frontiers in Marine Science

COMMUNITY CASE STUDY
published: 11 November 2020
doi: 10.3389/fmars.2020.545930

Assessing the Effectiveness of Coastal Marine Protected Area Management: Four Learned Lessons for Science Uptake and Upscaling

Dominique Pelletier[1,2]*

[1] Ifremer, LEAD, Nouméa, France, [2] Unité Ecologie et Modèles pour l'Halieutique, Département Ressources Biologiques et Environnement, Institut Français de Recherche pour l'exploitation de la mer, Nantes, Pays de la Loire, France

For almost two decades, marine protected areas (MPAs) have been a central instrument of coastal conservation and management policies, but concerns about their abilities to meet conservation goals have grown as the number and sizes of MPAs have dramatically increased. This paper describes how a large (15 years) program of transdisciplinary research was used to successfully measure MPA management effectiveness (ME)—how well an MPA is managed, how well it is protecting values, and how well it is achieving the various goals and objectives for which it was created. This paper addresses the co-production and uptake of monitoring-based evidence for assessing ME in coastal MPAs by synthesizing the experiences of this program conducted with MPA managers. I present the main outcomes of the program, many were novel, and discuss four ingredients (learned lessons) that underpinned the successful uptake of science during and after the research program: (i) early and inclusive co-design of the project with MPA partners and scientists from all disciplines, (ii) co-construction of common references transcending the boundaries of disciplines, and standardized methodologies and tools, (iii) focus on outcomes that are management-oriented and understandable by end-users, and (iv) ensuring that capacity building and dissemination activities occurred during and persisted beyond the program. Standardized monitoring protocols and data management procedures, a user-friendly interface for indicator analysis, and dashboards of indicators related to biodiversity, uses, and governance, were the most valued practical outcomes. Seventy-five students were trained during the projects and most of the monitoring work was conducted with MPA rangers. Such outcomes were made possible by the extended timeline offered by the three successive projects. MPA managers' and scientists *a posteriori* perceptions strongly supported the relevance of such collaboration. Local monitoring and assessment meets the needs of MPA managers, and forms the basis for large-scale assessments through upscaling. A long-term synergistic transdisciplinary collaboration between coastal MPA managers and research into social-ecological systems (SESs) would simultaneously (i) address the lack of long-term resources for coastal monitoring and SES-oriented research; (ii) increase science uptake by coastal managers, and (iii) benefit assessments at higher levels or at broader geographic scales.

Keywords: marine protected area, coastal management, transdisciplinary, monitoring and assessment, MPA effectiveness, science uptake, social-ecological system

OPEN ACCESS

Edited by:
Alistair James Hobday, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

Reviewed by:
Marco Andrello, Institut de Recherche Pour le Développement (IRD), France
Juan Carlos Villaseñor-Derbez, University of California, Santa Barbara, United States

***Correspondence:**
Dominique Pelletier
dominique.pelletier@ifremer.fr

Specialty section:
This article was submitted to Marine Conservation and Sustainability, a section of the journal Frontiers in Marine Science

Received: *26 March 2020*
Accepted: *23 October 2020*
Published: *11 November 2020*

Citation:
Pelletier D (2020) Assessing the Effectiveness of Coastal Marine Protected Area Management: Four Learned Lessons for Science Uptake and Upscaling. Front. Mar. Sci. 7:545930. doi: 10.3389/fmars.2020.545930

INTRODUCTION

Global change and local anthropogenic pressures are affecting marine and terrestrial ecosystems worldwide at a pace faster than ever before in human history (Halpern et al., 2008; Ceballos et al., 2017). Coastal ecosystems are particularly vulnerable to global changes through coastline erosion and extreme events, and to the adverse consequences of human activities. Among coastal ecosystems, coral reef ecosystems are under intense threats from multiple stressors (Ban et al., 2014; Darling et al., 2019, among others).

Marine protected areas (MPAs) have been a central instrument of coastal conservation and management policies for almost two decades, and strengthening MPA coverage, and effectiveness crucial for international agendas [e.g., Aichi Target 11 (Convention for Biological Diversity [CBD], 2014) and Sustainable Development Goal (SDG) 14[1]]. many recent papers have debated or documented the real degree of protection afforded by MPAs (Edgar et al., 2014; Campbell et al., 2018; Strain et al., 2019; etc.), pointing to the risk of "paper parks" that fail to meet their goals (Agardy et al., 2003; Rife et al., 2013). The unprecedented number of recent and sometimes large MPAs has raised the issue of their effectiveness at achieving high standards in environmental and social performance; a concern reflected in the creation of guidelines for performance assessments (Parks et al., 2004) and quality labels for effective MPAs[2,3] (Wells et al., 2016).

This paper refers to MPA management effectiveness (ME), a notion stemming from the International Union for Conservation of Nature (IUCN) World Commission on Protected Areas[4], and subsequently used by the Convention on Biological Diversity (CBD)[5]. ME pertains to "how well a protected area is being managed, and primarily the extent to which it is protecting values and achieving the various goals and objectives for which it was created" (Hockings et al., 2006). Values include ecosystem services and functions, biodiversity, landscape, and geomorphological features, as well as cultural, socioeconomic, and research- and education-related aspects. In this paper, the term assessment refers to MPA ME assessment, i.e., MPA ME is gauged with respect to the management goals and objectives. Wells and Dahl-Tacconi (2006) listed all benefits for MPAs of conducting such assessments. An indicator-based methodology for MPA ME assessment was produced through an international collaboration of managers and experts under the auspices of the IUCN (Pomeroy et al., 2005).

Most MPAs have a management plan stating the goals and objectives against which MPA ME effectiveness must be assessed. Monitoring and assessment should guide management interventions in the short and medium terms. Local monitoring and assessment of biodiversity generally also lay the foundations for higher-level (national and international) assessment needs through successive upscaling, e.g., for evaluating the good ecological status in European seas (European Union [EU], 2008) or for supporting international reporting or assessment (Convention for Biological Diversity [CBD], 2014; United Nations [UN], 2016, among others, see Weatherdon et al., 2017 for a list of international treaties and policies in need of data for assessments).

Periodic monitoring programs should provide consistent assessments over time. Monitoring is achieved with various operators including MPA staff, consultants, NGOs, and research scientists. Additional data are collected within research projects. Addison et al. (2015) showed that even where periodic monitoring existed, management agencies preferred to conduct qualitative MPA ME assessments based on expert interpretation of monitoring results. But they also observed a willingness from management practitioners to better utilize monitoring data in quantitative condition assessments.

The workflow from monitoring to assessment, and to final knowledge products (understood here as the set of outputs ready for dissemination to end-users), is rarely fully documented and reproducible, which is detrimental to the uptake of monitoring-based science by MPA managers and beyond. Similarly, the link between research data and decisions is not always explicit, resulting in a number of scientifically sound datasets not being used to inform policy and decisions (Weatherdon et al., 2017). This was particularly the case for MPA management, where very few MPAs reportedly used monitoring-based results to inform management (Gill et al., 2017). Strategic linkages are needed to ensure the use of ocean observations across scales to address management and policy needs at local, regional, and global scales (Evans et al., 2019). At intermediate scales, e.g. in the wider Caribbean region, the science-policy interfaces appear as a network of relationships, and the extensive use of science in policy is uncommon (McConney et al., 2016). At the European Union (EU) level, implementing the ecosystem approach requires a stronger integration of science, policy/management, and society, consistently with the CBD recommendations (Ramírez-Monsalve et al., 2016).

This paper discusses transdisciplinary experiences in an applied research program aimed at assessing MPA ME for coastal MPAs. The program involved close cooperation between MPA managers and scientists from several disciplines to conduct monitoring-based ME assessments. I present the approach, outcomes, and perceptions of the project partners. From this experience, I then identify and discuss four lessons learned early in the program that were essential to fostering science uptake. Finally, I propose ways to achieve longer-term synergies between scientists and MPA managers that will help to address some challenges of both research into coastal social-ecological systems (SESs) and, coastal monitoring and assessment.

[1] https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-14-life-below-water.html

[2] https://www.iucn.org/theme/protected-areas/our-work/iucn-green-list-protected-and-conserved-areas

[3] https://blueparks.org/

[4] https://www.iucn.org/commissions/world-commission-protected-areas

[5] https://www.cbd.int/protected/pow

PROJECTS AND METHODS

Overview of Projects

The research program consisted of three projects that took place successively from 2004 to 2017 to support science-based coastal management. Project 1 (LITEAU2-AMP, 2004–2006) aimed to develop decision-support diagnostic and exploratory tools for assessing MPA performance. Project 2 (PAMPA, 2007–2012) aimed to construct and document indicators of MPA ME together with corresponding monitoring protocols and assessment tools. Project 3 (AMBIO, 2012–2017) built on the previous two projects by developing and adapting monitoring, and assessment methodologies for biodiversity and uses (particularly for large MPAs), and transferring them to managers and consultants.

The three projects had four common features: (i) funding from management-oriented agencies; involvement of (ii) scientists from ecological, economic, and social sciences; and (iii) management practitioners from different MPA contexts; and (iv) a focus on the production of practical outcomes and decision-support tools for monitoring and assessing MPAs.

MPA Partners

The MPAs involved spanned five regions of the world, with two in mainland France and three in overseas territories in the Atlantic, Indian, and Pacific oceans (**Supplementary Material 1**). They corresponded to different institutional and governance settings, contrasting sizes, ages, and protection levels, from the small marine reserve to the large multiple-use marine park. In Project 2, the French MPA Agency was an active partner, and the French Coral Reef Initiative (Ifrecor) ensured the participation of overseas MPAs and assisted with communicating outcomes to other MPAs not in the project.

Project 3 chiefly concerned New Caledonian MPAs, including World Heritage properties and the Coral Sea Marine Park. The vastness of these MPAs was central in the project. Monitoring and assessment methods of Project 3 were also applied at La Réunion and Mayotte MPAs during the project.

Methods

The projects were built around workshops and intersessional activities, with an extensive program of outreach that brought partners, managers, and agencies together, facilitating broad discussions on MPA management. The overall program evolved as follows:

1. The initial workshops aimed to explicitly define management objectives, priorities and constraints as well as to provide contextual information and existing data for each MPA. Using a common template elaborated beforehand, these were held in each MPA, and in clusters for Mediterranean MPAs and for overseas MPAs.
2. Later workshops were on specific methodological topics: conducting indicator-based assessments, interpreting indicators and constructing dashboards, ingredients of socioeconomic assessments, and definition and dissemination of data-based products. All project partners were invited to foster transdisciplinarity and capacity building within the consortium.
3. The final series of workshops convened a broader audience to share outcomes with project outsiders, engage in discussions and seek additional inputs, with the goal of making the outcomes more generic and applicable for other MPAs.

Between the workshops, activities were conducted in each MPA and by the scientific team in charge of coordination and tool development. In Project 2, this team devised monitoring protocols and assessment methodologies, and generic templates and guidance documents for implementing the same approaches across sites and facilitating distant work across the five regions. The junior scientists from the coordination team developed the user interface and common references together with field experts. In Project 3, the coordination and development team played a similar role in a less geographically dispersed context.

At the ends of Projects 2 and 3, MPA managers and scientists were asked to express their perceptions on the project.

The outreach program was substantial in Projects 2 and 3: the methodologies and other scientific outcomes were transferred to the MPA managers (and to private operators and consultants for Project 3) through a series of meetings, presentations and public conferences that took place in different settings.

Projects' Outcomes

Initial Perceptions of MPA Managers and Scientists

The Project 1 workshops facilitated a broad discussion of MPA-related projects and management issues. The audience included scientists from the natural and social sciences, nine managers from different MPA contexts, and representatives from NGOs and agencies. A methodological framework for indicators (Beliaeff and Pelletier, 2011) and a common glossary were discussed. The exercise documented the interactions between the scientists and MPA managers, their respective expectations and constraints, and how mutually productive interactions could best be achieved (**Supplementary Material 2**).

MPA managers pointed out the contribution of MPA-focused research to adaptive management. They wanted an operational science-based toolbox to support management activities, in particular for MPA ME assessment. They underlined their MPA was involved in numerous research projects with little coordination among scientists, and a potential to unnecessarily interfere with local stakeholders. Scientists highlighted the need for better information from managers, including access to previous research projects and data. The group as a whole spoke in favor of structures to facilitate dialog between managers and scientists. These exchanges stimulated the partnership for Project 2, which included a number of the same participants.

Co-constructing the Project Framework and Approach

In Project 2, the four workshops held over the first year laid a consensus-based foundation and were crucial to promote

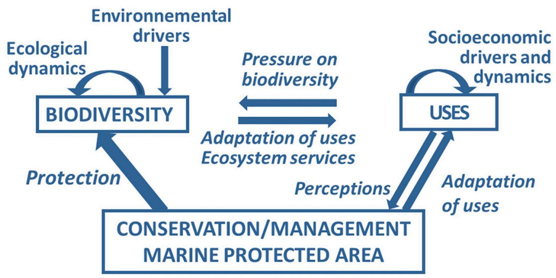

FIGURE 1 | Conceptual model used for Projects 2 and 3. The model depicts the relationships between biodiversity, uses, and management responses in the MPA. It was derived from the DPSIR (Driving forces-Pressure-State-Impact-Response) framework (Organisation for Economic Co-operation and Development [OECD], 1993), developed for indicator definition and widely used in environmental assessments (Beliaeff and Pelletier, 2011).

consistency across MPAs and disciplines. A conceptual model was proposed (**Figure 1**) and was subsequently used in Project 3. A glossary and a common formulation of management goals and objectives (**Table 1**) were produced. The goals spanned the three main domains reflected in the MPA management plans: biodiversity, uses and MPA governance The MPA managers listed possible interventions (or responses) to progress toward the achievement of each objective: regulation of activities, by law or agreements with users, communication and education, monitoring and enforcement. MPA ME assessment aimed to indicate where intervention was needed, and to guide managers toward the appropriate response.

The overall methodology of the project was agreed (**Figure 2**). Existing data had to be utilized, and where the data were lacking, observational protocols should be developed with the condition that they could be implemented by MPA staff or non-scientific staff.

Expectations from partners were diverse and high, and these workshops also provided a place to clarify what the project *would not* achieve. Equally important was the time-consuming task of writing a consortium agreement, which was essential for building trust and data sharing.

Ecological Data: Evaluating the Existing Data and Proposing New Protocols

Most existing data pertained to the conservation goals (1 and 2, **Table 1**). They had been collected from three sampling platforms: (i) diver-operated underwater visual censuses (UVC) using several designs and protocols to survey fish, invertebrates, benthic fauna and cover; (ii) catch and effort data collected either on board or from landings, from recreational and small-scale fisheries and from scientific surveys; and (iii) unbaited underwater video landers for fish and benthic cover. The adequacy of the sampling design for MPA ME assessment was evaluated during joint meetings, as many samples had been collected for other purposes. Out of 33 data sets, 22 were suited for assessing the ecological effects of protection. Metadata were documented using a common template. Technical training was concurrently provided to build the partners' capacity in MPA statistical assessment and appropriate sampling designs.

In Project 2, underwater video data were collected in two MPAs to provide spatially replicated data (Pelletier et al., 2012). During Project 3, the protocol was consolidated into a standardized operating procedure (Pelletier et al., 2016) to address monitoring needs for vast MPAs, and was extensively implemented (New Caledonia, Indian Ocean, and Cerbère-Banyuls, **Supplementary Material 1**). Field work was conducted with rangers, local fishers, and participatory management committees.

Protocols for Monitoring Recreational Uses

Characterizing and assessing human uses within and around the MPA was a priority for all MPA managers (**Supplementary Material 2, #6**). No data being available, an original standardized protocol comprising on-site user counts and interviews was devised with the managers. Interviews relied on a questionnaire to characterize use pressures and user perceptions fishers, catch, and fishing effort. Data was collected in each MPA over at least

TABLE 1 | Consensus-based formulation of MPA management goals and objectives that laid the foundation for subsequent work on the indicators and decision-support tools.

Management goal	Objectives
1. Sustainable exploitation of resources	Restore and maintain target species; Increase exploitable biomass with respect to minimum level
2. Restore and conserve biodiversity	Maintain communities and species representative of the ecosystem; Maintain ecosystem functions Conservation of particular species; Maintain representative habitats
3. Maintain and develop sustainable uses	Sustainability of uses in general; Maintain uses with patrimonial and social value; Contribute to sustainable territorial development
4. Implementation and sustainability of management	Efficiency of the management plan; Management organization; Implementation of control; Financial sustainability; Integration of the MPA with other management instruments
5. Participation and representation of stakeholders	Foster stakeholder involvement in MPA activities; Ensure stakeholder consultation; Involve local stakeholders in management; Favor consideration of the MPA in local coastal management
6. Social acceptance of MPA	Foster acceptance of MPA by populations; Contribute to reduction of conflicts between users
7. Knowledge improvement and dissemination	Education; Contribution to progress on knowledge of the marine environment

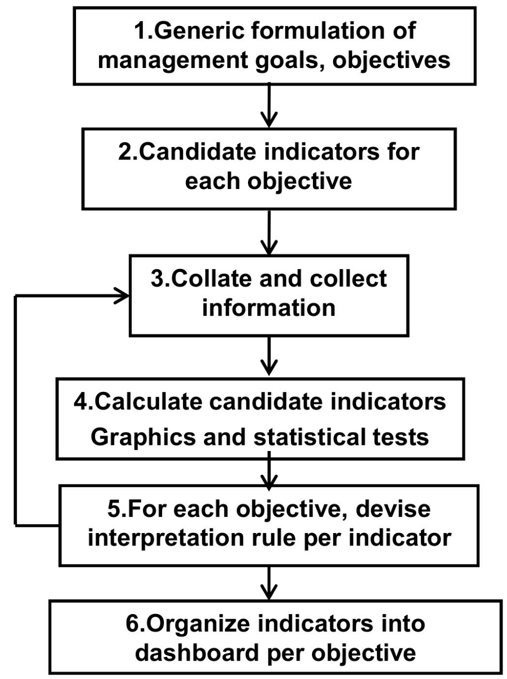

FIGURE 2 | Consensus indicator approach for Project 2.

12 months by or with MPA rangers (**Supplementary Material 3**). A database was constructed to facilitate the input and validation of all use-related data. During Project 3, the protocol for user counts was modified to address new operating constraints for MPA rangers. The consistency of data over time enabled the analysis of changes in MPA use at a decadal scale (Gonson et al., 2016).

Standardized Assessments: Indicators, Generic Tools, and Reference Data

Indicators relevant to each management objective were selected during workshops. The proposed ecological indicators were prioritized with MPA managers to address specific assessment needs, e.g., iconic species, sensitive habitats, target species or fishing gears which differed between MPAs and between ecosystems.

With respect to uses and users, pressure-related metrics obtained from user counts included the (i) number of boats or of users; (ii) number of boats moored, beached or anchored for boat-based activities; and (iii) number of fishers for shoreline fishing. Fishing-related metrics (effort in number of gears and/or time, and catch per unit effort) were computed from the questionnaires. Perception metrics also derived from the questionnaires described user awareness of MPA and fishing regulations, opinions on MPA effects and management, and perceptions of conflicts between users. The indicators related to MPA governance and to education and knowledge were iteratively co-developed during four workshops, and then prioritized by MPA managers (**Supplementary Material 4**).

An R-based user-friendly interface was developed to compute, plot and statistically analyze numerous ecological and use-related indicators (**Supplementary Material 5**). It was iteratively improved over 4 years (corresponding to an effort of ∼72 person. months) following extensive testing by partners. This required defining common data formats across ecological sampling protocols; common references for taxonomic and species traits, fishing gears; and a spatial reference table for handling georeferenced data in each MPA. Species and fishing gear references were interoperable with international references. Project 3 improved and reused the user interface (Pelletier et al., 2014), and further developed the spatial reference table for New Caledonia (Gonson and Pelletier, 2018). These tools enabled the efficient analysis of large underwater video datasets to produce the first large-scale baseline assessment of New Caledonian MPAs (Pelletier et al., 2020; Schohn et al., 2017a,b).

Management-Oriented Outputs: Indicator Scoring and Dashboards

The managers generally preferred simple non-technical assessments, but also wanted access to the underlying scientific evidence, either to reach a finer understanding or for assessment transparency.

In Project 2, the ecological indicators were scored using the color codes used for the Water Framework Directive (European Union [EU], 2000). Here, the colors scored the need for a response from the manager, from "no intervention required," to "strong intervention needed." Due to the lack of reference values for most indicators, color codes were agreed between the expert partners during two workshops. In Project 3, the wealth and broad coverage of data allowed color codes to be derived from indicator values.

The dashboards aimed to track progress toward each management objective and orient possible interventions. For the conservation goals, it relied on the conceptual model with indicators depicting the State (ecological) and Pressures (use-related) that might affect the State, and indicators likely to guide management toward the appropriate Response (MPA management intervention). For each MPA, results were compiled into a comprehensive report that enabled tracking the assessment from field collection (e.g., Tessier et al., 2011). Project 3's assessment reports comprised both a non-technical synthesis with radar plots for comparisons between sites, and detailed assessment results with dashboards (e.g., Schohn et al., 2017a,b).

Capacity Building and Dissemination

Both were essential during and after the projects. Capacity building occurred through interdisciplinary exchanges and shared methodologies. Monitoring activities conducted with rangers and managers provided additional opportunities for discussions. Tools and protocols were transferred to managers and consultants through presentations, trainings, and guides (Pelletier et al., 2014, 2016).

Student supervision substantially contributed to building capacity in management-oriented science, with 54 students in Project 2 (many interns were hired by the MPAs) and twenty in Project 3. Students were immersed in the projects' transdisciplinary approach and atmosphere, and several were subsequently hired in the field of marine monitoring, whether in NGOs, management agencies or MPAs, or they created their own business as consultants. They currently apply or adapt some of the approaches and skills learned (e.g., Gamp et al., 2016).

The numerous standardized deliverables ensured that the activities and outputs may be tracked and reproduced, and facilitated the dissemination of outcomes toward both partners and beyond the consortium. Dissemination to technical audiences, s.a. MPAs and agencies, and to the public, was given high priority through multiple presentations, roundtables and workshops in the different regions. The final conference of Project 2 gathered a broad audience of management practitioners and agencies, and the video recordings were made accessible on the Web[6].In Project 3, the use of underwater videos facilitated engaging knowledge exchange with local management committees and the public, who were able to discover (for some) "their" marine biodiversity and resources through the video clips provided.

Overall, these efforts resulted in direct and indirect assimilation of outputs during and beyond the projects, including for the construction of the French MPA dashboard (Agence des Aires Marines Protégées [AAMP], 2014; **Supplementary Material 3**).

A Posteriori Perceptions of the Project Partners

The MPA managers' perceptions were overall very positive (**Supplementary Material 6**). Among others, the utilization of existing MPA data was valued by both managers and rangers as it tested the usefulness of spending resources on monitoring, and sometimes improvements in sampling design were suggested. The information-rich outcomes were differently appreciated by the MPA managers (**Supplementary Material 6, #4**).

The scientists' perceptions were also supportive of the transdisciplinary dynamic. They enjoyed the tools as a time-saver for indicator analysis, the methodological workshops, and topical discussions on MPA governance, MPA ME assessment, indicator scoring, and dashboard construction. However, they felt that there was insufficient opportunity to publish science because all available time was required to develop tools, complete field work, effectively communicate and report to stakeholders, and to ensure the project's cohesion through coordination. Publishing such transdisciplinary science was also found difficult, despite the claims of journals, as experienced from feedback asserting that the science had only a "local" relevance.

The partners wanted to build on the project to establish a science-practitioner interface in the long term. Over a 2-year period following Projects 2 and 3, further events were successfully held to transfer outcomes to MPAs and agencies. However, despite the willingness of local practitioners, including beyond project partners, this network and dynamic were not supported at the institutional level and did not receive support from management agencies or research institutes. Science uptake thus occurred outside of an organized framework through (i) a persisting relational network; (ii) the tools provided and adopted by the MPAs; and (iii) the capacity transferred to management practitioners, scientists, and students.

[6]https://wwz.ifremer.fr/webtv_eng/Thema/Ressources-aquacoles/Colloque-PAMPA/

DISCUSSION

Four Learned Lessons That Fostered Science Uptake

Fostering the uptake of science in this extensive and successful transdisciplinary program can be summarized as follows:

- Lesson 1: Early and inclusive co-design of the project with MPA partners and scientists from all disciplines.
- Lesson 2: Co-construction of common references transcending the boundaries of disciplines and, standardized methodologies and tools.
- Lesson 3: Focus on outcomes that are management-oriented and understandable by end-users.
- Lesson 4: Ensuring that capacity building and dissemination activities occur during and persist beyond the program.

Lesson 1 is the prerequisite for constructing a transdisciplinary partnership, understood here as "different disciplines working together with non-academic collaborators to integrate knowledge and methods, to develop, and meet shared research goals achieving a real synthesis of approaches" (Kelly et al., 2019). This prerequisite was e.g., identified by Brandt et al. (2013); Cvitanovic and Hobday (2018), and Gurney et al. (2019). Transdisciplinarity was made possible here through the co-construction and consensus on the semantics, the conceptual model, and the common methodology. Our conceptual model was not an SES framework in the sense of Ostrom (2009) [e.g., implemented by Gurney et al. (2019)] or Mascia et al. (2017). It had to capture the transdisciplinary essence of the project while being simple enough to be appropriated by partners. It was also consistent with the goal of defining indicators for MPA ME assessment and for guiding management response, in relation to the DPSIR framework, which has an action-oriented perspective rather than an analytical purpose (Binder et al., 2013).

Lesson 2 was necessary to operationalize a common methodology for real-world problems. Tailored standardized methods and co-constructed user-friendly tools contributed to strengthening the interface between science and MPA management. Common references are particularly needed in projects that encompass several case studies and where objectives transcend disciplines, here MPA ME assessment. In a program addressing conservation in several Indo-Pacific countries, Gurney et al. (2019) defined key social-ecological attributes relevant to the program's objectives and applicable across multiple countries and management actions. Subsequently, they could implement the same monitoring protocols and indicators across sites. Our program produced numerous standardized outcomes (see sections "Ecological Data: Evaluating the Existing Data and Proposing New Protocols," "Protocols for Monitoring Recreational Uses," "Standardized Assessments: Indicators, Generic Tools and Reference Data") and notably a versatile user-friendly interface. Villaseñor-Derbez et al. (2018) developed a user-friendly web-based app to test ecological, socioeconomic and governance indicators for assessing the effectiveness of no-take marine reserves. Our interface differs in several ways: (i) it is not presently web-based, as first developed in 2011; (ii) it can handle a variety of ecological monitoring protocols; (iii) the set of indicators is not predefined to enable exploration of a wider spectrum of ecological and use-related indicators; and (iv) the scorecard is not produced by the interface. The last three development choices resulted from MPA manager preferences. The user interface was iteratively improved with end-users over 4 years, and is currently used by several scientists and by four MPAs for processing monitoring data.

More generally, decision-support tools should aim at broad utilization, while being tailored to the needs of managers and other users including scientists. Weatherdon et al. (2017) underlined this need for "iterative co-design of a user-friendly interface, standardized, comprehensive, and documented methods with quality assurance, consistent capacity, and succession planning, accessible data, and value-added products that are fit-for-purpose" as a condition to the production of knowledge conveying the information required by policy- and decision-makers. There are currently very few such interfaces for producing and analyzing knowledge products from monitoring data to support marine management and policy, whereas the demand from stakeholders for tools to support outcome-based approaches in environmental management is increasing (Hewitt and Macleod, 2017).

With regard to Lesson 3, several science needs initially expressed by MPA managers (**Supplementary Material 2, #6**), were addressed. Hence, monitoring protocols for characterizing and assessing use-related pressures and accounting for MPA manager constraints were developed and implemented by rangers and MPA staff. Monitoring of uses is rarely routinely integrated in MPA ME assessment (Tobin et al., 2014). Underwater video monitoring protocols were devised, and subsequently implemented by trained operators together with non-scientific staff. The devised protocols and data processing enabled producing maps of use-related pressures and biodiversity indicators[7] , thereby addressing another expressed need. Spatial information is crucial for all environmental decision-makers as a means of communicating about interventions (Hewitt and Macleod, 2017), particularly for MPAs. Last, uncertainties (**Supplementary Material 2, #6**) were accounted for through the statistical tests in the user interface, and the reliance on statistical significance in the indicator dashboards.

The usefulness of the outcomes largely reflected in the MPA manager perceptions (see section "A Posteriori Perceptions of the Project Partners"). Following the program's conclusion, the outcomes most reused by MPAs were the protocol for monitoring uses, the dashboard approach and its semantics, and the methodological guide for underwater video monitoring.

Lesson 4 dealt with dissemination and capacity building. The deliverables were standardized, understandable, and reusable by scientists from several disciplines, management practitioners, and management agencies (see section "Standardized Assessments: Indicators, Generic Tools, and Reference Data"). They were widely disseminated through networks or made freely accessible (open access archives and map servers), ensuring the spillover of outcomes beyond the program's partnership and timeline. Interestingly, the MPA managers largely communicated about Project 2 through seminars with peers, media interviews, MPA newletters, and activity reports (**Supplementary Material 7**). The fact that the final users of science spoke about the approach and outcomes themselves was considered a strongly positive indicator of science uptake. In Project 3, imagery-based evidence facilitated knowledge exchange with local stakeholders. Moreover, images provided a sense of pride and custodianship about the territory, with positive consequences for caring about their environment, a perception also shared by managers in another MPA context and contributing to science uptake (Cvitanovic et al., 2016). Local communities and stakeholders may be reached, either by involving them in management or through educational activities, thereby contributing to goals 6 (social acceptance of the MPA) and 7 (knowledge improvement and education) of the MPA management plans. Such science programs enhance trust building between MPA managers and community members (Cvitanovic et al., 2018).

Guidance documents and training for end-users were key resources for dissemination and capacity building. A similar experience was reported by Gurney et al. (2019) who trained practitioners in four countries and delivered a multilingual handbook during the program mentioned under Lesson 2. Capacity building is central to improving MPA ME and major regional gaps in conservation capacity have been identified (Elliott et al., 2018). Gill et al. (2017) showed that adequate staff capacity was the most important factor in explaining the response of fish to MPA protection; accordingly they also found that only 13% of MPAs reportedly used results from scientific monitoring (biological, social or management) to inform management. However, many MPA staff are willing to forge a stronger link between MPA ME and evidence-based management (Addison et al., 2015, see section "Introduction"). For junior scientists and MPA staff, our projects offered a favorable context for learning about "the main five focal areas of importance to contemporary conservation: policy, practice, collaboration, leadership and interdisciplinarity" (Elliott et al., 2018, see also Kelly et al., 2019). Furthermore, the projects provided junior staff with a highly beneficial sense of empowerment in conservation practice (Cvitanovic and Hobday, 2018).

Provision of Time Was a Crucial Enabling Ingredient

With a typical project duration of 2–4 years, establishing a transdisciplinary consortium is challenging as more time is needed to understand each other and work in harmony. For instance, a collaborative process between scientists, managers, and recreational fishers aimed at reshaping science-based conservation practice required 10 years to be successfully developed (Caudron et al., 2012). Our three projects successively built upon one another. The participation of several partners in two or three

[7] http://tiny.ifremer.fr/AMBIO_Maps

projects created continuity in the consortium, fostered the involvement of additional partners and the establishment of a transdisciplinary network. The extended timeline was also key for iterative testing of the methodologies with end-users.

The provision of time matters also because science uptake continues several years after the projects, here through the legacy afforded by the deliverables, the persistence of the relational network, the use of tools, the adoption of outcomes by MPAs, and the movement of former students into new conservation-related jobs. A delayed uptake may be explained by the relative novelty of the approaches. Transdisciplinary problem-oriented (here, assessment- and management-oriented) projects often give rise to innovations (Mainzer, 2011). The four conditions for the diffusion of innovation identified by Rogers (2003) were exemplified here: existence of early adopters, communication channels, provision of time, and acceptance by the concerned group or organization.

This experience demonstrated the amount of time and work needed to develop standardized approaches to monitoring and assessment. By the same token, the lack of time left to simultaneously publish in mainstream journals is an obstacle to engaging more academic scientists in such activities, notably early career scientists. As also underlined by Caudron et al. (2012) and Cvitanovic et al. (2015), the current measures of science impact ignore engagement activities, and institutional support is urgently needed to provide time and resources for such engagement.

Achieving Transdisciplinary Synergies Between Coastal MPAs and Research

Over this 15-year program, a range of outcomes, benefits, and problems were experienced by the coordination team and by the consortium (**Table 2**). The program's legacy expands perspectives for future cooperation serving both research and coastal management through monitoring and assessment activities. Similar time-series data on biodiversity, human uses of MPAs and MPA governance are necessary to assess MPA ME and to conduct transdisciplinary research into complex coastal SESs. Moreover, local monitoring must serve additional assessment and reporting needs at larger scales (see section "Introduction"), through Essential Biological Variables and Essential Ocean Variables (Muller-Karger et al., 2018). Local assessments must thus be both scalable enabling consistency across regions, in addition to being robust and locally informative. However, monitoring costs are still incurred at the local scale and likely exceed the MPA and science resources because (i) the involved ecological, socioeconomic and management territories are often vast,

TABLE 2 | Experienced benefits and difficulties in running these transdisciplinary MPA management-oriented projects.

Benefits	Difficulties
• Solid and friendly consortium, smooth project dynamics	• Communication, coordination and reporting were overly effort- and time-consuming
• Transparency and inclusiveness	• Developing generic and transferable tools, documenting them and communicating about them was overly time-consuming
• Consistent, standardized, and useful outcomes	• The science was not suited to high IF publications (less time, transdisciplinary works, «local» work)
• Tools suited to the needs of managers and scientists	• Will lasts as long as the resources last, despite sustained interest of parties
• Mentoring and experience sharing between MPA partners, including for MPAs beyond project partners	
• Satisfaction of the partners	• Finding funding sources for sustaining such collaborations is difficult (neither research nor management)
• Contributed to MPA goals (goal 7)	• Science uptake may occur several years after the project

TABLE 3 | Synergies between coastal MPAs and transdisciplinary research into SESs.

	Science	MPA
Provide	• Monitoring protocols	• Logistics and staff time for monitoring
	• Logistics and staff time for monitoring	• Up-to-date contextual information on MPAs
	• Assessment methodologies	• Scenarios (management, context)
	• Data management and archiving	• New questions and new observations grounded in practitioner expertise
	• Distanciated expertise	
	• Link with higher-level uses of data and assessments in relation to global challenges	
Get	• Data for research about social-ecological systems	• Assistance for monitoring and assessment methodologies and their implementation
	• Access to stakeholders via MPA	• Responses to questions involving science
	• Local knowledge from managers and stakeholders	• Validation of assessments by scientists

(ii) several facets of SESs must be monitored, and (iii) spatial replication is needed to appraise complex SESs and to assess ecological status (among others).

A cost-efficient partnership could be organized to sustain win–win science-management interactions in coastal MPAs (**Table 3**). The evolution of MPA managers' perceptions and the partners' willingness to engage in longer-term partnership at the science-practitioner interface suggested a collaborative model of applied research cofunded by research, policy-makers, and management agencies and that would target both transdisciplinary SES research and local MPA ME assessment with the view of upscaling to higher-level assessments.

On-site monitoring operated by both scientists and local experts such as management practitioners, would definitely benefit both research and management. Securing monitoring in the long-term then enables organizing transparent and reproducible data workflows together, including data collection, knowledge production and dissemination, and data management. *In situ* monitoring remains indispensable for environmental science and management. *Ad hoc* human resources and funding are dropping, despite increasing environmental challenges and calls for continued science-based evidence. Consolidating monitoring bases and organizing bottom-up and shared and consistent knowledge flows to document multiple assessment needs requires the joint efforts of both engaged scientists and local management practitioners.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: https://w3.ifremer.fr/archimer/doc/00385/49601/; https://archimer.ifremer.fr/doc/00256/36715/; http://archimer.ifremer.fr/doc/00000/6797/; https://archimer.ifremer.fr/doc/00050/16161/; http://archimer.ifremer.fr/doc/00351/46171/; https://doi.org/10.13155/51760.

ETHICS STATEMENT

The studies reported in the article and that involved human participants were reviewed and approved by the partners during the PAMPA project. The participants provided written informed consent to participate in the projects mentioned through the Project's Consortium Agreement.

AUTHOR CONTRIBUTIONS

DP conceived and wrote the article.

FUNDING

The Lit'eau program of the French Ministry of Ecology funded projects Liteau-AMP and PAMPA. The AMBIO project was funded by IFREMER, the New Caledonian Government and Provinces, the Conservatoire des Espaces Naturels of NC, the Ministry of Ecology. The French MPA Agency and the French Initiative for Coral Reefs (Ifrecor) co-funded the PAMPA and AMBIO projects.

ACKNOWLEDGMENTS

The main collaborators of the PAMPA project are gratefully acknowledged: Elodie Gamp, Yves Reecht, Claire Bissery, Emmanuel Tessier, Eric Charbonnel, Emmanuel Coutures, Pauline Malterre, Jérôme Payrot, Karine Pothin, Laurence Le Direac'h, Frédérique Alban, Jocelyne Ferraris, David Roos, Pierre-Gildas Fleury, Marion Jarraya, Philippe Lenfant, Pauline Malterre, Jean-François Laffon, Kévin Leleu, Bastien Preuss, Pascale Chabanet, Alexandra Gigou, Catherine Gabrié from Ifrecor, Gilbert David, Benoit Beliaeff, Bertrand Cazalet, Lionel Bigot, Patrice Francour, Jean-Antoine Tomasini, Laurent Wantiez, Laurent Vigliola, and Anne-Sophie Barnay from the French MPA Agency. The AMBIO project was realized with the help of Liliane Fiant and a great team of junior scientists, among which Charles Gonson, Thomas Schohn, Thomas Bockel, William Roman, Delphine Mallet, Charlotte Giraud-Carrier, Abigail Powell, and Jessica Garcia. This paper greatly benefited from the comments from two reviewers and the editor.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2020.545930/full#supplementary-material

REFERENCES

Addison, P. F. E., Flander, L. B., and Cook, C. N. (2015). Are we missing the boat? Current uses of long-term biological monitoring data in the evaluation and management of marine protected areas. *J. Environ. Manage.* 149, 148–156. doi: 10.1016/j.jenvman.2014.10.023

Agardy, T., Bridgewater, P., Crosby, M. P., Day, J., Dayton, P. K., Kenchington, R., et al. (2003). Dangerous targets? Unresolved issues and ideological clashes around marine protected areas. *Aqua. Conserv. Mar. Freshwater Ecosyst.* 13, 353–367. doi: 10.1002/aqc.583

Agence des Aires Marines Protégées [AAMP] (2014). *Marine Protected Areas Dashboard.* France: Agence des Aires Marines Protégées.

Ban, S. S., Graham, N. A. J., and Connolly, S. R. (2014). Evidence for multiple stressor interactions and effects on coral reefs. *Glob. Change Biol.* 20, 681–697. doi: 10.1111/gcb.12453

Beliaeff, B., and Pelletier, D. (2011). A general framework for indicator design and use with application to the assessment of coastal water quality and marine protected area management. *Ocean Coast. Manage.* 54, 84–92. doi: 10.1016/j.ocecoaman.2010.10.037

Binder, C. R., Hinkel, J., Bots, P. W. G., and Pahl-Wostl, C. (2013). Comparison of Frameworks for Analyzing Social-ecological Systems. *Ecol. Soc.* 18:26. doi: 10.5751/ES-05551-180426

Brandt, P., Ernst, A., Gralla, F., Luederitz, C., Lang, D. J., Newig, J., et al. (2013). A review of transdisciplinary research in sustainability science. *Ecol. Econom.* 92, 1–15. doi: 10.1016/j.ecolecon.2013.04.008

Campbell, S. J., Edgar, G. J., Stuart-Smith, R. D., Soler, G., and Bates, A. E. (2018). Fishing-gear restrictions and biomass gains for coral reef fishes in marine protected areas. *Conserv. Biol.* 32, 401–410. doi: 10.1111/cobi.12996

Caudron, A., Vigier, L., and Champigneulle, A. (2012). Developing collaborative research to improve effectiveness in biodiversity conservation practice. *J. Appl. Ecol.* 49, 753–757. doi: 10.1111/j.1365-2664.2012.02115.x

Ceballos, G., Ehrlich, P. R., and Dirzo, R. (2017). Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. *Proc. Natl. Acad. Sci. U S A.* 114:E6089. doi: 10.1073/pnas.1704949114

Convention for Biological Diversity [CBD]. (2014). *Global biodiversity outlook. Montreal: Secretariat of the Convention on Biological Diversity*. New York, NY: Convention for Biological Diversity.

Cvitanovic, C., and Hobday, A. J. (2018). Building optimism at the environmental science-policy-practice interface through the study of bright spots. *Nat. Commun.* 9:3466. doi: 10.1038/s41467-018-05977-w

Cvitanovic, C., Hobday, A. J., van Kerkhoff, L., and Marshall, N. A. (2015). Overcoming barriers to knowledge exchange for adaptive resource management; the perspectives of Australian marine scientists. *Mar. Policy* 52, 38–44. doi: 10.1016/j.marpol.2014.10.026

Cvitanovic, C., McDonald, J., and Hobday, A. J. (2016). From science to action: Principles for undertaking environmental research that enables knowledge exchange and evidence-based decision-making. *J. Environ. Manage.* 183, 864–874. doi: 10.1016/j.jenvman.2016.09.038

Cvitanovic, C., van Putten, E. I., Hobday, A. J., Mackay, M., Kelly, R., McDonald, J., et al. (2018). Building trust among marine protected area managers and community members through scientific research: Insights from the Ningaloo Marine Park. *Aus. Mar. Policy* 93, 195–206. doi: 10.1016/j.marpol.2018.04.010

Darling, E. S., McClanahan, T. R., Maina, J., Gurney, G. G., Graham, N. A. J., Januchowski-Hartley, F., et al. (2019). Social-environmental drivers inform strategic management of coral reefs in the Anthropocene. *Nat. Ecol. Evol.* 3, 1341–1350. doi: 10.1038/s41559-019-0953-8

David, G., Cazalet, B., Barnay, A., Charbonnel, E., Ferraris, E., Ferraris, J., et al. (2013). *Participatory approach to identify governance indicators for integrated coastal zone management, the case of marine protected areas*. Copenhagen: ICES, 68–73.

Edgar, G. J., Stuart-Smith, R. D., Willis, T. J., Kininmonth, S., Baker, S. C., Banks, S., et al. (2014). Global conservation outcomes depend on marine protected areas with five key features. *Nature* 506, 216–220. doi: 10.1038/nature13022

Elliott, L., Ryan, M., and Wyborn, C. (2018). Global patterns in conservation capacity development. *Biol. Conserv.* 221, 261–269. doi: 10.1016/j.biocon.2018.03.018

European Union [EU] (2000). *Directive 2000/60/CE of the European Parliament and Council of 23 October 2000, Water Framework Directive*. Belgium: European Union. Available Online at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060 (accessed March 19, 2020).

European Union [EU] (2008). *Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)*. Belgium: European Union. Available Online at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32008L0056 (accessed March 19, 2020).

Evans, K., Chiba, S., Bebianno, M. J., Garcia-Soto, C., Ojaveer, H., Park, C., et al. (2019). The Global Integrated World Ocean Assessment: Linking Observations to Science and Policy Across Multiple Scales. *Front. Mar. Sci.* 6:298. doi: 10.3389/fmars.2019.00298

Gamp, E., Tachoires, S., and Robert, C. (2016). *Pêche récréative?: Un guide pour vous orienter dans vos méthodes de suivis - Suivi et caractérisation de la pêche récréative dans les aires marines protégées*. France: Agence des aires marines protégées.

Gill, D. A., Mascia, M. B., Ahmadia, G. N., Glew, L., Lester, S. E., Barnes, M., et al. (2017). Capacity shortfalls hinder the performance of marine protected areas globally. *Nature* 543, 665–669. doi: 10.1038/nature21708

Gonson, C., and Pelletier, D. (2018). *Spatial reference table for South and North Provinces in New Caledonia*. France: IFREMER.

Gonson, C., Pelletier, D., Alban, F., Giraud-Carrier, C., and Ferraris, J. (2017). Influence of settings management and protection status on recreational uses and pressures in marine protected areas. *J. Environ. Manage.* 200, 170–185. doi: 10.1016/j.jenvman.2017.05.051

Gonson, C., Pelletier, D., Gamp, E., Preuss, B., Jollit, I., and Ferraris, J. (2016). Decadal increase in the number of recreational users is concentrated in no-take marine reserves. *Mar. Pollut. Bull.* 107, 144–154. doi: 10.1016/j.marpolbul.2016.04.007

Gurney, G. G., Darling, E. S., Jupiter, S. D., Mangubhai, S., McClanahan, T. R., Lestari, P., et al. (2019). Implementing a social-ecological systems framework for conservation monitoring: lessons from a multi-country coral reef program. *Biol. Conserv.* 240:108298. doi: 10.1016/j.biocon.2019.108298

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., et al. (2008). A Global Map of Human Impact on Marine Ecosystems. *Science* 319:948. doi: 10.1126/science.1149345

Hewitt, J. R., and Macleod, J. A. C. (2017). What Do Users Really Need? Participatory Development of Decision Support Tools for Environmental Management Based on Outcomes. *Environments* 4:88. doi: 10.3390/environments4040088

Hockings, M., Stolton, S., Leverington, F., Dudley, N., and Courrau, J. (2006). *Evaluating effectiveness - A framework for assessing management effectiveness of protected areas*. Switzerland: IUCN.

Kelly, R., Mackay, M., Nash, K. L., Cvitanovic, C., Allison, E. H., Armitage, D., et al. (2019). Ten tips for developing interdisciplinary socio-ecological researchers. *Soc. Ecol. Pract. Res.* 1, 149–161. doi: 10.1007/s42532-019-00018-2

Lemahieu, A., Pennober, G., David, G., Lavigne, F., Pothin, K., and Gérard, L. (2013). *Élaboration d'un protocole de suivi de la fréquentation au sein de la Réserve naturelle marine de la Réunion, France, Océan Indien*. France: Vertigo.

Mainzer, K. (2011). Interdisciplinarity and innovation dynamics. On convergence of research, technology, economy, and society. *Poiesis & Praxis* 7, 275–289. doi: 10.1007/s10202-011-0088-8

Mascia, M. B., Fox, H. E., Glew, L., Ahmadia, G. N., Agrawal, A., Barnes, M., et al. (2017). A novel framework for analyzing conservation impacts: evaluation, theory, and marine protected areas. *Ann. N Y. Acad. Sci.* 1399, 93–115. doi: 10.1111/nyas.13428

McConney, P., Fanning, L., Mahon, R., and Simmons, B. (2016). A First Look at the Science-Policy Interface for Ocean Governance in the Wider Caribbean Region. *Front. Mar. Sci.* 2:119. doi: 10.3389/fmars.2015.00119

Muller-Karger, F. E., Miloslavich, P., Bax, N. J., Simmons, S., Costello, M. J., Sousa Pinto, I., et al. (2018). Advancing Marine Biological Observations and Data Requirements of the Complementary Essential Ocean Variables (EOVs) and Essential Biodiversity Variables (EBVs) Frameworks. *Front. Mar. Sci.* 5:211. doi: 10.3389/fmars.2018.00211

Organisation for Economic Co-operation and Development [OECD] (1993). *OECD Environmental Indicators – Development, Measurement and Use*. Paris: OECD. Available online at: http://www.oecd.org/environment/indicators-modelling-outlooks/24993546.pdf (accessed June 7, 2020).

Ostrom, E. (2009). A General Framework for Analyzing Sustainability of Social-Ecological Systems. *Science* 325:419. doi: 10.1126/science.1172133

Parks, J. E., Pomeroy, R. S., and Watson, L. M. (2004). *How is your MPA doing??: a guidebook of natural and social indicators for evaluating marine protected areas management effectiveness*. Switzerland: IUCN.

Pelletier, D., Bissery, C., and Gonson, C. (2014). *Guide d'utilisation des outils PAMPA. Version 2.* France: IFREMER.

Pelletier, D., Carpentier, L., Roman, W., and Bockel, T. (2016). *Unbaited rotating video for observing coastal habitats and macrofauna. Methodological guide for STAVIRO and MICADO systems. AMBIO Project*. France: IFREMER. doi: 10.13155/46859

Pelletier, D., Charbonnel, E., Licari, M.-L., Lloret, J., Riera, V., Auscher, F., et al. (2005). *Synthèse des rencontres entre scientifiques et gestionnaires d'AMP. Rapport du projet LiteauII-AMP*. France: IFREMER.

Pelletier, D., Gamp, E., Reecht, Y., and Bissery, C. (2011). *Indicators of Marine Protected Area Performance for managing coastal ecosystems, resources and uses (PAMPA). Scientific Report PAMPA/WP1/Coord/5*. France: IFREMER.

Pelletier, D., Leleu, K., Mallet, D., Mou-Tham, G., Hervé, G., Boureau, M., et al. (2012). Remote High-Definition Rotating Video Enables Fast Spatial Survey of Marine Underwater Macrofauna and Habitats. *PLoS One* 7:e30536. doi: 10.1371/journal.pone.0030536

Pelletier, D., Selmaoui-Folcher, N., Bockel, T., and Schohn, T. (2020). A regionally scalable habitat typology for assessing benthic habitats and fish communities: Application to New Caledonia reefs and lagoons. *Ecol. Evol.* 10, 7021–7049. doi: 10.1002/ece3.6405

Pomeroy, R. S., Watson, L. M., Parks, J. E., and Cid, G. A. (2005). How is your MPA doing? A methodology for evaluating the management effectiveness of marine protected areas. *Ocean Coast. Manage.* 48, 485–502. doi: 10.1016/j.ocecoaman.2005.05.004

Ramírez-Monsalve, P., Raakjær, J., Nielsen, K. N., Santiago, J. L., Ballesteros, M., Laksá, U., et al. (2016). Ecosystem Approach to Fisheries Management (EAFM) in the EU – Current science–policy–society interfaces and emerging requirements. *Mar. Policy* 66, 83–92. doi: 10.1016/j.marpol.2015.12.030

Rife, A. N., Erisman, B., Sanchez, A., and Aburto-Oropeza, O. (2013). When good intentions are not enough …Insights on networks of "paper park" marine protected areas. *Conserv. Lett.* 6, 200–212. doi: 10.1111/j.1755-263X.2012.00303.x

Rogers, E. M. (2003). *Diffusion of Innovations*, 5th Edn. New York, NY: Simon and Schuster.

Schohn, T., Bockel, T., Carpentier, L., and Pelletier, D. (2017a). *Video-based baseline assessment of fish assemblages and habitats at Astrolabe, Petrie and Walpole remote islands and reefs in 2014, Coral Sea Natural Marine Park. AMBIO Project*. France: IFREMER. doi: 10.13155/51738

Schohn, T., Pelletier, D., and Carpentier, L. (2017b). *Video-based baseline assessment of fish assemblages and habitats of Entrecasteaux atolls, World Heritage and Coral Sea Marine Park. 2015 STAVIRO survey. AMBIO Project*. France: IFREMER. doi: 10.13155/51760

Strain, E. M. A., Edgar, G. J., Ceccarelli, D., Stuart-Smith, R. D., Hosack, G. R., and Thomson, R. J. (2019). A global assessment of the direct and indirect benefits of marine protected areas for coral reef conservation. *Div. Distrib.* 25, 9–20. doi: 10.1111/ddi.12838

Tessier, E., Pothin, K., Chabanet, P., Fleury, P.-G., Bissery, C., David, G., et al. (2011). *Définition d'Indicateurs de performance et d'un Tableau de bord pour la Réserve Naturelle Marine de La Réunion (Rapport du site atelier de La Réunion pour le projet PAMPA)*. France: IFREMER.

Tobin, R., Bohensky, E., Curnock, M., Golberg, J., Gooch, M., Marshall, N. A., et al. (2014). *The Social and Economic Long Term Monitoring Program (SELTMP) 2014 Recreation in the Great Barrier Reef*. Cairns: Reef and Rainforest Research Centre Limited.

United Nations [UN] (2016). *Summary of the first global integrated assessment*. New York, NY: United Nations.

Villaseñor-Derbez, J. C., Faro, C., Wright, M., Martínez, J., Fitzgerald, S., Fulton, S., et al. (2018). A user-friendly tool to evaluate the effectiveness of no-take marine reserves. *PLoS One* 13:e0191821. doi: 10.1371/journal.pone.0191821

Weatherdon, L. V., Appeltans, W., Bowles-Newark, N., Brooks, T. M., Davis, F. E., Despot-Belmonte, K., et al. (2017). Blueprints of Effective Biodiversity and Conservation Knowledge Products That Support Marine Policy. *Front. Mar. Sci.* 4:96. doi: 10.3389/fmars.2017.00096

Wells, S., Addison, P. F. E., Bueno, P. A., Costantini, M., Fontaine, A., Germain, L., et al. (2016). Using the IUCN Green List of Protected and Conserved Areas to promote conservation impact through marine protected areas. *Aqua. Conserv. Mar. Freshwater Ecosyst.* 26, 24–44. doi: 10.1002/aqc.2679

Wells, S., and Dahl-Tacconi, N. (2006). Why should we evaluate the management effectiveness of an MPA? *MPA News* 7, 2–3.

Conflict of Interest: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.