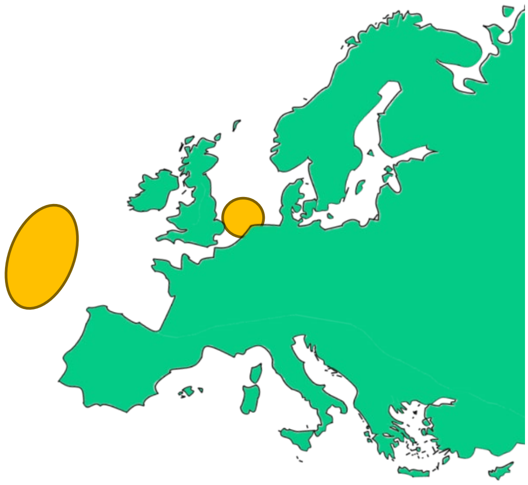
Case study



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

#20 Dolphinfish in the north-west Mediterranean

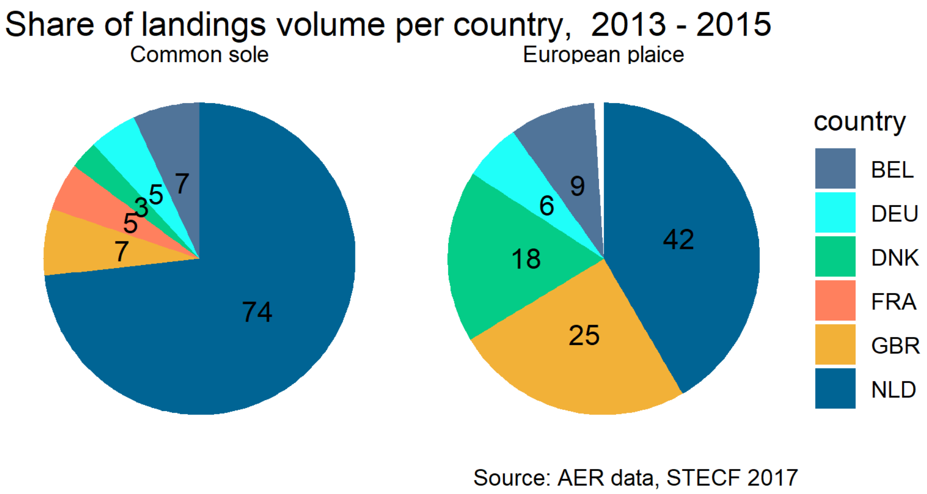
#21 Sardines and anchovies in the Bay of Biscay

Species background and economics

Sole (*Solea solea*) and plaice (*Pleuronectes platessa*) are the two main target species of the North Sea flatfish fishery. According to the latest biological advice, both stocks were within safe biological limits in 2018, although sole is still exploited at a slightly higher level than its Maximum Sustainable Yield (FMSY).

In recent years (2013-2015), about 13,000 tonnes of sole and 80,000 tonnes of plaice were landed representing a value of €100–€120 million for each stock (STECF, 2017). Most of the landings of sole and plaice are shared by fleets from six countries around the North Sea.

Sole is mainly caught by Dutch fleets (74%) and beam trawls (86%) while most of plaice is caught by Dutch, British and Danish fleets with beam- and demersal- trawls (figure 1).



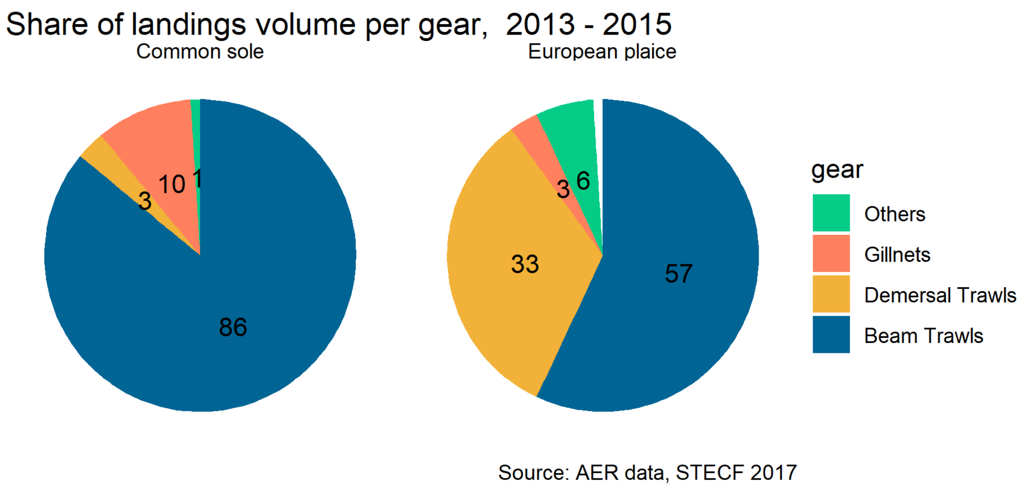


Figure 1 Average share of landings volume per country (top) and per gear used (bottom) for sole (left) and plaice (right) for the 2013-2015 period

Expected projections under climate change

Figure 2 Dutch flatfish trawler TX1 – VisNed

Bottom water temperatures in the North Sea are projected to increase by up to 2°C during the century under the IPCC business-as-usual RCP 8.5 scenario. Increases under RCP 4.5 are roughly half those under RCP 8.5, and differences between RCPs only emerge after about 2060. Net primary production is projected to decrease in the North Sea, those projections show considerable variability and the two RCPs are less distinct than for temperature.

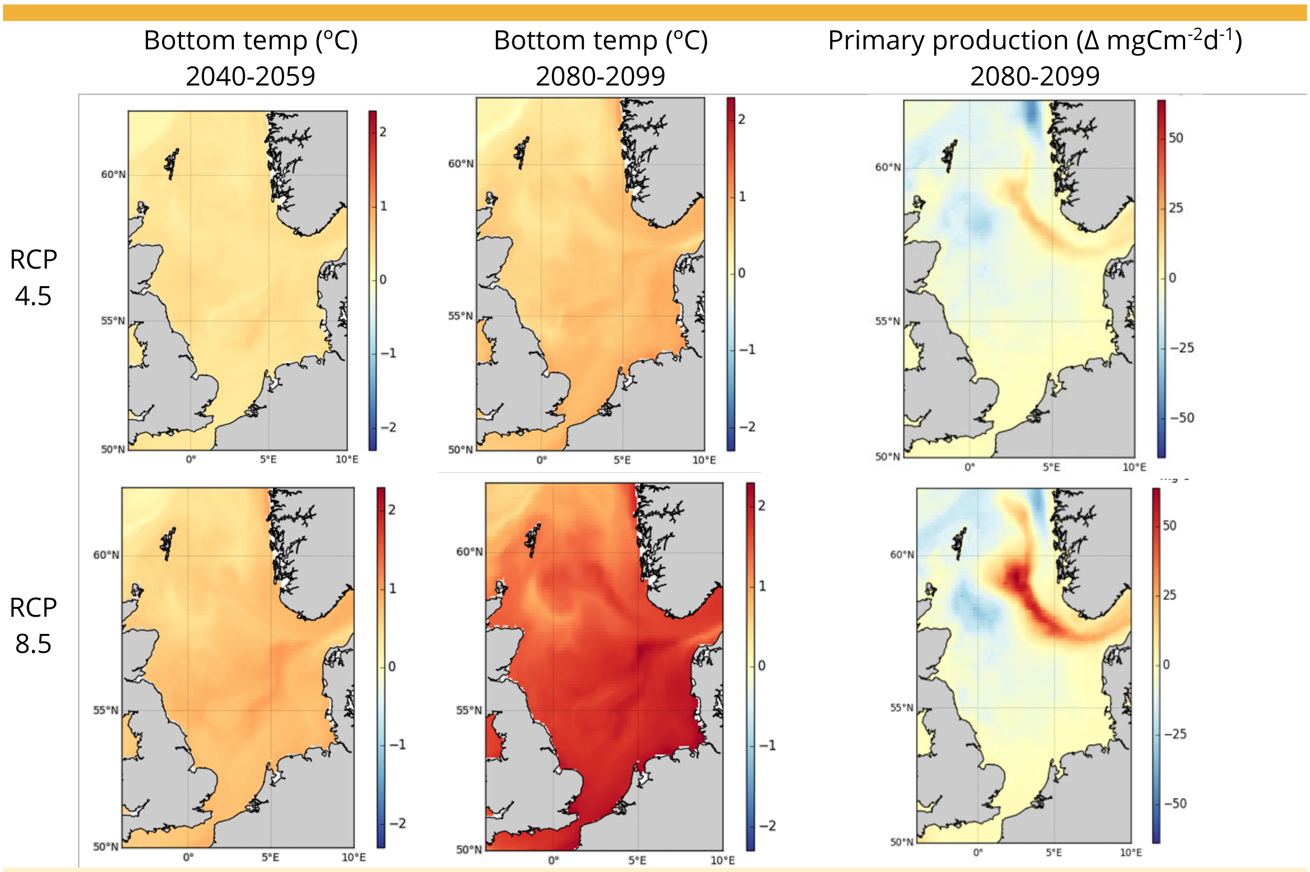


Figure 3 Change in bottom temperature for the near-future (1st column) and the long-term (2nd column) compared to the current situation. The third column shows the change in primary production between the current and long-term situations. The results are shown for RCP scenarios 4.5 (top row) and 8.5 (bottom row).

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'

- Personal independence, high mobility and consumerism
- Reduced taxes, stripped-away regulations
- Privatised public services
- High fossil fuel dependency
- Highly engineered infrastructure and ecosystems

'National enterprise'

- 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'

- High priority for welfare and environmental protection
- Cooperative local society
- Intense international cooperation
- Increased income equality
- Low resource intensity and fossil fuel dependency

'Local stewardship'

- 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 developments

Several aspects of the socio-economic development will be of particular interest for this fishery and have been developed together with stakeholders including representatives of the Dutch Cutter Fisheries association, a fishing company and policymakers such as the Netherlands Environmental Assessment Agency (PBL), the Ministry of Economic Affairs (EZ) and the Ministry of Infrastructure and the Environment (IenM).

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 each of the four CERES 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 fisheries, the North Sea flatfish fishery is sensitive to changes in fish price. In addition, beam trawls are fuel intensive fishing gears that are very sensitive to fuel price changes.

Technological: three important factors for the beam trawl 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 a lot of international collaboration (World Markets-WM and GS)

2) selectivity or survival of discards would improve only in the 'green' or 'environmental friendly' scenarios (GS and Local Stewardship - LS), in other scenarios, unwanted catch would become marketable

3) catch efficiency would increase in WM and NE only, environmental legislation wouldn't allow for it to happen in GS and LS scenarios.

Policy: the North Sea flatfish fishery will be influenced by two management strategies linked to policy including the level of exploitation and the access to the fishery. The levels of exploitation will derive 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 repartition keys of TACs into national quotas will also probably be modified.

Key research needs

Many challenges will be faced by the North Sea flatfish fishery. Access to the resource will likely change due to changes in the spatial distribution of the fish stocks and to the increasing amounts of space occupied by other activities that exclude fisheries from traditional fishing grounds.

Also, the Dutch flatfish fisheries will undergo a major transition in terms of fleet structure due to the EU-wide ban on pulse-trawling.

The influence of climate change on fish can be manifold. Changes in temperature, and food availability are expected to influence reproduction in terms of timing, magnitude and location as well as the development and survival of eggs and larvae (Fonds, 1979; Engelhard et al., 2011). In this context, species such as plaice and sole may show a distributional shift in abundance.

Fishers have already noted an expansion of sole and plaice fishing grounds to higher latitudes, away from warming coastal waters of the south-eastern North Sea. Also, the abundance of species such as squid, red mullet and gurnard, formerly not caught in the southern North Sea, has increased in recent years.

Such distributional shifts of species may influence the fishing dynamics, i.e. when, where and what to target, of the fishery. Adapting to changes in the distribution and productivity of flatfishes may be challenging given the socio-political development in the area and the limited space remaining for fishing.

Key questions are how future scenarios of climate change will impact the productivity and distribution of the key fishery species, and what the ramifications of changes are in marine spatial planning for the North Sea flatfish fishery.

CERES research

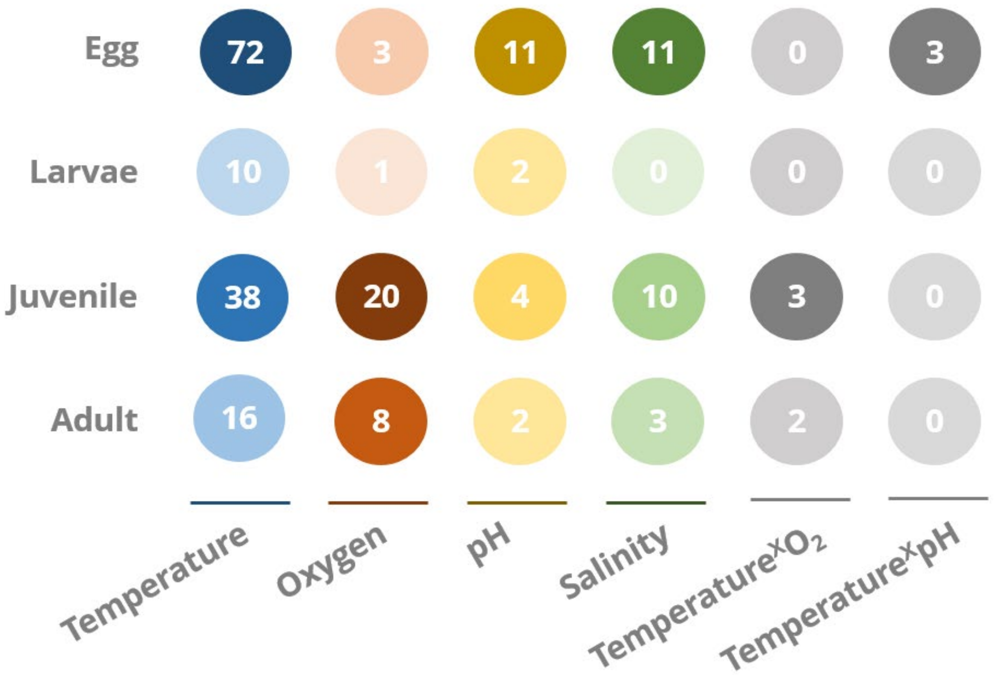
Many activities have been undertaken under the CERES project from a number of partner institutes.

- Scenario definition: Engagement of local stakeholders to co-develop regional scenarios including spatial developments in the Dutch EEZ under the four scenarios.
- Gap analysis: semi-structured literature review to find gaps in knowledge on the direct effects of climate (e.g. temperature, salinity, pH and dissolved oxygen) on plaice and sole.
- Time series analysis: Compilation and analysis of long-term time series data of the size of adult plaice and geo-statistical analysis of the spatial dynamics and migration patterns of plaice linked to food availability and temperature
- Biological projections: changes in the distribution of plaice in the North Sea under two IPCC scenarios (4.5 and 8.5).
- Fisheries projections: changes in the Dutch flatfish fishery with the four CERES scenarios using the SIMFISH model (Bartelings et al., 2015) applied for the 2015-2050 period & projection of the British flatfish fleet following the expected habitat suitability of sole and plaice under RCP4.5 and 8.5.
- Risk and opportunities for the fishery: bow-tie analysis identifying the risks, opportunities and mitigation measures associated with changes in the distribution and productivity of flatfish in a future environment.

Figure 4 Photo of the stakeholder workshop held 16/06/2017 in IJmuiden *Image credit: Wageningen Research – K.Hamon*

Biological consequences

Direct effects



- Sole ranked 9 out of 28 European fish and shellfish genera reviewed here (10 studies). Plaice ranked 7 out of 28 (14 studies).
- 11 out of 23 studies on North Sea flat fish were performed in the UK.
- Except for larvae all life stages were well covered.
- Metabolism (9) and growth (8) were the most common responses studied.
- Temperature (13) and Oxygen (8) were the most common responses studied.

An historical analysis of long-term changes in the body size and spatial distribution of plaice indicated that, over the past 115 years, multiple and different drivers have impacted this species during different time periods. While wars and high nutrient inputs from rivers lead to an increase of large plaice, fishing and climate change lead to lower average sizes of plaice in the North Sea.

The spatial dynamics, i.e. movement patterns of juveniles, and adult migration between feeding and spawning areas of North Sea plaice were investigated.

Given seasonal variation in the temperature and food conditions the evolutionary optimal movement and migration pattern were modelled. Model outcomes show that the predicted movement patterns are in broad agreement with observations.

Young plaice which were allowed to migrate away from the nursery grounds have approximately 25% more body mass those fish that had to stay within these grounds. This difference in body mass increases further, to approximately 40% as fish become older.

This approach is a first step towards a mechanistic full life cycle model of the spatial dynamics of plaice that can be used under different climate scenarios.

Furthermore, an analysis of the historical changes in the spatial distribution and abundance of North Sea plaice was performed using integrated nested Laplace approximation (INLA). Model results show ontogenetic changes in spatial distribution of plaice whereby smaller individuals are distributed in the coastal zone of the southern North Sea, moving gradually offshore to deeper waters as they grow larger.

Especially in quarter 3 small (i.e. juvenile) plaice is distributed in the coastal zone, whereas the larger individuals (>35 cm) are almost completely absent from the coastal zone and are found in more northern areas near and above the Dogger Bank.

From a historical perspective the analysis demonstrates a shift in distribution of plaice towards offshore, deeper and colder waters. Especially, a shift of juvenile plaice away from the coastal zone towards deeper and colder waters was predicted.

Several models were used to project the future distributions of sole and plaice in the North Sea. The results suggest that the abundance of plaice would decrease under RCP 4.5 and RCP 8.5 scenarios, with similar trends up to 2050 and an acceleration of the decrease in abundance afterwards in the RCP 8.5 scenario (see results of the SSDBEM model in deliverable 2.3).

Suitability maps of the North Sea, suggest that southern areas becomes less favourable as bottom temperatures are outside the preferred temperatures for most ages of plaice (see Figure 6) and geo-statistic projection of plaice using on temperature and depth preferences show that juvenile plaice specifically avoid the coastal areas (see results of the INLA model in deliverable 2.3).

While the different modelling approaches agree on the trend for plaice, results are more contrasted for sole. The SSDBEM projects a decrease in abundance, while the suitability maps from the species distribution model (SDM) project an increase of suitability (on average).

The southern North Sea also seems to be slightly less favourable for sole but this would be compensated by an increase in suitability in the central North Sea (Figure 6).

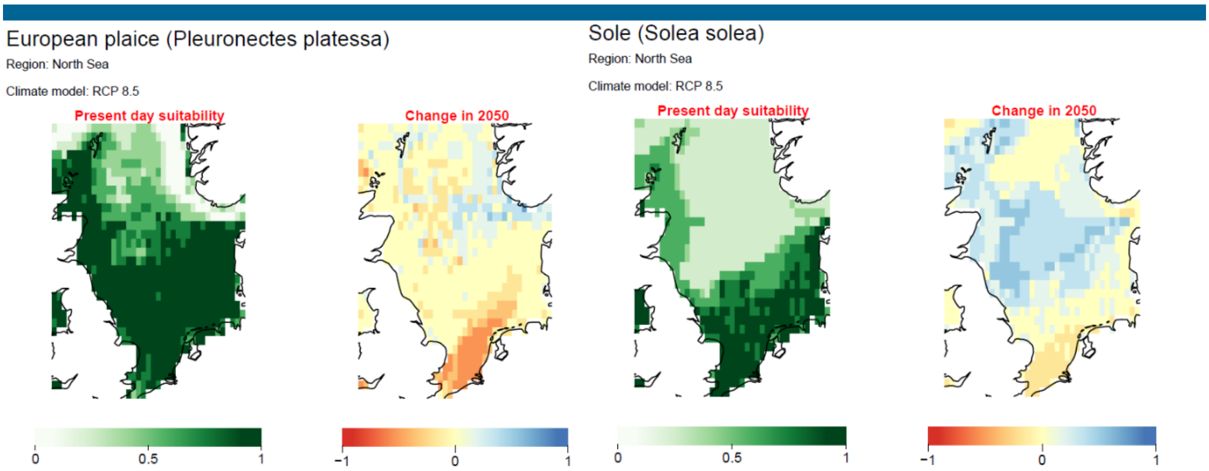


Figure 5 Suitability maps for plaice (left) and sole (right) under the RCP 8.5 scenario in the North Sea, assuming an RCP8.5 emissions scenario. (green scales) present day 'habitat suitability' averaged across all SDMs for the reference period 1997 to 2016; (red-blue scales) change in habitat suitability in the 30 year time-slice 2040–2060 – centred on 2050, compared to the present day reference period. Red indicates a deterioration in habitat suitability, blue indicates an improvement.

Change in habitat suitability and the poleward shift of fish stocks can also bring in new species.

Among the species mentioned by fishers as alternative to current target species, the habitat suitability of squid and mullet is expected to increase (+ 8.2 ± 27% in RCP 4.5 and + 17 ± 35% in RCP 8.5 for squid and (+ 24 ± 37% in RCP 4.5 and + 57 ± 100% in RCP 8.5 for mullet). However habitat suitability is expected to decrease for grey gurnard.

Economic consequences

The economic consequences of the scenarios on the Dutch North Sea flatfish fishery were evaluated with the SIMFISH model (Bartelings et al., 2015) over the period 2015-2050. Simulation results show that the Dutch flatfish fishery (using pulse trawls as in the calibration data) was resilient to change.

The factors most likely to negatively impact the Dutch fleets (in terms of profitability and number of vessels remaining in the fishery) are the increased fuel price and the decrease of quota due to stricter application of MSY (at the ecosystem level in the Global Sustainability scenario) or MEY (in the World Market scenario) (see Figure 7). This is particularly relevant because of current developments in the fishery where the fuel efficient pulse trawl will be banned from 2021, and Brexit may lead to renegotiations of the quota distribution by country (to see all the results of the modelling see deliverable 4.1).

Technological improvement leading to better fuel efficiency and increasing fuel price would both lead to better economic performances of the fleets. The distribution of sole and plaice or the area closures had surprisingly little impact on the economic performances of the fleets.

Unfortunately, the spatial scale used to run the model, using 16 areas for the whole North Sea did not capture the change in distribution happening at a finer scale.

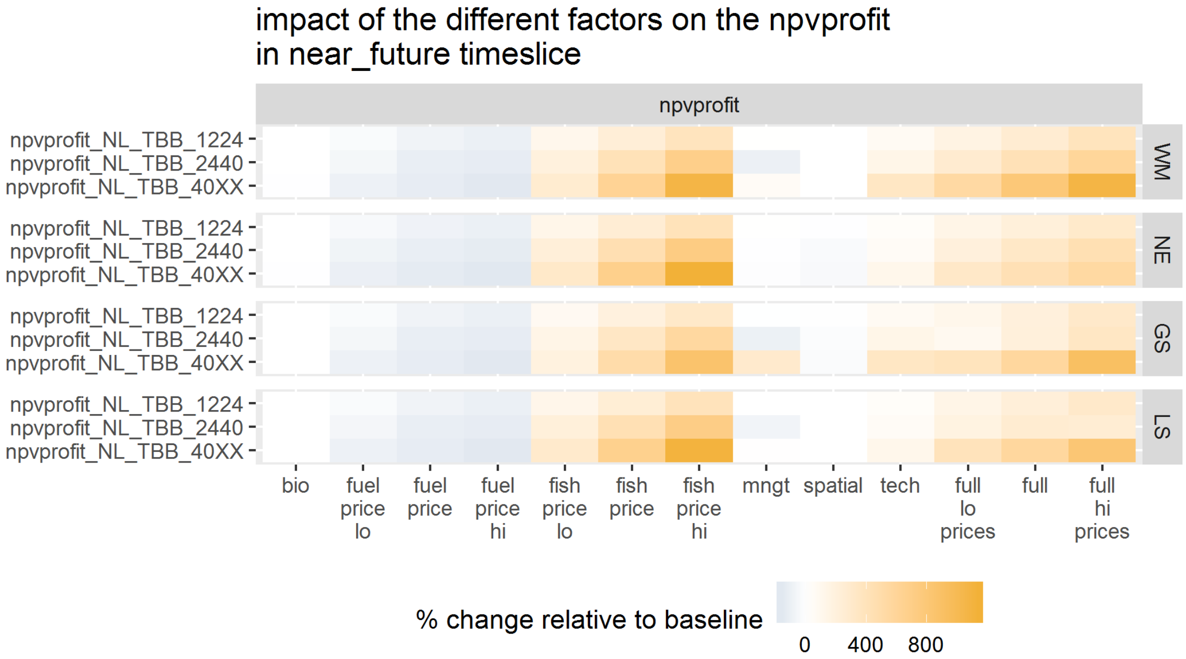


Figure 6 Net present value (NPV) of profit of the three Dutch beam trawling fleets targeting flatfish in the North Sea. Results are expressed as % change relative to a baseline

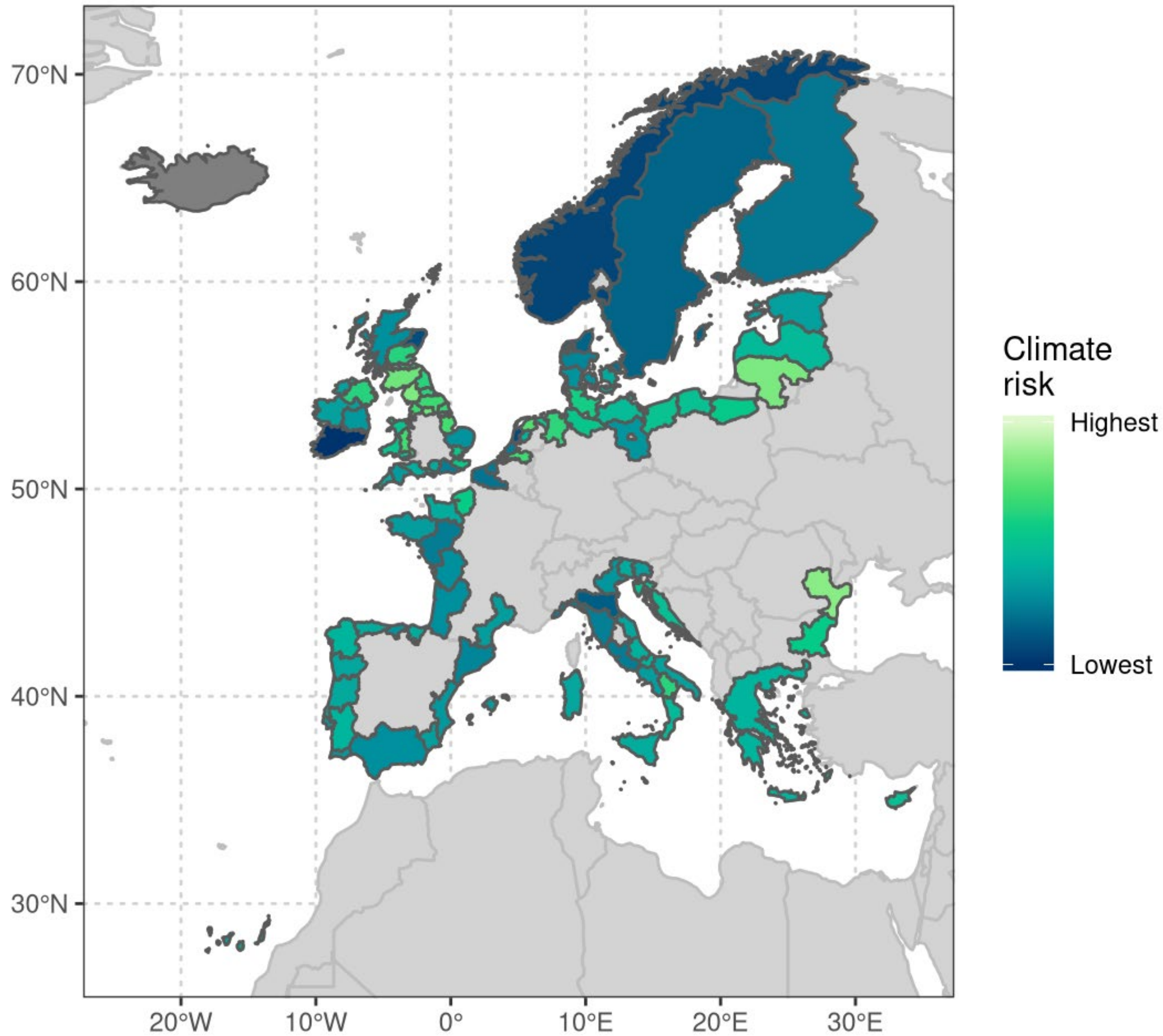


Figure 9 Map of the regional climate risk. Colour scale is linear in the value of the corresponding score, but is presented without values, as they have little direct meaning. National-level borders are shown for reference. *Credit : Mark Payne*

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.

North Sea fleets in this storyline have a moderate-high climate risk. High climate hazard of the stocks is only partially offset by moderate profitability (vulnerability).

Mitigation measures

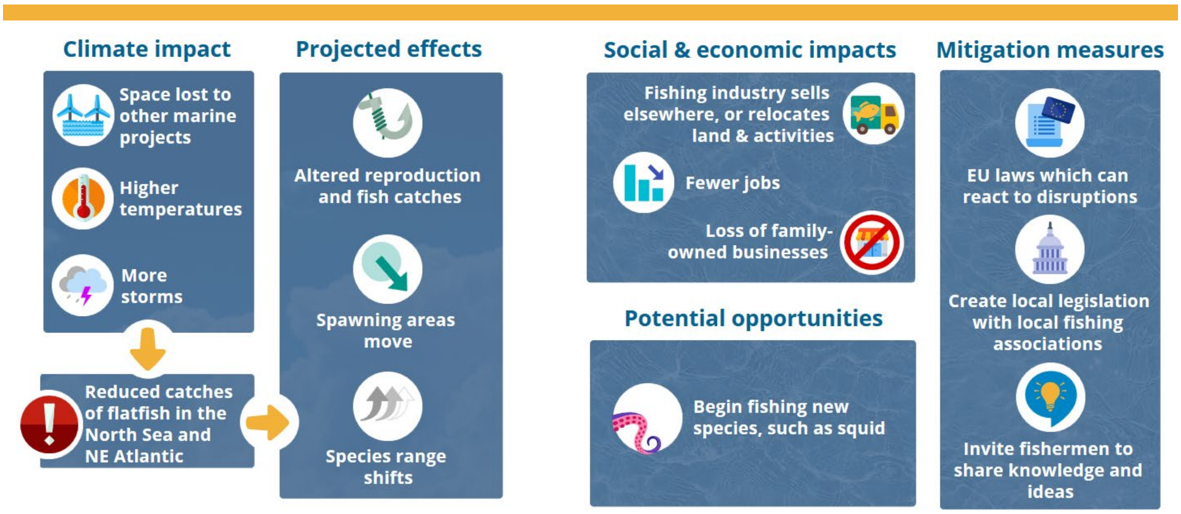


Figure 9 Bowtie of mitigation measures, based on discussions with stakeholders. Full bowtie available at http://bit.ly/CERESstorylinesFlatfish

To limit the impacts of some of the climate related developments in the North Sea, some mitigation measures could be used:

- Allow innovation development
- Use habitat for multi-sectorial development to relieve the spatial pressure of the North Sea and limit the amount of area closures to fisheries
- Shorten the value chain and sell locally
- Exploit new species
- Develop market for new and bycatch species
- Scientifically investigate adaptive behaviour of fish and marine ecosystems to climate change

Policy recommendations

Based on bowties & internal discussions, recommendations include adapting legislation at the EU and national level providing more room to innovate and technological development.

With species on the move and the stability of quota allocation, flexibility in the implementation of the landing obligation (LO) will be required. Alternatively, fully documented fisheries could be substituted to a strict implementation of the LO. Generally, adaptive legislation will have to be designed with local stakeholders.

Further reading

CERES publications

Engelhard GH, Pinnegar JK, Hunter E (in prep.) Climate, conflict and commerce: Decadal impacts of environmental and anthropogenic change reflected in the world's longest fish size time-series. To be submitted to *Fish and Fisheries.*

Reports and Online sources

Capuzzo E, Lynam CP, Barry J, Stephens D, Forster RM, Greenwood N, McQuatters-Gollop A, Silva T, van Leeuwen SM, Engelhard GH (2018) A decline in primary production in the North Sea over 25 years, associated with reductions in zooplankton abundance and fish stock recruitment. Global Change Biology 24: e352-e364. doi: 10.1111/gcb.13916.

Engelhard et al. (2011) Nine decades of North Sea sole and plaice distribution. ICES J. Mar. Sci. 68: 1090-1104.

Matthijsen J. et al. (2018), The Future of the North Sea. The North Sea in 2030 and 2050: a scenario study. PBL Netherlands Environmental Assessment Agency, The Hague. http://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2018-the-future-of-the-north-sea-3193.pdf

Scientific, Technical and Economic Committee for Fisheries (STECF) - The 2017 Annual Economic report on the EU Fishing Fleet (STECF 17-12); Publications Office of the European Union, Luxembourg .