This publication is part of PTQ2020-011287, funded by MCIN/AEI/10.13039/501100011033 and by the European Union NextGenerationEU/PRTR.

ECOAZUL - MED

Policy Recommendations on adaptation in the current context of climate change in the Spanish Mediterranean coast for the sectors of aquaculture, fishing, and coastal tourism

ALBA DE LA VARA

This publication is part of PTQ2020-011287, funded by MCIN/AEI/10.13039/501100011033 and by the European Union NextGenerationEU/PRTR

MINISTERIO DE CIENCIA E INNOVACIÓN

Financiado por la Unión Europea NextGenerationEU

Plan de Recuperación, Transformación y Resiliencia

AGENCIA ESTATAL DE INVESTIGACIÓN

Index

1. The ECOAZUL-MED project

Current trends of overexploitation and degradation of marine and coastal ecosystems demonstrate that measures taken to ensure sustainable development are insufficient. This problem is aggravated in the current context where, according to the 5th report of the Intergovernmental Panel on Climate Change (IPCC), **the temperature increase observed since the 1950s will continue unequivocally and irreversibly in the coming decades** due to greenhouse gas emissions. Throughout this century, continued greenhouse gas emissions will cause further warming and new changes in all components of the climate system. Oceans have absorbed more than 90% of the additional energy generated between 1971 and 2010 and 30% of anthropogenic CO_2 emissions. From 1900 to 2016, surface waters, considered those from the surface to a depth of 700 meters, warmed globally at an average of about 0.7°C per century. This progressive warming will inevitably impact different sectors of the **blue economy**, defined by the European Commission as activities associated with seas, oceans, and coasts. These economic losses will particularly affect sectors exposed to climate conditions, such as fishing, aquaculture, tourism, or energy, with adverse effects on gender and social equity (IPCC, 2023).

The **Mediterranean region** is considered by the scientific community as a *hotspot* of Climate Change because it provides an amplified warm climate signal (Giorgi, 2006). Additionally, this region is highly favorable for the development of extreme weather events (e.g., heatwaves, heavy precipitation). In the coming decades, climate models project an increase in the frequency and/or intensity of these events (Darmaraki et al., 2019; González-Alemán et al., 2019; IPCC, 2019). These factors make densely populated Mediterranean coasts, such as the Spanish eastern coast, susceptible to suffer negative impacts on the blue economy, with consequent socioeconomic losses. The blue economy is an essential source of wealth and prosperity for the Mediterranean, as it provides opportunities for growth, employment, and investment. Therefore, the development of a strategic vision for sustainable development, as well as the guarantee of policies and actions aimed at promoting the blue economy, are of vital importance in the current context of climate change.

Specifically, aquaculture, fishing, and tourism are relevant sectors of the blue economy as they have traditionally contributed to social and economic development on the Spanish Mediterranean coast. Indeed, tourism is one of the largest sources of income nationally. In particular, in our country, tourism, in general, accounted for 12.4% of GDP in 2019[1], with a greater weight observed in coastal communities that promote "sun and beach" tourism. Aquaculture also constitutes a vital economic activity nationally, with a harvest of 327,309 tons and a first-sale value of 629 million euros[2] in 2021. The Spanish fishing sector ranks first in the European Union, both in volume and economic[3] value. Coastal areas are characterized by their great appeal to the "sun and beach" tourism industry and "nature sports tourism", which represents a significant portion of the economy in coastal countries.

Currently, the availability of solid and reliable information from systematic research on the impact of climate change on the blue economy is limited. In this sense, the only available tool to obtain such information is climate models used for future climate projections. The ECOAZUL-MED project aims to generate, for the first time, a publicly accessible web tool that provides climate information from high-resolution regional climate simulations, allowing anticipation of the effects of climate change on aquaculture, fishing, and tourism under different emission scenarios for the next 40 years in the Spanish Mediterranean coast. This will make relevant climate information available to society (businesses, public administration, and other stakeholders) for planning these economic activities and highlighting the need for adaptation to climate change in the coming decades on the Spanish coast, which is essential to ensure sustainable development. Moreover, it is important to emphasize the relevance of considering comprehensive approaches in this type of analysis that not only include environmental scientific-technical elements but also frame within an adequate study of relevant social, economic, and contextual characteristics to estimate the effects that such projections may have and assist in making more effective decisions (see Figure 1).

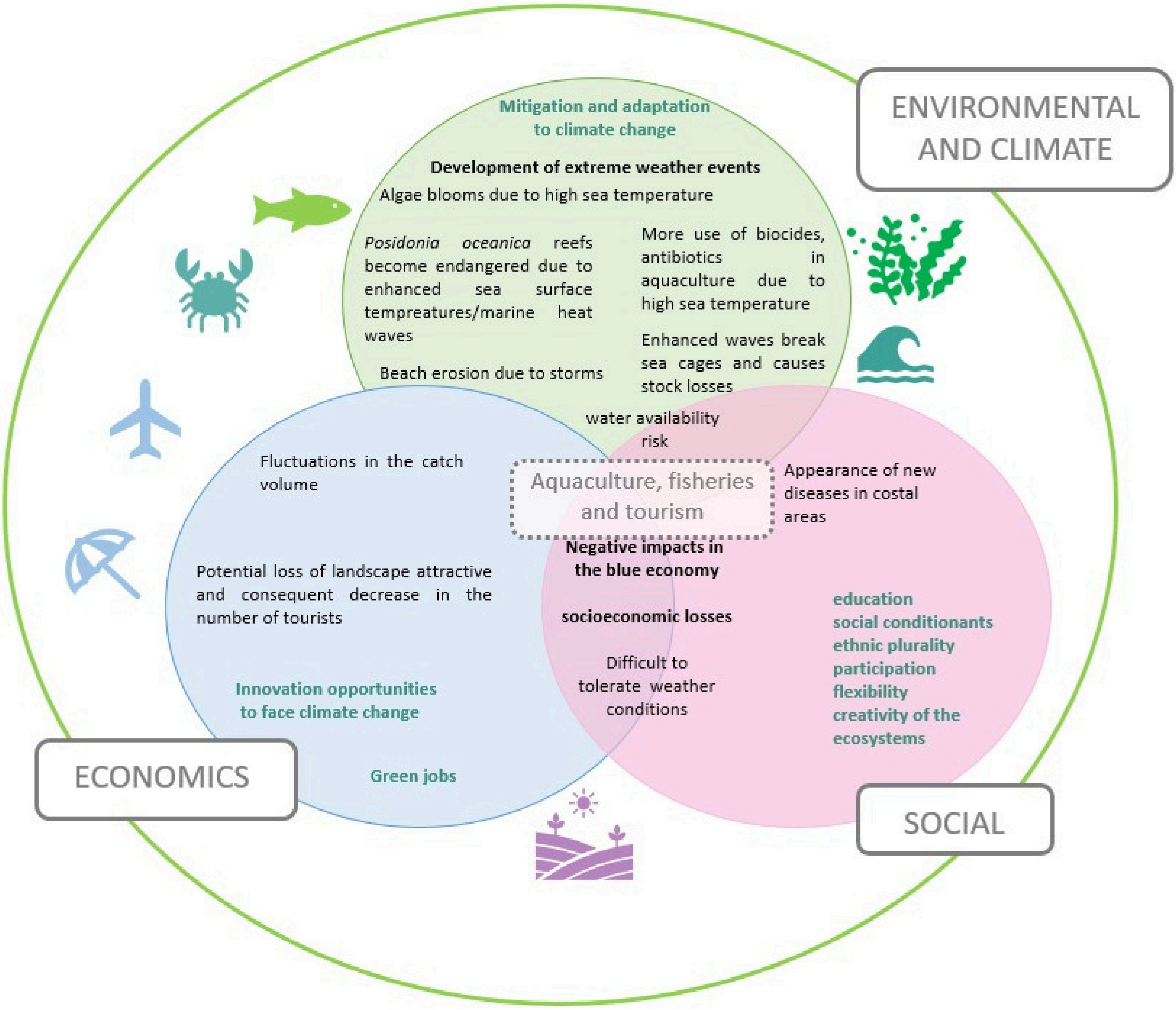

Figure 1. Holistic Approach of the ECOAZUL-MED Project

2. Objective of this document

The main objective of this document is to provide local and regional decision-makers in the fields of adaptation of the aquaculture, fishing, and coastal tourism sectors with information that enables them to make better-informed decisions to ensure the sustainable development of these three key sectors of the blue economy in the Spanish Mediterranean coast. The information presented in this report is derived from various activities carried out within the context of the ECOAZUL-MED project. This includes quantitative information from a rigorous analysis of climatic data derived from historical high-resolution regional coupled climate simulations and scenarios (rcp45 and rcp85) from the MedCORDEX coordinated modeling initiative. Additionally, it draws from information gathered through participatory activities (surveys, focus groups, etc.) involving relevant stakeholders from the three sectors targeted by the tool, as well as from a bibliographic review

3. Future Climate Conditions

The most relevant conclusions drawn from the analysis conducted for the Spanish Mediterranean coast within the context of the ECOAZUL-MED project during the preparation of the climate web tool are summarized below. These will serve as a reference for framing the potential socio-economic impacts derived from them, as well as proposing a set of adaptation measures for the different sectors to future climate conditions. It should be noted that the tool considers changes in future climate (2025-2064) compared to a control period (1976 to 2005).

- In the coming decades, thermal discomfort will increase in summer due to the overall increase in **maximum air temperature at 2 meters**. It will increase on average in summer between 1 and 2°C in the period of 2025-2034. In 2055-2064, the summer increase is more pronounced and will reach up to 3-4°C more than in the control period.

- In the future, the number of days with **atmospheric heatwave conditions** will increase in all seasons. In summer, the increase can reach up to 15-20 days in the decade 2025-2034. In the long term (2055-2064), the increase in the number of days with heatwave conditions can reach up to 40 days or more in summer, which could become the new normal.

- The **relative air humidity** tends to decrease over land with some local increase in 2025-2034. In this period, the magnitude of the change will not exceed 0.02 pu (parts per unit) compared to the control period. In the more distant future, 2055-2064, the decrease becomes even more general and more pronounced, ranging from 0.02 to 0.04 pu.

- In 2025-2034, **precipitation** will experience small changes compared to the control period. The decrease in summer precipitation will intensify in the coming decades.

- The % of days with **heavy precipitation** in 2025-2034 will experience a overall increase ranging between 2-4% per season. Although the average precipitation remains similar to the control period, or slightly reduced, the frequency of days with heavy precipitation increases.

- The **summer thermal conditions are extending, and they will continue to do so, towards the adjacent months**. The extension of the high tourist season towards late spring-early autumn may be possible, but caution should be taken regarding potential interferences between thermal comfort and heavy precipitation. This issue requires continuous monitoring in the coming years to confirm this trend of extending the tourist season on the Spanish Mediterranean coast, which is currently likely.

- The **sea-surface temperature** will experience a general increase in all seasons in the study region. The rise will be more pronounced in summer and autumn, reaching a magnitude close to 1ºC (or even higher locally) in the period 2025-2034. The increase in the summer season for 2055-2064 will be around 1.5-2ºC in most of the region of interest, especially in the northern portion, reaching values close to 2.5ºC.

- The number of days with **marine heatwave conditions** will increase on the Spanish Mediterranean coast. In summer, the increase in the number of days with marine heatwave conditions compared to the control period will be around 30-40, approximately, in the period 2025-2034. In 2055, the summer increase in number of days will be more pronounced, reaching up to 60-75 days more than in the control period.

- The **sea-surface salinity** will undergo moderate changes in all seasons in the interval 2025-2034. Overall, there will be a decrease in salinity, with local increases. The maximum increase will be of magnitude 0.1-0.2 psu (practical salinity units), while the maximum decrease in surface salinity will reach 0.6-0.8 psu. In the more distant future, 2055-2064, the decrease will become predominant in the region, while there will be practically no increase. The decrease will reach a maximum magnitude of 0.6-0.8 psu.

- The **module of the speed of the marine currents** at a depth of 50 meters will experience small changes in all seasons, generally ranging between ±0.05 m/s in 2025-2034. In the period 2055-2064, there will be a widespread increase in the speed of the currents, which will increase in magnitude up to a maximum of 0.05-0.1 m/s in localized areas such as, for example, in the Alboran Gyres.

4. Potential socioeconomic impacts of future climate conditions and relevant adaptation measures

Below is a summary of the potential socio-economic impacts derived from the projected climate conditions in each of the sectors, as well as possible adaptation measures to address them.

4.1. Touristic Sector

4.1.1. Socioeconomic Impacts

An increase in the maximum daily air temperature of 1-3.5ºC in summer could lead to a loss of thermal comfort, resulting in increased use of air conditioning and changes in the hours during which residents and tourists enjoy the destination. Additionally, it could lead to a change in destination preferences among foreign tourists, reducing the flow of tourists and, therefore, demand for the service sector.

An increase in the number of days of land heatwaves between 5 and 40 days in summer would initially generate a loss of thermal comfort, which could lead to a possible rejection of tourists towards destinations affected by frequent and heavy heatwaves. In this sense, some individuals, for health reasons (possible increase in mortality) or thermal comfort, would change the timing of their vacations in the destination. The use of air conditioning in all spaces would increase, leading to increased expenses and a potential increase in solar energy to cope with the increased expenses for this reason.

An increase in the number of days with summer-like conditions (daily maximum temperature above 25ºC) in spring or autumn, ranging from 2 to 16. In this case, the impacts would be positive as it would increase thermal comfort in spring or autumn, and would also improve it in winter. This could extend the tourist season to the extremes (June, September-October), improving seasonal adjustment.

An increase in the number of days of heavy precipitation in all seasons (2-4% per season) could potentially be negative if destinations do not implement adaptation measures to avoid flooding and inundations. Destinations should therefore adapt their resilient management and have plans to adapt to extreme weather events. Communication (warnings) for tourists regarding these types of situations should be managed so that they are aware of the circumstances and the danger of these extreme events, to avoid accidents and misfortunes (dry river beds, sea conditions during these phenomena, etc.). This could also have a negative impact on infrastructure and the quality of water and coastal sands.

An increase in sea-surface temperature of between 0.8 to 3ºC in summer, in the tourism sector, would not be problematic in terms of tourists' comfort. However, if this temperature generates problems for local flora and fauna, or worsens the quality of bathing water, these problems would ultimately affect tourists. In particular, this could pose a greater disadvantage for foreign tourists, who may prefer other destinations (e.g., Riviera Maya, Mexico). It could also lead to a loss of thermal comfort due to an increase in tropical nights.

An increase in the number of days of marine heatwaves between 10 and 70 days in summer, as mentioned earlier, could lead to a change in destination preferences among foreign tourists and discomfort among visitors. Similarly, tourists would not perceive it as a negative aspect unless changes happen in the quality of bathing water, biodiversity of the area, etc.

A decrease in sea-surface salinity of up to 0.8 psu, tourists would not perceive it as a negative unless it affects marine ecosystems, etc.

Regarding the impact of future climate conditions on aspects such as employment or the gender gap, negative effects can be mitigated if destinations and the tourism sector itself implement adaptation measures. In this sense, destinations should minimize the impact that negative effects of climate change can have on atmospheric elements and take advantage of those that could result in "positive" outcomes to extend the tourist season and the daily stay of tourists on the beach. To minimize negative effects, urban and architectural design measures in destinations would be necessary. These measures should be implemented in the short term because the process of climate change, for now, is unstoppable.

4.1.2. Adaptation Measures

Coastal tourism in the Spanish Mediterranean coast will transform in the coming years to adapt to climate conditions and avoid potential negative socio-economic impacts while striving to ensure sustainable development[4]. Some relevant measures in this regard are summarized below.

HOSPITALITY SECTOR

- Improving energy efficiency in buildings by implementing actions such as renovating energy-related systems (heating, air conditioning, ventilation, lighting, appliances), integrating renewable energy sources, improving insulation and sealing, and eliminating thermal bridges. Additionally, replacing lighting with LED alternatives to reduce the environmental footprint and energy consumption of the building.

- Implementing measures aimed at water saving, such as inspecting water losses in facilities, promoting circular economy principles in water consumption, reducing water usage, and contributing to mitigating water scarcity in the Mediterranean region.

- Monitoring carbon and water footprint to reduce resource usage. Initiatives like "Hospitality for Climate" provides tools for emissions reduction in the hospitality sector.

- Adhering to initiatives promoting the use of sustainability tourism indicators aligned with the Sustainable Development Goals (SDGs), focusing on economic, socio-cultural, and environmental aspects.

- Developing a well-planned tourist calendar and effectively communicating corresponding tourist events, promoting activity during seasons other than summer.

PUBLIC ADMINISTRATION

- Promotion of spatial planning in tourist destinations through sustainable and healthy urban planning that promotes energy rehabilitation, the design of public spaces with efficiency and sustainability parameters, the expansion of green spaces, the design of an efficient public transportation network for sustainable and healthy mobility, and the reduction of greenhouse gas emissions to mitigate climate change.

- Ensuring compliance with and reviewing the Climate Change and Energy Transition Law, which aims to reduce greenhouse gas emissions, promote renewable energy, emissions-free mobility, end of hydrocarbon exploitation, environmental education, and biodiversity protection, among other objectives.

- Development of local and regional climate change adaptation plans to reduce potential negative socio-economic impacts derived from climate conditions.

- Encouraging the adoption of sustainable tourism indicators aligned with the Sustainable Development Goals (SDGs), focusing on economic, socio-cultural, and environmental aspects.

- Promotion of tourism activity during seasons other than summer.

R&D+i

- Investment in R&D&I in sustainable and healthy urban planning aimed at promoting energy rehabilitation, the design of public spaces with efficiency and sustainability parameters, the expansion of green spaces, the design of a public transportation network for sustainable and healthy mobility, and the reduction of greenhouse gases to mitigate climate change.

- Development of climate service tools or alert systems that allow for the anticipation of extreme weather events such as heatwaves or heavy precipitation with potential socio-economic risks, which could affect destination selection and/or activity planning.

- Improvements in water treatment science and technology, water management, and drinking water supply.

- Development of Nature-Based Solutions, which according to the European Commission are "Solutions to societal challenges that are inspired and supported by nature; they are cost-effective and provide environmental, social, and economic benefits while helping to increase resilience."

- Enhancement of communication, dissemination, and awareness-raising regarding tourism and climate change.

CITIZENSHIP

- Responsible consumption of resources in tourist destinations, such as energy and water.
- Use of public transportation.
- Preference for sustainable destinations.

4.2. Aquaculture Sector

4.2.1. Socioeconomic Impacts

An increase in the daily maximum air temperature of 1-3.5°C in summer, although the air temperature would not have a direct effect on aquaculture, could indirectly impact the reproductive physiology of fish, increase the occurrence of pathological events, etc. Additionally, some species may not tolerate this change and may not be able to be cultured.

With an increase in the number of days of land heatwaves between 5 and 40 days in summer, similar effects to those mentioned in the previous point would be expected. Additionally, during extreme temperature episodes, oxygen levels in the water could decrease. This could increase the mortality rate in cultivated species that do not tolerate this temperature increase.

An increase in the number of days with summer conditions (daily maximum temperature above 25°C), in spring or autumn, between 2 and 16, could favor less growth in individuals, as they would invest their energy in coping with this change instead of increasing biomass. Effects similar to heatwaves. It could affect water flow and oxygen levels.

An increase in the number of days of heavy precipitation in all seasons (2-4% per season) could lead to a higher risk of floods and problems in continental aquaculture facilities. Additionally, it would make work in the marine environment (feeding, maintenance, etc.) more difficult and potentially increase possible damage to cages and marine facilities. It could also induce changes in salinity, which could affect the physiology of cultivated species.

An increase in sea-surface temperature of between 0.8 to 3°C in summer could have mixed effects. On one hand, it could favor fish growth. On the other hand, it could modify the physicochemical conditions of the water, for example, reducing the concentration of dissolved oxygen in the water, which affects the fish's ability to metabolize and assimilate food. The thermocline would be very pronounced, and there would not be good nutrient exchange, leading to food not reaching the culture (for example, in bivalve cultures). Additionally, the temperature rise could lead to an increase in some pathogen populations, favoring infectious and parasitic diseases. Although it is difficult to assess the overall net effect, it is clear that there will be one.

An increase in the number of days of marine heatwaves between 10 and 70 days in summer would lead to similar effects as in the previous point, but more aggravated, especially if the heatwave has a longer duration, as this would imply a sustained temperature increase.

A decrease in sea-surface salinity of up to 0.8 ups would have little effect on the species currently being cultivated in marine facilities.

Regarding the impact of future climate conditions on aspects such as employment or gender gap, climate change poses a significant challenge for the sector. Its effects on marine aquaculture would primarily result directly from:

- Increasingly extreme weather conditions at sea: currents, waves, winds, etc.

- Rising sea temperatures and their effects on oxygen levels, as well as pathologies.

Indirectly, it would be affected by:

- The global impact on plant productions used in feed manufacturing, such as soybeans, corn, etc.

Poor animal health leads to economic losses due to mortalities or diseases, resulting in losses and business closures. Some jobs may be lost, and they would need to be adapted to the new climate situation to maintain them. As for the gender gap, it could possibly become an indirect problem due to the aforementioned job losses.

4.2.2. Adaptation measures

In a sector as exposed to climate conditions, adaptation will increasingly become an essential aspect to consider to ensure its future viability. Below are presented a set of climate adaptation measures to guarantee the sustainability of the sector.

AQUACULTURE PROFESSIONALS

- Selection of suitable locations from an environmental (including climatic aspects), technical, legal, and socio-economic standpoint to enhance the success of cultivation.
- Utilization of cages and other infrastructures that are safer, more sustainable, and more resistant to strong hydrodynamics resulting from extreme weather conditions, such as heavy precipitation.
- Enhanced phytosanitary monitoring of cultivated species to prevent the proliferation of diseases.
- Procurement of insurance policies offering adequate coverage against risks derived from climatic extremes.
- Utilization of climate service tools or alert systems allowing anticipation of future climatic or weather conditions, including extreme weather events like heatwaves or heavy precipitation, to enhance activity planning.
- Adoption of an ecosystem-based approach to aquaculture (EBM), aiming to promote sustainable development, equity, and resilience of interconnected socio-ecological systems.

PUBLIC ADMINISTRATION

- Promotion of responsible consumption, labeling, and new commercially viable species with greater tolerance to climate conditions.

- Intensification of phytosanitary monitoring of cultivated species to prevent disease proliferation.

- Encouragement of oceanic aquaculture.

- Protection of *Posidonia oceanica*, a key seagrass from a socio-economic standpoint that buffers hydrodynamics, oxygenates the water column, and acts as a CO_2 sink, mitigating climate change, among other services.

- Promotion of feeding systems not based on fish oil or meal supply and with a low carbon footprint, such as biofloc.

R&D+i

- Intensification of efforts in R&D+i for the generation of tools enabling optimal site selection for cultivated species considering climatic and meteorological criteria.

- Enhancement of research aimed at closing the life cycle and cultivation of resilient species against climate conditions.

- Promotion of R&D&I for the generation of new materials (or their improvement) for the construction of cages and other infrastructures that are safer, more sustainable, and more resistant to strong hydrodynamics derived from extreme weather conditions.

- Protection of Posidonia oceanica fields, a key species from a socio-economic perspective that dampens hydrodynamics, oxygenates the water column, and acts as a CO_2 sink, mitigating climate change, among other services.

- Encouragement of research into feeding systems not based on the supply of fish oils or meals and with a low carbon footprint, such as biofloc.

CITIZENSHIP

- Flexibility in introducing new species into the diet that are more resilient to climate conditions and therefore cultivable.

- Responsible consumption of products from aquaculture.

4.3. Fishing Sector

4.3.1. Socioeconomic Impacts

An increase in the maximum daily air temperature of 1-3.5°C in summer would lead to a rise in sea temperature, causing disruptions in marine ecosystems and changes in the behavior of target species for fleets, which would likely move to deeper waters. This could displace migratory species both spatially and temporally (such as tuna, bonito, and swordfish), making resource management more challenging. Additionally, it would negatively affect the conservation of catches onboard vessels during the journey to port, resulting in increased costs in this area.

An increase in the number of days of land heatwaves of between 5 and 40 days in summer would have a rapid impact on the sea and, consequently, the same consequences mentioned in the previous section.

An increase in the number of days with summer-like conditions (daily maximum temperature exceeding 25°C) in spring or autumn, ranging from 2 to 16 days, could alter the temporal distribution of commercially important fish stocks. Currently, there are good fishing seasons in spring, as well as at the end of summer and the beginning of autumn. This temperature range would decrease and directly affect distribution and catches.

An increase in the number of days of heavy precipitation in all seasons (2-4% per season) would directly impact the reproduction of species dependent on freshwater inputs (rivers), such as sardines and anchovies, potentially altering their spawning patterns and the entire cohort of those species.

An increase in sea-surface temperature of between 0.8 to 3°C in summer could change the distribution of species, increasing the populations of some and/or others, making resource management more challenging. This would affect surface-dwelling bluefish species, and an increase in this range could directly impact the presence/absence of horse mackerel, mackerel, sardines, anchovies, and tunas in their usual fishing grounds.

An increase in the number of days of marine heatwaves of between 10 and 70 days in summer would result in a rise in sea temperature, causing disruptions in marine ecosystems and changes in the behavior of target species for our fleet, which would likely move to deeper waters. This could change the distribution of species, increasing the populations of some and/or others, making resource management more challenging. It is likely that species typical in our fishing grounds would move to other areas to maintain their optimal temperature range. Additionally, it would negatively affect the conservation of catches onboard vessels during the journey to port, leading to increased costs.

A decrease in sea-surface salinity of up to 0.8 ups could potentially alter marine ecosystems and species behavior. Salinity could affect marine species, both commercially important ones and others in the ecosystem. It is possible that species currently thriving in the current salinity range may move to areas with higher salinity.

When it comes to the impact of future climate conditions on aspects such as employment or the gender gap, climate conditions always have an impact. In any case, fishing is affected by multiple factors: energy costs, consumption habits, competition, lack of generational turnover, overfishing, etc. Climate change is affecting the typology of species caught. As conditions change, fish alter their habits. This has favored certain fisheries, for example, with the increase in white shrimp in certain areas of the Mediterranean, while disadvantaging others. There is no clear relationship between the gender gap and climate conditions.

4.3.2. Adaptation Measures

In this sector, which is widely exposed to the impacts of climate change, it will be necessary to find adaptive measures to ensure its future viability. Some relevant measures in this regard are summarized below.

FISHERIES PRACTITIONERS

- Adjustment of fishing efforts based on the biomass of stocks, which in turn may be influenced by climate conditions.
- Utilization of climate services tools or alert systems to anticipate future climatic or weather conditions, including extreme events such as heatwaves or heavy precipitation, to enhance activity planning.
- Collaboration of the fishing sector with other economic sectors to promote diversification (e.g., tourism).

PUBLIC ADMINISTRATION

- Promotion of responsible consumption, labeling, and new commercial species with greater tolerance to the region's climate conditions by public administrations and institutions.
- Promotion of research and development to improve understanding of the causes of population changes, their new routes, etc., in order to properly manage stocks.
- Protection of key species from a socioeconomic perspective, such as Posidonia oceanica meadows, a key phanerogam from a socioeconomic perspective that mitigates hydrodynamics, is a reproduction and breeding area, and acts as a CO_2 sink, mitigating climate change, among other services.
- Establishment of protected areas, where extraction is canceled or limited to mitigate population changes resulting from environmental conditions.

R&D+i

- Research and development (R&D) for the development of climate services tools or alert systems that allow anticipating future weather or climate conditions, including extreme events such as heatwaves or heavy precipitation, to improve activity planning.
- Promotion of research and development (R&D) to enhance understanding of the causes of population changes, their new routes, etc., in order to properly manage stocks.
- Promotion of research to increase the selectivity of fishing gear and techniques.

CITIZENSHIP

- Flexibility in introducing new species into the diet that are more resilient to climate conditions.
- Responsible consumption of seafood products.

5. Conclusions

The projected climate conditions in the region in our study for the coming decades indicate:

- An increase in maximum air temperature at 2 meters in all seasons, especially in summer.
- An increase in the number of days with heatwaves, both marine and terrestrial.
- A rise in sea-surface temperature.
- A trend towards decreased sea-surface salinity.
- Slight changes in precipitation, with an increase in the number of days with heavy precipitation in all seasons.

These conditions imply a series of structural changes in the three sectors to ensure their sustainable development against potentially adverse climate conditions. In this context, **TOURISM** is one of the main sources of income at the national level. In particular, coastal tourism on the Spanish Mediterranean coast will face transformations in the coming years to adapt to climate conditions and avoid possible negative socioeconomic impacts while ensuring its sustainable development. **An increase in maximum daily air temperature and an increase in the number of days with heatwaves in summer** could cause a loss of thermal comfort, leading to a change in destination preferences among foreign tourists, reducing the flow of tourists and, therefore, the demand for the service sector. **An increase in the number of days of heavy precipitation in all seasons (2-4% per season)** could potentially be negative if destinations do not implement adaptation measures to prevent flooding. This report proposes measures based on user profile: (i) Hospitality sector; (ii) Public administration; (iii) R&D sector; (iv) Citizenship. Specifically, for the **Hospitality Sector**, measures related to improving energy efficiency in buildings, water savings, monitoring of carbon and water footprint, the use of sustainable tourism indicators, and the creation of new tourism calendars are proposed. For **Public Administration**, improving spatial planning in tourist destinations, ensuring compliance and revision of the Climate Change and Energy Transition Law, developing local and regional climate change adaptation plans, promoting the adoption of sustainable tourism indicators, and promoting tourism activity in seasons other than summer are proposed. In terms of **R&D+i**, greater investment in sustainable and healthy urban planning, the development of climate service tools or alert systems, improvements in water treatment science and technology, development of Nature-Based Solutions, and enhancing communication, dissemination, and awareness-raising on tourism and climate change are proposed. Regarding **Citizenship**, responsible consumption of resources, use of public transport, and preferential selection of sustainable destinations are proposed.

AQUACULTURE also constitutes a vital economic activity at the national level, with a harvest in 2021 of 327,309 tons and a first-sale value of 629 million euros. **An increase in sea-surface temperature in summer could have contrasting effects**. On the one hand, it could favor fish growth. On the other hand, it could modify the physicochemical conditions of the water, for example, reducing the concentration of dissolved oxygen in the water, which affects the fish's ability to metabolize and assimilate food. The temperature rise could lead to an increase in some pathogen populations, favoring infectious and parasitic diseases. **An increase in the number of days of heavy precipitation in all seasons** could lead to a higher risk of flooding and problems in continental aquaculture facilities. Additionally, it would make work in the marine environment more difficult and potentially increase damage to cages and marine installations. **Adaptation measures** for **Aquaculture Professionals** are based on the selection of suitable sites (taking into account the climatic component), the use of safer, more sustainable cages and other infrastructures with greater resistance to hydrodynamics, intensification of phytosanitary monitoring of cultivated species, contracting insurance policies with coverage against adverse weather events, the use of climate service tools or alert systems, and the adoption of an ecosystem approach to aquaculture (EAA).

For the **Public Administration**, the promotion of responsible consumption, labeling, and new species is proposed, as well as the intensification of phytosanitary monitoring of cultivated species, promotion of oceanic aquaculture, greater protection of Posidonia oceanica meadows, and the promotion of feeding systems not based on the supply of fish oils or meals and with a low carbon footprint. Moving on to the **R&D+i sector**, an intensification of efforts is mentioned for the generation of tools that allow optimal site selection, taking into account climatic and/or meteorological factors, promoting the closure of the life cycle and cultivation of species resilient to environmental conditions, generating new materials (or improving existing ones) for the construction of cages and other infrastructures, protecting Posidonia oceanica meadows, and promoting feeding systems not based on the supply of fish oils or meals and with a low carbon footprint. As for **Citizenship**, greater flexibility is proposed in introducing new species into the diet that are more resilient to climate conditions and responsible consumption.

The Spanish **FISHING SECTOR** ranks first in the European Union, both in terms of catch volume and economic value. In this sector, which is widely exposed to the impacts of climate change, it will be necessary to find adaptive formulas that ensure its future viability. In this regard, an **increase in sea-surface temperature in summer** could change the distribution of species, increasing the populations of some and/or others, making the proper management of resources more difficult. The usual species in our fishing grounds would likely move to other areas to maintain their optimal temperature range. Additionally, it would negatively affect the conservation of catches on board vessels during the journey to port, leading to increased costs. Adaptation measures for **Fisheries practitioners** include adjusting fishing efforts based on stock biomass, using climate service tools or alert systems, and collaborating with other economic sectors. For the **Public Administration**, promotion of responsible consumption, labeling, and new commercial species is proposed, as well as improving understanding of the causes of population changes, protecting key species from a socioeconomic perspective, such as Posidonia oceanica meadows, and establishing protected areas where extraction is restricted or prohibited to mitigate population changes due to environmental conditions. In the **R&D+i sector**, it is recommended to enhance research for the development of climate service tools or alert systems, improve understanding of the causes of population changes, and increase the selectivity of fishing gear. Similarly to aquaculture, it is expected that **Citizenship** will increase their flexibility in introducing new species into their diet that are more resilient to climate conditions and engage in responsible consumption of products.

6. References

Colantonio, A. (2009) Social sustainability: a review and critique of traditional versus emerging themes and assessment methods. In: Horner, M., Price, A., Bebbington, J. and Emmanuel, R., (eds.) Sue-Mot Conference 2009: Second International Conference on Whole Life Urban Sustainability and Its Assessment: Conference Proce. Loughborough University, Loughborough, pp. 865-885. ISBN 9780947974.

Darmaraki, S., Somot, S., Sevault, F., Nabat, P., Narvaez, W. D. C., Cavicchia, L., Djurdjevic, V., Li, L., Sannino, G., Sein, D.V. (2019) Future evolution of marine heatwaves in the Mediterranean Sea. Climate Dynamics, 53(3), 1371-1392. https://doi.org/10.1007/s00382-019-04661-z.

Giorgi, F. (2006) Climate Change Hot-Spots. Geophysical Research Letters, 33(8). https://doi.org/10.1029/2006GL025734

González-Alemán, J.J., Pascale, S., Gutierrez-Fernandez, J., Murakami, H., Gaertner, M.A., Vecchi, G.A. (2019) Potential increase in hazard from Mediterranean hurricane activity with global warming. Geophysical Research Letters, 46(3), 1754-1764. https://doi.org/10.1029/2018GL081253.

IPCC, 2019: Summary for Policymakers. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)].

IPCC, AR6 SYR (2023). Synthesis report of the IPCC sixth assessment report (AR6)–Summary for Policymakers. Available at: https://www.ipcc.ch/report/sixth-assessment-report-cycle/.

Olcina Cantos, J, Miró Pérez, J.J., 2017. Actividad turística y cambio climático en la Comunidad Valenciana. Alicante: Universidad de Alicante, Instituto Universitario de Investigaciones Turísticas; Valencia: Agència Valenciana del Turisme, 130. https://doi:10.14198/2017-Actividad-Turistica-Com.

7. Contact

Alba de la Vara

adelavara@kveloce.com

+34 963 25 02 93