great quantities of CO2 over their lives (around 33 tonnes), which is then stored in the seabed once they die and sink. This blue carbon service, in addition to the revenues from tourism and whales contribution to fisheries by supporting and enhancing rich phytoplankton population, made the current whales population value being estimated at 1 trillion dollars.

Overfishing is sapping the strength of the ocean, by being still the biggest impact to its biodiversity. This represents a real issue for the industry in terms of declining catches and profits and related social impacts.

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Overfishing has also an impact on blue carbon: recent research[1] estimated that from 1950 to 2014 the world's fishing fleets have extracted 318.4 million metric tons of large fish.

This resulted in extracting nearly 40 million tonnes of carbon, which prevented nearly 22 million tonnes of carbon to be sequestered in the seafloor, and in the emission of carbon from fuel burning and processing. The same study advocates that if fisheries subsidies did not exist, half of this fishing activity would not even had been possible.

When overfishing is combined to Climate Change, which has several impacts on its own (increased temperature, salinity, hypoxia and acidification), it is clear that fisheries are under an intense pressure. **Whilst ending overfishing would help on the fisheries level, it would also help fighting the climate emergency.** Fish populations would increase, as well as their health and resilience. This would in turn restore food webs and ensure the proper functioning of the biological pump. Benefits of avoiding habitat disturbance and destruction are not limited to biodiversity protection, but also relate to climate by decreasing carbon emissions while increasing its sequestration.

By ending overfishing and redesigning fisheries management, important benefits can be delivered on a number of scales. Some of the key actions include setting fishing limits below MSY or precautionary advice and managing the climate and ecosystem impacts of fishing to protect food webs, habitats and ecosystem functioning. The allocation of quota to the least damaging fleets (as already included in Article 17 of the CFP) should be further implemented, as it could really help the transition to a more sustainable fleet. Part of that would be to stop subsidising fuel tax.

Finally, governments should recognise ending overfishing as climate action and include it in the Nationally Determined Contributions for monitoring progress towards the achieving and delivering of the Paris Agreement.

[1] Mariani, Gaël, et al. "Let more big fish sink: Fisheries prevent blue carbon sequestration—half in unprofitable areas." Science advances 6.44 (2020): eabb4848.

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CLIMATE CHANGE IMPACTS ON THE WEST OF SCOTLAND DEMERSAL FISHERIES: PAST AND FUTURE CHANGES

Dr Alan Baudron, Marine Scotland Science

ClimeFish is a Horizon2020 EU project, which ran from April 2016 to March 2020. Its objectives included assessing and forecasting the climate threats and opportunities for EU aquatic food production and developing management plans to mitigate these threats and utilise the opportunities in cooperation with stakeholders. Fifteen case studies were considered (both marine and freshwater fisheries and aquaculture), among which the West of Scotland demersal fisheries in partnership with Marine Scotland and Seafish.

West of Scotland demersal fisheries have a mixed nature, targeting multiple species: the case study focused on cod, whiting, haddock, saithe, anglerfish and hake. This fishery is already facing numerous challenges: the stocks of cod and whiting have been depleted for several years, the Nephrops fishery is characterised by high levels of bycatch of young gadoids (especially whiting), and finally predation from grey seals on cod is increasing, which is thought to hamper the recovery of the cod stock.

In addition, **West Scotland waters are warming, which is causing fish distributions to change**. Data show an expansion of southern species across the North East Atlantic, especially in northern areas[2]. Some expansion of northern species occurs in the north, but contractions have been identified in mid and southern areas. However, both changes in suitable habitat areas and density dependent use of these areas are responsible for the observed changes in fish distribution, which are not exclusively driven by temperature. **Warming is also affecting fish body sizes.** Cod, haddock, whiting and saithe in the West of Scotland were considered in a recently published study[3], whose results show trends in relation to the mean length-at-age: both an increase in juvenile length and a decrease in adult length were observed in concomitance with temperature increase.

[2] Baudron, Alan Ronan, et al. "Changing fish distributions challenge the effective management of European fisheries." Ecography 43.4 (2020): 494-505.
[3] Ikpewe, Idongesit E., et al. "Bigger juveniles and smaller adults: Changes in fish size correlate with warming seas." Journal of Applied Ecology (2020).

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Warming will likely affect species composition: in future, we are likely to see a decline in biomass of cold-water species and an increase in biomass of warm-water species[4].

Looking towards the future and considering how to mitigate the impact of warming waters, stakeholders in the case study were asked about their objectives for the future of West of Scotland fisheries. The first would be to recover the cod stock, then to maximise landings of emerging species and finally to maximise landings of whiting post recovery.

To assess how these objectives could be achieved, ClimeFish worked on biological forecasting, exploring alternative fishing strategies under climate change and using a food web ecosystem model including temperature. The model simulated two climate scenarios of medium (RCP4.5) and severe (RCP8.5) warming. Different ranges of the case key species' fishing mortality were explored for both scenarios at medium (2014 to 2030) and long term (2031 to 2050).

Results from the medium warming scenarios indicate the possibility to achieve the recovery of cod above Bpa, while whiting is recovering only above Blim. This because the model considers cod as a predator of whiting, so predation on whiting is increasing by recovering cod. Recovery was achieved with all fisheries mortalities considered on the medium term, however on the long term it was only achieved with the lowest possible fishing mortality on whiting and a high fishing mortality on saithe. Saithe is a predator of both juvenile whiting and cod, thus increasing fishing pressure on saithe would allow these two stocks to recover.

Looking at the severe warming scenarios, cod and whiting can both be recovered above Bpa. However, cod biomass shows some fluctuations and a decline can be expected before 2050. When considering fishing mortalities, recovery was achieved with all possible fishing mortalities on the medium term, **however, on the long-term, recovery of cod was only possible with zero fishing mortality**. Whiting would perform better in warmer waters and could possibly sustain higher fishing mortalities.

[4] Serpetti, Natalia, et al. "Impact of ocean warming on sustainable fisheries management informs the Ecosystem Approach to Fisheries." Scientific reports 7.1 (2017): 1-15.

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The ClimeFish case study also performed risk assessment analysis to account for factors that could not be modelled. Stakeholders gave a substantial input to this task. Overall, **some threats were identified** and the most severe ones include extreme weather, which could cause poor working conditions; collapse of cold water species; changes in distribution, which could mean a reduction in cold water species biomass; and changes in catch composition, potentially leading to lack of quotas and choke species scenarios. The analysis also identified **potential opportunities**: shifts in species' distribution could mean an increase in warm water species biomass, which in turn would provide new catch potential. The rise in emerging species biomass could allow fishermen to access new markets.

Fifteen climate adaptation measures were identified in order to mitigate risks and utilise opportunities, eight of these are applicable at industry level, while the remaining are in relation to the policy level.

Measures at the industry level are all based on three key points: avoiding cod bycatch to reduce fishing mortality, targeting emerging species to maximise landings and improving safety on board to mitigate the risk associated with storms.

At the policy level, the adaptation measures concern enabling the access to quota and markets for emerging species, ensuring flexible management to account for changes and improving monitoring and infrastructure to reduce the risk of adverse working conditions.

The final product of ClimeFish was a decision support software, publicly available on climefish.eu, containing all the results from modelling simulations as well as the outputs of the risk assessment.

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INTRODUCING THE SOMBEE PROJECT: SCENARIOS OF MARINE BIODIVERSITY AND EVOLUTION UNDER EXPLOITATION AND CLIMATE CHANGE

Bruno Ernande, Yunne Shin et Ghassen Halouani, Ifremer

SOMBEE stands for Scenarios Of Marine Biodiversity and Evolution under Exploitation and climate change (sombee.org). The project is funded by BiodivERsA and the Belmont Forum, starting in 2019 and running until 2022, and involves a consortium with international partners from France, Spain, Germany, The Netherlands, UK, China, Canada, Turkey and Peru.

Scenarios are invaluable tools to guide long term strategic policies, prompt management actions and increase public awareness on future threats to biodiversity. In the marine realm, there has been a landmark publication on the projections of climate change impact on fish biomass in the future. An ensemble of global ecosystem models were run together and showed the decrease of close to 1/5 of the fish biomass compared to today by the end of the century (scenario RCP8.5). These projections only include climate impacts and do not take into account pollution or fisheries overexploitation. **A big knowledge gap still remains about the synergistic effects of climate change and fishing on marine biodiversity and about the role of fish adaptation and evolution on multidecadal timescales**.

Marine fish populations adapt to global changes through the modification of their traits including their life-history and physiology (via phenotypic plasticity or evolution). It is clear that exploited fish species evolved towards small-bodied, early maturing, highly fecund life-histories. These changes result from the interplay between selective pressures (fishing pressure and climate change) and trade-offs in energy-allocation between growth and reproduction.

These changes often tend to increase individual fitness, however intensive fishing favours genetic drift by diminishing effective population size. This, together with selection, erodes genetic diversity and thus decreases the evolutionary potential of populations.

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In light of this, the SOMBEE project aims at understanding if the eco-evolutionary dynamics of exploited fish life-history traits and populations will dampen (evolutionary rescue) or worsen (evolutionary trap) global change impacts on future marine fish biodiversity and its sustainable use. This will be done by projecting future intra- and inter-specific biodiversity dynamics in marine fish communities, as well as their effects on ecological and economic sustainability of fisheries, under scenarios of fishing and climate change.

SOMBEE will conduct its work in six regional marine ecosystems (North Sea and English Channel, Gulf of Lions, Black Sea, Yellow Sea, Northern Current Humboldt System, Pacific Coast of Canada) and **aims at co-building policy relevant scenarios which include mitigation and adaptation measures, by engaging stakeholders in consultations at the local scale**.

The project will choose a set of global scale climatic (RCPs) and socio-economic (SSPs) scenarios which will then be downscaled to the local and regional scale. **Downscaling of RCPs will allow to predict the distribution of species at the local scale while downscaling of SSPs with the engagement of local stakeholders will ensure the socio-economic relevance of human activity scenarios, notably fishing and management scenarios.** These downscaled scenarios will then feed the evolutionary-ecosystem model that will account for the genetic and physiological determinism of fish life history traits, and how this in turn will affect the dynamics of populations, communities and food webs. The modelling framework will be based on an existing model, OSMOSE.

The OSMOSE model assumes opportunistic predation based on spatial co-occurrence and size adequacy between a predator and its prey. It is a spatial model: at the beginning of each time step, the species start to move randomly in the habitat and at the end of each time step different configurations are possible: when both spatial co-occurrence and size adequacy happen, this means success in predation. Different sources of mortality are applied (natural mortality, fishing mortality or predation) and if there is success of predation, the individuals will grow and then reproduce, with new larvae being distributed again in the habitat.

When applied to the **English Channel case study within the SOMBEE project,** the model considered 14 species (representing 90% of landings), 5 planktonic groups and 5 benthic groups.

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The model was also used to analyse the impact of Climate Change in the English Channel, by simulating the scenarios RCP4.5 and RCP8.5. Overall, results from the simulations found different patterns: the biomass of some species, like red mullet and horse mackerel, could increase, while other species such as whiting and pouting would see a decrease in their biomass. For all the species analysed, the growth rate was the main driver for their responses to Climate Change.

The evolution of reference points (F and FMSY) with Climate Change was compared across species with the OSMOSE model. Cold water species, like North Sea cod and whiting in the English Channel are likely to have both MSY and FMSY declining with climate warming.

The SOMBEE project will develop a new version of OSMOSE, called EvOSMOSE, by adding a set of modules. An evolutionary sub-module, to describe how the genetics of fish determine their traits throughout the life cycle and how it responds to selection pressures due to climate change and fishing. A bio-energetic module, which will describe how bio-energetics will respond to temperature, food abundance and oxygen. Finally, a bio-economic sub model, that will describe how management policies and fishing practices interact with population dynamics and traits dynamics and how this affects the profitability and sustainability of the fishing sector.

Finally, under the SOMBEE project, a questionnaire is available online aiming at understanding how stakeholders in the English Channel and the other Cases Studies (North Sea, Gulf of Lions, Black Sea, Yellow Sea, Northern Humboldt current system and Pacific Coast of Canada), perceive the effect of Climate Change and fisheries on fish resources[5].

[5] Questionnaire available here: http://sombee.org/new-online-survey-how-do-you-perceive-the-effects-of-climate-change-and-fisheries-on-fish-resources/

QUESTIONS & ANSWERS

Who should bear the financial cost of the transition to a lower or zero carbon emission fisheries industry? Should it be the sector itself or should this be supported by national governments?

Ernesto Penas: Even before the CFP, the EU had a very generous structural policy which contributed financially to promote and support all the necessary changes to ensure the adaptation of the fishing industry to the future and to its challenges. This structural policy still exists and supports fishermen, however it is important that it is designed to help the industry tackling the challenges ahead, not to preserve the status quo. The structural policy has traditionally been used to preserve certain practices from the past, while it should accompany the industry in introducing the necessary changes as a result of global warming.

Jerome Jourdain: I agree with Ernesto, the CFP has been contributing to the promotion of the energetic transition for 15 years. However, to date no vessel owner would take the risk to make changes on his/her fishing boat or gears as it is not profitable. The fisheries sector does not have the research and development means that the maritime transport industry has and the technology available is very expensive. In France there are many ongoing projects on the use of hydrogen, but none of them has materialised for fisheries professionals as this technology demands space for hydrogen storage on board and a series of facilities on land. Thus, it is fundamental that these aspects are considered and supported financially as well in order to promote the transition to a more climate friendly sector.

We heard from the various presentations about the importance of scenarios and their use in order to understand how to adapt to changes in the future. However, how do we communicate these scenarios results to both policy makers and the industry?

Yunne Shin: This is a very complicated task, even within the scientific community. We would talk about what the different scenarios foresee in terms of human growth population, of the oil price evolution, of the governance framework. This is a very broad and global issue, so people might not feel concerned at the local scale.

Thus, the effort to downscale the scenarios results to the local scale is very important. In the dialogue with different stakeholders, it is usually difficult to make decisions on the short term and have immediate consensus among stakeholders, while it is much easier to get agreement when discussing long term objectives. This helps showing that there is a common view for the future. Thus, long-term targets can be unpacked in the corresponding management options which, going backwards, can be applied to the present situation.

Alan Baudron: The ClimeFish project occurred in two cycles and a stakeholder meeting was organised for each of them. We first presented the tools we were going to use and explained the objectives we wanted to achieve, asking for suggestions, and then presented them the results obtained. At the end of the project, we had a staekholders forum showing the developed decision support software, running participants through a user guide session and explaining how to interpret the software results. We hope that we have been successful in communicating the findings and also in using stakeholders inputs in our work. As scientists, we are always trying to communicate and explain as clearly as possible, however stakeholders requests can be very complicated to model.

Some presentations focused on the actions that can help mitigating Climate Change. What can facilitate the uptake of these actions and how can we unleash their potential? How feasible are they?

Rebecca Hubbard: One of the solutions is restoring our fish populations and transitioning to more selective fisheries. We have commitments already within legislation to end overfishing, which is a fundamental part of transitioning to more sustainable systems. The Commission could propose criteria for allocating quota to the most socially and environmentally beneficial parts of the fleet. Another key action that would be very helpful would be to eliminate fuel subsidies (for transport sectors as well). Also, transitioning to more sustainable gears, less fuel would be used. Thus, there are several processes that incentivise the transition. Finally, having a more holistic approach to fisheries management, not just related to setting TACs at MSY, but including an ecosystem impact assessment of fishing activities, would facilitate the transition.

Jerome Jourdain: Climate Change and biodiversity loss are global issues and the EU policies, while it needs to improve, are already on the forefront of addressing these challenges. The EU fleet is very advanced from the economic and social point of view. It is important to remember that the fisheries sector is rather a victim of Climate Change than a culprit: while its impact on the GHG emissions is very low, it is being affected by the consequences caused by other sectors' emissions. Other sectors have pollution rights, which can be exchanged as quotas, but this system does not apply to fisheries. Finally, there are clearly technological limits to the transition process and more R&D is needed to ensure that more climate friendly fisheries are also profitable for the sector.

CONCLUSIONS

Jacopo Pasquero
Chairman of the NWWAC Focus Group Climate & Environment

Climate Change has been described in many different ways: pressure, challenge, risk, opportunity. This already tells us about the complexity of the issue. Science is a fundamental ally to increase our understanding, especially through future scenarios which can support the development of management strategies for adaptation and mitigation. However, projections need to be integrated with stakeholders' perceptions in order to better understand how the sector can be prepared and guided towards future changes. In this context, clear communication of scientific results to resource users and managers is key.

This workshop has already provided a great opportunity for scientists and fisheries stakeholders to listen to each other and exchange views. However, communication will not be sufficient on its own, if the sector's needs are not considered and supported by adaptive legislation and financial aid.

It is also worth mentioning the importance of the international policy dimension in the fisheries-climate interface: international fora such as the Convention on Biological Diversity (CBD), the United Nations Framework Convention on Climate Change (UNFCCC) and the International Maritime Organisation (IMO) will determine the future of fisheries with regards to climate change and will be translated into regional and national policies, including in the context of the EU Green Deal. All fisheries stakeholders should take part in these discussions proactively to ensure their views are heard when ocean-based climate adaption and mitigation measures are addressed.

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