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Halting seagrass loss to protect tourism in the Ria Formosa

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Executive Summary

This policy brief presents and synthesises scientific results derived from numerical modelling applied to the Ria Formosa lagoon system, assessing system responses under climate change scenarios and scenarios of seagrass habitat loss/degradation, and identifying the main implications for the provision of ecosystem services directly relevant to tourism in the region. The results were validated through a participatory workshop involving researchers, public environmental management authorities (APA, ICNF, and the Maritime Authority), producer associations, tourism operators, and municipalities. Field-based expertise from these stakeholders corroborated and further enriched the model projections, indicating that the degradation trends observed on the ground are faster and more severe than those predicted, thereby reinforcing the urgency of the proposed measures.

Main research findings

The Ria Formosa is a prime tourism destination, accounting for a significant share of national coastal tourism revenues. The region currently receives approximately 12 million visitors per year for a resident population of about 500,000 inhabitants, resulting in inherent environmental pressures driven by increased tourism intensity and compounded by global changes, particularly climate warming.

Numerical model projections for the Ria Formosa indicate that the decline of seagrass meadows, combined with rising temperature, may trigger cascading impacts on ecosystem services and on the economic and cultural activities that depend on them.

Participatory validation of these projections, nevertheless, revealed that the rate of degradation observed in the field substantially exceeds model predictions. In the critical case of seagrass meadows, researchers from CCMAR with more than 20 years of continuous monitoring of Ria Formosa have documented losses exceeding 50% of total area over a 13-year period, whereas the model projects a moderate decline of 8%. Even more concerning, the annual reductions observed *in situ* approach values that the model predicts over several decades, indicating a marked acceleration of degradation processes. Workshop participants further identified direct anthropogenic pressures—namely illegal fishing, habitat damage caused by anchoring systems and propellers, unregulated maritime traffic, and unplanned expansion of aquaculture—as currently more immediate and severe threats than climate-related effects themselves. In particular, a potential decline in Regulation and Maintenance Services is anticipated, with associated effects on the touristic attractiveness of the lagoon system, including products linked to "Blue Flag Beaches" and "Iconic Nature." In parallel, a potential decline in traditional fisheries is projected, with possible consequences for local seafood availability, diversity, and gastronomic experience. The clam (*Ruditapes decussatus*), for example, shows a severe decline observed *in situ*, with a documented loss of 60 hectares of productive areas designated under the Aquaculture Area Allocation Plan (PAqAT), in contrast to the model projections of a slight increase.

Emblematic species such as seahorses, which once supported one of the largest populations in Europe, have experienced population declines exceeding 60% over recent decades, driven by illegal capture for export to China, where they reach very high commercial values. Sea cucumbers have likewise been subject to intensive illegal harvesting for the same market. Cockles showed marked declines between 2011 and 2013, associated with increased illegal fishing effort and the widespread capture of individuals below the minimum legal landing size. In addition, seahorse-watching requires urgent regulation to limit the impacts of boat-based visits, which may affect both seahorse populations and the seagrass beds that underpin essential habitats and iconic species in the Ria Formosa. The exponential increase in recreational and tourism vessels—many operating without updated registration—accelerates shoreline erosion, disturbs sensitive species, and contributes to the mechanical degradation of seagrass meadows.

The expansion of aquaculture, particularly oyster farming, was identified as an economically relevant activity that nevertheless lacks clearly defined carrying-capacity criteria. The absence of operational limits on culture densities, number of vessels, or tourism load perpetuates case-by-case decision-making, often driven by economic pressure, thereby compromising the ecological resilience of the system.

In light of this scenario, and in the context of the approval of the Floresta Azul programme, the restoration and conservation of national seagrass meadows should be operationalised as a priority and without delay. The convergence between scientific projections and empirical knowledge indicates that the window of opportunity for effective action is rapidly narrowing. Accordingly, the full and rapid implementation of all measures already identified as necessary for the conservation and restoration of the Ria Formosa's seagrass meadows is recommended, strengthening the system's ecological resilience and the sustainability of the activities that support the local economy.

Key measures to implement

- **Prohibit vessel traffic in areas identified as seagrass habitat**, with official cartographic delineation, *in situ* signage, and integration into relevant spatial/planning instruments.
- **Ban anchoring and the use of anchors in seagrass areas**, promoting low-impact alternatives (*e.g.*, relocating official mooring/anchoring areas to adjacent zones not overlapping seagrass beds; adjusting landing/boarding points) where compatible with conservation objectives.
- **Prohibit fishing activities (commercial and recreational) within seagrass areas**, establishing exclusion zones, specifying permitted gears in adjacent areas, and defining buffer zones where technically justified.
- **Regulate seahorse-watching tourism in the Ria Formosa**, including licensing, carrying capacity, codes of conduct, minimum distances, limits on observation time, and mandatory operator training.
- **Establish an updated and mandatory registry of recreational vessels**, including the enforcement of daily limits for tourism operators, the definition of navigation zones, restricted areas and ecological corridors, and the implementation of sensor-based monitoring systems or integrated surveillance during peak-season months.
- **Define operational carrying-capacity criteria for aquaculture, recreational boating, and tourism**, including: (i) assessment of the carrying capacity of existing oyster farming areas; (ii) establishment of maximum cultivation densities per m^2; (iii) monitoring of waste and sedimentary impacts; and (iv) clarification of responsibilities for the removal of waste and abandoned structures.
- **Ensure effective enforcement and compliance**, through regular surveillance (patrols and, where applicable, remote monitoring), clear control procedures, and a deterrent sanctions regime, with fines proportionate to severity and repeat offences.
- **Promote effective inter-institutional coordination** among the Maritime Police, ICNF, APA, Port Authorities, GNR, and municipalities, including the establishment of more effective reporting mechanisms and targeted awareness-raising campaigns for tourists and local residents

- **Remove litter from seagrass meadows** through actions involving citizens and scientists.
- **Remove invasive species** (e.g., *Caulerpa prolifera*) through actions involving citizens and scientists..

Proposed recipientes:

- Directorate-General for Natural Resources, Safety and Maritime Services (DGRM)
- Portuguese Environment Agency (APA) — Algarve River Basin Administration (ARH Algarve)
- Institute for Nature Conservation and Forests (ICNF)
- Ria Formosa Natural Park Co-management Committee
- National Maritime Authority — Port Captaincies of Faro, Olhão and Tavira
- National Republican Guard (GNR)
- Maritime Police
- Municipalities
- Non-governmental organizations (NGOs)

Setting the scene

Coastal and ocean areas host essential ecosystem services (ES) that underpin a wide range of blue economy activities and human settlements worldwide [1]. Tourism is among these activities and has shown a growing trend in the Mediterranean and southern Europe, particularly in coastal areas that attract large numbers of visitors [2]. In fact, coastal tourism has been identified as one of the five priorities of the European Union (EU) Blue Growth Strategy [3]. In 2022, Portugal recorded a nominal increase of 72.7% in the Gross Value Added generated by Tourism (GVAT) compared with 2021, with revenues from this activity representing 12.2% of national Gross Domestic Product (GDP), and the most significant increase (96%) occurring in coastal areas [4]. However, intense pressure from tourism and other human activities in coastal areas can contribute to the degradation of marine ecosystems and the services they provide, potentially leading to significant consequences for tourism destinations [5, 6]. In the current context—where the Portuguese economy depends substantially on tourism on the one hand, and faces the challenges of the climate crisis on the other—it is essential to assess the risks that climate change and extreme weather events pose to national tourism, especially when combined with other sources of environmental disturbance.

This challenge is further exacerbated by institutional and governance weaknesses that hinder the integrated management of ecosystems under multiple pressures. Overlapping mandates among authorities (Portuguese Environment Agency (APA), Institute for Nature Conservation and Forests (ICNF), the Maritime Authority, and municipalities), misalignments between territorial planning instruments (*e.g.*, Coastal Zone Management Plans, Natural Park management plans, and municipal instruments), and the absence of operational carrying-capacity criteria collectively constrain the effective implementation of conservation measures, even when these are scientifically robust and socially recognized as necessary.

Tourism is strongly dependent on ES. Provisioning services supply food, water, and energy, among other needs; regulating services play a vital role, as ecosystems regulate climate patterns, which is crucial for tourists' destination choices. Likewise, many tourism activities are located in regions prone to natural hazards such as floods or hurricanes. ES can substantially reduce the risks of natural

disasters by strengthening coastal protection. In addition, cultural ES are paramount for visitor satisfaction, providing aesthetic appreciation, recreational activities, or spiritual and religious experiences.

Food web models consider both structural aspects (*e.g.*, biomass) and functional components (*e.g.*, energy flows between ecological groups). Consequently, they provide valuable information on ecosystem functioning and can account for direct and indirect effects within the food web, which are reflected in ES.

The Ria Formosa coastal lagoon

Given the importance of the Algarve for tourism in Portugal, the study area for this project was the Ria Formosa, a coastal lagoon system extending along the eastern section of the Algarve's south coast [7]. The Ria Formosa is characterised by high biological diversity and habitats of recognised ecological value, supporting essential ecosystem services—including biodiversity support functions, regulation and improvement of water quality, coastal protection, and landscape value—which together underpin a tourism activity of major territorial, social, and economic relevance, with a growing trend.

Figure 1 - The Ria Formosa coastal lagoon at the Southern coast of Portugal (extracted from https://www.algarvetouristguide.com/)

Methodology synthesis

A baseline food web model was developed for the Ria Formosa (Fig. 2). Based on the model outputs, ecosystem services with direct relevance to tourism were identified (*e.g.*, potential regulation of water chemical quality, coastal protection, traditional fisheries, birdwatching).

Based on projected temperature increases for the Ria Formosa under the SSP5-8.5 scenario, and assuming an expected 40% reduction in seagrass meadow area over the coming decades, pressure scenarios were defined and the model was simulated for the 2025–2060 period, enabling the assessment of future trajectories and potential impacts on tourism-related ecosystem services.

Preliminary model results were subjected to a social validation process through a participatory workshop held on 9 October 2025 at the University of Algarve. The event brought together researchers from CCMAR, CIIMAR, and CinTurs; public environmental management authorities (Portuguese Environment Agency (APA) / Algarve River

Basin Administration (ARH Algarve), Institute for Nature Conservation and Forests (ICNF)); municipal representatives (Municipality of Olhão); aquaculture producer associations; and local tourism operators.

The methodology followed co-production of knowledge principles, integrating ecological science with institutional expertise, sectoral practices, and empirical knowledge. The workshop unfolded in four sequential stages: (i) presentation of model results; (ii) critical comparison between scientific projections and field-based knowledge, identifying convergences and divergences; (iii) group work in heterogeneous teams to discuss ecological pressures and formulate mitigation measures; and (iv) collective prioritization of measures through plenary voting.

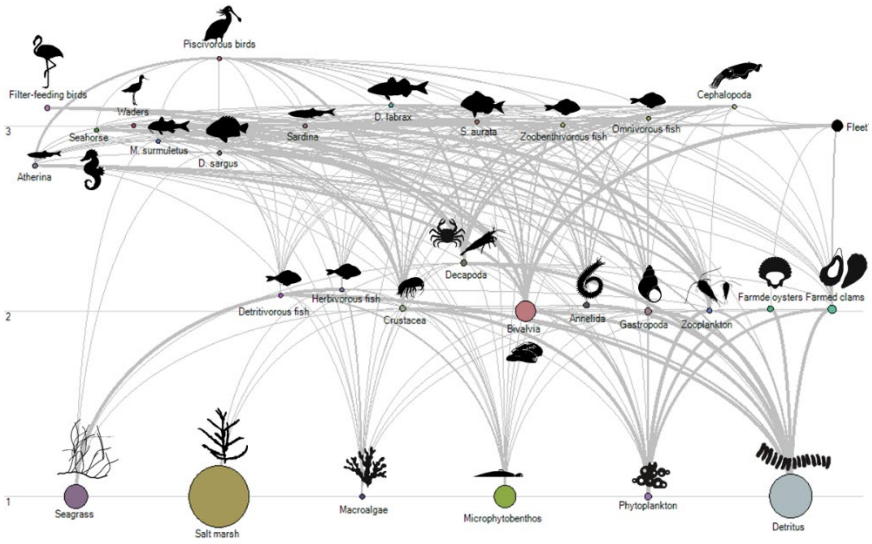

Figure 2 - Conceptual diagram of the food web model developed for the Ria Formosa within the SHIFT-MARES project.

Key projections from scenario simulations for the Ria Formosa

Numerical model projections suggest that a reduction in the extent/cover of seagrass meadows in the Ria Formosa, together with rising temperature, may lead to:

- **Potential decline in regulating and maintenance services** (e.g., regulation of water chemical quality, control of coastal erosion), with a loss of tourism attractiveness of the system, particularly for products associated with **"Blue Flag Beaches"** and **"Iconic Nature."**
- **Potential decline in traditional fisheries**, with expected effects on the availability and diversity of local resources, potentially resulting in reduced variety and authenticity of gastronomic experiences associated with the Ria Formosa.
- **Seahorse-watching tourism** stands out as an area requiring **urgent regulation**, in order to minimise impacts associated with vessel approach and traffic. These impacts may compromise not only seahorse populations, but also seagrass beds, which constitute critical habitat for emblematic species and for the ecological integrity of the system.

Priority measures to reverse the current trajectory and strengthen the Ria Formosa's resilience to global change

The measures listed below derive from the results obtained within the SHIFT-MARES project, as well as from scientific evidence produced by other studies carried out by research teams from several national R&D centres [*e.g.*, 8]. These measures were validated and prioritized through voting by participants in the participatory workshop, including researchers, environmental managers, aquaculture producers, and tourism operators.

The collective prioritization process identified three intervention areas considered most urgent by stakeholders: (1) tourism education and visitor awareness; (2) effective enforcement and the control of illegal fishing; and (3) full protection of seagrass meadows. These priorities reflect a shared consensus that effective conservation requires the simultaneous implementation of prevention (through education), law enforcement (through enforcement), and the protection of key structuring habitats.

- **Implement a tourism education and visitor awareness programme, identified as the highest priority by workshop participants, focused on reducing anthropogenic pressures through targeted campaigns directed at tourists, residents, and operators, including codes of conduct and communication on habitat fragility.**
- **Prohibit vessel traffic** in areas identified as seagrass habitat, with **official cartographic delineation**, ***in situ* signage**, and **integration into relevant spatial/planning instruments**.
- **Ban anchoring and the use of anchors** in seagrass areas, promoting **low-impact alternatives** (*e.g.*, **eco-mooring fields**) where compatible with conservation objectives.
- **Prohibit fishing activities** (commercial and recreational) within seagrass areas, establishing **exclusion zones**, specifying **permitted gears in adjacent areas**, and defining **buffer zones** where technically justified.
- **Regulate seahorse-watching tourism** in the Ria Formosa, including **licensing**, **carrying capacity**, **codes of conduct**, **minimum distances**, **limits on observation time**, and **mandatory operator training**.
- **Establish operational ecological carrying-capacity criteria, with quantifiable metrics for different uses (aquaculture, recreational boating, and tourism), identified by workshop participants as an essential measure for sustainable planning.**
- **Ensure effective enforcement and compliance**, through regular surveillance (patrols and, where applicable, remote monitoring), clear control procedures, and a **deterrent sanctions regime**, with fines proportionate to severity and repeat offences. Efficient enforcement was identified as the second highest priority by workshop participants, recognizing that the absence of effective control perpetuates illegal practices.
- **Remove litter from seagrass meadows** through actions involving **citizens and scientists**.
- **Remove invasive species** (e.g., *Caulerpa prolifera*) through actions involving **citizens and scientists**.

Conclusion

To ensure the sustainability and continuity of tourism activities in the Ria Formosa region over the coming decades, the immediate and effective, comprehensive protection of seagrass meadows is recommended. The convergence between scientific projections and empirical knowledge, as evidenced through the participatory validation process, confirms that observed ecological degradation exceeds model predictions, thereby narrowing the window of opportunity for effective action.

Implementing local conservation and active management measures—aimed at reducing direct pressures and restoring habitat—constitutes a critical intervention to strengthen the lagoon system's ecological and functional resilience, mitigating vulnerability to globally driven pressures, including climate change. When implemented in a coordinated manner and supported by adequate resources, these measures are essential to mitigate vulnerability to global pressures, including climate change, and to address direct anthropogenic pressures which, according to consolidated empirical evidence, currently represent the most immediate threats to the ecological balance of Ria Formosa.

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