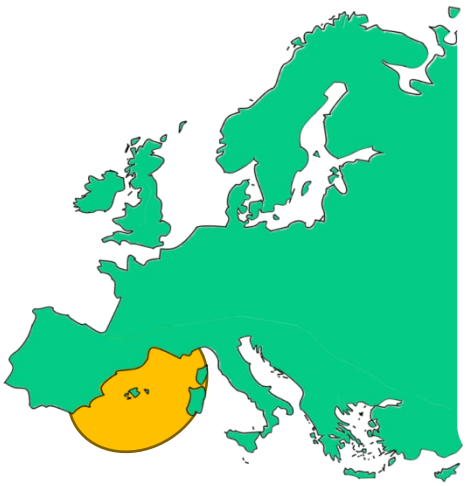
Case study



#22 Sardines and anchovies in the north-west Mediterranean

#23 Hake in the Aegean Sea and eastern Mediterranean

#24 Bluefin Tuna in the north-west Mediterranean

Species background and economics

During the last three decades the number of sardines (*Sardina pilchardus*) and anchovies (*Engraulis encrasicolus*) has declined sharply in the Northwest Mediterranean Sea. This has also led to a sharp decline in fisheries landings.

The combined landings of sardines and anchovies in the early 1990s in Catalonia were ~ 50,000 tonnes for a total va lue of approximately €100 million. In recent years, combined landings were about 10,000 tonnes with a value of €25 million.

From 1993 to 2016, the size of the purse seine fleet along the Spanish coast and midwater trawl fleet along the French coasts has decreased from 163 to 82 vessels.

These declines were associated with changes in the environment as well as excessive fishing pressure in the early 1990s.

Additionally, surveys of the abundance of early life stages (eggs and larvae) of small pelagic fish indicate increased abundance of the round sardinella (*Sardinella aurita*), a previously rare species in the area spreading from the south.

Several lines of evidence, therefore, suggest that profound changes have occurred in the pelagic ecosystems.

Expected projections under climate change

Across the Western Mediterranean, the following is projected to occur during the 21st century:

- increases in air temperatures between 2.2 and 5.1ºC
- decreases in rainfall between 4 and 27%
- longer periods of drought, related to an increased frequency of days with temperatures above 30ºC
- Rises in sea level of around 35 centimetres
- Salinisation (increased salt content) and acidification of coastal and offshore waters

Increases in primary productivity is expected to increase towards the mid-21st century and decrease at the end of the century to values similar to current ones. The projection of habitat suitability indices for *Engraulis encrasicolus* and *Sardinella aurita* show an important loss of spawning habitat for the former and an increase in the presence of the non-indigenous latter species.

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

The decrease in the abundance of the traditional target species of small pelagic fisheries, sardine and anchovy, is having an important effect on fisheries productivity.

They have suffered a reduction in fishing units to half of the former fleet size and the economic viability of the fisheries are uncertain.

The increase in abundance of the round sardinella cannot mitigate the economic impact of productivity loss, as this species has very low commercial value.

Key research needs

Current research shows that the productivity of these small pelagic fish stocks is negatively affected by increased temperatures that reduce reproductive success in the winter-spawning sardine.

The summer-spawning anchovy can be affected also by extreme temperatures, such as the anomalous hot summers of 2003 and 2006. Further climate-related impacts are suspected to be driving slow growth in sardines and anchovies, likely due to changes in the ocean's biological productivity. Key research actions to understand the physiological response of small pelagic species to the new environmental conditions are needed.

Although the dynamics of early life stages (eggs, larvae) are well-known and information on late juveniles and adults is routinely obtained from fisheries-related research, the key aspects of recruitment and requirements of early juvenile are little known.

Figure 1 Larva of Sardinella aurita. *Credit: Ana Sabatés (ICM-CSIC)s*

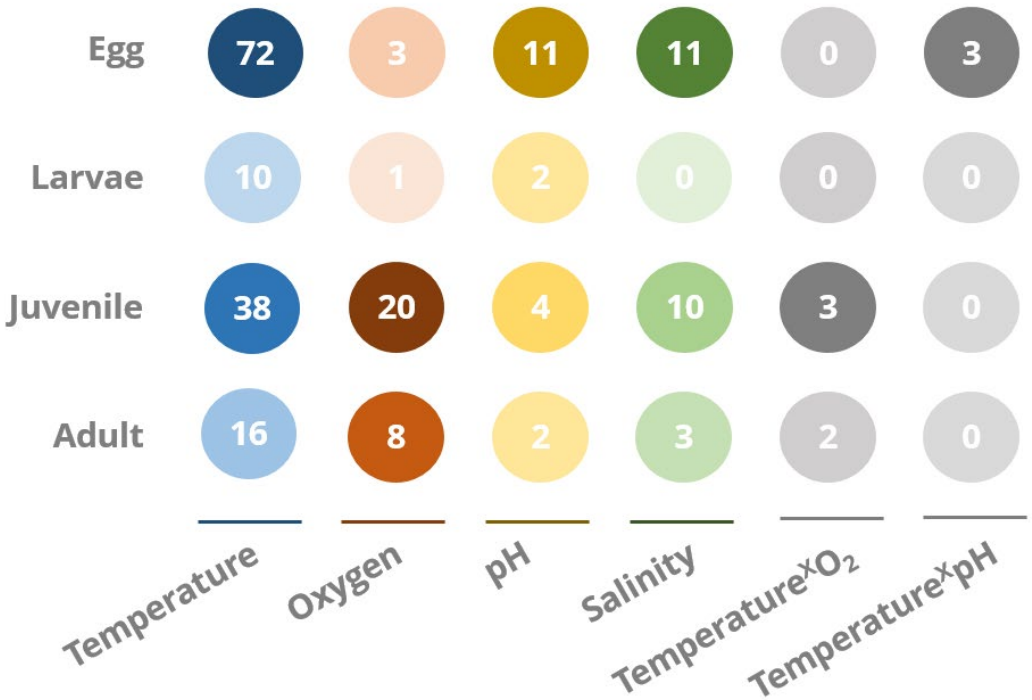
CERES research

The CERES Project has:

- Conducted a Gap analysis of knowledge of the direct climate impacts comparing small pelagics in these regions with other European fisheries targets and regions
- Compiled >25 years of survey data on the abundance of sardine, anchovy and round sardinella and landings of pelagic fisheries
- Applied statistical models (GAMs) to examine whether changes in the abundance of small pelagics and landings of fisheries were related to changes in local climate-driven factors (e.g. sea surface temperature) and regional oceanographic drivers (e.g. Atlantic Multidecadal Oscillation, Western Mediterranean Oscillation).
- Engaged stakeholders (local fisheries managers and fishers) to discuss ongoing changes in the small pelagic fishery
- Developed a conceptual map of risks and mitigation measures (BowTie) regarding climate impacts on these small pelagic fishes

It is observed that current conditions in the last two decades are not optimal for small pelagics fisheries production.

Biological consequences



- Sardine ranked 17 out of 28 European fish and shellfish genera reviewed (4 studies). Anchovy ranked 13 out of 28 (5 studies).
- No study was found for the NW Mediterranean.
- All European studies were focusing on embryos, including larval stages once
- Temperature was the only stressor analysed.
- The most common response studied was development (6).

Direct effects

The three environmental variables used to define the spatial distribution of suitable habitat of small pelagic fish p were SST (Sea Surface Temperature), SSS (Sea Surface Salinity) and CHL (Chlorophyll-a).

The future environmental conditions were derived from the biogeochemical model for two RCPs (4.5 and 8.5) and for the central and final decades of the 21st c. (2050s and 2090s).

In RCP4.5 temperatures are forecast to increase progressively in the 2050s and 2090s, while salinity would not vary markedly between 2050s and 2010s and show a significant increase in 2090s.

Chlorophyll is forecast to reach higher values in the northern half of the study area.

Comparing the spatial distribution of early life stages of both species it is apparent that the potential spawning habitat of round sardinella tends to be restricted to richer, fresher waters at shallow depths, principally around the Ebre Delta.

Conversely, anchovy eggs and larvae are predicted to be distributed over the deep continental shelf, avoiding the water masses adjacent to the Ebre river delta.

In effect, this means that the potential spawning habitat of both species does not overlap extensively, and both species could coexist in the area with low competition, at least at the level of early life stages.

Although our analysis is concerned only the relationship between environmental variables and abundance of early life stages of anchovy and round sardinella.

This is true at least in the case of anchovy, where excessive fishing pressure can also contribute to explain the decreasing abundance in eggs and larvae between the very high levels reported in the 1980s, with values of 1500-2000 eggs / 10 m^2 not uncommon, and the 2000s-2010s period, when values higher than 600 eggs / 10 m^2 are exceptional.

Recent stock assessments show that spawning stock biomass for this

species was very low from 2000 until 2015 approximately, when the stock was diagnosed as overexploited.

The difference maps of suitability between 2050s and 2010s (Fig 2) under RCP4.5 show important habitat loss for anchovy early stages both in 2050s and 2090s.

In the case of round sardinella, some loss of habitat is appreciated around the Ebro delta for eggs, but the probability of finding eggs and larvae will be generally higher than historically.

Note however that the maximum differences are observed for the 2050s decade. The results under RCP8.5 (not shown) are in the same line, although the differences between 2050 and 2010 are even higher.

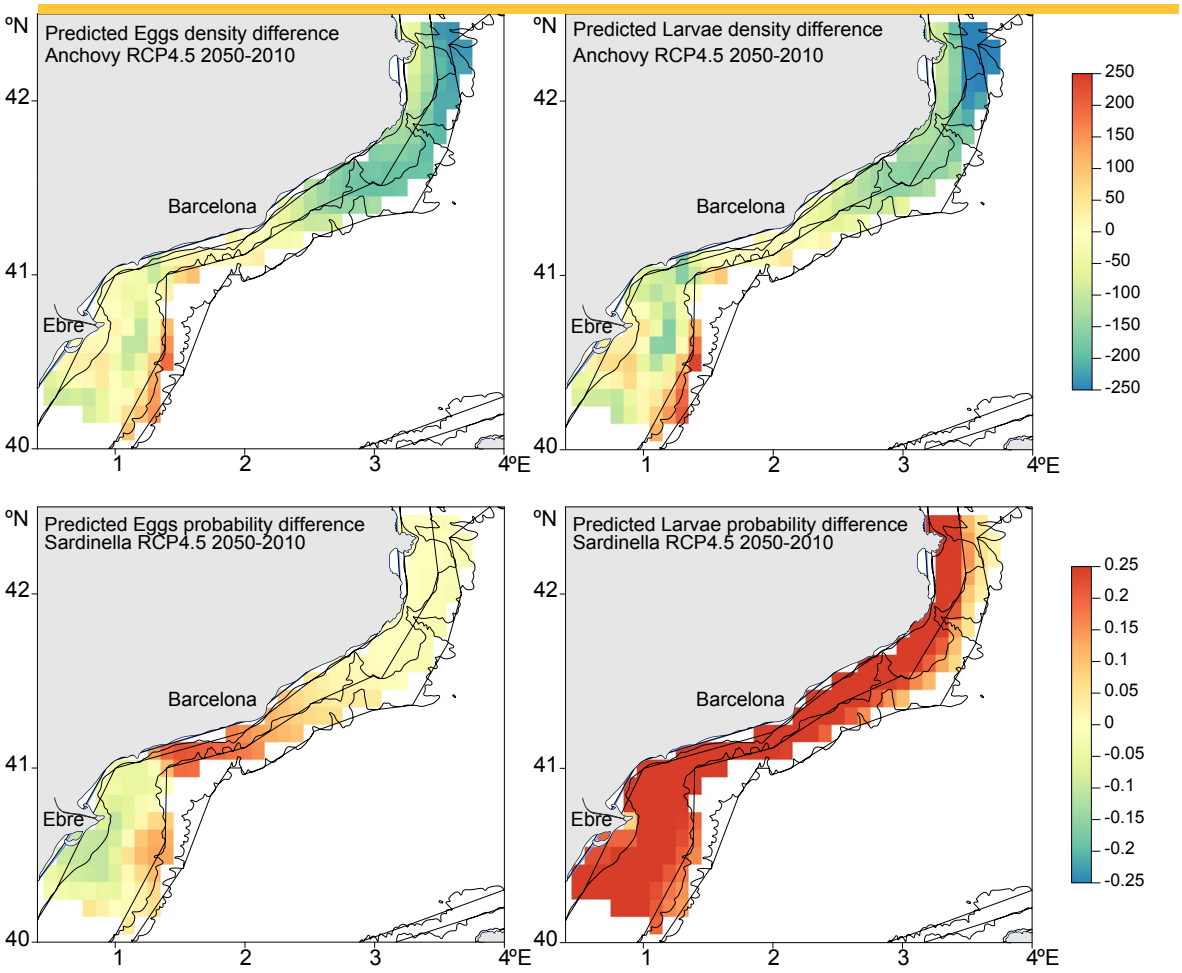
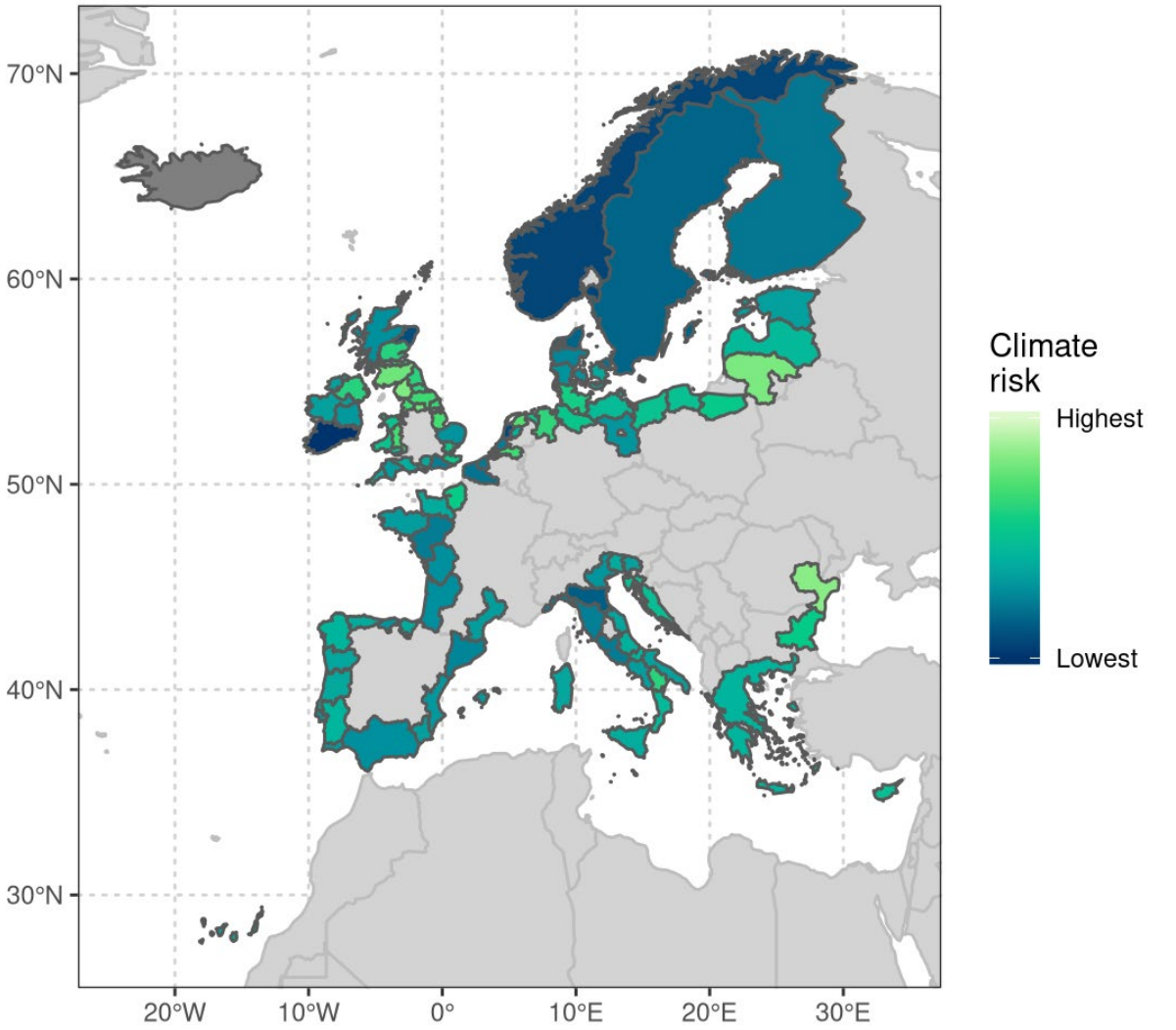


Figure 2 Changes of spawning habitat suitability of Engraulis encrasicolus and Sardinella aurita during the 21st c. under RCP4.5. Comparison of 2050 to 2010.

Economic consequences

Although no formal economic analysis has been carried out, the increase in abundance of the round sardinella cannot mitigate the economic impact of productivity loss of the main two commercial species of the fleet (sardine and anchovy), because round sardinella species has very low commercial value.

Climate-ready solutions



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 low climate risk. Good profitability (low vulnerability) and the general nature (low exposure) of the fleets, offset the moderate hazards of the stocks.

Mitigation measures

Measures to mitigate the anticipated effects of climate change should aim at reducing fishing mortality of juvenile individuals to enhance the productivity of the stock.

Policy recommendations:

CERES researchers have developed the following recommendations for these species in the north-west Mediterranean

- Protecting sardine/anchovy nursery areas in the Bay of Biscay
- extending the current fishing winter ban of two months to protect sardine recruitment to two additional months in summer to protect anchovy recruitment.
- investigate more selective fishing techniques based on pre-catch identification to avoid catching undersized individuals that are not marketed and released dying at sea.
- promote new markets for alternative stocks/resources, such as valorisation of round sardinella.

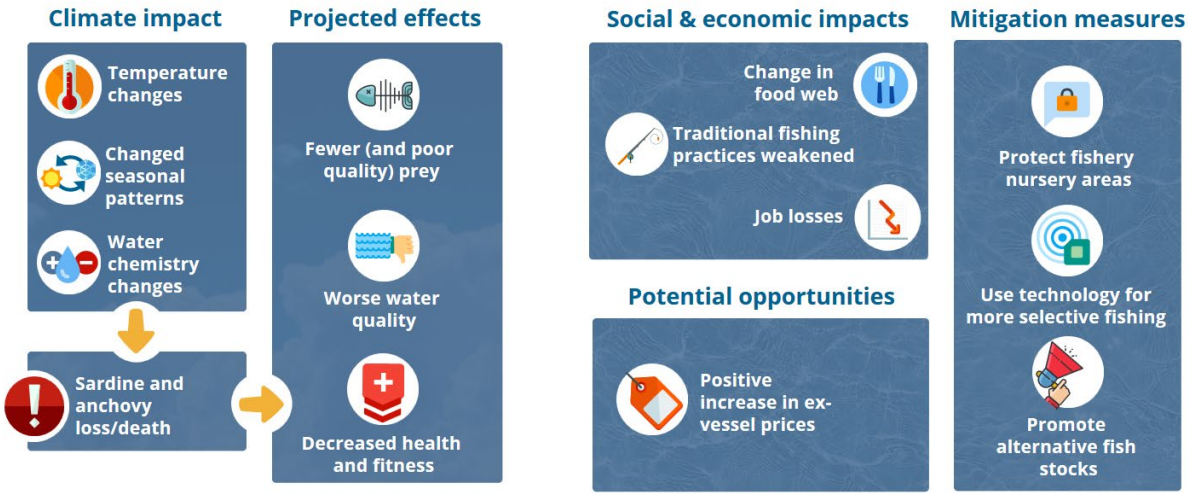


Figure 4 BowTie analysis based on stakeholder feedback. All full BowTies available http://bit.ly/CERESbowties2020 *Image: Katy Smyth*