

# The Ecological Observing System of the Adriatic Sea (ECOAdS): structure and perspectives within the main European biodiversity and environmental strategies

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## Abstract

This Policy Brief succinctly presents the Ecological Observing System of the Adriatic Sea (ECOAdS), aimed at integrating the ecological and oceanographic dimensions within the conservation strategy of the Natura 2000 network, and to propose a way to go for its future development and maintenance. After a definition of marine ecological observatories, we describe the current structure of ECOAdS, its key components and potential relevance in relation to the main European strategies for biodiversity and marine observation for the next decade. Finally, we suggest some actions that could be undertaken for the future development of ECOAdS, targeting possible perspectives in different regional, macro-regional, national and European strategic contexts. This Policy Brief is one of the outcomes of the Interreg Italy-Croatia Project ECOS (ECological Observing System in the Adriatic Sea: oceanographic observations for biodiversity; <https://www.italy-croatia.eu/web/ecoss>), which had the main purpose to design and carry out the first steps for the establishment of ECOAdS.

## Keywords

Adriatic Sea, Ecological Observatory, Biodiversity, Natura 2000 sites

## Introduction

Marine observatories are globally widespread observing and experimenting infrastructures aiming to collect high-resolution oceanographic data, both in coastal and offshore areas, in order to assess their environmental status, variability and trends, induced by anthropic and climate changes (Crise et al. 2018). Marine observatories are prerequisite for producing knowledge and supporting evidence-based decisions addressed towards sea management. For such decisions to be effective, the knowledge should integrate all components of marine ecosystems in a holistic manner, including biological and ecological processes, which are intrinsically entangled with the oceanographic ones (Benedetti-Cecchi et al. 2018; Carr et al. 2010). Marine ecological observatories incorporate such an approach and represent a further advancement of the marine observatory perspective, recommended at the European and the global level (Benedetti-Cecchi et al. 2018; Carr et al. 2010; Duffy et al. 2013; Muelbert et al. 2019). Specifically, they broaden the spectrum of marine observations, arrange and maintain harmonized and coherent long-term ecological observations, and link marine ecosystem monitoring with the effectiveness of the protection and restoration measures. Crucial to this kind of observatories is the integration of the ecological connectivity concept (UNEP 2019), which is one of the main driving forces of the functioning of marine ecosystems, embracing the complex interconnections among natural processes, species and their life cycles, and the environment (Carr et al. 2003; Carr et al. 2010; Maxwell et al. 2015; Manea et al. 2019; Manea et al. 2020). Ecological observatories should be fed by researchers, policy makers, environmental agencies, and the civil society, all participating to collect a variety of knowledge and viewpoints and to favour innovation,

develop information and foster management at the proper spatial scales (Bourgeron et al. 2018). The establishment and implementation of marine ecological observatories are also fundamental for the achievement of the United Nation Sustainable Development Goals (SDGs), mainly SDG14 “Life below water” (Biermann et al. 2017), contributing as well to the effective protection and restoration of the marine environment.

In this Policy Brief we present the main traits of the Ecological Observing System of the Adriatic Sea (ECOAdS), which was designed and started to be developed within the Interreg Italy-Croatia project ECOSS (ECological Observing System in the Adriatic Sea: oceanographic observations for biodiversity; [www.italy-croatia.eu/ecoss](http://www.italy-croatia.eu/ecoss)), and to propose perspective actions for its future maintenance. The project ECOSS, carried out from January 2019 to June 2021, involved ten partners from Italy and Croatia, with the overall purpose to contribute to the improvement of the conservation status of the habitat types and species of the coastal and marine Natura 2000 (N2K) sites in the Adriatic Sea. To achieve this goal, different actions were undertaken to integrate the ecological and oceanographic dimensions with the protection strategies of the N2K marine sites.

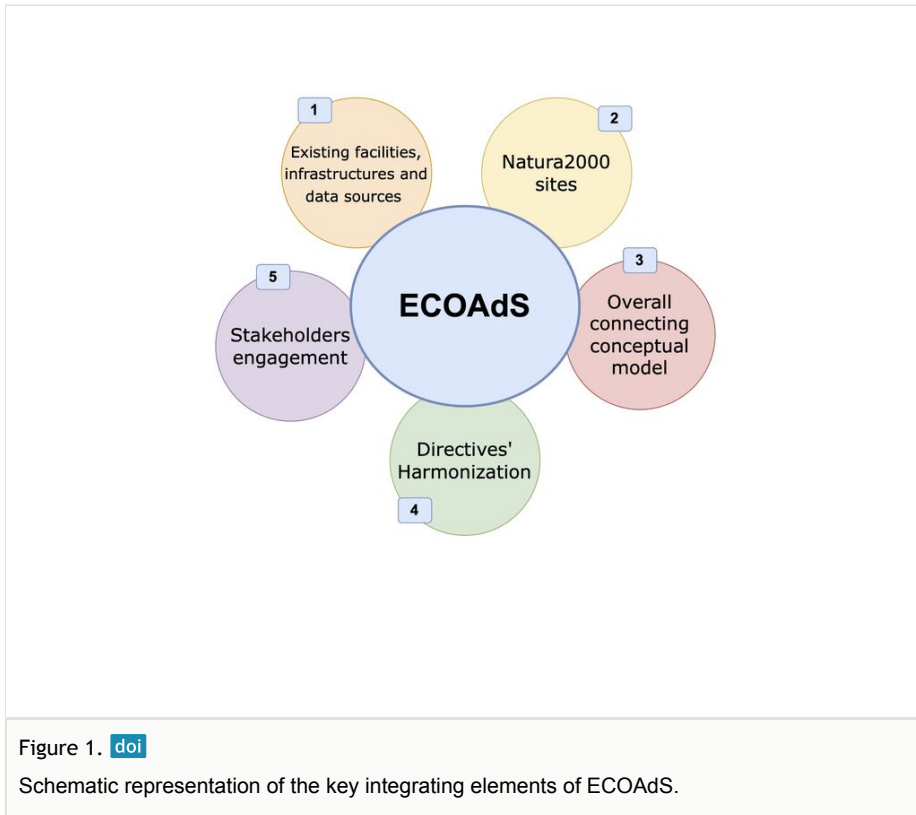
Indeed, the Adriatic Sea is a strategic area for the establishment of an ecological observatory, due to the concurrent presence of biodiversity richness, sensitive habitats and ecosystems, numerous ongoing monitoring and research activities. The heavy and diversified human pressures, as well as the economic interests, make this basin one of the most impacted regions of the Mediterranean Sea (Micheli et al. 2013). Moreover, the Adriatic is scarcely covered by marine protected areas (Bastari et al. 2016; Manea et al. 2019; Manea et al. 2020) and the implementation of the N2K network in the basin is ongoing, but suitable and fulfilled management plans and adequate monitoring programs are still lacking (Fraschetti et al. 2018; Orlikowska et al. 2016).

In this Policy Brief, first we will succinctly describe the present structure of ECOAdS, its key components and their potential relevance in relation to the main European strategies for biodiversity and for marine observation for the next decade. Next, we will suggest key perspectives to develop ECOAdS within different regional, macro-regional, national and European strategic contexts. Whenever needed, for details we will refer to the project deliverables, which are all publicly available on the project webpage ([www.italy-croatia.eu/ecoss](http://www.italy-croatia.eu/ecoss)), and to the ECOAdS web portal (<https://ecoads.eu/>), which has been specifically developed for the public access to information, tools and services of the observatory.

## **ECOAdS: the Adriatic Ecological Observing System**

ECOAdS was aimed to integrate the existing ecological and oceanographic research and monitoring in the Adriatic Sea within the N2K conservation strategies, focusing on the area under the jurisdiction of Italy and Croatia. Thus, it is contributing to the protection of N2K habitats and species, especially for those sites without management and monitoring plans, which are the majority in the focus area. ECOAdS lays its foundation on the incorporation of ecological connectivity and it supports the adoption of an ecosystem-based approach to management as well (UNEP 2011; Jonsson et al. 2020).

The key integrating elements of ECOAdS (Fig. 1) are accessible through the ECOAdS web portal (De Maio et al. 2021; <https://ecoads.eu/>), which provides an overarching view of information on available resources. It connects to existing geospatial services from both ECOSS partners and external initiatives (such as Copernicus, EMODnet, LTER networks) and it develops and makes available tools for interlinking information on N2K sites, parameters, directives, target species and habitats. The portal is conceived as an open platform to be enriched and improved in the coming years with the contribution of new or existing projects, data, and tools to support evolving requests and needs. It implements an open science approach and it is addressed to a wide stakeholder community (e.g., environmental managers, policy-makers, researchers, citizens).



Specifically, the ECOAdS key elements (Fig. 1) are:

1. The existing facilities, infrastructures and data resources in the area (Vilibić and ECOSS partnership 2019; Vilibić and ECOSS Partnership 2020) – Grounded on the ECOSS partners' knowledge and expertise, an inventory of the several monitoring initiatives and research programs and of the fixed-point observing systems (i.e. pylons, buoys, tide gauges, oceanographic platforms, coastal stations) in the Adriatic has been made available (Manea et al. 2020; Manea et al. 2021a; <https://ecoads.eu/>), evidencing through a SWOT analysis their major

- strengths, weaknesses and gaps. A wide variety of data are collected in the area, ranging from those related to the quality of transitional, coastal and marine waters, to the monitoring of N2K target species and habitats (e.g., dolphins, sea turtles, seagrass meadows, coralligenous outcrops) and other biotic components (e.g., plankton communities). These observing and monitoring systems hold different aims and maturity levels. In particular they lack a coherent and harmonized coordination, from the local to the whole Adriatic basin scale. It should be highlighted that none of them has a transnational nature. The list of the observing systems, of the ongoing monitoring activities and the links to the data sources are available on the ECOAdS web portal, in the sections dedicated to the sites and to the observing systems (<https://ecoads.eu/sitesoss/>), and to the information resources (<https://ecoads.eu/inforesource/list/>).
2. The N2K sites - The N2K network of protected areas, both at land and at sea, is the main biodiversity conservation instrument in Europe, legally based on the Habitats and Birds directives (European Commission 1992 and European Commission 2009; HD and BD, respectively). Six N2K sites (<https://ecoads.eu/>) have been considered as case studies within the ECOSS project (<https://ecoads.eu/sites/natura2000/>), reviewing their management goals and objectives, their socio-economic contribution to local activities, the knowledge on their target species and ecological processes and related protection status, and the existent monitoring activities (Markov and ECOSS Partnership 2019; Ciriaco et al. 2019; Golec and ECOSS Partnership 2020; Miočić-Stošić et al. 2020). This analysis evidenced overall a lack of management plans and coordinated and systematic monitoring both in Italy and in Croatia.
  3. An overall connecting model – A conceptual model has been developed in order to highlight the key role of ECOAdS for linking the social, ecological and oceanographic dimensions with the conservation of the coastal and marine environment and its management (Cataletto et al. 2019; Gianni et al. 2020; Gianni et al. 2021a; Gianni et al. 2021b). Several aspects of the management of the N2K sites have been identified, broken down into different parts and connected according to the main relationships among them. Examples of the application of the models are available on the ECOAdS web portal, in the tools' section of each N2K site (<https://ecoads.eu/sites/natura2000/>).
  4. The directives' harmonization (Manea et al. 2021b; Oggioni et al. 2021) - ECOAdS has been tested as a monitoring platform that may respond and contribute to the requirements of the main EU directives, in particular the Habitats and Birds (European Commission 1992 and European Commission 2009), the Water Framework (European Commission 2000; WFD), the Marine Strategy Framework (European Commission 2008; MSFD) and the Maritime Spatial Planning (European Commission 2014; MSPD) directives. The harmonization and optimization of the existing monitoring and management frameworks, at national and trans-regional levels, are actually a crucial issue for the most effective and coordinated application of directives. As a part of ECOAdS, we assessed the level of implementation of these policy documents to the focus area following their general objectives and targets of protection, approach to conservation, spatial application, reporting period,

human activities and derived pressures considered, ecosystem services approach (if entailed), criteria and performance indicators definition, and indications for monitoring (Manea et al. 2021a). Then, we proposed the harmonization and prioritization of monitored variables, necessary for the setting up of a coherent ecosystem-based monitoring system, rooted in the ecosystem-based management (EBM) core elements (Manea et al. 2021b).

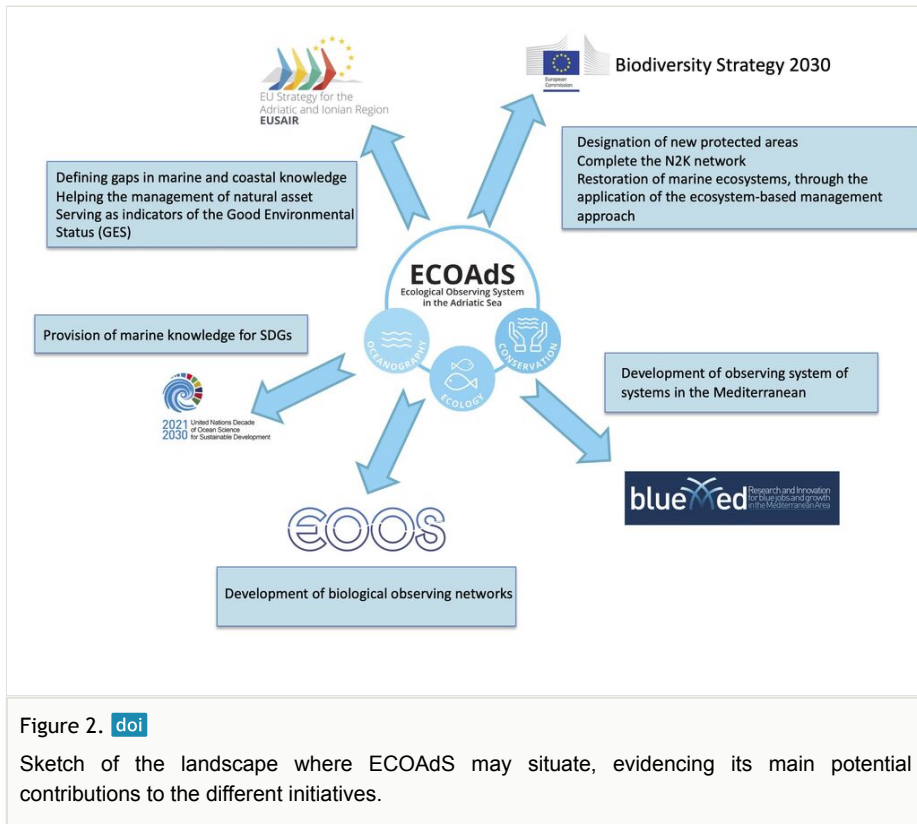
5. The stakeholder involvement – Complex ecological and conservation issues require scientific evidence to be used alongside other types of knowledge in order to find the best and most feasible solutions. This calls for the development of a well-organized participatory process, which has started within the ECOSS project, aiming at including in the development of ECOAdS a plurality of voices and a wide range of knowledge, including local and indigenous knowledge, together with these derived from scientific communities and methods. In three dedicated workshops, we involved MPA managers, NGOs, and PhD students, with the aim of starting to share visions about what the main needs, expectations and challenges in the design and development of ECOAdS could be. Convincingly, the structure of the ECOAdS portal has been improved addressing the main needs, requirements and gaps that emerged during this participatory process.

## ECOAdS in the wider frame of European strategies and Research Infrastructures

ECOAdS may effectively contribute to the fulfillment of relevant macro-regional and European strategies and programmes for the next decade (Vilbić and ECOSS Partnership 2021; Fig. 2), in particular:

- The EU Strategy for the Adriatic and Ionian Region (EUSAIR; <https://www.adriatic-ionian.eu/about-eusair/>), which aims to create synergies and foster coordination among all territories in the Adriatic-Ionian Region. The EUSAIR 2021-2027 strategic plan proposes a list of “Flagships” for each thematic pillar, which addresses the main challenges of macro-regional importance consistent with national needs and EU policy objectives for a greener, low-carbon and more connected Europe. Pillar 3 “Environmental quality” includes the Flagship “Promotion of sustainable growth of the Adriatic Ionian region by implementing Integrated Coastal Zone Management (ICZM) and Maritime Spatial Planning (MSP) also to contribute Common Regional Framework (CRF) on ICZM of Barcelona Convention and the monitoring and management of marine protected area”, which aims at:
  1. promoting sustainable development and facilitate adoption of coastal and maritime spatial plans (MSPD, ICZM Protocol) by defining gaps in marine and coastal knowledge,
  2. identifying conflicts and propose sustainable options for action,
  3. helping the management of natural, social, economic and spatial assets in the Adriatic-Ionian region,

4. serving as indicators of the Good Environmental Status (GES) of marine waters of the Adriatic and Ionian Seas.



- The EU Biodiversity strategy for 2030 ([https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030\\_en](https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_en)), which states the need of improving and widening the network of protected areas and developing of an EU Nature Restoration Plan, in order to step up the protection and restoration of the nature. The Strategy foresees the enlargement of marine protected areas network, which should cover 30% of the EU Seas and about 10% with a strict protection. The designation of new protected areas helps to complete the N2K network and to fulfill national protection strategies, with clearly defined conservation objectives and measures. Beside this, the EU Nature Restoration Plan foresees the restoration of marine ecosystems, through the application of the ecosystem-based management approach.
- The BlueMed Initiative (<http://www.blued-med-initiative.eu/>), whose Implementation Plan (Trincardi et al. 2020) provides a medium-term operational tool to develop sustainable Blue Economy in the Mediterranean area. The Plan is supporting the development of an observing system of systems in the Mediterranean, able to better understand the complexity of marine ecosystems and their functioning, to measure and assess their evolution under different stressors, and to manage marine resources sustainably.



- The Global Ocean Observing System (GOOS) 2030 Strategy (IOC 2019) and the European Ocean Observing System (EOOS; <https://www.eoos-ocean.eu/>) Implementation Plan, which call for a shift in philosophy in ocean observations towards a fully integrated global observing system. Such a system should be able to capture essential physical, chemical, biological, and ecological ocean properties, from global/EU to local and coastal scales, mapping existing ocean observing infrastructures and capabilities related to biological observing networks.
- The Implementation Plan for the United Nation Decade of Ocean Science for Sustainable Development (Ocean Decade, OD; <https://www.oceandecade.org/>) 2021-2030 (UNESCO-IOC 2021), which aims at facilitating a paradigm that will shift the design and delivery of qualitative and quantitative ocean knowledge, creating solutions that will contribute to the UN 2030 Agenda for Sustainable Development (<https://unric.org/it/agenda-2030/>).

## ECOAdS perspectives after the project ECOSS

We foresee the medium- and long-term sustainability of ECOAdS through realization of various activities within the above-mentioned frame, which includes creation of efficient cross-Adriatic collaborations, transparent data sharing following FAIR principles (Findability, Accessibility, Interoperability, Reuse; Wilkinson et al. 2016), and effort to minimize the duplication of activities, thus also facilitating the financial issues. Here we individuate some possibilities - among the many (thoroughly investigated in Vilibić and ECOSS Partnership (2021)) - that could be undertaken in the short- and medium-term, at the national and Adriatic level. Besides, we address also the technological issues and delineate the main narrative that should keep inspiring the development of ECOAdS.

The overall ECOAdS framework, the action plans proposed for the monitoring and management of the N2K sites, and the web portal, could contribute to a more effective and coordinated implementation of the directives (HBD, WFD, MSFD, MSPD) at the national and regional/county level in Italy and Croatia. Therefore, it is within the context of the ministerial and regional or county policies that the outcomes and the development of ECOAdS find proper governance and management, as well as a financial support. The main components and attributes of ECOAdS could be applied to the wider Adriatic macro-region, using the policy and financing instruments available in the area (e.g. Interreg ADRION, EUSAIR). The Adriatic could, in this way, become an exemplary case study for the whole Mediterranean Sea, also in agreement with the BlueMed Implementation Plan.

Many Environmental Research Infrastructures (RIs), included in the European and national RIs roadmaps at different stages of their development, are active in the Adriatic Region (e.g. Danubius RI, eLTER RI, EMBRC-ERIC, ICOS ERIC, JERICO S3, LifeWatch ERIC). ECOAdS could rely on, contribute to, and benefit from these RIs, sustaining their components that are under development in the Adriatic area. The RIs will be relevant for the long-term maintenance and financial sustainability of ECOAdS, in particular when a joint collaboration and coordination among them, which is required and arising at the national and EU level, will be realized. ECOAdS could represent the opportunity to boost



such collaboration in the Adriatic Sea, by representing and developing a co-located system with shared research and monitoring tasks allowing its modular, multi-purpose and fit-for-purpose uses.

Next, the technological development and the engagement of Small and Medium Enterprises, which has not been addressed during the ECOSS project, is a prerequisite for the future development of ECOAdS, embracing and leveraging the emerging technologies, thus enhancing cross-border collaboration with the private sectors. ECOAdS could be the suitable platform for developing and testing innovative in situ technologies (e.g., from chemical, imaging, acoustic, and molecular sensors to robotic platforms) and for the improvement of data storage, data discovery, computation capabilities and modelling, which might support novel ecological views and perspectives. This will be in line with the action plan of the European Green Deal ([https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal\\_en](https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en)), by investing in environmental-friendly technologies and supporting industry to innovate, sustaining the legally binding conservation and restoration targets.

Finally, we highlight ECOAdS role in fostering and addressing the ultimate goal - to procreate a shift in our way of living and a profound transformation of our socio-economic systems, as sustained also by the EU Biodiversity Strategy for 2030: "Protecting and restoring nature will need more than regulation alone. It will require action by citizens, businesses, social partners and the research and knowledge community, as well as strong partnerships between local, regional, national and European level." To this respect, ecological research within ECOAdS is called to become "Action Ecology" (White et al. 2015), i.e.:

1. collaborative and transdisciplinary, able to incorporate sociological into ecological researches,
2. innovative and aggregative, relying on large datasets and rapid synthesis for theory testing and development,
3. designed and realized with the intention to inform policy and management, providing immediate and effective insights into current, pressing issues.

Moreover, to effectively contribute to a necessary cultural shift, ECOAdS should incorporate into its plans a new narrative, where Nature protection and restoration shall not be a strategic specialty within our economic system, but rather become an ethical challenge and transformation, moved by the ultimate goal to attain the health and durability of natural and human communities, instead of profits (Berry 2001; Bearzi 2020).

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## Conflicts of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## References

- Bastari A, Micheli F, Ferretti F, Pusceddu A, Cerrano C (2016) Large marine protected areas (LMPAs) in the Mediterranean Sea: The opportunity of the Adriatic Sea. *Marine Policy* 68: 165-177. <https://doi.org/10.1016/j.marpol.2016.03.010>
- Bearzi G (2020) Marine biology on a violated planet: from science to conscience. *Ethics in Science and Environmental Politics* 20: 1-13. <https://doi.org/10.3354/esep00189>
- Benedetti-Cecchi L, Crowe T, Boehme L, Boero F, Christensen A, Grémare A, Hernandez F, Kromkamp JC, Nogueira Garcia E, Petihakis G, Robidart J, Sousa Pinto I, Zingone A (2018) Strengthening Europe's Capability in Biological Ocean Observations Future Science Brief 3 of the European Marine Board. In: Muñiz Piniella Á, Kellett P, Larkin K, Heymans JJ (Eds) Future Science Brief 3 of the European Marine Board. [ISBN ISBN: 97894920435].
- Berry W (2001) *Life is a miracle: an essay against modern superstition*. Counterpoint, Berkeley, CA.
- Biermann F, Kanie N, Kim RE (2017) Global governance by goal-setting: the novel approach of the UN Sustainable Development Goals. *Current Opinion in Environmental Sustainability* 26-31. <https://doi.org/10.1016/j.cosust.2017.01.010>
- Bourgeron P, Kliskey A, Alessa L, Loescher H, Krauze K, Virapongse A, Griffith DL (2018) Understanding large-scale, complex, human–environmental processes: a framework for social–ecological observatories. *Frontiers in Ecology and the Environment* 16 <https://doi.org/10.1002/fee.1797>
- Carr M, Neigel J, Estes J, Andelman S, Warner R, Largier J (2003) COMPARING MARINE AND TERRESTRIAL ECOSYSTEMS: IMPLICATIONS FOR THE DESIGN OF COASTAL MARINE RESERVES. *Ecological Applications* 13: 90-107. [https://doi.org/10.1890/1051-0761\(2003\)013\[0090:cmateij2.0.co;2](https://doi.org/10.1890/1051-0761(2003)013[0090:cmateij2.0.co;2)
- Carr MH, Woodson CB, Cheriton OM, Malone D, McManus MA, Raimondi PT (2010) Knowledge through partnerships: integrating marine protected area monitoring and ocean observing systems. *Frontiers in Ecology and the Environment* 9 (6): 342-350. <https://doi.org/10.1890/090096>
- Cataletto B, Bandelj V, Gianni F, ECOSS Partnership (2019) D4.1.2 Report on the relationships between ecosystem-level management goals with ecological variables and oceanographic processes and the performance indicators. Zenodo <https://doi.org/10.5281/zenodo.6200752>
- Ciriaco S, Menon S, Franzosini C, ECOSS Partnership (2019) D4.3.1 Review of the knowledge of the ecological processes in the selected Natura 2000 sites. Zenodo <https://doi.org/10.5281/zenodo.6200186>
- Crise A, Ribera d'Alcalà M, Mariani P, Petihakis G, Robidart J, Iudicone D, Bachmayer R, Malfatti F (2018) A Conceptual Framework for Developing the Next Generation of Marine OBServatories (MOBs) for Science and Society. *Frontiers in Marine Science* 5 <https://doi.org/10.3389/fmars.2018.00318>

- De Maio E, Menegon S, Sarretta A, Oggioni A, Tagliolato P, Manea E, Bergami C, Pugnetti A, ECOSS Partnership (2021) D5.2.1 ECOSS Web Data Portal. Zenodo. <https://doi.org/10.5281/zenodo.6106661>
- Duffy JE, Amaral-Zettler L, Fautin D, Paulay G, Rynearson T, Sosik H, Stachowicz J (2013) Envisioning a Marine Biodiversity Observation Network. *BioScience* 63 (5): 350-361. <https://doi.org/10.1525/bio.2013.63.5.8>
- European Commission (1992) Council Directive 92/43/EEC of May 21 1992 on the conservation of natural habitats and of wild fauna and flora. Official Journal of the European Communities.
- European Commission (2000) Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive. Official Journal of the European Union.
- European Commission (2008) Directive 2008/56/EC of the European Parliament of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive. Official Journal of the European Union.
- European Commission (2009) Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds. Official Journal of the European Union.
- European Commission (2014) Directive 2014/89/EC of the European Parliament of the Council of 23 July 2014 establishing a framework for maritime spatial planning. Official Journal of the European Union.
- Frascchetti S, Pipitone C, Mazaris A, Rilov G, Badalamenti F, Bevilacqua S, Claudet J, Carić H, Dahl K, D'Anna G, Daunys D, Frost M, Gissi E, Göke C, Goriup P, Guarnieri G, Holcer D, Lazar B, Mackelworth P, Manzo S, Martin G, Palialexis A, Panayotova M, Petza D, Rumes B, Todorova V, Katsanevakis S (2018) Light and Shade in Marine Conservation Across European and Contiguous Seas. *Frontiers in Marine Science* 5 <https://doi.org/10.3389/fmars.2018.00420>
- Gianni F, Bandelj V, Cataletto B, Manea E, Bergami C, Bongiorno L, Oggioni A, Pugnetti A, Ciriaco S, Franzosini C, Golec I, Pećarević M, Rova S, Pranovi F, ECOSS Partnership (2020) D3.3.1 Report on the key oceanographic processes and performance indicators for Natura 2000 marine sites. Zenodo <https://doi.org/10.5281/zenodo.6200410>
- Gianni F, Bandelj V, Cataletto B, Manea E, Bergami C, Bongiorno L, Oggioni A, Pugnetti A, Ciriaco S, Franzosini C, Caramori G, ECOSS Partnership (2021a) D4.2.2 Report on the application of the conceptual model linking oceanographic processes, performance indicators and management questions for target species. Zenodo <https://doi.org/10.5281/zenodo.6203553>
- Gianni F, Bandelj V, Cataletto B, Manea E, Bergami C, Bongiorno L, Oggioni A, Pugnetti A, Ciriaco S, Franzosini C, Caramori G, ECOSS Partnership (2021b) D4.3.2 Report on the application of the models linking oceanographic processes and management questions. Zenodo <https://doi.org/10.5281/zenodo.6203840>
- Golec I, ECOSS Partnership (2020) D3.2.1. Report on the ecological monitoring, conservation strategies and management questions of Natura 2000 marine sites. Zenodo <https://doi.org/10.5281/zenodo.6135905>
- IOC (2019) The Global Ocean Observing System 2030 Strategy. IOC, Paris. GOOS Report 239.

- Jonsson P, Hammar L, Wåhlström I, Pålsson J, Hume D, Almroth-Rosell E, Mattsson M (2020) Combining seascape connectivity with cumulative impact assessment in support of ecosystem-based marine spatial planning. *Journal of Applied Ecology* 58 (3): 576-586. <https://doi.org/10.1111/1365-2664.13813>
- Manea E, Di Carlo D, Depellegrin D, Agardy T, Gissi E (2019) Multidimensional assessment of supporting ecosystem services for marine spatial planning of the Adriatic Sea. *Ecological Indicators* 101: 821-837. <https://doi.org/10.1016/j.ecolind.2018.12.017>
- Manea E, Bongiorno L, Bergami C, Pugnetti A (2020) Challenges for marine ecological observatories to promote effective GMS of Natura 2000 network. In: Alfaré L, Ruoss E (Eds) *Governing future challenges in protected areas*. CNR Edizioni, 23-39 pp.
- Manea E, Bergami C, Bongiorno L, Oggioni A, Pugnetti A, ECOSS Partnership (2021a) D4.4.1 Report on the interactions, synergies and gaps among the WFD, MSFD and H&BD for an effective management of the marine ecosystems. Zenodo <https://doi.org/10.5281/zenodo.6204134>
- Manea E, Bergami C, Bongiorno L, Capotondi L, De Maio E, Oggioni A, Pugnetti A (2021b) A transnational marine ecological observatory in the Adriatic Sea to harmonize a fragmented approach to monitoring and conservation. *Advances in Oceanography and Limnology* 12 (1). <https://doi.org/10.4081/aiol.2021.9811>
- Markov M, ECOSS Partnership (2019) D4.1.1 Report on the characterization of the selected Natura 2000 sites. Zenodo <https://doi.org/10.5281/zenodo.6136088>
- Maxwell S, Hazen E, Lewison R, Dunn D, Bailey H, Bograd S, Briscoe D, Fossette S, Hobday A, Bennett M, Benson S, Caldwell M, Costa D, Dewar H, Eguchi T, Hazen L, Kohin S, Sippel T, Crowder L (2015) Dynamic ocean management: Defining and conceptualizing real-time management of the ocean. *Marine Policy* 58: 42-50. <https://doi.org/10.1016/j.marpol.2015.03.014>
- Micheli F, Halpern B, Walbridge S, Ciriaco S, Ferretti F, Fraschetti S, Lewison R, Nykjaer L, Rosenberg A (2013) Cumulative Human Impacts on Mediterranean and Black Sea Marine Ecosystems: Assessing Current Pressures and Opportunities. *PLoS ONE* 8 (12). <https://doi.org/10.1371/journal.pone.0079889>
- Miočić-Stošić J, Pleslić G, ECOSS Partnership (2020) D4.2.1 Review of the knowledge of the target species at the selected Natura 2000 sites. Zenodo <https://doi.org/10.5281/zenodo.6199909>
- Muelbert J, Nidzieko N, Acosta AR, Beaulieu S, Bernardino A, Boikova E, Bornman T, Cataletto B, Deneudt K, Eliason E, Kraberg A, Nakaoka M, Pugnetti A, Ragueneau O, Scharfe M, Soltwedel T, Sosik H, Stanisci A, Stefanova K, Stéphan P, Stier A, Wikner J, Zingone A (2019) ILTER – The International Long-Term Ecological Research Network as a Platform for Global Coastal and Ocean Observation. *Frontiers in Marine Science* 6 <https://doi.org/10.3389/fmars.2019.00527>
- Oggioni A, Tagliolato P, Sarretta A, De Maio E, Menegon S, Manea E, Bergami C, Pugnetti A, ECOSS Partnership (2021) D5.3.1 Set of tools supporting ECOSS case studies and activities. Zenodo <https://doi.org/10.5281/zenodo.6204340>
- Orlikowska E, Roberge J, Blicharska M, Mikusiński G (2016) Gaps in ecological research on the world's largest internationally coordinated network of protected areas: A review of Natura 2000. *Biological Conservation* 200: 216-227. <https://doi.org/10.1016/j.biocon.2016.06.015>
- Trincardi F, Cappelletto M, Barbanti A, Cadiou J-, Bbataille A, Campillos Llanos M, Chacón Campollo E, Trujillo Quintela A, BlueMed CSA (2020) BlueMed Implementation

Plan. Deliverable 2.9. [http://www.blumed-initiative.eu/wp-content/uploads/2020/07/blumed-preliminary-implementation-plan\\_version-complete.pdf](http://www.blumed-initiative.eu/wp-content/uploads/2020/07/blumed-preliminary-implementation-plan_version-complete.pdf).

- UNEP (2011) Taking steps toward marine and coastal ecosystem-based management - An introductory guide. <https://www.unep.org/resources/report/taking-steps-toward-marine-and-coastal-ecosystem-based-management-introductory..>
- UNEP (2019) Frontiers 2018/19: Emerging issues of environmental concern. <https://www.unep.org/resources/frontiers-201819-emerging-issues-environmental-concern>.
- UNESCO-IOC (2021) The United Nations Decade of Ocean Science for Sustainable Development (2021-2030) Implementation Plan. UNESCO, Paris (IOC Ocean Decade Series, 2021).
- Vilibić I, ECOSS partnership (2019) D3.1.1 Report on the assessment of existing ecological monitoring programs and observing systems. Zenodo <https://doi.org/10.5281/zenodo.6089353>.
- Vilibić I, ECOSS Partnership (2020) D5.1.1 Report on data/information availability and infrastructure/tools requirements. Zenodo <https://doi.org/10.5281/zenodo.6089606>.
- Vilibić I, ECOSS Partnership (2021) D3.5.1 Long-term strategy and roadmap of the Ecological Observing System in the Adriatic Sea. Zenodo <https://doi.org/10.5281/zenodo.6105808>
- White R, Sutton A, Salguero-Gómez R, Bray T, Campbell H, Cieraad E, Geekiyanage N, Gherardi L, Hughes A, Jørgensen PS, Poisot T, DeSoto L, Zimmerman N (2015) The next generation of action ecology: novel approaches towards global ecological research. *Ecosphere* 6 (8). <https://doi.org/10.1890/es14-00485.1>
- Wilkinson M, Dumontier M, Aalbersberg IJ, Appleton G, Axton M, Baak A, Blomberg N, Boiten J, da Silva Santos LB, Bourne P, Bouwman J, Brookes A, Clark T, Crosas M, Dillo I, Dumon O, Edmunds S, Evelo C, Finkers R, Gonzalez-Beltran A, Gray AG, Groth P, Goble C, Grethe J, Heringa J, 't Hoen PC, Hooff R, Kuhn T, Kok R, Kok J, Lusher S, Martone M, Mons A, Packer A, Persson B, Rocca-Serra P, Roos M, van Schaik R, Sansone S, Schultes E, Sengstag T, Slater T, Strawn G, Swertz M, Thompson M, van der Lei J, van Mulligen E, Velterop J, Waagmeester A, Wittenburg P, Wolstencroft K, Zhao J, Mons B (2016) The FAIR Guiding Principles for scientific data management and stewardship. *Scientific Data* 3 (1). <https://doi.org/10.1038/sdata.2016.18>