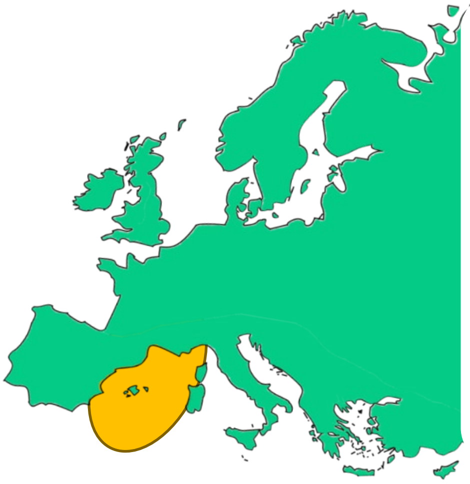
Case study



#24 Bluefin Tuna in the north-west Mediterranean

#1 Rainbow trout in north-west Europe

#2 Rainbow trout in the eastern Mediterranean

Species background and economics

Atlantic bluefin tuna is targeted by different international fisheries attaining a high market value worldwide.

This large, migratory apex predator is managed by the International Commission for the Conservation of Atlantic Tunas (ICCAT) in two stocks.

For the Eastern stock (east of the 45ºW meridian), the main spawning areas are located in the Mediterranean, where tuna migrates in May–June to reproduce. A major proportion of this stock returns to their foraging grounds in the North Atlantic during July–August whereas part of the population remain overwintering in the Mediterranean Sea.

The catches of Eastern Atlantic bluefin tuna reaches 15000 metric tons, with a dock value in of 0.19 billion USD and an end value of 0.82 billion USD (data for the Atlantic Ocean).

This species had some major changes in their distribution, as suggest the raise and disappearance of an important fishery in Brazil in 1960s, or the return of the species to Norwegian sea after 50 years not present in that area and increasing abundance in several areas of the North Atlantic after 2012. In the mid-1970s, scientists began to see how the breeding population of Atlantic bluefin tuna decreased year after year.

This happened in the face of growing market demand and consequently the significant increase in catches. Catches reached 50,000 tons per year in the 1990s and a lot of illegal fishing activity was reported.

It was considered that the species could reach a point of collapse and therefore, in 2007, The International Commission for the Conservation of Atlantic Tunas, ICCAT, established a special plan for the recovery of the species that has produced very good results.

The main measure taken was to drastically reduce fishing quotas, to just over 10,000 tons, by implementing control systems in parallel to reduce illegal captures. Another very important measure was to ban fishing for bluefin tunas that had not yet reached the reproductive age, increasing the minimum size to 30 kilos.

As for the techniques used in fishing, it was forbidden to locate tuna banks from light aircrafts, and various temporary and spatial closures were also established for certain fleets. Since then, the Atlantic Eastern bluefin tuna stock is recovering.

Atlantic bluefin tuna is considered one of the most vulnerable species to climate change and harvesting among tuna and billfish species.

Expected projections under climate change

It has been demonstrated that the reproductive habitats for this species and the survival of their offspring are sensitive to climate change, particularly warming, in the western stock.

No studies have yet addressed the plausible effects of climate change on the reproductive habitats in the eastern stock.

In the Mediterranean Sea, climate change is driving a gradual rise of water temperature, stronger stratification of the water column, increasing heatwaves and a proliferation of marine species that are better adapted to a warmer environment, a process so called 'tropicalisation.'

Such variability is driving changes in the abundance and distribution of bluefin tuna, which seem to be vulnerable to warmer temperatures and therefore is likely to influence the offspring survival and distribution of spawners' habitats in the future. The effects based on a mechanistic understanding of the ecology of the species and the ecosystem and the expected impact of climate change in this species is not clear yet.

Large-scale increasing trends in water temperature could potentially lead to higher BFT recruitments through the direct positive influence of temperature on larval survival. However, interanual variation in this species' recruitment in the last years challenges the hypothesis of a direct simple effect of temperature on the offspring survival, suggesting that other factors can play also a key role in the recruitment process.

Potential continuity in the current expansion of adult bluefin tuna during summer to new areas in the North Atlantic already seen after 2012 after the different climate scenarios need to be tested.

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 developments

The International Commission for the Conservation of Atlantic Tunas (ICCAT), in charge of the management of this species, is not considering socio-economic aspects in the assessment models used for management. Implementing a socio-economic model requires a lot of information, especially economic information from fleets.

To make projections it is necessary to define the basic structure of an operational model that reflects the dynamics of the population by age along with a stock-recruitment relationship and a Management Procedure that encompasses the dynamics of the fleet and a Harvest Control Rule whose application each year feeds back the operating model.

Key research needs

Atlantic bluefin tuna has a confined timing and location of spawning in the Mediterranean Sea which make this species very sensitive to climate change. Critical habitats for larval survival and growth include water temperatures > 19°C to 20°C, and mesoscale structures such as the occurrence of salinity fronts, both of which are expected to be affected by CC in the future. Important impacts of CC are expected on the reproductive traits of the species such as timing, distribution and condition of spawners, as well as the abundance of recruits.

A major heat wave observed in 2003 in Mediterranean waters resulted in very high survival of eggs and larvae leading to a remarkable good recruitment and the strongest year class dominating in the catches from the Japanese longline and the Spanish baitboat fishery data. Our capability to predict heat waves need to improve if extraordinary strong year classes are to be detected.

It is critical to develop mechanistic models of the recruitment dynamics and reproductive timing and location of bluefin tuna to understand the regional environmental drivers of inter-annual differences in spatial patterns of larval performance, recruitment and spawning strategies. The socio-economic consequences of changes in distribution and abundance in different climate change scenarios need to be investigated.

CERES research

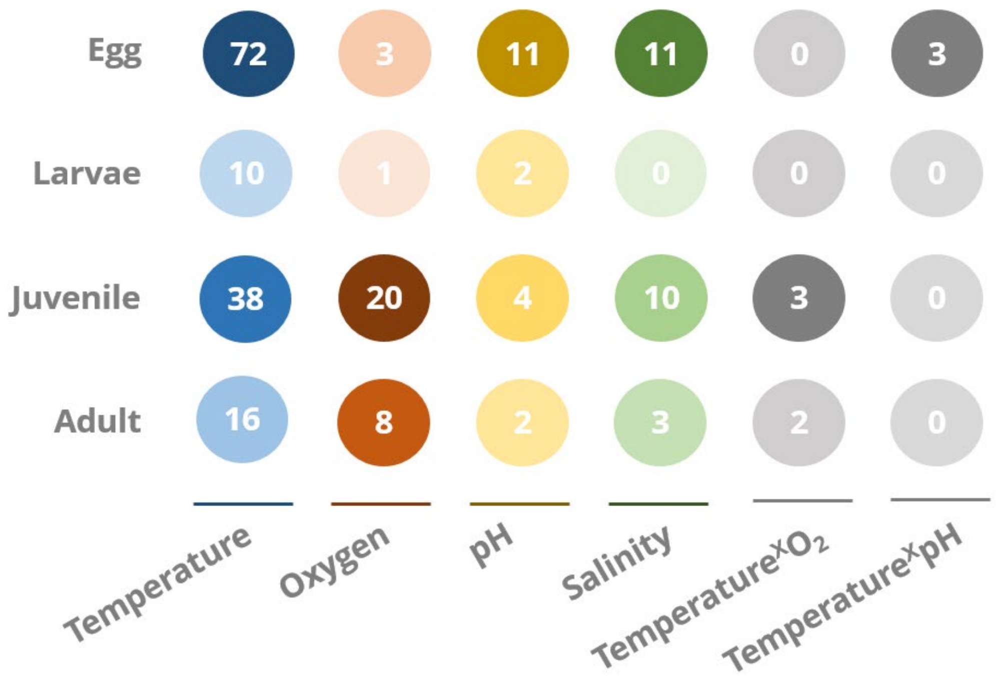
- Performed a semi-structured literature review to identify gaps in knowledge on how climate-driven changes in direct factors (temperature, salinity, pH and dissolved oxygen) will impact Atlantic bluefin tuna
- Conducted experiments to examine the effect of temperature, salinity and pH on the growth, developmental time and survival of eggs and larvae.
- Compiled and analysed time series data on the reproductive timing of tuna across all spawning grounds to examine how water temperature, feeding conditions, and climate indices affect spawners condition.
- Compiled and analysed monitoring data on the temporal and spatial distribution of larvae and spawners from fisheries data, tracking data and adult condition of Atlantic bluefin tuna in the Western Mediterranean to analyses of the spatio-temporal variability of environmental variables that influence the geographical survival of larvae and therefore recruitment.

- Developed a spatially-explicit larval survival index as a function of temperature that can be compared to current fisheries dependent recruitment indices.
- Projected changes in recruitment success under climate change scenarios RCP 4.5 and 8.5 based on larval survival and reproduction habitats
- Projected changes in adult distribution under two climate change scenarios (RCP 4.5 and 8.5) in the Mediterranean and the Atlantic
- First attempt to develop simulations with uncertainties with projections based on economic variables including survey of economical data for main fishing fleets in Mediterranean Sea.
- Conducted a Bow-Tie analysis to identify risks and mitigation measures of the impacts of CC on Atlantic bluefin tuna in the NW Mediterranean
- Consulted stakeholders, mainly scientists involved in the assessment of this species and the head of the ICCAT Atlantic-Wide Research Programme for Bluefin Tuna to compile information for the bow-tie analysis and their perspectives on the stock in the light of climate change.

Figure 1 Live bait boat heading for the capture of Atlantic bluefin tuna in the Gibraltar Strait area

Biological consequences

Direct effects



- Blue fin tuna ranked 22 out of 28 European fish and shellfish genera reviewed here (2 studies).
- All studies were done in Spain and focussed on growth as the response value.
- Both studies used temperature as stressor and worked on early life stages (1xembryo, 1x feeding-larvae)

The timing of reproduction for this species is constrained by the lower temperature of 20ºC for eggs and larvae to survive. Recruitment increases at higher temperatures. The areas used for reproduction coincide with those with the highest probability of larval survival due to temperature, however, some spawning is observed in areas with suboptimal thermal habits more related to the location of salinity fronts. Years with heatwaves, such as 2003, result in high recruitment and strong year classes that dominate catches in the fisheries.

Based on the assumption that growth and survival of Atlantic bluefin tuna larvae are influenced by temperature, forecast scenarios suggests increasing abundance of recruits both under the RCP 4.5 and 8.5 scenarios, particularly from 2050 onwards and a general expansion of spawning habitats, due to the temperature increases.

However, there is high uncertainty due to differences in the models performance. It is not possible to forecast the relationships between heatwaves and recruitment in the future since only the the Mediterranean model available from the Copernicus Marine Service (CMEMS-MED version v02 and sv03, http://marine.copernicus.eu was able to reproduce the heatwave in 2003 whereas the other models used in CERES were not able to reproduce heatwaves.

Therefore, forecasting of heatwaves is very uncertain. There is a plausible northwards expansion of the adults due to increasing temperatures.

Economic consequences

The platform chosen to develop the bio-economic model was FLBeia. This software allows to perform simulations with uncertainties in the framework of FLR with projections based on economic variables, such as profit at the same time as catches, effort and biomass. Its experimental use for the first time in the case of Atlantic bluefin tuna in this project has laid the foundations for the development of such models for this species in the future but unfortunately bio-economic projections could not be made by several limitations encountered in the research. The economic information collected was insufficient to establish the fleet behavior model added to the complexity of the fleets related to this stock. Temperature scenarios were incorporated as abundance indices adjusted to the SPiCT production model, but the absence of convergence did not allow to generate conclusive results.

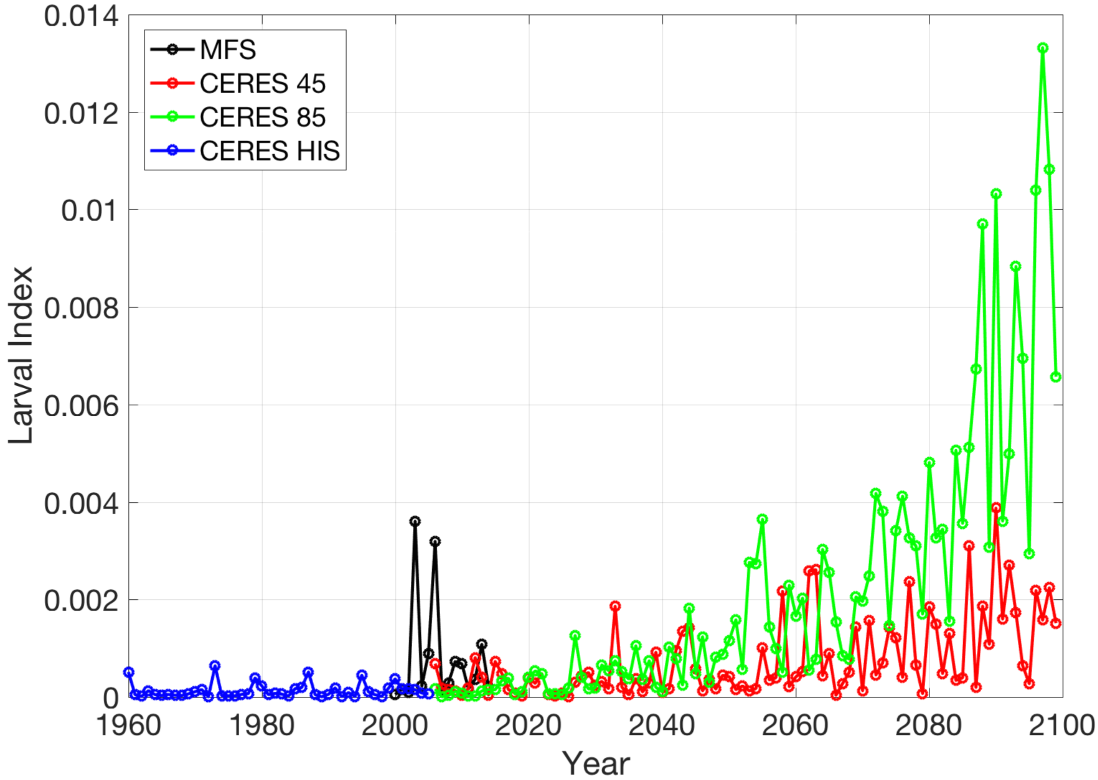


Figure 2 Time series of the potential larval survival index for Atlantic bluefin tuna obtained from different models. In blue the POLCOMS historical run, in blue the Copernicus Marine Service (CMEMS-MED version v02 and sv03, in red POLCOMS RCP 4.5 and in green POLCOMS RCP 8.5.

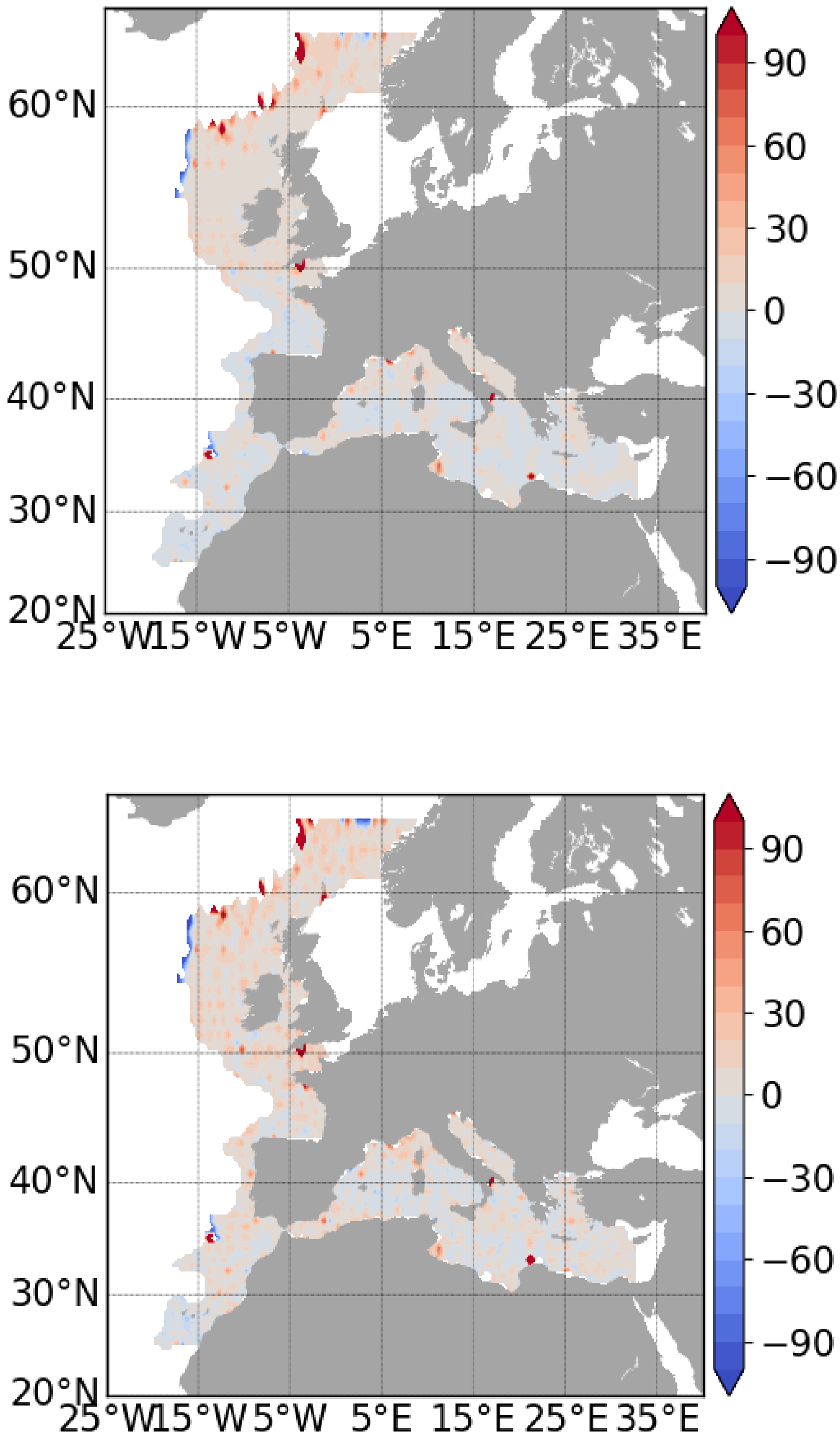


Figure 3 Adult distributions changes. A) RCP 4.5, MSY 0.6, 2050 and b) RCP 8.5, MSY 0.6, 2050

Climate-ready solutions

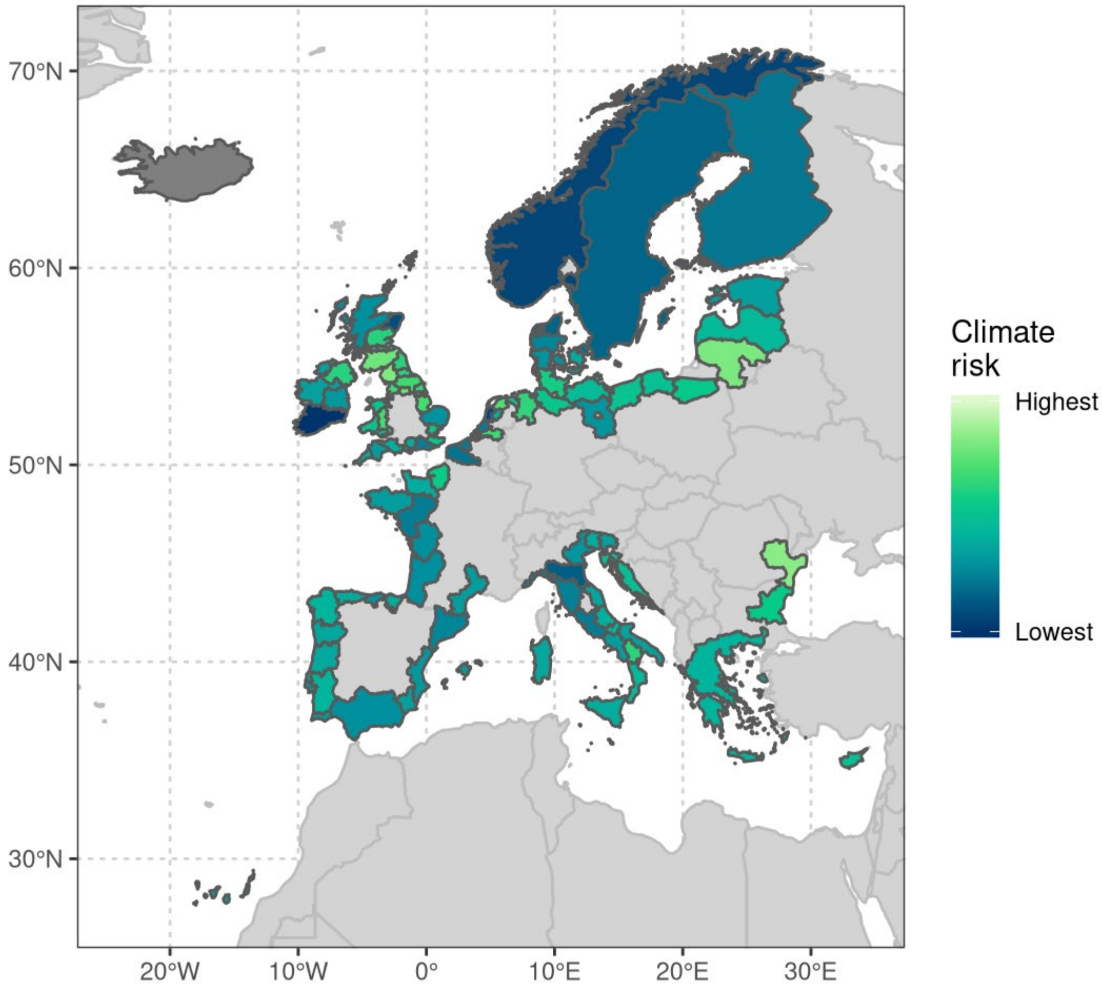


Figure 4 Map of the regional climate risk. Colour scale is linear in the value of the corresponding score, but is presented without values, as they have little direct meaning. National-level borders are shown for reference. *Credit : Mark Payne*

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.

Low climate hazards of the stocks are strengthened by the general nature (low exposure) and moderate-high profitability (low vulnerability) of the fleets.

For bottom-up - mitigation measures

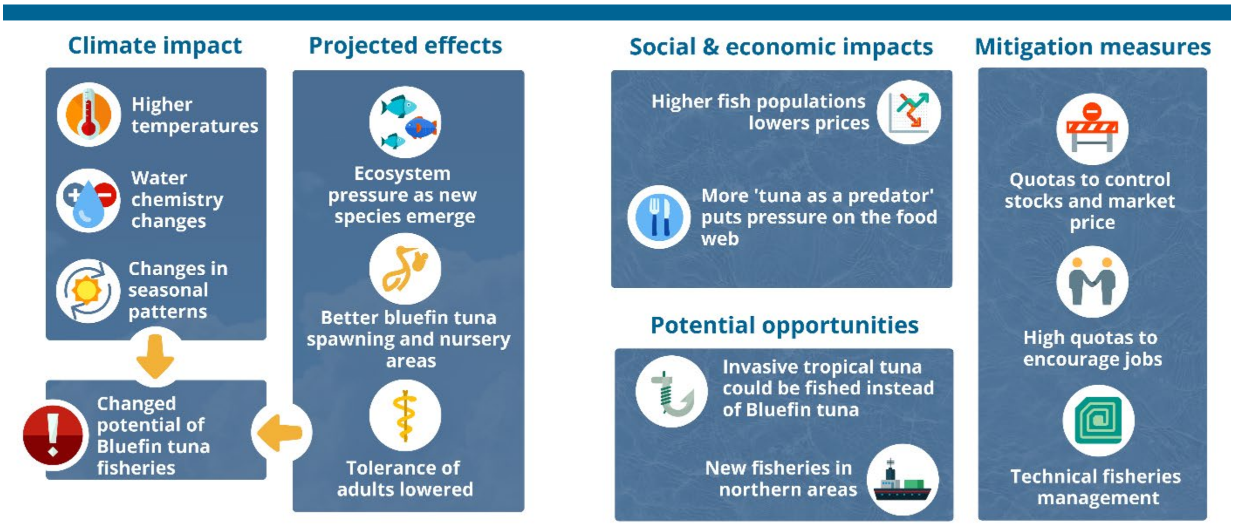


Figure 5 BowTie analysis based on stakeholder feedback. Full bowtie available http://bit.ly/CERESbowtieTuna

Policy recommendations

The Atlantic Bluefin tuna is managed at International level through ICCAT and it is not related to any specific national policy.

Due to concerns about the stock, in 2007 ICCAT established a multi-annual recovery plan for Atlantic Bluefin tuna now changed to a management plan since the stock is recovering. Therefore, at the moment, there is no policy that needs correction.

No policy has been developed specifically to account for potential effects of climate change in the species but the tight control of the stock through the management plans suggest the stock is being carefully monitored. National policies adopt what is decided at the stock level in ICCAT.

The multi-annual recovery plan included a drastic decrease in fishing quotas, control systems to avoid illegal fishing, increasing minimum size at capture, temporal and spatial closures for some of the fleets. They were all mandatory. Fishermen had to accept them. So there is already the experience where fishermen changed their catch.

However, this stock is having a lot of pressure to increase captures by many countries so we need to keep a careful eye on the trends of the stock and the associated management. The fleets that exploit this stock have a high adaptation capacity since many of them are industrial. The highest vulnerability will be shown by countries depending on the artisanal fisheries and effort should be directed towards ensuring the artisanal fisheries.

For this species, as for other large migratory species, we need structures that go beyond the national or regional scale. We need to work at the trans-oceanic level. They do not have any impact on this species since for this species it is needed a broader dimension than the national plans. In any case, the climate adaptation plans of Spain are not considering the impact of climate change on the fisheries in general.

The EU's common fisheries policy should ensure that data are collected for this species in their whole spatial distribution range (since distribution changes are envisioned), and should ensure fishery-independent indices are available that consider habitat changes.

It can also play a role for the interaction with other fisheries since a spatial change in the distribution of the species may lead to interaction with other fisheries.

Further reading

CERES publications

Reglero P., Balbín R., Abascal F.J., Medina A., Álvarez-Berastegui D., Rasmuson L., Mourre B., Saber S., Ortega A., Blanco E., de la Gándara F., Alemany F., Ingram G.W.Jr., Hidalgo M. 2018. Pelagic habitat and offspring survival in the Eastern stock of Atlantic bluefin tuna. *ICES Journal of Marine Science* 2018. Doi:10.1093/icesjms/fsy135

Reglero P., Ortega A., Balbín R., Abascal F. J., Medina A., Blanco E., de la Gándara F., Álvarez-Berastegui D., Hidalgo M., Rasmuson L., Alemany F., Fiksen Ø. 2018. Atlantic bluefin tuna spawn at suboptimal temperatures for their offspring. *Proceedings of the Royal Society B: Biological Sciences*, 10, 285(1870). pii: 20171405. doi: 10.1098/rspb.2017.1405.

Reports and Online sources

www.planettuna.com