One Earth

Article

Breaking down barriers: The identification of actions to promote gender equality in interdisciplinary marine research institutions

Graphical abstract

Highlights

- Gender equality is a human right and is important for ocean sustainability
- Women are less likely than men to be in positions of leadership
- Women face non-gendered and gendered challenges working in marine research
- A range of strategies can be applied to support women's leadership

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In brief

Gender diversity is important for achieving equality and ocean sustainability challenges. However, women are less likely to be in positions of leadership within academic interdisciplinary marine research institutions. We highlight the non-gendered and gendered challenges they experience as a leader that affect their role, mental wellbeing, success, and career progression. Accordingly, we present actionable strategies, systems, and processes that can be implemented by academic interdisciplinary marine research institutions and the scientific community to improve gender equality.

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Breaking down barriers: The identification of actions to promote gender equality in interdisciplinary marine research institutions

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SCIENCE FOR SOCIETY Gender equality is a fundamental human right, and it is essential for addressing ocean sustainability challenges in the 21st century. Interdisciplinarity is also critical to navigating these challenges, and evidence has shown that women leaders can increase the success of interdisciplinary marine research. However, men are more likely to be in positions of leadership within marine research institutions, indicating that the system has not been designed to adequately support women scientists. Furthermore, interdisciplinarity can present unique and additional challenges to women scientists and may exacerbate the existing gender-specific issues experienced in marine research. We show that women face the challenges of working in academia but also experience additional challenges due to their gender. This is particularly the case for women who belong to minoritized and disadvantaged groups (e.g., due to their ethnicity or nationality). It is important to highlight the challenges that women leaders face. This research has implications for academic marine research institutions and the science community.

SUMMARY

Interdisciplinary research is paramount to addressing ocean sustainability challenges in the 21st century. However, women leaders have been underrepresented in interdisciplinary marine research, and there is little guidance on how to achieve the conditions that will lead to an increased proportion of women scientists in positions of leadership. Here, we conduct in-depth qualitative research to explore the main barriers and enablers to women's leadership in an academic interdisciplinary marine research context. We found that interdisciplinarity can present unique and additional barriers to women leaders (e.g., complexity and lack of value attributed to interdisciplinary research) and are exacerbated by existing gender-specific issues that women experience (e.g., isolation and underrepresentation and stereotyping). Together these barriers overlap forming the "glass obstacle course"—which is particularly challenging for women in minoritized groups. Here, we provide a list of concrete, ambitious, and actionable enablers that can promote and support women's leadership in academic interdisciplinary marine research.

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INTRODUCTION

> We cannot all succeed when half of us are held back.—Malala Yousafzai.

It is increasingly acknowledged that a diversity of leaders, perspectives, and disciplines are essential for navigating the complexity of environmental problems,[1,2] including the socio-ecological challenges facing marine environments.[3–6] While it has become commonplace that marine research, like any other science, benefits from the inclusion of diverse scientific disciplines, the value of diversity in gender, ethnicity, nationality, and other aspects (including disabilities) continues to be challenged.[1,7] The goal of gender equality has been reflected in the setting of global commitments,[8] including the Sustainable Development Goals (SDGs) (e.g., SDG 5)[9] and the United Nations Decade of Ocean Science for Sustainable Development (2021–2030).[10] In the context of this study, gender equality refers to ensuring that women have the same rights and responsibilities,

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are given the same opportunities and resources, and are not treated less favorably on the basis of their specific gender.[11] For example, SDG 5.5 specifically aims to ensure that there are equal opportunities for women's leadership at all levels of decision-making in political, economic, and public life.[12]

While the SDGs focus specifically on gender equality, there is also research that shows that women leaders encourage and drive innovation, creativity, and scientific discovery,[13] cultivate a more collaborative and inclusive research environment,[14] and remove hierarchical power imbalances that have the potential to derail collaboration among researchers from different disciplines.[15] Throughout this article, we use the terms "women" and "leader." We recognize that gender is not binary and we respectfully include and acknowledge the experiences and challenges of all who identify as women and/or womxn and also acknowledge that these and other challenges also exist for non-binary individuals.[16] For the purpose of this study, a "leader" is defined as a researcher who holds some form of leadership role at any level within an academic institution (i.e., leading a research institution, team, project, or program). Leadership roles are multifaceted and vary across regions and cultures; however, they often require leaders to assume a greater administrative and managerial load and service duties in addition to their research role.

Despite the importance of diversity and inclusivity, gender inequity is pervasive across academic interdisciplinary marine research institutions.[17–19] In the context of this study, gender equity is defined as the practices and ways of thinking that assist in working toward equality, including ensuring women are given opportunities and resources that are proportional to their needs. Equity differs from equality in that it acknowledges that underrepresented groups do not start from the same point, may face different systemic barriers, and therefore may require additional support to overcome these barriers.[11] Interdisciplinary marine research integrates perspectives and approaches from the natural, physical, and social sciences, which had previously been pursued independently, to create synthetic understandings.[20] Research indicates that women are less likely than men to be in positions of leadership.[21,22] Following trends in other science, technology, engineering, and mathematics (STEM) disciplines, previous studies suggest that the proportion of women in leadership positions declines along the "leaky pipeline," in the career trajectory from higher education to research.[23–26] Other studies have shown that, despite similar proportions of women and men who enroll in undergraduate and graduate programs and acquire postdoctoral roles, leadership positions are predominantly held by men.[27] Earlier work has also shown that the leaky pipeline phenomenon can be further accompanied by gender inequity in terms of earnings,[23,28,29] funding,[22,30] awards,[31] and publishing (e.g., authorship, number of citations, and leadership and membership of editorial boards[32–34]). Women often have shorter careers,[35] receive more manuscript rejections,[36–38] and are less likely to publish in prestigious journals.[39] While we acknowledge that each country, institution, and discipline (whether natural or social science) will have its own specific context, studies suggest that women scientists from around the world are experiencing gender-specific biases that impede their advancement in research careers and attainment of leadership positions.[40]

Pursuing gender equality in interdisciplinary marine research is critical. Gender equality is a fundamental human right and is essential for addressing sustainability challenges.[41,42] But, without understanding the gender-specific barriers that women face in relation to career advancement, it is impossible to ascertain how to navigate them.[43] There is a growing body of work that has enhanced understanding of the perceived gender-specific barriers and enablers to the advancement of women in STEM and related fields. Some of this research has gone so far as to suggest that the academic system has not been designed and developed to adequately support women scientists[38] or other minoritized groups.[44,45] As a result, women experience unconscious bias, cultural prejudices, stereotyping, and expectations, as well as bullying and sexual harassment,[46] which can inhibit career progression in STEM and put them at a significant disadvantage compared with their male colleagues.[21,28,47–49] This has previously been described as a "labyrinth" or "glass obstacle course."[50,51] Together, these metaphors convey the various unequal and unseen gendered processes that are experienced by women scientists in the workplace and prevent women from rising to leadership positions within academia.[50,52] It is also important to note that the challenges experienced by women scientists are not experienced equally, but rather interact and accumulate with additional attributes, including race,[1] nationality,[33] sexual identity, disability, age, culture, and caring responsibilities.[16,53,54]

Targeted actions are therefore needed to improve the conditions that will support an increased proportion of women scientists in positions of leadership. Research in STEM and related fields have put forward a range of potential enablers and strategies, including flexible working arrangements, institutional support, networking, support networks, mentoring, and role models.[17,49,55–57] To date, however, there has been limited research into the barriers and enablers experienced at the intersection between gender and interdisciplinarity, particularly within the context of marine research. This is pertinent for a number of reasons. First, interdisciplinary research is paramount to addressing ocean sustainability challenges in the 21st century.[58] It is increasingly recognized that knowledge generation through single discipline science is no longer adequate;[15] "… biologists alone cannot solve the loss of biodiversity, nor chemists in isolation negotiate the transition to renewable energy."[59] Interdisciplinarity enables a more comprehensive understanding of problems, issues, and complex phenomena, broadens the toolbox of methods and approaches used by scientists and actors, creates new knowledge on the multi-scale interactions between marine ecosystems and society, and generates more robust and relevant outputs.[60,61] Second, recent evidence has shown that women leaders can increase the success of interdisciplinary marine research.[15] "Women are well positioned to make major advances in interdisciplinary research, they may like to integrate across fields and approaches, work well in teams, and be committed to connecting their research with societal concerns"[62] (p72). Thus, women's leadership will be significant to the future growth and success of interdisciplinary marine research. Third, the barriers to conducting interdisciplinary research are considerable in comparison with single disciplines.[63] Interdisciplinarity can present unique and additional challenges to women scientists and may exacerbate the existing gender-specific issues experienced in marine research.[64] Barriers include: the lack of recognition of and discrimination

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against interdisciplinary research,[65,66] disciplinary interaction (e.g., communication and power hierarchies between natural and social science), issues with integrating divergent disciplines in a meaningful way due to different epistemologies,[67] and a lack of specific funding for interdisciplinary marine research.[68] Still, resources and human capital remain insufficient for overcoming current and future sustainability challenges.[69] It is counterproductive for sustainability, if women are being subtly and systematically excluded from leadership opportunities, whether intentionally or otherwise.[70] Interdisciplinary marine research environments must become more gender-inclusive, empowering, and appealing places for women scientists and potential leaders to work.

Here, we aim to address knowledge gaps on the barriers and enablers of women's leadership in academic interdisciplinary marine research. The study has three main objectives: (1) to develop a comprehensive understanding of the main challenges and barriers of working in academia and undertaking interdisciplinary marine research, as perceived by women leaders; (2) to develop a comprehensive understanding of the *gendered* challenges or barriers experienced by women leaders; and (3) to identify enablers of women's leadership, including the promotion of and subsequent success of women's leadership (e.g., systems, processes, and strategies). In-depth qualitative research was conducted using semi-structured interviews and self-completion surveys. 34 women leaders participated in the study, representing 27 nationalities (see Table S1). The study was undertaken during the COVID-19 pandemic, a global event that brought to light many of the issues we see reflected in the responses.[71,72]

We find that interdisciplinarity can present unique and additional challenges to women leaders working in academic marine research. Interdisciplinary research is perceived to be undervalued and complex and requires leaders to engage with a variety of disciplines, which can present challenges e.g., due to differences in terminology, epistemologies, and power relationships. These challenges are exacerbated by existing gender-specific issues that women experience (e.g., isolation and underrepresentation and stereotyping). These barriers intersect and overlap forming the "glass obstacle course"—and are particularly challenging for women with multiple disadvantaged or minoritized statuses (e.g., ethnic minorities and leaders in the Global South). We propose a range of systems, processes, and strategies that can promote and support women's leadership in academic interdisciplinary marine research. Social enablers (e.g., support and encouragement from supervisors and peers and informal networking) were the most frequently discussed, suggesting that support for women scientists may come from people, rather than training or institutional structures. By exploring the views of women leaders we can help to reframe the conversation around women's careers in academia, with important implications for academic interdisciplinary marine research institutions, the science community and, more broadly, ocean sustainability. These insights can help to guide the design of gender equity initiatives, policies, and frameworks that make steps toward gender equality in interdisciplinary marine research.

RESULTS

Themes as derived from data analysis are presented as an analysis hierarchy. The analysis hierarchy provides an overview of the coding results, and themes were ordered from those mentioned most frequently to those least frequently mentioned. However, it should be noted that frequency simply refers to the number of times each of the themes was mentioned by participants, not the level of importance that participants placed on any specific issue. Specific themes, within each of the three research objectives, are detailed in the following subsection (see Table S2 for the overall sum totals for each theme).

Challenges of interdisciplinary marine research

Our first objective was to identify the main challenges for leaders working in academia and undertaking interdisciplinary marine research from the perspective of women leaders. These are intended to be the non-gender-specific barriers that participants mentioned they had experienced as leaders. However, there is a potential bias in the data, as we intentionally sampled women leaders. In addition, we assume that the participants themselves selected themes related to this cluster of challenges, as opposed to the next cluster of challenges related to gender-specific challenges. Thus, it is impossible to confirm that these challenges are ungendered, but they are perceived to be ungendered.

Most participants acknowledged that they had experienced challenges as a leader (n = 30; 88.2%); four participants had not faced any general challenges as leaders (11.8%). The analysis identified 21 challenges. As described in the methods, they were categorized into the following themes: (1) institutional, (2) practical and process, (3) social, (4) financial, (5) individual, (6) political, and (7) other (see Table 1). The ten most frequently discussed academic and interdisciplinary challenges (or subthemes) are presented in Figure 1. Further information on each of the subthemes (with example quotes) are shown in Table S3.

Institutional challenges were the most common theme, highlighted by the majority of participants (see Table S2). Of these, the most commonly discussed institutional challenges were: (1) limited institutional support and capacity (n = 15), (2) academic or workplace culture (n = 13), and (3) institutional structure and policies (n = 13; Table 1). Challenges identified under institutional support and capacity included a lack of physical infrastructure to facilitate interdisciplinary marine research, as well as limited access to support and scientific staff. Participants discussed administrative overburden due to a lack of support within departments (e.g., for research management, teaching, and financial management). This was seen to take leaders away from their research responsibilities and demotivated them. For example, one participant stated that "Instead of having the time and creativity to spend on exercising leadership, I spend a lot of it on administrative duties. Most of these do not require my input, but we are a small team with lots of responsibilities" (ID19).

The second most commonly discussed institutional barrier was that of academic or workplace culture. Participants discussed the competitive nature of academia, workload, and the expectation to work long hours, but also the presence of toxic and hostile working conditions (Table 1). For example, "Things like when I was part time, that perception that you can't be a leader and serious about your work if you're part time" (ID13). A third institutional barrier concerned institutional structure and policies (Table 1). Participants commented on issues including hierarchical structures, bureaucracy, and discrepancy between individual, team, and institutional goals. For example, one

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Table 1. Analysis hierarchy of non-gender-specific challenges to women's leadership

Theme	Subtheme	Frequency[a]	No. of sources[b]
Institutional	limited institutional support and capacity	31	15
	academic or workplace culture	21	13
	institutional structure and policies	17	13
	career progression and job insecurity	9	7
	isolation and integration	8	6
	poor leadership within institutions (e.g., from superiors)	6	4
Practical and Process	lack of recognition of interdisciplinary marine research	43	17
	working with researchers from other disciplines	28	13
	complexity of interdisciplinary marine research	22	13
	publishing	7	7
	leading and managing staff	8	6
	lack of leadership training	6	5
Social	racial discrimination and prejudice	28	14
	age discrimination	22	12
	inequality	12	8
Financial	lack of available and suitable funding	26	15
Individual	demanding workload	16	10
	gaining credibility or authority	9	6
Political	socio-political challenges	10	6
Other	no general challenges	4	2
	miscellaneous[c]	17	11

The themes derived from research participants, related to the challenges that leaders experience as a result of working in academia and undertaking interdisciplinary marine research (n = 34). The themes are ordered from most frequently mentioned to least frequently mentioned.
[a]Frequency refers to the number of times a theme was coded across all interview transcripts.
[b]The number of sources represents the number of unique interviewees (i.e., participants) who raised the theme during the interview process (maximum potential n = 34).
[c]Miscellaneous topics described by participants (e.g., poor science communication and switching to online teaching).

participant commented, "I find University/funding bureaucracy to be one of the biggest barriers in academia. I find being a strong and fair leader requires doing things that are right and just, doing things that are creative, and doing things that one may not have budgeted for at the outset. In all cases, these things (and understanding they are not mutually exclusive) tend to be difficult for rigid university systems to accept" (ID33). Other institutional challenges included: (1) career progression and job insecurity (n = 7), (2) isolation and integration (n = 6), and (3) poor leadership within institutions (e.g., from superiors; n = 4; Table 1).

In addition to institutional challenges, participants identified several practical and process barriers that influence interdisciplinary leadership (Table 1). Of these, the most commonly discussed subthemes were related to the challenges of being an interdisciplinary researcher. First, the lack of recognition and value attributed to interdisciplinary marine research was seen as a barrier (n = 17). As exemplified by one participant: "… I find my research misunderstood and I sometimes feel cut-off from disciplinary collaboration. I find that most of my invitations to collaborate in consortia is to do research on capacity building or societal outreach" (ID10). The challenges of working with researchers from other disciplines was also commonly identified (n = 13). One participant stated: "… it is still very much compartmentalized—social and natural scientists do not mix or communicate with one another. In my work on marine social-ecological systems, this is quite the challenge—especially amongst natural scientists" (ID22). Closely associated with this, participants discussed the complexity of undertaking interdisciplinary marine research (n = 13): "It requires patience and stamina to lead processes to reach shared understanding and agreement of challenges, priorities and goals across disciplines, cultures, terminologies, that often differ from the discipline-specific priorities and goals" (ID11). Other practical and process challenges related to: (1) leading and managing staff, (n = 6), (2) publishing (n = 7), and (3) the lack of leadership training (n = 5; see Table 1).

By examining the challenges for leaders working within academia and undertaking interdisciplinary marine research, we were able to study biases and inequalities across different dimensions of human diversity and their intersections ("social challenges"; n = 22, 64.7%). Social issues and multiple forms of discrimination combined and intersected the experiences faced by academics. One participant stated "I think that age, place and race play important roles too, and that gender is only one aspect that may challenge leadership in marine interdisciplinary research" (ID7). Multiple participants had experienced or observed discrimination and prejudice as a result of their race, ethnicity, or nationality (n = 14). For example, "[as] a woman of color, I especially feel that I need to do 'extra' work or be 'extra' good at what I do in order to be seen or heard as a reliable

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Figure 1. The ten most frequently discussed academic and interdisciplinary challenges

The most commonly discussed academic and interdisciplinary challenges and gendered challenges experienced by women leaders (n = 34). For the purpose of this study, a "leader" is defined as a researcher who holds some form of leadership role at any level within an academic institution (i.e., leading a research institution, team, project, or program).

and valued voice" (ID34). Participants discussed the implications of this discrimination, for example, in terms of isolation and exclusion from career progression: "… it was just accepted there's no black woman, with a PhD, that can fill in positions" (ID2). Participants were also discriminated against due to their age (n = 12): "… I won a big research grant and became both project Leader and Tenure Track Professor at my university. This time was hard, because colleagues subtly tried to question the fact that I deserve this grant. I was the first of the faculty that received it at a quite young age" (ID7).

Another social challenge was inequality (n = 8). For example, working in the Global South presented additional challenges for women academics (e.g., due to the lack of research capacity and funding, publishing, and progress in the field of interdisciplinary marine research). One participant commented: "[It is] harder because of our 'developing country' status [a challenge] has been access to funding for research and student support. There is no national or even regional science fund to which we can apply annually, as is the norm for many developed countries" (ID29). Finally, while mentioned less frequently, participants also outlined a range of financial, individual, political, and other challenges (summarized in Tables 1 and S3).

Gendered challenges experienced by women leaders

First, participants were asked whether they had experienced unique challenges, compared with males in the same position. Within our study, 24 out of our 34 (70.6%) participants perceived from their experiences that interdisciplinary marine research was more challenging for women leaders and they would expect to spend more time on overcoming issues compared with male colleagues. One participant stated: "Marine and interdisciplinary research are traditionally considered as male dominant area thus having a female leading the project is assumed as 'less convincing'" (ID18). Some perceived that it placed them in a double bind due to gender stereotypes and negative perceptions of interdisciplinary marine research. This was exemplified by one participant who stated: "I think a lot of single discipline senior men view interdisciplinary work as fluffy and not solid. So that's a definite barrier" (ID13). This was in contrast to seven participants who thought that it was not more challenging for women leaders (23.5%) and two participants who were unsure (5.9%). For example, some participants considered that interdisciplinary marine research may be more suited to women's skill sets or values (e.g., communication skills, multitasking and flexibility). One participant stated: "I think women more easily see the value of interdisciplinary science. And they more clearly see that it is actually a particular skillset, working across the disciplines in an effective way is a particular skillset. And I don't think that is often recognised by, or it's less likely to be recognised by males" (ID14).

Second, participants were asked whether there were unique challenges for women scientists seeking to lead interdisciplinary marine research compared with discipline-specific research. Within the study, 17 out of 32 (53.1%) thought that interdisciplinary marine research was more challenging than

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Table 2. Analysis hierarchy of gendered challenges to women's leadership

Theme	Subtheme	Frequency[a]	No. of sources[b]
Social	isolation and underrepresentation	51	24
	stereotyping	41	19
	expectations of women	41	19
	engagement in external activities	18	12
	power imbalances	13	8
	lack of awareness of gender issues	6	5
Practical and process	parenthood and caring responsibilities	51	27
	"glass ceiling"	22	14
	job insecurity	8	5
	gender pay gap	4	4
Individual	gaining credibility	40	22
	bullying	25	14
	self-confidence	12	7
	acceptance of women leaders	10	8
	sexual harassment	8	7
	appearance	6	4
Institutional	institutional policies and support	23	13
	workplace and academic culture	9	8
	hiring and evaluation	7	6
	institutional structures	4	3
Financial	lack of suitable funding opportunities	3	3
Other	no gender-based challenges or unable to identify them	24	13
	miscellaneous[c]	11	7

Analysis hierarchy of themes derived from research participants related to gendered challenges to women in leadership within academic interdisciplinary marine research institutions (n = 34). The themes are ordered from most frequently mentioned to least frequently mentioned.
[a]Frequency refers to the number of times a theme was coded across all interview transcripts.
[b]The number of sources represents the number of unique interviewees (i.e., participants) who raised the theme during the interview process (maximum potential n = 34).
[c]Miscellaneous topics described by participants (e.g., lack of expertise in mentorship and the COVID-19 pandemic).

discipline-specific research for women leaders. Participants commented on the additional demands and mental load required for interdisciplinary marine research (e.g., gaining new skills and knowledge and engaging with a range of disciplines) that can negatively affect women leaders who are time poor (e.g., due to domestic burden). One participant stated: "[Women scientists] might be challenged with learning new research methods which require broad knowledge of different disciplines applied to marine research. Again, time—burden makes it challenging to seek sufficient time to seek new or advanced knowledge" (ID23). This contrasted with 11 participants who did not think that interdisciplinary marine research was more challenging for women to lead compared with discipline-specific research (34.4%) and 4 participants were unsure (12.5%). For example, some participants thought that interdisciplinary marine research presented more opportunities for women compared with single-discipline research because: (1) it has greater (gender) diversity and representation, (2) it is a newer, open, and less-competitive research area, and (3) it is more forward-looking and is more fluid compared with discipline-specific science. As exemplified by one participant, "…, because the mono-disciplines have been developed for centuries and they are more competitive and for women it's more difficult also for cultural reasons. And interdisciplinary science is something newer and perhaps because it's a more open new niche there are more opportunities for women in this niche" (ID31).

Third, participants were asked to reflect on the gendered challenges they faced as a woman leader in interdisciplinary marine research. Over 60% of participants perceived that they had faced gendered challenges and identified the types of barriers and challenges (21/34; 61.8%). However, just under 40% of participants stated that they had not faced any specific gender-based challenges or were unable to identify them (n = 13; 38.2%). In total, 23 specific barriers were identified and categorized into the following themes: (1) social, (2) practical and process, (3) individual, (4) institutional, (5) financial, and (6) other (see Table 2 and Figure 1). The ten most frequently discussed gendered challenges (or subthemes) are presented in the right column of Figure 1. Further information on each of the subthemes (with example quotes) are shown in Table S4.

Social barriers were the most commonly discussed gendered challenge by participants (see Table S2). This theme was further described by six subthemes (see Table 2). Of these, the most frequently mentioned social challenges were (1) isolation and underrepresentation (n = 24), (2) stereotyping (n = 19), and (3) expectations of women (n = 19). First, participants commented

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on the feeling of isolation as a woman leader in academia due to the male-dominated environment and lack of women role models. One participant stated "… the men who have these positions, it's not like they're male chauvinists, not at all, but how did we end up in this situation where all the professors are male? It's got to be something that is not an accident" (ID5). Second, over half of participants considered stereotyping to be an issue in academia. Participants highlighted various gendered stereotypes that they had observed within academia and there was some variation across disciplines, countries, and cultural contexts. This included women academics being considered as: (1) less able leaders, (2) having an inferior performance on quantitative or mathematics-related tasks, (3) being weaker and less able to take on physical tasks (e.g., during fieldwork), (4) having caring characteristics (e.g., compared with men who are associated with confidence, dominance, and self-reliance), and (5) being mothers or carers rather than scientists and leaders. Experience of this stereotyping was exemplified by one participant who referred to "… the ancient setting with women taking care of children and home, and men as being busy businessmen or hunters, whatever, is also shown in the academy" (ID8).

Third, expectations of women research leaders were also seen as a social challenge; these are the internally and externally applied beliefs of how women leaders should behave and the standards they should meet. Many participants perceived that there are double standards when comparing men and women working in academia. As illustrated by one participant: "I think the expectations for women by women and men, like by everyone, are higher … if a woman does something wrong or whatever it's like well they should know better, men get away with it because they're men, but women should know better" (ID13). Furthermore, participants discussed the perception that women are expected to work harder than male colleagues to be successful and are subject to greater judgment (e.g., their work and behavior): "… females have to work harder to get the results and the buy-in" (ID27). Although mentioned less frequently, other social challenges related to: (1) engagement in external activities (e.g., experiencing stereotyping and sexualized behaviors when undertaking fieldwork, cruises, and stakeholder engagement; n = 12), (2) power imbalances (i.e., the unequal distribution of control and power held by men and women; n = 8), and (3) a lack of awareness of gender issues in wider society (n = 5; see Table 2).

In addition to the social challenges outlined above, participants also discussed several practical and process challenges (see Table 2). Most participants mentioned that parenthood and caring responsibilities were a barrier to women's leadership (n = 27). Some highlighted that women leaders often had to make a decision and trade-off between work and having children, which was not perceived to be the same for the majority of men. Of those who had decided to have children, they continued to face trade-offs and barriers after they had given birth, particularly during the COVID-19 pandemic. As one participant stated: "… many female colleagues suffer from being both a leader and top researcher and a mother. This has been especially an issue during COVID-19" (ID7). Women scientists experienced isolation and the challenge of balancing work and home life, which had career implications (e.g., being unable to attend conferences, meetings, and fieldwork trips, as well as having negative effects on their career trajectory). One participant described how they "… have a huge responsibility as a mother, wife and care-taker of the family. These expectations weigh heavily on me and imposed limitations on my capabilities to excel in academia" (ID23).

Participants also highlighted the often unseen and unsanctioned barriers that prevented women academics securing leadership positions (n = 14). This is commonly known as the "glass ceiling": "… the glass ceiling that is often talked about is very much there and it comes in extremely cyclic forms and it's most powerful if one doesn't talk about it openly" (ID9). Participants discussed the lack of equitable access to leadership positions for women scientists and situations where they themselves or colleagues had been blocked, delayed, or held back from promotions and career opportunities (e.g., due to gender stereotypes and external responsibilities, such as parenthood). For example, "… there is prejudice in the university work environment: women take longer to be promoted and must publish more than men for the same promotion" (ID28). This was in addition to challenges, such as job uncertainty or insecurity (e.g., due to short-term contracts and having to move for work; n = 5) and the gender pay gap (i.e., men having higher salaries; n = 4).

Participants also identified several individual (i.e., personal) challenges facing women leaders. Over 60% of participants perceived that gaining credibility was a barrier for women scientists, as many had an expectation of different or diminished interests or abilities due to their gender (n = 22); exemplified in the following: "… there are some things that don't come to us for granted, you don't get it straight away, you have to roll twice as much so there's that barrier in terms of prompt recognition, so we don't get recognition as fast" (ID29). In addition, they had been given different tasks to men: "There's still an expectation that in a meeting of senior scientists, any women present are the best people to take the minutes" (ID6).

Bullying was also identified as an individual challenge (n = 14). Participants recalled subtle workplace discrimination, particularly from senior colleagues, and observed belittling, misogynistic unprofessional remarks, and incidences of microaggressions. For example, "I was told that I would never make it to full professor because everyone knows female professors are ruining the University … [also] men have challenged the way I have said something i.e. the pitch of my voice" (ID17). Microaggressions included "mansplaining," which describes an explanation, usually offered by a man, which is patronizing, condescending, or ignores women's experience and knowledge.[73] Another type is "hepeating" which occurs when a male colleague appropriates comments or ideas that were originally highlighted by a woman and is praised for them being his own. However, some participants also highlighted times when there had been more blatant forms of bullying, including arguments with men in the workplace. This was highlighted by one participant who said that: "I have once had a conflict with a senior colleague (a professor) that got a bit out of hand, where he on the phone strong-armed me and said he would personally take care I would not have [anything] to do with the topic-area about which we were in disagreement" (ID12). Other individual challenges, included: (1) women scientists lacking confidence in their ability (n = 7), (2) limited acceptance

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Table 3. Analysis hierarchy of enablers of women's leadership

Theme	Subtheme	Frequency[a]	No. of sources[b]
Social	support and encouragement from superiors	54	21
	support and encouragement from peers	27	16
	informal networking	23	14
	formal networking	12	7
	role models for women scientists	10	8
	male allies	5	5
	support and encouragement from family and friends	4	4
Practical and process	mentoring schemes	31	14
	increasing visibility and exposure of women scientists	14	9
	offering leadership training and schemes	12	8
	career planning and coaching	10	8
	offering interdisciplinary research training	10	5
Institutional	implementing diversity, equity and inclusion policies	21	13
	creating a family-friendly environment	19	12
	improving academic or workplace culture	17	13
	raising awareness and understanding of gendered issues	12	8
	providing women scientists with opportunities for leadership	14	9
	increasing institutional support and capacity	12	7
	offering flexible working	7	5
Individual	adopting specific characteristics and/or behaviors	54	20
	putting women scientists forward for career opportunities	16	11
	adopting research strategies	17	12
Financial	providing funding for women scientists	14	11
Other	miscellaneous[c]	10	9
	no strategies or enablers	2	1

Analysis hierarchy of themes derived from research participants, related to enablers of women's leadership within academic interdisciplinary marine research institutions (n = 34). The themes are ordered from most frequently mentioned to least frequently mentioned.
[a]Frequency refers to the number of times a theme was coded across all interview transcripts.
[b]The number of sources represents the number of unique interviewees (i.e., participants) who raised the theme during the interview process (maximum potential n = 34).
[c]Miscellaneous topics described by participants (e.g., evaluation of institutions and 360° reporting).

of women leaders (n = 8), (3) sexual harassment, and (4) appearance (i.e., being judged on their physical characteristics). Finally, while mentioned less frequently, participants also outlined a range of institutional, financial, and other gendered challenges (summarized in Tables 2 and S4).

Enablers of women's leadership

Our third objective was to identify enablers of women's leadership, including the promotion, and subsequent success, of women's leadership (e.g., systems, processes, and strategies). Participants were asked to suggest enablers that they had observed or applied as a leader, without having a list of enablers to select from. Thirty-three participants identified strategies and enablers that could be used to support women in leading interdisciplinary marine research. There were 25 subthemes, categorized as follows (1) social, (2) practical and process, (3) institutional, (4) individual, (5) financial, and (6) other (see Table 3). The ten most frequently mentioned enablers (or subthemes) are presented in Figure 2. Further information on each of the subthemes (with example quotes) are shown in Tables S5 and S6.

The majority of participants highlighted social strategies or enablers (see Table S2). Of these, the most frequently mentioned subthemes were support and encouragement from (1) superiors (n = 21), (2) peers (n = 16), and (3) informal networking (n = 14; Table 3). Participants perceived that support and encouragement from superiors was an important enabler: "A leader that embraces and supports you makes a big difference" (ID1). Participants highlighted the support they had received as part of their careers, as well as how they supported and encouraged their staff. This was followed by receiving support and encouragement from peers, which was mentioned by approximately half of participants. Many participants highlighted the value of being able to talk about their experiences with other groups of women in similar contexts. The type of support and encouragement included giving staff or peers a safe space to discuss any issues; encouragement to apply for roles, promotion, leadership opportunities, and awards; providing feedback (e.g., on research and development); acting as an advocate and increasing visibility. One participant stated "We female-identifying scientists must support each other in getting forward with our careers instead of competing with each other" (ID8).

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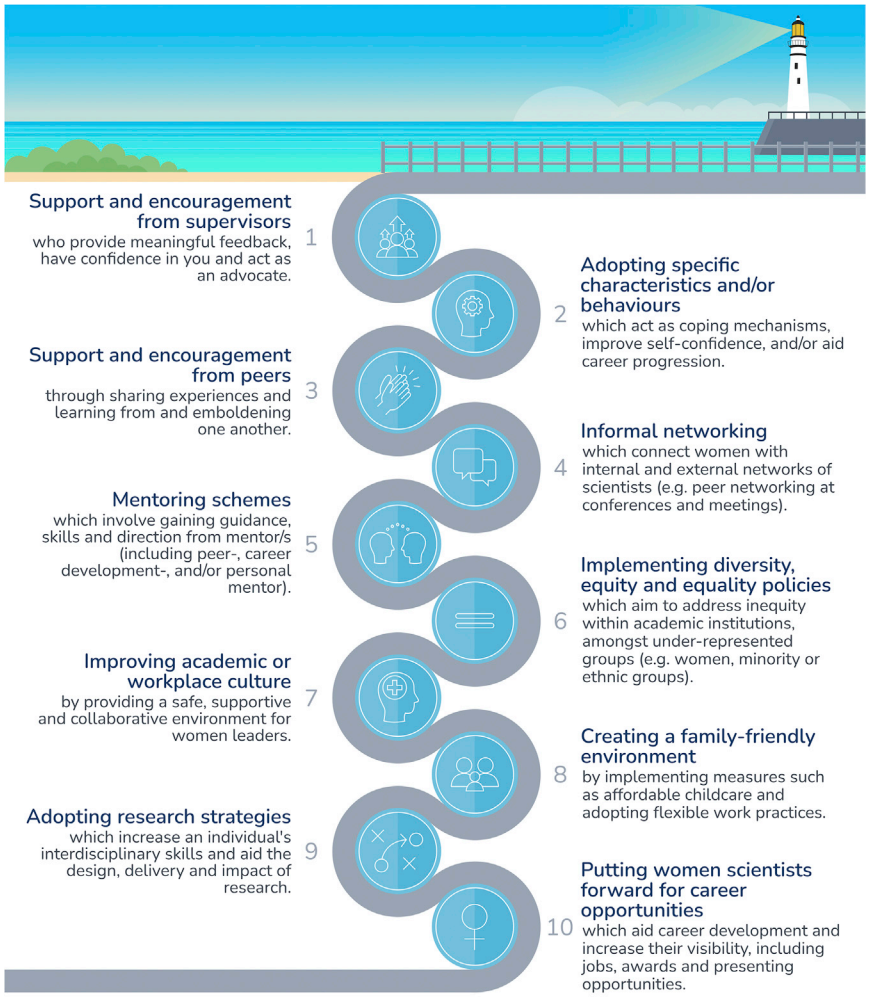

Figure 2. The ten most frequently discussed enablers of women's leadership

The most commonly discussed enablers of women's leadership, including systems, processes, and strategies (n = 34). For the purpose of this study, a "leader" is defined as a researcher who holds some form of leadership role at any level within an academic institution (i.e., leading a research institution, team, project, or program).

Another enabler was informal networking, which included networking with colleagues in the workplace, as well as with the wider research community (e.g., at conferences, meetings, and via social media). One participant described how they had encouraged networking and connected their staff with researchers with similar interests: "… let's get that person partnered with somebody with that knowledge or skill set, or, hey, let's go grab that person down the hall to have them interact with, or those sorts of things" (ID14). Although mentioned less frequently, other social enablers included: formal networking (e.g., through established networks or organizations for women; n = 7), role models (n = 8), male allies (n = 5), and gaining support and encouragement from family and friends (n = 4).

Practical and process strategies were also commonly highlighted. Mentoring schemes were the most frequently mentioned enabler (n = 14). As exemplified by one participant, "No scientist can thrive in complete isolation, and none of the success I have experienced could have been achieved without supportive collaborators, mentors and organizations" (ID10). Another identified enabler was the use of mechanisms to increase visibility and exposure of women scientists (e.g., through the media, social media, and on podcasts; n = 9). Raising awareness and visibility of women scientists was perceived to increase career success, as well as to help promote the uptake of women academics into STEM. One participant stated that, "… the advantage of being a lot in the press and getting a lot of public outreach done and being in the media, that sooner or later most people have heard about my work and then actually it's not so difficult anymore" (ID30). The remaining practical strategies related to professional development. Specifically (1) offering leadership training and schemes to women scientists (n = 8) and (2) offering planning and coaching to help women academics to achieve career progression (n = 8).

Institutional strategies were also a commonly raised category, yielding seven subthemes (see Table 3). The implementation of diversity, equity and inclusion policies was seen as an important strategy (n = 13), and included references to unconscious bias training, gender quotas, gender neutral applications, and equal pay. One participant stated "In my university, we are strong in gender promotion and gender equality. We have a Gender and Development Office that ensures gender is mainstreamed in the policies, plans, activities" (ID21). Creating a family-friendly environment within academic institutions (n = 12) was seen as important. For example, by implementing measures, such as affordable childcare, adopting flexible work practices, and facilitating reentry after maternity leave: "I think that the universities should be more giving, they should give more support to mothers so that they can keep working, and not get so alone" (ID29). Other institutional strategies included (1) improving academic or workplace culture (n = 13), (2) raising awareness and understanding of gender issues (n = 8), (3) providing women scientists with opportunities for leadership (n = 9), (4) increasing institutional support and capacity (n = 7), and (5) offering flexible working arrangements (n = 5). Finally, individual, financial and other challenges were also discussed (summarized in Tables 3, S5, and S6).

DISCUSSION

It is long established that a diversity of leaders is essential for identifying innovative solutions for complex environmental challenges.[1,2] This is particularly the case for interdisciplinary marine research, which draws on diverse forms of knowledge, methods,

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and skillsets and mobilizes diverse networks, to navigate marine socio-ecological challenges.[20] Yet, women scientists are less likely to be in positions of leadership within academic interdisciplinary marine research institutions and projects compared with their male colleagues. This study sought to better understand the main barriers and enablers to women leadership's in interdisciplinary marine research. A broad framing of leadership was employed (i.e., leadership of research institutions, teams, projects, or programs) reflecting the multi-dimensional nature of academic leadership and the cultural practice of different geographical contexts. This paper provides novel insights at the intersection between gender and interdisciplinarity within the context of marine science.

Challenges of interdisciplinary marine research

Through this study, we developed a comprehensive understanding of the main challenges and barriers of working in academia and undertaking interdisciplinary marine research, as perceived by women leaders. Leaders face a range of challenges stemming from their role in academia and interdisciplinary marine research. Many of these challenges are likely to be non-gendered. This finding is reinforced by previous research that has identified the challenges faced by leaders (regardless of gender) working within academia more broadly.[64,74,75] It is unsurprising, as mechanisms within academia tend to reproduce dominant orders and persisting hierarchies and inequalities.[76] However, we acknowledge there may be some overlap with gendered challenges, as academic institutions, processes, and careers have been described as gendered in multiple aspects.[77]

Institutional barriers, such as limited institutional support and capacity, academic or workplace culture, and institutional structure and policies, were highlighted by participants. As highlighted previously, many barriers are embedded into institutional and departmental practices.[55] Leaders discussed the lack of available support and capacity within their institutions (e.g., aiding research, teaching, and administration) and the limited or restrictive institutional structure and policies, identified in previous research as hierarchical structures.[78] In combination, these two institutional challenges were perceived to affect a leader's ability to undertake research (e.g., due to lack of administrative support), apply for and successfully obtain funding, progress with their research goals, and undertake career development. The leaders also experienced issues associated with academic or workplace culture. Previous research has shown that the academic culture in marine research[64] and other STEM disciplines more broadly, is associated with explicit and implicit norms, such as long working hours and having high workloads.[43]

The study results suggested that interdisciplinarity presents a significant barrier. This is due to the various disciplines and fields encompassed within interdisciplinary marine research (i.e., being a jack of all trades and keeping up with the literature), the upskilling required, the various actors to engage with (e.g., academic and stakeholder groups), and the time required to build effective interdisciplinary collaborations. There was also a perception of a lack of recognition and value attributed to interdisciplinary marine research. Interdisciplinary marine research was seen to be marginalized and underfunded in comparison to natural science disciplines. There were also challenges connected with working with researchers from other disciplines, due to differences in terminology, epistemologies, and power relationships. Overall, the study suggested that interdisciplinary marine research presents an additional layer of complexity for scientists and can be more challenging and demanding than single discipline research. This is consistent with the findings of previous studies examining interdisciplinarity in marine research[68] and in STEM more broadly.[65,79–82] For example, research suggests that interdisciplinary marine research is highly complex and presents a steep learning curve for both men and women, transitioning from single discipline science.[64] Furthermore, the multifaceted nature of interdisciplinary marine research can put academics at a disadvantage in terms of research productivity when compared with single disciplinary science.[83]

Third, we identified that not all leaders experience the same challenges, and that their individual experiences were dependent to some degree on the social environment they had worked and work in (i.e., social challenges[54]). Bias and prejudice can affect a scientist's workplace experiences and inhibit career progression, but the impact of "glass ceilings" are more pronounced for specific groups. In line with previous research, challenges experienced by leaders were compounded when considering race, ethnicity, nationality, age, and socio-economic status.[33,84,85] For instance, scientists belonging to minoritized groups can face a "double bind" caused by the interplay between racism, sexism, and other systematic biases and cultural barriers.[85–88] Indeed, previous work suggests that minoritized groups are still underrepresented within marine research,[89] government,[27] and conservation and environmental organizations.[90]

A lack of diversity in STEM can be attributed to gatekeeping, systemic issues of neo-colonial and globalization research practices and direct harm to individuals and groups.[33] Policies and management hierarchies can maintain the status quo, where the cultural majority remain in positions of power and dominance, similar to that where male hierarchies can lead to gendered monocultures. Cultural biases may disadvantage women and ethnic groups who do not model leadership behavior on traditional white male styles of management.[16,52] Our study also highlighted the inequity between scientists in the Global North and South, with the Global North being advantaged in terms of capacity, funding, and publishing. These unequal research conditions have resulted in the phenomenon of parachute science,[91] in addition to the underuse of non-English-language science.[92] Our findings are in line with earlier research, which highlighted that the combination of persistent geographic bias has resulted in scientists in the Global South being significantly underrepresented in publishing, which may further contribute to their underrepresentation in future leadership positions.[1,66] Overall the lack of diversity and inclusion of underrepresented individuals and groups can lead to missed opportunities to harness the perspectives and ways of knowing held by diverse experts,[33] which is required to advance social equity and address ocean sustainability challenges in the 21st century.[93]

Gendered challenges experienced by women leaders

This study provides novel insights on the perceptions on the intersection between gender and interdisciplinarity. Our exploratory study suggests that interdisciplinary marine research may be more challenging for women leaders compared with

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men. Over 70% of women leaders that took part in this study perceived that interdisciplinary marine research was more challenging for women, as they experience a range of gendered barriers, including expectations of women and a lack of trust and acceptance of women leaders (see below for further details). Previous research suggests that women are more drawn to interdisciplinary marine research, have various skills, values, and behaviors that make them suited to this type of research,[62] and can increase the success of interdisciplinary marine research.[15] Despite their suitability and expertise for interdisciplinary marine research, it appears that women leaders still face more challenges than men in the same field.

There was less agreement as to whether there were unique challenges for women scientists seeking to lead interdisciplinary marine research compared with discipline-specific research. On the one hand, participants thought that interdisciplinary marine research presented additional challenges for women leaders. Interdisciplinary marine research is an emerging approach and presents further complexity for leaders and therefore increases work and mental loads. These challenges may be greater for women due to the gendered challenges they face in the workplace as well as the domestic burden they experience. On the other hand, participants thought that interdisciplinary marine research was not any more challenging than discipline-specific research and actually may benefit women leaders. This reflects the findings of previous research.[94] Participants reported various reasons, including (1) interdisciplinary marine research being a newer, open, and less competitive research area, (2) there being higher diversity and representation in interdisciplinary marine research, and (3) interdisciplinary marine research being a more forward-looking and more fluid area when compared with discipline-specific science.

The notion of barriers to women's leadership has received considerable attention in related fields (e.g., ecology and conservation[55]), STEM,[54,84,95] and in academia more broadly.[47,96] Research is strong on identifying barriers encountered by women scientists in academia; however, such research has rarely explored the barriers faced by women leaders in interdisciplinary contexts and within marine science. Reflecting the results of previous studies, we find that the majority of women have experienced a wide range of additional barriers and challenges owing to their gender (i.e., gendered challenges).[47,54,84,97] This suggests that the barriers experienced within interdisciplinary marine research are of a similar nature to those encountered in other STEM fields. The women leaders articulated a wide range of barriers they had experienced, which together form the "labyrinth" or the "glass obstacle course."[50] These barriers affect their day-to-day role, mental wellbeing, job satisfaction, success, and career progression.[54,84,96] Gendered barriers are socially constructed and reflect the societal views of what men and women should or should not be, or can and cannot do, and how people should relate to each other in households and society.[98,99]

Social barriers were the most commonly discussed gendered challenge discussed by participants. In line with previous studies, women felt isolated and underrepresented, often due to the male-dominated environment (also referred to as the "boys club" or "old boys club"[70]) and lack of women scientists occupying upper divisions of academia. Previous research has shown that women scientists can face a "chilly climate" when exposed to masculine institutional cultures and patriarchal systems.[100–102] These environments maintain male dominance and make it difficult for women scientists to feel comfortable and gain authority.[103] This has important implications, as women scientists may feel stressed, isolated, marginalized, demoralized, and subsequently are demotivated from seeking career progression.[27,104]

Gender stereotyping and expectations were also pervasive issues identified through our study. Stereotyping occurs when people assign characteristics to (members of) groups regardless of actual variation in people's characteristics. In agreement with previous research, participants recalled situations where they had observed or received subtle or blatant comments that reinforced stereotyping of who "does" science.[54] These stereotypes reflect previous work in STEM.[99,105–107] Stereotypes paint women scientists as having low status and power, which can lead to stigmatization and for others to devalue them.[43] This is significant as it may make it more difficult for women academics to reach positions of leadership, gain respect from colleagues, and influence, and can prevent them from fully realizing opportunities in their careers.[108]

Women leaders in this study also contended with prejudice, due to biased expectations of how they should behave and the standards they should meet. This aligns with previous findings which show that women scientists face differential expectations and that double standards apply, meaning that for women to succeed they have to work harder than men in equivalent positions. Moreover, women face a higher bar to pass than men do to advance in their career.[108] Participants in our study perceived that they were subject to greater judgment and discussed the idea of a "tightrope." If they showed too much agency or confidence, they were described as "bossy," but, if they were too communal, they were deemed an ineffective leader. Research has shown that successful women leaders often engender hostility or are not liked and are judged for violating gender stereotypic expectations (i.e., "backlash effects"[52,109]). Overall this can lead to fewer women taking on leadership roles, due to negative evaluations and/or the greater incidence of women being appointed to "glass cliffs," which are situations associated with greater risk and being open to more criticism.[110]

Women leaders also identified two key practical and process challenges that are consistent with the existing literature. First, our study highlighted that some of the challenges facing women are compounded due to parenthood and caring responsibilities and they have been disproportionately impacted during the COVID-19 pandemic. These findings are consistent with previous studies in STEM.[53,84,111,112] Participants highlighted that they often have to make a decision between work and being a mother, because research was often seen as incompatible with raising a family; a finding consistent with an earlier study.[28] The choice of having children or not was perceived to weigh more heavily on the career goals of women scientists due to the disproportionate responsibility women assume for domestic duties. In addition, it was perceived that parenthood had resulted in a slower rate of career advancement due to balancing work and home life, and it was often exacerbated by un-family-friendly structures and policies, the culture of academic institutions (e.g., long hours, required travel and relocation), and un-career-friendly family structures.[113]

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Women face social reproduction burden (or domestic burden) due to the unpaid and undervalued work that women undertake as mothers, carers, and teachers, particularly during the COVID-19 pandemic.[114] This confirms the findings from previous research.[43,84,115] Slow career progression combined with an unsupportive environment has been shown to result in poorer research "track records" for women scientists[83,116] and even abandonment of research careers.[28] Second, in this study, career progression was also perceived to be inhibited due to the often unseen and unsanctioned barriers that prevented women from securing leadership positions (i.e., the "glass ceiling"[109,117]). There was a feeling that fewer women were tapped on the shoulder compared with men and they were being excluded from career advancement opportunities. This affirms previous work that has identified the glass ceiling as a career-hindering barrier in academia.[47]

Taking the findings together, this study highlights that interdisciplinary marine research may be more challenging for women leaders compared with men. Women leaders experience a host of challenges associated with working within academia and undertaking interdisciplinary marine research. These challenges exacerbate the existing gender-specific issues they experience in marine research.[64] Our study suggests that these barriers can overlap and intersect—and are particularly challenging for women in minoritized groups due to prejudice, discrimination, and inequality. More in-depth analysis is required to examine whether there are unique challenges for women scientists seeking to lead interdisciplinary marine research compared with discipline-specific research. Overall, enablers are required to tackle the complex and diverse challenges facing women in interdisciplinary marine research.

Enablers of women's leadership

This study adds to the substantial evidence base documenting the barriers that women scientists experience in STEM, but focuses specifically on actionable strategies to support women leaders within academic interdisciplinary marine research institutions. Participants highlighted a range of formal and informal mechanisms for supporting women leaders.

Social enablers were the most frequently mentioned type of enabler, which aligns with previous research.[49,70,95,116] Previous studies suggest that support for women scientists comes from people, rather than training or institutional structures.[84] Participants reflected on the importance of having an internal and external network of support during their career and having role models and encouragement from various sources (e.g., from leaders, peers, male allies, and family and friends).[118,119] For example, women leaders and role models can provide advice on how to successfully negotiate the academic labyrinth, increase empowerment, counteract the negative effects of stereotypes,[21] and pave the way for women scientists that come after them.

Networking opportunities (informal and formal mechanisms) were also seen as an important social enabler for the promotion and success of women's leadership, consistent with previous findings.[101,103,120] Previous research suggests that career advancement is often dependent on building good social networks (or "social capital") and can involve breaking into the "boys club" or creating a women's club.[51] Networking can create a community of belonging and resistance,[121] support women scientists in forging a scholarly identity,[122] and provide them with information and material support (e.g., information relevant to career advancement[116,120]) and intellectual and political resources to deal with gender bias and discrimination.[57] Formal networks were discussed and included engaging with networks, such as the Gender in Aquaculture and Fisheries network, the Organization for Women in Science, and Women of the Reef. However, informal networks were mentioned more frequently. Women leaders predominantly discussed the significance of meeting and socializing with academic peers in the workplace. They highlighted the importance of informal networks for collaboration, as well as their role as a safe space for women to vent, share their experiences, and discuss how to navigate being a woman and interdisciplinary scientist in marine research. Previous research has shown that women tend to underestimate their personal networks far more than men and that face-to-face meetings are important for developing women's networks.[123] These findings are particularly interesting in a time when face-to-face networking has been limited due to the COVID-19 pandemic. It will be important to find out more about how this has impacted women's leadership and how the next generation of leaders will form such informal networks across disciplines.

Practical and process enablers were also important for supporting women's leadership and could help to reduce gender disparity within academic settings.[103,124–126] Practical strategies included mentoring, raising the visibility and awareness of women scientists, professional development training (e.g., leadership and interdisciplinary research skills), and career planning and coaching. However, mentoring was the most popular strategy. Various forms of mentoring were discussed, including peer, career development, and/or personal mentoring. Mentoring can be implemented by academic institutions in addition to external organizations (e.g., learned societies and research networks). Mentoring is increasingly recognized as a critical element for supporting career progression,[64,109] particularly for academics from minoritized or underrepresented groups.[127,128] Previous research suggests that mentees gain career development guidance, psychological, and moral support and encouragement, it can increase their resilience[129] and sense of voice,[130] and can alleviate their uncertainties about academic life.[17] Consequently, mentored academics are more likely to get promoted to positions of leadership, have increased commitment to the institution (i.e., reduced attrition), and receive more grant income.[116,131,132]

Mentoring needs to be effective, rather than just existing as an institutional measure. Well-designed and implemented mentoring can drive transformation toward a fair and safe scientific culture[16] and provide a significant return on investment.[17,116] Academic institutions that draw on best practices will be more likely to deliver successful, multi-dimensional, and inclusive mentoring programs.[16,133,134] It is beyond the scope of this study to examine specific dimensions of successful mentoring practices and examples of effective programs. However, previous research has identified a range of attributes that are important for mentoring programs,[135–139] for example (1) integration of mentoring schemes into a broader program that targets institutional change in combination with improving women's

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individual development (i.e., the "bifocal approach"), (2) clear delivery objectives for the mentoring program (i.e., for the mentor, mentee, and the institution), (3) delivery of training sessions and resources for mentors and mentees within the program (e.g., development of mentoring skills, guidance on the mentor-mentee relationship, and training around the challenges faced by women and minorities in academic institutions), and (4) rigorous evaluation of the program. Successful mentorship is vital to career success and satisfaction for both mentors and mentees. Yet challenges continue to inhibit faculty members from receiving effective mentorship. Given the importance of mentorship on faculty members' careers, future studies must address the association between a failed mentoring relationship and a faculty member's career success, how to assess different approaches to mediating failed mentoring relationships, and how to evaluate strategies for effective mentorship throughout a faculty member's career.

Our study also highlighted the importance of institutional enablers. Institutions are important for creating an inclusive and diverse research community and to overcome barriers experienced by academics and minoritized groups.[7,48,140,141] This includes the implementation of policies, systems, and processes that address diversity, equity, and inclusion (e.g., unconscious bias training, gender quotas, gender neutral applications, and equal pay), which has previously been advocated for.[8,11,142] Although mentioned by participants, alternative mechanisms to support women were more popular, i.e., providing them with development opportunities, and improving the culture of academia within interdisciplinary marine research. This is in line with previous research.[22,143,144].

Participants also highlighted the challenges they had faced during the COVID-19 pandemic and encouraged the employment of policies that could help tackle inequalities associated with parenthood and caring responsibilities. This included creating a family-friendly environment (e.g., provision of affordable childcare) and offering flexible working for carers.[22,53] Research has shown that such measures are essential for making leadership roles more accessible and inclusive[145] and in recruiting, retaining, and advancing high-quality faculty staff.[55] They also highlighted the importance of improving the academic or workplace culture for women leaders (e.g., providing a supportive environment, asking individuals and groups to call out toxic behavior, and changing the culture of working long hours). Research suggests that women have higher levels of job satisfaction, productivity, and less social isolation when working in a positive or supportive departmental climate.[146] Other commonly discussed enablers included raising understanding and awareness of gendered issues, offering more opportunities for women' leadership and increasing institutional support and capacity (e.g., providing more administrative support), which have been acknowledged previously.[140,147]

Applying enablers of women's leadership

The enablers presented may help to progress toward gender equity and inclusion in interdisciplinary marine research. A conscious and targeted approach will be important for creating an academic environment that offers equal opportunities to women leaders and giving them the ability to influence strategic decisions in marine research and beyond.[22] This research may have a variety of applications at various scales (e.g., individual, project, team, department, program, and institution level). These findings can serve as a roadmap for institutions wishing to promote and support women's leadership in interdisciplinary marine research, particularly those from underrepresented groups (e.g., ethnic minorities and scientists from the Global South). Institutional enablers, in particular, may aid planning and design of gender or broader equity, diversity, and inclusion action plans. Institutions and the wider scientific community increasingly need to address deeply embedded institutional and cultural issues and commit to increased action and accountability to accelerate positive change.[33]

In addition, these findings may also be useful at the individual level, for both women and men wishing to enter leadership positions, or those currently in leadership positions. It may aid women in identifying strategies for change and career development (e.g., training, mentoring, and networking) and help them to advocate for such opportunities within internal and external institutions. However, gender equity is not a "woman's problem"[54]—women should not solely have the responsibility to support one another.[104] Men will need to be allies and "lean in" to their roles in addressing gender inequity in academia[148] as they have distinct opportunities to be influential advocates to create change.[149]

In highlighting these enablers, we do not wish to deny the complexity of the gender gap, the scale of gender discrimination in society, and the cultural practice of different geographical contexts. Nor do we imply that these enablers should serve as prescriptions of a set of strategies applicable in all contexts. Rather, we aim to highlight the range of potential options available for application at a variety of scales and call attention to the need to tackle the invisible and often unspoken challenges facing interdisciplinary marine leaders, particularly those from minoritized groups.

Limitations and future research

Through this study, we have developed a deeper understanding of the barriers and enablers of women's leadership in interdisciplinary marine research contexts. This study is exploratory in nature and is not comprehensive, nor is it intended to be. Therefore, there are important limitations to our study that are worth consideration. Reflecting on these limitations helps to provide recommendations for future research, which can further explore and tackle the gender inequity observed in interdisciplinary marine research and academia, more generally.

First, the barriers and enablers to women's leadership are based on the perceptions of a selection of women leaders working in academia and specializing in interdisciplinary marine research (see Table S1). We used a non-probability approach, purposive and snowballing techniques, and had specific inclusion and exclusion criteria; hence, it is not a representative sample of the wider population of interdisciplinary marine women leaders. Nevertheless, this exploratory study provides a useful look into the types of barriers that may be experienced by women leaders and how to address these challenges in various interdisciplinary marine research settings. Future research is required to build on this study. Interdisciplinary

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marine research may have been a limiting concept and instead it may be organized in a different way across regions and cultures. Studies could focus on the barriers and enablers of women's leadership in geographic regions that are often underrepresented or excluded from interdisciplinary marine research (e.g., the Global South and non-OECD countries). For example, examining any regional differences in barriers and enablers (e.g., comparison of the Global North versus Global South). This would provide valuable insights into geographic differences and provide recommendations on how to better foster and support gender and geographic representation within institutions and funding structures. In addition, the criteria excluded women leaders working on interdisciplinary marine research and practice in wider sectors, such as NGOs and government bodies. Therefore, researchers could explore the perception of women working in these broader interdisciplinary marine settings, who also have a key role in tackling ocean sustainability challenges.

Second, women leaders were invited to participate in and co-author this research (see Note S1). Our choice to collaboratively produce this research is consistent with a growing number of scholars who underscore the importance of co-producing gender research with those who have everyday, expert, and/or scientific gender knowledge. This process can: (1) help to produce more rigorous knowledge of important practical experiences and (2) flatten power hierarchies that can be felt within traditional research, as it brings in minoritized groups to the center of knowledge produced about and by them.[150,151] Although every effort was made to reduce bias, inviting participants to be co-authors on the paper may have influenced their responses to our questions about barriers and enablers of women's leadership.

Third, we examined (1) challenges associated with academia and interdisciplinary marine research and (2) gendered challenges experienced by women leaders. Challenges associated with academia and interdisciplinary marine research appear to be the non-gender-specific barriers that participants had experienced as a leader. Such challenges have been discussed previously in the context of the academia and interdisciplinary marine research. However, given the exploratory nature of the study and survey sample it is impossible to confirm that they are ungendered. Further research could explore whether and the extent to which the academic and interdisciplinary challenges are also experienced by men (i.e., non-gendered) or whether they are gendered challenges. Moreover, the extent to which gendered challenges are being addressed within academic institutions across the world could be productively explored through future research.

Fourth, through this study, we elucidated a range of enablers for supporting women's leadership. However, we were unable to assign relative importance to, or the effectiveness of, each of the systems, processes, and strategies identified in the study. Furthermore, we were unable to determine the career stage at which these enablers are most effective (i.e., early, mid, and late career). Thus, while outside of the scope of this study, we believe that additional research is needed to evaluate the effectiveness of the enablers in practice, when applied at different career stages, to determine the most appropriate strategy or suite of approaches for promoting and supporting women's leadership in interdisciplinary marine research. This would also require the development of a holistic evaluation and monitoring program, building on literature examining the impact of interventions, such as mentoring programs.[16,127] Interventions are gradually on the rise in various institutions, but their effectiveness has had little exploration.

Finally, we acknowledge that the articulation of women participants presents a potentially limited perspective of the barriers and enablers. Intersectionality issues emerged through the interview responses (i.e., coded as "social challenges"), which is reflective of the different experiences of participants, and aligns with research on intersectionality.[140] In the absence of nuanced detail, it enabled us to provide a higher-level overview of the overlap between social categorizations, such as gender, race, ethnicity, nationality, and age, as they apply to groups of women leaders interviewed as part of the research. Future studies may wish to focus specifically on intersectionality issues in interdisciplinary marine research and explore the issues raised here. For example, whether women with different academic positions or levels of leadership, ethnicities, cultural backgrounds, and family circumstances (e.g., parent or carer) experience different barriers and enablers in interdisciplinary marine research.

Conclusion

Interdisciplinary marine research is, and will continue to be, paramount to addressing ocean sustainability challenges in the 21st century. The greatest innovation, science, and discoveries will occur when academic institutions harness the power of diversity, of which gender is a critical component. However, to date, women leaders have been underrepresented in interdisciplinary marine research. Interdisciplinary marine research environments must become more gender-inclusive, empowering, and appealing places for women scientists to work. Through in-depth qualitative research, this exploratory study examines the main barriers and enablers to women's leadership in an interdisciplinary marine research context. The research identified that the majority of women leaders in this study experience a "glass obstacle course" of barriers and challenges, which have affected their day-to-day role, success, and career progression. Leaders experience challenges associated with working in academia and undertaking interdisciplinary marine research and they are exacerbated by gendered barriers facing women scientists. Our initial research suggests that these barriers overlap and intersect and are particularly challenging for women in underrepresented groups (e.g., ethnic minorities and leaders in the Global South). The study also articulated a range of enablers to promote and support women's leadership. They include: institutional reforms that affect the way both men and women work (e.g., parental leave), social support systems, mentoring, and networking. The implementation of such enablers are not just the responsibility of the women. Gender inequality is a societal issue and targeted actions will need to be applied at various scales (e.g., individuals, teams, programs, departments, institutes, institutions) using both formal and informal mechanisms to achieve transformative change. Going forward, these insights could be used to inform the design of gender equity initiatives, policies, and frameworks that transform barriers into enablers of women's

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leadership, which make steps toward gender equality in interdisciplinary marine research and navigating contemporary challenges to marine socio-ecological systems.

EXPERIMENTAL PROCEDURES

Resource availability

Lead contact

Further information and requests for resources should be directed to and will be fulfilled by the lead contact, Rebecca Shellock (rebecca.shellock@anu.edu.au).

Materials availability

This study did not generate new unique materials.

Data and code availability

The data underlying this article cannot be shared publicly due to privacy of individuals that participated in the study. The data will be shared on reasonable request to the corresponding author.

Choice of approach

We wanted to gain an in-depth understanding of experiences and perspectives of 34 global women leaders representing different nationalities, institutional contexts, and types of leadership roles within academic interdisciplinary marine research institutions. A qualitative approach was selected due to the epistemological and ontological position of the study. Epistemology concerns the question of what is or should be regarded as acceptable knowledge in a discipline.[152] We aimed to produce rich and subjective data and were concerned with generating key concepts. Furthermore, we perceived that: (1) there would be multiple realities and truths based on individual constructions of reality and (2) that realities are constantly changing and evolving.[153] This aligns with interpretivism and the "qualitative" paradigm. The ontological position of the study also influenced how the research was formulated and delivered. Questions of ontology are concerned with the nature of social entities: (1) whether social entities can and should be considered objective entities that have a reality external to social actors, or (2) whether they can and should be considered social constructions built up from the perceptions and actions of social actors.[152] We perceived that social phenomena from our study would be derived from social interactions that are continually changing (i.e., "Constructionism"), which aligns with the ontological orientation commonly associated with qualitative research strategies.[152,153]

Data collection

To address the objectives of this paper, the coordinating authors (R.S., C.C., M.M., M.C.M., J.B., R.K., I.v.E.P., and P.T.) engaged with women interdisciplinary marine research leaders from around the globe. In line with previous work,[54] the common characteristic between all participants was their self-identification as a "woman" in interdisciplinary marine research. While recruitment was for "female-identifying" participants, none of the participants were asked to disclose any detail about their gender identity. The use of "woman" or "women" in this study is acknowledged as presenting an inadequately binary view of gender. However, it is intended to encompass all expressions of female gender identities of the participants in the absence of nuanced detail. Future studies may wish to use a specific gender identity frame of analysis to explore the issues raised here.

The study intended to explore the experiences and perceptions of being a woman leader in interdisciplinary marine research using an intersectional lens. Intersectionality was first introduced by Kimberlé Crenshaw in 1989[154] and is a "theoretical framework for understanding how multiple social identities such as race, gender, sexual orientation, socio-economic status, and disability intersect at the micro level of individual experience to reflect interlocking systems of privilege and oppression (i.e., racism, sexism, heterosexism, classism) at the macro social structural level"[155] (p1267). Using an intersectional lens, we can attempt to better articulate the invisible positions of women scientists who experience multiple disadvantaged statuses.[156,157]

A recruitment email was sent to all women leaders (see Note S1) and they were invited to participate in this research and co-author subsequent publications. The survey was administered between January and June 2021, and each leader had the option of answering the questions via semi-structured interviews (n = 8) or by providing a written response (n = 25). In the case of interviews, the questions were shared with the participants in advance to allow them time to carefully consider their responses and to provide in-depth recollections of their experiences. The interviews were conducted over Zoom and Webex and lasted on average 55 min (ranging from 33 to 69 min).

The study employed an information-oriented, maximum variation approach to sampling (based on Flyvbjerg[158]). The goal of this sampling strategy was not to include all women leaders working in academic interdisciplinary marine research. Instead, it was used to ensure the inclusion of a variety of perspectives and exploration into the types of barriers that may be experienced by women leaders and how to address these challenges in various interdisciplinary marine research settings. The cases were selected on the basis of maximizing diversity of participants (i.e., diversity of leadership, disciplines, and geographic regions) and ensuring the inclusion of diverse perspectives to avoid overlap in geographic areas and where participants were most accessible to the research team (e.g., due to logistical constraints, the study was undertaken in English[159]). The coordinating authors identified relevant participants through "purposive" and "snowball" sampling, which are widely employed methods of sampling in qualitative research.[152,160] The following criteria was used to select participants for the study: (1) they held a form of leadership role at any level (i.e., leading a research institution, team, project, or program), (2) they worked within an academic institution, and (3) their research focused on marine socio-ecological systems. A broader definition of leadership (and hence criteria) was selected for two reasons. Firstly, due to the multi-dimensional nature of leadership within academia, which varies across regions and cultures. Second, previous research suggests that there are still relatively few women reaching more senior positions of leadership (e.g., leading research institutions).[22] This wider definition of leadership enabled us to understand the barriers and enablers to various leadership roles that women have secured in the field and this also aided data collection.

Purposive sampling is a form of non-probability sampling and it was used to sample participants who were relevant to the topic and fitted a specific profile,[161] so that those sampled were relevant to the research questions being posed.[152] We first targeted women leaders within the coordinating author's professional networks (and web searches) and then asked those participants to share contacts who they believed would be relevant to the study (i.e. "snowball" sampling). This step was also used to identify women leaders in underrepresented geographic locations during the first stage (including Africa, Asia, and Latin America and the Caribbean). This was repeated at the end of each subsequent interview, and prospective participants were invited to participate. Leaders were contacted if they met the aforementioned criteria. Overall, 25 participants were identified by the coordinating authors, with a total of 21 taking part in the study. This approach was selected as there was no accessible sampling frame for the population from which the sample is to be taken.[152] Furthermore, by virtue of there being fewer women leaders, the network of interdisciplinary marine women leaders is subsequently quite small; hence, this was the most feasible approach. This was supplemented by 12 participants identified through the snowballing technique, who were selected based on the criteria.

The coordinating authors made a concerted effort to identify women leaders across the world, but there were challenges with identifying participants in specific regions (e.g., Africa and the Middle East). This may be attributed to the personal networks of the coordinating authors and participants and the inclusion and exclusion criteria set for the study. The criteria excluded women leaders working on interdisciplinary marine research and practice in wider sectors, such as NGOs and government bodies. In addition, interdisciplinary marine research may have been a limiting concept and instead it may be organized in a different way across regions and cultures. As highlighted previously, expansion of interdisciplinary marine research (e.g., marine social science) has predominantly been focused within academic institutions in Western regions.[68] Overall, as a result of this approach to sampling, the 34 cases spanned 27 countries (see Table S1).

Survey instrument

A qualitative research approach was adopted in this study to provide a more in-depth and comprehensive exploration of the three study objectives. Qualitative approaches have been employed in similar studies, for example, in identifying strategies for building and managing trust at the marine-science-policy

interface[162] and tips for developing interdisciplinary socio-ecological researchers.[61] A survey instrument was developed by the coordinating authors to ensure a consistent approach and was produced in two forms: (1) a self-completion survey and (2) an interview guide. Questions pertained to: (1) the main barriers and challenges that they had experienced as a leader in academia and interdisciplinary marine research contexts, (2) the main gender-based barriers and challenges that they had experienced as a woman leader in academia and interdisciplinary marine research contexts, and (3) the strategies or enablers that can be used to successfully develop women scientists in leading interdisciplinary marine research (see Survey instrument; Note S2). Participants were asked about the main barriers and challenges they had experienced as a leader. This question helped to us to understand the broader range of issues that women leaders had experienced in academic institutions and to examine the multiple disadvantaged or minoritized statuses (i.e., intersectionality). This was followed by a question that focused specifically on gendered challenges (i.e., those experienced due to being a woman leader in academia). Qualitative pre-testing was undertaken to ensure the adequacy of the survey instrument (e.g., providing insights into participants' comprehension of the materials). The guide was peer-reviewed by three external researchers specializing in marine social science and was piloted among the coordinating authors and refined accordingly. Minor changes to language and wording were made to the guide to improve the clarity and context specificity of questions. This was particularly important because, for many participants, English was not their first language. Data collection was undertaken by seven of the eight coordinating authors (R.J.S., C.C., M.M., M.C.M., J.B., R.K., and I.v.E.P.).

Data analysis

Interview transcripts were professionally transcribed to ensure their accuracy. The transcripts and written responses were then analyzed using NVIVO 12 qualitative data analysis software. The research objectives formed the basis of the coding, and the analysis of raw data was completed following an inductive approach, based on grounded theory analysis.[163] Based on best practice, there were three main stages to data analysis.[164] The first was initial coding. The purpose of initial coding was to start the process of categorization and assigning meaning to the data, comparing incident-to-incident, and to look for emergent patterns in the data.[165] The raw data (surveys and interview transcripts) were broadly coded against the three research objectives. Each transcript was coded against a set of descriptors designed to identify emergent themes and to capture the key elements of these themes.[152] Using participants' own words to derive and summarize key themes ("*in vivo*" coding) allowed the research findings (key themes) to emerge naturally from the interviews, without the restrictions imposed by more structured methodologies.[166] Hence, the results are a direct reflection of the language and words commonly used by the research participants, as opposed to the potentially subjective interpretations of the coordinating authors.[167]

The second stage was focused coding. During this process, the researchers pursued a selected set of central codes throughout the entire dataset and study. This required decisions to be made on which initial codes were most prevalent or important, and made the most analytical sense to ensure data were categorized incisively and completely (i.e., assessing the adequacy of codes from the initial coding stage[164,167]). The third stage was theoretical coding. Theoretical coding integrated and synthesized the categories derived from coding and analysis. Initial coding fractures the data while theoretical codes "weave the fractured story back together again"[168 (p.72)] to identify key themes and concepts.[152] This stage resulted in the barriers and enablers being categorized into eight themes (where applicable), and was based on previous research.[169,170] They included (1) practical and process (i.e., the implementation and application of actions, rather than theory and ideas), (2) institutional (i.e., relating to academic interdisciplinary marine research institutions), (3) social (i.e., stemming from social interactions and networks within the academic or workplace environment), (4) financial (i.e., connected to the availability and suitability of funding), (5) material (i.e., related to materials, such as documents and social media), (6) individual (i.e., at the personal level), (7) political (i.e., associated with policy and decision-making), and (8) other (i.e., miscellaneous topics).

Two practices were undertaken to ensure the validity of the emerging themes and subthemes. First, three of the coordinating authors (R.J.S., C.C., and M.M.) each performed initial coding for a subset of the transcripts (n = 5), which were selected based on the level of detail and length of the interviews, with the assumption they would cover most themes.[171] Collective author reflection on the themes during the group synthesis and preparation of this paper further verified their relevance and value. The coordinating authors then collectively discussed and further refined the findings, before distributing them to study participants.[161] Second, the themes were continually verified against the raw data from which they were derived (following previous studies, e.g., Norström and co-workers[161,172]). This iterative process aided the development of a coherent synthesis of key themes (and subthemes).[173,174] Data analysis was undertaken by the lead author to maintain independence of interpretation. All 34 of the participants were included as co-authors on the paper and they were involved in the validation and interpretation of findings (i.e., "respondent validation"). Participants did not have access to the data and were unable to modify the results. Instead, they validated and interpreted the findings by providing written feedback on the draft manuscripts (e.g., adding additional text to aid interpretation of the data) or by discussing the findings with the lead author. This is in line with best practice, which recommends sharing findings and providing participants with the opportunity to clarify, corroborate or approve the findings.[152]

SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.oneear.2022.05.006.

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AUTHOR CONTRIBUTIONS

Conceptualization, R.J.S., C.C., M.M., M.C.M., J.B., R.K., and I.v.E.P.; methodology, R.J.S., C.C., M.M., M.C.M., J.B., R.K., and I.v.E.P.; investigation, R.J.S., C.C., M.M., M.C.M., J.B., R.K., and I.v.E.P.; formal analysis, R.J.S., C.C., M.M., and M.C.M.; validation, all authors; writing – original draft, R.J.S.; writing – review & editing, all authors.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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