CERES

Case study

#11 Meagre at the Atlantic coast

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

#13 Seabass and seabreem in the eastern Mediterranean

Species background and economics

Meagre (*Argyrosomus regius*) is an important resource, both for fisheries and aquaculture. This species is distributed along the Atlantic Northeast, Atlantic Eastern Central and Mediterranean Sea.

It is a fast-growing species, with high fecundity and may attain over 180 cm in total length and 50 kg in weight, reaching over 200€ per specimen.

These characteristics, make meagre particularly valuable for small-scale commercial and recreational fishers, as well as to the processing industry due to the diversity of products that can be developed (e.g. fillets, slices). Therefore, its production for aquaculture has been heavily promoted.

The total production of meagre in Europe attained 23,400 t in 2016, and a market average value of 7-12 €/kg for specimens above 2kg, thus representing a market value of €222 million. Meagre is produced in several Mediterranean countries (France, Italy, Spain, Egypt, Greece, Turkey, Malta and Portugal), mainly in cages but also in earth ponds.[1,2,3,4]

Its commercial size is above 1.5 kg that can be reached in only 15 months depending on temperature (sea bream reaches 400 g in the same time).

Growth is heavily depressed at water temperatures below 17°C, and seems to be optimal at 24°C.

Therefore, this emerging species might be a good option for farming in the Mediterranean Sea and Atlantic coast of Europe in a future, warmer climate.

Expected projections under climate change

CERES has examined the effects of two, carbon emission scenarios. In RCP (representative concentration pathway) 4.5, the carbon concentrations stabilise at ~650 ppm shortly after 2100 due to more rapid reduction of carbon emissions. In RCP 8.5, emissions create concentrations of carbon up to 1370 ppm[5].

Based on projections for eastern Atlantic and Mediterranean, sea surface temperature will increase up to 2°C for Atlantic coastal areas of southern Europe by the end of this century under RCP 8.5 (Figure 2b,c). Under scenario RCP 4.5, warming is about half that projected for RCP8.5 (e.g. 1°C) (Figure 2a,c)

Figure 1 *Argyrosomus regius* from aquaculture in SW Portugal. *Credit : Pedro Pousão-Ferreira*

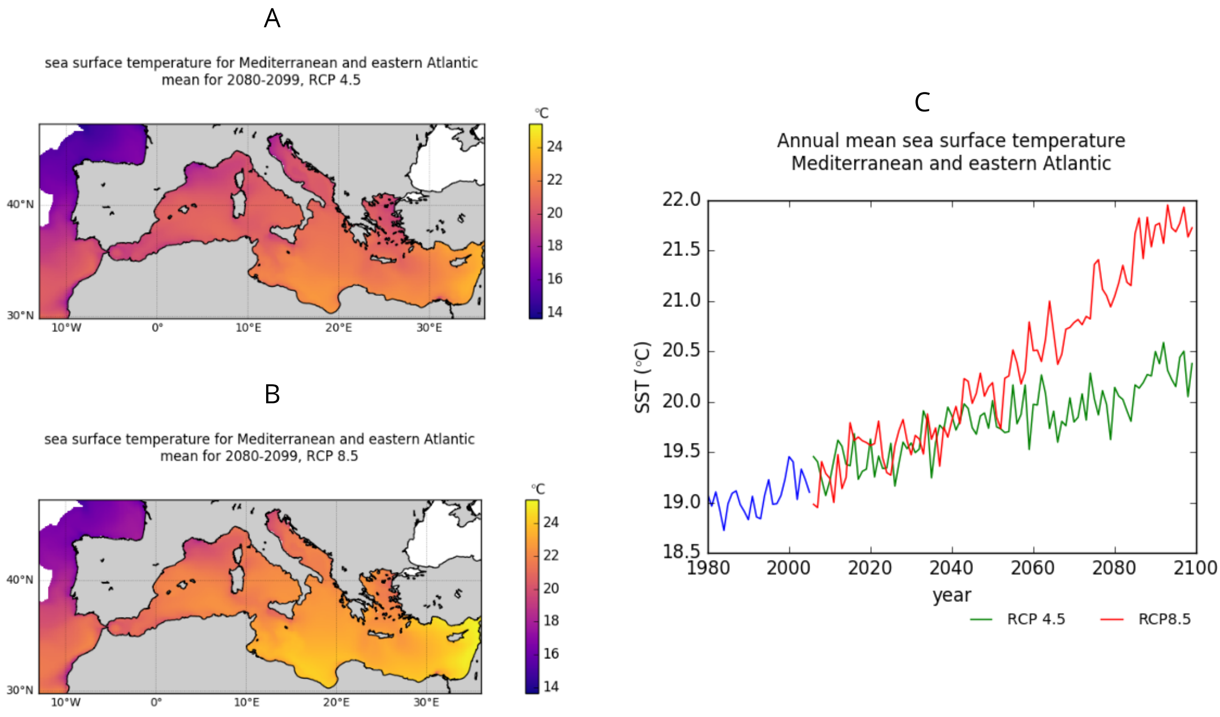


Figure 2 Projected change in sea surface temperature for the Southern European region (a,b) Mean temperatures for 2080-2099 compared to 2000-2019 under (a) RCP 4.5 and (b) RCP 8.5. (c) Annual mean for the same region. The white area at the left (a,b) is not part of the modelled domain.

The natural variability of sea surface pH in the Mediterranean and South Atlantic is rather large, due to the presence of contrasting coastal and open ocean environments and the ample seasonal change in temperature typical of mid-latitudes marine systems.

It is likely that local effects may offset the overall long-term acidification with a decrease reaching up to 0.4 in specific regions of the globe, but on average in the Mediterranean and South Atlantic region pH will only slightly diminish (up to 0.06) in the long term.

Sea surface salinity will increase up to 0.2 psu for eastern Atlantic and Mediterranean coastal areas of southern Europe by the end of this century under RCP 8.5, and up to 0.1 psu under RCP 4.5 (Figure 3a,b,c).

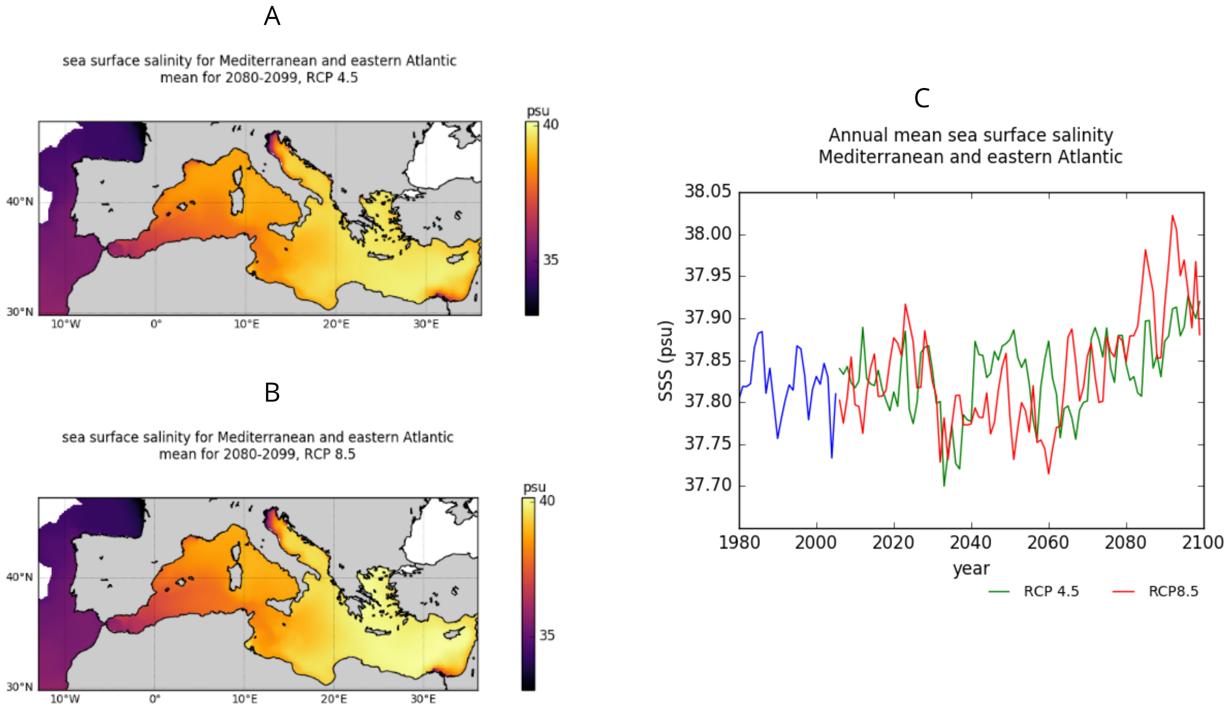


Figure 3 Projected change in sea surface salinity for the Southern European region (a,b) Mean sea surface salinity for 2080-2099 compared to 2000-2019 under (a) RCP 4.5 and (b) RCP 8.5. (c) Annual mean for the same region. The white area at the left (a,b) is not part of the modelled domain.

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 Portuguese government has defined aquaculture as strategic sector, and has established financial frameworks that hope to triple production (to 30,000 t) by 2023.

Under the four RCP scenarios[6], the projected seafood demand for Portugal decreases except in the World Markets Scenario (RCP 8.5, SSP5), where demand is projected to increase 100,000 t by 2100. This increase in demand is explained by the demographic and *per capita* GDP growth that is expected to occur under this scenario. Currently, both for the administrative and the environmental aspects, the expansion of aquaculture and other activities in this region has been highly regulated by the government. This includes monitoring for food security and disease.

The current scenario in this region seem to follow the direction of the RCP 4.5 Global Sustainability scenario, with increasing costs of production mitigated by valuing the product's quality and by efforts to achieve certification for sustainable aquaculture. The expected scenario for Southern Europe and Mediterranean aquaculture is the global sustainability scenario, protecting the public and preventing the deterioration of marine environments. Under this scenario, it is expected a strong decrease in human population, but a moderate economic growth in *per capita* GDP.

A decrease in *per capita* consumption of seafood is expected, following the decrease in human population growth, with major consequences for the future demand for marine aquaculture products and hence the need for fishmeal and fish oil.

Fish, fishmeal and fish oil are traded world-wide, but greater emphasis is placed on sustainable and ethical production. Binding international quality standards are reached and this results in strict regulation of aquaculture practices (e.g. chemical inputs, feed supply, etc.) as well as 'traceability'.

Ecolabel certification schemes assume greater prominence (e.g. organically produced, 'fair-trade', ethically produced, sustainably produced). Expansion of large-scale offshore aquaculture facilities together with windfarms offshore are expected, as well as wide-scale technology transfer between countries. It will become increasingly difficult to obtain licences to build new aquaculture facilities because of environmental concerns.

Key research needs

There is increasing interest in the culture of fast-growing, large marine fishes such as meagre as alternatives to the commonly cultured European sea bass and gilthead sea bream.

Meagre is resistant to bacterial diseases experienced by other marine species such as seabream and seabass[7], and has a higher optimal range in temperatures for the growth of juveniles (26-30 ºC) compared to sea bream (25 ºC) and sea bass (22-25 ºC)[8,9,10].

Meagre also allows the development of many value-added products to address the modern consumers who are increasingly looking for more convenient and ready-to-cook seafood products.

Climate change may boost production yields due to warm temperature tolerance, but it also poses threats to the aquaculture of this species due to exposure to parasites and ensuring optimal feed from sustainable sources while maintaining high nutritional quality.

To increase the production of meagre in aquaculture the following research is needed:

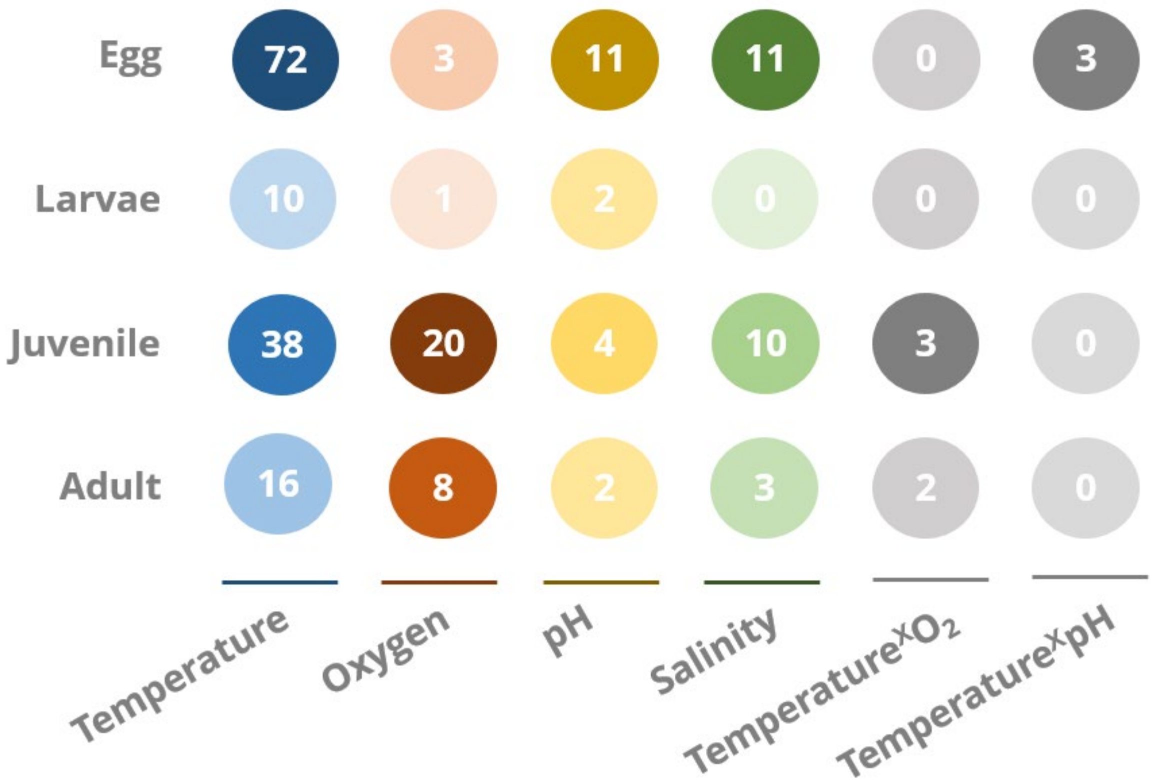
- Assess how drastic changes in environmental conditions may affect farmed meagre resilience.
- Investigate meagre behavioural changes induced by climate change that might affect species success.
- Understand how direct (e.g. warming, acidification) and indirect effects (e.g. diseases, jelly fish blooms, parasites) of climate change might affect the productivity of farmed meagre.
- Assess how climate change may influence farmed meagre quality and safety for consumers.

Figure 4 *Argyrosomus regius* juvenile meagre produced at IPMA aquaculture pilot station. Credit: Pedro Pousão-Ferreira, IPMA.

CERES research

- Reviewed the published research to identify gaps in knowledge on how meagre is affected by factors directly influenced by climate change (temperature, pH, oxygen and salinity)[11,12,13,14,15]
- Evaluated the effect of sudden environmental changes on survival and growth of larvae and post-larvae of meagre
- Assessed the effect of temperature on growth rate, survival and feed efficiency of juvenile meagre (Figure 4)
- Examined the combined effect of temperature, acidification and food on growth, survival and stress biomarkers of farmed juvenile meagre juveniles
- Examined the impacts of acidification and jellyfish exposure on the survival of juvenile meagre
- Engaged stakeholders to produce a Bow-Tie of the climate-driven risks and opportunities for meagre production.

Biological consequences



(Note that there are no datasets available on this species to provide any analysis)

Direct effects

The exposure of newly hatched larvae to sudden change in both temperature (T) and salinity (S) (- 3°C; - 10 psu) for 4 hours[16]. Both had decreased survival after 24 hours. Both T and the interaction of TxS resulted in a 14% decrease in survival compared to controls.
Decreases in S resulted in 9% decrease in survival. Juvenile meagre (4 g) subjected to projected (end of century) warming (+4ºC; 22ºC) during 30 days suffered no mortality and grew significantly faster[17].

At the warm temperature, both heat shock proteins and antioxidant enzymes were upregulated indicating stress.

Similarly, juvenile meagre (50 g) reared during 3 months at 20 or 24 °C suffered no mortality and fish at the warmer temperature had a 1.6-times higher specific growth rate, 1.4-times higher protein retention efficiency and 1.5-times lower food conversion ratio. Projected warming will, therefore, likely increase the growth performance of meagre.

Juvenile meagre (4 g) subjected to ocean acidification (-0.5 pH; i.e. 7.5 pH or pCO_2 1500 µatm) during 30 days suffered no mortality and exhibited no major changes in weight and length compared to controls.

Acidification played a minor role in catalase activity, whereas generally provoked slight increases in the antioxidant activity.[17] However, when combined with other stressors such as warming, acidification antagonized the co-occurring stressor effect (Figure 5).

As far as behaviour is concerned, acidification significantly affected fish behaviour (e.g. decreased fish exploration and shoal cohesion, and reversed fish preference to turn leftwards compared to control conditions) that may translate into deleterious ecological impacts.[18]

In contrast, the combination of warming and acidification reduced shoal cohesion and loss of lateralisation.

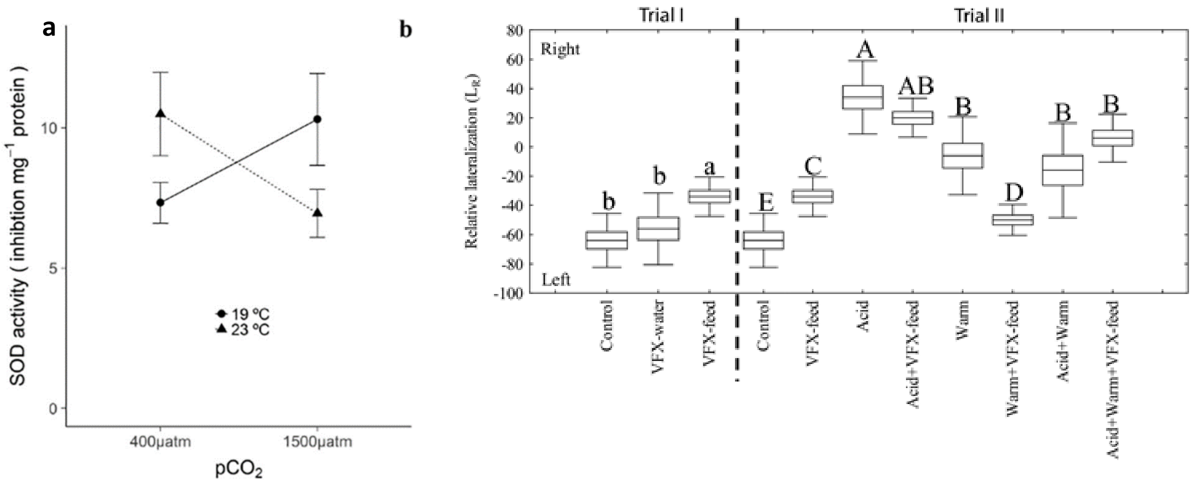


Figure 5 a) Super oxidase dismutase activity in *A. regius* muscle of juvenile meagre produced at IPMA aquaculture pilot station under warming and/or acidification[17]. b) Relative lateralization in *A. regius* after 28 days of exposure to VFX, warming and acidification. Different lower-case letters indicate significant differences between treatments in Trial I, whereas upper case letter indicate significant differences between treatments in Trial II ($p < 0.05$). Abbreviations: Acid – simulated acidification; Warm – simulated warming; VFX-water – fish exposed to VFX via water; VFX-feed – fish exposed to VFX via feed[18].

Indirect effects

Juvenile meagre (2.0-2.5 cm total length) were maintained at 18ºC two levels of ocean acidification (7.7 pH and 7.3 pH) for 8 days and then exposed to the jellyfish *Aurelia coerulea* (4-7 cm bell diameter) for 30 min.

This test the effect of pH on the ability of fish larvae to escape from jellyfish (Figure 6).[19]

No fish mortality was observed, but the number of encounters with jellyfish was higher in both acidification treatments compared to the non-acidified treatment (Figure 7). As far as fish oxidative and thermal stress responses are concerned, generally acidification led to significantly increased levels of heat shock proteins (HSP), catalase (CAT) and glutathione S transferase (GST), and decreased levels of lipid peroxidase (LPO).

In contrast, for jellyfish, acidification treatments induced significantly higher levels of HSP and GST in mesoglea and gonads.

Under acidification conditions the increased number of encounters with jellyfish will likely led to a higher vulnerability of meagre to jellyfish predation especially of larvae and juvenile specimens.

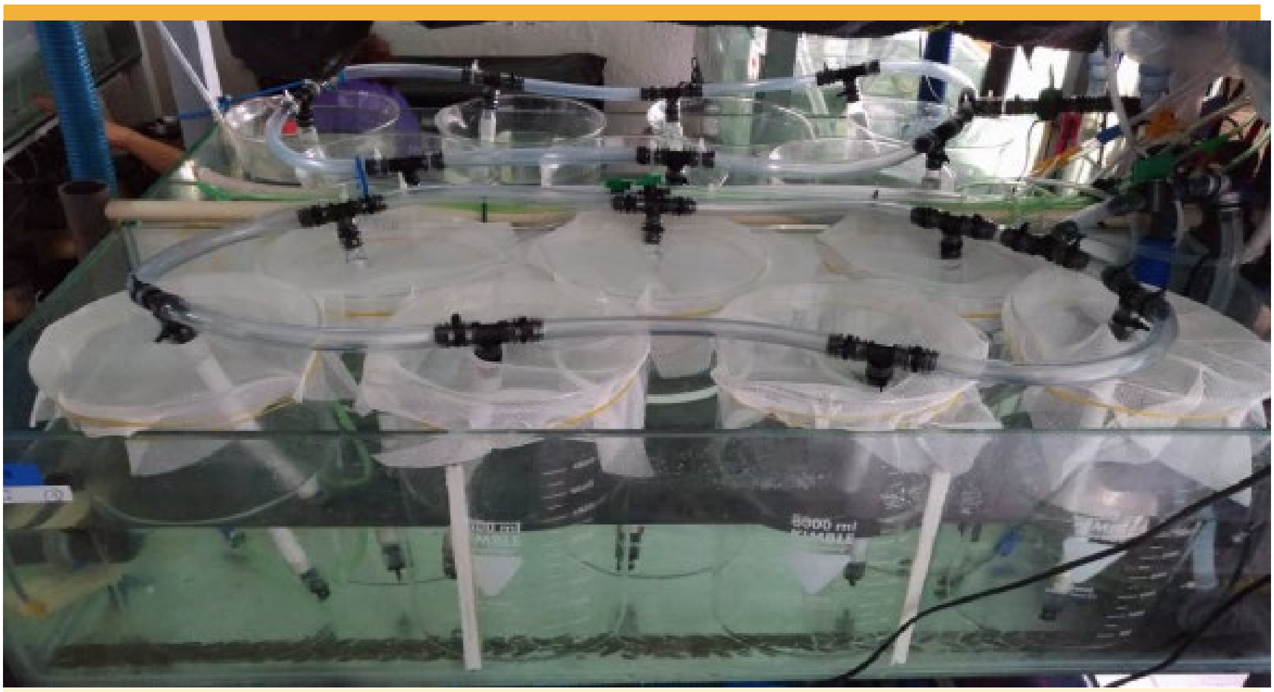


Figure 6 Experimental trial related to jellyfish work with meagre. *Credit: Vera Barbosa, IPMA*

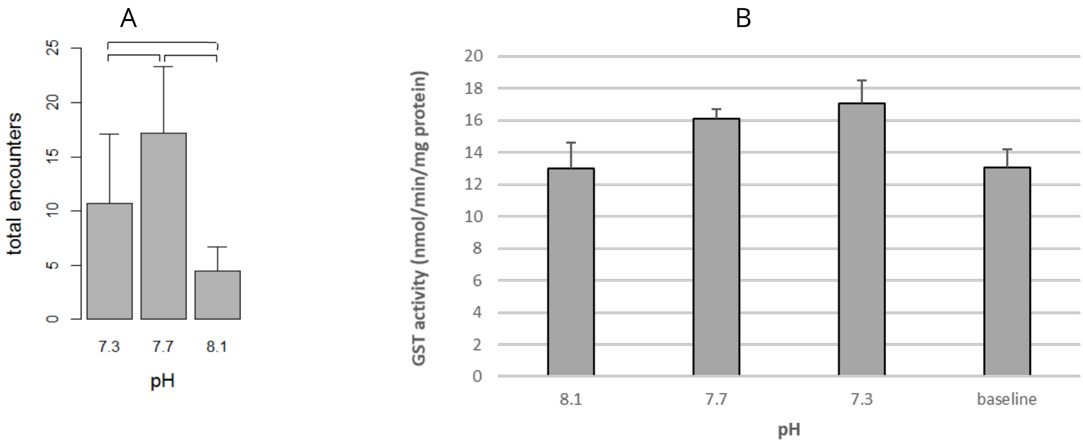


Figure 7 a) Number of encounters between meagre and jellyfish at different pH[19]. b) Gluthathione S transferase activity in jellyfish under acidification[19].

Fish reared in earth pond systems are greatly influenced by the seasonality of weather conditions.

The occurrence of diseases (e.g. parasitosis, vibirosis) have a higher incidence during summer (north hemisphere) with higher temperatures[20].

Compared to other species, meagre is less susceptible to diseases (e.g. amylodinioses – *Amylodinuium occellatum*), but drastic environmental changes can negatively affect fish condition. The expected increase of water temperature might result in 30% higher risk of amylodiniososes occurrences that may affect meagre production.

Climate-ready solutions

Bow-tie analysis is one of the adopted risk assessment techniques of IEC/ISO 31010.

The Bow-Tie for this storyline was built based on an online questionnaire that included the contribution of 3 stakeholders.

The resulting Bow-Tie (Figure 8) has been discussed with stakeholders (e.g. Associação Portuguesa de Aquacultores, APA) for validation and updating of the current information. The main causes and drivers for changes to meagre aquaculture production potential were identified, as well as the potential consequences, mitigation and opportunities.

For bottom up, the two most relevant mitigation measures identified were: a) Technology: new RAS facilities/sea cages adapted to stronger storms/fighting new diseases (requires financial input from companies or government); and b) Government incentives: fiscal benefits for those who present “green” farming strategies (requires government to commit financially).

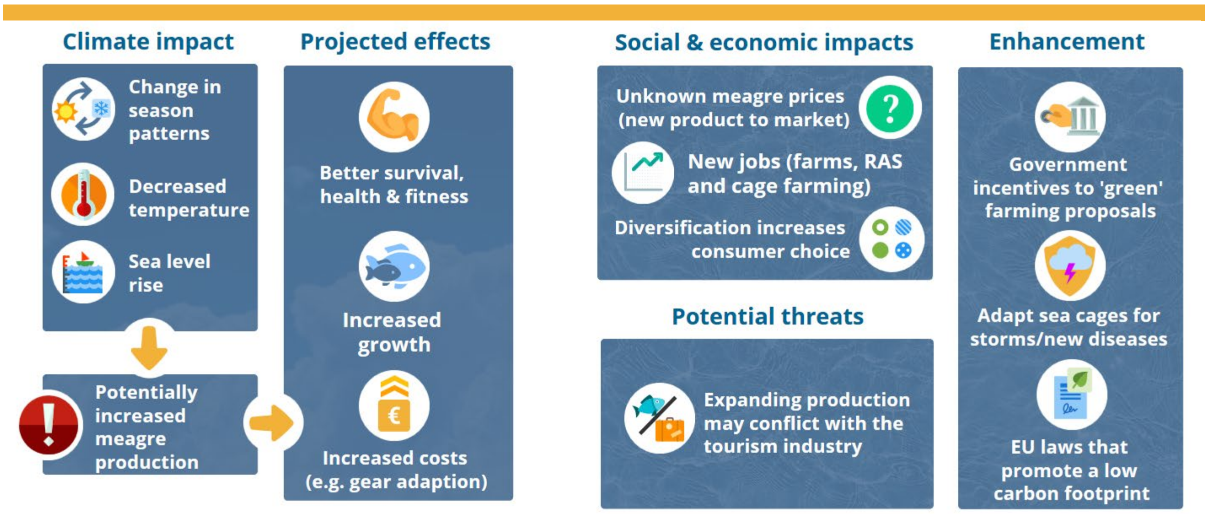


Figure 8 BowTie analysis based on stakeholder feedback. All full BowTies available http://bit.ly/CERESbowties2020

Policy recommendations

The list below shows some stakeholder that are involved in supporting the aquaculture of meagre in Europe.

In order to overcome current and future problems related to meagre aquaculture, extensive collaboration between these stakeholders needs to be encouraged to promote the successful expansion, sustainability and social acceptance of this industry:

1. State and EU Government support through policy and funding
2. Entrepreneurs and investors (e.g. Fish Farmers and associations)
3. Institutions providing governance for the industry (e.g. Directorates for the Management of Natural Resources, Environmental Agencies, Governmental Research Institutions, Food and Veterinary Authorities
4. Other institutions related indirectly with governance of offshore and inshore aquacultures
5. Access and funding to local educational and research institutes (e.g. Universities)
6. Communication and interaction with other local businesses and associations, as well as individual citizens

The main top-down policy recommendations for the meagre farming industry are the following:

- Adopt new legislation on animal welfare (e.g. ensuring the utilization of sustainable ingredients in feeds focused on meagre production) and adjust coastal production areas according effects on meagre productivity with the involvement of local/regional governmental bodies
- Control programmes for meagre diseases and parasites
- Stimulate quality label certification schemes able to differentiate sustainable and high quality meagre products for the market

Further reading

Non-CERES publications

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[4]Ribeiro, L., Moura, J., Santos, M., Colen, R., Rodrigues, V. Bandarra, N., Soares, F., Ramalho, P., Barata, M., Moura, P., Pousão-Ferreira, P., Dias, J. 2015. Effect of vegetable-based diets on

growth, intestinal morphology, activity of intestinal enzymes and haematological stress indicators in meagre (*Argyrosomus regius*). Aquaculture, 447: 116–128.

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[8]Mehmet, K., Murat, S., Barış, A. 2017. Thermal tolerance and preferred temperature range of juvenile meagre acclimated to four temperatures. Journal of Thermal Biology. 65.

[9]Dülger, N., Kumlu, M., Türkmen, S., Ölçülü, A., Eroldoğan, O.F., Yılmaz, H.A., Öçal, N. 2012. Thermal tolerance of European Sea Bass (*Dicentrarchus labrax*) juveniles acclimated to three temperature levels. Journal of Thermal Biology, 37(1): 79-82.

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[15]Saavedra, M., Pereira, T.G., Sousa, S.B., Mendes, A.C., Pousão, P. 2018. Combined effect of temperature and dietary protein on meagre, *Argyrosomus regius*, juveniles growth and muscle cellularity. World Aquaculture 2018, Montpellier, France.

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[6]Pinnegar, J.K., Engelhard, G.H., Eddy, T. 2018. CERES Deliverable D1.2 Final report on exploratory socio-political scenarios for the fishery and aquaculture sectors in Europe, European Commission Grant Agreement Number: 678193, 62pp.

[16]Ribeiro, L., Castanho, S., Almeida, C., Silva, A., Candeias-Mendes, A., Pousão-Ferreira, P. 2018. Extreme climatic events on the survival of newly hatched larvae of marine fish species. Book of Abstracts- LACAQUA 2018 - Aquaculture for Peace, 23-26 October, Bogota, Colombia.

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