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PERSPECTIVE
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Disentangling Obstacles to Knowledge Co-Production for Early-Career Researchers in the Marine Sciences

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Knowledge co-production involving researchers and non-academic actors is becoming increasingly important for tackling sustainability issues. Coastal and marine social-ecological systems are one example where knowledge co-production is important, yet also particularly challenging due to their unique characteristics. Early-Career Researchers (ECRs) often face specific obstacles when engaging in the process of knowledge co-production. In this perspective paper, we shed light on the particular characteristics of knowledge co-production in marine social-ecological systems and the obstacles ECRs in the marine sciences face. Based on these obstacles, we discuss actions that can be taken at various organizational levels (institutional, community, supervisor, and individual) in order to leverage change towards a more inclusive environment for ECRs engaging in knowledge co-production. We conclude that both bottom-up (individual to institutions) and top-down (institutions to individual) actions are required. However, we emphasize the responsibilities of institutions to create conditions in which the needs of ECRs are met. This will be necessary to adequately support ECRs engaging in knowledge co-production and thus contribute to tackling sustainability challenges in coastal and marine social-ecological systems.

Keywords: transdisciplinary research, stakeholder engagement, actionable science, career development, co-design, co-development

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INTRODUCTION

Coastal and marine social-ecological systems (SES) increasingly face challenges that threaten their sustainable use and development. Such challenges include resource overuse, coastal development, pollution, and social injustice that stands in stark contrast with soaring actors' and public demand for participation (Nash et al., 2017; IPCC, 2019; Dahdouh-Guebas et al., 2020). In order to foster sustainable use of coasts and the ocean, the United Nations has proclaimed the 'Decade of Ocean Science for Sustainable Development' (2021-2030). The 'Ocean Decade' accentuates the need for improving the translation of scientific knowledge into tangible action for more evidence-informed and effective management of coastal and marine systems (Ryabinin et al., 2019).

One such way of advancing evidence-informed decision-making is through the co-production of knowledge, and research processes that include non-academic actors[1] (e.g., Tengö et al., 2014; Miller and Wyborn, 2018; Partelow et al., 2020; Caniglia et al., 2021; Schneider et al., 2021). Knowledge co-production can be defined as "iterative and collaborative processes involving diverse types of expertise, knowledge and actors to produce context-specific knowledge" (Norström et al., 2020, p. 183). Such processes hold different temporal phases that aim to ensure early and continuous collaboration between actors, for example through building partnerships across different knowledge systems and understanding project design as a collaborative process (Steger et al., 2021). While variations of knowledge co-production have been applied for many decades in different disciplines, its diverse modes of operation are just starting to be understood (Chambers et al., 2021).

Participatory research and especially knowledge co-production pose a range of challenges (Berkes, 2011; Cvitanovic et al., 2015; Oliver et al., 2019; Walsh et al., 2019). These include structural issues of academic systems, practice orientation vs. scientific excellence, high workload and time pressure, as well as limited access to (knowledge) networks for turning research into action (Deininger et al., 2021; Rogga and Zscheischler, 2021). These challenges are amplified for Early Career Researchers (ECRs) due to common limitations in terms of funding, time, experience, and networks (e.g., Felt et al., 2013; Haider et al., 2018; Fam et al., 2020; Schrot et al., 2020). Thus, identifying and addressing obstacles to knowledge co-production, especially from the perspective of ECRs, may help to better support the generation of co-produced knowledge and ultimately the utility of science for society. Both, the challenges and benefits of knowledge co-production are enhanced in complex systems with a large diversity of local, industrial, academic, and cultural actors such as in marine[2] SES.

The aim of this perspective paper is to better understand the obstacles that ECRs face when engaging in knowledge co-production processes in the context of marine sciences, and to provide guidance for how ECRs can be better supported and enabled to overcome these obstacles. We explore and discuss 1) characteristics of knowledge co-production in marine SES, 2) common obstacles faced by ECRs during these processes, and 3) possible action pathways for mitigating these obstacles. ECRs, in this context, are defined as students and scholars who are at the undergraduate, graduate, or post-graduate level up to 5 years post-PhD.

This perspective paper is based on a survey addressing ECRs in marine research (n=46, including both closed- and open-ended questions) and two workshops that were hosted as part of the International Conference for Young Marine Researchers (ICYMARE) in January and October 2021, complemented by the personal experiences of the authors who are mainly ECRs. More details on the methods can be found in the **Supplementary Material**.

KNOWLEDGE CO-PRODUCTION IN MARINE SOCIAL-ECOLOGICAL SYSTEMS

Marine SES have unique characteristics that make the co-production of knowledge specifically relevant, but at the same time particularly challenging. Through a collaborative mapping exercise, we identified nine overarching themes across environmental, social, and knowledge subsystems that we considered distinctive to marine SES: system boundaries, environmental complexity, accessibility, timescales, governance and administration, actor diversity and objectives, justice and equity, local and Indigenous knowledge, and data and monitoring. Even though the themes may also apply for other SES, the descriptions (**Table 1**) show that especially in the social subsystems of marine SES, strong collaboration and synthesis between diverse actors and management aspects are required.

Our survey showed that the fields of application are diverse, including fisheries, ocean and coastal governance, ecosystem restoration, natural resource management, adaptive capacity for climate change adaptation, Blue Carbon, recreational spaces (beaches, offshore), gender equality, and intersectionality. ECRs mentioned nature conservation (72%) as the main goal of designing a project involving non-academic actors, followed by filling an academic knowledge gap (70%), serving a societal need (57%), and achieving policy impact (57%). Community adaptation (35%), business opportunities (11%) and industrial adaptation (11%) were mentioned less frequently.

OBSTACLES TO KNOWLEDGE CO-PRODUCTION FACED BY ECRS IN THE MARINE SCIENCES

Through the survey and workshop, we identified a variety of obstacles ECRs in the marine sciences face in the planning and implementation of knowledge co-production approaches. The obstacles are structured into personal, engagement, and institutional obstacles; however, many are interlinked, as discussed in the subsequent section of this paper. Phrases in

[1] In this paper, we refer to 'actors' rather than 'stakeholders', reflecting the importance of the active engagement of non-academic individuals and organizations in knowledge co-production approaches.

[2] In this paper, we define the coastal and marine SES as a continuum spanning from the coast to the open ocean, including Areas Beyond National Jurisdiction (ABNJ). As we particularly discuss the 'wet part' of such SES, we will further refer to 'marine SES' and 'marine research' for simplicity.

TABLE 1 | Particular characteristics of marine SES that create challenges for the co-production of knowledge, yet enhance its utility.

Sub-systems	Themes	Descriptions
Environmental	**System boundaries**	Many features of marine SES transgress administrative boundaries (see governance and administration)
		Seascape features are less obvious in contrast to landscapes, which is why the ocean is regularly treated a "big blue space" in intergovernmental management agendas
		Difficulty to set clear boundaries due to the high interconnectedness of the ocean (e.g., migrating fishes, distribution of pollutants) and lack of stationary boundaries
	Environmental Complexity	Particularly diverse ecosystems, which are increasingly exploited by industry and stressed by climate change
		Larger delineation of ocean spaces with stronger compared to terrestrial systems (e.g., physical – depth, temperature)
	Accessibility	Most areas are inaccessible without significant effort (including higher costs for research and management)
		Disconnect between where resources are extracted (ocean) and location of actors (land), which complicates issues of accessibility rights and accountability
	Timescales	Rapid human-made changes (climate change, habitat destruction, pollution) and therefore urgent need for action
		More dynamic change and more rapid turnover of actors and resources compared to terrestrial systems
		Long lasting changes and slow-onset processes, such as uptake of CO_2 in the ocean and subsequent ocean acidification
Social	**Governance and administration**	Overlapping administrative boundaries created by different frameworks (e.g. Exclusive Economic Zone, Large Marine Ecosystems, Regional Seas) and management tools (e.g. Integrated Coastal Zone Management, Marine Spatial Planning, Marine Protected Areas)
		Comparably abstract definition of the ownership of resources (unresolved marine tenures, tragedy of the commons)
		Very challenging to enforce rules and have accountability, especially outside economic zones in Areas Beyond National Jurisdiction
		Different and sometimes overlapping levels of government governing the marine space, as well as lack of regional governance frameworks as opposed to terrestrial systems, where regional agreements are common
	Stakeholder diversity and objectives	Many actors with divergent views, values, and backgrounds
		Spatial overlap of different user groups at the interface of marine and terrestrial systems, including different interests such as tourism, fishing, aquaculture, conservation, renewable energy, seabed mining, extractive industries, shipping
		Contradicting objectives and political administration due to unclear boundaries (e.g., in mangrove SES)
	Justice and ethics	Historic exclusion and discrimination of many local and Indigenous communities
		Sudden exclusion of actors and severe punishments for communities who have relied on marine ecosystem services for centuries (e.g., "no entry" rules imposed in conservation areas)
Knowledge	**Local and Indigenous knowledge**	Local and Indigenous knowledge and cultural perceptions are often overlooked but particularly important to incorporate
		Relational values of the marine system are harder to grasp, as our relationship with some commonly inaccessible ecosystems is not as close as with land-based ecosystems (e.g. value of deep-sea ecosystems compared to tropical forests)
		Challenges in transmitting local and Indigenous knowledge to future generations due to changing SES boundaries, lifestyles, and environmental conditions
	Data and monitoring	Marine systems are more difficult to monitor because of their three-dimensional extent and have limited vantage points for good visibility (e.g. satellite observation can only detect changes in higher ocean layers), difficulty to access because of challenging environmental conditions and remoteness, and relative paucity of dedicated resources
		Lack of social data and knowledge related to social-ecological interactions
		Relatively higher amount of uncertainty in environmental and biological knowledge as a result of limited/scarce data and information

quotation marks are citations from the survey and a full list of obstacles including ratings by the survey participants can be found in the **Supplementary Material (Table S1)**.

Personal Obstacles

Even though personal obstacles are highly diverse and context specific, several overarching themes emerged clearly from the survey and workshop. The first commonly mentioned obstacle emerges at the very beginning of the research process with the determination of a research topic and search for a suitable supervisor. Marine SES, being particularly complex systems, often require integration of knowledge from different scientific fields. Study programs, however, are still often bound to specific scientific disciplines, which one participant described as "*lack of institutional support to engage in 'non-traditional' research methods*", which is also recognized by other studies (e.g. Pannell et al., 2019; Andrews et al., 2020). Similarly, the ability to self-advocate in the face of institutional barriers or conflict situations was mentioned by 42% of respondents as a major obstacle. Some participants (27%) reported discrimination based on their age and/or gender, e.g. in the context of politicians, who were "*skeptical or disrespectful of the work of ECRs*". Similarly, a respondent shared that "*as a 'young' looking female*", her work would often be "*overlooked or co-opted by male team members*". This also highlights the intersectionality of these challenges in terms of age, gender, race, or academic background (e.g. Schmidt and Neuburger, 2017). In combination with stress due to short-term contracts and career uncertainty (71%) as well as difficulties to manage a healthy work-life balance (45%) (see also Susi et al., 2019; Andrews et al., 2020), the mental load for ECRs induced by these personal obstacles can drastically decrease the individual's confidence. This may impede the career development of ECRs who engage in knowledge co-production, and exclude those without strong support systems or with additional responsibilities, such as caring obligations. While we included those challenges under personal obstacles, we acknowledge their systemic causes further discussed in the section "Action pathways for mitigating obstacles".

Engagement Obstacles

Marine SES are often highly contested systems subject to widely diverging interests, requiring the engagement of diverse actors in

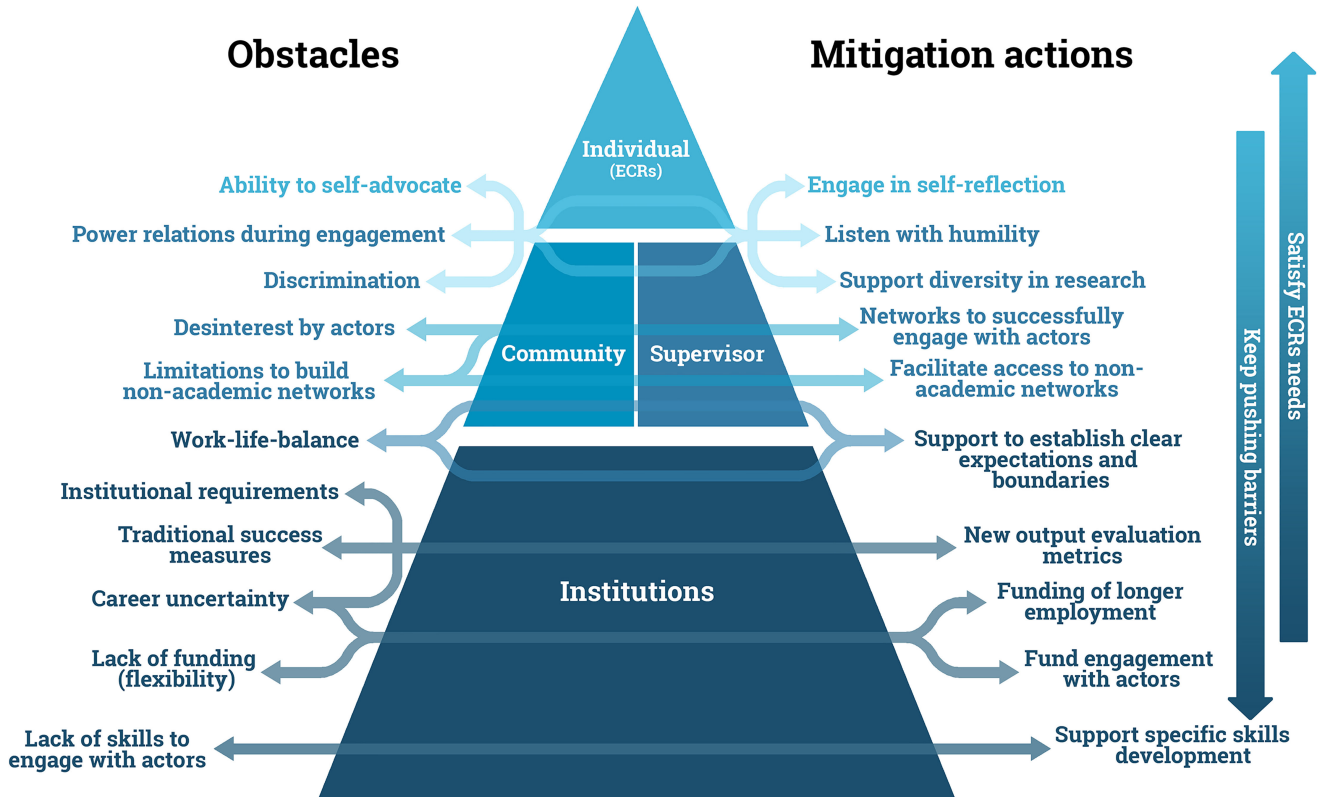

FIGURE 1 | Summary of obstacles (left) to be tackled at different organizational levels (pyramid) with corresponding mitigating actions (right) and action pathways (horizontal arrows). The pyramid represents the hierarchy of needs with *institutions* (bottom) that are to be met before the needs at the *individual* level (top) can be resolved. The *community* (peer and broad scientific community) and *supervisory* level (middle) were considered as support systems to overcome obstacles and improve the engagement with local actors. Vertical arrows on the right side represent top-down and bottom-up actions that are needed to leverage change towards a more inclusive environment for ECRs engaging in knowledge co-production.

the social and political arena. Results from our survey and workshop found various barriers for ECRs to engage with diverse non-academic actors. ECRs often have had limited time or opportunity to build strong networks and personal relations with relevant actors beforehand due to their career stage. Consequently, identifying and being able to effectively engage with diverse actors represents a significant obstacle (41%). During the engagement phase, another major obstacle that emerged was disinterest by actors as a result of previous negative interactions with researchers (67%), and/or due to a lack of perceived value-added to the local context (52%). This disinterest requires critical self-reflection of the researchers, both early-career and advanced, in conducting participatory approaches (Beck et al., 2021). However, power relations created during the engagement are particularly amplified for ECRs due to the commonly prevalent age differences between ECRs and non-academic actors, such as decision-makers (Evans and Cvitanovic, 2018; Fritz and Binder, 2020). Establishing and maintaining meaningful relationships with non-academic actors, hence, represents a major obstacle for ECRs engaging in participatory approaches. The COVID-19 pandemic has increased the degree of uncertainty among ECRS and drastically impacted place-based research (e.g., *via* inability to travel to field study sites), further limiting opportunities for engagement (Vandebroek et al., 2020; Köpsel et al., 2021).

Institutional Obstacles

Most of the obstacles broached by survey participants are academic or institutional in nature. Apart from finding a suitable supervisor (see section "Personal obstacles"), survey participants cited academic expectations affecting the methodological approach (50%). The iterative, inherently messy and nonlinear nature of knowledge co-production processes and the contested nature of many marine SES can make it difficult or unsuitable to adhere to rigid thesis deadlines (e.g., timing, format) (Fisher and Phelps, 2006). In addition, pre-defined departmental/institutional requirements often fail to accommodate the added complexity of working with non-academic actors, and expectations to meet such requirements was mentioned as a major obstacle by 33% of survey respondents.

The scientific culture expecting high output in short timeframes often leaves insufficient room for actor engagement, especially for the process of building relationships, which forms the basis of responsible engagement. These requirements are often connected

to expectations of funding agencies and elucidate the obstacles caused by a lack of research flexibility due to funding requirements (32%) as well as a general lack of funding (32%) for sufficient in-depth engagement. Long-term data availability is particularly challenging for marine SES (**Table 1**), and can often only be addressed by long-term programs or investment in partnerships that enable access to historical data (Lundquist et al., 2016). Frequently, such long-term partnerships involve senior collaborators rather than the ECRs themselves, reinforcing the dependence on others for important networks. Even though the lack of funding also applies to more advanced researchers, it is particularly challenging for ECRs. For example, 5 survey participants (3 master, 2 PhD) reported that their work was self-funded, and 20 survey participants (10 master, 5 PhD, 5 PostDoc) reported that they are funded through scholarships, which often reduces the overall research performance both during the degree and throughout the researchers' careers (Horta et al., 2018). Overall, shortcomings in funding of ECRs limit the capacity to produce adequate research results, while also generating tangible, salient outputs that are tailored to context and decision-makers.

ECRs engaging in knowledge co-production are additionally challenged by the need to prove academic ability within a system that relies on traditional measures of success, which are not appropriate for knowledge co-production processes. ECRs must balance traditional academic expectations with more practical engagement, which is often under-valued, ultimately resulting in insufficiently robust assessment of ECR performance (Newig et al., 2019). Similarly, the "soft skills" relevant for engagement (interpersonal skills, facilitation, networking) are often not recognized or taught in academia (Bednarek et al., 2018) - as was mentioned by 50% of survey respondents as a major obstacle. This obstacle may be exacerbated for ECRs with a background in environmental sciences (the majority of survey respondents) who have less guidance developing 'soft skills' in comparison to those with a social science or systems backgrounds, for example. Although such obstacles are relevant at all career stages, they are especially important for ECRs who are more reliant on personal research outputs to prove their academic potential and to gain access to more secure jobs and funding.

ACTION PATHWAYS FOR MITIGATING OBSTACLES

Obstacles for ECRs engaging in knowledge co-production approaches are manifold. Yet, the agency of ECRs to identify and overcome persistent obstacles is limited and often depends on the academic environment (e.g. support by senior researchers, availability of courses), or institutional structure (e.g. funding, measures of success). Hence, the mitigation of obstacles is required at several organizational levels.

In the following, we discuss possible actions at the institutional, community, supervisor, and individual, personal level that can support ECRs to engage in knowledge co-production and in their future career development in this field (**Figure 1**). With this, we seek to find an equilibrium between addressing and acknowledging systemic drivers, while also highlighting the actions ECRs can take to better succeed in navigating such challenges.

Institutional Level

Firstly, funding mechanisms should allocate more resources for longer and full-time employment, flexibility, and coverage of travel costs because engagement must be formally budgeted for. This is particularly important to reduce the stress due to career uncertainty and managing a work-life balance for ECRs. We recommend funding bodies, such as the US National Oceanic and Atmospheric Administration, European Research Executive Agency (Horizon Europe), Western Indian Ocean Science Association, and funding bodies at national levels, should help navigate the local context and potential conflicts, maintain regular communication with grantees, and require engagement and holistic research impact planning in funding agreements (Arnott et al., 2020; Cvitanovic et al., 2021c; Landrum et al., 2022).

Secondly, traditional measures of success need reconsidering for projects that aim at knowledge co-production. This includes a different evaluation of output, which is not measured in research publications, but rather in products that benefit non-academic actors (e.g. reports, tools, infographics, community oriented newsletters, media appearances, public lectures and workshops). It also has to be considered that positive outcomes are much more diverse than *products*, and often rather relate to *processes*. Such 'alternative' metrics include the use of knowledge in decision-making, as well as impacts on individuals, group interactions, organizations, and political processes - which may be intangible (relationships, trust, changes in attitude, mutual learning) (Cooke et al., 2020; Cvitanovic et al., 2021a; Karcher et al., 2021). This calls for a diversification of 'excellence' criteria (i.e., going beyond 'traditional' metrics such as impact factors, funding acquired, number of publications and citations) when considering hiring/promotion, and considering alternative metrics reflective of societal impact, actor engagement, or applicability (e.g. Mitchell and Willetts, 2009; Daedlow et al., 2016; Klein and Falk-Krzesinski, 2017; Kraemer-Mbula et al., 2020).

Lastly, the entrance to participatory approaches needs to be facilitated by universities. ECRs often have a disciplinary background and therefore require a different set of courses to learn the relevant soft-skill for engaging with non-academic actors. This could include more courses on strategies on how to engage with diverse actors (e.g. decision-makers and politicians), to stimulate collaboration (Oliver et al., 2019), and to approach issues from the perspectives of other actors. More recognition and acceptance of 'non-traditional' inter- or transdisciplinary science and scientists may increase opportunities for future ECRs to contribute to the field.

Community Level

This paper refers to two types of 'community level': communities of peer-support and the broader scientific community. Finding people that work on similar topics and establishing a community of support can be extremely beneficial for ECRs. Communicating about difficulties that arise within the knowledge co-production

process can help ECRs develop pathways to overcome obstacles by creating networks that help with finding the right methodology, courses and literature[3], and can also provide support at a personal level (e.g. dealing with feelings of isolation, imposter syndrome, mental health). The ICYMARE network, from which this perspective paper emerged, is an excellent example of a bottom-up collaborative initiative that supports ECRs in building a community and working towards a common goal.

However, certain actions to overcome persistent obstacles to knowledge co-production are also the responsibility of the broader scientific community. A major obstacle mentioned in the survey was a disinterest in engagement by non-academic actors resulting from previous negative interactions with researchers, such as *parachute science*, which is still widespread in marine science. *Parachute science* refers to neo-colonial practices characterized by scientists from the Global North conducting research in the Global South without responsibly or authentically engaging with the local context and simply extracting data for publication (Stefanoudis et al., 2021). This particular obstacle highlights the need to address these issues on a systemic and community level to mitigate distrust that may jeopardize the engagement of ECRs and future researchers with non-academic actors (Schmidt and Pröpper, 2017).

Supervisor Level

At the supervisory level, mitigating actions should include more responsive leadership, which focuses on the career progression and security of ECRs (Susi et al., 2019). This may include support to self-advocate in response to institutional barriers and better capacity planning to maintain a healthy work-life balance. Mental health – which is particularly challenging for ECRs and researchers engaging in knowledge co-production (Cosentino and Souviron-Priego, 2021; Sellberg et al., 2021) – should be an open topic between supervisors and ECRs. Establishing a clear set of expectations and boundaries is crucial. While facilitating access to networks of academic peers in their field is an important role for any academic supervisor, in the context of knowledge co-production and engagement of non-academic actors, the relevance of this role is further enhanced given the importance of trust and long-term collaborations in establishing impactful and reliable relationships beyond academia (e.g., Cvitanovic et al., 2021b). Supervisory support should include creating entry points within their existing networks for ECRs and being open to transdisciplinary collaboration. Finding additional suitable mentors may also create space to discuss problems from another angle. More diverse representation of backgrounds, ages, and genders is also needed to not only make knowledge co-production approaches more inclusive but also to overcome biases in traditional (western) science (Swartz et al., 2019).

Individual Level

On a personal, individual level, we identified two main ways to mitigate obstacles: engaging in self-reflection, and focusing on the process. A constant attention to self-reflection can help ECRs regularly check their learning process (Naveed et al., 2017) by prioritizing self-growth and building confidence in their academic work. Tracking and discussing successes and goals with supervisors and community members may further enhance confidence while also enhancing the ability to openly communicate capacity limits or difficulties with administration and colleagues. The process of self-reflection also includes listening with humility when engaging with non-academic actors which in turn creates a space where those actors can see the value created by the engagement (Brugger et al., 2016; Breckwoldt et al., 2021). Additionally, focusing on the process is crucial to avoid being side-tracked by other interests and activities. Finding a balance between ambition and practicality is extremely important to manage a healthy work-life balance while accomplishing high quality research (Andrews et al., 2020).

[3]Literature resources to be used as a starting point for ECRs engaging in knowledge co-production can be found in the **Supplementary Material**.

CONCLUDING THOUGHTS

Knowledge co-production with non-academic actors in research is a complex but rewarding process. While it has gained significant attention over the last years, it is not easy to conduct, especially for ECRs. Knowledge co-production can be described as both a research process and a process of personal development for the researcher who conducts it. ECRs should acknowledge the non-linear and messy nature of the processes, which can lead towards meaningful engagement and relationship building. When designed carefully, knowledge co-production approaches can produce highly desirable outcomes for both actors and researchers, as well as the sustainable management of marine SES.

In this paper, we shed light on the obstacles that ECRs in the marine sciences face when engaging in knowledge co-production. Mitigating these obstacles requires action at several levels. Hence, both bottom-up and top-down actions are required to leverage change towards a more inclusive environment for ECRs engaging in knowledge co-production. Bottom-up actions for ECRs include pushing academic boundaries by looking for and supporting 'non-traditional' metrics of success and impact, and working towards the establishment of interdisciplinary boards. Substantial top-down actions from institutions are required to create conditions that meet the needs of ECRs to enable and support them to engage in knowledge co-production. With this, we want to emphasize the responsibilities of institutions to address deep-rooted systemic problems, including funding limitations, ultimately creating improved career prospects for ECRs engaging in knowledge co-production.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**. Further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

Ethical clearance for the survey was reviewed and provided by an independent ethics board at the Leibniz Centre for Tropical Marine Research following the principle of prior informed consent. All participants were informed about the background and aim of the survey, consent was necessary before proceeding to fill the survey, and participation in the survey was voluntary. Participants were informed about the use, storage and processing of the data in accordance with art. 12 GDPR. The collected information was treated confidentially, and data are made available only in anonymized form.

AUTHOR CONTRIBUTIONS

LR initiated and led the work that built the basis for this perspective paper. XE and MK initiated and conducted an initial "Open Forum" in January 2021, from which further work was inspired. LR and MK led the survey design and implementation. All authors contributed to the survey design as well as planning and implementation of the workshop in October 2021. LR led the writing and wrote the paper with input from all authors. XE, LR, and EW designed **Figure 1**. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2022.893489/full#supplementary-material

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