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Marine protected areas as living labs? Lessons learned & future perspectives

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Marine Protected Areas (MPAs) management usually involves bringing multiple stakeholders together, to construct policy-relevant research programs and science-based tools for adaptive management. Here, we present the conclusions of a transdisciplinary workshop that aimed at reviewing experiences in the co-design of EBM research in MPAs. We find that MPAs represent powerful instruments for conducting real-world experiments, *de facto* acting as living labs in support of ocean governance.

Along with the need for ecosystem-based management, there has been increased recognition of the importance of stakeholder engagement in the design, implementation and dissemination of research in support of Ecosystem-Based Management (EBM) of marine social-ecological systems¹. As development of the blue economy accelerates, collaborative partnerships become more complex with the diversification of sectors, jurisdictions and concerns involved, particularly in coastal areas². Addressing this complexity is essential to enable coordination across multiple uses, manage political challenges, and support the effective management of cross-sectoral externalities to achieve conservation objectives³. Bellanger et al.⁴ highlight the importance of improving our understanding of the sources and magnitude of transaction costs associated with cross-sectoral coordination, in order to help identify opportunities for a holistic and integrated management. They also emphasize the need for sustained stakeholder engagement and adaptive institutional capacity to ensure the effective implementation of such management. From a research perspective, the move towards EBM has also led to a call for increasing collaborations between researchers and stakeholders at multiple scales, and for enhanced integration of academic and non-academic knowledge as part of transdisciplinary research approaches, as illustrated by the call for actions by the International Oceanographic Commission published in the spring of 2025, as part of the United Nations Decade for Ocean Science. Indeed, such integration is at the heart of ocean sustainability science⁵. While several definitions of transdisciplinary research exist, a common feature across definitions is the delivery of innovation in both understanding and practice, through integration of existing knowledge from all available sources, perspectives and cultures. Indeed, the aim of such

research is to support societal transformation towards a sustainable future, building on place-based social learning processes⁶.

Marine Protected Areas (MPAs *sensu lato*, including e.g. Marine Parks, Reserves, Multiple Use Management Areas, Special Management Areas for certain maritime activities, etc.) have largely been considered from a biodiversity conservation perspective. The term “Protected”, however, often does not specify “from what” and “for what”. These areas provide opportunities to establish governance arrangements bringing together multiple stakeholders, in institutionalized arenas that can support the long-term co-construction of integrated policy and policy-relevant research programs⁷. Indeed, MPAs meet several criteria put forward by analyses of successful Common-Pool Resource (CPR) management systems^{8,9}, demonstrating that well-designed CPR management systems actively involving local stakeholders and incorporating traditional knowledge are prone to positive marine conservation outcomes¹⁰.

As shown in these analyses, successful CPR management depends on the definition of the resource system perimeter and rules for appropriation and use, the participation of interested parties in the rule design, the existence of effective monitoring capabilities and graduated sanctions, as well as of conflict resolution mechanisms and support for locally defined rules from higher regulatory levels¹¹. In doing so, they are likely to help achieve several aspects that Bellanger et al.⁴ highlight as key to improving coordination and reducing transaction costs, including supporting research to reduce uncertainties and organizing transparent methods for collecting information and interpreting data, while also facilitating the emergence of mechanisms to reconcile diverging preferences, and establishing effective enforcement regimes. Such reduction in regulation costs is crucial for ensuring resource use that is in line with sustainability¹².

MPAs thus offer a useful test of the “living lab” concept, defined by ref. 13 as a partnership gathering “companies, public agencies, universities, users, and other stakeholders” collaborating in the co-creation, exploration, experimentation, and evaluation of possible courses of action, in real-life contexts. Living labs usually refer to explicitly defined areas: a living lab is thus a geographically defined space for researchers and stakeholders to identify research questions (co-design), and experiment approaches to solutions, creating new knowledge (co-creation)¹⁴. This concept of living lab is on the rise, with a growing number of case studies being described, although their systematic assessment is lacking¹⁵. In the context of marine biodiversity conservation, the approach seems promising, in response to calls for a stronger integration of solution-oriented, transformative research approaches with the development of adaptive management decision-making, as illustrated by the recent works published in this journal^{16,17}. In

particular, the approach may help address the trade-offs associated with prioritizing and implementing protection measures in marine space, by enabling the experimentation of multiple types of regulations, including strict protection within existing MPAs, which is increasingly being called for¹⁸.

While the living lab approach has been used under various circumstances, common elements include (i) the collaboration of science and society within transdisciplinary research approaches; (ii) their embeddedness in the real world, and (iii) experimentation¹⁹. The recent discussion has also pointed to the need to clearly differentiate between the living lab and the experiment, i.e. between the real-world lab and the real-world experiment²⁰. Two characteristics for living labs (as opposed to the experiments that can be conducted there) are their long-term nature and the provision of an organizational frame, i.e. an experimental space²⁰. In this sense, MPAs with their long-term nature and their organizational frame indeed appear to meet the requirements of living labs.

In order to assess the extent to which MPAs can be considered as a case of living labs, we organized a workshop associating scientists of various disciplinary backgrounds with MPA managers, to review and confront past experiences (including successes and failures) with respect to the co-design of EBM research in MPAs, and identify future needs and opportunities for the development of this research. Here, we present a summary of these lessons learned, and discuss the implications for the future of collaborative research in MPAs.

Approach

The three-day workshop was organized from 14th to 16th November 2023 in Brest (France) as part of the HOPOPoP Project. It brought together 27 participants, 19 scientists from various disciplinary backgrounds in natural and social sciences, as well as 8 MPA managers from multiple geographical regions in France, the UK, Spain as well as North America and Australia.

Participants in the workshop had long experience in managing and carrying out research in MPAs of varying age, size and statutes, in a broad range of biogeographical and socio-political contexts from the global North (Fig. 1). These included the Saguenay-St. Lawrence Marine Park (Canada, est. 1998), the Stellwagen Bank National Marine Sanctuary (USA, est. 1992), the Reserva Mariña de Interese Pesqueiro Os Miñarzos (Spain, est. 2007), the North Devon Biosphere Reserve (UK, est. 2002), as well as three Marine Protected Areas in Australia [Ningaloo Marine Park (est. 1987), the Kimberley Region - Commonwealth waters (est. 2013) and the Great Barrier Reef Marine Park (est. 1975)], and four in France: the Iroise Marine Natural Park (est. 2007), the Marine Natural Park of Arcachon Bay (est. 2014), the Côte Bleue Marine Park (est. 1983) and the National Natural Reserve of 7 Iles (est. 1976). In addition to the above MPAs, which were used as a basis for the review of lessons learned during the workshop, participants had a range of experiences relating to the study and management of other marine protected areas around the world.

Our three guiding questions for the workshop were:

1. What knowledge is relevant to supporting MPA management, considering disciplinary perspectives, observational methods, data, models, as well as local knowledge?
2. What are the most effective collaboration approaches to integrate research and management in day-to-day operations of MPAs, and to deal with diverging expectations?
3. How can we track the impacts of collaborative approaches and outcomes?

First, participating scientists and MPA managers at the research-management interface in these different regional settings presented their

experiences, with a focus on the above three questions. A template was provided to participants ahead of the workshop to describe the MPA they worked with, as well as their responses to each of the three guiding questions in that particular context. This material served as the foundation for comparing experiences across the different case studies during the first session of the workshop, which took place over two half-days. Next, three sub-groups were formed, mixing researchers and managers, to discuss lessons learned and identify key priorities related to each question, using a consensus-based approach. This second stage of the workshop extended over another half-day. The conclusions of the sub-group dialogue were the shared and discussed in a plenary session, and synthesized collectively into key lessons learned. This last stage of the workshop extended over the final half-day.

Key lessons learned

What science is relevant to supporting MPA management? Workshop participants agreed that MPAs should be considered as social-ecological systems²¹, stressing the need for a transdisciplinary understanding of system components, interactions and drivers (Fig. 2). This includes the ecology of marine habitats and species, the uses of exploited marine resources and areas, and the values associated with these uses and areas, including heritage values. Such understanding must consider multiple spatial scales and connectivity patterns, within and outside MPAs, as well as multiple temporal scales. This conversation highlighted the need for long-term data acquisition on these different components to help elicit the nature, intensity and directions of changes²².

In addition to these ecological and human dimensions, it is key to also consider stakeholder perceptions and representations, how they may differ, and how they may affect attitudes and behaviors towards management (e.g., concerning enforcement and compliance). Indeed, which impacts matter and should be measured is bound to the different time scales of interest, hence the co-construction of research programs in collaboration with MPA managers and stakeholders is likely to play a key role in determining those that are monitored²³.

Participants highlighted the need for collaborative research to follow the principles of Findable, Accessible, Interoperable and Reusable (FAIR) knowledge production²⁴, enabling the production of open, quality-verified data which can be trusted by stakeholders. The use of multiple research tools, including models, to address different needs at different phases of a project was also stressed as an important requirement for successful stakeholder engagement²⁵. Useful information derives from the many different sources of knowledge, including scientific knowledge as well as indigenous and local traditional ecological knowledge, which can be integrated with scientific knowledge to support management decision-making processes^{26,27}.

An important question debated in the workshop regarded the role of scientists in collaborative research, at the interface of information provision and developing management recommendations. This was considered a question which researchers should be consciously addressing when engaging in collaborative MPA research²⁸. Likewise, the role of stakeholders needed reflection: Do stakeholders engaged in contract-based science contribute information and collaborate in aspects of the analysis? Or do they also “co-create” the whole project together with the researchers²⁹ as one would expect in a living lab setting?

What are effective collaboration approaches to integrate research and management in day-to-day operations of MPAs? The reviewed experiences illustrate that collaborations between research and management can take various forms. They can be restricted to limited engagement of stakeholders in well-delimited research actions, or of scientists in

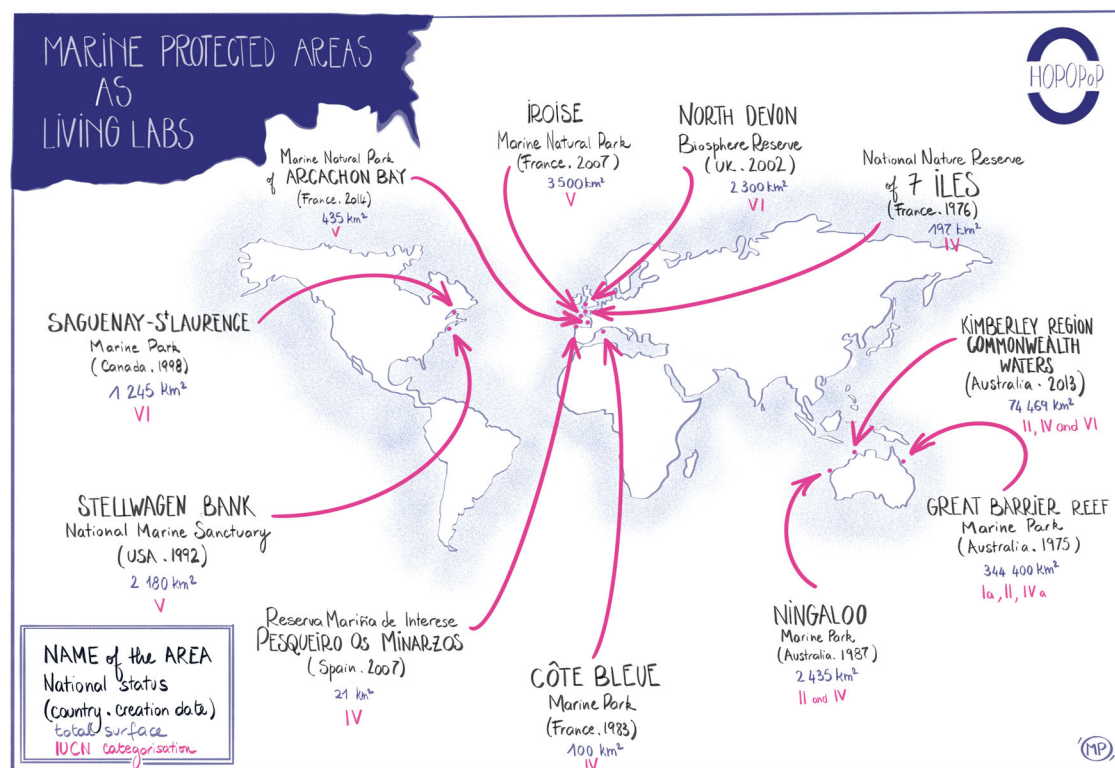


Fig. 1 | Marine Protected Areas in which the workshop participants had working experience, as managers and/or researchers.

management (e.g., consultation, advice, monitoring, participation in the scientific council of MPAs). They can also involve stronger engagement and shared leadership, including for example the co-supervision of studies and students, the co-organization of events, or the contribution to governance and scientific advisory boards. At the other end of the spectrum, they can involve contributions to designing management plans of MPAs, developing transdisciplinary projects, and participating in long-term collaborative research programs (Fig. 3). To qualify as collaborative, Mauz et al.³⁰ stress that projects must be agreed with all partners, and benefit and contribute to all, at least in one of the project steps. Applying these criteria often tends to reduce what can be considered as a collaborative project. Workshop participants agreed that, while the degree of formalization of collaboration varies from informal/tacit to formal agreements, effective collaboration will always benefit from informal and frequent interactions, which help build trust. While these informal interactions may play a significant role in supporting collaborative research, they also highlight the need to raise awareness about the associated flow of information across multiple levels of the social and political networks interacting with an MPA³¹.

This also raises the question of the appropriate degree of formalization of collaborative work, from person-dependent, trust-based, tacit to more formalized arrangements. A higher degree of formalization may be required when people do not know each other well and/or when situations and people change, as well as when expectations diverge. Although as already noted, trust may benefit from frequent, informal interactions. Participants agreed that the initial institutionalization of governance arrangements can help specify roles and responsibilities and avoid practices that would negatively affect this trust, creating conditions and resources for successful long-term collaborations⁷.

The workshop participants also stressed the need to elaborate concrete answers to urgent questions in the day-to-day operations of MPAs. Medium to long-term collaborations contribute to the development of actionable knowledge to address immediate questions, as they lead to improved understanding of the social-ecological system in and around the MPA and their actors^{32,33}. It also helps with scoping of data needs (present and future), models, research outputs and thematic expertise. Time, human resources and anticipation of future data needs, as well as unexpected situations, such as the risk of change or lack of time of key persons facilitating the collaborations, are essential to effective collaborations for enhancing sustainability in MPAs³⁴.

How can we track the impacts of collaborative approaches and outcomes? Participants emphasized that evaluating the impacts of collaborative approaches to MPA research is a crucial yet often overlooked issue—particularly concerning who should be responsible for carrying out such evaluations (Fig. 4). Researchers usually need to demonstrate tangible outcomes for the resources spent in such collaborations, which are not always well tracked. Indeed, trade-offs in the allocation of research resources between the conduct of standard research protocols (data collection, analysis and modeling) and the engagement in collaborative activities, may require significant time. While MPA managers may often consider this as part of their daily job, participants also stressed the practical need for them to justify the time allocated to these collaborations.

Evaluating impacts is also important to justify replicating and/or scaling up of collaborations that have been deemed to have positive impacts. This requires a clear specification of the objectives of collaborations such as: (i) improved knowledge (problem identification, solutions), (ii) scientific outputs (data, methods), (iii) mediation and education, (iv) management

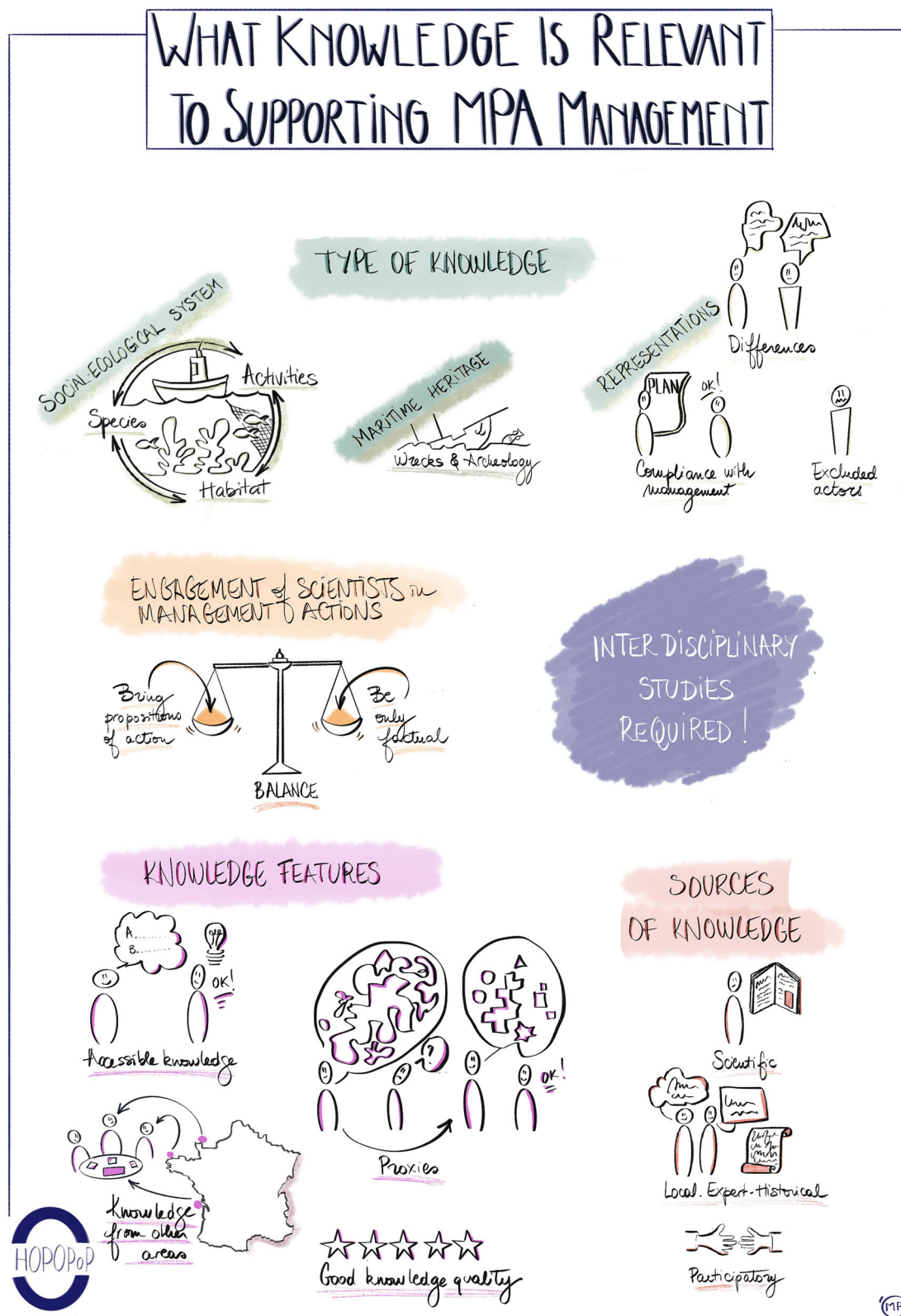


Fig. 2 | Knowledge relevant to supporting MPA management.



Fig. 3 | Effective collaboration approaches to integrate research and management in day-to-day operations of MPAs

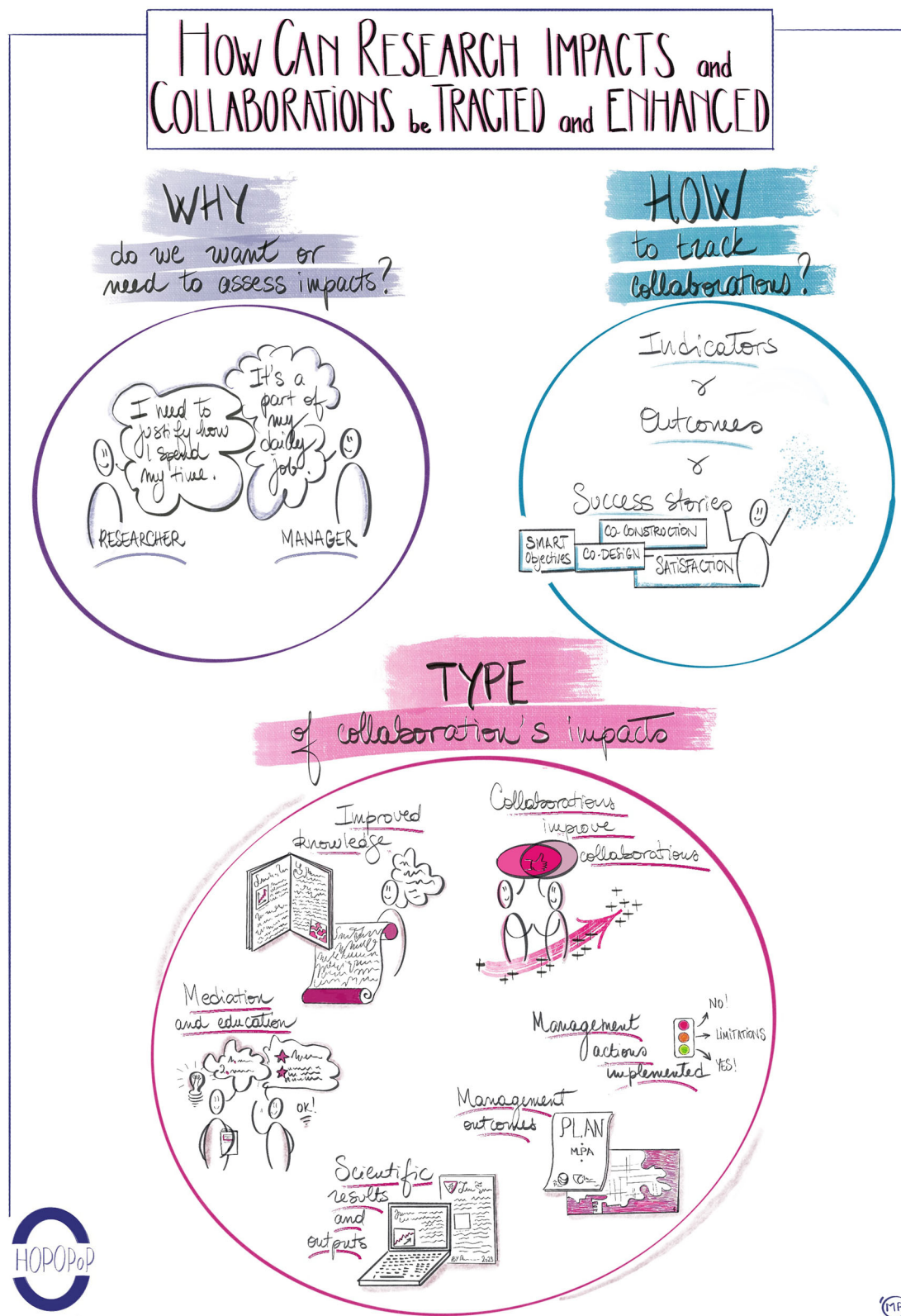


Fig. 4 | Tracking the impacts of collaborative approaches and outcomes

actions, (v) management outcomes, as well as (vi) the quality of collaboration and how it evolves over time.

Participants also emphasized the importance of integrating collaboration principles into the co-design of research programs to enable the evaluation of collaborator satisfaction and perceptions/representations throughout the process. Such evaluation frameworks should, as much as possible, be co-constructed along with systems of data collection, and developed so as to be applicable to other future collaborative initiatives^{35,36}.

As already stressed, participants highlighted the fact that many collaborations rely on informal relationships between individual managers and scientists, the quality and outcomes of which are difficult to monitor formally. The implication of this is that the impacts of these informal collaborations are also largely untracked. Despite this, participants acknowledged that there are many indicators to formally track collaboration impacts (e.g. number, types and duration of partnerships, types and levels of funding for research, meeting records, visiting staff agreements, co-supervision of students or early-career researchers), relating to both the process and the associated outcomes of collaborations³⁷.

Alongside formal evaluation protocols, participants emphasized the importance of capturing and preserving stories that cover a wide range of outcomes, including successes and failures in collaborative research, as these narratives can serve as powerful tools for communicating lessons learned and supporting effective and adaptive MPA management.

Discussion

Among the diverse forms of research collaborations, some are driven by participatory research processes, engaging stakeholders and managers in research; while others are driven by the management process, engaging scientists and stakeholders in MPAs management (e.g. management plan design and evaluation, dashboard of indicators, see Pelletier³⁴). At the interface of these two perspectives, the living lab approaches promote reciprocal collaborations, with capacities to reconcile or at least make explicit any diverging expectations or agendas.

We found that MPAs are a particularly relevant example of such living labs. They provide both the legitimacy and the motivation for developing participatory research approaches, and experiments to support management within their boundaries. In this context, research can help inform response to management issues, as well as help tracking management effectiveness (e.g. dashboard of indicators of success). To a large extent, adaptation of management responses hinges on credible and accepted science, which can be a strong outcome of collaborative research undertaken in MPAs. This is because it enables incorporating the views and concerns of users from the outset, increasing the effectiveness of MPA research.

While MPAs thus seem particularly relevant examples of living labs, workshop participants also highlighted the need to strengthen the reflexive analyses on the outcomes of collaborative research processes. This could involve developing evaluation protocols, building on cross-study comparisons. For example, Bernert et al.³⁸ provide a first template on how to report on living labs in order to enable learning. Research on the outcomes of alternative levels of protection within an MPA, in terms of social-ecological outcomes, and of the overall support and effectiveness of regulations, can also prove particularly useful to support management decision-making³⁹.

The question of how the impacts of collaborative research, both in terms of process and outcomes, can better be tracked is key to these reflexive approaches and will require further analysis, taking into account the diversity of collaboration set-ups and degrees of formalization. Finding ways to account for the informal collaborations and information transfers which take place in MPA research would also help understand the role of these in the success of adaptive management processes.

Finally, our discussions brought to our attention the fact that, in most cases, MPAs only represent a fraction of the social-ecological systems that could be included in living lab experiences. There is thus a need to identify interactions between changes occurring within and outside MPAs, as well as the drivers and the consequences of these changes. In addition, there is a need to evaluate the scalability of the experiments led within MPA perimeters, to support broader social-ecological system management.

Conclusion

Our workshop confirmed that MPAs have been operating as living labs for a long time, providing useful lessons learned from practical experience. The discussions highlighted the potential value-added of institutionalizing MPAs as living labs, to promote further, more systematic transdisciplinary research and transformative change. Such an approach could be developed as part of broader-scale research on the potential for coordinated testing and evaluation of the impacts of alternative management approaches, within and outside MPAs, and across multiple sectors and jurisdictions⁴⁰. In this perspective, and in addition to enabling strong research-management collaborations, MPAs can also support wider collaborations with stakeholders and citizens concerned with the coordination of multiple maritime uses to achieve conservation objectives.

Data availability

No datasets were generated or analysed during the current study.

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Author contributions

OT, CM: Conceptualization, Supervision, Methodology, Investigation, Writing – original draft, Writing – review & editing. MP: Conceptualization, Methodology, Investigation, Writing – review & editing, Visualization. FA, GC: Conceptualization, Methodology, Investigation, Writing – review & editing. AB, FB, DB, DC, EC, ML, LLD, KL, PLN, SL, RD, ME, MG, BCH, DP, IP, PP, PPr, MCR, PS, MAS, AV: Investigation, Writing – review & editing.

Competing interests

The authors declare no competing interests.

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