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EDITED BY

Athanasios Mogias,
Democritus University of Thrace, Greece

REVIEWED BY

José Lino Vieira De Oliveira Costa,
University of Lisbon, Portugal
Richard William Stoffle,
University of Arizona, United States

*CORRESPONDENCE

Angel Borja
✉ aborja@azti.es

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Bridging the gap between marine science and policy: communicating for an informed society and decision-making

Angel Borja^{1*}, Julie Bremner^{2,3}, Kathrin Kopke⁴, Sigi Gruber⁵,
Martin Alessandrini⁶, Alice Estrela⁷, Erasmia Kastanidi⁸,
Miguel C. Leal⁷, María C. Uyarra¹ and Michael Elliott^{9,10}

¹AZTI, Marine Research, Basque Research and Technology Alliance (BRTA), Pasaia, Spain, ²Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, United Kingdom, ³Collaborative Centre for Sustainable Use of the Seas, School of Environmental Sciences, University of East Anglia, Norwich, United Kingdom, ⁴University College Cork, Cork, Ireland, ⁵DG Research & Innovation, Brussels, Belgium, ⁶Foundation Tara Océan, Paris, France, ⁷Science Crunchers, Lisbon, Portugal, ⁸HCMR, Hellenic Centre for Marine Research, Athens, Greece, ⁹International Estuarine & Coastal Specialists (IECS) Ltd., Leven, United Kingdom, ¹⁰School of Environmental & life Sciences, University of Hull, Hull, United Kingdom

This paper emphasizes the role of effective science communication in bridging the gap between marine research and policymaking. It highlights the need for clear, objective, fit-for-purpose and engaged communication of scientific findings to policymakers and society to counter misinformation and promote informed decision-making processes. Hence, it is essential for scientists to use multiple communication channels to reach diverse audiences with clear, jargon-free language and engaging methods, tending to a holistic approach combining logical evidence-based with emotional engagement of society. Ocean literacy is key in raising public awareness and promoting behavioral changes for a new narrative on the future of the ocean. We recommend increasing funding for science communication, engaging with target audiences early, ensuring high-quality scientific evidence, and presenting positive and negative aspects of findings, showing the emotional side of the stories. Public support for marine protection and conservation policies can be enhanced, leading to effective management of marine ecosystems.

KEYWORDS

science to policy, social-traditional media, ocean literacy, ocean advocacy, narrative about the ocean

1 Introduction

Environmental policies and regulations are driving marine conservation, monitoring and assessment worldwide [e.g., Oceans Act or Clean Water Act, in USA, or Marine Strategy Framework Directive (MSFD) or Birds and Habitats Directives, in European Union (EU)] (Borja et al., 2008), with increasing funds in the last two decades for its associated research [Lewis et al., 2023; Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO), 2024]. Indeed, EU funded projects are specifically requested to place resources in disseminating and communicating research. However, the lessons learnt from marine research programmes, have set the need for communicating scientific results to society and policymakers more effectively, with administrators and scientists working together in disseminating knowledge in different ways to suit different audiences,

and preserving scientific credibility (Elliott et al., 2017). This is especially urgent in times in which most news is consumed via social media and the risk of unverified and non-evidence-based information and disinformation that is shared have increased (Al-Rawi et al., 2021). Hence, marine scientific communication should serve as the primary link between scientific actions on protection, conservation and assessment of the ocean, on different actors (e.g., scientists, society, policymakers) (Safford et al., 2017). The final aim of this communication is an adequate management of marine resources, as highlighted by CRUSK (Center for the Utilization of Scientific Knowledge), in the Institute for Social Research, and School of Natural Resources, both at the University of Michigan, in a special issue presenting the findings from a 2 years seminar between Great Lake fishery and marine scientists and various state and federal agency managers (Talhelm et al., 1987).

Science communication has many definitions, but it is understood as a collection of practices that convey scientific ideas, methods, and knowledge to inform, educate, and raise awareness of science-related topics, fostering a sense of curiosity about scientific discoveries. It focuses on presenting complex and reliable scientific information in a clear, accurate, and accessible way for diverse audiences beyond the scientific community. As a structured effort, science communication ensures that non-scientists can engage with and understand scientific knowledge (Horst et al., 2016; Davis et al., 2018; Agnew et al., 2023). The ability for scientists to reach society and policymakers has long been challenging (Elliott et al., 2017).

There is an epistemological divide that past studies have documented—that is, marine scientists stipulate that they know about the oceans and marine managers, resource users, and the general public do not know. Hence, the problem from the science perspective is to educate these not-knowing people and social groups. This epistemological divide occurs as a foundation in most scientific studies and structures science engagement with managers and the public. Most scientists actually want to share their research findings so these can be useful to managers and the public. However, scientists are not formally trained to know about people, their marine related culture, and their resource-based communities, and communication of scientific findings depends on mutual trust which is a long-standing social survey measure (Cologna et al., 2025).

Having better communication can contribute to bridge the gap between science and policy (Choi et al., 2015), specifically across the many different topics of the marine environment (Borja et al., 2017). However, the success of scientific communication depends on the awareness of scientists of the role that research plays in the public debate in opinion making and education. Scientific findings and their interpretation may raise complex ethical, legal, and social questions, in which ineffective communication can be costly to science and society (Fischhoff and Scheufele, 2013).

The increasing field of ocean literacy has been shown to be central in raising awareness and promoting behavioral changes across society (Uyarra and Borja, 2016; Ashley et al., 2019; McKinley et al., 2023). Furthermore, it has also been shown to be effective for successful and sustainable marine management (Elliott et al., 2025).

Despite the common agreement on the crucial role of ocean literacy, there is a scarcity of literature attempting an

empirical evaluation of science communications efforts and their effectiveness, and into evaluating enhanced trust in terms of democratic legitimacy (Kappel and Holmen, 2019). These authors express the need to focus on the aim of enhancing social acceptance of science and improvement of science-supported beliefs in society. There appears to be an overall decline in specialized scientific, and environmental journalism, and an increase in ambiguity between reporting of fact vs. opinion (Van Witsen and Takahashi, 2018).

All types of media are influential, and indeed necessary, in communicating scientific messages. This is important as research has shown that environmental policies and legal instruments require public support to be successful (de Groot and Schuitema, 2012; Agnew et al., 2023). However, eye-catching headlines can perpetuate incomplete information (Koelmans et al., 2019). There is an increasing speed in the dissemination of “fake news,” with social media combined with the inability and difficulty for it all to be counteracted. This means that factual science is always having to be reactive instead of proactive (Aïmeur et al., 2023). This is exacerbated by the contrasting qualities of scientific inquiry and digital media. While science is a slow and methodological process that frequently highlights uncertainties, digital media prioritizes immediacy, increasing the risk of spreading inaccurate or incomplete information (Agnew et al., 2024).

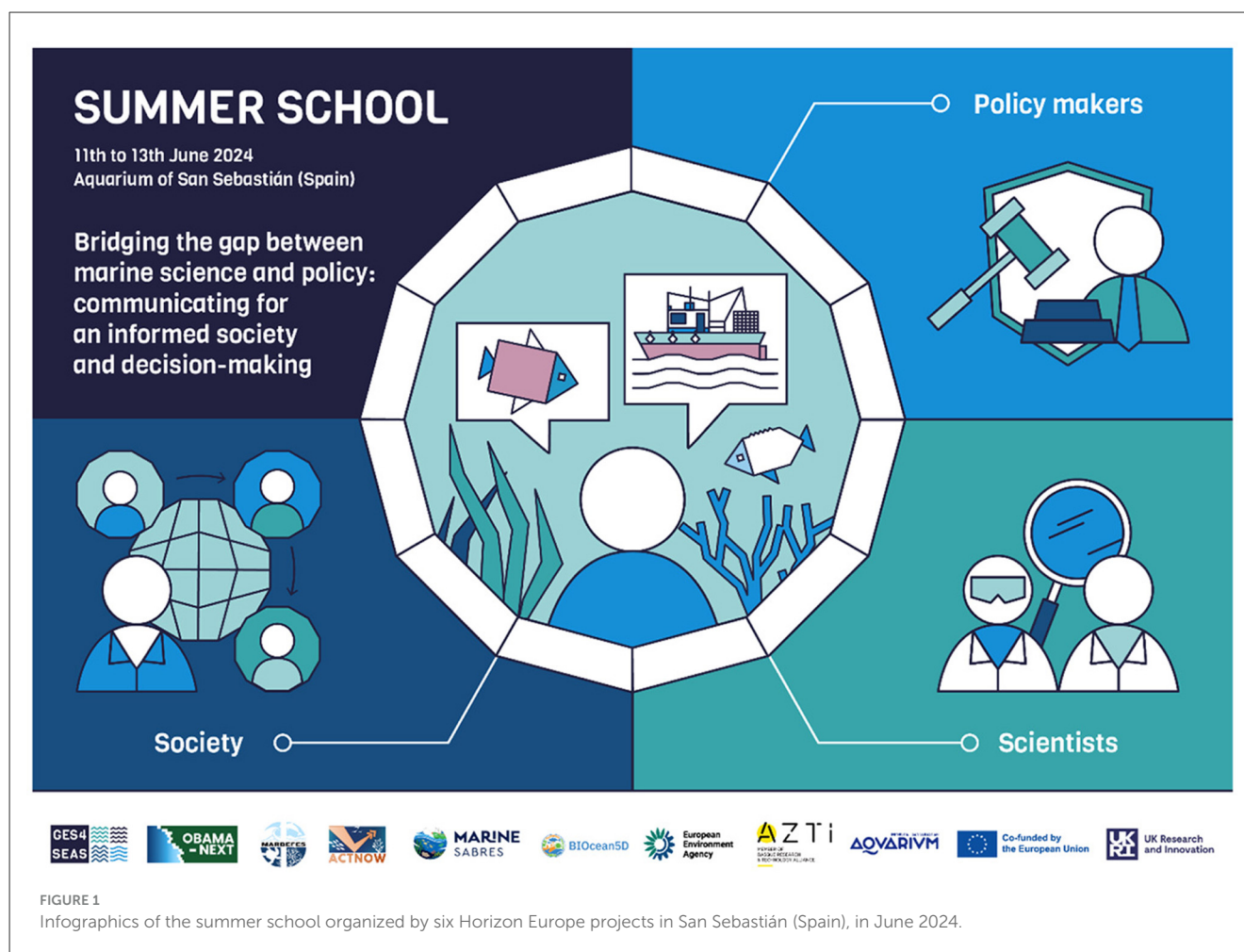
In trying to counter these problems and to cover these gaps in science-policy-society communication, six Horizon Europe funded projects, dealing with marine biodiversity topics, joined forces in a common action, by organizing a summer school, in San Sebastián (Spain), in June 2024 (Figure 1). The summer school was especially aimed at early career researchers (ECR) to provide support and tools for them to play a better role in science communication and the science-policy and science-society interface. Its main objective was for expert scientists, journalists, practitioners and managers to share their knowledge, experience, and tools, both in theory and practice. It also aimed to generate engagement for better and more efficient transmission of scientific ideas and research outputs, making marine conservation science available for policymakers and society.

This manuscript presents the experiences, findings, recommendations and conclusions from those days of debate between presenters and attendees, structured in four sections.

2 From science to policy

For scientists to influence and shape policymaking with their research, it is important to first understand the policy decision-making processes, especially what are the policy goals, how decisions are made, and who are the key actors (Elliott et al., 2025). Hence, research needs to be planned strategically for impact, for which it needs to be relevant and fulfill the needs of policymakers. It is necessary to be clear and separate pure scientific curiosity from the demand for science to address real problems posed by policymakers.

In essence, scientists need to enter the debate regarding “science-led policy and policy-led science”: (i) speak up in the policy debate: networking to establish visibility and trustworthiness in policy circles; (ii) connect with relevant policymakers/other

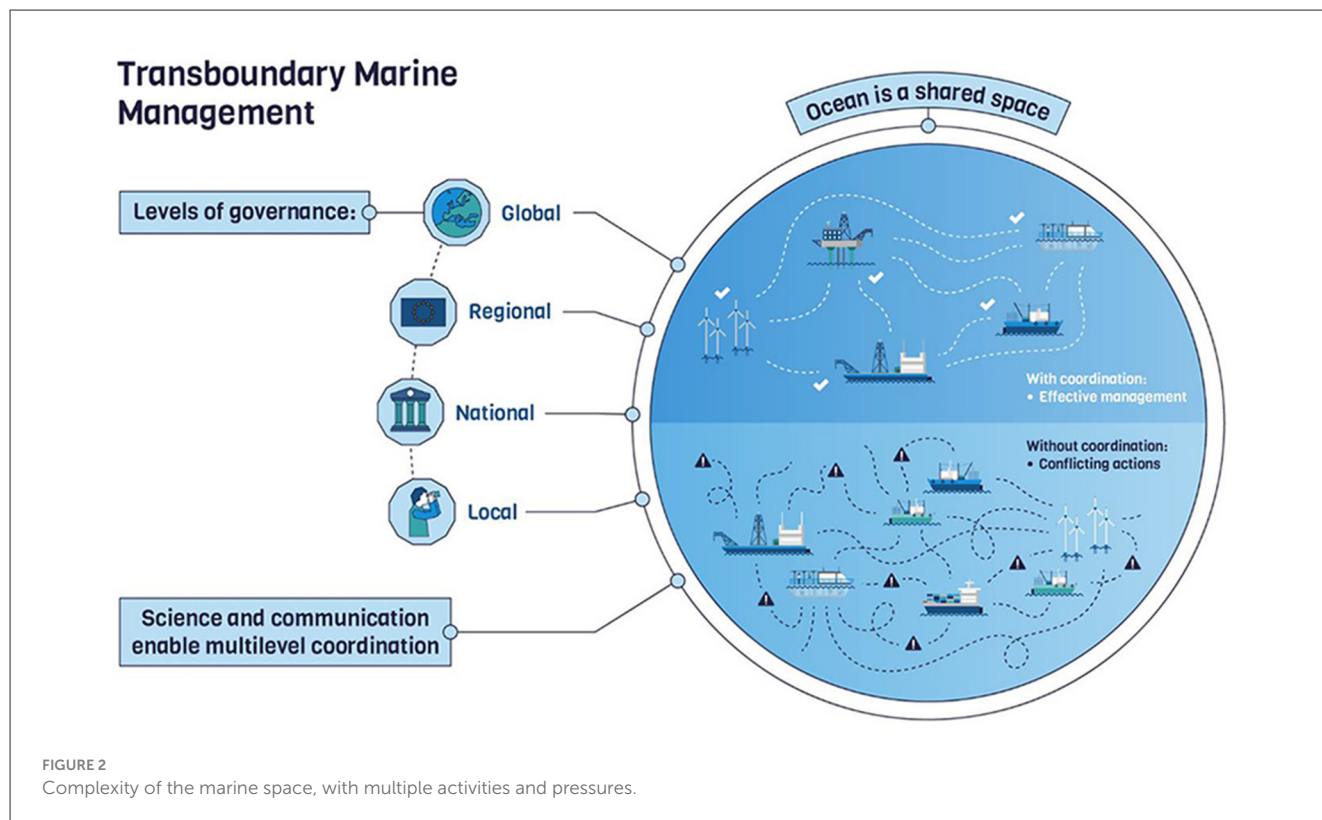


stakeholders; (iii) use what is learnt from these contacts to make research findings pertinent, in the context of wide knowledge; (iv) become bilingual in science and policy, using different approaches; (v) captivating stories (backed up with facts); (vi) time-pressed audience: short, simpler formats, avoid jargon/technical details, use understandable narratives and visualizations; and (vii) start with conclusions and easily digestible scientific evidence, with concise cross discipline synthesis.

Scientific results and findings contribute to shaping policy and regulation, particularly by supporting the implementation at national or local level concerning strategies and regulations in marine conservation e.g., in the EU: Green Deal, Biodiversity Strategy, or Nature Restoration Regulation. Scientific findings should also inform public consultations or impact assessments. Equally important is their role in guiding strategic programming in research, as well as global efforts like the UN Decade of Ocean Science and the UN Decade on Ecosystem Restoration (Borja et al., 2022). It is therefore of utmost importance to be aware of these different policy contexts, integrating them into science and research planning and development. A win-win for more informed and effective decision-making processes and at the same time, effective policies contribute to more research funding, public trust in science and research results and enhanced accountability of the work of scientists and researchers.

Environmental management spans cascading scales from global initiatives (e.g., the Kunming-Montreal Global Biodiversity Framework) to regional governance (e.g., the EU MSFD, European Commission, 2008), national and local decision-making (Cormier et al., 2022). Implementation of global and regional agreements and country-level policy decisions are the responsibility of national governments. Government policymaking for the marine environment is particularly complex because our seas and the ocean transcend borders, so marine resource management is a multi-jurisdictional problem taking place in a very busy space (Figure 2). Transboundary marine management requires that communication and policy-implementation need to be integrated to produce coherent and equivalent outcomes, e.g., if science and its communication between adjacent countries are not harmonized then transboundary marine management cannot be achieved (Elliott et al., 2023).

Governments must balance nature protection against their other responsibilities and needs including national security, societal wellbeing, food and energy security, trade and international relations. To produce sound marine policy, they need sound and defensible scientific advice, harmonizing science-led policy and policy-led science. This relies on fit-for-purpose science (accessible, understandable, timely and credible). The main types of relevant advice are grouped around environmental status (quality of the



marine environment, to meet national regulations, e.g., under the MSFD and international commitments, concerning the protection of the marine environment under the Regional Sea Conventions), management of marine activities (with legally-defendable evidence and advice on the impacts of human activities and on different management intervention options) and responses to unexpected events or emergencies such as oil spills.

Many stakeholder groups will have a view into marine management; all have a role in the public debate, but robust scientific advice can be influential in helping governments navigate the diversity of views and opinions that policy development generates. This “honest advocate” role (Rose et al., 2018; Gregory et al., 2024) uses the best available scientific information to produce evidence-based advice. Evaluating and communicating science in a trustworthy way is a key attribute of this type of advice and core principles include (i) the pursuit of objectivity, (ii) message clarity, and (iii) communicating confidence in the evidence base.

Objectivity (“being based on facts and not influenced by personal beliefs or feelings”) comes from considering all angles of the topic rather than only those that support a given preference. Advisors can demonstrate objectivity by following the scientific process; through designing robust methodologies, incorporating all the available evidence and appraising it systematically, reporting all relevant findings and using them to justify recommendations. That scientific method requires rigorous setting and testing hypotheses, having quality assured and controlled methods, testing the falsification of facts, being subject to international peer-review, and having verifiable data (Medawar, 1975). Doing this reduces the chances of advice morphing into “issue advocacy” or lobbying for a favored option, which can impact credibility (Gregory et al., 2024).

Clarity is essential for communicating complex concepts to non-experts. This is as true for advice to governments as it is for communicating with other stakeholder groups (Elliott et al., 2025). Advice riddled with jargon and unusual acronyms is unlikely to be helpful for a government policymaker, since they are not always experts in the topic. We acknowledge that all fields have their own terms and style, but breaking down these barriers is a major challenge that has to be achieved. The language used must be purpose and audience-specific; some jargon can be necessary to ensure specific information is conveyed correctly, but accessible language should be used to maximize uptake (Rose et al., 2018) and avoid advice being ignored (Borowiec, 2023). Scientific writing tends toward lengthy texts filled with detail; while this is appropriate for communicating to peers and may sometimes be necessary for particularly complex issues (IPCC, 2023; FAO, 2024), short, clear, unambiguous communication, where feasible, is more digestible (Kröger et al., 2018). Details can be provided in appendices, supplementary material or accompanying technical reports, i.e., the outputs rather than the outcome of the research (Elliott et al., 2025) (Box 1).

The scientist may be an advisor to a policymaker or there may be an intermediary advisor between scientist and policymaker who communicates the science. It is also necessary for the advisor to familiarize themselves with the policy/regulatory context and specific evidence needs of the relevant policymaker, and to contextualize their contribution around them. Most importantly is to clearly *say something*; governments want to know what to do, when to do it, where to do it, how to do it and why. Governments either employ their own advisors or engage

BOX 1 Scientific reports.

Scientists are aware of the pathway from detailed scientific reports to the final policy-relevant and formatted material. For example, overall marine quality status reports (e.g., Reker et al., 2019; HELCOM, 2023) start as lengthy scientific documents, each on a particular subject (e.g., the status of sea mammals in an area) with many graphs and tables and large accompanying databases. The text will contain many caveats and qualifying remarks and detailed explanations of what the data show and how the conclusions have been derived. That information is then synthesized and summarized as each ecological component is merged with other components and the supporting data left to appendices which may or may not be attached to main documents. A third stage shows that ecological information is merged with the synthesis from other fields such as legislation, economics or societal summaries. Perhaps fourth and fifth stages show all of this information then reduced to a briefing paper (e.g. 40–50 pages) and then a policy brief of perhaps 4–6 pages suitable for a minister or policy maker. Those summaries are unlikely to be written by the scientists who generated the information but perhaps by advisors. By these latter stages, all caveats and qualifying remarks will have been lost such that what started as “this feature may have been widespread and it may be interpreted and this or that occurring” becomes “this feature occurs”—i.e., metaphorically what started as a gray area becomes black-and-white!

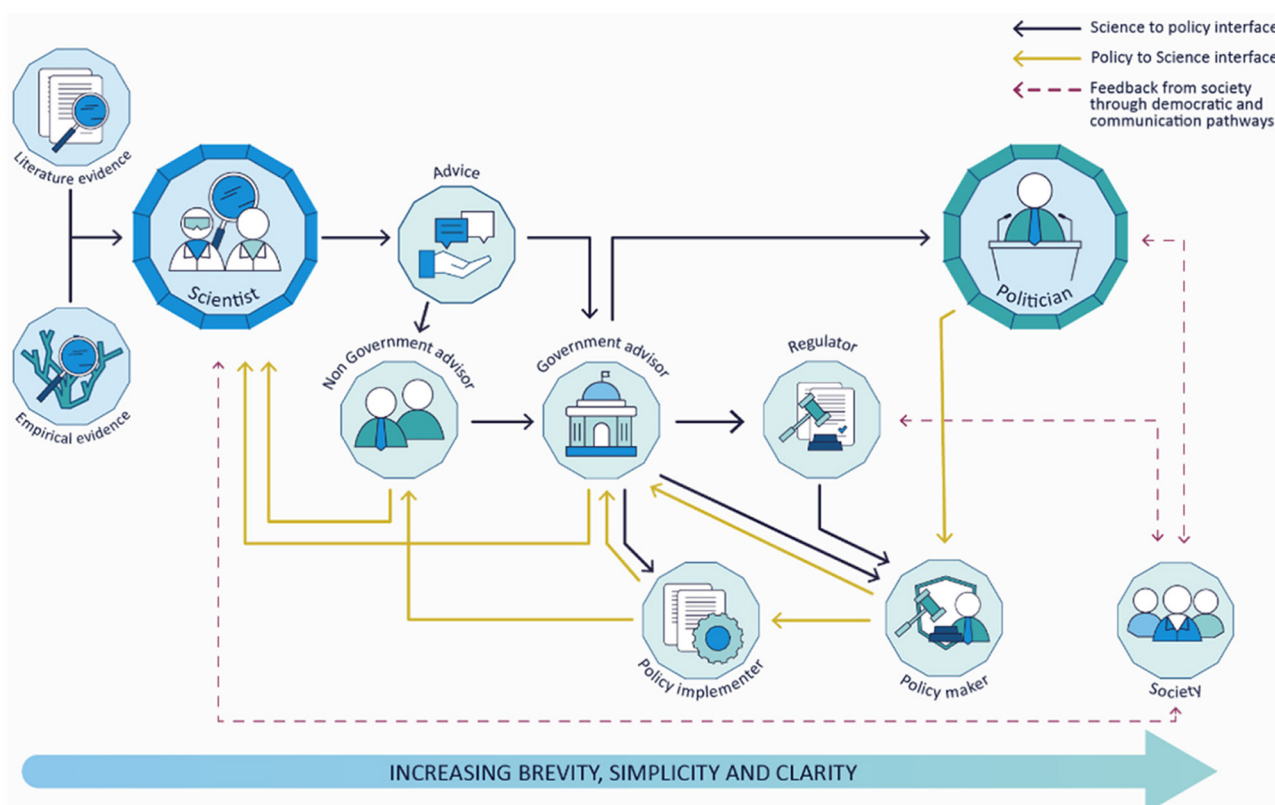


FIGURE 3
The science-policy and policy-science interfaces with an accompanying role for all stakeholders through wider society.

non-government scientists but a familiar saying is “advisors advise and politicians decide.”

This can be seen as three types of interface pathways as shown in Figure 3: (i) a cascading upwards from scientists to policymakers (black lines); (ii) a reverse cascade from the policymakers and implementers giving direction to the advisors and then to the scientists (yellow lines), and (iii) the role and influence of members of society on those parts of this scheme with whom they come into contact (dashed lines). This indicates that society talks directly with scientists (dissemination and giving ideas for research, citizen science), regulators (through consultation) and politicians (through the ballot box and constituents as the result of disseminating evidence!). It is unlikely that society would engage with the other advisors, etc., directly. Although that wider

society would include lobbying groups such as environmental non-government organizations. Furthermore, the research funding agreed by the policymakers and politicians determines the amount of evidence available, either through literature or empirical studies; that funding allocation may be the result of societal concern or a perceived inadequate science base.

This leads to the final point here: it is important to effectively communicate the degree of confidence in the evidence as this tells the policy-implementer/policymaker how certain the advisor scientist is about their recommendations. Traditionally, scientists use statistical tests accompanying hypothesis testing, or at least testable questions to appraise evidence. These tests may not be easily understood and require time to interpret, which some policymakers could lack. Furthermore, scientists may give a long

list of caveats or qualifying remarks which could blur key outcomes and hence the use of science by policymakers and others, so it should be the role of advisors in communicating these effectively, sometimes through institutions and agencies (Box 2). “Traffic-light” or scale-based methods are an intuitive way to communicate uncertainty (Figure 4) and are used in various situations including conveying evidence on environmental status (Evans et al., 2018), human impacts on the environment (Moore and Smale, 2020), or offshore windfarm effects on fisheries species (Gill et al., 2025). Following these principles should enable advisors to produce scientific advice that is targeted, helpful and trusted.

3 From science to the world

In the case of scientists, the most traditional way to communicate their results has been through scientific papers. Writing scientific papers for Early Career Researchers can be challenging, and Box 3 shows some recommendations, as well as useful links to increase knowledge about this, not only for them, but for any author.

However, this communication channel is mainly for other scientists, and science communication has evolved significantly due to new technologies, digital platforms, and changing social and cultural attitudes (Agnew et al., 2024). In Europe, two key narratives have influenced science communication: one underscores the increasing disconnect between science and the public, while the other focuses on fostering connections through dialogue, engagement, and participation. Similar narratives exist globally but with unique regional perspectives, i.e., colonial influences in Latin America (Nielsen, 2022). Communicating science effectively is challenging, as messages must be based on evolving evidence while competing against misinformation (Holford et al., 2023). Key challenges include the complexity of scientific concepts, diverse audiences, misinformation or false narratives or biases (e.g., “blue or greenwashing”), incomplete existing communication, and barriers such as language accessibility (Agnew et al., 2024).

A scientifically literate society requires accessible scientific information that informs the public and promotes active participation in wider discourse around scientific knowledge and informed decision-making. While increasing accessibility includes sharing scientific work, e.g., via pre-prints and open access, in this context it must involve making research easier to understand, as technical jargon often restricts conversations between scientists and other disciplines. Here, plain-language summaries can enhance the public ability to assess evidence and use of technology can help interpret research in context. Ultimately, scientists must take responsibility for making their research both available and comprehensible to the public (Holford et al., 2023). This is increasingly recognized by academia, where scientists are expected to publicize research findings and generate impact, and by the research funding organizations, who have raised expectations for scientists to go beyond publication in academic journals. In general, there is a consensus that society needs science for informed decision-making and to inform relevant wider societal discourse (Agnew et al., 2023).

Providing more and improved access to evidence-based scientific information can be supported by science communication, that adheres to clear and intuitive presentation formats, includes effective visuals and infographics and uses stories to which audiences can connect. Most importantly, science communication needs to support the audiences to critically engage with information and its production (Holford et al., 2023; Agnew et al., 2023). Effective science communication requires selecting appropriate dissemination tools and communication pathways that align with available budget, time constraints, and audience needs. For example, establishing an online presence through websites, social media, blogs, or podcasts is valuable, but the most suitable platform depends on the target audience. Furthermore, target audiences need to be engaged where they are, which means the science communicator needs to co-occur with their audience, i.e., at locations and events such as conferences, industry events, schools, or through preferred media formats such as films, policy briefs, or infographics to enhance accessibility. Developing meaningful science communication strategies takes time, effort, and resources but is essential for informed decision-making and public engagement (Agnew et al., 2023, 2024).

To support evidence-based marine science communication, both the scientific and policy communities must be aware of public narratives on marine issues, including misinformation and misperceptions. Direct collaboration between scientists and policymakers through focus groups and workshops can foster better understanding, clearer communication, and easier integration of research into policy. Marine science communication must effectively convey evidence-based knowledge while addressing misinformation, incomplete narratives, and adopt best practices for reaching diverse audiences, including disadvantaged groups. This includes addressing the barriers faced by marginalized groups by bridging language and cultural barriers and ensuring transparent access to evidence-based scientific information across regions (Agnew et al., 2023, 2024).

In this context, social media has emerged as a transformative tool for science communication, allowing researchers to reach broader audiences, engage with stakeholders from several fields, and actively counteract misinformation (Figure 5). Social media platforms allow for the immediate and direct transfer of scientific knowledge, and feedback from the audience, contrary to traditional academic publishing, which involves lengthy peer-review processes, with limited accessibility and often not accessible language, or mainstream media, which often lack deep scientific coverage (Shu et al., 2017). This advantageous immediacy of social media is particularly valuable in marine science, where timely and ready to communicate research findings can inform conservation actions, policy decisions, and public awareness campaigns (Nisbet and Scheufele, 2009).

Each social media platform offers distinct advantages in disseminating general science:

- (i) Twitter (X), Bluesky or Mastodon are hubs for academic engagement, where researchers can share findings, discuss ongoing projects, and contribute to science-policy discussions (Darling et al., 2013; Kopke et al., 2019). Tools, such as hashtags, feeds and trending topics further enhance the visibility of scientific results, stimulating discussions on

BOX 2 The European Environment Agency, working at the edge of science and policy.

The European Environment Agency (EEA) works together with 38 European countries, more than 400 institutions and around 2,000 experts, organized in 13 Eionet groups, supported by 7 European Topic Centers (e.g., in biodiversity and ecosystems; climate change adaptation and mitigation, data integration and digitalization, human health and environment, resource use and circular economy or sustainability transitions; more information in <https://www.eionet.europa.eu/etcs>). The EEA delivers data, information and knowledge about the European environment, supporting European and national policies. This support is related to informing policy implementation, assessing systemic challenges and supporting countries in knowledge co-creation, and in sharing and use of this knowledge in taking informed decisions around the environment challenges.

The strategic objectives from EEA-Eionet, for 2021–2030 are: (i) supporting policy implementation and sustainability transitions; (ii) providing timely input to solutions for sustainability challenges; (iii) building stronger networks and partnerships; (iv) making full use of the potential of data, technology and digitalization, and (v) resourcing shared ambitions.

Regarding the strategic approach to marine activities, the EEA addresses the pressures and state of the marine environment through different European directives, such as the Marine Strategy Framework Directive, the Bathing Water Directive, the Water Framework Directive, the Habitats and Birds Directive, the Biodiversity Strategy and the Zero Pollution Action Plan. Also, the EEA promotes the transition to sustainability of the maritime sectors through the Maritime Spatial Planning Directive, the Sustainable Blue Economy Strategy, the Fisheries and Ocean Marine Action Plan, the Common Fishery Policy, the EU Strategy on offshore renewable energy and the Port Reception Facilities Directive. It will also influence the new EU Nature Restoration Law as well as the composition of the databases EMODnet and WISE Marine, jointly with their Secretariats.

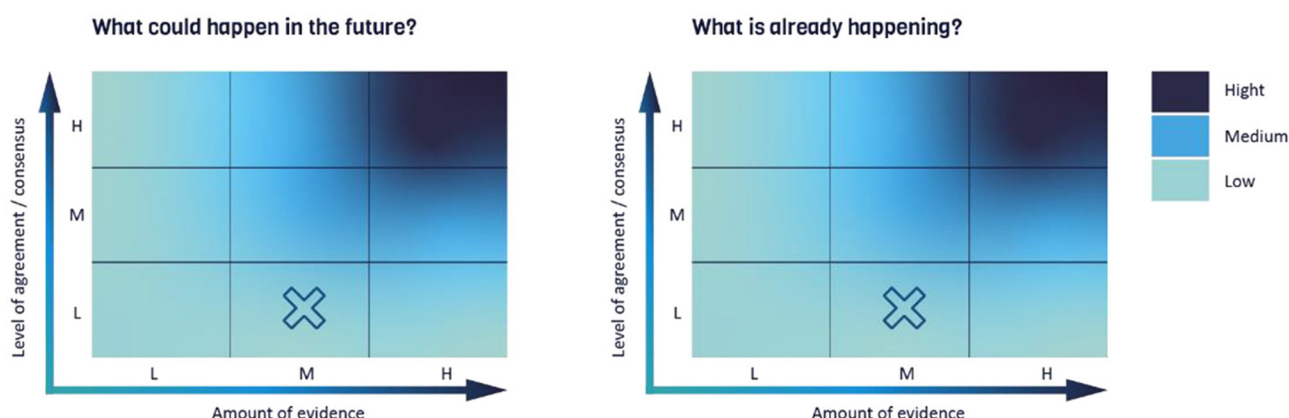


FIGURE 4

An example of an adapted “traffic-light” method for communicating uncertainty in an evidence base to policymakers. This confidence assessment is a combination of the amount of evidence available and the level of scientific consensus on the issue; the topic of the assessment is climate change impacts on UK subtidal habitats. Inspired by Moore and Smale (2020).

issues such as ocean acidification, overfishing, and marine biodiversity loss, with important consequences for global environmental health and society.

- (ii) Instagram has its focus on more visual storytelling concepts, being particularly effective for raising awareness in the public using creative infographics or short videos depicting, e.g., marine research, conservation efforts, or endangered species.
- (iii) Facebook, ResearchGate and LinkedIn facilitate structured engagement by providing spaces for professional networking, detailed scientific discussions, and multi-disciplinary collaborations.
- (iv) YouTube serves as a platform for more in-depth content, such as explainer videos and documentary-style narratives that explore marine science topics.

Despite the advantages, social media is also a vehicle for misinformation and disinformation, thereby allowing rapid spreading of so-called “fake news” and challenging effective and trustworthy science communication (Holford et al., 2023; Agnew et al., 2023), as contents are often shared without rigorous fact-checking (Pennycook and Rand, 2019). Their algorithms also direct readers/users to similar content, thereby creating

a “snowballing effect,” amplifying sensational content, making emotionally charged or misleading stories spread faster and wider than factual, evidence-based information (Vosoughi et al., 2018). This prejudicial dynamic needs a highly proactive approach from the scientific community to ensure that credible, research-based content remains visible and accessible to diverse audiences. In consequence, misleading narratives, such as climate change denial or misinformation about marine conservation efforts, can compromise public trust in scientific evidence and hinder policy action.

To mitigate the spread of fake news, technological and societal solutions have been suggested. One approach is the development of automated systems, such as artificial intelligence (AI), to detect and flag fake content. However, these methods still face challenges due to the complexity and sophistication of fake news, which closely mimic truth, making it difficult for AI to recognize the veracity of the information posted (Aïmeur et al., 2023). Indeed, recent studies suggest that AI is more effective at generating fake content than at identifying it (Paschen, 2020). It is acknowledged and emphasized that AI can only find already uploaded information whether fake or trustworthy but by doing this it gives credibility to views, perhaps

BOX 3 Writing scientific papers by Early Career Researchers (ECR).

There is much literature on guidance for ECR and others on how to write successful papers. This box summarizes the main tips and recommendations when preparing a paper, based on the experience of the authors. More information can be found in the links provided.

1 - Six things to do before writing your manuscript:

- Think about why you want to publish your work, and whether it is publishable, by responding to these questions: (i) have I done something new and interesting?; (ii) is there anything challenging in my work?; (iii) is my work directly related to a current hot topic?; (iv) have I provided solutions to some difficult problems?
- Decide what type of the manuscript to write: there are many, but the most usual are full or original articles; letters/short communications; review papers or perspectives/opinion pieces and editorials.
- Choose the target journal: The most common way of selecting the right journal is looking at the articles you have cited in your own manuscript. Each publisher has its own tool for selecting the right journal, but you can consult this [global one](#).
- Pay attention to journal requirements in the Guide for Authors although many journals allow a free-form submission that only has to be revised to the journal standard after acceptance.
- Pay attention to the structure of the paper: the most usual is Introduction (What did you/others do? Why did you do it?), Methods (How did you do it?), Results (What did you find?) and Discussion (What does it all mean?), but consult the journal web page.
- Understand publication ethics to avoid violations, such as plagiarism, fabrication of data, or falsification, but see [publication ethics](#).

2 - Eleven steps to structuring a science paper editors will take seriously: The suggested order of writing a paper, after the previous section, is presented below.

- After having the overall concept in your mind, make short notes as guidance.
- Prepare the figures and tables you want to include, to better shape your message.
- Write the Methods, since is the easiest section.
- Write up the Results, since they are very familiar for you (use past tense for what you did and present tense for what the results now show).
- Write the Discussion: finalize the Results and Discussion before writing the Introduction.
- This is because, if the discussion is insufficient, how can you objectively demonstrate the scientific significance of your work in the introduction?
- Give Recommendations for what are the next steps in developing your work.
- Write a clear Conclusion, related to the objective of your research, able to be communicated also through social media (this is not the same as the Abstract).
- Write a compelling Introduction, explaining the problems to be solved and the objectives of your research—give the Aim(s) (the big idea), the Objectives [what has to be done to fulfill the aim(s)] and the Hypotheses or testable questions.
- Write the Abstract, summarizing the problem, objectives, main findings and main conclusion.
- Compose a concise, descriptive and compelling Title.
- Select Keywords for indexing and perhaps create a Graphical Abstract.
- Write the Acknowledgments, including funding.
- Write up the References.

3 - Writing the first draft of your science paper—some dos and don'ts:

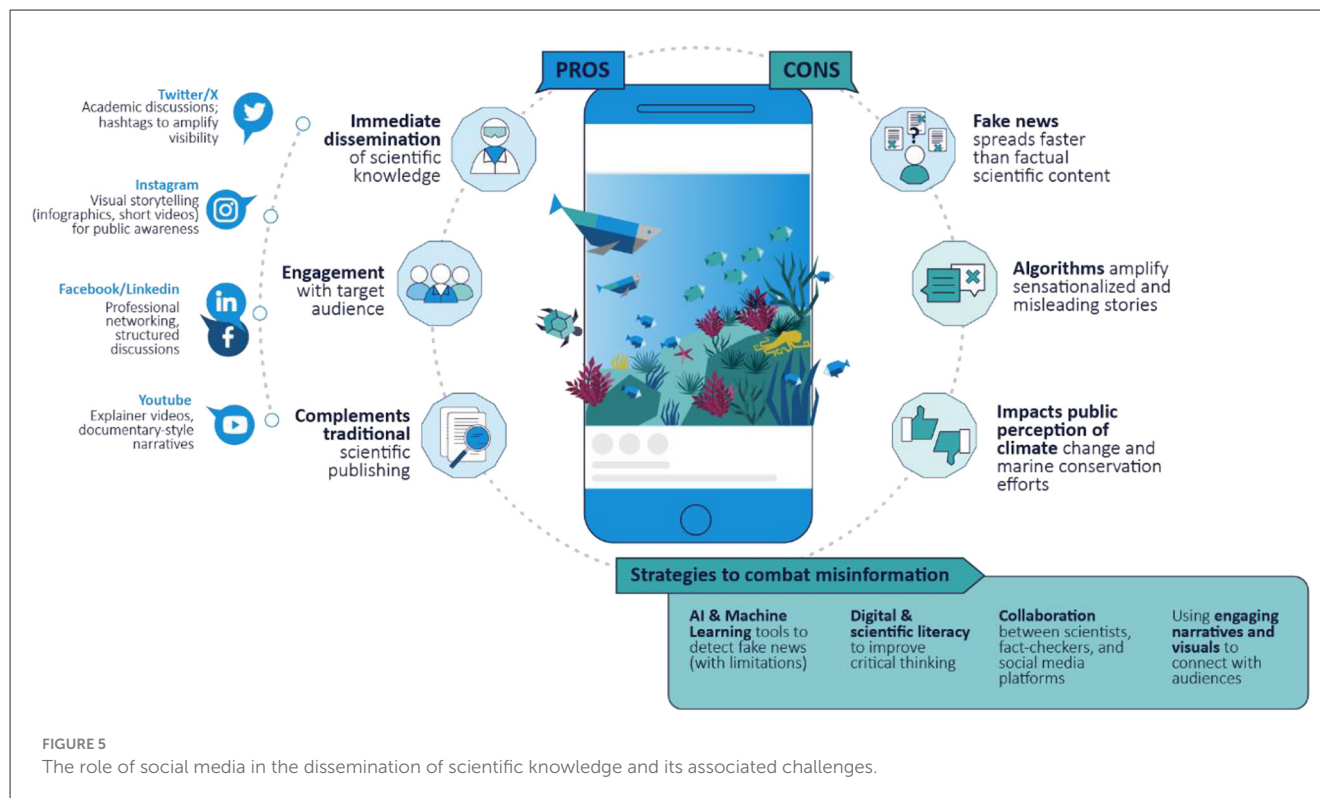
- Each author has his/her own ways to proceed. Here, we present some usual recommendations:
- Think about the topic you want to present, for some days or weeks (message to be transmitted, flow, etc.)
- Make figures and tables (even those that eventually can be shown as supplementary material)
- Write as quickly as possible, as if thinking out loud
- Get everything down
- Ignore spelling, grammar, style, in this first version
- Skip troublesome words
- Correct and rewrite only when the whole text is on paper
- If you are several authors, do not split the manuscript among the co-authors (but you can ask the co-authors for specific paragraphs and points to be included), it is better to write a first complete draft and then the co-authors can amend and add new text. Make sure an experienced author does the final edit for consistency. In this way, the internal coherence of the paper is assured.

by amplifying the points and not reproducing the uncertainties and caveats.

Another important strategy involves media literacy, stimulating the public to critically evaluate the information read online (Dame Adjin-Tettey, 2022). The collaboration between social media platforms, fact-checkers, and researchers is emphasized to improve the credibility of information and correct false narratives (Aïmeur et al., 2023). Therefore, addressing misinformation and disinformation requires more than the mere presentation of facts; it involves a holistic approach combining logical reasoning with emotional engagement of the public, using visually compelling content coupled with narrative elements in a way that resonates with the target audience values and concerns, bearing in mind that policymakers, environmental organizations, industry stakeholders, and the society each have distinct informational needs. Only

through this approach will it be possible to reinforce trust and encourage the sharing of information within broader digital communities (Aïmeur et al., 2023).

Social media has the potential to bridge the gap between marine science and policy by fostering a more dynamic and participatory model of science communication. However, both its creation and dissemination are based on brevity and therefore not being able to give detailed argument. While the rapid spread of misleading narratives presents challenges, it also underscores the necessity for scientists to actively engage with digital platforms and leverage their immediacy to communicate research findings effectively. By integrating evidence-based communication strategies, fostering public trust, and harnessing the strengths of various social media networks, marine scientists can play a pivotal role in shaping informed discussions. This perhaps enables influencing



policy decisions and advancing the sustainable management of ocean resources.

4 From science to societal solutions

Engaging society in looking for solutions based on scientific knowledge needs to increase awareness about the problems that the ocean is facing (Gelcich et al., 2014). One of the ways of changing public perceptions is promoting ocean literacy, to ensure that it encompasses diverse knowledge, values and experiences (McKinley et al., 2023). Since the term ocean literacy was proposed, its principles have spread widely (Costa and Caldeira, 2018). Despite this, what we know about the effectiveness of ocean literacy initiatives in societal behavioral changes is still quite limited (Ashley et al., 2019) and, when available, the relationship between knowledge and behavior change is demonstrably surprisingly low (Stoll-Kleemann, 2019).

In this context, non-formal educational methods can assist in promoting ocean literacy, which often allows further engagement, e.g., citizen science initiatives have played an important role, offering learning opportunities, enabling individuals to engage in ocean environments and generating new data. Marine litter (Kawabe et al., 2022), invasive species (Encarnação et al., 2021) or climate change (Pecl et al., 2019) are some topics in which citizen science has been crucial making society aware about the challenges the ocean faces.

Bioblitz, dedicated citizen-science biodiversity surveys to collect and identify as many species as possible within a short period and area, is an interesting approach (Rode and Torkar, 2023). A type of marine BioBlitz (BioMARathon; Salvador et al.,

2022), is an international citizen science competition designed to monitor marine and coastal biodiversity on a global scale integrating different local events. For compiling and validating those citizens' observations, the MINKA platform (<https://minka-sdg.org/>) has been specifically developed.

Also, outdoor activities, particularly in green and blue environments, allow citizens to connect with marine systems. Exposure to nature has shown to not only increase the connection with nature, but booster pro-environmental behaviors (Pouso et al., 2023), the ultimate goal of ocean literacy.

Regardless of the tools used, whether they are innovative (e.g., virtual reality) or more traditional tools (e.g., artistic sculptures), museums, exhibits, festivals and large events, are important venues providing the opportunity for hands-on activities. An important event of this kind is the European Researchers Night, at which organizations all around Europe offer a wide range of marine-related activities. Scientists, artists, musicians, actors, etc., participate using diverse and more creative tools (e.g., films, infographics, storytelling, jokes, etc.) aiming to simplify the complexity of science and especially connect to society at large (Roche et al., 2018).

Among these tools, game-based learning has been considered a powerful approach to education since the 1970s (Djaouti et al., 2011) which saw the increase in development of many role playing and educational board games, including games that focused on sustainable resource usage (Chapman, 1973; Munro, 1979). These are both *serious* but entertaining games where knowledge is gained through problem-solving. The use of such games in conservation, environmental governance and ocean literacy has increased since the mid-1990s (Rodela et al., 2019). This can communicate the complexities and interactions linking human behavior, resource

use, climate change and policy making (Katsaliaki and Mustafee, 2012; Tiller et al., 2025). With technological advances, and rapidly developing digital communication trends, digital serious games are becoming very popular. However, physical experiential activities (e.g., role playing and board games) in a classroom/meeting room are valuable tools for enabling players to experiment with different strategies and observe outcomes in risk-free environments (Tiller et al., 2025). These games can be developed to mimic real world problems, such as those identified in the case studies of many European projects linking environment society and policy making (Box 4).

Players are presented with a safe environment where they can experiment with alternative decision-making options and where they can explore the consequences of their actions, while learning about complex interdisciplinary issues like marine governance and conservation in simplified environments. Following scenario approaches these games can force players to make choices, prioritizing different development goals such as economic growth, social equity or environmental protection. This experiential phase of learning is usually followed by a debriefing phase. This reflective discussion is an essential part of the process allowing to draw lessons and critically reflect on the game process and outcomes, as well as identify links and similarities to real world situations. When participants can reflect on their actions and choices this can be communicated to the rest of the group which can potentially change attitudes and increase collaboration.

5 Final discussion and recommendations

The increase of “alternative facts” and “fake news,” in traditional and social media (Al-Rawi et al., 2021), is disrupting the way in which scientists have been communicating. In addition, news media more often focus on bad news rather than good news, e.g., some excessive media headlines using emotive language emphasizing the “collapse” of marine ecosystems due to ocean “calamities” (Duarte et al., 2015). This has led to several authors advocating for a change in narrative about the future health status of the ocean, increasing overall appreciation of our marine environment (Borja et al., 2022). Changing this narrative, using either traditional or new communication channels, to approach society and policymakers, should be rooted, as suggested also by the European Commission et al. (2019), in (i) high-quality science proving fit-for-purpose advice; (ii) effective methods for analysis of the scientific evidence for such advice; (iii) an intermediation between science and policy; and (iv) transparent and impartial process, reminding that scientists must give advice and politicians must make the decisions, based on the information provided.

From the debate while preparing this manuscript, during the summer school, and from different sources (Seeyave et al., 2017; European Commission et al., 2019; Seys et al., 2022), some recommendations for better marine scientific communication to society and policymakers can be presented:

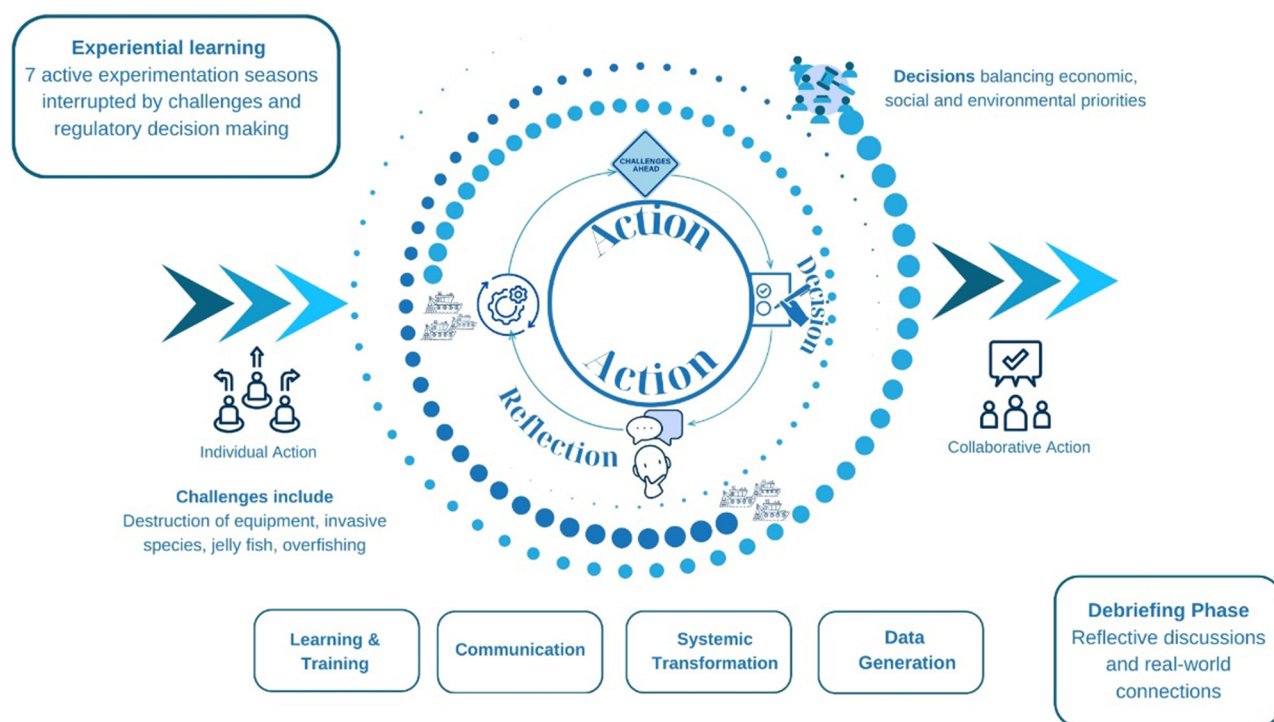
- Train or certify (marine) scientists to know about people, their marine related culture, and their resource-based communities, including advanced social science courses for a better

understanding of communication to managers and the public at large.

- Science funding bodies, research institutions and scientists should change their culture, stimulating science communication, promoting the use of multiple channels, especially those reaching young people. This needs increasing funds dedicated to communication; e.g., the European Marine Board Communications Panel recommends that marine science institutions should dedicate at least 10% of their staff time to communication (Seys et al., 2022).
- Engage early and regularly with the final target audiences of your communication. At this time, it is important to clarify the boundaries between science, advice, and politics, defining together the questions for scientific advice that should be solved.
- Science communicators should connect across disciplines and sectors, including non-scientific domains, increasing the collaboration and interaction with all potential stakeholders, adapting the media channel, the language and the message to each of them “to make the invisible visible” (Seys et al., 2022).
- Ensure the highest quality of scientific evidence in communication and advice. Use the full scope of good impactful science, focusing on facts required by the target audience in forming an opinion or taking a decision. Marine scientists must ensure rigorous synthesis of scientific evidence which is fully referenced and supported.
- Scientists should avoid presenting only negative facts or bias, showing the positive side of any story, in social, economic and environmental terms. They should avoid emotive language and leave “environmental evangelism” to populist outlets. The rigor in expert consultation needs to consider also the potential conflicts of interest, which should be communicated to the target audience, including to policymakers.
- One of the main problems nowadays in communicating science is that an increasing number of people and decision-makers do not really want to hear about science, because it contradicts myths and lies that they believe and want to continue to believe. Therefore, the great challenge is to get these people to hear what scientists have to say, combating the tendency for them to always speak only to those who are already “convinced.” To combat this limitation, some authors (e.g., Bisbal, 2024) have recommended that scientists (i) must be clear about the decision context; (ii) lead resolutely but listen attentively; (iii) understand the “best available science” mandate; (iv) secure and trust a reliable science provider; (v) take a peek into the future; (vi) learn so you can teach; and (vii) support the scientific enterprise.
- Often, the news that scientists must deliver is not pleasant and this ends up demobilizing people (e.g., news related to climate change or environmental sustainability). How to solve this dilemma of not lying to people and not alienating Current communication approaches seem insufficient for effectively communicating some inconvenient truths (Voci and Karmasin, 2024). New transdisciplinary research (including natural and social sciences, from politicians, to journalists, educators, scientists and communication professionals) is required to analyze these problems, develop innovative solutions and explore alternative approaches (including ocean

BOX 4 An example of a serious game application.

Beyond education and training, serious games can be used as a potential tool that can trigger change through engaging stakeholders with conflicting views to develop collaborative forms of management and as a potential research methodology where players can generate data sets or validate scenarios (Rodela et al., 2019). Serious games, in particular role-playing simulation games, offer a reflective communication approach capable of stimulating a critical, value-based discourse between science and society, which is key for the integration of scientific knowledge in the socio-political space. However, from the design phase, it is important to consider the intended purpose of game development and use, the tools and game format to be used and the relatedness to real world challenges. During the summer school, participants were engaged in an experiential serious game aiming to enhance understanding on the complexity of pressures caused by the combine effects of current unsustainable fishing practices and climate change, as well as the difficulties in establishing correct policy measures to reduce impact. That game was arranged in seven phases, at the end of which the participants were faced with a challenge that disrupts their actions and the continuation of the game. These challenges were attributed to specific events (jelly fish blooms, or extreme weather events) or other longer-term pressures such as invasive species or overfishing. These challenges were then followed by a choice of regulatory decisions, which required the participants to balance economic, social or environmental priorities. The challenges had cumulative impacts on the fishing activities, increasing the difficulty of performance from one round to the next. Throughout the game the roles of “fishers,” were separate from the roles of decision makers, as a way of experiencing exclusion from the decision-making processes. After the final phase participants were given the opportunity to form multi-stakeholder groups and propose solutions collaboratively.



literacy), and reevaluate the education received by future communicators (Voci and Karmasin, 2024).

- It is very important to analyze, assess and communicate the uncertainties associated with the evidence presented. This requires the use of uncertainty analysis, which should be presented in a way to be understood by the target audience. This means that you need to explain the path from evidence to the advice provided, ensuring that the audience can take a decision with all the information available at the time of communication.
- Most importantly, most of the above recommendations may be achieved through adequate and improved ocean literacy, which is key to getting wider stakeholders able to cope with science, the evidence and the information available.

Hence, by improving science-policy and science-society communication, we are confident that public understanding

and support for marine protection, conservation and restoration policies can be enhanced, leading to more effective management of marine ecosystems and a change in narrative about the future of the ocean.

Author contributions

AB: Conceptualization, Funding acquisition, Project administration, Writing – original draft, Writing – review & editing. JB: Writing – original draft, Writing – review & editing. KK: Writing – original draft, Writing – review & editing. SG: Writing – original draft, Writing – review & editing. MA: Writing – original draft, Writing – review & editing. AE: Visualization, Writing – original draft, Writing – review & editing. EK: Writing – original draft, Writing – review & editing. ML: Visualization, Writing – original draft, Writing – review & editing. MU: Writing –

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AE was employed by Science Crunchers. ME was employed by International Estuarine & Coastal Specialists (IECS) Ltd.

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