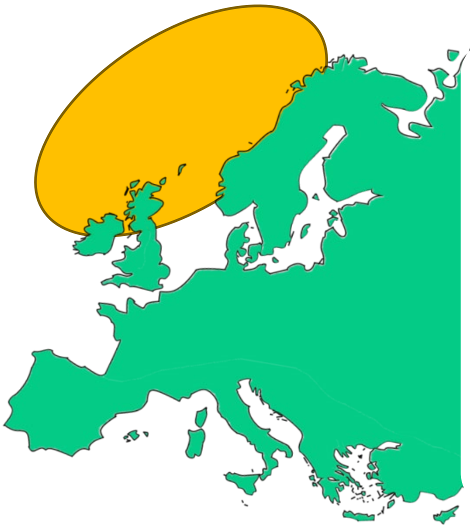
CERES

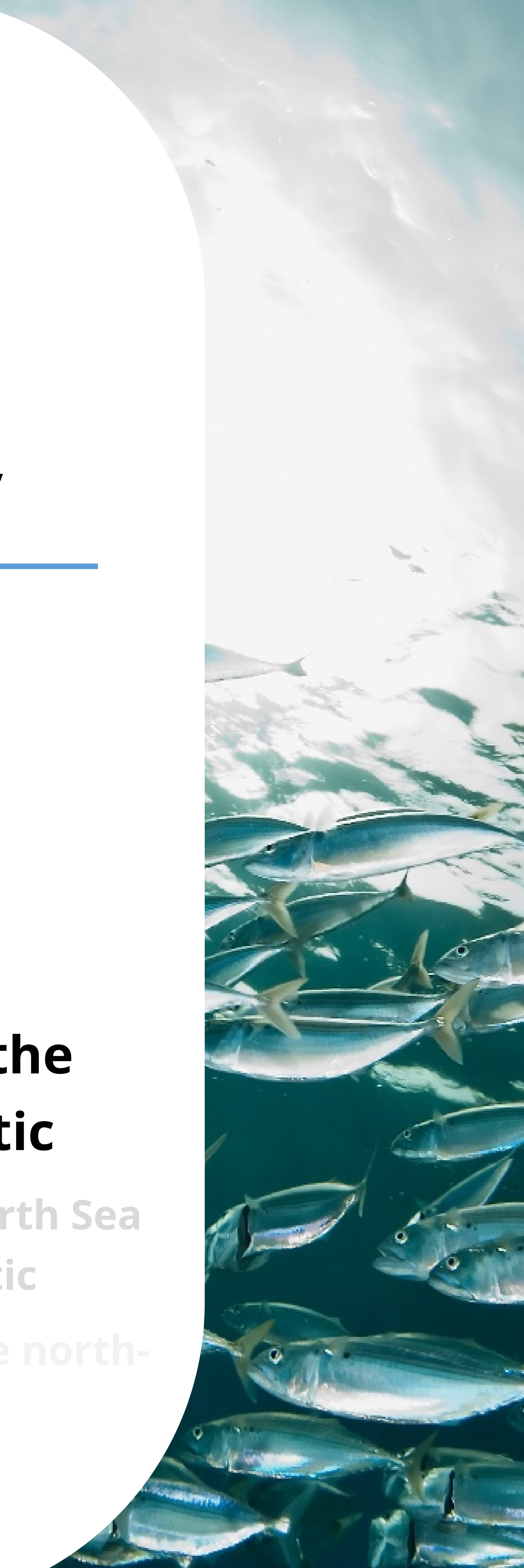
Case study



#18 Mackerel in the north-east Atlantic

#19 Flatfish in the North Sea and north-east Atlantic

#20 Dolphinfish in the north-west Mediterranean



Species background and economics

This storyline focusses on the Atlantic mackerel (*Scomber scombrus*) fishery in the Northeast Atlantic (NEA). Atlantic mackerel is a highly migratory species and is distributed from Morocco along the European coast to northern Norway, including the North Sea, Skagerrak, Kattegat, the Baltic Sea as well as the Mediterranean and the Black Sea.

In the NEA, stock sizes and migration patterns of different spawning stocks/components have changed over time and consequently have its international fishery and management.

Several nations exploit the mackerel stocks using a variety of techniques defined by both the national fleet structure and the behaviour of mackerel.

In 2014, after arising issues and questions regarding access rights to the main fishing grounds, the EU, Norway and the Faroe Islands agreed on a management strategy for 2015 and the subsequent five years. The total declared quotas for 2015 and 2016, however, still exceeded the TAC advice of ICES.

In 2015 mackerel represented by far the most landed species in the EU (261 thousand tonnes) with a corresponding value of €281 million. In 2015 the main fleets operating in the mackerel fishery were the UK, Ireland, Spain, Germany, Denmark, and the Netherlands.

Expected projections under climate change

Sea surface temperatures are projected to rise by up to 4°C over the 21st century under the high-emissions RCP 8.5 scenario.

Projected increases are highest to the north of Iceland and south of 45°N, with the region between 50 and 65°N experiencing increases of only around 1°C in the off-shelf area, 2-3°C on-shelf.

Under the moderate-emissions RCP 4.5 scenario the projected changes are similar in distribution but about half the size.

Much of this region is influenced by the Gulf Stream, which varies in position and strength between global models, so these values should be treated as uncertain (Figure 1).

Productivity has only been projected for the eastern part of the region, within 200 km of the shelf break.

The projections show declining productivity under both scenarios near mainland Europe, but static production off Iceland and in the far north.

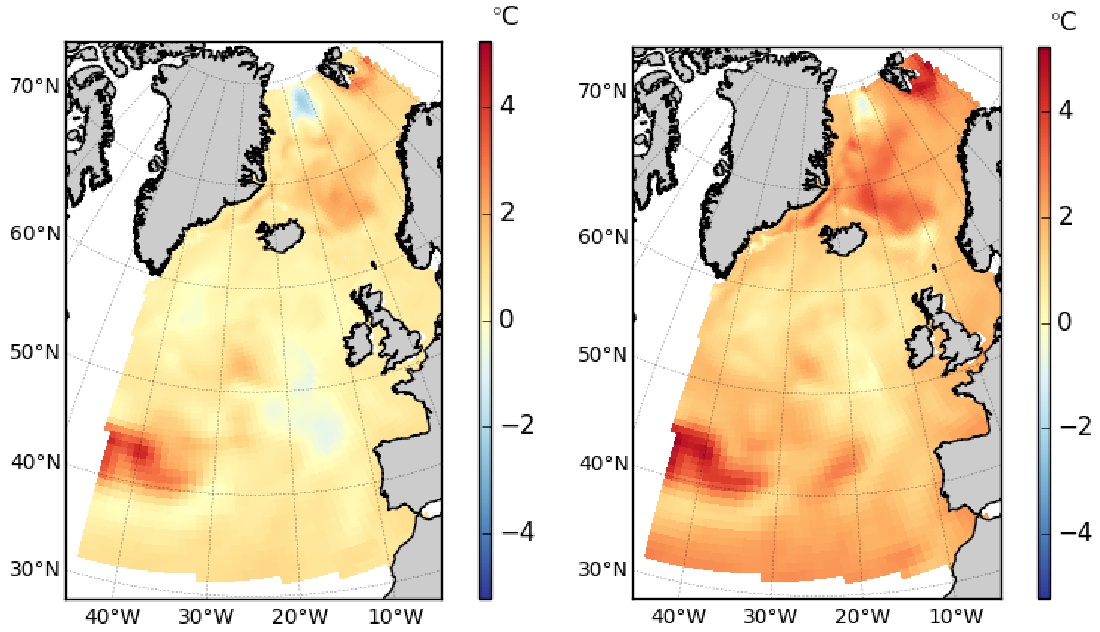


Figure 1 Projected change of sea surface temperature for Northeast Atlantic for 2080-2099 compared to 2000-2019 under RCP 4.5 (left) and RCP 8.5 (right) (Copyright Susan Kay).

Socio-economic developments

Four climate and economic scenarios were tested. The “World Markets” (*WM*) - Scenario (SSP5) focusses on international trade and maximum profit strategies with an interest of continued fossil fuel extraction, hence combining it with significantly increasing CO_2-emissions and rising temperatures (RCP 8.5) (IPPC, 2014; Pinnegar *et al.*, 2016).

The “Global Sustainability” (*GS*) - Scenario (SSP1), in contrast, places emphasis on sustainable fisheries combined with policies trying to mitigate heavy CO_2-emissions (RCP 4.5).

The “National Enterprise” (*NE*) - Scenario (SSP3) aspires an increasing focus on nationalism, which leads to high fossil fuel dependencies and corresponds to RCP 8.5.

Finally, in the “Local Stewardship” (*LS*) - Scenario (SSP2) the long-term sustainability in a self-sufficient and regional way is important and by doing so automatically reducing heavy CO_2-emissions, which makes it correspond to RCP 4.5.

'World Markets'	**'National enterprise'**
• Personal independence, high mobility and consumerism • Reduced taxes, stripped-away regulations • Privatised public services • High fossil fuel dependency • Highly engineered infrastructure and ecosystems	• National isolation and independence • Protection of national industry • High resource intensity and fossil fuel dependency • Low investment in technological development and education • Low priority for environmental protection
'Global sustainability'	**'Local stewardship'**
• High priority for welfare and environmental protection • Cooperative local society • Intense international cooperation • Increased income equality • Low resource intensity and fossil fuel dependency	• Promotion of small scale and regional economy • Less attention for global (environmental) problems • Moderate population growth • Income of industrialised and developing countries converge • No overarching strategy to manage ecosystems

Table 1 Outline of the four social-political scenarios developed by CERES partners and stakeholders

Several aspects of the socio-economic development will be of particular interest for this fishery:

Economic: Similar to all Northeast Atlantic fisheries, the mackerel fishery is sensitive to changes in fish price. In addition, pelagic trawlers and purse seiners are fuel-intensive and, thus, costs are very sensitive to changes in fuel price.

Technological: an important factor for the pelagic fishery will likely develop differently in the scenarios: fuel efficiency is expected to improve in all cases but at a faster rate in the scenarios with more international collaboration (*WM* and *GS*)

Management: two aspects of management will influence the NEA mackerel fishery, the levels of exploitation and the access to the fishery. The levels of exploitation were derived from variants of MSY: *WM*: Maximum Economic Yield ~0.8 MSY; *NE*: Maximum Social Yield (maximum vessels and employment) ~1.1 MSY (because we expect issues in negotiation); *GS*: Maximum ecosystem yield – all species must be within safe biological limits ~0.6 MSY (Kempf et al. 2016); *LS*: MSY for commercial species ~ MSY. Access to the fishery will likely undergo important transformations in the scenarios. EEZ beyond 12nm could be claimed back as national waters and closed to foreign fleets (NE).

Access to fishing rights through trading (international trading in WM and GS, no trading in NE) and the relative stability key concerning national quotas will probably also be modified in future.

Key research needs

A shift of the NEA Mackerel population to the North-west has already been noticed and are thought to have occurred due to a combination of an increased stock size and an increase in water temperatures, which then lead to a larger habitat and hence food availability.

As a consequence, other northern countries have joined in targeting mackerel now.

In 2012, for example, catch in front of Iceland and Greenland started to significantly increase. Hence, this shift in both feeding and spawning area already had and will still have significant effects on all fisheries targeting mackerel and their economy, especially regarding access rights to the main fishing grounds.

It is therefore important to study how these predicted biological changes induced by climate variations will further influence main fishing grounds and which affects this will have on the corresponding fishery.

Consequently, there is a need of knowing which parts of the industry might benefit or suffer from these biological changes but also from different management decisions that might be implemented to help preventing more extreme biological changes or, in contrast, would worsen things.

This knowledge is important to implement adaptation strategies as well as technical interactions leading to trade-offs and potential conflicts.

Climate-ready scientific advice is needed that accounts for technical interactions between fleets and species as well as how ecological changes needed to improve assessments of the impact of alternative fishing strategies on yield and value as well as the state of fish stocks

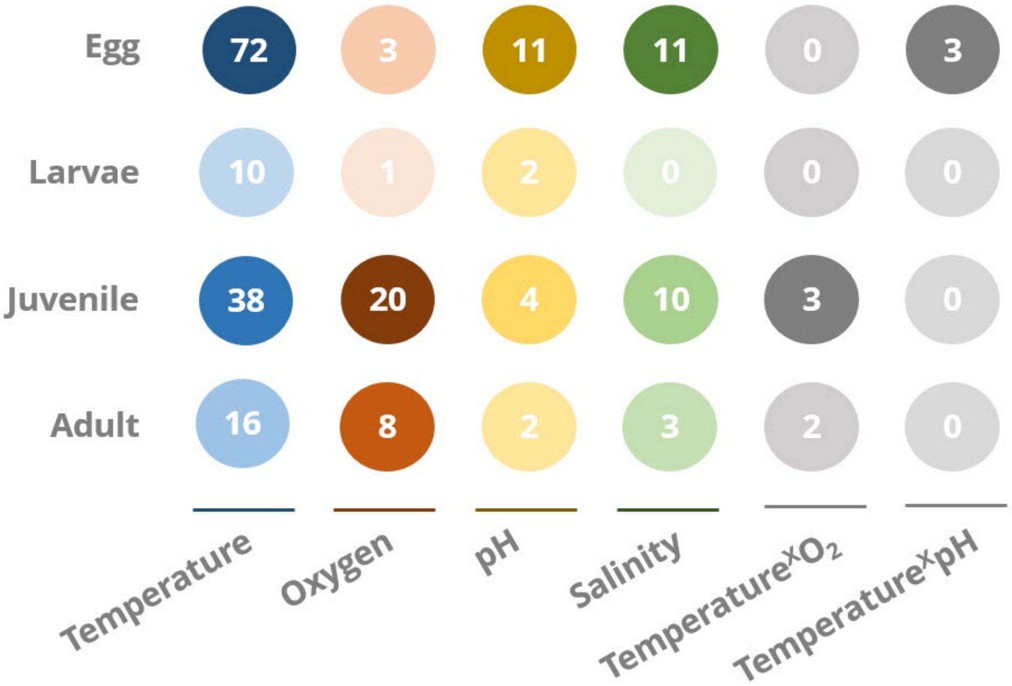
Figure 2 Pelagic fish trawler targeting, inter alia, mackerel (Copyright Dr. Uwe Richter).

Direct effects

CERES has:

- Conducted a systematic literature review, a GAP analysis and a meta-analysis to examine direct effects of climate change (warming, acidification, deoxygenation) on survival and growth physiology of commercially important European fish and shellfish.
- Developed biological models and projected the medium (2040-2060) and long-term (2090-2100) impacts of climate change on the distribution and productivity of NEA mackerel.
- Developed a bioeconomic model for NEA mackerel and projected the impact of four CERES Scenarios (GS, WM, NE, LS) on the profitability of fleets targeting NEA mackerel until 2050.
- Engaged stakeholder to regionalise CERES scenarios and developed a conceptual map (BowTie) of the major risks and mitigation measure of climate change on fleets targeting NEA mackerel

Biological consequences



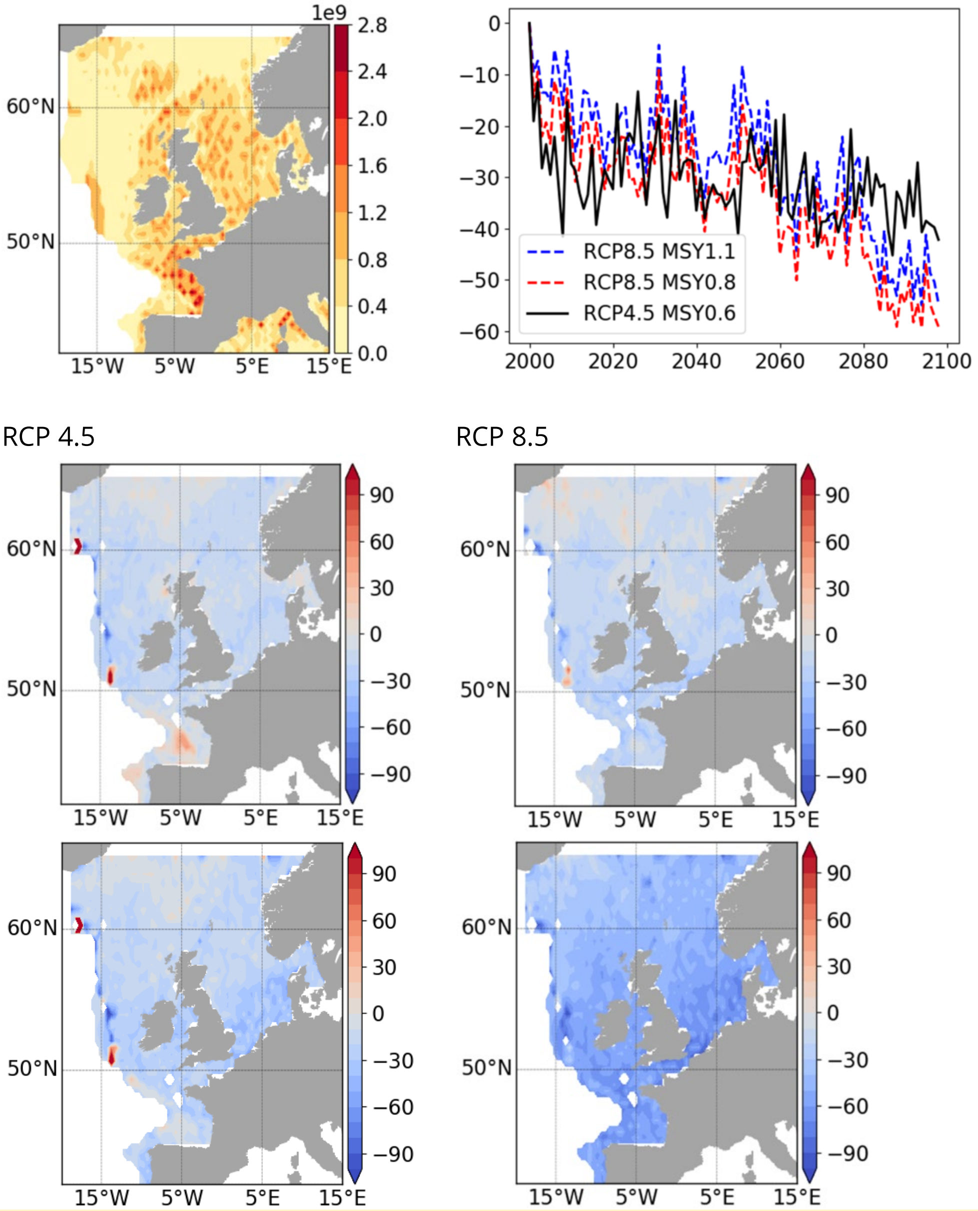
- Mackerel ranked 17 out of 28 European fish and shellfish genera reviewed here (3 studies).
- All three studies were done in Spain.
- All studies focussed on temperature.
- Growth was the most common response studied.
- Most studied life stage was embryos

The SS-DBEM model was run for the three socio-economic scenarios in CERES and describes the changes in distribution and abundance for herring.

Figure 3 shows the impact of climate change and fishing, on the total biomass of mackerel within the NEA.

This figure is for comparison of the effect of climate only, and the same MSY was applied within the models (0.8). Under all scenario there is the potential for a decline in total biomass of over 30% by the end of the century.

Comparison of scenarios indicates that from 2040 onward trends in population are going to be equally driven by changes in the environment and fishing pressure.



a) Biomass in 2000 (left) and percentage change from 2000 onward over the Northeast Atlantic (right).

b) Percentage change per grid cell comparing 2000-2010 time period to 2040-2050 time period.

c) Percentage change per grid cell comparing 2000-2010 time period to 2090-2100 time period.

Figure 1 Potential change in mackerel biomass a) distribution expressed as biomass per 250 km^2 and trend averaged over space for mean biomass compared to the year 2000 for all scenario; b-c) map of percentage change comparing different time period. Results from SS-DBEM model runs done for CERES at PML.

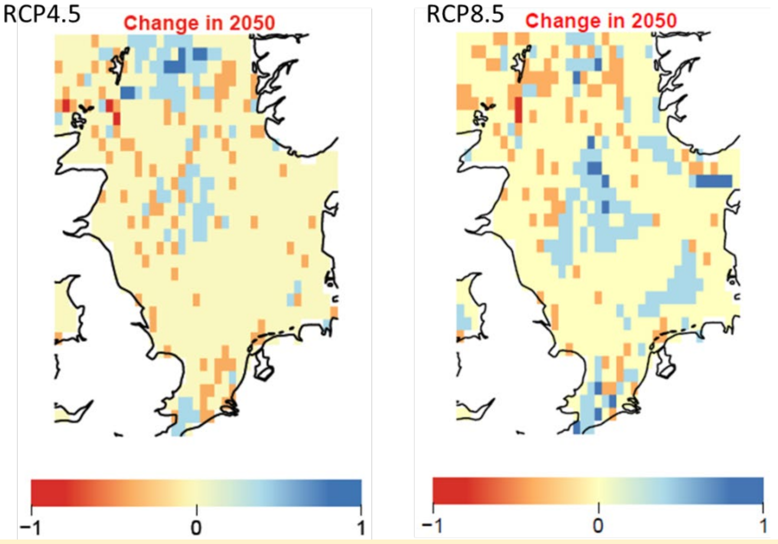


Figure 2 Change in habitat suitability in the North Sea for Atlantic Mackerel by mid-century (2050) under RCP 4.5 (left) and RCP 8.5 (right). Results from Species Distribution Model (CEFAS).

Economic consequences

In WP4.1 the bio-economic optimisation and simulation model FishRent (http://fishrent.thuenen.de/) was applied to understand how fisher may respond to different management options (socio-economic scenarios), environmental changes and their subsequent biological effects.

All of the four socio-economic scenarios already mentioned before were tested.

The model takes into account different policy and economic frameworks, differing in MSY objectives, TACs, quota trading, access to other nations waters, fish prices and fuel costs. The focus in this storyline lies on NEA mackerel and biological data was selected and formatted accordingly.

Catch, effort and economic data of the five main European countries (Germany, Denmark, Netherlands, UK, Ireland) and Iceland targeting NEA mackerel were sustained, formatted and adapted for the model input.

In general, this study showed that possibly exceptional recruitment and/or biomass peaks with a subsequent decrease has major impacts on the different fleet segments.

In some scenarios tested in this study different fleet segments might be more profitable than the baseline scenario, however, it should be noted that still all scenarios decrease in profitability over time compared to the starting year of the model (2014; Figure 5).

Already in 2030 the fishery for mackerel for all segments might not be profitable anymore. No matter in which scenario, the buffer between total costs and revenue was basically non-existent anymore until 2030 for most segments, so another additional factor impacting these fisheries might have fatal consequences.

In the near-future, only the small-scale Irish and Icelandic segments increased their revenues to a slightly higher level than at the beginning, especially under the low fuel/high fish price increase. They build up a buffer again and might be even slightly more profitable than at the beginning, depending on the fuel and fish price increases and if no additional negative impact occurs.

Hence, under these assumptions, the UK, Irish and Icelandic segments could be the winners particularly in the GS and LS scenario as they mainly targeted modelled mackerel and were not as affected as the segments also performing a pronounced NSAS herring fishery.

Moreover, especially the Irish segments target other very high priced species, which were not included in the model. If these incomes stay relatively stable it will help to compensate losses resulting from such a decrease in NEA mackerel.

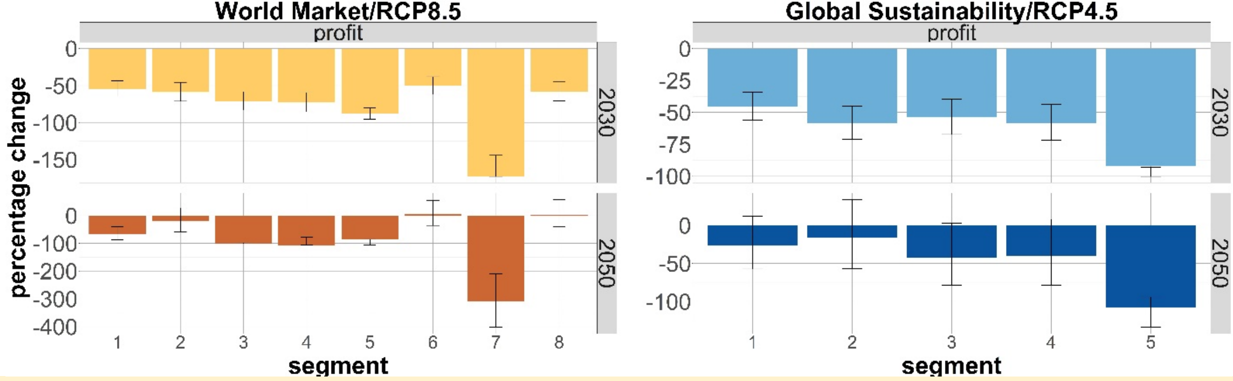


Figure 5 The difference (%) between the World Market (yellow) and Global Sustainability (blue) scenarios in comparison to the start year (2014) with the Median prices (bars) and upper and lower extremes of fish and fuel prices combinations (error bars). These differences can be seen for each segment and their profit in 2030 and a near-future (2050) timeframe. (1 = Netherlands (>40m); 2 = UK (>40m); 3 = Danish Pelagic Trawler (>40m); 4 = Danish Purse Seiner (>40m); 5 = Germany (>40m); 6 = Iceland (>40m); 7 = Ireland (>40m); 8 = Ireland (24-40m)). Results from the FishRent Model (TI-SF).

When comparing the alternative to the baseline scenario, especially under the National Enterprise and Local Stewardship scenarios, the Dutch, Danish and German fleets might decide to expand their target internationally focussing on other species, such as mackerel in the Mediterranean, Baltic Sea or Atlanto scandian herring.

This problem is actually fairly realistic with the prospect of Brexit, since a large part of NEA mackerel is currently situated in the UK EEZ (Martí and Ojamaa; 2017).

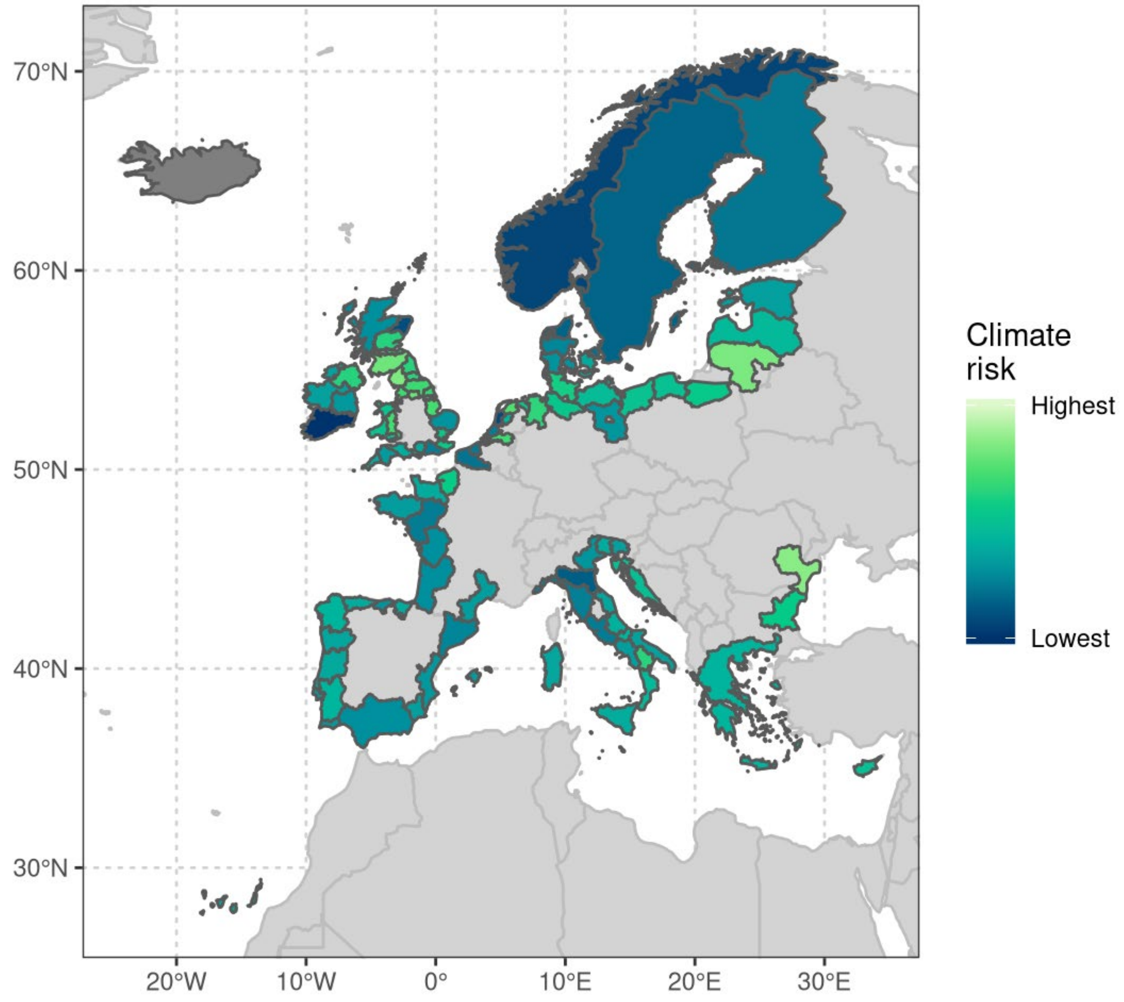


Figure 6 Map of the regional climate risk. Colour scale is linear in the value of the corresponding score, but is presented without values, as they have little direct meaning. National-level borders are shown for reference. *Credit : Mark Payne*

A climate vulnerability assessment for the European fisheries sector was conducted using the IPCC climate-risk assessment framework, including aspects of climate hazard, exposure and vulnerability.

The risk of European fishing fleets (421) and regions (102) to climate-driven changes in fish stocks was assessed based on the ecological characteristics of species landed (157 species in EU STECF) and the economic characteristics of these analysis units.

Considerable variation exists in climate risk, even within a single country (e.g. the UK), due to regional differences in the traits of species landed and economic indicators such as the dependence on fishing and the GDP / capita of fleets (e.g. GDP / capita). Risks are relatively low for Scandinavian countries due their relative wealth. Fleets in this storyline have a variable climate risk. Fleets show good profitability (low vulnerability) but a wide distribution of hazards and exposures, depending on the fleet.

For bottom-up - mitigation measures

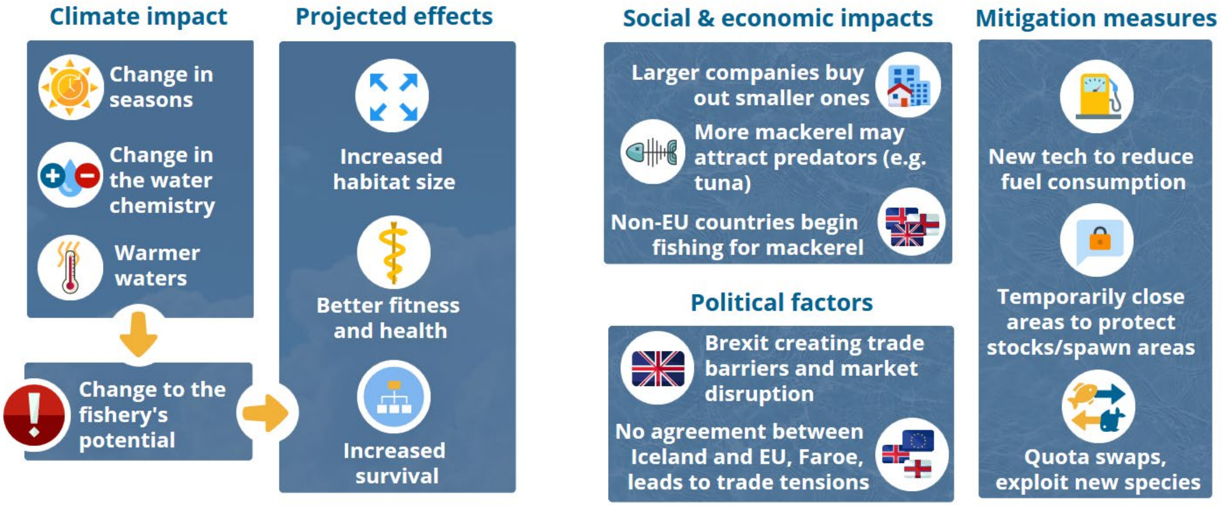
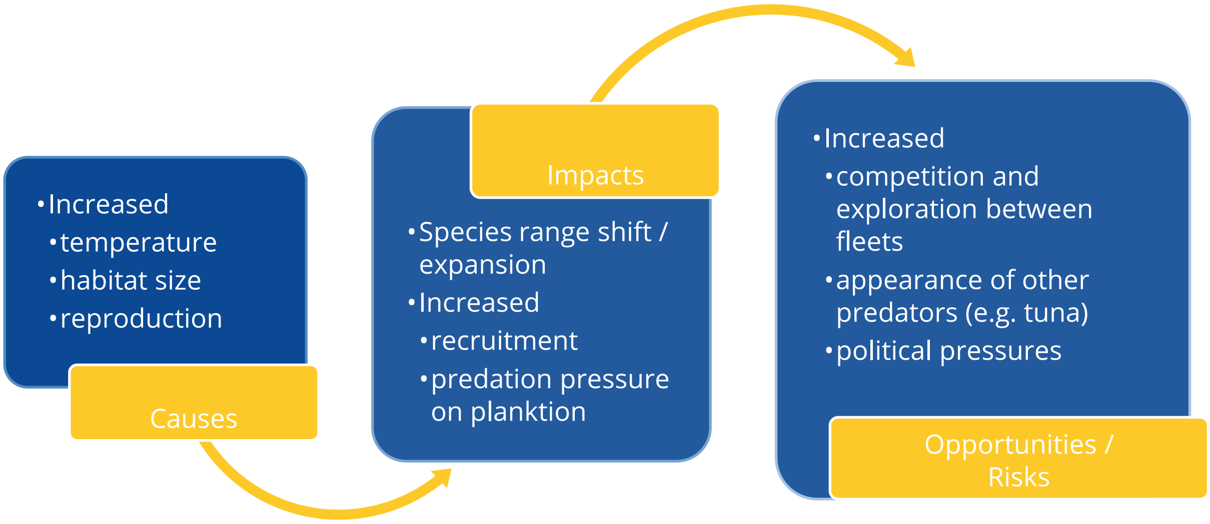


Figure 7a BowTie analysis based on stakeholder feedback. All full BowTies available http://bit.ly/CERESbowties2020

Policy recommendations



- Increased
  - temperature
  - habitat size
  - reproduction

Causes

Impacts

- Species range shift / expansion
- Increased
  - recruitment
  - predation pressure on planktion

- Increased
  - competition and exploration between fleets
  - appearance of other predators (e.g. tuna)
  - political pressures

Opportunities / Risks

Control / Enhancement measures:

1. New technologies (e.g. more selective gears, reduced fuel consumption)
2. Regional stock quotas (Relative stability principle revised)
3. Exploit new species moving into the Northeast Atlantic area (e.g. tuna)

Figure 7b Summary of causes of change, their impact and potential opportunities and/or risks.

Further reading

CERES publications, reports and online sources

Asthorsson O, Valdimarsson H, Gudmundsdottir A, Óskarsson G. Climate-related variations in the occurrence and distribution of mackerel (*Scomber scombrus*) in Icelandic waters. ICES Journal of Marine Science. 2012; 69:1289-1297.

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