CREATE

Flagship papers

Deliverable 3.2.2

Work Package no 3

Activity no 2

Authors: National Research Council, Euro-Mediterranean Center on Climate Change Foundation, Energy Institute Hrvoje Pozar, IUAV University of Venice, Abruzzo Region, PAP/RAC Priority Action Programme Regional Activity Centre, Institute of Oceanography and Fisheries, County of Split-Dalmatia

28/06/2023

Public

contact:davide.bonaldo@cnr.it

Final – Public

Document History

Name (Institution)	Date	Change	Version
CNR	May 2023	First Draft	CNR
CNR, all	June 16, 2023	Second Draft	CNR, all
CNR, all	June 28, 2023	Third Draft	CNR, all

Table of Contents

1. Introduction

This document contains two Flagship Papers envisioned as outputs of the CREATE (Climate REsponses for the AdriaTic REgion) Italy-Croatia Interreg project. Both Flagship Papers align with the direction of the EUSAIR (EU Strategy for the Adriatic and Ionian Region) macro-regional strategy and its potential connections with the Interreg Italy-Croatia 2021-2027 Programme. The goal of these papers is to outline strategic perspectives at the intersection of the two initiatives, facilitating the engagement of a broad and diverse community in fostering sustainable and climate-resilient growth in the Adriatic area, addressing the objectives of the EUSAIR Pillar 3 – Environmental Quality, in particular, in the case of Flagiship paper 1, the Flagship: Promotion of Sustainable Growth of the Adriatic-Ionian region by implementing ICZM and MSP also to ICZM Protocol of the Barcelona convention and, in the case of flagship paper 2, on the monitoring and management of Marine Protected Areas.

2. Towards a climate-adaptive Maritime Spatial Planning in the Adriatic area (CREATE Flagship paper 1)

2.1. Executive summary

This chapter represents the first of the two Flagship Papers envisioned as outputs of the CREATE (Climate REsponses for the AdriaTic REgion) Italy-Croatia Interreg project. Both Flagship Papers align with the direction of the EUSAIR (EU Strategy for the Adriatic and Ionian Region) macro-regional strategy and its potential connections with the Interreg Italy-Croatia 2021-2027 Programme. The goal of these papers is to outline strategic perspectives at the intersection of the two initiatives, facilitating the engagement of a broad and diverse community in fostering sustainable and climate-resilient growth in the Adriatic area, addressing the objectives of the EUSAIR Pillar 3 – Environmental Quality, Flagship: Promotion of Sustainable Growth of the Adriatic-Ionian region by implementing ICZM and MSP also to ICZM Protocol of the Barcelona convention and the monitoring and management of Marine Protected Area. Focusing on the case of the Adriatic Sea, the present paper introduces the relevance of explicitly tackling the effects of climate change in maritime spatial planning, the challenges associated with this process, and the heritage and possible contributions from the Interrag IT-HR Programme in this direction.

2.2. Multi-scale climate change impacts in the Adriatic coastal regions

The Mediterranean Sea is a well recognised climate change hotspot (Giorgi 2006; Lionello et al. 2006; Giorgi and Lionello 2008; Diffenbaugh and Giorgi 2012; Lionello 2012; Lionello and Scarascia, 2018). In this region, the intensity and trends of various climate-related hazards, such as rising air and sea temperatures, sea level rise, decrease in precipitation, changes in atmospheric circulation and increased occurrence of extreme events like local floods (MedECC, 2020) are amplified with respect to the global average (Vautard et al. 2014; Dosio and Fischer 2018; Lionello and Scarascia 2018; Nikulin et al. 2018).

Located at the northernmost end of the Mediterranean basin, the Adriatic Sea has long been recognized as a natural laboratory for marine science and, more recently, for climate science, thus being at the forefront of scientific and management challenges that hold global relevance. Its relevance is primarily due to its particular geographical and geological setting, its role as a key component of larger-scale Mediterranean thermohaline circulation, its biological and ecological significance, and the coexistence of multiple sea uses with its economic assets along the coasts and in the mainland, all acting as sources of anthropogenic stress. While there are still knowledge gaps and unanswered research questions, the recognition of the importance of marine dynamics in this region encouraged an early establishment of long-term observatories. For instance, the Acqua Alta oceanographic tower, located approximately 15 km of the Venetian coast, serves as one of the world's longest directional wave series, see Pomaro et al., 2018). Furthermore, extensive analysis of historical multi-disciplinary data together with modern numerical modelling efforts have been undertaken to comprehensively characterise recent trends and provide future climate projections, albeit with ongoing research endeavours and uncertainties. Various national and international initiatives, including the Interreg Italy-Croatia Programme, have addressed the impacts of climate change, resulting in the identification of a complex network of effects across multiple scales and socio-economic sectors.

The effect of potential moderation of the meteo-marine climate, indicated by a tendency towards reduced storminess (Makris et al., 2016; Bonaldo et al., 2020), in line with the trends observed at the Mediterranean scale, is obliterated and overcome by the competing impact of rising sea level (Lionello et al., 2017), resulting in an overall increase of storm-related and flooding hazards, particularly along low-lying coastal plains (Antonioli et al., 2020). Rising sea levels are also among the main threatening factors for the intensification of salt water intrusion along river branches (Bellafiore et al., 2021), coastal water bodies (Baric et al., 2008), and surface aquifers (Da Lio and Tosi, 2019). Simultaneously, recent trends in other physical parameters such as temperature and salinity indicate a tendency towards warmer and saltier conditions, leading to stronger stratification, thus weakening the Adriatic thermohaline circulation (Tojčić et al., 2023). These changes can potentially have severe impacts on deep-sea ventilation and oceanic processes at the Mediterranean scale. The Adriatic Sea has also been identified as a hotspot for marine heat waves (MHW), particularly during spring and summer, with the number of MHW days per year increasing from a few units to around one hundred between 1982-2020 (Juza et al., 2022). The effects of this trend can be highly disruptive in shallow coastal and transitional environments, particularly in shoals and tidal flats, where organisms and communities typically live close to their tolerance limits (Dominguez et al., 2021). The tendency toward overall dryer hydrological regimes, together with the effects of water management strategies implemented in the last decades, resulted in a drop in fresh water discharge on the order of 30% with respect to the mid-twentieth century statistics (Philandras et al., 2011; Syvitski and Kettner, 2007; Cozzi and Giani, 2011). These changes showed cascading effects on sediment supply and coastal erosion (Bonaldo et al., 2018). Looking ahead to the end of the century, regional projections for the Adriatic Sea and its hydrographic basin, under a severe climate change scenario (RCP 8.5), indicate a trend towards reduced precipitation frequency and increased intensity, with autumn and winter wetter conditions, and drier conditions in spring and summer. In such conditions, the occurrence of severe droughts, like the one experienced by large areas of Europe reaching its climax in summer 2022, is expected to become more frequent. Even though it is unlikely that such events will become commonplace (Bonaldo et al., 2023), it should be noted that their impact on water availability will be amplified by the increased water demand for agriculture needed to compensate for higher evapotranspiration caused by rising air temperatures. On the other hand, the shift towards fewer but more intense precipitation events poses a dual challenge, affecting both the hydraulic safety of urban areas and the quality of coastal waters, with potential implications for various coastal activities. Anticipated changes in the timing and intensity of basin-scale freshwater and nutrient fluxes, along with the modifications to the thermohaline setting and circulation patterns of the Adriatic Sea, are quite likely to impact ecosystem dynamics at different scales.

In a basin such as the Adriatic Sea, in which offshore and coastal processes, as well as sea uses, are intricately interconnected with land-based pressures and economic activities, it becomes evident how climate change not only disrupts individual components, but also permeates the entire relational network of the system. Further propagation of climate change impacts has the potential to reconfigure the relative significance, priorities, and sustainability of management actions and policies, and the trade-offs among various alternative options.

2.3. MSP and ICZM in the Adriatic region

In the context of increasingly complex of sea uses, pressures, and uncertainties, together with a growing awareness of the importance of the Blue Economy, Maritime Spatial Planning (MSP) has gained global significance as a valuable tool for managing multiple activities in marine and coastal regions while promoting sustainable growth objectives and mitigating the conflicts (Ehler and Douvere, 2009). Simultaneously, in pursuit of establishing a unified framework for an integrated management of the coastal zone in the Mediterranean basin and achieving the goals outlined by the Barcelona Convention (Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, signed in 1976 and amended in 1995), a Protocol on Integrated Coastal Zone Management (ICZM) was adopted in 2008. The implementation of this protocol is facilitated by the United Nations Mediterranean Action Plan (UNEP-MAP) and the coordinated by the Priority Actions Programme/Regional Activity Centre (PAP-RAC). The ICZM Protocol, enforced in 2011, stands as the first supranational legal framework for coastal zone management (Rochette et al., 2012). Although not originally conceived as directly linked with MSP, it incorporates certain concepts of marine planning aimed to the sustainable utilization of resources, environment conservation, and stakeholder involvement in the decision-making process. In 2017 the definition of the Conceptual Framework for MSP in the Mediterranean (hereinafter CF), adopted in Tirana by the COP20 formally recognised MSP as a main tool for the implementation of ICZM, in particular in the marine part of the coastal zone. The CF highlights the importance of incorporating the Ecosystem Approach (EcAp) into MSP, emphasizing the importance of addressing land-sea interactions within the planning process. By integrating MSP into ICZM through the CF, it establishes a shared foundation for MSP implementation across Mediterranean region, thereby promoting a unified approach to marine and coastal planning at the Mediterranean. The integration also has implications for the availability and accessibility of the data (Ramieri et al., 2019).

In the Adriatic region, the development of coastal and marine planning processes following the ICZM-MSP paradigm capitalizes the experiences of several initiatives, both at the Mediterranean and at the macro-regional level. SHAPE (Interreg IVA IPA, 2011-2014) was one of the earliest efforts towards the implementation of the ICZM protocol in the Adriatic Sea and propose a framework for MSP and ICZM. RITMARE (2012-2017), a Flagship Project funded by the Italian Ministry of University and Research, dedicated two research lines to MSP processes and, while tackling the problem at the National scale, had an important role in creating a multidisciplinary network connecting the marine research community around this topic. ADRIPLAN (DG MARE, 2013-2015) was the first pilot project to test an MSP project in the Adriatic-Ionian Region with a direct link with the EUSAIR strategy. MEDTRENDS (Programme MED, 2014-2015), analysed 20-year scenarios of marine economic growth at the transnational level in EU Mediterranean countries, highlighting interactions, conflicts and negative effects, also with some insight in a climate change perspective. SUPREME (DG MARE, 2017-2018) supported cross-border cooperation initiatives for the implementation of MSP in the EU Member States of the Eastern Mediterranean basin. More recently, additional efforts have been undertaken in the framework of MSP-GREEN (2022-2024), funded by the European Maritime Fisheries and Aquaculture Fund, aligning with the MSP goals of the European Green Deal.

2.4. Challenges and opportunities for climate-proof and climate-smart MSP in the Adriatic-Ionian region

Incorporating climate change adaptation and mitigation considerations into planning processes, leading respectively to “climate-proof” and “climate-smart” plans, offers a potential to enhance the economic sustainability of climate response and capitalize on conservation opportunities in climate bright spots (Gattuso et al. 2018; Queirós et al., 2021). However, the efficient inclusion of the climate change factor into planning processes remains a main global challenge for MSP, and only few attempts and initiatives making notable progress in this regard (Frazao Santos et al., 2020).

There are significant obstacles to achieving a more comprehensive “climate-smart” and “climate-proof” planning approach for marine and coastal regions. These obstacles include structural barriers such as insufficient stakeholder engagement and fragmented governance, as well as knowledge gaps regarding key elements of the system. One challenge is the difficulty in assessing relevant information on future changes in hydrological and biogeochemical cycles, meteo-marine climate, sediment dynamics, and ecosystem evolution, particularly those related to the land-sea interactions and connected feedbacks. It is challenging to quantitatively assess the extent of climate impacts on sea uses using robust metrics, which are crucial for MSP-informed decision-making. Furthermore, characterization of coastal oceanographic processes, reconstruction of recent climate trends, projection of future evolution, and monitoring the effects of climate and management strategies, require the ability to resolve small-scale variability over multi-decadal time scales. This presents another significant challenge for both numerical modelling and observations.

From a modelling perspective, addressing climate analysis presents various challenges, including the substantial computational power and storage requirements needed for high resolution and multi-decadal simulation. Process parameterizations, coupling between different systems or processes (e.g. atmosphere-ocean and waves-currents), and accurate initial and boundary conditions are also non-trivial concerns. On the other hand, observations face significant limitations in terms of coverage and duration of available time series data. Collecting *in situ* meteo-oceanic data during extreme events is practically feasible only through autonomous units such as moorings or gliders. Beyond the inherent difficulty in characterizing the effects of climate change on sea uses, a significant gap in the translation of climate information into an actionable knowledge that can be easily understood and utilized by planners and stakeholders remains. This knowledge should clearly and quantitatively address trade-offs and uncertainties.

All mentioned is required for the development of dynamic MSP and to properly address ongoing changes, together with the acknowledgement of possible biases and gaps in stakeholders' perception of climate impacts and their awareness of available information. This is crucial for effective implementation and ensuring responsiveness to these changes. Furthermore, coastal marine dynamics are closely interconnected with causal loops and fluxes originating or controlled from the mainland. However, existing policy frameworks typically only partially and fragmentarily consider these pressures and feedback in regulating sea and land uses. It is essential to bridge this gap and develop comprehensive policies that will fully account all aspects.

In the Mediterranean region, the climate dimension in the MSP-ICZM framework was facilitated by the PAP-RAC through the introduction of a specialized tool called the "Climate Action and MSP Planning Tool" (available at https://msp.iczmplatform.org/planning-tools/climate-action-and-msp-planning-tool/). This tool provides guidance on identifying climate change impacts on different sectors, exploring potential responses, and assessing the co-benefits and trade-offs associated with the considered options. It serves as a valuable resource for incorporating climate considerations into the planning processes and enhancing the integration of climate actions within the MSP.

In the Adriatic region, MSP needs to face densely used multi-country space in which climate-related drivers of change, in particular global warming and sea level rise, will create needs for re-definition of spaces dedicated to the use and protection of specific ecosystems, taking into account shifts in habitats and limits of migrations. In particular protected areas, fisheries, and aquaculture will experience change and may give way to new conflicts about use of space and environmental impacts. In this context of the Adriatic region, the Interreg Italy-Croatia Programme (2014-2020) played a significant role in fostering cross-boundary cooperation and promoting initiatives related to blue innovation, resilience-building, environmental and cultural heritage protection, and low-impact maritime transport. All efforts laid a strong foundation for marine and coastal planning at the local and regional levels. With a specific focus on climate change adaptation in the Adriatic region, the CREATE project (2022-2023) assessed the key achievements of the Programme, including the knowledge base and successful implementation stories. As part of this assessment, an "Inventory of Knowledge Products" (available at https://programming14-20.italy-croatia.eu/documents/5629765/0/D3.1.2_Inventory_knowledge_DEF.pdf/6eeb421f-5913-7366-724c-9e03aa079385?t=1683105296348) has been developed, providing a ready-to-use tool initiating the decision-making process related to climate adaptation. Additionally, the "Adaptation Handbook" (available at https://programming14-20.italy-croatia.eu/web/create/docs-and-tools) showcases a range of representative and easily transferable case studies that can serve as practical examples for climate responses in the Adriatic region.

2.5. References

Antonioli, F., Falco, G.D., Lo Presti, V., Moretti, L., Scardino, G., Anzidei, M., Bonaldo, D., Carniel, S., Leoni, G., Furlani, S., Marsico, A., Petitta, M., Randazzo, G., Scicchitano, G., Mastronuzzi, G. (2020). Relative Sea-Level Rise and Potential Submersion Risk for 2100 on 16 Coastal Plains of the Mediterranean Sea. *Water* 2020, 12, 2173.

Baric, A., Grbec, B., Bogner, D. (2008). Potential Implications of Sea-Level Rise for Croatia. *Journal of Coastal Research*, *242*(2), 299–305. https://doi.org/10.2112/07A-0004.1

Bellafiore D., Ferrarin C., Maicu F., Manfè G., Lorenzetti G. et al (2021) Saltwater intrusion in a Mediterranean delta under a changing climate. *Journal of Geophysical Resesearch - Oceans* 126:1–23. https://d oi.o rg/1 0.1 029/2020JC016437

Bonaldo, D., Bucchignani, E., Pomaro, A., Ricchi, A., Sclavo, M., Carniel, S. (2020). Wind waves in the Adriatic Sea under a severe climate change scenario and implications for the coasts. *International Journal of Climatology*, *40*(12), 5389–5406. https://doi.org/10.1002/joc.6524

Bonaldo, D., Antonioli, F., Archetti, R., Bezzi, A., Correggiari, A., Davolio, S., de Falco, G., Fantini, M., Fontolan, G., Furlani, S., Gaeta, M. G., Leoni, G., lo Presti, V., Mastronuzzi, G., Pillon, S., Ricchi, A., Stocchi, P., Samaras, A. G., Scicchitano, G., & Carniel, S. (2018). Integrating multidisciplinary instruments for assessing coastal vulnerability to erosion and sea level rise: lessons and challenges from the Adriatic Sea, Italy. *Journal of Coastal Conservation*, *23*(1). https://doi.org/10.1007/s11852-018-0633-x

Carson, M. (2015). Acting locally to mitigate globally: climate action in the Anthropocene. *Journal of Environmental Studies and Sciences*, 5(1), 58–60. https://doi.org/10.1007/s13412-015-0225-0

Cozzi, S., Giani, M., (2011): River water and nutrient discharges in the Northern Adriatic Sea: Current importance and long-term changes. *Continental Shelf research*, 31, 1881-1893.

Da Lio, C., Tosi, L. (2019) Vulnerability to relative sea-level rise in the Po River delta (Italy). *Estuarine, Coastal and Shelf Science* 228:106379. https://doi.org/10.1016/j.ecss.2019.106379

Diffenbaugh N.S., Giorgi F. (2012) Climate change hotspots in the CMIP5 global climate model ensemble. *Climatic Change* 114, 813–822. doi: 10.1007/s10584-012-0570-x

Domínguez, R., Olabarria, C., Woodin, S. A., Wethey, D. S., Peteiro, L. G., Macho, G., Vázquez, E. (2021). Contrasting responsiveness of four ecologically and economically important bivalves to simulated heat waves. *Marine Environmental Research*, 164(December 2020). https://doi.org/10.1016/j.marenvres.2020.105229

Dosio A, Fischer E.M. (2018) Will Half a Degree Make a Difference? Robust Projections of Indices of Mean and Extreme Climate in Europe Under 1.5°C, 2°C, and 3°C Global Warming. *Geophysical Research Letters* 45, 935–944. doi: 10.1002/2017gl076222

Ehler, C., Douvere, F. (2009) Marine spatial planning: a step-by-step approach. Paris, France, Unesco, 99pp. (IOC Manuals and Guides 53), (ICAM Dossier 6). DOI http://dx.doi.org/10.25607/OBP-43

Frazão Santos, C., Agardy, T., Andrade, F., Calado, H., Crowder, L. B., Ehler, C. N., García-Morales, S., Gissi, E., Halpern, B. S., Orbach, M. K., Pörtner, H. O., Rosa, R. (2020). Integrating climate change in ocean planning. *Nature Sustainability*, *3*(7), 505–516. https://doi.org/10.1038/s41893-020-0513-x

Gattuso, J. P., Magnan, A. K., Bopp, L., Cheung, W. W. L., Duarte, C. M., Hinkel, J., … Rau, G. H. (2018). Ocean solutions to address climate change and its effects on marine ecosystems. *Frontiers in Marine Science*, 5(OCT). https://doi.org/10.3389/fmars.2018.00337

Giorgi, F. (2006) Climate change hotspots. *Geophysical Research Letters* 33, L08707. doi: 10.1029/2006GL025734

Giorgi, F., Lionello, P. (2008) Climate change projections for the Mediterranean region. Glob. Planet. Change 63, 90–104. doi: 10.1016/j.gloplacha.2007.09.005

Juza, M., Fernández-mora, À., Tintoré, J. (2022). Sub-Regional Marine Heat Waves in the Mediterranean Sea From Observations : Long-Term Surface Changes, Sub-Surface and Coastal Responses, *9*(March). https://doi.org/10.3389/fmars.2022.785771

Lionello P, Malanotte-Rizzoli P, Boscolo R, Alpert P, Artale V et al. (2006) The Mediterranean climate: An overview of the main characteristics and issues, in Mediterranean climate variability, eds. Lionello P, Malanotte-Rizzoli P, Boscolo R (Elsevier), 1–26. doi: 10.1016/s1571-9197(06)80003-0

Lionello, P. (2012) The Climate of the Mediterranean Region: From the Past to the Future. Elsevier Science. doi: 10.1016/C2011-0-06210-5

Lionello, P., Conte, D., Marzo, L., Scarascia, L. (2017). The contrasting effect of increasing mean sea level and decreasing storminess on the maximum water level during storms along the coast of the Mediterranean Sea in the mid 21st century. *Global and Planetary Change*, *151*, 80–91. https://doi.org/10.1016/j.gloplacha.2016.06.012

Lionello, P., Scarascia, L. (2018). The relation between climate change in the Mediterranean region and global warming. *Regional Environmental Change* 18, 1481–1493. doi: 10.1007/s10113-018-1290-1

Makris, C., Galiatsatou, P., Tolika, K. *et al.* Climate change effects on the marine characteristics of the Aegean and Ionian Seas. *Ocean Dynamics* 66, 1603–1635 (2016). https://doi.org/10.1007/s10236-016-1008-1

MedECC (2020) Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future. First Mediterranean Assessment Report [Cramer, W., Guiot, J., Marini, K. (eds.)]. Union for the Mediterranean, Plan Bleu, UNEP/MAP, Marseille, France, 632 pp., ISBN: 978-2-9577416-0-1, doi:10.5281/zenodo.4768833.

Nikulin, G., Lennard, C., Dosio, A., Kjellström, E., Chen, Y. et al. (2018). The effects of 1.5 and 2 degrees of global warming on Africa in the CORDEX ensemble. *Environmental Research Letters* 13, 65003. doi: 10.1088/1748-9326/aab1b1

Queirós, A.M., Talbot, E., Beaumont, N.J., Somerfield, P.J., Kay, S., Pascoe, C., … Nic Aonghusa, C. (2021). Bright spots as climate-smart marine spatial planning tools for conservation and blue growth. *Global Change Biology*, 27(21), 5514–5531. https://doi.org/10.1111/gcb.15827

Pomaro, A., Cavaleri, L., Papa, A., Lionello, P. (2018). Data Descriptor : 39 years of directional wave recorded data and relative problems , climatological implications and use. *Scientific Data*, *5*, 1–12. https://doi.org/10.1038/sdata.2018.139

Rajczak, J., Pall, P., Schär, C. (2013). Projections of extreme precipitation events in regional climate simulations for Europe and the Alpine Region. *Journal of Geophysical Research: Atmospheres*, *118*(9), 3610–3626. https://doi.org/10.1002/jgrd.50297

Ramieri, E., Bocci, M., Markovic, M. (2019). Linking Integrated Coastal Zone Management to Maritime Spatial Planning: The Mediterranean Experience. In: Zaucha, J., Gee, K. (eds) Maritime Spatial Planning. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-319-98696-8_12

Rochette, J., Wemaëre, M., Billé, R., du Puy-Montbrun, G. (2012). A Contribution to the Interpretation of Legal Aspects of the Protocol on Integrated Coastal Zone Management in the Mediterranean. UNEP/MAP, Priority Actions Programme—Regional Activity Centre, Split, 72 p. + annexes. Retrieved from https://www.pap-thecoastcentre.org/regional_medpartnership_workshop/documents/ICZM%20Protocol_Legal%20aspects.pdf.

Syvitski, J.P.M., Kettner, A.J. (2007): On the flux of water and sediment into the Northern Adriatic Sea. *Continental Shelf Research* 27, 296-308.

Tojčić, I., Denamiel, C., Vilibić, I. (2023), Kilometer-scale trends and variability of the Adriatic present climate (1987–2017). *Climate Dynamics* (2023). https://doi.org/10.1007/s00382-023-06700-2

Vautard R, Gobiet A, Sobolowski SP, Kjellström E, Stegehuis A et al. 2014 The European climate under a 2°C global warming. *Environmental Research Letters* 9, 34006. doi: 10.1088/1748-9326/9/3/034006

3. Perspectives for Marine and Coastal Protected Areas in the Adriatic-Ionian region (CREATE Flagship paper 2)

3.1. Executive summary

The present paper, the second of the two flagship papers envisioned by the CREATE Project, introduces an overview of marine protection initiatives in the Adriatic-Ionian area as well as the challenges for the future and the opportunities from the Interreg Italy-Croatia programme.

3.2. Protected areas in the Adriatic Ionian Region: the present state

Protected areas are dedicated to the long-term protection of the nature from anthropogenic influence. Throughout the past century, the original scope of conserving landscape and wildlife has progressively been expanded in order to include diverse instances and objectives, ranging from biodiversity conservation to socio-economical objectives and ecosystem services. While the protection of terrestrial environments took off at the end of the nineteenth century, noteworthy accelerations in the protection of marine environments were achieved only in the second half of the twentieth century (Watson et al., 2014). At present, the latest global initiative has set the goal of protecting 30% of the land and ocean area by 2030. This initiative, also referred to as “30 by 30”, is one of the 23 Targets for 2030 in Landmark UN Biodiversity Agreement adopted in 2022 by the Kunming-Montreal Global Biodiversity Framework, and has its counterpart in the EU policy by the EU Biodiversity Strategy 2030. This strategy aims at establishing a coherent Trans-European Nature Network based on the existing Natura 2000 network and on the enhancement of the green infrastructure system throughout the Union (EEA 2020), which should increase the connectivity and the efficiency of protected areas. Although country-based implementation solution can collectively achieve the EU goals, and the designation of additional protected areas as well as the definition of the protection schemes is under the responsibility of the Member States, cross-country cooperation has been found to be more efficient in terms of area required to achieve the conservation targets (Hermoso et al., 2020).

In this direction, the Adriatic-Ionian region is a perfect testing site for actions aimed at fostering a coordinated, basin-scale macroregional response to protection challenges in the very near future. The Adriatic-Ionian region is a complex system characterised by a multiplicity of terrestrial, coastal, and marine ecosystems and encompassed among many countries (Italy, Slovenia, Croatia, Montenegro, Bosnia and Herzegovina, Albania, and Greece) characterized by different economies and environments. In this diverse picture, the Adriatic and Ionian seas have historically been a common capital of utmost importance for different needs and uses. This led to strong opportunities for socio-economic development at the cost of strong anthropic pressures on the environment. The conservation of the health status and endemic conditions of this basin, alongside with the importance of limiting the intensity of the exploitation processes, gained only recently some relevance in the political agendas. As a result, even though the EU achieved the goal of 10% of the seas under protection in 2020, the Adriatic-Ionian region is lagging behind with the smallest extent of MPAs in the Mediterranean (3.57% of the marine area), and a very small fraction (0.07%) of strictly protected areas (Sovinc 2021). Threats to the good environmental status of the marine and coastal areas in the region have been modulating their relative weight over time. A long-lasting persistence of overfishing practices (Legović, 2008) has been progressively flanked by an intensification of marine litter production spreading, impacting marine habitats and species as well as ecosystem services and crucial economic sectors (Vlachogianni et al., 2018, and references therein). In the same time, increasing tourism in coastal areas led to manifold impacts related to overbuilding on the shoreline, affecting coastal ecosystems and possibly disrupting natural sediment dynamics on the beach thus contributing, together with reduced sediment supply, to increasing coastal erosion (e.g. Zunica, 1990), water quality and, as more recently acknowledged, underwater noise related with nautical activities (Petrizzo et al., 2023). Climate change overarches the whole picture with impacts on different natural processes, from the physical drivers of ecosystem dynamics, such as thermohaline regimes and circulation (Tojčić et al., 2023), marine heat waves modulation and intensity (Juza et al., 2022), hydrological regimes, extensive salinization of coastal and transitional water bodies (Baric et al., 2008; Bellafiore et al., 2021) and aquifers (Da Lio and Tosi, 2019), up to the timing and patterns of the biogeochemical cycles and the possible creation of favourable conditions for habitat shifts in the region (e.g. Vitelletti et al., 2023).

3.3. Challenges and opportunities

The successful implementation of MPAs is a narrow path through diverse scientific, technical and socio-economical challenges, starting from the thorough identification and characterization of the sites to be protected and proceeding with the solution of conflicts with other sea uses, up to the actual management, governance, and surveillance issues.

Sparsity, discontinuity and fragmentation of the observations in marine systems is a major blocking factor for the identification and characterization of the sites to be protected. This is particularly relevant in a network perspective, in which conservation strategies should be harmonized accounting for connectivity needs and spatial interrelations involving the mobility of species, and the biotic and abiotic factors driving the ecosystem dynamics need to be investigated consistently. Furthermore, the limited availability of long-term observations in marine environments hampers the assessment of multidecadal trends in physical and biological quantities and processes, thus preventing the detection of climate impacts and the effects of management actions.

Conflicts are intrinsically connected with conservation initiatives (Redpath et al., 2013), and the issues they can generate in the management of a protection measure can include numerous direct and indirect socioeconomic and environmental costs, from the consequences of a partial or delayed implementation up to undermining the overall functioning and reliability of the governance structure devoted to environmental public action. Conflicts in protection initiatives are multi-dimensional phenomena that involve space and time scales (e.g. local vs regional vs global, short-term vs long-term goals), institutions (conflicts between jurisdictional prerogatives, or among local and National authorities), and the disagreement on the equity of the distribution of the benefits from the protection measures and the efficiency of the measures, if any, envisaged to compensate the losses for the economical sectors impacted by the established restrictions (Beuret et al., 2018). While some sources of conflict are related to the very structure of the decisional process, typically associated with feelings of exclusion from the decision making and the perception of a lack in transparency and communication, some sectors (like fisheries and tourism, both economically and politically strategic assets in the Adriatic-Ionian region) are intrinsically more likely to undergo negative impacts from protection actions (Canovas-Molina and Frapolli, 2020), and as such more likely to give rise to conflicts.

Even when a protection measure is put in place and a management plan is defined, political and bureaucratic constraints slow down the implementation of the policies and modification of the plan in response to changes in environmental conditions, available knowledge, and protection priorities. The effect of this form of friction in the transmission from decision to implementation increases rapidly with the increase of involved actors, and factors and targets considered in the management plan (Vitelletti and Bonaldo, 2020).

As the creation of an adequate and shared knowledge base is a necessary, if not sufficient, condition for the success of a protection initiative, a dedicated effort should be dedicated to the establishment of sound infrastructures for long-term multidisciplinary monitoring of the marine environment. In this direction, and even more so in a network perspective, Manea et al. (2020) emphasize the importance of an agreed conceptual framework, if necessary at the supra-national level, for the harmonization of monitoring schemes and quantities, metrics and procedures for data collection. The implementation and maintenance of open science data platforms, can be a further added value fostering knowledge sharing and co-production at different levels, encouraging the inclusion of stakeholders and the civil society while facilitating the cooperation among academic and research institutions and environmental protection agencies. Alongside with the improvement of the knowledge-building capacity, Vitelletti and Bonaldo (2020) point out that the requirements for a more efficient management of protected areas include the decentralization of the management system and the simplification of the legislation burdening the administrative procedures, while enhancing the involvement of local communities and setting objectives through different time spans, including relatively short-term goals.

Maritime Spatial Planning (MSP) has globally been gaining increasing importance as a tool for managing multiple uses of marine and coastal regions while addressing sustainable growth objectives and minimising the conflicts (Ehler and Douvere, 2009). At the Mediterranean level the inclusion of MSP into the Integrated Coastal Zone Management (ICZM) Protocol, following the Conceptual Framework adopted in 2017 by the COP20, fosters the adoption of successful practices and tools developed for MSP into a common planning approach at the basin scale, hence downscalable at the EUSAIR level. Furthermore, when adaptively conceived in a climate-change perspective, protection initiatives can be the backbone for a climate-proof (fostering adaptation to climate change) and climate-smart (fostering mitigation) maritime spatial planning (Gattuso et al. 2018; Frazão Santos et al., 2020; Queirós et al., 2021). A typical example is given by the multiple positive outcomes given by the protection of seagrass meadows, which act as nursery for juvenile fish (thus fostering ecological conservation, Olson et al., 2019) while counteracting coastal erosion and flooding by enhancing hydrodynamic energy dissipation (enhancing coastal resilience, also to climate-related risks, Unguendoli et al., 2023) and contributing to carbon sequestration (and therefore to climate change mitigation).

In the ambitious strive toward the 30 by 30 objective, the “Other Effective Area-based Conservation Measures” defined by the UNEP Convention on Biological Diversity (2018) as “geographically defined area other than a Protected Area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the in situ conservation of biodiversity, with associated ecosystem functions and services and, where applicable, cultural, spiritual, socioeconomic, and other locally relevant values” (https://www.cbd. int/doc/c/9b1f/759a/dfcee171bd46b06cc91f6a0d/sbstta-22-l-02- en.pdf, last visited June 22, 2023), appear as a strategic opportunity to complement the necessary enhancement of the existing MPA network. By practically envisaging conservation as a complementary effect of other sea uses, OECMs allow the participation of a potentially large number of diverse subjects in the decision and management processes (Gurney et al., 2023; Rodrìguez-Rodrìguez et al., 2021), thus partially reducing the conflicts associated with setting conservation as a primary objective. Due to the broad reach of their definition, the identification of OECMs can be based on different criteria and aim at different degrees of protection. In this perspective, wrecks and decommissioned structures worldwide have a great potential as OECMs for ecosystem conservation, with possible synergies with cultural heritage preservation and valorization (Pearson and Thompson, 2023). Although at present no OECM has been formally designated in the Adriatic-Ionian Region (https://www.protectedplanet.net/en, last accessed 26 June, 2023), there is an increasing interest in their adoption in the framework of the macro-regional strategy (Sovinc 2021).

3.4. Recent achievements and perspectives: the role of the Interreg Italy-Croatia Programme

International initiatives at different scales have pursued different aspects of the implementation and management of marine protection measures. MedPAN is a network of managers responsible for MPAs in the Mediterranean, created in 2008 and aiming at sharing knowledge, experiences, and management tools (https://medpan.org/en/, last visited 26 June, 2003). MEDTRENDS (Programme MED, 2014-2015) focused on analysing 20-year scenarios of marine economic growth across EU Mediterranean countries at a transnational level, highlighting interactions, conflicts and negative effects, while also providing insights from climate change perspective, with a special focus on MPAs. MPA-ADAPT (Interreg-Med, 2016-2018) directly addressed the inclusion of climate change adaptation into MPA management by fostering cross-border and cross-basin cooperation in the development of common tools for vulnerability assessment and environmental monitoring.

15

In the 2014-2020 Programming Period the projects implemented in the Interreg ITA-CRO Programme provided several opportunities for an improvement of environmental protection in the Adriatic-Ionian region, with an obvious focus on the Adriatic basin. ADRIREEF tackled the exploitation of natural and artificial Adriatic reefs in support to blue economy. The comprehensive database on reefs and wrecks in the area produced by this project (Minelli et al., 2021) provides an important piece of information toward the identification of possible sites to be endowed with some protection measure such as OECMs. Adriadapt produced tools and guidelines for adaptation in coastal areas, highlighting the role of MPAs and OECMs as green options for adaptation (http://adriadapt.eu/adaptation-options/marine-protected-areas-and-other-effective-area-based-conservation-measures/, last accessed 27 June 2023). In the effort towards the definition of climate adaptation paradigms in coastal and transitional environments, CHANGE WE CARE identified criteria and recommendations for climate monitoring in the Adriatic Sea, addressing integration and standardisation of observation protocols, the implementation of open data and open science principles, and the requirements for ensuring long-term durability of monitoring programmes in terms of funding, collaboration networks, and education of professional profiles. ECOSS established a trans-boundary ECOlogical observing system in the Adriatic Sea (ECOAdS), integrating ecological and oceanographic research and monitoring in Italy and Croatia with the Natura 2000 conservation strategies, with specific attention to the establishment of a multi-sectorial public engagement process aiming at aligning the results of this activity to societal needs and expectations. SOUNDSCAPE extended the monitoring and assessment capacity in the area by establishing common methodologies for the quantification of underwater noise and its impact on marine life. HATCH capitalised the results of previous Interreg ITA-CRO projects by fostering the harmonization and management of data in a MSP perspective.

The 2021-2027 programming period is characterised by a consolidation of the convergences between the EUSAIR macroregional strategy and the Interreg ITA-CRO Programme. This is an unprecedentedly timely opportunity for improving cross-border cooperation toward a more coordinated protection, planning and management paradigms, the construction of more efficient governance structures, and a tighter connection between science and social instances.

3.5. References

Baric, A., Grbec, B., Bogner, D. (2008). Potential Implications of Sea-Level Rise for Croatia. *Journal of Coastal Research*, *242*(2), 299–305. https://doi.org/10.2112/07A-0004.1

Bellafiore D., Ferrarin C., Maicu F., Manfè G., Lorenzetti G., et al (2021) Saltwater intrusion in a Mediterranean delta under a changing climate. Journal of Geophysical Research - Oceans 126:1–23. https://d oi.o rg/1 0.1 029/2020JC016437

CBD. (2018). Convention on biological diversity. COP 14. Decision 14/8. Protected areas and other effective area-based conservation measures. Available online from: https:// www.cbd.int/decision/cop/?id=13650 (Accessed 22/06/2023)

Da Lio C., Tosi L. (2019) Vulnerability to relative sea-level rise in the Po River delta (Italy). Estuarine, Coastal and Shelf Science 228:106379. https://doi.org/10.1016/j.ecss.2019.106379

Ehler, C. and Douvere, F. (2009) Marine spatial planning: a step-by-step approach. Paris, France, Unesco, 99pp. (IOC Manuals and Guides 53), (ICAM Dossier 6). DOI http://dx.doi.org/10.25607/OBP-43

European Environment Agency (EEA), 2020. Briefing no. 05/2020: Building a coherent Trans-European Nature Network, PDF - TH-AM-20-005-EN-N - ISBN 978-92-9480-240-8 - ISSN 2467-3196 - doi: 10.2800/960913; HTML - TH-AM-20-005-EN-Q - ISBN 978-92-9480-239-2 - ISSN 2467-3196 - doi: 10.2800/997935 last visited June 22, 2023.

Frazão Santos, C., Agardy, T., Andrade, F., Calado, H., Crowder, L. B., Ehler, C. N., García-Morales, S., Gissi, E., Halpern, B. S., Orbach, M. K., Pörtner, H. O., & Rosa, R. (2020). Integrating climate change in ocean planning. *Nature Sustainability*, *3*(7), 505–516. https://doi.org/10.1038/s41893-020-0513-x

Gattuso, J. P., Magnan, A. K., Bopp, L., Cheung, W. W. L., Duarte, C. M., Hinkel, J., … Rau, G. H. (2018). Ocean solutions to address climate change and its effects on marine ecosystems. *Frontiers in Marine Science*, 5(OCT). https://doi.org/10.3389/fmars.2018.00337

Gurney, G. G., Adams, V. M., Álvarez-Romero, J. G., & Claudet, J. (2023). Area-based conservation: Taking stock and looking ahead. In *One Earth* (Vol. 6, Issue 2, pp. 98–104). Cell Press. https://doi.org/10.1016/j.oneear.2023.01.012

Hermoso, V., A. Morán-Ordóñez, M. Lanzas, L. Brotons Designing a network of green infrastructure for the EU *Landscape and Urban Planning*, 196 (2020), Article 103732, 10.1016/j.landurbplan.2019.103732

Juza, M., Fernández-mora, À., Tintoré, J. (2022). Sub-Regional Marine Heat Waves in the Mediterranean Sea From Observations : Long-Term Surface Changes , Sub-Surface and Coastal Responses, *9*(March). https://doi.org/10.3389/fmars.2022.785771

Legović, (2008) Impact of the demersal fishery and evidence of the Volterra principle to the extreme *Ecological Modelling*, 212 (2008), pp. 68-73

Manea, E., Bongiorni, L., Bergami, C., Pugnetti, A. (2020) Challenges for Marine Ecological Observatories to Promote Effective GMS of Natura 2000 Network - The Case Study of ECOAdS in the Adriatic Sea. in Alfarè L.T. & Ruoss E. (eds) 2020: Governing Future Challenges in Mediterranean Protected Areas. CNR Edition 2020, 156 p., DOI: 10.26383/978-88-8080-402-4

Minelli, A., Ferrà, C., Spagnolo, A., Scanu, M., Tassetti, A. N., Ferrari, C. R., Mazziotti, C., Pigozzi, S., Jakl, Z., Šarčević, T., Šimac, M., Kruschel, C., Pejdo, D., Barbone, E., De Gioia, M., Borme, D., Gordini, E., Auriemma, R., Benzon, I., Vuković-Stanišić, Đ., Orlić, S., Frančić, V., Zec, D., Orlić Kapović, I., Soldati, M., Ulazzi, S., and Fabi, G.: The ADRIREEF database: a comprehensive collection of natural/artificial reefs and wrecks in the Adriatic Sea, Earth Syst. Sci. Data, 13, 1905–1923, https://doi.org/10.5194/essd-13-1905-2021, 2021.

Navarrete-Fernández, T., Bermejo, R., Hernández, I., Deidun, A., Andreu-Cazenave, M., Cózar, A. (2022). The role of seagrass meadows in the coastal trapping of litter. *Marine Pollution Bulletin*, *174*. https://doi.org/10.1016/j.marpolbul.2021.113299

Olson, A. M., Hessing-Lewis, M., Haggarty, D., Juanes, F. (2019). Nearshore seascape connectivity enhances seagrass meadow nursery function. *Ecological Applications*, *29*(5). https://doi.org/10.1002/eap.1897

Pearson, N., and Thompson, B. S. (2023). Saving two fish with one wreck: Maximizing synergies in marine biodiversity conservation and underwater cultural heritage protection. *Marine Policy*, *152*. https://doi.org/10.1016/j.marpol.2023.105613

Petrizzo, A.; Barbanti, A.; Barfucci, G.; Bastianini, M.; Biagiotti, I.; Bosi, S.; Centurelli, M.; Chavanne, R.; Codarin, A.; Costantini, I.; et al. First assessment of underwater sound levels in the Northern Adriatic Sea at the basin scale. Scientific Data 2023, 10, 137.

17

Queirós, A. M., Talbot, E., Beaumont, N. J., Somerfield, P. J., Kay, S., Pascoe, C., … Nic Aonghusa, C. (2021). Bright spots as climate-smart marine spatial planning tools for conservation and blue growth. *Global Change Biology*, 27(21), 5514–5531. https://doi.org/10.1111/gcb.15827

Redpath, S.M., Young, J., Evely, A., Adams, W.M., Sutherland, W.J., Whitehouse, A., Amar, A., Lambert, R.A., Linnell, J.D.C., Watt, A., Gutierrez, R.J., Understanding and managing conservation conflicts, *Trends in Ecology and Evolution* 28 (2013) 100–109, https://doi.org/10.1016/j.tree.2012.08.021.

Rodríguez-Rodríguez, D., Sánchez-Espinosa, A., Abdul Malak, D. (2021). Potential contribution of OECMs to international area-based conservation targets in a biodiversity rich country, Spain. *Journal for Nature Conservation*, *62*. https://doi.org/10.1016/j.jnc.2021.126019

Sovinc, A. (2021). Analysis of Marine (Water) Protected Areas in EUSAIR and Proposals for Corrective Measures. Final Report. Available at https://www.adriatic-ionian.eu/wp-content/uploads/2021/10/Analysis-of-Marine-water-Protected-Areas-in-EUSAIR-and-Proposals-for-Corrective-Measures-with-annexes.pdf last visited June 22, 2023.

Unguendoli, S., Biolchi, L. G., Aguzzi, M., Pillai, U. P. A., Alessandri, J., Valentini, A. (2023). A modeling application of integrated nature based solutions (NBS) for coastal erosion and flooding mitigation in the Emilia-Romagna coastline (Northeast Italy). *Science of the Total Environment*, *867*. https://doi.org/10.1016/j.scitotenv.2022.161357

Tojčić, I., Denamiel, C. Vilibić, I. Kilometer-scale trends and variability of the Adriatic present climate (1987–2017). *Climate Dynamics* (2023). https://doi.org/10.1007/s00382-023-06700-2

Vitelletti, M. L., Bonaldo, D. (2020): Response to Climate Change in Coastal and Marine Protected Areas: Threats and Opportunities, in Alfarè L.T. & Ruoss E. (eds) 2020: Governing Future Challenges in Mediterranean Protected Areas. CNR Edition 2020, 156 p., DOI: 10.26383/978-88-8080-402-4

Vitelletti, M.L., Manea, E., Bongiorni, L., Ricchi, A., Sangelantoni, L., Bonaldo, D. (2023). Modelling distribution and fate of coralligenous habitat in the Northern Adriatic Sea under a severe climate change scenario. *Frontiers in Marine Science*, *January*, 1–19. https://doi.org/10.3389/fmars.2023.1050293

Watson, J., Dudley, N., Segan, D. *et al.* The performance and potential of protected areas. *Nature* 515, 67–73 (2014). https://doi.org/10.1038/nature13947

Zunica, M. (1990). Beach Behavior and Defences along the Lido Di Jesolo, Gulf of Venice, Italy. *Journal of Coastal Research*, *6*(3), 709–719. http://www.jstor.org/stable/4297730