

the ocean circulation – particularly for salinity – and the biodiversity in this area with potential effects on fish species of commercial interest (Section 3.5). These changes in the ecosystem can strongly impact economies and coastal communities that might need to adapt to the declining abundance of traditional target species and/or to the increasing abundance of other species, which previously were secondary to the local market.

The ecological and socio-economic consequences (e.g. on tourism, aquaculture, fisheries) of jellyfish outbreaks on the shorelines are relevant worldwide, and the development of prediction tools is critical to anticipate and mitigate the arrival of the jellyfish blooms (Section 3.4). While the Portuguese Man-of-War is not native to the Mediterranean Sea, their appearance had been reported several times during the past decade in the Gulf of Cadiz and in the Western Mediterranean. OSR5 presents a new forecasting system for the spread of this jellyfish which shows good skills during a strong event in 2018. The main potential benefits of this new forecasting system are to support coastal managers, and to minimise associated socio-economic losses.

Section 3.6 discusses the benefits of integrating the CMEMS variables in combination with trawl surveys into the modelling of fishery independent data for predicting fish species distribution in the Adriatic and Ionian basins. An integrated ecosystem approach is discussed, which incorporates anthropogenic and other environmental stressors into the advice for fisheries management. The results robustly demonstrate that the combined use of data improves the species distribution in the models.

The presence of invasive species in the Mediterranean Sea is much higher than in other European seas, and understanding the reasons behind the range expansion of this invasive species is important for minimising any possible impacts to the already highly pressurised Mediterranean marine ecosystem. OSR5 describes in Section 4.5 sightings of the invasive lionfish *Pterois miles* in the Ionian Sea, together with an analysis of ocean temperature in this region, and in 2019, warm water conditions have favoured the northward spread of this thermophilic species along the coast of the Mani Peninsula and the Greek mainland. These results are critical for ecological modellers and regional stakeholders involved aiming to monitor the spread of this generalist predator in their waters.

Black Sea:

In this 5th issue of the CMEMS OSR, topics tackled for the Black Sea include aspects of the basin-scale circulation, as well as discussing hypoxia monitoring in the northwestern part of the basin. The general circulation

in the Black Sea features a cyclonic gyre encompassing the entire basin (Rim Current). OSR5 provides a new method for the Black Sea Rim Current ocean monitoring indicator (Section 2.7). Results over the period 1993–2019 show Rim current speed variations of 30% in close relation to the atmospheric circulation (e.g. wind) and an increase in Rim Current speed of ~0.1 m/s/decade.

During the 1970s to 1990s, large areas of the Black Sea, particularly along the Romanian and Ukrainian coasts, had been hit by severe hypoxia predominantly driven by eutrophication, and this dead zone reached up to 40,000 km² at its extreme in the 1990s. OSR5 (Section 3.8) analyses a Benthic Hypoxia index in this area over the period 1992–2019 depicting general recovery from the preceding eutrophication period (1980s), but also a re-increase in the severity of benthic hypoxia for the years 2016–2019 which is attributed to warming atmospheric conditions. Results demonstrate that a joint consideration of oceanographic and climate conditions and riverine and coastal nutrient discharge, incorporated into an operational indicator such as presented in this study could be a critical tool in support of coastal management and marine protection strategies.

1.2. Knowledge and data for international Ocean governance

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1.2.1. What is international Ocean governance?

Covering 71% of the Earth's surface and holding 99% of the area that can be inhabited by life, the Ocean plays a pivotal role in sustaining life on Earth, including through the provision of climate regulation, food, energy, and many other resources. The Ocean, or 'blue', economy in Europe alone was estimated to have a turnover of €750 billion in 2018 (European Commission 2020) and there is significant interest in developing this further through increased jobs and by supporting innovation. However, over-exploitation of the Ocean as a result of human activities is a very real challenge, and coupled with increasing pressures from climate change impacts and pollution, its ability to continue supporting life on Earth is threatened. There is hence a balance to be achieved: in order to continue supporting life on Earth and to achieve the Sustainable Development Goals (SDGs), the Ocean must be productive, clean, healthy, and resilient. For this, we must ensure that human impacts on the Ocean and its

resources are managed sustainably. Given the interconnected nature of the Ocean, and that the majority of its volume lies outside of nation's Exclusive Economic Zones (EEZs), strong international cooperation is needed for the sustainable management of the Ocean as a global common through international Ocean governance. This includes rules, agreements, processes and institutions, which need to be organised in a way that ensures that the human use of the Ocean will be sustainable into the future.

At the core of the international Ocean governance system lies the United Nations Convention on the Law of the Sea (UNCLOS – United Nations 1982). This is an international agreement that defines both the rights and responsibilities that nations have when using and managing the Ocean and its resources. Building on this foundation, laws, frameworks, institutions and jurisdictional rights have been established at different regulatory levels (local, national, regional, international) and for different marine sectors (e.g. shipping, fishing, and research). However, this has made the Ocean governance system very fragmented, and there is often a lack of coordination between different organisations and governance systems. Coupled with this are the challenges of ratifying and enforcing laws and regulations, especially in areas beyond national jurisdiction (ABNJ), of gaining international agreements for governance in a timely manner, and of gaps in the legal framework, especially linked to emerging sectors (e.g. seabed mining).

More coordination is therefore needed across regulatory systems and marine sectors, and all stakeholders should be involved in the process of developing and implementing governance regulations for the sustainable management of the Ocean and its resources.

1.2.2. The role of Ocean observation and data in international Ocean governance

Knowledge underpins Ocean governance, and provides the means to understand the Ocean and its functioning, and develop appropriate measures for its sustainable management and use. Ocean observing allows the collection of data to monitor and report on the state of the Ocean, make predictions about its future, and to assess the impact of governance regulations and success towards achieving the intended sustainability goals. Observational data also help to ensure that the development of economic activities in the Ocean are indeed sustainable.

In order to plan for and assess the sustainable use of the Ocean, a wide range of different types of data, from different sources and different providers are required.

Significant investment in Ocean observing systems and personnel, along with appropriate maintenance and support, is required in order to collect these data, and efficiency and coordination across Ocean observing systems are critical (EMB 2021). These are challenges that the Global Ocean Observing System¹ (GOOS) and the Group on Earth Observations² (GEO) are working to improve at the international level. Within this context the European Global Ocean Observing System³ (EuroGOOS), the European Ocean Observing System⁴ (EOOS), and the European Commission's Foreign Policy Instrument Action on international Ocean governance: EU component to global observations⁵ (EU4OceanObs), are tackling these challenges at the European level. Data sharing and interoperability between marine data infrastructure are also key enablers for effective international Ocean governance.

1.2.3. The European state of play

In 2016, the European Commission published its Joint Communication on International Ocean Governance (IOG): An agenda for the future of our oceans (European Commission 2016), which aligned strongly with the UN 2030 Agenda for Sustainable Development (United Nations 2015) and specifically the targets of Sustainable Development Goal 14 (Life Below Water). The Communication outlined the European Commission's 50 planned actions for developing Ocean governance, not only in Europe but also internationally. The Communication was structured around three priority areas, one of which was 'strengthening international Ocean research and data': recognising the critical role that data and knowledge play in supporting the Ocean governance system.

The Joint Communication was followed by a report published in 2019, which examined the progress made towards implementing the 50 actions (European Commission 2019). The report highlighted the annual publication of the CMEMS Ocean State Report as one of the direct actions taken by the European Commission towards developing international Ocean governance. This report was initiated as a means to 'promote ocean research, data and science with the aim of developing comprehensive, reliable, comparable and accessible Ocean knowledge to improve policy-making, drive innovation and facilitate a sustainable "blue" economy'.

In addition, in 2019 the European Commission, together with the European External Action Service, established the IOG Forum.⁶ The IOG Forum provided a platform for stakeholders within and beyond Europe to engage in interactive cross-sectoral and cross-boundary dialogue on Ocean challenges and governance

solutions in support of the follow-up of the EU's IOG Agenda. A diversity of stakeholders from across the globe have engaged with this initiative through a series of expert workshops, consultations and events, and the final recommendations⁷ were launched during a high-level event on 20 April 2021. As well as continuing to align with the UN 2030 Agenda for Sustainable Development, the future of the EU's IOG Agenda will also align closely with the European Green Deal,⁸ the EU 2030 Biodiversity Strategy⁹ and the aims of the UN Decade of Ocean Science for Sustainable Development.¹⁰

The activities of the IOG Forum have elicited a number of priority areas for action that are recommended to be addressed in the future EU IOG Agenda to ensure a clean, healthy, productive, resilient, and understood Ocean. The priority area on improving the Ocean knowledge system focuses on ensuring that future Ocean governance is knowledge-based and driven by inclusive and effective knowledge-policy interfaces.¹¹ This priority area emphasises the need to intensify transdisciplinary co-designed research to address key knowledge gaps, integrate knowledge from relevant stakeholders and knowledge sources, and ensure strong observations and data capacity. The EU has many strong initiatives that it can build on in order to take a leading role in addressing these recommendations including the European Data Strategy, 8th Environment Action Programme, Horizon Europe, and the Destination Earth/Digital Twin Ocean initiative.

1.2.4. The international state of play

In recent years there has been focus on the development of a new legal instrument under UNCLOS, which covers the conservation and sustainable use of marine biological diversity in areas beyond national jurisdiction (BBNJ).¹² This process formally began in 2015 and a revised draft text was published by the UN in early 2020.¹³ Negotiations are ongoing, and data and observations will be key in supporting its implementation, as was highlighted in the Intergovernmental Oceanographic Commission of UNESCO (IOC) Report of the Executive Secretary¹⁴ at its meeting on 3 February 2021, where the IOC proposed a State of the Ocean Report, to provide annual information about Ocean variables, and the status of Ocean observations (among other information). Strong data and observations will also be required to monitor progress towards commitments made as part of the Paris Agreement and the Convention on Biological Diversity. The upcoming UN Climate Change Conference (COP26) and the Convention on Biological Diversity's COP15, both to be held in 2021, offer critical opportunities to

increase ambition and cooperation towards Ocean sustainability at the international level. Several nations, and the EU, have also committed to designating three new marine protected areas in the Antarctic, the successful management of which will rely on international cooperation for data sharing and observational infrastructure in these areas.

Ocean observations and data have also gained increased attention in other international fora. In the 2016 Tsukuba Communiqué, the Science and Technology ministers of the G7 group Member States (G7 Science and Technology Ministers 2016) recognised the importance of developing stronger scientific knowledge in order to develop 'appropriate policies to ensure the sustainable use of the seas and Ocean'. In order to achieve this, they stated their support for a number of actions linked to enhancing Ocean observations globally, promoting Ocean science and improving data sharing infrastructures, and strengthening collaboration to encourage regional developments in observing capabilities and knowledge networks. Subsequently, as presented in the G7 Future of the Seas and Oceans Working Group Statement to the OceanObs'19 Conference,¹⁵ the G7 established a dedicated Coordination Centre for Ocean observation platforms, which will be interlinked with other G7 priority areas¹⁶ and will interface with GOOS.

The OceanObs conferences, held every 10 years, are an opportunity for the Ocean observing community to discuss progress and define goals for the coming decade. At OceanObs'19 the importance of establishing effective collaborations with multiple stakeholders to advance effective Ocean governance was specifically recognised (Speich et al. 2019).

1.2.5. Where do we need to go from here?

Through all of the Ocean governance initiatives presented above, there is a clear message calling for improved co-ordination and increased stakeholder engagement in the co-design of Ocean research, observations and data. There is also a call for Ocean governance to be based on a sound foundation of knowledge that is effectively translated and available for use in policy-making so that sustainable and resilient management practices can be implemented. The Ocean observations and data communities have an integral part to play in both of these aims, including through actions such as the Ocean State Report. Knowledge cannot be developed without Ocean observations and data, and to support the co-ordination of Ocean governance at a global level, data need to be open, interoperable and guided by principles such as FAIR (Findable,

Accessible, Interoperable, Resuable). The observations and data communities are key stakeholders in Ocean governance, and should be engaged in dialogues around Ocean governance.

Notes

1. <https://www.goosocean.org/>.
2. <https://earthobservations.org/index.php>.
3. <https://eurogoos.eu/>.
4. <https://www.eoos-ocean.eu/>.
5. <https://www.eu4oceanobs.eu/>.
6. <https://webgate.ec.europa.eu/maritimeforum/en/frontpage/1469>.
7. <https://3rd-iog-forum.fresh-thoughts.eu/wp-content/uploads/sites/89/2021/04/IOG-recommendations-2021-WEB.pdf>.
8. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.
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10. <https://oceandecade.org/>.
11. <https://webgate.ec.europa.eu/maritimeforum/sites/default/files/iog-discussion-paper-2020-v5.pdf>.
12. <https://www.un.org/bbnj/>.
13. <https://undocs.org/en/a/conf.232/2020/3>.
14. <https://oceanexpert.org/event/2805#documents>.
15. <http://www.oceanobs19.net/>.
16. <http://www.oceanobs19.net/wp-content/uploads/2019/09/G7-Joint-Statement-to-OceanObs19.pdf>.

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