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The worldwide disruption caused by the beginning of the COVID-19 pandemic has dramatically impacted the activities of marine scientists working towards the goals of the UN Ocean Decade. As in other disciplines, marine early-career researchers (ECRs) are essential contributors to the development of novel and innovative science. Based on a survey of 322 of our peers, we show that the pandemic negatively impacted marine ECRs in ways that further exacerbate existing structural challenges such as social isolation, job insecurity, and short-term contracts, competitive funding, and work pressure. Furthermore, we find that the success and wellbeing of marine ECRs depends heavily on networking opportunities, gaining practical experience, collecting data, and producing publications, all of which were disrupted by the pandemic. Our analysis shows that those in the earliest stages of their careers feel most vulnerable to long-term career disadvantage as a result of the pandemic. This paper contributes to the empirical body of work about the impacts of the pandemic on marine science and offers recommendations on how marine ECRs should be supported to achieve the UN Ocean Decade's goal of producing "the science we need for the ocean we want."

Keywords: early career scientists, intersectional, institutional responses, marine science, reflexive science, SARS-CoV-2, UN Ocean Decade.

Introduction

Healthy oceans are closely linked to environmental sustainability, prosperity, and human well-being (Hoegh-Guldberg and Bruno, 2010; Fleming *et al.*, 2015; Bennett, 2019). Recognizing the importance of marine environments for humanity, the United Nations declared 2021–2030 as the Decade of Ocean Science for Sustainable Development (www.oceandecade.org, last accessed 25/11/2021, referred to as the UN Ocean Decade hereafter). Future ocean challenges include (but are not limited to) climate change, biodiversity loss, marine pollution, overfishing, environmental justice, and conservation (Sumaila *et al.*, 2016; Hossain *et al.*, 2018; Jungblut *et al.*, 2020; Brasier *et al.*, 2021; Cosentino and Souviron-Priego, 2021; Raatikainen *et al.*, 2021; Willis *et al.*, 2022). These

issues present "wicked problems", where the correct way forward is rarely self-evident (Jentoft and Chuenpagdee, 2009) and requires that biological, social, and governance questions be studied and evaluated simultaneously (Chapman, 2017; Jung *et al.*, 2022). Finding solutions for these problems is thus a transdisciplinary challenge by nature (Jung *et al.*, 2022).

Early career researchers (ECRs) in marine science are crucial to solving the complex problems of the UN Ocean Decade. We take ECRs to be PhD candidates, postdoctoral researchers, research assistants, and other researchers generally within 5 years of completing their highest degree, allowing for career breaks. Over the next decade, many ECRs will undertake novel scientific endeavours while training and developing skills to become the next

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generation of scientific leaders. To succeed in research and academia, ECRs are expected to master a vast variety of specialized skills, including (but not limited to) conducting fieldwork, running complex laboratory experiments, processing and publishing data, teaching and education, and more recently, outreach, communication, and inter-, multi-, and transdisciplinary collaborations.

In the meantime, ECRs must navigate daunting personal and professional demands in the critical first years of their scientific careers (Andrews *et al.*, 2020; Christian *et al.*, 2021). Problems that affect all of academia, such as short-term contracts or unpaid work (Osiecka *et al.*, 2021), can have disproportionate effects on ECRs who may need to complete their research on shorter time scales, for example, with a single short field season. At the same time, environmental scientists, such as those working in marine science, are vulnerable to stress and trauma-related impacts from studying environmental issues (Pihkala, 2020). In order to address marine science questions, ECRs are encouraged to foster collaborations with diverse disciplines. The pressure to develop an interdisciplinary skill set can leave marine ECRs particularly vulnerable in terms of their mental health, work-life balance, and job security (Cosentino and Souviron-Priego, 2021). As a result of such pressures, research has recognized that ECRs are more than six times as likely to suffer anxiety and depression compared to the general population (Evans *et al.*, 2018; Andrews *et al.*, 2020; EMB, 2021; Jung and Vigliano Relva, 2021). These vulnerabilities are further exacerbated for those from marginalized groups who face the many intersectional gender and racial inequities that exist within academia (Andrews *et al.*, 2020; Cosentino and Souviron-Priego, 2021).

Additional challenges for marine ECRs have arisen since the outbreak of the novel coronavirus SARS-CoV-2 and the associated disease, COVID-19 (Sohrabi *et al.*, 2020; referred to hereafter as “the pandemic”). To limit the spread of the virus, governments worldwide issued various control measures, such as closing workplaces and restricting travel and social interactions. As a result, universities were closed and international travel, fieldwork, working group meetings, and scientific conferences were cancelled, postponed, or moved online (Albéniz *et al.*, 2021; Scharf, 2021). Many research cruises were cancelled, resulting in year-long gaps in time series data, which cannot be recuperated once the time has lapsed (Viglione, 2020b; Link *et al.*, 2021). Cruise protocols were altered to accommodate COVID-19 risk mitigation and in some instances fewer researchers were able to participate in research cruises, which prevented some ECRs from participating altogether (Corlett *et al.*, 2020; Viglione, 2020a). Similarly, laboratory access was restricted, causing delays in the collection of data that are crucial for the completion of short-term projects, which most ECRs are hired under (Paula, 2020). In addition, methods important for social scientists such as field visits, focus group discussions, interviews, and participant observation were hindered or moved online. All of these restrictions impacted marine ECRs, who face shorter contracts and deadlines in which to complete field or laboratory work (Deininger *et al.*, 2021; Rölfer *et al.*, 2022). Many marine researchers also collaborate on large, interdisciplinary research teams and were unable to meet in person during the pandemic, potentially impacting the quality of long-term collaborations and the work they deliver (Schiermeier *et al.*, 2020). Because collaboration, networking, and institutional support are particularly important for ECRs, the pandemic has

disproportionately impacted them worldwide (Byrom, 2020; Paula, 2020; Woolston, 2020). Finally, delayed publications have larger impacts on those with short-term contracts and who face pressure to publish to boost their CVs (Levine and Rathmell, 2020; Myers *et al.*, 2020; Pardo *et al.*, 2020; Woolston, 2021a).

To better understand the impact of the pandemic on marine ECRs, the Orienting Young Scientists of EuroMarine network (OYSTER; www.euromarinetwork.eu/content/oyster) surveyed ECRs from EuroMarine and other European marine research institutes in 2020. Our aim was to capture how marine ECRs have been affected by the restrictions brought about by the COVID-19 pandemic. To achieve this aim, we address the following research questions:

- (1) How have marine ECRs been personally and professionally affected by the closures of laboratories and workplaces due to COVID-19?
- (2) How have marine research practices been affected by the closures of laboratories and workplaces due to COVID-19?
- (3) Have some demographic groups been more negatively affected than others by the closures of laboratories and workplaces due to COVID-19?

We present the results of an online survey about how ECRs have been affected by the pandemic. We highlight cross-cutting themes emerging from the survey results, followed by recommendations for improving the well-being and efficacy of marine ECRs.

Methods

Members of the OYSTER network collaboratively designed a survey based on their own experiences during the early stages of the pandemic and on the insights from the previous OYSTER survey (Wieczorek *et al.*, 2019). The survey consisted of 34 questions and 15 sub-questions associated with the following five themes: demographics, impacts upon access to the workplace, institutional support, impacts on research practices, and future outlook (Table 1). To capture both qualitative and quantitative responses, the survey employed a mix of closed and open question designs including multiple-choice, multiple answers, five-point Likert scale, and open answers (Bryman, 2016). Table 1 provides a summary of the themes of the survey questions, a description, as well as an overview of the question types and numbers. For the full list of survey questions please refer to Supplementary Material S1.

The survey questions, design, and dissemination strategy were approved by the University of the Highlands and Islands (Scotland, UK) Research Ethics Committee (reference no. 1686). This ethics approval included a privacy statement, detailing how data would be used and stored. Details from the ethics application can be viewed in the Supplementary Material S2.

The survey was hosted on the JISC online survey platform (JISC Online Surveys, 2021) and was launched on the 7 October 2020 and closed on the 6 November 2020. Anonymous responses from marine ECRs who either worked for EuroMarine-affiliated institutions or who resided in Europe were recruited using both purposive and snowball sampling techniques (Biernacki and Waldorf, 1981; Bloor and Wood, 2006). In the context of this survey, ECRs are defined as PhD candidates, postdoctoral researchers, research assis-

Table 1. Overview of the themes investigated in the survey, indicating the type, and number of questions as they relate to the themes.

Section/Theme	Description	Question type	Question numbers
Demographics	General demographic questions (age, gender, location, living situation) and questions about career stage.	Yes/No, Multiple Choice, Open	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
Impacts upon access to workplace	Impacts of the pandemic upon access to the workplace and adequacy of home office set-ups.	Yes/No, Multiple Choice	13, 14
Institutional support	Perceptions of institutional support and adequacy of support, and to collect details of what was provided. Provision of funding extensions.	Yes/No, Multiple Choice, Likert Scale, Open	15, 16, 23, 24, 25
Research practices	Assessing work priorities. Perceptions of the pandemic's impact on productivity and the effect of working from home on current work. Whether these changes will remain post-pandemic. Specific impacts upon marine science. Impacts of the pandemic upon professional development.	Yes/No, Ranking, Likert Scale, Open	17, 18, 19, 20, 21, 22, 26, 31, 34
Future outlook	Looking forward at the future for ECRs in marine science and marine science as a whole.	Yes/No, Multiple Choice, Likert Scale, Open	26, 27, 28, 29, 30, 32, 33

tants (researchers employed by research institutes), and other researchers generally within 5 years of completing their highest degree, allowing for career breaks. A list of EuroMarine affiliated institutes can be found on the EuroMarine webpage www.euromarinetwork.eu (last accessed 03/12/2021).

For the purposive sampling, targeted emails were sent to EuroMarine members ($n = 60$), and publicly available email addresses were obtained from European marine research institutes and relevant network homepages ($n = 550$). The email call-text is available in Supplementary Material S3. The snowball sampling involved asking the email recipients to pass the survey on within their own networks. In addition, an interactive Twitter campaign was published by the OYSTER Twitter account (>660 followers at the time of the survey launch) which advertised the survey and encouraged respondents to forward it within their networks. This campaign included seven tweets whose impressions ranged from 1100 to 6500 (an example of which can be seen in Supplementary Material S4).

Our initial analysis of the results followed the themes set out in Table 1. The data were then analysed in an iterative way, with the qualitative and quantitative responses informing interpretation of one another. For the quantitative data, the responses to the closed questions were analysed in three phases: exploratory, descriptive, and theory-testing. For the exploratory phase, Multiple Correspondence Analysis was carried out in R (version 1.2.5033) using the FactoMineR package (Lê *et al.*, 2008) to identify correlated variables, hidden patterns in the dataset, and to reduce the dimensionality of the data. This analysis did not identify any pattern or redundancy, so all quantitative data were inspected and analysed through descriptive statistics. Additional information about this analysis is provided in Supplementary Material S5. Qualitative responses (open-answer questions) were coded using an inductive descriptive approach (Saldana, 2015). The respondents of the survey could choose not to answer open-ended questions. Overall, the open-ended questions had an average response rate of 68% ($\pm SD$ 33%). Some open questions were designed to allow respondents to elaborate on choices they had made in the closed questions. For example, respondents

were asked to answer the following question using a Likert scale: “Overall, how would you rate the effect of Covid-19 and the related measures on your career in the long term?” followed by an open question: “Why?”. These open-ended questions had the lowest response rate among respondents with an average of 34% ($\pm 14\%$). Other open questions were exploratory in nature (e.g., “What do you think Early Career Researchers in marine sciences could contribute to the world post-Covid-19?”; see Supplementary Material S1 for other questions). These open-ended questions had an average response rate of 67% ($\pm 37\%$) among respondents. A more detailed overview of the response rate per question is provided in Supplementary Material S6.

In the following sections, we report pertinent issues and themes that were identified during the mixed methods analysis of the survey data. After we observed no statistical significance in the quantitative responses, we organized the presentation of the results around both the thematic structure of the survey and the objectives presented above. We then interpret the survey results in the context of existing literature before offering specific recommendations on actions which can help marine ECRs overcome the impacts of COVID-19.

Results

Demographics

A total of 343 respondents from 24 countries, working in 38 marine-related sub-disciplines, completed the survey. Respondents were affiliated with 40 EuroMarine institutes and 54 other institutes. Among them, 21 responses were excluded as they were not part of the target population (i.e., marine scientists, ECRs, and working for institutes in Europe or EuroMarine). After these exclusions, a total of 322 responses were analysed.

The majority of respondents were PhD students, and females were more likely to respond to the survey than males. The proportion of respondents per career stage and gender is shown in Figure 1. Statistical analyses did not find any gender effect on answers to the other questions (see below and “Discussion”).

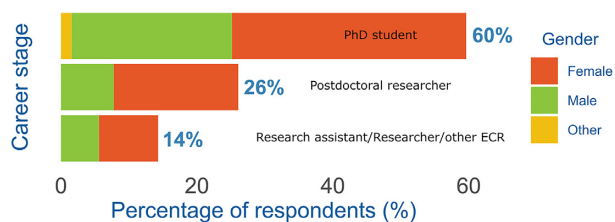


Figure 1. Percentage of survey respondents per career stage and gender ($N = 322$). Career stages included PhD student, postdoctoral researcher, and other early-career researcher (ECR) without a permanent position. Gender included three categories: female, male, and other, the latter being those respondents that did not identify with female or male.

Table 2 shows other pertinent demographic information, specifically related to age, career stage, type of employment, living arrangements, or most important place of work. To highlight some key insights, 72% of respondents were between the age of 26 and 35 and most (60%) were PhD students. About 45% of respondents were employed full-time with a temporary contract of >1 year and only 5% of respondents had a permanent contract (either full- or part-time). A further 25% were receiving scholarships. As for living arrangements, 39% lived with a partner, and another 30% lived alone. Most respondents (56%), considered their desk or office to be their most important place of work, while 27% considered the laboratory to be their most important workplace. Lastly, around 16% of respondents had care duties at the time of participating (prior to October 2020). Of those who had care duties, 53% cared for their children, 10% cared for another person’s children, whilst 28% cared for their parents. A further 8% responded that they had “other” care duties, which included caring for grandparents, an aunt and cousin, girlfriend, and a sick pet.

Table 2. Demographic summary of the respondents to the OYSTER COVID-19 survey ($N = 322$).

Age	Career stage	Type of employment	Living arrangement	Most important place of work
21–25: 11.5%	PhD students: 60.2%	Casual employee (hourly pay): 1.2%	Living alone: 30.1%	Field: 14.9%
26–30: 41.3%	Postdoctoral researchers: 26.1%	Fellowship/scholarship/stipend: 25.1%	Shared accommodation (not family): 2.2%	Laboratory: 27.3%
31–35: 31.1%	Other early career researcher (within 5 yr of completing PhD): 11.5%	Part time with <1 yr contract but not permanent: 1.8%	Living with family (including children): 16.4%	Desk or office: 55.9%
36–40: 10.2%	Research assistant: 2.2%	Part time with >1 yr contract but not permanent: 7.1%	Living with friends: 12.7%	Other (unspecified): 1.9%
41–45: 4%		Part time with permanent contract: 0.6%	Living with partner: 38.6%	
≥45: 1.2%		Full time with <1 yr contract: 8.3%		
Undisclosed: 0.6%		Full time with >1 yr contract but not permanent: 45.1%		
		Full time with permanent contract: 4.4%		
		Student without financial support: 2.7%		
		Unemployed: 3.7%		

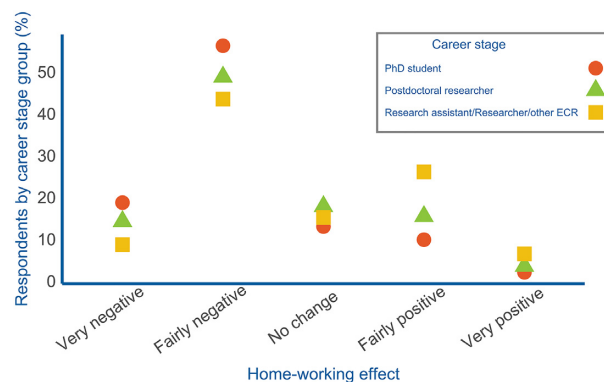


Figure 2. Distribution of how marine early-career researchers (ECRs) at different career stages felt about working from home during the first eight months of the COVID-19 pandemic. Respondents rated the effect of working from home on their current research project on a Likert scale that ranged from “very negative” to “very positive.” PhD students were least likely to experience positive impacts and most likely to experience negative impacts of working from home.

Impacts upon productivity and day-to-day research

The results show that the pandemic impacted productivity and day-to-day work patterns. At the time of the survey, working from home had a negative impact on most ECRs (69%), with 16% reporting very negative impacts, and 53% fairly negative impacts on the progress of their current research project (Figure 2). PhD students were more likely to report negative impacts from working from home, while research assistants, researchers, or other unspecified ECRs were more likely to report positive impacts (Figure 2).

Most survey respondents felt increased pressure to be productive during the early stages of the pandemic. Relative to pre-pandemic pressure, 61% of respondents felt much more (26%) or a little more (35%) pressure to be productive (Figure

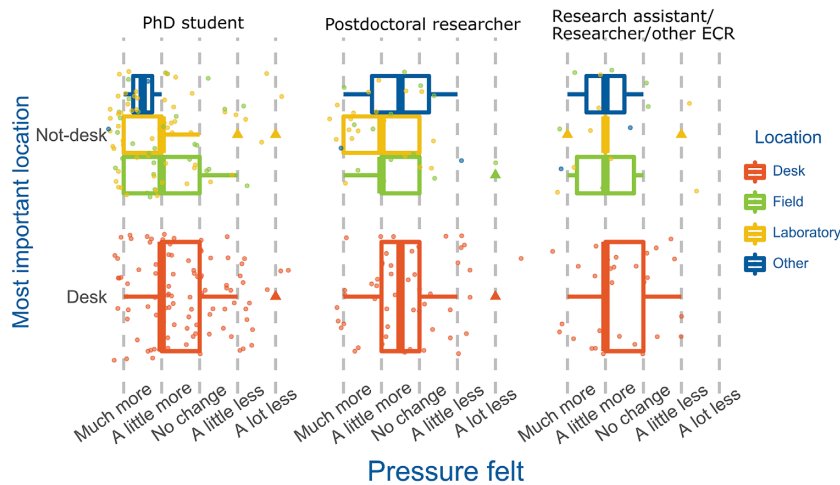


Figure 3. Distribution of the level of pressure to be productive felt by marine early-career researchers (ECRs) during the pandemic as a function of the most important work location. Work locations included desk, field, laboratory, and other locations. Responses are indicated per respondent career stage. The differences between desk and non-desk work locations are highlighted to show that those whose work is predominantly desk-based felt relatively less pressure to be productive during the pandemic.

3). This was especially true for PhD researchers, who reported feeling greater pressure than postdoctoral researchers. Furthermore, respondents whose pre-pandemic work was desk-based felt less pressure to be productive, while ECRs whose work depended on lab- or field-work to acquire data or samples felt much more pressure by comparison (Figure 3).

The qualitative data from the survey supported this finding, suggesting that the abrupt move to working from home had negative consequences for many respondents. Some respondents linked the pressure of working from home to negative impacts on their mental health and well-being, for example:

“I found the work life balance suffered. I worked longer hours and was less productive because I felt guilty for not achieving what I needed. It started affecting my sleep”.

(Respondent 169, male, PhD student, Ireland)

As illustrated above, reasons for decreased research productivity included feelings of personal responsibility for declines in productivity. Respondents also reported losing productivity due to the need for more online meetings, technical challenges, and a disjointed approach to online work in their team. Some reported that their productivity was sporadic, with working from home introducing new distractions, including juggling online commitments, while other respondents reported some benefits such as saving time commuting and being able to better focus at home, explaining that they found extra time to work on data analysis and writing.

Importance of social connections for ECRs

The social isolation of the first months of the pandemic had negative effects on the ability of ECRs to do their work. Respondents reported that personal and professional interactions with colleagues are important for productivity and well-being:

“One online meeting per week does not replace the social interactions with your colleagues. Without those interactions, productivity decreases since the best ideas and solutions usually come up in discussions. Also, living on your own in a foreign country does not get easier during a lock

down. It certainly has a negative impact on productivity when all that is left to do is either write a paper or call your friends back home since real life meetings are not allowed”.

(Respondent 202, female, post-doctoral researcher (unemployed), The Netherlands)

This quote highlights the interplay between personal and professional challenges during the pandemic. It exemplifies several key themes that were present in the survey responses: isolation, the challenges of relocation and integration for work, and communication difficulties caused by the shift to online meetings. Even those who had many online meetings found that this contact did not replace the informal social interactions that ECRs need to thrive in the workplace. Furthermore, many ECRs relocate internationally to take academic opportunities, and respondents reported that this made them particularly vulnerable during the pandemic as they may not speak the local language and are far from family and friends.

Communication and collaboration are important parts of scientific work environments, both within a discipline and in multidisciplinary projects, and ECRs benefit from proper integration in their research group where these skills can be practiced. This integration with their research group suffered during the pandemic as professional relationships were disrupted. Almost half of the respondents highlighted that the communication with their research group was somewhat worse (36%) or much worse (12%) due to the pandemic (Supplementary Figure S1). However, when asked about their relationship with their direct supervisors, a majority of respondents (74%) answered that the short-term changes brought about by the pandemic did not change their relationship (Supplementary Figure S2). This difference in impact indicates that well-established relationships between ECRs and their direct supervisors were more resilient to the challenges posed by the pandemic than the relationships ECRs have with their wider research group. When asked about what supervisors did well or poorly to support ECRs during the pandemic, communication was the most common response (Supplementary Figure S3). Taken together, these results suggest the importance of supervisors for maintaining communication links between ECRs

and their research group. The respondents valued good communication with supervisors and their research group, and were negatively impacted when it was missing.

Anticipated long-term impacts on marine ECR careers and job security

While the long-term impacts of the pandemic are still unclear, at the time of the survey, ECRs were already concerned about the disadvantages that the disruption may create. Respondents were concerned about the pandemic's impact upon their future careers, with 70% of respondents stating that the pandemic would have a somewhat negative (57%) or very negative (14%) impact on their careers in the long term (Supplementary Figure S4). In the qualitative parts of the survey, respondents provided reasons for this. Some suggested that the pandemic will have implications for global science priorities and that funding opportunities would shift as a result of the pandemic:

"I also expect that future research funding will shift towards the health sector, increasing the pressure on the marine community".

(Respondent 100, female, PhD student, Germany)

In addition, ECRs reported that they had fewer opportunities to build the skills necessary to be a successful researcher. Some respondents were concerned about gaps in their CVs due to cancellations caused by the pandemic:

"Funding calls cancelled, funded projects delayed, less research productivity due to doubling teaching tasks. The result, a blank year in the research CV".

(Respondent 190, female, post-doctoral researcher, Spain)

The pandemic also affected the potential for ECRs to travel and meet peers, which is essential for their professional development and future job prospects:

"Despite the best attempts by various organizations, the opportunities for proper networking have not been there which can be hugely damaging for early career scientists".

(Respondent 49, female, post-doctoral researcher, Belgium)

Another respondent highlighted the added financial burden and insecurities associated with the impacts of the pandemic, and how this would have long-term impacts on their career development:

"I'm a woman. Unemployed. Fighting every day for my right to finish my PhD. Will I ever be able to financially support me and my family with this line of work? If this situation continues, I will have to look for another 'career' path to put food on the table—[even] though I want to continue my chosen profession".

(Respondent 64, female, PhD student (unemployed), Germany)

These quotes demonstrate some of the long-reaching setbacks that this generation of marine scientists are concerned about in the aftermath of the pandemic. Some respondents had already taken steps towards changing their careers (6%) or wanted to change careers (19%) as a result of the pandemic (Supplementary Figure S5). However, despite expected negative impacts, many ECRs (39%) did not want to change

careers (Supplementary Figure S5). It is also worth noting that the remaining third of the respondents had not thought about the possibility of a career change at all when asked in the survey. Thus, even when anticipating negative impacts and faced with long-term uncertainty, the majority of ECR respondents remain dedicated to their careers in marine science.

Outlooks specific to marine science

Looking forward, most respondents (62%) felt that marine research would be affected by the pandemic over the coming decade (Supplementary Figure S6). However, for day-to-day marine science research practices, respondents were more or less evenly split about whether they foresaw permanent changes (Supplementary Figure S7). The qualitative comments revealed a number of potential reasons for impacts of the pandemic on marine science, including cancellation and postponement of fieldwork (especially research cruises) and gaps in time-series data:

"[Impacts come from] sea cruise cancellations and the impossible lab work which primarily affected those who have short contracts".

(Respondent 117, male, post-doctoral researcher, France)

Gaining specialized experience in laboratory and field settings is essential for many marine ECRs to build a professional skillset and, due to the short-term nature of many early-career employment contracts, ECRs have a small window of opportunity to gain this type of experience. The responses to the survey suggest that the cancellations caused by the pandemic have created a generation of ECRs who have missed important opportunities to gain relevant scientific skills. As for opportunities to make up for the lost time, at the time of the survey, only 17% of respondents knew that their funding would be extended, giving them the chance to compensate for research opportunities lost due to pandemic delays (Supplementary Figure S8).

By contrast, some marine ECRs were optimistic about the value of their skills and innovations, with some seeing themselves as vital to marine science's ability to develop solutions to future challenges such as climate change and food security. There was hope that the pandemic might spur a change in attitudes towards scientific practices and the role of ECRs, with greater appreciation for multi- and transdisciplinarity, facilitated by ECRs:

"I think despite the difficult times we have been through, Early Career Researchers have the chance to do a lot to change the scenario. I think it is time that we look for ways to work together with society and exchange ideas. We can drop the top-down approach science in general has always used and become more horizontal".

(Respondent 106, female, post-doctoral researcher, France)

Some positive aspects of the pandemic for marine ECRs

When asked whether the pandemic and related measures had a positive impact on their personal or professional lives, the largest proportion of respondents chose not to answer or reported that they had not experienced any positive impacts. However, some respondents reported positive effects on their personal and professional lives. Many of these reflected on

the benefits of having more time and flexibility as a result of working from home, for example:

“At the beginning it was harder to get the rhythm and routine but once I got that it was more flexible, allowing me to focus my attention on other things if my energy levels were low and then coming back to work when I felt better, I think overall this increased my productivity because I became more efficient when actually working”.

(Respondent 316, female, PhD student, Belgium)

Other responses showed that positive aspects were a result of the changes to work patterns. Some enjoyed the flexibility in prioritizing their work:

“I had the time to reassess my priorities and focus on areas that were left behind due to constant lab work”.

(Respondent 160, male, PhD candidate, Slovenia)

For others, benefits came from greater free time and relief from commuting:

“More time in the day due to no commute, so overall productivity was the same/increased as I have more time”.

(Respondent 156, female, post-doctoral researcher, Ireland)

In regard to research practices, some respondents highlighted that the move to online platforms created a more equal space for ECRs to engage with their scientific network worldwide (e.g., at online conferences and workshops):

“I think that the move to online conference formats levels the playing field for ECRs compared to more senior researchers and thereby increases their visibility”.

(Respondent 66, female, post-doctoral researcher, Germany)

In some cases, the pandemic and the associated restrictions prompted respondents to reassess professional priorities, considering the value of interdisciplinarity and placing their work in a broader context that serves society:

“It opened opportunities to me that broadened my perspective over marine science. So, I can think more substantially how my research could contribute to society. And from now on I intend to give this kind of direction to my work, i.e., combining ecology with societal demands”.

(Respondent 106, female, post-doctoral researcher, France)

For some, the pandemic provided relief from unfavourable work environments, respite from a stressful lab or office situation, and the removal of some competition pressure. For others, the pandemic brought them to a breaking point that has ultimately led to actions to improve their mental health:

“Covid has forced me to confront the anxiety that I have been experiencing for several years, and I am now seeing a therapist for it”.

(Respondent 170, female, post-doctoral researcher, Ireland)

Despite the many negative impacts detailed in the previous sections, the possibility to work from home was something that respondents wanted to keep, with 71% preferring to have an option to work from home in the future (Supplementary Figure S9). While the pandemic led to drastic change

and many negative consequences for ECRs, some positive aspects such as more time, flexibility, independence, equal opportunity, and personal growth were acknowledged.

Discussion

Our results echo other studies not focused on marine ECRs (e.g., Alam *et al.*, 2020; Carr *et al.*, 2021; de Wit and Altbach, 2021; Pereira, 2021; Yildirim and Eslen-Ziya, 2021) which have argued that the pandemic has exacerbated the many intersectional challenges that ECRs face in their careers. In particular, the impacts of pressures such as funding insecurity, short-term contracts, and productivity demands have been further affected by cancelled field and laboratory work, a lack of networking opportunities, and disrupted social connections. As a result, there is an imminent need for coordinated actions to help ECRs overcome the setbacks they face as a consequence of the pandemic. In the long term, there is cause to transform the marine science landscape to enable and empower ECRs to address important and urgent global challenges. Part of this transformation requires training ECRs to work in inter- and multi-disciplinary ways. It is also important to invest in transdisciplinary collaborations that allow marine scientists to engage with other ocean stakeholders and to reflect on their contributions to marine science both now and in the future. The deliberate integration of social science theories and methods that facilitate reflection on the nature and state of marine science will be crucial for this process, as will institutional changes, which we present in Table 3. Here, we take the perspectives from our mixed-methods study and use them to formulate empirically-based recommendations for long-term remediation of pandemic impacts. Given that the situation is ongoing and rapidly changing, the effectiveness of these should be assessed by further reflexive work that employs methods that overcome the limitations of online surveys (e.g., interviews, participant observations).

Demographics

Reflecting on the response rates to this survey, we acknowledge that we likely have a non-random sample of the ECR population. The relatively large proportion of PhD students is expected since there are more PhDs than other ECRs in employment, and because the survey was launched from an ECR network that engages junior academics (OYSTER, EuroMarine). The response was also skewed to female respondents (62%), which may be the result of females being more likely to contribute data to surveys than males (Smith, 2008). Although we see no statistically significant gender effects in our results, other work has shown that female academics have been disproportionately affected during the pandemic (Squazzoni *et al.*, 2021). Gender-specific, existing structural challenges which hinder career progression for early-career women in academia have been well described (e.g., Knights and Richards, 2003; Giakoumi *et al.*, 2021) and caring responsibilities have previously been highlighted as a factor that ECR women may struggle with (Caretta *et al.*, 2018). This hindrance due to household and childcare duties has been exacerbated by the pandemic (Deryugina *et al.*, 2021). Overall, only 16% of our survey respondents had care duties (Supplementary Figure S10). This low number may be explained by the cohort we have targeted in the survey: many ECRs are of an age where they are not yet caring for their own children, nor

Table 3. Detailed recommendations for improving the well-being and efficacy of marine ECRs.

What can individual institutions do?		
General recommendation	Specific recommendations	Potential pitfalls
(1) Assist at-risk ECRs	<ul style="list-style-type: none"> • Raise awareness about ECR challenges at the institutional level through taking “bottom-up” and collaborative approaches (e.g., by consulting with ECRs about their experiences). • Initiate proactive assistance for at-risk ECRs. • Ensure optimal career development and support for ECRs by training principal investigators to recognize signs of distress. • Improve access to specific support with adequate funding (mental health, child care, international student support, etc). 	<ul style="list-style-type: none"> • Treating inclusiveness as a tick-box exercise. • Failure to follow-up with ECRs who are in distress, increasing disappointment. • Forcing unethical disclosures of vulnerable peoples.
(2) Encourage a culture of openness and accountability	<ul style="list-style-type: none"> • Foster transparent, open, and timely two-way communication between ECRs and managers. • Appoint dedicated personnel to take responsibility for communications at various institutional levels. • Provide training and resourcing for those who are responsible for communication. 	<ul style="list-style-type: none"> • Treating communication strategies as an after-thought. • Burdening junior staff or ECRs with communication roles.
(3) Provide flexible approaches to work	<ul style="list-style-type: none"> • Allow part-time work from home. • Facilitate hybrid modes of teaching and learning. • Create shared working spaces that can foster collaboration. • Evaluate new working conditions collaboratively with ECRs. 	<ul style="list-style-type: none"> • Implementing paternalistic strategies that ultimately undermine flexible working. • Favours those who are able to attend in-person work.
(4) Foster meaningful networking and social engagements	<ul style="list-style-type: none"> • Ensure equal opportunities for ECRs and senior researchers to attend face-to-face conferences and workshops in the future. • Connect ECRs with peers and colleagues. • Use a mix of formal and informal structures for networking. • Financially support ECRs to attend networking and social engagements. 	<ul style="list-style-type: none"> • Wasting time with too many events that have no follow-up or concrete outcomes for participants. • Networking and social spaces are not inclusive.
What needs to change across the marine science community as a whole?		
General recommendation	Specific recommendations	Potential pitfalls
(5) Re-assess current funding models	<ul style="list-style-type: none"> • Provide greater flexibility in funding opportunities, especially in relation to extension of funding in light of delays caused by the pandemic. • Implement approaches that facilitate security of tenure for ECRs. • Reduce the incidence of unpaid work in marine sciences. • Reconsider the short-term contract model for research projects. • Create more research grant opportunities for ECRs to act as principal investigator. 	<ul style="list-style-type: none"> • Disadvantage those who rely on short-term contracts for flexibility. • Place an unfair burden of responsibility on ECRs.
(6) Re-evaluate research metrics	<ul style="list-style-type: none"> • Acknowledge set-backs in career progression caused by the pandemic (e.g., CV and publication gaps). • Consider other metrics and research outputs (e.g., Altmetric, engaged scholarship, public communication). • Provide ECRs with adequate transferable professional skills and teach them to communicate these in alternative job markets to facilitate transition to non-academic careers. • Assess a candidate based on their complimentary and life skills. 	<ul style="list-style-type: none"> • Focus on <i>h</i>-index, publication number, citations and amount of funding obtained only.
(7) Ensure ECR networks are meaningful and beneficial	<ul style="list-style-type: none"> • Support international networks and organizations that create online networking possibilities for ECRs in addition to face-to-face and hybrid events. • Give ECRs a voice at decision-making level within marine science networks. • Connect ECRs with senior researchers in marine science networks. • Offer financial and professional benefits to contributing ECRs. • Organize and structure the events to benefit a diverse audience. • Seek professional technical support for larger events. 	<ul style="list-style-type: none"> • Increase administrative workload for ECRs. • Treat this as tick-box exercise for public perception. • Treat ECR networks as a “kid’s club”.
(8) Recognize the role of the ocean and champion marine researchers	<ul style="list-style-type: none"> • Encourage ECR engagement with global opportunities for change (e.g., UN Ocean Decade). • Train and support marine ECRs to work with policy and decision makers. 	<ul style="list-style-type: none"> • Increase voluntary and unpaid workload of ECRs.

for their aging parents. It will therefore be important for employers to monitor and address existing and pandemic-specific challenges, especially for women, to ensure that the pandemic has not and will not introduce more gender inequalities into an already compromised system (Mackenzie, 2015).

Immediate impacts of the pandemic

The immediate impacts of the pandemic were not distributed evenly, nor were they straightforward to assess. Our results provide a cross-sectional snapshot of ECR experiences seven to eight months after the first lockdowns. According to the qualitative and quantitative responses in the survey, factors such as gender, career stage, contract type, location, field work requirements, and home circumstances all played a role in how ECRs experienced the first months of the pandemic. This suggests that the pandemic amplified existing advantages and disadvantages and that impacts were intersectional and complex.

Positive impacts of the pandemic were more often reported by ECRs in more senior stages of their careers, notably postdoctoral fellows (Figure 3) and PhD students more frequently reported feeling negative impacts and increased pressure (Figures 2 and 3). This difference may be explained by postdoctoral fellows being relatively more established in their careers than PhD students, but with fewer personal care duties (i.e., for children or aging parents) than other non-ECRs. These results are also in line with other work on intersectional challenges in academia (Cosentino and Souvion-Priego, 2021) and may be explained by PhDs' relative inexperience with navigating professional challenges compared to more senior ECRs. Furthermore, the sudden move to online spaces for working, meeting, and networking had an effect on ECRs' ability to form social connections. Given that PhD students are often new to their research group and institute, they may have been more severely impacted by losing the opportunity to build social connections with their new colleagues. Another cause may be the lack of integration of PhDs in research groups compared to more senior ECRs due to the structure of research projects. While this varies by country and institute, PhD students are often on contracts no longer than 4 years, and work in a narrower field of research, while more senior researchers may collaborate with more people during the coordination and execution of their projects. Thus, compared to their more senior colleagues, PhD students have less contact with other researchers in their day-to-day work and are more vulnerable to isolation.

Whilst the online environment has its benefits, formal online meetings with colleagues do not provide the same social cohesion as informal in-person interactions, as would occur in an office setting (Srivastava *et al.*, 2021). While institutions and national bodies need to foster such online networking activities, they cannot replace face-to-face interactions and we therefore recommend that ECRs be supported to attend in-person events with their ECR peers (e.g., conferences) and with their research groups (e.g., team-building days) when possible. We also recommend that particular attention should be given to ECRs who are new to the country or express feeling isolated, and to ECRs for whom changes in productivity and behaviour have been observed. In the longer term, efforts must be made within individual institutions, led by supervisors and research teams, to ensure that ECRs are welcomed into research spaces and able to create vital social connections. Our

survey results also show that, in most cases, communication with research groups was either unchanged or negatively affected by the pandemic (Supplementary Figure S1). Thus, well-established relationships between ECRs and their supervisors were more resilient to the challenges posed by the pandemic than the relationships ECRs have with their wider research group. This indicates that supervisors are crucial for building and maintaining social connections (Andrews *et al.*, 2020) and we recommend following guidance on how to foster healthy research groups (Maestre, 2019). International organizations and networks must also aim to create an inclusive environment where ECRs can interact with established scientists and each other, whether face-to-face or in an online format (Table 3).

As for connecting ECRs with their peers, there is a growing trend to establish early career networks which are strongly driven by the UN Decade and its associated ECOPs (Early Career Ocean Professionals) programmes (Giron *et al.*, 2020; Sugimoto *et al.*, 2020; Simpson *et al.*, 2021). While this is perceived by many as a positive step to support ECRs by helping them form professional networks, we should be mindful of the free labour ECRs contribute within these networks and find ways to recognize this contribution. Such ECR networks and initiatives should be run in a manner that empowers and integrates marine ECRs into existing marine science organizations. We argue that this is possible by focusing on: (i) integrating ECRs at the decision-making level, (ii) connecting them to like-minded ECRs, (iii) providing financial, professional, and in-kind support, (iv) compensating for inequalities, and (v) supporting ECRs in developing their careers.

Long-term impacts of the pandemic

The long-term negative impacts of the pandemic may not yet be empirically observable, but our survey highlighted ECRs' views on what these impacts may be. The respondents were concerned about snowballing negative impacts on this generation of ECRs caused by a lack of the types of networking opportunities that are crucial for finding jobs (Hefferman, 2021). Hybrid models are now increasingly considered for conference and workshop attendance (Niner and Wassermann, 2021). While these provide important opportunities, such approaches need careful consideration and application to ensure that accessibility is maintained and inequities are not amplified. Given limited funding for ECRs, senior academics may be more likely to attend conferences in person while ECRs may be encouraged to simply join online (Table 3).

Another long-term impact identified in the survey is that many ECRs missed crucial opportunities to learn new skills and acquire knowledge in the field and laboratory. The negative effects of missing these capacity-building opportunities will extend beyond the marine research projects (which now also have gaps in their observational data) to impact a generation of ECRs who are missing relevant work experience. Furthermore, our results show that ECRs who rely mainly on field and laboratory work experienced more pressure to be productive (Figure 3). This finding supports earlier insights that ECRs who rely on work that can only be carried out in specific time frames (e.g., season-dependent sampling campaigns) were particularly affected by the pandemic disruption (Inouye *et al.*, 2020).

While ECRs worry that they have missed opportunities to develop important skills, more general job insecurity is a

well-established concern (e.g., Osiecka *et al.*, 2021). Challenges with funding, specifically the extension of existing funding, served to increase the pressure felt by ECRs, especially considering disruptions to research timelines and the ability to meet deadlines. Notably, at the time of our survey (i.e., eight months after the start of the pandemic), only 17% of respondents had positive confirmation of funding extensions (Supplementary Figure S8). As such, there is a need for institutes and funding bodies to take a more proactive, flexible approach for the duration of the pandemic regarding project timelines. Project leaders also need to ensure timely and clear communication about the funding opportunities and extensions available to ECRs (Table 3). Insecurities around funding extensions impact ECRs' ability to complete their current projects, which has consequences for their individual career progression. Furthermore, the impact of the pandemic must also be considered when assessing research performance in the long term (Table 3). It has been argued that hiring committees must go beyond hiring people based on traditional metrics such as the *h*-index, which can reflect outdated ideas of academic productivity (Kreiner, 2016; Davies *et al.*, 2021). We add to this the assertion that ECRs should be free to highlight any pandemic-related shortcomings in their CVs and that these should be accounted for along with the intersectional disadvantages that the pandemic exacerbated.

(Some) positive impacts of the pandemic

While the vast majority of survey respondents clearly reported no positive impacts of the pandemic on their personal and professional lives, the restrictions caused by the pandemic had some positive impacts for some respondents. Respondents who experienced positive impacts from the pandemic and resulting changes to work reported feeling more responsible for their own outputs and appreciated the new flexibility. Furthermore, the pandemic has highlighted the benefits and possibilities of hybrid working arrangements which can cater for individual family and accessibility needs. Many workplaces are now considering hybrid working models, which consequently lead to a more inclusive workplace (Chung *et al.*, 2021). Based on the results of our survey, we agree that these should be implemented in workplaces after the pandemic restriction measures are lifted (Table 3). Principal investigators and institutions need to ensure that ECRs have access to a suitable workspace (either at home or in the office), which includes adequate equipment and privacy to engage in their day-to-day work as well as virtual networking activities (Table 3).

Limitations and future research

This article presents insights from a non-random sample of highly diverse ECRs and was performed in the early stages of the pandemic (October–November 2022). The pandemic is still ongoing, with several waves having already taken place across much of Europe at the time of writing (Woolston, 2021b). Since the survey data collection, widespread vaccination has saved tens of millions of lives (Watson *et al.*, 2022). As such, some of the negative impacts reported in this paper may have been exacerbated with the ongoing restrictions, while other challenges may have been overcome or dealt with. It is therefore imperative that future research considers the new vulnerability and opportunities for ECRs that have been brought about by the pandemic and how they intersect with other existing career-progression challenges.

Conclusion

The coincidence of the pandemic and the beginning of the UN Ocean Decade presents an opportunity for enquiry into and reflection on the vulnerabilities that marine scientists, especially ECRs, experience. While the pandemic has arguably affected all researchers in one way or another, the pandemic has worsened inequities already present within academia. Marine ECRs, especially those at the earliest stage of their careers, now deal with negative impacts from the pandemic that further exacerbate structural problems within academia such as short-term contracts, limited funding, and the disruption to family life caused by pressure to relocate for academic positions. These structural problems intersect with disadvantages that arise from discrimination based on gender, family status, race, and (dis)ability.

Despite these challenges, we argue that the structural problems that affect marine science ECRs can be improved and refined in the wake of this crisis if individuals (i.e., supervisors and principal investigators) as well as marine science institutions choose to act deliberately to support, empower, and integrate marine ECRs, paying special attention to disadvantaged and underrepresented groups as the pandemic continues (as outlined in Table 3). Examples of targeted institutional support include the provision of free childcare, especially to women or employees who have relocated to accept the position, or the provision of free mental health services, especially to the most junior ECRs.

The coming decade will bring global challenges such as climate change, biodiversity loss, marine pollution, overfishing, and environmental injustice. Humanity's best chance at tackling these challenges is by generating innovative scientific input for the benefit of decision-makers, practitioners, and stakeholders alike. Supporting marine ECRs in overcoming both existing and pandemic-related setbacks is a crucial element of this endeavour, and is essential for achieving the UN Ocean Decade's goal of producing the "science that we need for the ocean we want".

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Supplementary data

Supplementary material is available at the *ICESJMS* online version of the manuscript.

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Author contribution statement

AS and EF are joint lead-authors on this work and have the right to list their name first in their CV. AMW, LCG, and MLA were part of the lead team and are listed in order of contribution. The rest of the author team is listed alphabetically.

- Conceptualization: AS, EF, AMW, LCG, MLA, IB, TTD, ML, SP, and GS.
- Survey design: AS, EF, and LCG.
- Ethics: EF and AMW
- Survey distribution: AMW, MLA, IB, and ML.
- Qualitative data analysis: AS, EF, AMW, LCG, MF, and GS.
- Quantitative data analysis: LCG, MLA, TTD, and MF.
- Producing figures: MLA, ML, MF, CG, and NLM.
- References and citations: AMW and GS
- Writing the original manuscript: AS, EF, AMW, LCG, and MLA.
- Review and editing: all authors.

Data availability statement

The raw data generated for this study cannot be publicly available due to restrictions imposed by ethics requirements and agreements with research participants. Selected data that does not breach any ethics requirements are available on request from the corresponding author. All scripts for data visualiza-

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