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Opinion Article

Data Sharing, Public Engagement and Innovation: the Open Science Pillars to Support Knowledge-Based Marine Strategies

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Opinion

In the last decades, Open Science has progressively been recognized as a pillar for the United Nations and European policies, evolving to pursue its principles and face its challenges. Carlos Moedas, who has recently served as European Commissioner, said that “Excellent science is the foundation of future prosperity, and openness is the key to excellence”. He also added that “Today, we make a crucial step to turn Open Science into a reality, in which knowledge circulates freely through digital and collaborative technologies.” The Director-General of UNESCO, Audrey Azoulay, stated that “Open Science could help science unleash its full potential and take up the challenges facing our contemporary societies”. This article briefly explains what Open Science means, the main actors, the reasons and the significant benefits to planning or evaluating any scientific research and politician strategy. The work mainly targets open marine science and its high value for a long-term, knowledge-based, environmental governance. Some activities carried on by the National Institute of Oceanography and Applied Geophysics (OGS, Italy) are brought as examples of its strategy for pursuing Open Science principles at the national and global levels in compliance with the UN and EU requirements. OGS is an internationally oriented public research institution that operates and develops its mission in the European Research Area (ERA) internationally.

Open Science Fundamental Principles and Importance

Open Science is a broad umbrella term encompassing several aspects. It expresses values that, in theory, should be the basis of scientific activity and research, but, in practice, it represents a change in the *modus operandi*, a revolution started a few decades ago [1]. Open Science is the lever for broader and equal knowledge sharing through free access to data and information. The circulation of scientific results allows for their more rapid legitimization, and it mitigates the possibility to apply researchers' bias to knowledge, reducing the dissemination of unreliable information [2]. Open Science facilitates comparison and cross-testing of data acquired from multiple and different sources. Legitimated knowledge must drive towards a thoughtful and far-sighted environmental policy. The first step is increasing the collaboration among researchers at any level, from sharing monitoring methodologies and data management plans to rewarding open publication of data outcomes. Cooperation outside the academic community is also crucial. Many purpose-oriented solutions can lead to this additional step:

- 1) Citizens can be involved in the work of researchers through citizen science activities, enhancing ocean literacy and marine research optimization. Citizen science raises public awareness of topical issues and provides researchers with a valuable data source that increases temporal and spatial coverage of measurements while reducing costs;
- 2) Appropriate language and means of communication can make the research results understandable to everyone, for example, using social networks;
- 3) Collaboration between science and industry contributes to environmental sustainability of anthropogenic activities;
- 4) The advancement of open, web-based technologies is the essential prerequisite, the Open Science engine to put these concepts into practice. With respect to this, the EU is funding the development of the free, multidisciplinary; European Open Science Cloud (EOSC) and Open Research Europe (ORE) environments. EOSC enables to publish, find, and re-use data, tools, and services for research, innovation, and educational purposes [3]; ORE is an open access platform for the publication of research stemming from Horizon 2020 and Horizon Europe.

Multiple benefits come from sharing data and knowledge, such as more efficiency of scientific productivity through reducing duplication, more data quality and integrity through a more significant evaluation and scrutiny by the scientific community, economic benefits through the support of sustainable innovation, and greater trust and support for public policies and investments in research.

Marine Open Science at OGS

On a global scale, OGS participates in the challenge for a transparent and accessible sea and ocean, linked to the UN Ocean Decade, and in implementing global data platforms, supporting the sea-related objectives of the UN 2030 Agenda for Sustainable Development. Over the past ten years, the Institute has invested heavily in Open Science through a dedicated program that strengthened and developed the National Oceanographic Data Centre (NODC), managed by OGS. The Centre is dedicated to collecting, validating, storing, and distributing marine data mainly acquired by OGS and the Italian scientific community. It promotes the FAIR principles according to which the data must be findable, accessible, interoperable, and reusable [3]. The Centre is part of the UNESCO worldwide network of Oceanographic Data Centres. Besides managing the Italian marine data, the Centre also participates in numerous international projects to foster Open Science, such as EUROqCHARM, ENVRI-FAIR, and EMODnet. EUROqCHARM aims to standardize monitoring methods to understand and address the problem of plastic pollution in all environmental compartments. The project will also provide policy-makers with best practices in the form of internationally valid standards and recommendations. ENVRI-FAIR project intends to link the Environmental Research Infrastructure Cluster (ENVRI) to the European Open Science Cloud (EOSC), improving the Fairness of all data and services offered by ENVRI [4]. The marine Open Science of OGS benefits from the synergies with three major research infrastructures, coordinated for their Italian



part by OGS (EURO-ARGO, ECCSEL and PRACE-Italy), with the marine observatories managed by OGS and with the European Copernicus CMEMS programme. Concerning this latter OGS addresses the ecological modelling component of the Mediterranean Sea, freely and operationally distributed. The Institute develops and manages the Seismic data Network Access Point (SNAP) [5,6], which collects and provides open access to over 100.000 km of seismic lines and 350.000 square km of multibeam profiles in the Mediterranean Sea. In addition, OGS hosts the Antarctic Seismic Data Library System (SDLS), relating to data collected in Antarctica by all research institutions worldwide. This marine geophysical infrastructure is fully interoperable with major international data-sharing initiatives. OGS participates in the European Marine Observation and Data Network (EMODnet), the European Commission's long-term Blue Growth - Marine Knowledge 2020 strategy initiative. EMODnet makes *in-situ* marine data readily available online. "Collect data once and use it many times" is the founding principle of EMODnet that has become one of the leading communities in the world for marine data services in ten years. In particular, the Institute is a partner of EMODnet Bathymetry, where all bathymetric data available in Europe are harmonized and integrated to produce an open Digital Terrain Model (DTM) for the European sea regions. Furthermore, it is the scientific coordinator of EMODnet Chemistry, the online platform which gives free access to high-quality data, maps and charts on marine pollution [7]. Besides research and official monitoring data, EMODnet Chemistry manages and shares data collected through citizen science-based web applications. In this regard, OGS has developed *AvvistAPP*, an application for smartphones that allows citizens to provide information on *Mnemiopsis leidyi*. This invasive species poses risks to the marine ecosystem and fishing. In addition, the App enables citizens to collect sightings of 18 additional marine taxa (ctenophores, jellyfish, sea turtles, dolphins, salps and noble pen shell) [8]. OGS is among the Marine Data Crowdsourcing (MADCROW) partners who have developed a multi-parametric black box equipped with numerous sensors to collect a variety of marine data, such as temperature, salinity, and pH [9]. Once installed on boats, the black box enables citizens to acquire and transmit measurements through passive sensing activities. These data are readily accessible and interoperable through a web-based system. Lastly, the Institute is a reference for the management of data on marine litter in Europe and beyond: it participates in the work of the G20 technical group for the harmonization and standardization of monitoring and data management methods on marine plastics, and collaborates with the National Marine Data and Information Service of China to strengthen marine water quality data interoperability between Europe and China [10].

Conclusions

Open Science represents the foundation for scientific research, and all efforts to achieve it raise and improve the research quality and integrity. Doing Open Marine Science means making every step of research open, transparent and reproducible to

generate "The Science We Need for the Ocean We Want", the UN Ocean Decade motto. The free dissemination of legitimated scientific knowledge facilitates the implementation of the "Share, Open, Negotiate" strategy, according to which politicians are required to involve citizens in the decision making process; society must be kept informed of the risks posed to the marine domain and agree on the actions to face them. We all are concerned so that everyone can give a valuable contribution to shape the future. Even if undertaken on a local scale but following a global vision, every little sharing action can bring enormous benefits to our sea and our ocean.

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