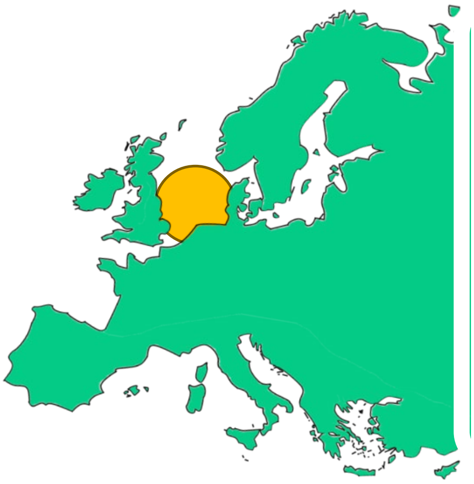
CERES

Case study



#17 Gadoids in the North Sea

#18 Mackerel in the north-east Atlantic

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

Species background and economics

Mixed demersal fisheries in the North Sea include valuable target species such as Atlantic cod (*Gadus morhua*), haddock (*Melogrammus aeglefinus*), saithe (*Pollachius virens*) and hake (*Merluccius merluccius*).

Complex biological interactions impact the productivity of these species and their fisheries.

Further, the fisheries are in the midst of changing management principles such as relatively stability due to Brexit.

Fleet and stock dynamics are also influenced by the extent of closed fishing areas (e.g. Marine Protected Areas) as well as the EU Common Fisheries Policy (CFP) with its objective of Maximum Sustainable Yield (MSY).

Gear techniques may make it impossible to reach MSY for all stocks at the same time, since the F_{MSY} for each stock corresponds to different levels of fishing effort and fleets may be constrained by the stock with the smallest relative quota, the 'choke stock.'

This choke stock can be the least productive stock (e.g. cod) or the stock with quota imbalance compared to historical rights allocations (e.g. hake).

Under the landing obligation, fishers may suffer economic losses if they are unable to fully exploit more productive stocks.

The magnitude and complexity of these technical, management issues is expected to increase due to climate change (e.g. by altering stock productivity and patterns of species distribution such as increasing the spatial overlap of stocks with markedly different fishing quotas.

Mixed demersal fisheries in the North Sea are, therefore, an excellent example of the complex interactions between climate change and fisheries policy and the need for policies and the sector to adapt to avoid serious disruption of fishing opportunities.

Expected projections under climate change

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

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

Primary productivity is projected to decline in the North Sea (Figure 1b) with more marked reductions in the northern regions.

In coastal areas, primary production is projected to slightly increase due to increases in run-off and nutrient availability. Note that change in primary production along the coastline is not included due to issues with the nutrient run-off.

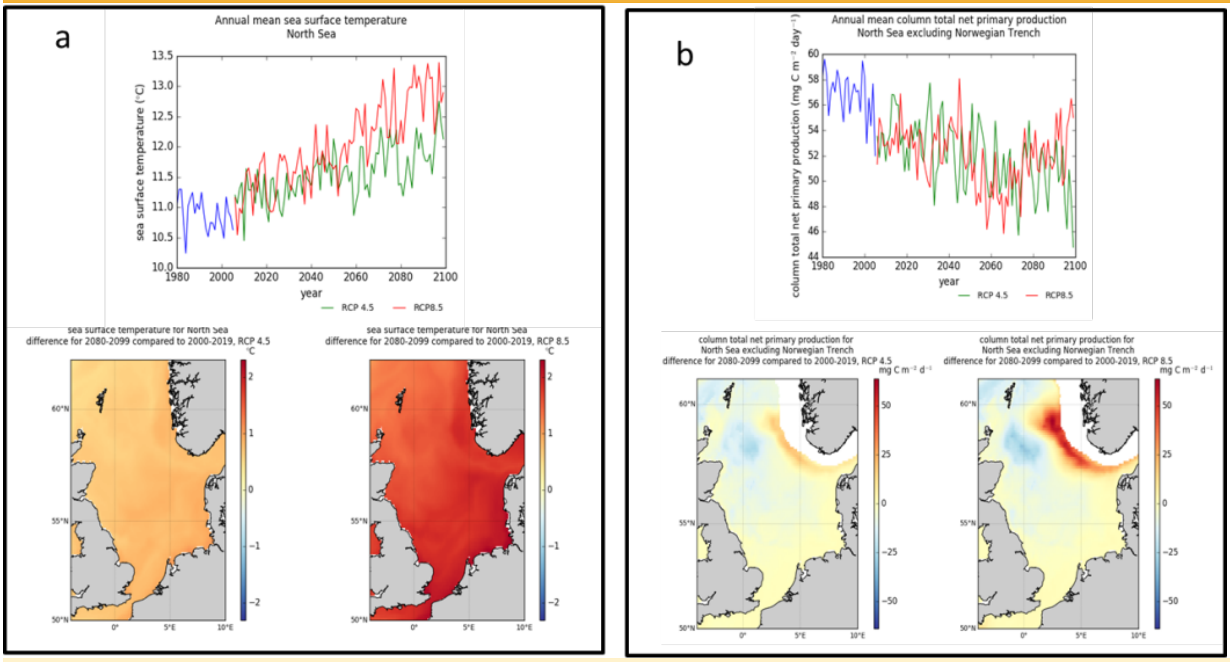


Figure 1 Trend for the average North Sea a) temperature, b) primary production (mgC/m^2/day) and their comparison between present and future temperature under both RCP 4.5 and 8.5. Note that the Norwegian trench was excluded as it is heavily influenced by Baltic outflow, which is not adjusted for the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

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 CO_2-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 CO_2-emissions (RCP 4.5).

The 'National Enterprise'-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'-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.

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 the Global Sustainability (GS) scenario suggests that large areas would be devoted to renewable energy as well as nature protection (Mathijssen et al 2018).

Economic: All fisheries including those targeting gadoids in the North Sea are sensitive to changes in fish price. In addition, beam trawls are fuel intensive fishing gears that are very sensitive to fuel price changes.

Technological: for beam trawlers, three important factors are projected to develop differently in the scenarios.

First fuel efficiency is expected to improve in all cases but at a faster rate in scenarios with a lot of international collaboration (World Markets-WM and GS).

Second, selectivity or survival of discards would improve only in the green scenarios (GS and Local Stewardship - LS), in other scenarios, bycatch would become marketable.

Third, catch efficiency would increase in WM and NE only, environmental legislation would not prohibit this in GS and LS scenarios.

Management: two aspects of management will influence the North Sea mixed demersal fisheries.

First, levels of exploitation would develop according to MSY for commercial species in LS, Maximum Economic Yield ~0.8 MSY in WM, Maximum Social Yield (maximum vessels and employment) ~1.1 MSY in NE (negotiation issues are expected) and based on Maximum Ecosystem Yield of ~0.6 MSY in GS (all species must be within safe biological limits - Kempf et al 2016).

These contrasting scenarios suggest important transformations in the access to the fishery. 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

Research on the technical interactions is needed to identify trade-offs and their consequences and to define alternative options for balancing conflicting objects.

Scientific advice that accounts for technical interactions between fleets and species as well as ecological effects is needed to improve assessments of the impact of alternative fishing strategies on yield and value as well as the state of fish stocks.

The fact that key species of the demersal (and pelagic) fish community exist at either their high or low latitudinal extreme in the North Sea is underscored by the strong seasonal changes in distribution/composition and will make these fisheries target very sensitive to climate change.

Furthermore, the high diversity of habitats, the high population density and the large number of active sectors (e.g. shipping, fishing, windfarms and tourism) makes the North Sea one of the most complex 'hot spots' of anthropogenic effects worldwide.

For North Sea species progress has been made in investigating the causes of the variability of growth and productivity over time, especially when trends are observed beyond the annual fluctuations.

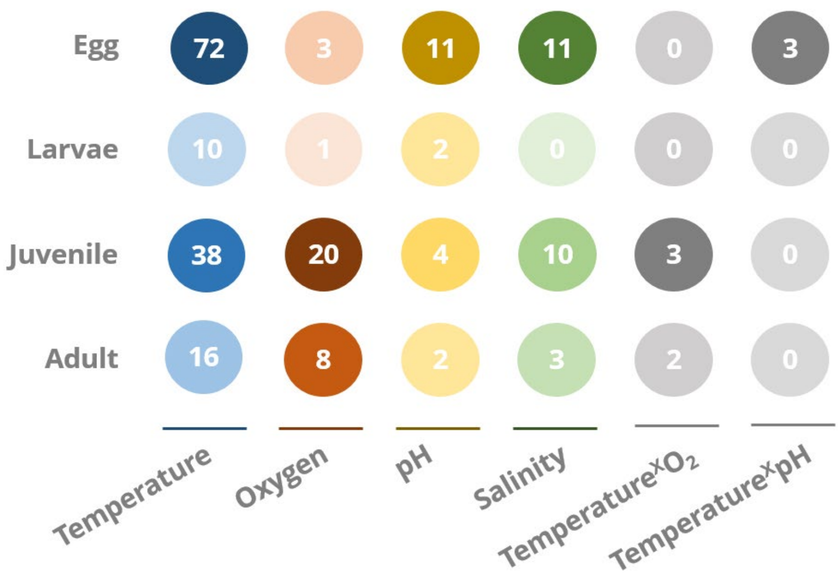
In particular, the role of increasing temperature has often been emphasised, as this can affect many biological processes. Six out of eight commercial species in the North Sea underwent concomitant growth reductions, and this coincided with a 1-2°C increase in water temperature. Smaller body sizes decreased the yield per-recruit of these stocks by an average of 23%.

The recruitment success of North Sea cod may also have decreased because of reduced plankton availability for the early life stages in warming waters. Moreover, spatial distributions of fish stocks are shifting, and this has been attributed to recent climate change.

CERES research

- 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 including gadoids in the North Sea.
- Compiled long-term data sets and performed statistical analyses to examine how species richness of the fish community may have changed in recent years.
- Developed biological models and projected the medium (2040-2060) and long-term (2090-2100) impacts of climate change on the distribution and productivity of saithe, haddock, hake and cod in the North Sea
- Applied a bioeconomic optimization and simulation model (FishRent) to identify potential adaptation or mitigation needs for the North Sea mixed demersal fisheries under changing environmental conditions (e.g. changed species distribution pattern) and economic conditions (e.g. changing fish prices, fuel costs).
- CERES Scenarios and simulations were discussed with stakeholders and WP4 partners and adjusted to the North Sea mixed demersal fishery targeting gadoids

Results



- Cod ranked 10 out of 28 valuable European fish and shellfish reviewed here (8 studies).
- Studies were either from the Baltic or the Atlantic, but not from the North Sea.
- Most studies on cod were investigating juveniles
- Growth was the most common response studied.
- Temperature was the most common stressor studied.

Biological

Significant increases in species richness were found during both winter and summer survey periods, and were linked to an increase in more southerly (Lusitanian) species.

This increase was linked to increases in the winter water temperatures, potentially increasing the thermal suitability of the North Sea for these species. In contrast, the absence of a warming trend during summer has not excluded northerly (Boreal) species beyond their thermal threshold, thus explaining their persistence in the region.

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

Figure 3 shows the impact of climate change, as expressed through RCP 8.5 and RCP 4.5, on the stock biomass of each of four species in the North Sea.

	RCP 4.5		RCP 8.5	
Species	**Habitat suitability (%)**	**Latitudinal shift (km and direction)**	**Habitat suitability (%)**	**Latitudinal shift (km and direction)**
Eur. Hake	20 ± 44	29.2 ± 120 South	42 ± 93	47.4 ± 180 South
Eur. Plaice	1.6 ± 14	32.2 ± 62 North	-4.7 ± 18	56.2 ± 94 North
Haddock	-5.1 ± 17	14.1 ± 36 North	-13 ± 21	24.2 ± 54 North
Saithe	-28 ± 37	31 ± 120 South	-36 ± 41	55.1 ± 210 South

Table 1 Change in habitat suitability and population displacement (latitudinal shift) for North Sea Gadoids. Results are from changes by 2050 under RCP 4.5 (left) and RCP 8.5 (right). Results for the Species Distribution Model runs done at CEFAS.

This figure is for comparison of the effect of climate only, and the same MSY was applied within the models (0.8).

All species are severely impacted by the warming of the North Sea under RCP 8.5; the warming happening under RCP 4.5 also has an impact but potential decrease in total biomass is by 25% maximum compared to the 60% decline by the end of the century in RCP 8.5.

Table 1 shows how these trends in abundance are linked to reduction in suitable habitat, as well as a latitudinal shift of the population centre.

	Trend across all scenario Change in mean North Sea biomass (%)	End of century biomass change (%) RCP4.5 MSY 0.6	End of century biomass change (%) RCP8.5 MSY 1.1

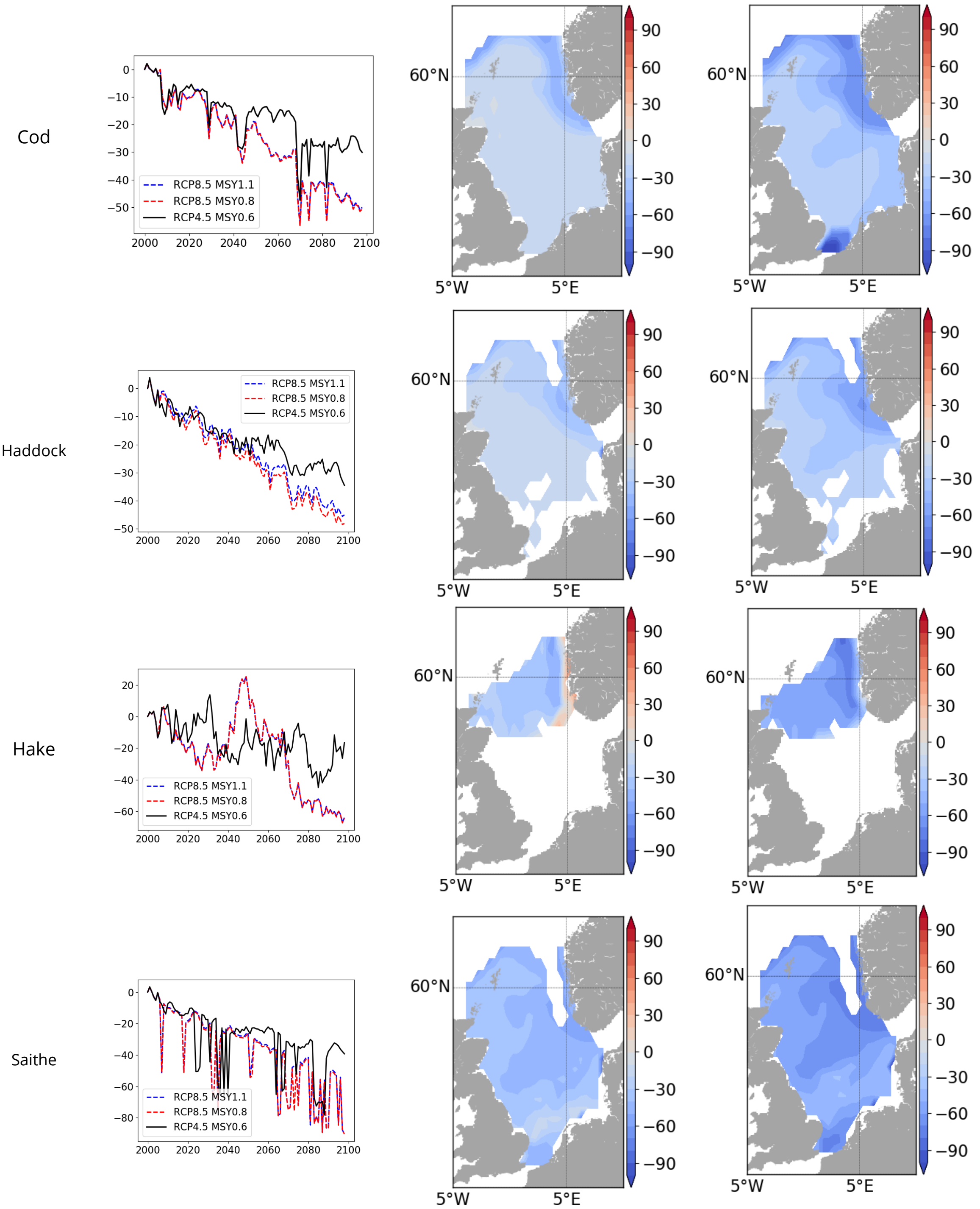


Figure 1 Potential change in gadoid species biomass a) trend averaged over space for mean biomass compared to the year 2000 for all scenario; b-c) map of percentage change comparing present time to end of century. Results from SS-DBEM model runs done for CERES at PML.

Economic consequences

In WP4 the FishRent model was applied taking into account the most important species in the North Sea mixed demersal fisheries (cod, haddock, hake, saithe).

The four CERES scenarios (WM, NE, GS and LS) were aimed to be incorporated into FishRent. However, we needed to use the results of applying two Brexit scenarios as proxy for the CERES national enterprise scenario.

In a moderate Brexit scenario (MB) the modelled EU vessels were excluded from fishing in the UK EEZ and hence these vessels needed to fish their quotas outside the UK EEZ.

In turn the modelled UK vessels were no longer allowed to fish in EU waters and hence could only fish its quotas within the UK EEZ. For ICES rectangles partly in or out of the UK EEZ the quotas were distributed proportionally to the percentage of the rectangle being in the UK or the EU EEZ.

For the hard Brexit (HB) scenario, the modelled TAC was distributed between the UK and the EU following a zonal attachment principle.

The fleets suffered from changes in the accessibility of the best fishing grounds, which will most likely be also a problem following changes in species distribution due to climate change.

Zonal attachment as basis for the distribution of fishing opportunity would lead to dramatic changes for several countries surrounding the North Sea.

The NE scenario assumes that fishing is only possible within the national EEZ and the results will most likely not be very different from a HB scenario.

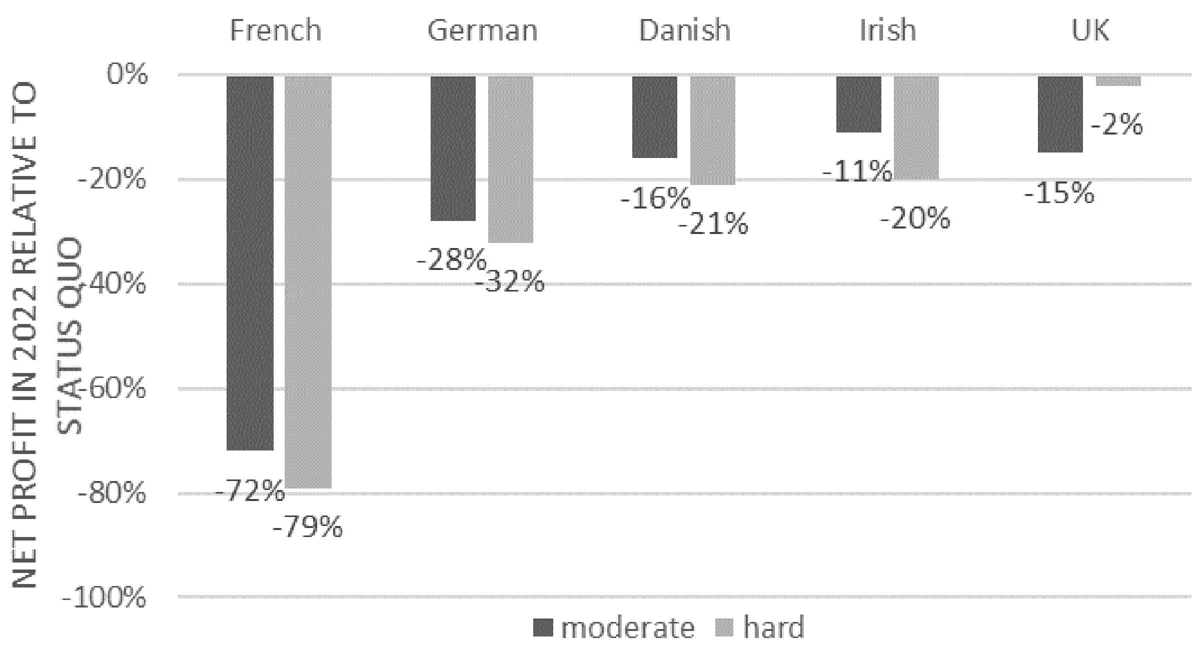


Figure 4 Change in net profits in 2022 relative to status quo for modelled fleets (bottom trawlers with a vessel size > 15m from France, Germany, Denmark, Ireland and the UK) under the moderate and hard Brexit scenario.

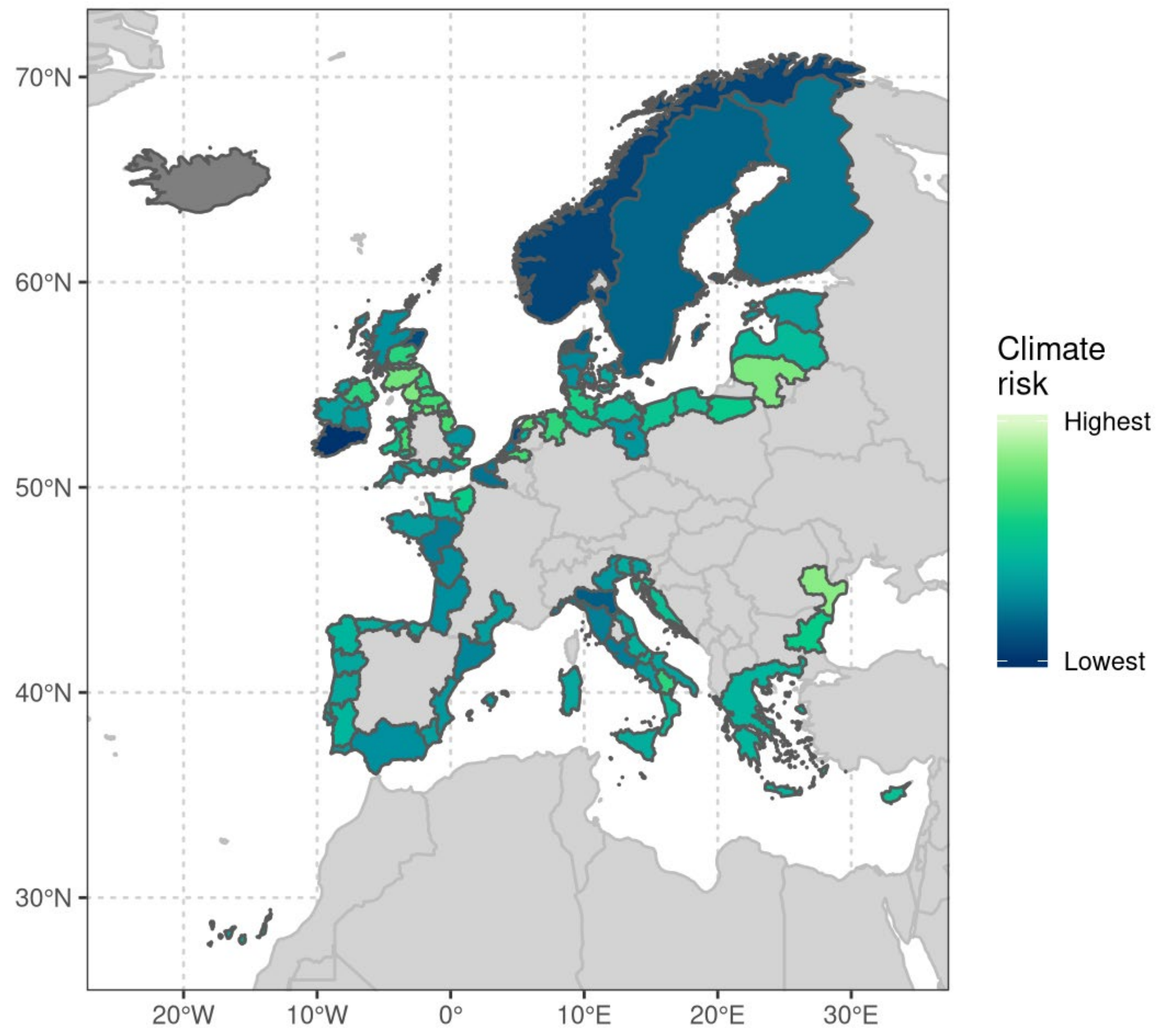
Climate-ready solutions

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-high climate risk.

The high hazard of the stocks offsets the good profitability (low vulnerability) of the fleets



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*

Policy recommendations

Based on bowties + internal discussions, crucial problems concerning the industry are:

1. Organic standards / certification / traceability;
2. Licensing / catch quotas;
3. Staff recruitment and retention;
4. Competition/monopolisation.

Other problems concerning the industry are: (1) Branding and marketing; (2) EU legislation; (3) Indirect effects of climate change on your business (e.g. storms and flooding leading to higher costs). The one to two most important problems faced by the industry currently are: 'When aiming at MSY in the North Sea demersal fishery there might be trade-offs between economic optimisation and biological and social benefits (e.g. employment).

For instance, management needs to address the recovery of the North Sea cod stock while still allowing fishing on more productive stocks caught at the same time in the North Sea mixed demersal fishery. Thus, technical interactions may prevent reaching MSY for all stocks at the same time, since Fmsy for the different stocks correspond to different levels of fishing effort.'

The one to two most important problems faced by the industry in the next 5 to 10 years are: 'The landings obligation will be of concern in the next years. Under the landing obligation the fleets may not be able to fully exploit the more productive stocks, which negatively affects their economic returns. '

The one to two most important problems faced by the industry in the long term (decades) are: 'The magnitude of the problems described above will further increase due to climate change (e.g. changing stock productivity, changing species distribution patterns and increased spatial overall of highly and little productive stocks), which is hence a serious problem for the actual distribution key of fishing opportunities as well as the relative stability in general.'

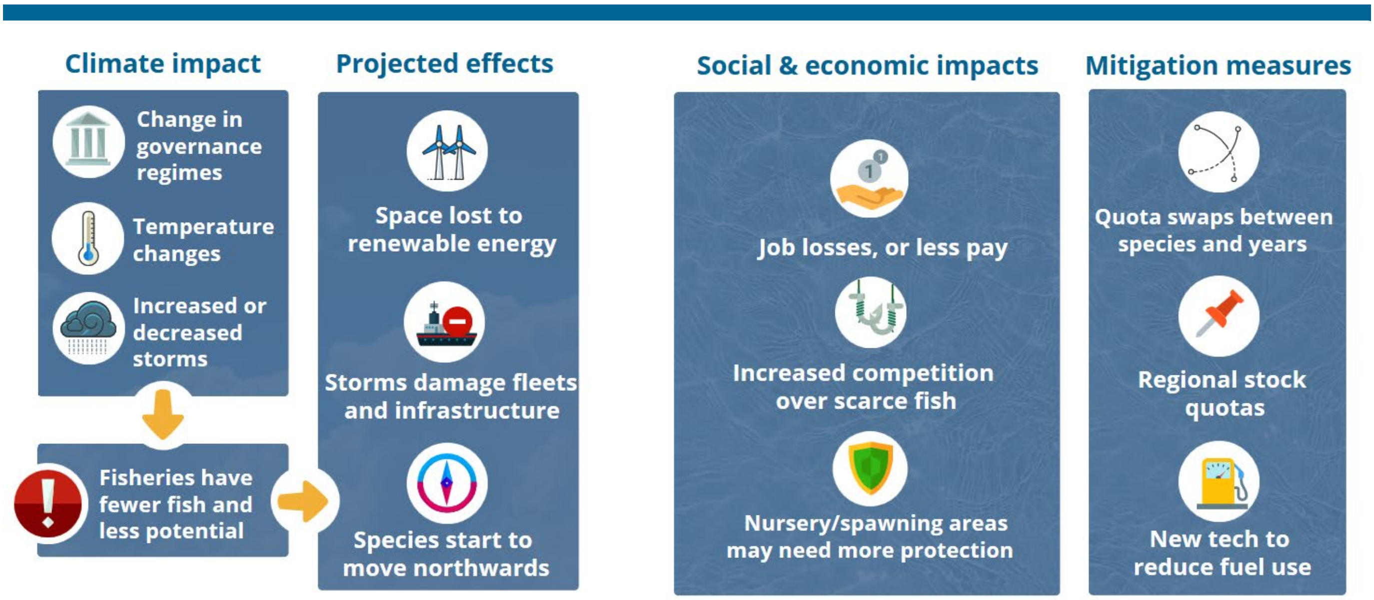


Figure 2a. BowTie analysis based on stakeholder feedback. All full BowTies available http://bit.ly/CERESbowties2020 *Image: Katy Smyth*

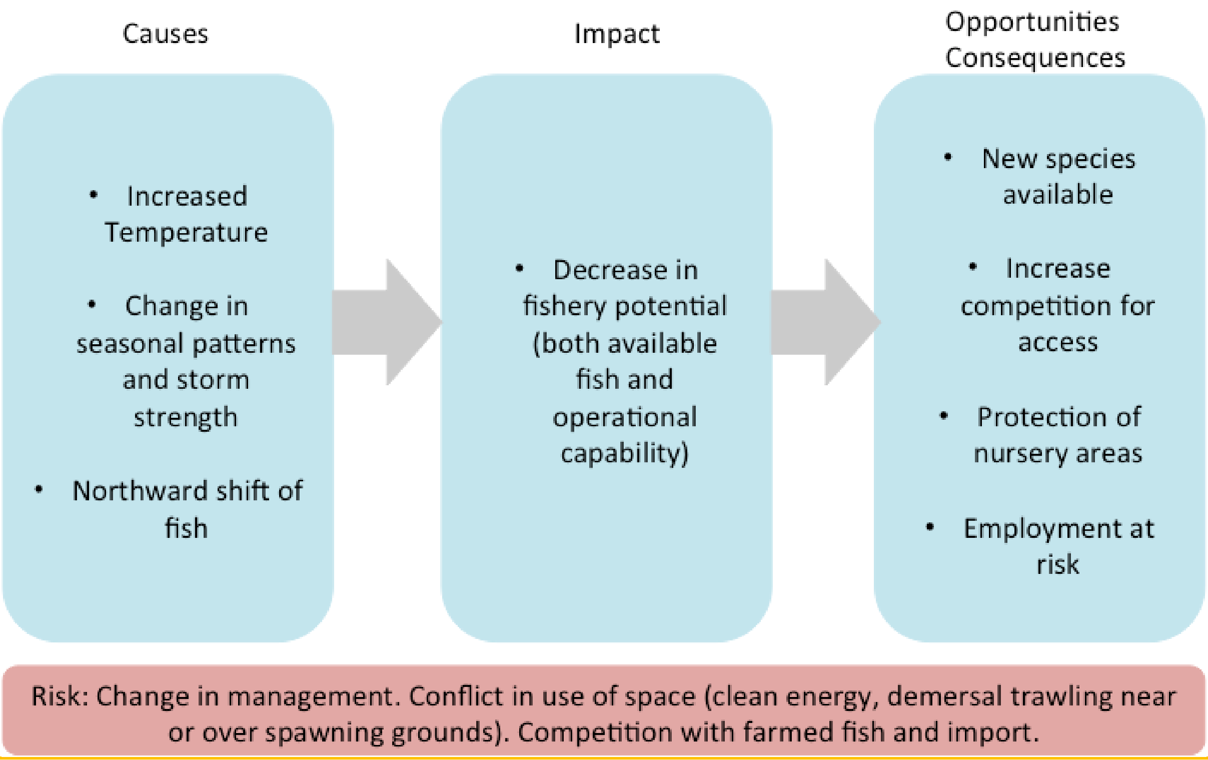


Figure 4b Summary of causes of change, their impact, and potential opportunities, consequences and/or risk

Further reading

CERES publications, reports and online sources

IPCC. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L. A. Meyer (eds.)]. IPCC, Geneva, Switzerland. 2014; 151 pp.

Pinnegar J, Engelhard GH, and Eddy T. Climate change and European aquatic RESources, Deliverable D1.2. Final report on exploratory socio-political scenarios for the fishery and aquaculture sectors in Europe. 2016; 62pp.

Simons SL, Bartelings H, Hamon KG, Kempf AJ, Döring R, and Temming A. Integrating stochastic age-structured population dynamics into complex fisheries economic models for management evaluations: the North Sea saithe fishery as a case study. ICES Journal of Marine Science: Journal du Conseil. 2014; 71:1638-1652