Case study

#16 Herring in the North Sea

#17 Gadoids in the North Sea

#18 Mackerel in the north-east Atlantic

Species background and economics

Atlantic herring has been, and still is, one of the most commercially important pelagic fish species in the Northeast Atlantic (NEA).

Typically aggregated in large, dense schools, mixtures of herring stocks exist, with each stock exhibiting a specific pattern of spawning and migration patterns (e.g. autumn vs. spring spawner).

Several fleets target NEA herring as a directed fishery for human consumption using various types of trawl gear.

In the North Sea (NS), purse seiners also land herring as by-catch in large industrial fisheries.

Trawlers operate mainly in ICES subareas 4 and 7d targeting NS autumn spawning herring.

Due to recovery plans and harvest control rules, this stock is now considered to be harvested within safe biological limits (even below FMSY in 2015).

The total allowable catch (TAC) has increased from approximately 200 thousand tonnes in 2011 to nearly 450 thousand tonnes in 2016.

During this time period, a profitable herring roe fishery has also developed.

The five main EU Member States (MS) targeting NS herring in 2015 were, in order of importance, the Danish, UK, Dutch, German and Swedish fleets.

The NS pelagic fleet with vessels over 40m made on average €30,200 in gross profit per sea day in 2015. The same segment in the NEA made on €16,000 per vessel per day.

Expected projections under climate change

The North Sea is projected to warm by ~2°C by 2100 under a high emissions (business as usual) climate change scenario (RCP8.5) and by ~1°C under the moderate emission scenario (RCP 4.5).

The warming is somewhat uniform across the North Sea, though more intense in coastal areas (Figure 1a).

The warming is accompanied by an overall decrease in primary production in the North Sea (Figure 1b) with more marked reduction in the northern regions.

The maintained or slight increase in primary production in coastal area is due to increase in run-off and increase in nutrient availability for the primary producers.

Note that change in primary production along the coastline is not included due to issues with the nutrient run-off.

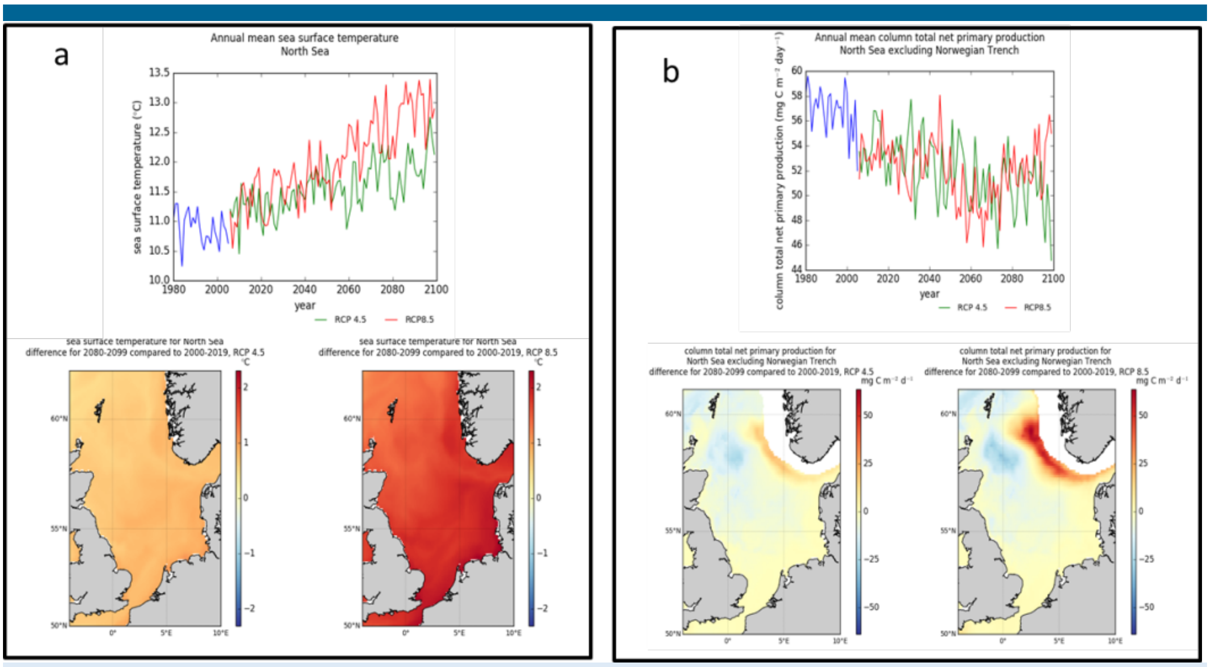


Figure 1 Trend for the average North Sea a) temperature, b) primary production (mgC/m^2/day) and their comparison between present and future temperature under both RCP 4.5 and 8.5. Note that the Norwegian trench was excluded as it is heavily influenced by Baltic outflow, which is not adjusted for the RCPs.

Scenarios describing future society and economy

CERES uses models to estimate economic developments in Europe's fishery and aquaculture based on select, pre-defined physical and socio-economical future scenarios.

These future scenarios were specified by industry partners and stakeholders in the first year of CERES (e.g. fish prices, fuel prices, technological advancements, regional policy issues, etc.).

'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

Socio-economic effects

Four climate and economic scenarios were tested. The 'World Markets'-Scenario (SSP5) focusses on international trade and maximum profit strategies with an interest of continued fossil fuel extraction, hence combining it with significantly increasing CO2-emissions and rising temperatures (RCP 8.5) (IPPC, 2014; Pinnegar et al., 2016).

The 'Global Sustainability'-Scenario (SSP1), in contrast, places emphasis on sustainable fisheries combined with policies trying to mitigate heavy CO2-emissions (RCP 4.5) (IPCC, 2014; Pinnegar et al., 2016). The 'National Enterprise'-Scenario (SSP3) aspires an increasing focus on nationalism, which leads to high fossil fuel dependencies and corresponds to RCP 8.5 (Pinnegar et al., 2016).

Finally, in the 'Local Stewardship'-Scenario (SSP2) the long-term sustainability in a self-sufficient and regional way is important and by doing so automatically reducing heavy CO2-emissions, which makes it correspond to RCP 4.5 (Pinnegar et al., 2016).

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

Marine spatial planning: energy at sea (mainly wind farms) and marine protected areas are expected to take up more space at the expense of fishing activities in all scenarios.

The smallest changes are expected in the National Enterprise (NE) scenario where only a few extra zones would be devoted to energy production while in the Global Sustainability (GS) scenario large areas would be also devoted to nature protection (Mathijssen et al 2018).

Economic: Similar to all North Sea fisheries, the NSAS herring 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: three important factors for the pelagic fishery will likely develop differently in the scenarios:

1) fuel efficiency is expected to improve in all cases but at a faster rate in the scenarios with more international collaboration (World Markets-WM and GS);

2) selectivity would improve only in the green scenarios (GS and Local Stewardship - LS);

3) catch efficiency would increase in WM and NE only, environmental legislation would not permit this in the GS and LS scenarios.

Management: two aspects of management will influence the NSAS herring 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) or only accessible to sustainable gears (GS). 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

Northeast Atlantic herring is considered to be harvested at a sustainable level but the mixture of sub-components with different migration and spawning patterns (e.g. autumn vs. spring spawners) increases the complexity of stock separation and distribution. Over the last years, a profitable herring roe fishery developed during the spawning season.

In case of North Sea autumn spawning (NSAS) herring, continued low recruitment despite high biomass levels have occurred in the past years affecting the biomass (Nash and Dickey-Collas, 2005; Gröger et al., 2009; Payne et al., 2009; Nash et al., 2009; ICES, 2018b).

They suggested three different causes for this problem:

1) A shift in the planktonic community of the North Sea due to oceanic climate changes, which results in less food availability and suitability impairing the survival of young NSAS herring larvae.

2) Changes in the physical environment, such as increasing bottom-water temperatures close to the main spawning areas, also primarily affecting young herring larvae as they are thought to be primarily influenced by environmental factors related to climate (e.g. inflows of warmer, nutrient-rich oceanc waters from the North Atlantic).

3) High population density causing low recruitment, although they state that this is unlikely as also shown by Gloe (2018).

These complexities will have further impacts on the corresponding fisheries and their economic performance. It is therefore important to study how and to which degree these predicted biological changes will further influence main fishing grounds and which affects this will have on the corresponding fishery (e.g. which segments might be able to cope best; Figure 2).

Furthermore, it is important to identify fleet segments most challenged to implement adaptation strategies as well as technical interactions leading to trade-offs and potential conflicts.

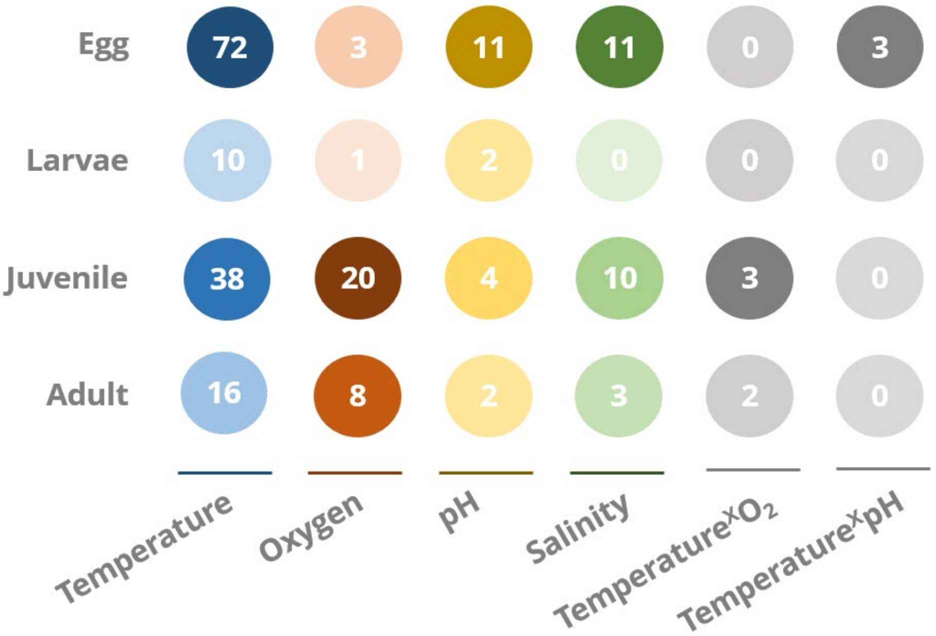
Climate-ready scientific advice is needed that accounts for technical interactions between fleets and species as well as how ecological changes needed to improve assessments of the impact of alternative fishing strategies on yield and value as well as the state of fish stocks.

Figure 2. Pelagic fish trawler targeting, inter alia, herring (*Copyright P&P*).

CERES research

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.
- Examined experiments of temperature tolerance of early life stages of Atlantic herring
- Developed biological models and projected the medium (2040-2060) and long-term (2090-2100) impacts of climate change on the distribution and productivity of NS herring.
- Developed a bioeconomic model for NSAS herring and projected the impact of four CERES Scenarios (GS, WM, NE, LS) on the profitability of fleets targeting NSAS herring 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 NSAS herring



- Herring ranked 1 out of 28 European fish and shellfish genera reviewed here (32).
- 14 out of 15 studies on North Sea herring were performed in the UK.
- Mainly embryos were studied (13)
- Growth was the most common response studied (9).
- Temperature was the most common stressor studied (12).

Results

Biological

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 climate change and fishing impacts on the total biomass of North Sea herring. Under all scenarios there is potential for a change in total abundance of over 25% by 2050 and 50% or more by end of the century.

Inter-annual variability is great in each scenario but there is a clear decrease in Herring biomass within the North Sea with the Southern part being affect more strongly than the northern part (change of ~90% and ~60%, respectively, under RCP 8.5 MSY 1.1 by end of century). This is driven by the decrease in habitat suitability that is more pronounced under RCP 8.5 (Figure 4).

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

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.

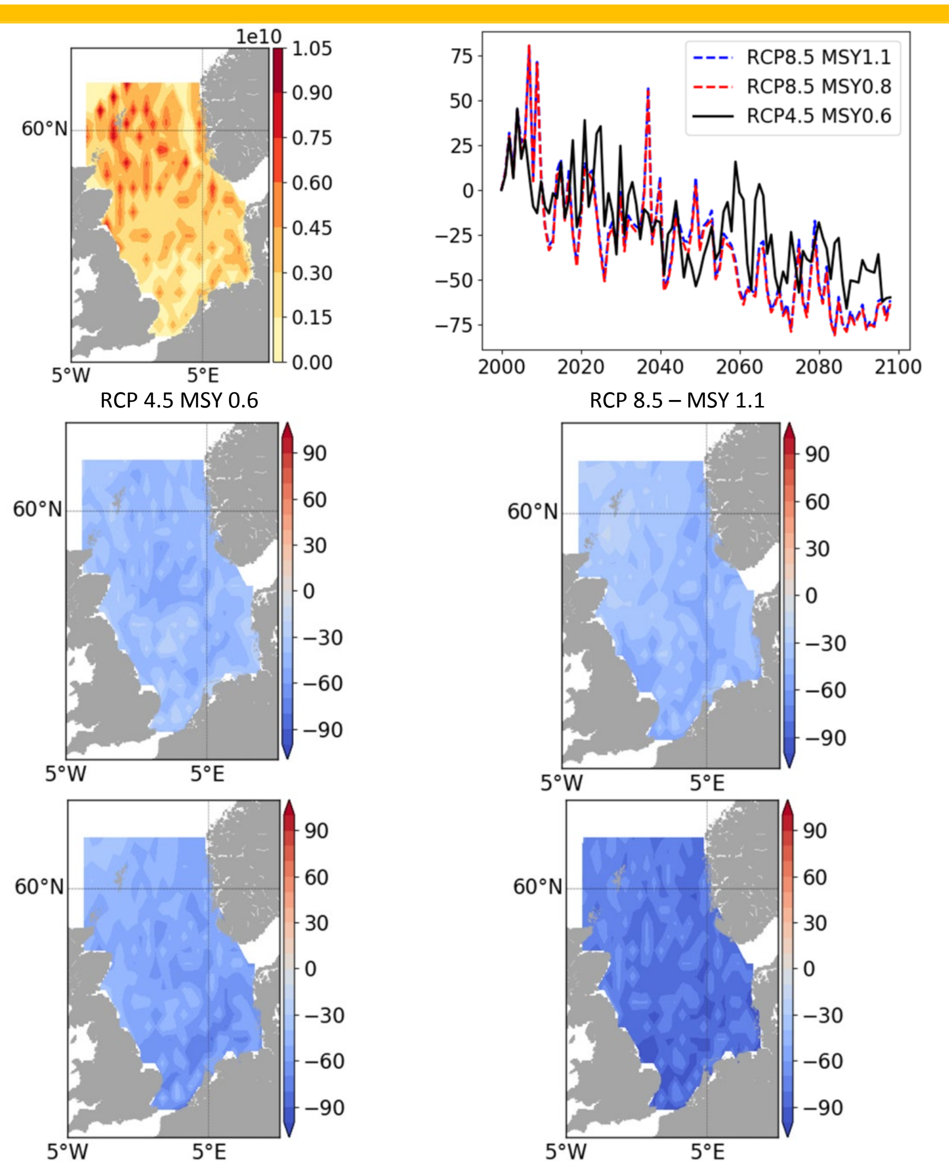


Figure 1 Potential change in herring biomass a) distribution expressed as biomass per 250 km^2 and trend averaged over space for mean biomass compared to the year 2000 for all scenario; b-c) map of percentage change comparing different time period. Results from SS-DBEM model runs done for CERES at PML.

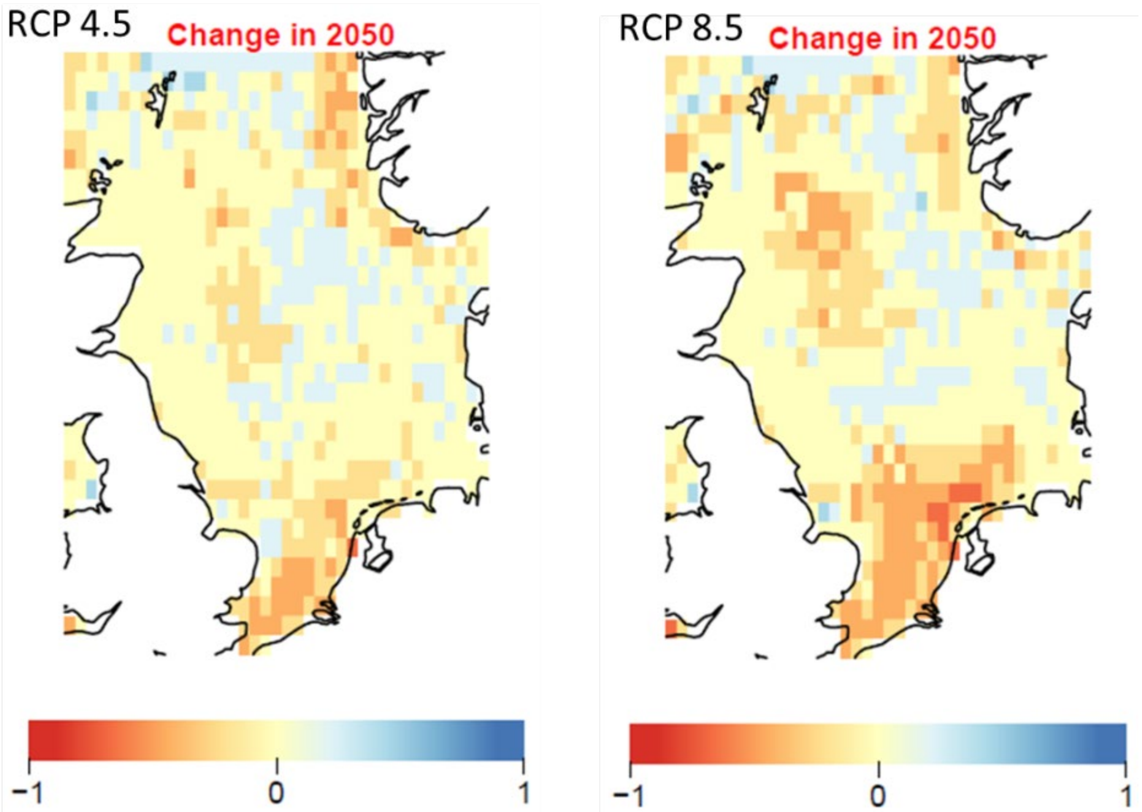


Figure 2 Change in habitat suitability for North Sea herring by mid-century (2050) under RCP 4.5 (left) and RCP 8.5 (right). Results from Species Distribution Model (CEFAS).

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 affects (e.g. recruitment failures).

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 NSAS herring and biological data was selected and formatted accordingly. Catch, effort and economic data of the four main European countries (Germany, Denmark, Netherlands, UK) targeting NSAS herring 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 herring 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.

Depending on the fuel and fish price increases and if no additional negative impacts occur, the UK segment could be the winner particularly in the NE, GS and LS scenario as it targeted NEA mackerel, which was also included in the model, to a large extend.

Hence, they were not as affected as the other four segments performing a more pronounced NSAS herring fishery.

When comparing the alternative to the baseline scenario, the Global Sustainability (GS) scenario seemed to produce better results for the segments catching NSAS herring.

Continued low recruitment is going to be a problem for those fleets but could be buffered with corresponding management strategies, such as implemented in the GS scenario.

The losses will, however, be difficult to substitute by similar products and their quality.

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 most of the NSAS herring stock is currently situated in the UK EEZ (Martí and Ojamaa; 2017).

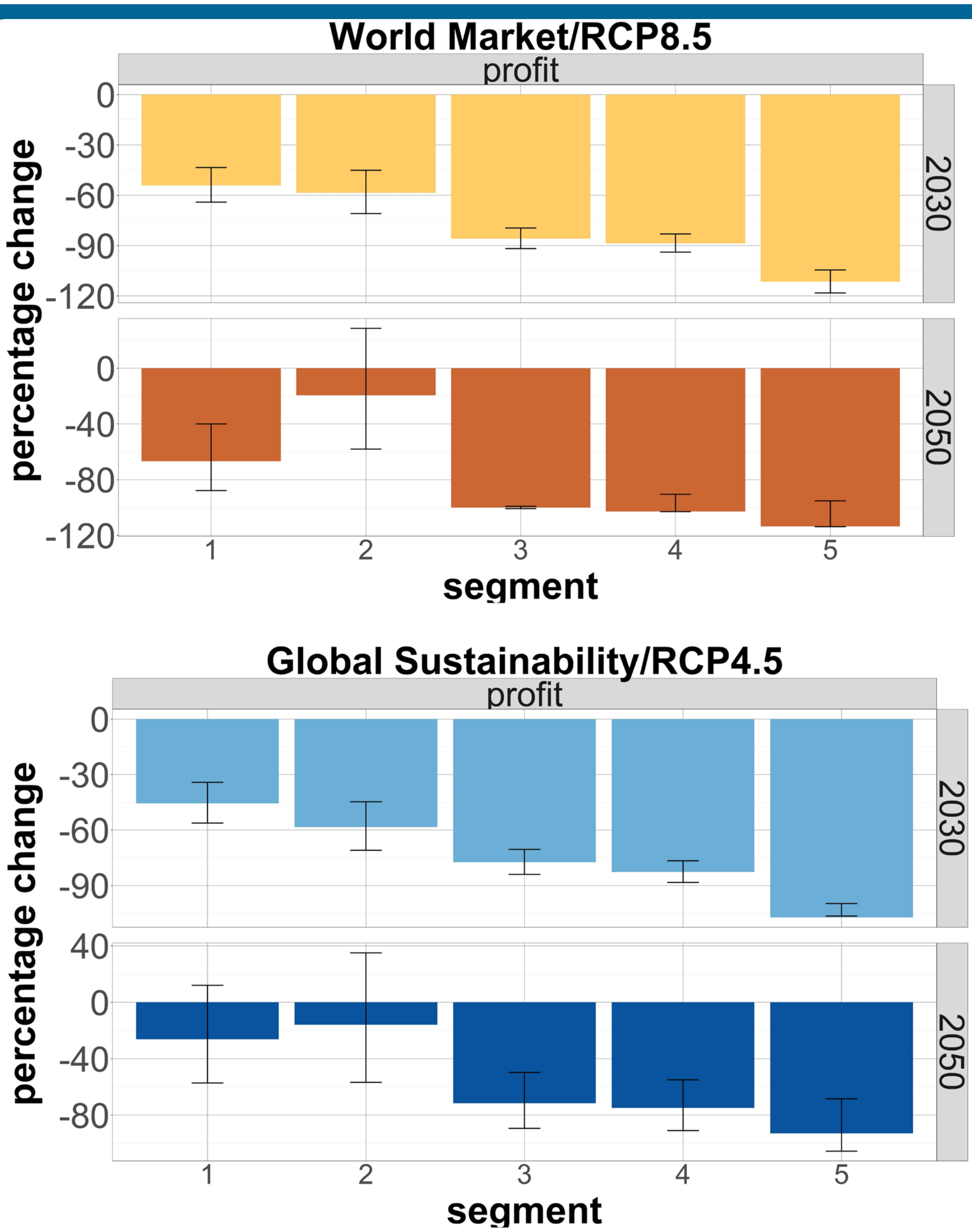


Figure 5 The difference (%) between the World Market (yellow) and Global Sustainability (blue) scenarios in comparison to the start year (2014) with the Median prices (bars) and upper and lower extremes of fish and fuel prices combinations (error bars). These differences can be seen for each segment 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)).

Climate-ready solutions

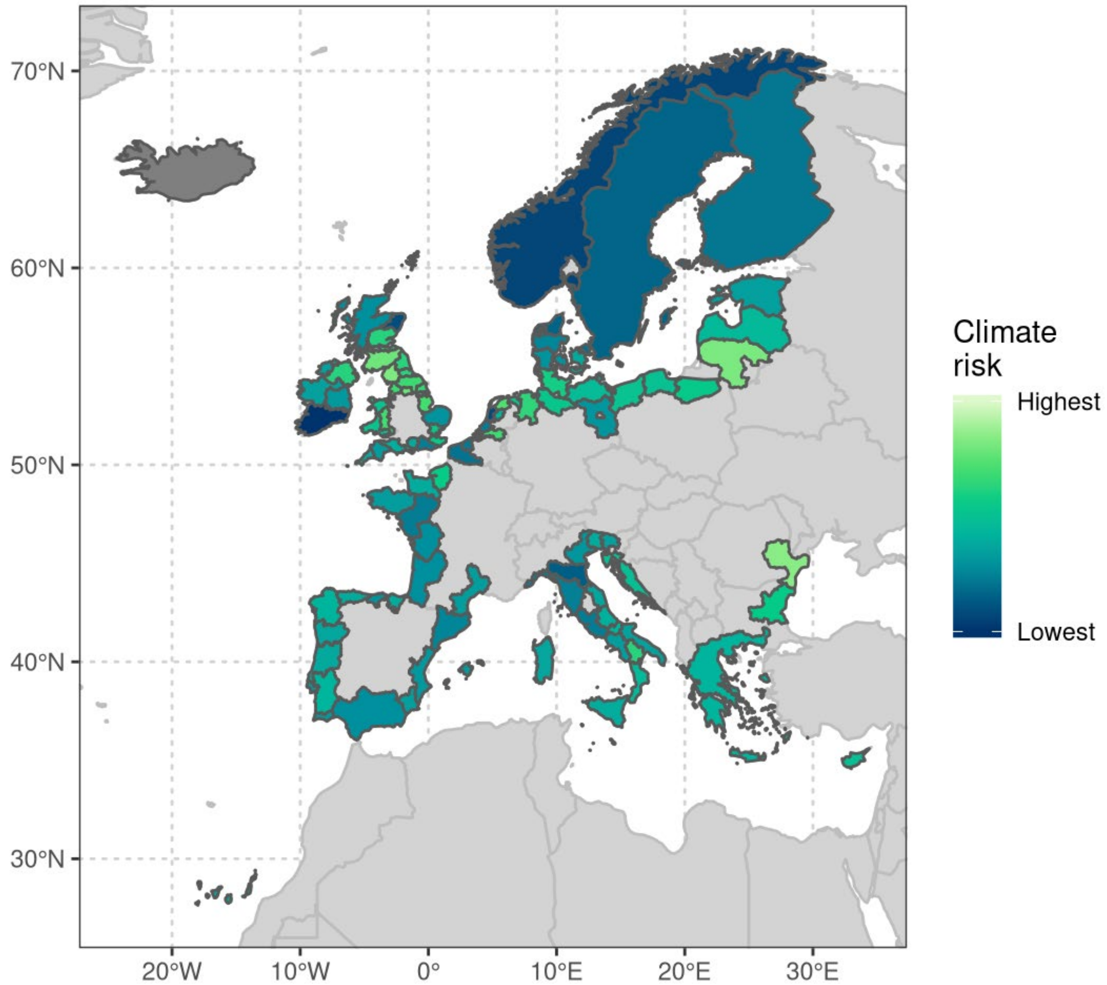


Figure 6 Map of the regional climate risk. Colour scale is linear in the value of the corresponding score, but is presented without values, as they have little direct meaning. National-level borders are shown for reference. *Credit : Mark Payne*

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 moderate climate risk. A wide distribution of hazards is balanced by the moderate specialisation (exposure) and profitability of the fleets.

Policy recommendations

Herring are demersal spawners and are therefore affected by bottom trawling, which destroys spawning habitats in the southern North Sea (especially the English Channel).

This again reduces the chances of egg survival and reduces recruitment. Currently, North Sea herring is considered to be harvested at a sustainable level and is MSC certified.

An additional issue for these pelagic fisheries will be the consequences of Brexit on fishing opportunities and quota availability for the remaining eight EU member states, also causing new trade barriers and disruption of the market (Figure 6).

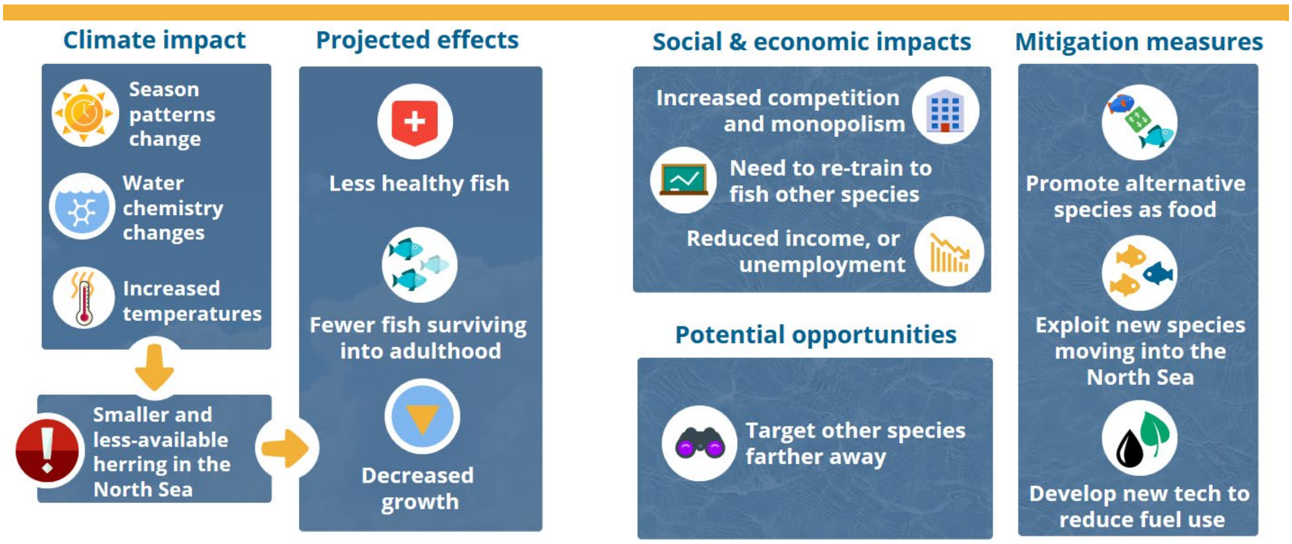


Figure 7a. BowTie diagram for herring. Full BowTie available at http://bit.ly/CERESbowtieHerring (*Copyright Katie Smyth).*

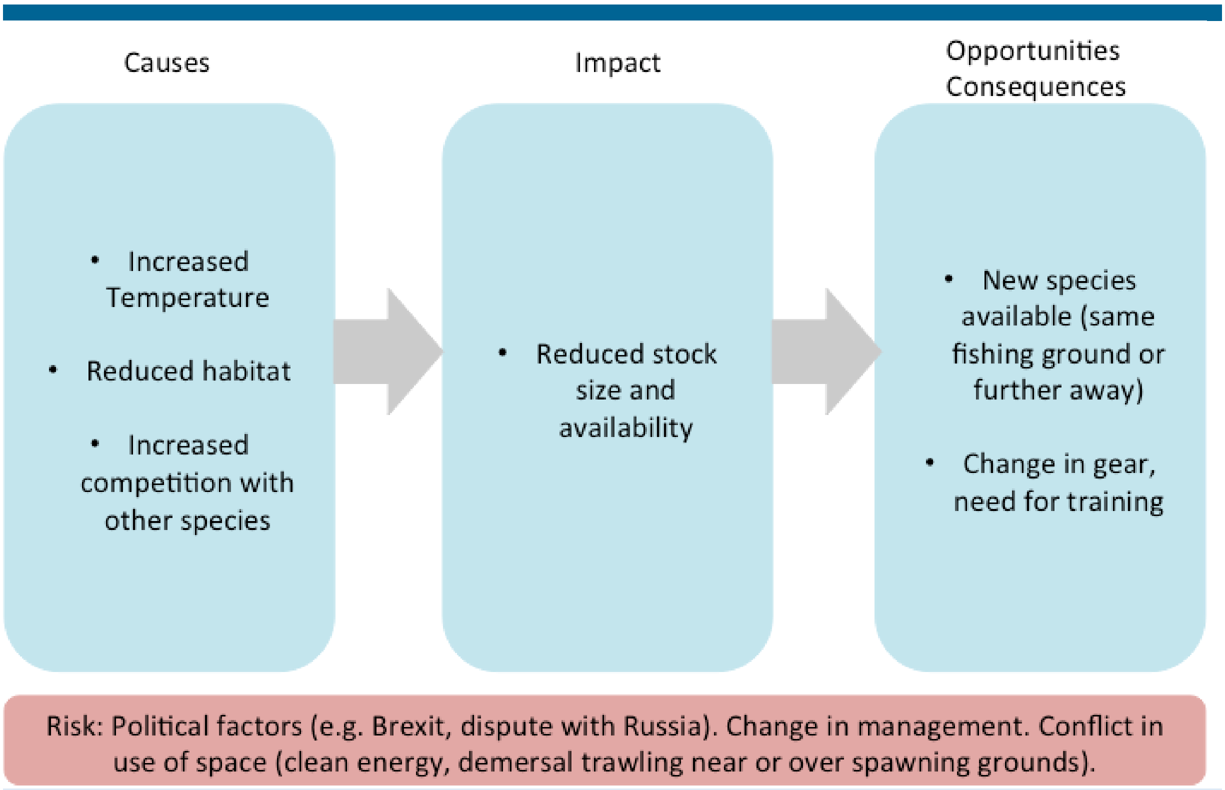


Figure 7b. Summary of causes of change, their impact, and potential opportunities, consequences and/or risk.

Further reading

CERES publications, reports and online sources

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