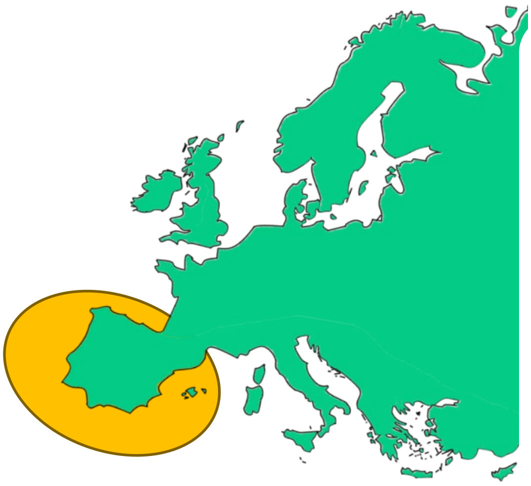
Case study



#12 Seabass and seabreem in the Western Mediterranean and south Atlantic

#13 Seabass and seabreem in the eastern Mediterranean

Species background and economics

Gilthead seabream (*Sparus aurata*) and European seabass (*Dicentrarchus labrax*) are the main marine finfish species currently farmed on a large scale in southern Europe.

They are common throughout the Mediterranean Sea and are also found along the eastern Atlantic coast, from the United Kingdom to the Canary Islands (seabream) or from Norway to Senegal (seabass).

In the 1980s, both species were successfully reproduced in captivity and intensive rearing systems were developed (especially sea cages or land-based tanks).

The seabream and seabass prevailing production techniques in this area are floating net cages consisting of only on-growing stage involving all processes concerning feeding fingerlings up to fish (Figure 1).

On average, seabream reaches commercial size after one and a half years, whereas seabass is generally harvested when they weigh 300 g to 500 g, which takes from 1.5 years to 2 years, depending on water temperature. The total aquaculture production of seabream and seabass in Europe was around 443,412 tons in 2018[1,2].

The first-sale value of seabream and seabass in Mediterranean aquaculture was 2,094 million € in 2018[1,2].

The main producer's countries in West Europe were Spain, Italy and France.

Spain harvested volumes of 14,930 tons of seabream and 22,460 metric tons of seabass in 2018 and thereby ranked third within European production for that year[2,3].

Figure 1 Aquaculture cages for seabream in the Canary Islands (Spain) *Credit: IEO*

Expected projections under climate change

Projections of climate-driven changes in key environmental parameters in European marine waters, have been made for Representative Concentration Pathways (RCPs) 4.5 and 8.5, i.e. lower and higher carbon concentrations[4].

Sea surface temperatures (SSTs) are projected to increase ~ 3°C during the century, with greater increases in the Western Mediterranean (FAO 37.1) than in the Atlantic coasts of southern Europe (FAO 34.1 and 27.9).

The average increase under the World Market Scenario (RCP 8.5) is about 3°C in the Mediterranean Sea and up to 2°C for the Atlantic areas of southern Europe. Increases under the Global sustainability scenario (RCP 4.5) are roughly half those under RCP 8.5, and differences between RCPs 8.5 and 4.5 only start to emerge after about 2040 (Figure 2).

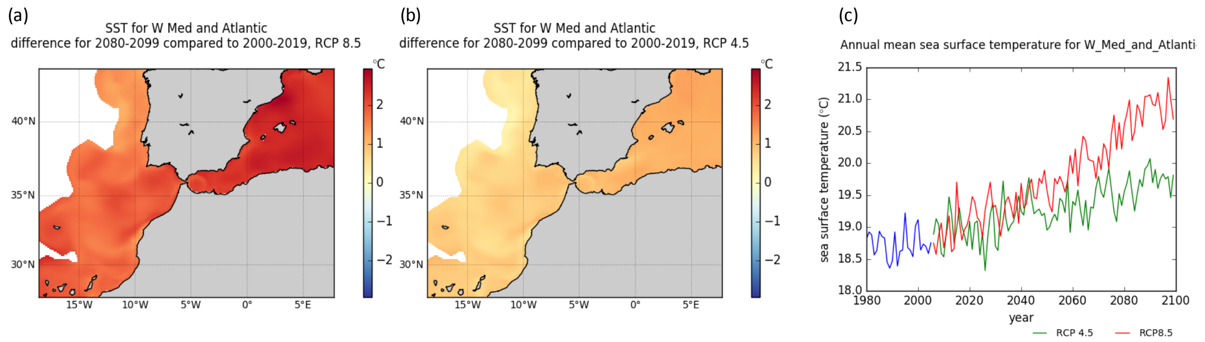


Figure 2 Projected changes in sea surface temperature for Western Mediterranean/Atlantic coasts of Southern Europe. Mean temperatures for mid and end-century under RCP 8.5 (a) and RCP 4.5 (b). (c) Annual mean for the same region

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

Four socio-political storylines have been developed, that differ in their focus on consumerism versus environmental goals and their entrenched versus international outlook:

1. Global Sustainability (RCP 4.5 & SSP1)
2. Local Stewardship (RCP 6.0 and SSP2)
3. National Enterprise (RCP 8.5 and SSP3)
4. World Markets (RCP 8.5 and SSP5)[5].

Aquaculture plays a very significant role in the development socioeconomic of the coastal areas in the Western Mediterranean and Atlantic Coasts of Southern Europe, in addition to the preservation of the maritime and fishing culture.

Focus on Spain, aquaculture is an economic activity that has a wide tradition and socially relevant in many of its coasts. This primary sector, of which this country is the main producer in the European Union, is made up of micro, small and medium fish farms.

Under World Market Scenario (RCP 8.5), intense expansion in cage culture (seabream and seabass) is expected in this area but large-scale marine aquaculture facilities operated by a small number of multinational companies.

The need for higher initial capital investment for more robust cages and mooring systems resistant to extreme storms and waves will increase in costs for the design of new facilities.

The population would be exposed to the variation in employment, by the destruction of jobs and by changes in the proportion of local and temporary workers. It would also important the variation of access to the product by the consumer in the market by an increase in sale prices.

However, bearing in mind that the strategy for the Sustainable Development of Spanish Aquaculture[6] promotes in Spain the development of sustainable and environmentally friendly aquaculture activity, the most plausible scenario in this region would be the Global Sustainability Scenario (RCP 4.5).

Under this scenario, a decrease in the human population in these areas is expected along with a concomitant decrease in per capita consumption of fish products. 'Co-location' of large-scale aquaculture facilities together with offshore windfarms will be promoted with higher investments in offshore aquaculture.

This version of the future would also see attempts to reduce the reliance on wild-caught fish stocks to produce fishmeal and fish oil.

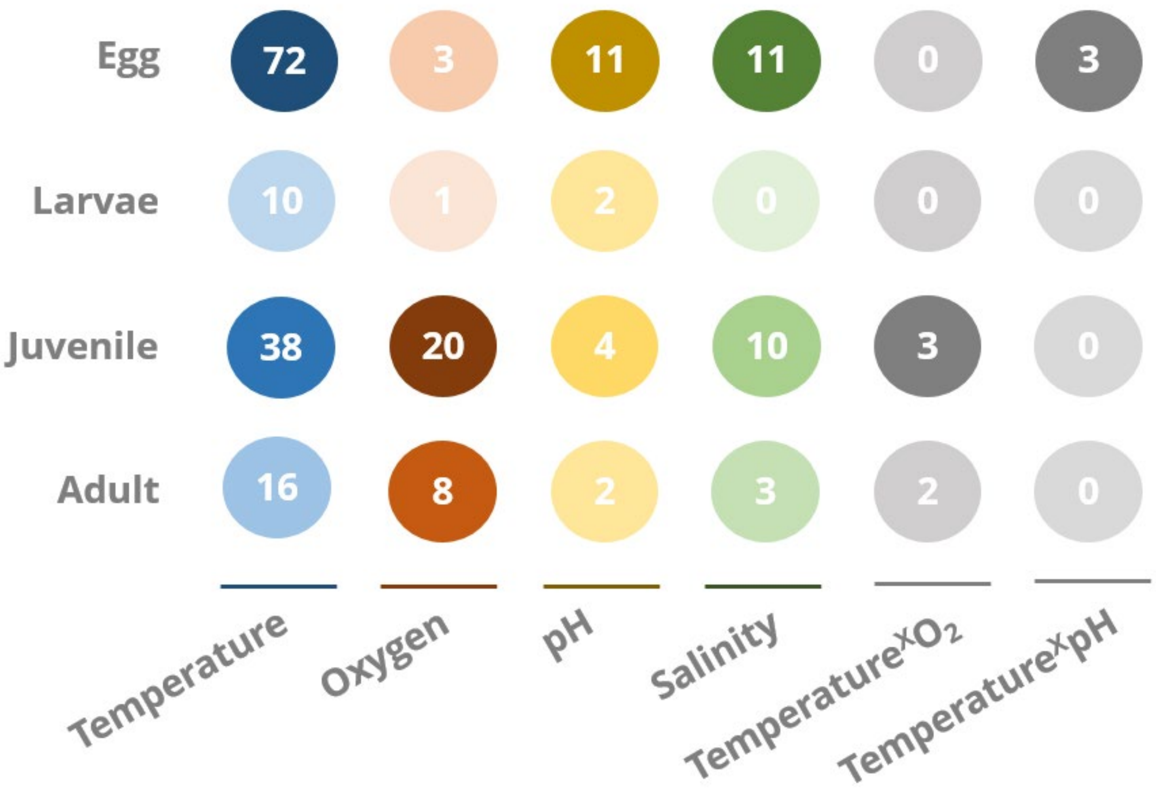
Key research needs

- Production systems that safeguard animal optimal condition and that take sufficiently care about the preservation of the surrounding environment: good water quality, responsible handling routines, and minimization of escapes.
- More research efforts in fish farm engineering and farming systems Development of more robust equipment as well as a larger degree of automation for operations such as feeding and maintenance. Development of new systems to fix the fish cages which makes them more resistant to waves.
- Increasing knowledge of physiological changes in aquatic species as a consequence of climate change. Selective breeding for tolerance higher temperatures.
- Control of new diseases and implementation of biosecurity programs.
- Finding sustainable and efficient alternatives to reduce dependency on wild stock for farmed fish feed production. Substitution of fish oil and fish meal; new feed formulas in accordance with the ecosystem.
- Spatial planning for aquaculture zoning and site selection modelling tools to manage competition for space in coastal areas.
- Development of risk management systems. A meteorological forecast that warns with sufficient advance and precision of the possibility of extreme weather events (torrential rains), together with the development of response protocols.

CERES research

- Modelled of environmental conditions and projected change for mid and end-century under different scenarios in Western Mediterranean and Atlantic coasts of Southern Europe.
- Literature review including an analysis of existing databases, general literature, unpublished data and grey literature on climate change related stressors and aquatic organism productivity and physiology on seabream and seabass.
- Conducted experiments on the direct effects of climate change on seabream and seabass including work on the upper thermal tolerance (CTmax) of European seabass larvae and juveniles, and the effect of temperature and feed restriction on the growth performance of juvenile seabream.
- Examined how direct (warming and acidification) and indirect (exposure to jellyfish and toxic algae) effects of climate change may interact to influence the productivity of farmed seabream.
- Utilized modelling tools to analyse climate-driven changes to aquaculture productivity at the individual and local- scale.
- Examined bioeconomic effects of climate change on farm-level productivity of seabream and seabass using the "typical farm approach".
- Updated a global fishmeal and fish oil (FMFO) model using data from FishSTAT, Comtrade, and Sea Around Us.
- Conducted a Bow-Tie analysis to conceptualize CC and other potential risks and stressors impacting fish farms for seabream and seabass in the Western Mediterranean and Atlantic coasts of Southern Europe.

Biological consequences



- Seabass ranked 8 out of 28 European fish and shellfish genera reviewed here (12 studies). Sea bream ranked 17 out of 28 (3 studies).
- 11 studies were done in the Western Mediterranean, 6 of them in Spain.
- Most studies focused on juveniles (6) and embryos (3)
- The most common response studied was growth (10) followed by mortality (5).
- The most common stressor studied was temperature (8).

Direct effects

Different experiments have been performed to a better understand the adaptive capacity of seabream and seabass to extreme temperatures expected under the scenarios 4.5 and 8.5:

Estimation of critical thermal limits (CTmin & CTmax) in seabream and seabass larvae and early juveniles. Early experiments reported no significant effect of heating rate on Critical Thermal Limits in seabass larvae. Experiments in seabass and seabream early juveniles observed a slight widening of the critical thermal window with size[7].

Effect of temperature on growth rate, survival and feed efficiency of juvenile bream (*Diplodus vulgaris*). Fish were subjected to warming conditions (+5ºC; 23ºC) during 56 days and compared to a control treatment (18ºC). Mortalities were not significantly affected by temperature. Yet, fish exposed to warmer temperature exhibited significantly higher weight and length[8,9].

Study of the combined effect of temperature and food in gilthead seabream juveniles. Alevins were reared at three different temperatures: 23º (control), 25º and 27ºC; and fed to two different ration sizes (optimum feeding rate and feed restriction) during 60 days (Figure 3A). No mortality was observed during the experiments. Higher temperatures promoted increased growth regardless of the food restriction. No significant effect of temperature increased on the coefficient of variation for weight and condition factor was observed. Higher temperatures promoted increased intake. In general, stress biomarkers were not significantly affected by temperature or feed restriction except lipid peroxidation[10].

Indirect effects

Two experiments were conducted examining mortality and disease resistance of seabream to indirect factors (jellyfish and toxic algal).

Experiments about acidification and jellyfish exposure impact on juvenile bream. *Diplodus vulgaris* juveniles were subjected to two levels of acidification conditions (7.7 pH and 7.3 pH) for 8 days (8 days of acclimation and 30 minutes of exposure) compared to a control treatment (8.0 pH) (Figure 3B). Fish were put in the same tank with the jellyfish *Aurelia coerulea* and the encounters with jellyfish registered to test the effect of pH fish larvae's ability to escape from jellyfish. Results showed that the number of encounters with jellyfish was higher in both acidification treatments compared to the control treatment. Acidification conditions result in a higher vulnerability of bream to jellyfish predation especially of larvae and juveniles[11,12,13,14].

Evaluate the impact of toxic algal exposure on farmed juvenile seabream under warming and acidification. Juvenile seabream was subjected to warming conditions (+3ºC and +6ºC; i.e. 21ºC and 24ºC) during 20 days of acclimation, 5 days of exposure where fish was fed with naturally contaminated mussels with paralytic shellfish poisoning toxins and 5 days of depuration. No mortalities or changes in swimming behaviour were registered throughout the experiment. Toxins were detected in fish only after 4 and 5 days. Significantly higher accumulation of toxins was only found at 24ºC. This work shows evidence that seawater warming may promote toxins accumulation in fish during harmful algal blooms[15,16].

As a summary of direct (temperature, pH, food) and indirect (HABs, jellyfish) effects of CC on seabream and seabass:

- Mortalities rates are not significantly affected by temperature, pH or feed restriction.
- Seawater warming promotes increased growth (SGR) regardless of food restriction.
- Seawater warming may promote toxin accumulation in fish during HABs.
- Acidification conditions result in a higher vulnerability of bream to jellyfish predation.

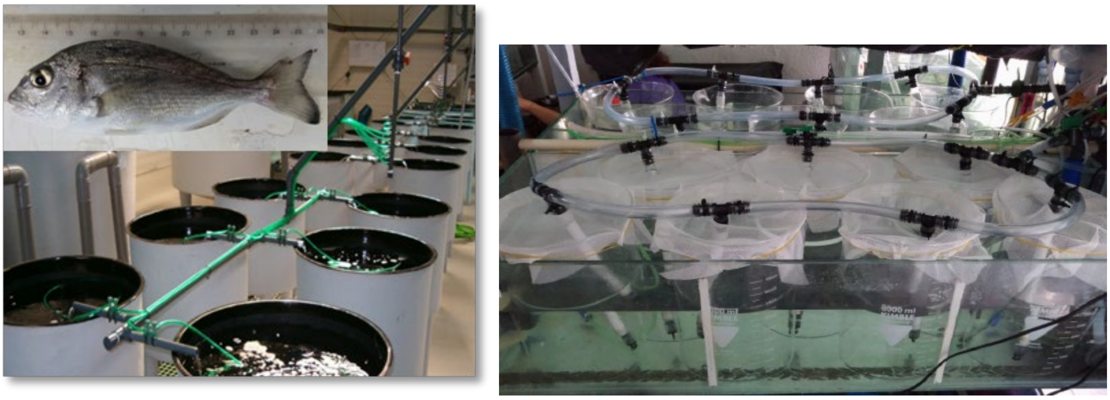


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Figure 3 Left - Experimental tanks and a seabream specimen at IEO facilities (*Credit: IEO*). Right - Experimental trial related to jellyfish exposure impact on juvenile bream (*Credit: Vera Barbosa*).

Modelling impacts on aquaculture productivity

We have used seabream growth models and the FARM population model to quantify the impact of climate change on the productivity and environmental effects of seabream farming in Western Mediterranean[17].

For that, we have simulated the culture practices of a typical seabream farm in Castellón, Spain (W Mediterranean). The seabream growth model and the FARM production model were validated against current conditions to match reported growth and production estimates in the typical Mediterranean farm.

The validated models were used to simulate present (2000-2019), mid-century (2040-2059), and late-century (2080-2099) conditions under two emission scenarios: RCP 4.5 –more conservative, and RCP 8.5 –more severe.

Seabream growth and profit tend to decrease as climate change progresses under both emission scenarios. These parameters always reach their minimum value under the high emission scenario (Figure 4A and 4B). In fact, fish do not reach harvest size in the far-future under the high emission scenario (Figure 4A) and the farmer would need to extend the culture period. Under both emission scenarios, the feeding efficiency of seabream diminishes as climate change progresses (i.e. the FCR increases).

Feeding efficiency is on average lower in the RCP 4.5 scenarios, except for the far-future where the average efficiency is similar for both emission scenarios (Figure 4C).

Under RCP 4.5, the consumption of DO through respiration, which reflects the energy expenditure of the animal, decreases over time (Figure 4D), but as this is combined with a reduced feeding efficiency the fish grow less.

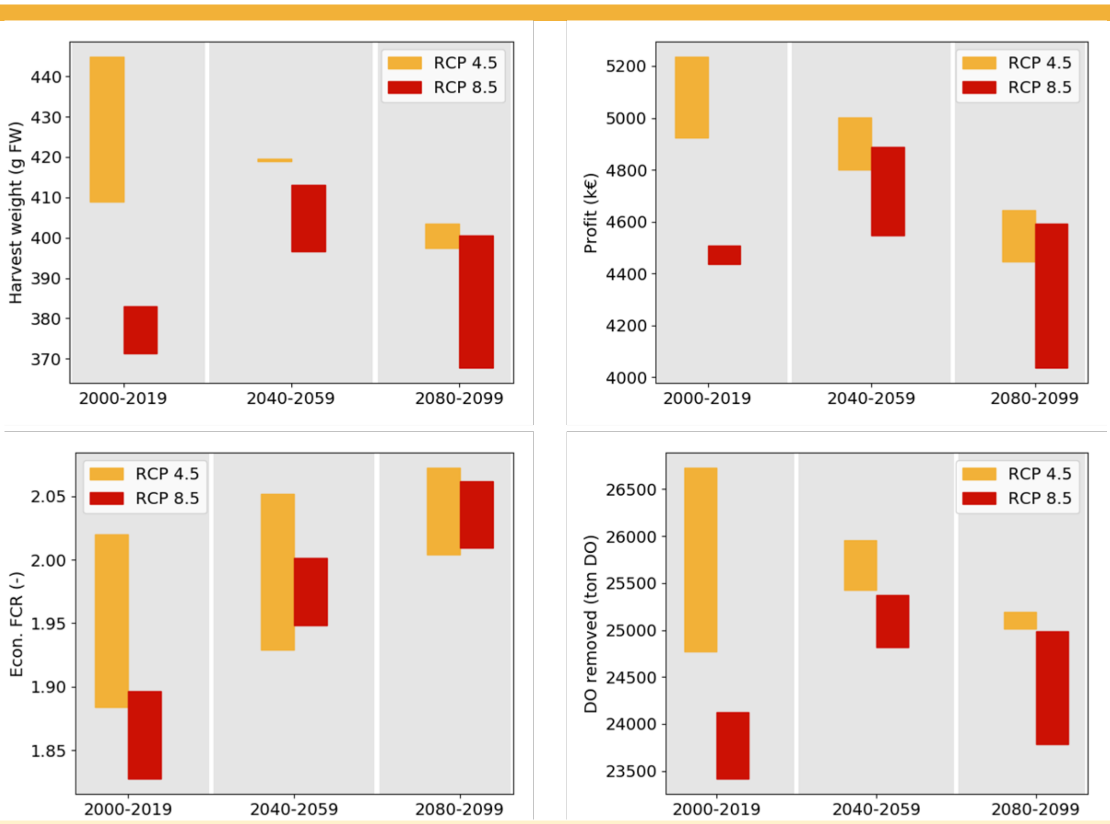

Figure 4 FARM outputs for the typical seabream farm in the Western Med under different climate change scenarios. Orange and red bars represent the range (spread) of simulation values for low- and the high- emission scenario, respectively. The drivers for the different climate change scenarios were obtained from the POLCOMS model as detailed in the text. LW: live weight; DO: dissolved oxygen.

Economic consequences

Effects of climate change on farm-level profitability-Typical farm approach

To represent the seabream and seabass sector in the Western Mediterranean and Atlantic Coasts of Southern Europe, a typical seabass farm was defined for the Canary Islands with an annual production of 1224 metric tons (ES-BSS-1224)[18].

The main cost factors are similar to other typical farms in the Eastern Mediterranean. Feed costs are most prominent (61.67% of overall cash costs) following by stocking costs (18.13%) and labour costs (9.16%) also rank within the five main cost factors.

In addition, maintenance of buildings and facilities, veterinary costs (TR) and insurance as well as other variable costs (ES) are important, whereas overall energy costs account for less than 0.5 % of the overall cash costs.

Profitability was calculated by considering feed conversion ratio and total harvestable biomass under RCP 4.5/8.5 environmental conditions from physiological models (WP 3) as well as projection ranges of energy prices (fuel, electricity) fish prices and fish feed price assumptions. The latter was based on a combination of different feed component prices (e.g. of agricultural products) from literature and the output of the global fishmeal and fish oil model[19].

This typical seabass farm for the Canary Islands achieves the highest profit margin among the farms analysed for this sector (39%), however, transport costs to the Spanish mainland for the first sale would be 34% higher, leading to a minimum profit margin of 29%.

Aquaculture production on the Canary Islands, however, also receives subsidies to balance higher costs of the insularity location as costs for supplies from the mainland are expensive and competition on the export market is hampered by high transport costs. Therefore, these European subsidies for ultraperipheral regions (POSEICAN programme for the Canary Islands) were also considered in the economic analysis.

This seabass farm shows increased profit under all scenarios when considering the future cost and price changes only, even if subsidies are no longer granted under the WM and GS scenarios as assumed within the analysis. LS scenario is the most favourable for this typical fish farm.

When considering future potential price variation of the uncertainty analysis, this typical farm has an overall >95% probability to increase profits under the WM, NE and LS scenarios when taking potential future price changes into account. However, under the GS scenario, there is a chance of profits reduced by 23% compared to today’s operating earnings when the future price development is unfavourable.

Compared to other production regions, the Canary Islands might have a production advantage due to current more stable water temperature conditions (18-24°C throughout the year) than in the Mediterranean, however, this would require further exploration before reliable conclusions could be drawn.

Most additional mid- and long-term costs for the Spanish farm are allocated to depreciation. In conclusion, this typical fish farm has an economic buffer on a long-term scale, which could, for example, be used to balance potential higher investments that might become necessary under future climate change impacts.

These could include investments in more robust equipment that endures extreme weather events or allows further automation of feeding and maintenance of the marine cage farms to reduce maintenance effort by staff. However, due to the ultraperipheral location of the Canary Islands, higher transport costs to the buyers' market must be considered as well.

These costs are partly balanced by subsidies, but in case they are no longer granted, for example under a WM scenario, this could lead to a local disadvantage.

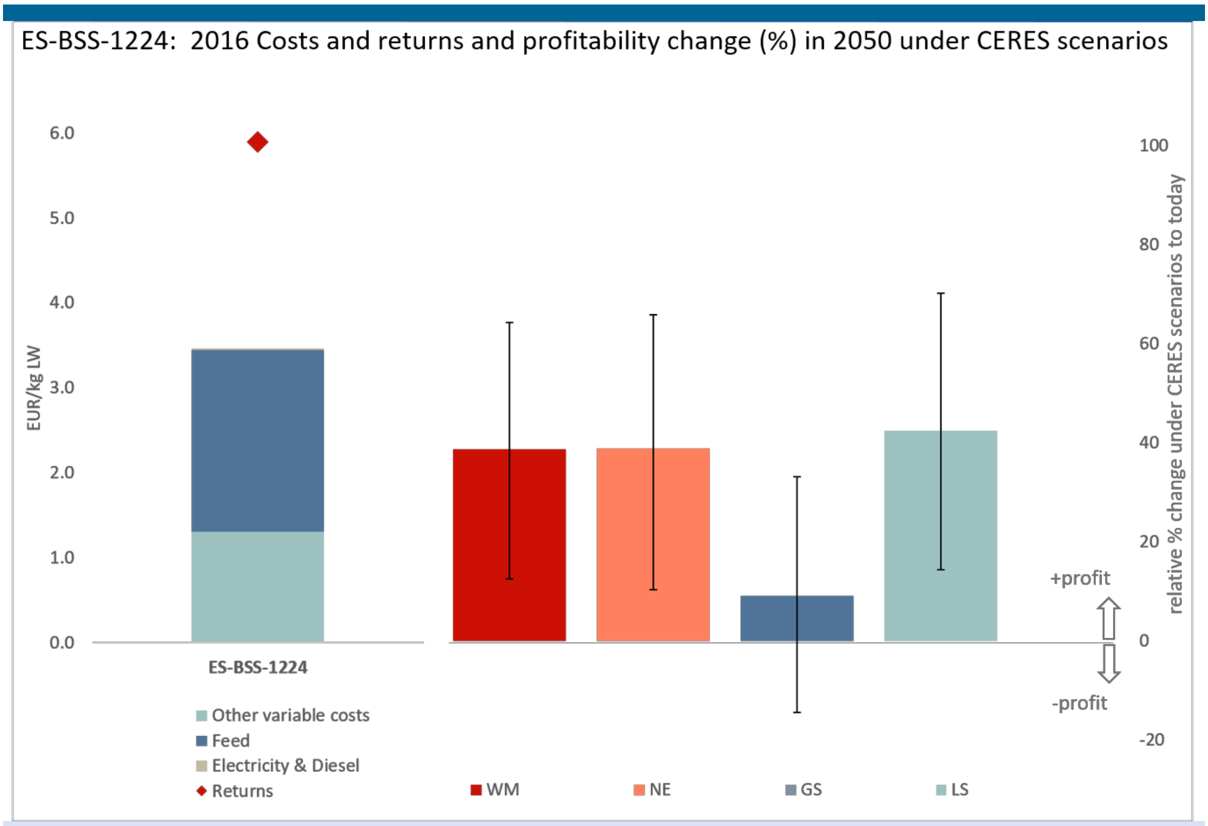

Figure 5 Stacked plot of cost and returns of typical Spanish seabass farm (ES-BSS-1224) in 2016 (left) and relative changes in profitability (returns against costs) in the year 2050 under the CERES scenarios World Markets = WM, National Enterprise = NE, Global Sustainability = GS, Local Stewardship = LS compared to today (right). Error bars indicate 95% upper and lower probability ranges from Monte Carlo simulation results on potential price variation.

Climate vulnerability

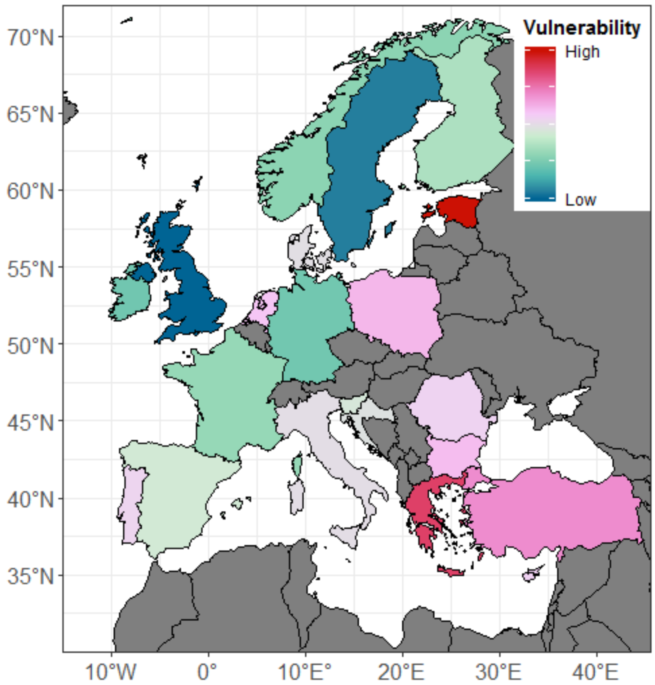

Figure 6 Climate vulnerability assessment for Europe. Colour scale is linear in the value of the corresponding score, but is presented without values, as they have little direct meaning. *Picture credit: Myron Peck*

- A climate vulnerability assessment (CVA) was conducted on the European aquaculture sector using the FAO model of Exposure + Sensitivity + Adaptive Capacity.
- The CVA included the physiological and farming methods of seven species (Atlantic salmon, seabass, seabream, trout, carp, mussels, oysters and clams) representing > 95% of the value for the region.
- Based on available economic data, the vulnerability of 22 countries – the top producers in the Europe28 as well as Norway and Turkey – was ranked and relative values are shown (right)
- By 2050 in RCP8.5, projected warming reduced the suitability of culture conditions for seabass and seabream in the Western Mediterranean Sea. Indirect threats of climate change (e.g. increases in disease or jellyfish blooms) were not included in this analysis.
- Many of the firms growing seabass and seabream in the Mediterranean region are relatively large and, therefore, have better adaptive capacity in terms of potential technological innovation in the future.
- National-level vulnerability was variable in the Western Mediterranean because countries had a different: i) level of economic reliance on aquaculture, ii) portfolio of species grown and iii) progress towards implementing climate adaptation plans.

Climate-ready solutions

Bow-Tie analysis was performed in order to conceptualize CC and other potential risks and stressors impacting fish farms for seabream and seabass in the Western Mediterranean and Atlantic coasts of Southern Europe (Figure 7)[20].

The Bow-Tie analysis was carried out using an online questionnaire that was completed by different stakeholders.

Results of bow-tie analysis showed that climate change may result in a decreased production potential for seabass/seabream in the W Mediterranean and S Atlantic.

Too high temperatures may result in an increase of pathogens and difficulties in reproduction increasing the costs for hatcheries.

The damage in the floating structures caused by the increase of storms may result in the net break and consequent fish escape. On the other hand, a saturation of the market with more adult fish may result in a decreased market price, changes in general industry structure and reduced employment.

Fisheries management strategies and government intervention in the form of quotas, subsidies or promotion of new species to consumers could help to mitigate some of the negative effects for producers. Also, the promotion of the use of native species could minimize the repercussions of the fish escapes on biodiversity.

New fast-growing native species as greater amberjack or meagre could be a good alternative. Meagre has a better growth rate compared to seabass and seabream and more tolerance to higher water temperature. This species could be a very good adaptation option for SBSB farming.

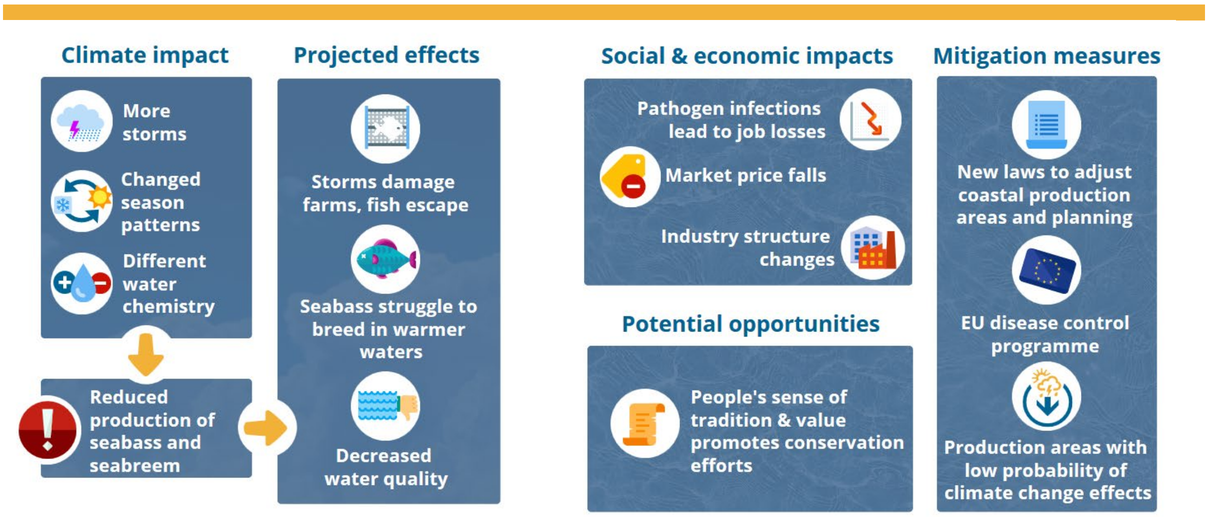

Figure 7 BowTie analysis based on stakeholder feedback. All full BowTies available http://bit.ly/CERESbowties2020

Policy recommendations

In order to local adaptation of the sector to climate change, it is necessary to streamline and simplify certain administrative procedures. The administrative rigidity and the slowness of the procedures make the administrative authorization procedure long and expensive. Also, difficulties to modify the essential conditions of the concession (occupied surface area and maximum authorized capacity), represent a huge burden on the arrival of new investors.

These improvements include the revision of the legislation that affects the new licenses and the concessions for the relocation of facilities, among others[21].

There is a need to integrate aquaculture with other sectors (fishing, agriculture, urban development) that share and use common resources (land, water, feed, etc.) and to concentrate on different spatial scales (farms, zones dedicated to aquaculture, the body of water)[22].

Proper planning and management of aquaculture sites can assist with the adaptation to climate change. To select the most appropriate sites, it is essential to determine the possible threats through a risk analysis[22,23]. Floating cages should be solidly fixed to the bottom or to a support structure, even using submersible systems that make them more resistant to waves.

The probability of dissemination of diseases can be limited by increasing the minimum distance between farms and implementing severe biosecurity programs in aquaculture complexes or areas.

Therefore, it will be necessary to establish specific support for the aquaculture sector to the improvement in the facilities in order to make them more resistant and the creation of specific insurance for the sector to cope with possible adverse impacts of extreme events[24].

Diversification of species can favour for natural selection and for adaptation[22]. The rearing of a larger number of species represents a form of insurance and offers better adaptation possibilities under different climate change scenarios, especially as to unexpected events such as diseases or problems related to the market. Development of techniques for rearing and production of the new species for aquaculture include the culture of lower trophic level species and the promotion of the use of native species to minimize the repercussions of the fish escapes on biodiversity.

Among emerging species could be found the meagre, which has a better growth rate compared to seabass and seabream and more tolerant to higher water temperature. Another new fast-growing native species of considerable interest for the industry is greater amberjack.

Finally, the implementation of an ecosystem approach in aquaculture should be the way forward to improve the governance of the sector[23]. The integrated multi-trophic aquaculture is an optimal way to implement this approach. It would be necessary the existence of economic and/or fiscal incentives at the national, regional and local levels to facilitate for entities that develop aquaculture with an ecosystem approach.

The productive sector does not know the current adaptation plans but considers the need to improve governance and financing lines[21]. Although no adaptation measures are being taken in response to climate change, they are considered for the future.

Further reading

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