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Persistent gender bias in marine science and conservation calls for action to achieve equity

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ABSTRACT

The increasing consideration of gender balance in conservation science and practice has been reflected in the setting of global commitments. Yet, women remain under-represented in science and conservation decision-making. We compiled and analyzed data on the representation of women in hiring, publishing, funding, and leadership positions in European Union marine sciences and conservation. To explore scientists' perceptions of gender imbalance in marine sciences and conservation more broadly, we conducted a global survey and analyzed 764 questionnaires from 42 countries. Participants were also asked to identify measures that promote gender equity. We found a consistent pattern of women being under-representated across institutions and nations characterized by a relatively balanced representation of men and women in early career stages and a growing gap in later stages, with women occupying only 13% to 24% of senior positions. The same pattern was found in publishing, funding, and leadership of research institutes. Survey results demonstrate that most marine scientists are aware of the general and persistent gender bias, and perceive that it may compromise our ability to effectively solve conservation problems. Measures that increase fairness in evaluations (e.g. for hiring) and that support work-life balance ranked high, whereas gender-oriented measures, such as gender-specific scholarships, received less support. Our findings suggest that mechanisms promoting a fairer share of family responsibilities and transparent processes in hiring and evaluation are the most promising path to a more balanced participation of women in scientific leadership and conservation decision-making. Such measures may benefit not only women but diversity more generally.

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1. Introduction

Gender equality and women's empowerment is one of 17 Global Goals that make up the United Nations 2030 Agenda for Sustainable Development to accelerate progress towards a more equitable, sustainable future for all (United Nations, 2015). Yet worldwide, women face biases and barriers in most aspects of their scientific career, from publishing, funding, and hiring to promotion to senior positions (Grogan, 2019). On average, men publish more articles than women (de Kleijn et al., 2020), while articles with women in first, last, and corresponding authorship positions, receive fewer citations than those with men in these positions (Larivière et al., 2013). Women are less successful than men when applying for public research funding (Van der Lee and Ellemers, 2015), rate lower based on identical job applications presented with a male name (Moss-Racusin et al., 2012), and are employed less in laboratories led by high-achieving male faculty members (Sheltzer and Smith, 2014). This evidence suggests that gender bias in science is deeply ingrained and self-perpetuating.

In the European Union (EU), imbalances between women and men in science emerged as a major policy concern in the late 1990s. Since then, aiming to counter these imbalances in STEM fields (i.e. Science, Technology, Engineering and Mathematics), the EU issued a large body of legislation. Specifically, gender equality and gender 'mainstreaming' (i.e. the integration of gender perspectives in the preparation and evaluation of policies) in academic research has become one of the priorities for the European Research Area (European Commission, 2012). In 2017, while EU gender assessments reported women to be 48% of doctoral graduates, women made up only a third of the EU's researchers and only 24% of higher academic and research positions were filled by women (European Commission, 2019).

The under-representation of women in senior and leadership positions in science is a global issue. In the USA, 53% of biology PhD graduates were women in 2015, yet they composed 35% of the professoriate with PhDs in biology (Hechtman et al., 2018). Also, women made up 21% and 5% of full science and engineering professors, respectively (Shen, 2013). In Australia, women comprised 56% of postdoctoral biology academics in 2016 but only 18% of professors, and held 14.5% of senior-level positions in the STEM fields (Commonwealth of Australia, 2019). Similarly, women made up 14% of university chancellors and vice-chancellors at Brazilian public universities and 17% of South African universities (Huyer, 2015). This global phenomenon is referred to as the "leaky pipeline", likening advancement (from PhD student, early career research, professor, etc.) in STEM careers to a series of connected pipes, leaking more women than men at particular junctures (Shaw and Stanton, 2012).

Herein, we analyzed data from different sources to examine women representation in marine sciences and conservation and found evidence of a persistent leaky pipeline. We then explored the perception of women and men members of the scientific community regarding gender inequality and its consequences on marine conservation. Importantly, we identified key measures for reducing gender bias and for promoting gender equity in research and academia, and provide a first assessment of the scientific community's support for different portfolios of countermeasures. It is important to clarify that, in this article, we use the term "gender" referring to binary gender (i.e. women and men) as in the EU's official documents, acknowledging that minority genders also face biases in science (Cech and Pham, 2017) and that these issues are likely more severe for individuals that combine different aspects of human diversity (e.g. race, gender, sexuality, physical disability). While it is crucially important to highlight that women face different biases in their working environment depending on their race, age, sexuality and other dimensions of diversity (e.g. Williams et al., 2014), for the purpose of this study we considered women as one group based on gender. Additional research and actions addressing biases and discrimination that account for intersectional aspects of diversity are key priorities.

2. Material and methods

We obtained data on the representation of men and women at different career stages from the French National Centre for Scientific Research (CNRS; www.cnrs.fr/mpdf/), the Academia in Italy (http://ustat.miur.it/), and the Spanish National Research Council (CSIC; https://www.csic.es/sites/default/files/informe_mujeres_investigadoras_2019.pdf). None of the institutions obtained data on the representation of non-binary and other minority genders. Data for all institutions correspond to the year 2017 and to the field of natural sciences since specific data on marine natural sciences were unavailable. In general, when direct data focusing on marine science and/or marine conservation were unavailable, we used data in close related fields that encompass research in marine science and conservation. Data about EU standard academic career in STEM were extracted from EU reports (European Commission, 2019) and correspond to the year 2016. Regarding scientific leadership in France, we searched the CNRS directory (https://annuaire.cnrs.fr/l3c/owa/annuaire.recherche/index.html). Data for the Italian research institutes: National Research Council (CNR), the Italian Institute for Environmental Protection and Research (ISPRA), the Italian National Institute of Oceanography and Applied Geophysics (OGS), and the Italian National Inter-University Consortium for Marine Sciences (CONISMA) were obtained from websites (https://www.cnr.it/; https://www.isprambiente.gov.it/en; https://www.inogs.it/en) and direct interviews with personnel. For the Spanish institutions CSIC and the Oceanographic Center of Vigo (IEO-Vigo), we obtained relevant information from the institutions' websites (https://www.csic.es/sites/default/files/informe_mujeres_investigadoras_2019.pdf; http://www.repositorio.ieo.es/e-ieo/handle/10508/11359?show=full).

With regard to publishing, we estimated the proportion of EU-affiliated women first and last authors of articles, published between 2009 and 2019, in journals belonging to different quartiles (as an indication of their quality). The journals were categorized into four groups as ranked in 2017 by the Web of Science for "biodiversity conservation", "ecology", "fisheries" and "marine & freshwater biology" (see Table A1 in SI Appendix for search specifics). In group A, we included the two highest-ranked multidisciplinary journals (i.e. "Nature" and "Science"). In groups B, C, and D, we included the two top journals belonging to first, second, and third quartiles, respectively (i.e. B: "Trends in Ecology and Evolution" and "Annual Review of Marine Science", C: "Biogeosciences" and "Behavioural Ecology", and D: "Ecotoxicology and Environmental Safety" and "Journal of Experimental Marine Biology and Ecology"). We identified the gender of the first and last authors of EU-affiliated institution for a total of 480 articles (Table A2). To assess the authors' gender, we searched online for the authors' profile, curriculum vitae and pictures (as in Wu et al., 2020). While it is conceivable that we misidentified and miscategorized non-binary (or other minority gender) individuals whose physical appearance fits the stereotypes of "woman" or "man", this manual approach is less prone to errors when compared to automated approaches (see Holman et al., 2018). For each journal group, we estimated the weighted average of female and male author percentages.

The European Research Council (ERC) provided us with data on the percentages of male and female applicants and grantees in the section LS8 Ecology, Evolution, and Environmental Biology for the three ERC grants: Starting, Consolidator, and Advanced covering the period 2013–2018. Percentages were averaged across this period. We also obtained the percentages of applicants and grantees per gender for the Marie Skłodowska-Curie Individual Fellowships (section "Environment and Geosciences" comparable to ERC's section L8) for 2014–2018. To obtain data regarding female and male participants in EU COST (European Cooperation in Science and Technology) projects related to marine sciences and conservation, we performed a keyword search in the COST website (https://www.cost.eu/cost-actions/browse-actions/) using: "marine", "conservation", "fisheries" or "ecology" which identified 12 relevant actions (Table A3) for which data were available (funding period 2004–2022).

To assess perceptions of marine scientists and practitioners regarding the role of women in marine sciences and conservation, we administered an on-line questionnaire (see SI Appendix) via social media. We also sent the link to the questionnaire via email to lists in universities, research centers, and colleagues working in environmental non-governmental organizations, asking them all to share the link with their contacts. We used a convenience sampling approach because it is affordable, easy and the subjects are readily available (Wright, 2005; Etikan et al., 2016). Internet surveys with convenience sampling have been used to assess perceptions towards conservation in previous studies (e.g. Loyau and Schmeller, 2017). After providing demographic information (e.g. gender, age, country of affiliation, position), participants were asked to indicate the extent to which they agreed with a set of statements using a 5-point Likert scale, ranging from “strongly disagree” to “strongly agree”. Finally, participants selected among 13 measures, collected from the authors' experience and relevant literature (e.g. Hill et al., 2010) for promoting gender equity. The selection frequency of each measure determined its rank.

Questionnaires missing information were discarded. The questionnaire of the only respondent who identified neither as a woman nor as a man was also discarded because the sample size for minority genders (gender group “other” in the questionnaire) was too small. Hence a total of 764 questionnaires were retained for analyses. We re-coded the response to the survey to binary variables (agree or strongly agree = 1; otherwise = 0) and fitted the data to logistic regressions with respondents' age, gender (man, woman), location of affiliated institution (European, non-European), field of research (natural sciences, other), and career stage (student/PhD candidate, early-career, mid-career, senior/leadership position) as explanatory variables. We focused on the perception of the following statements: (a) more male scientists in senior positions; (b) more male scientists publishing in top journals; (c) more male scientists obtaining research grants; (d) more male scientists leading science-policy fora; (e) gender balance influences conservation outcomes positively. A stepwise best fitted model selection based on Akaike Information Criteria (AIC) was performed to derive a

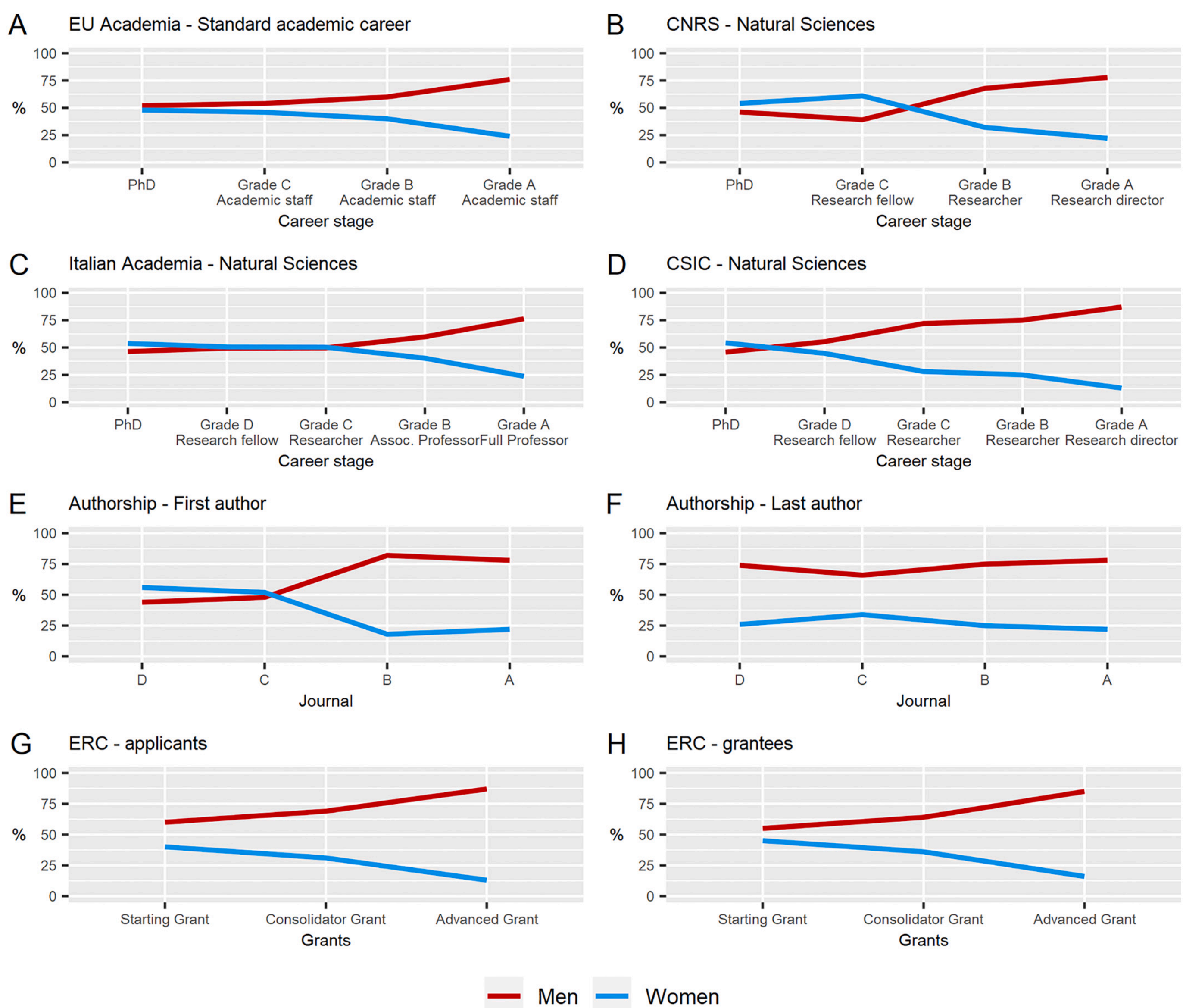

Fig. 1. Representation of men and women in a) EU Academia; b) the French National Centre for Scientific Research (CNRS); c) Italian Academia; and d) the Spanish National Research Council (CSIC), e) publications as first authors in journals of group D (third quartile), C (second quartile), B (first quartile) and A (top ranked multidisciplinary journals); f) publications as last authors in journals of group D, C, B, and A; g) applications for Starting Grants, Consolidator Grants, Advanced Grants of the European Research Council (ERC); and h) ERC grant awards. Data on the representation of non-binary and other minority genders were unavailable.

parsimonious final model for each statement (SI Appendix; Table A4). The analyses were performed using R v 3.6.1 (R Core Team, 2019).

3. Results

Data obtained from EU research institutions regarding the representation of women in different scientific career stages, demonstrated a clear and consistent pattern (Fig. 1A-D). While a relative gender balance was observed among PhD students and graduates, the gap widens as one moves towards more senior positions. The same pattern is apparent across institutions and nations, with the proportion of women in senior positions varying from 13% to 24%. Very few women have obtained positions as heads of their EU research institutes (Table 1), and only recently (after 1990). Moreover, in 2019, the percentage of women directors in the 24 marine laboratories affiliated to the French CNRS was 24%, and 33% of the Spanish Institute of Marine Science directors have been women over the past 80 years (1939–2019).

Greater gender balance in authorship was apparent for journal groups C and D (i.e. journals of the second and third quartiles, respectively). For the highest-ranked multidisciplinary journals, i.e. Nature and Science (group A), and journals in the first quartile (group B), women represented 22% and 18%, respectively (Fig. 1E). Regarding senior (last) authorship, a large gap between women and men exists across all groups of journals, with women representing between 22% and 34% (Fig. 1F).

Regarding research funding, ERC data demonstrated the same pattern; the percentages of men and women applicants and grantees were similar for Starting Grants and then diverged for grants awarded to those in later career stages (Fig. 1G & H). For all grant types, the ratio of female to male grantees was greater than the same ratio among applicants, indicating a greater success rate among women. Yet, the percentage of female applicants dropped substantially for the Consolidator and even more for the Advanced Grants, for which only 13% of applicants and 16% of grantees were women. These percentages echo the decreasing representation of women in advanced scientific career stages. Greater gender balance in early career stages was also reflected in the data for the Marie Skłodowska-Curie Individual Fellowship. Applicants for these fellowships in the period 2014–2018 were 45% female and represented 50.5% of those awarded grants. Women scientists led 25% of EU COST projects and were vice-leaders in 42% of projects in the fields of marine sciences and conservation ($n = 12$).

Most survey respondents were women (75%), affiliated with European-based institutions (57%), and from a natural sciences background (86%). Most respondents perceive that men hold more senior positions (Fig. 2). More women than men perceive that men publish more frequently in top journals, lead more science-policy fora, and obtain more research grants, however, most respondents neither agree nor disagree with these statements. Most participants (71%) perceive that gender balance positively influences conservation outcomes, although less men than women hold this opinion (Fig. 2).

The regression model results showed that gender and location of the affiliation institute were the two factors that explained the variability in responses for all the statements (Table A4; Figs. A1–A5 in Appendix). Women were more likely to agree with the statements than men and those based in non-European institutes more likely to agree with the statements than respondents in European institutes. For statements 2 to 5 (Figs. A2–A5), the likelihood of agreement also appeared to change with age, dependent upon research fields or career stages.

Four out of the 13 measures for promoting gender balance: 1) establishing infrastructure supporting family responsibilities, 2) transparent hiring procedures, 3) consideration of periods of inactivity (e.g. family leaves), and 4) gender-blind evaluation, always ranked first across respondent groups categorized by gender and/or location (Fig. 3, Table A5). Conversely, gender-specific scholarships, gender-specific tenure track positions, and cluster hire of women to foster their careers, consistently ranked last. Finally, the ranking of six measures varied among groups. These results suggest that while some measures are clearly general priorities, support and potential efficacy of others is likely context dependent.

4. Discussion

Diverse data sources and approaches reveal a persistent gender bias across different dimensions of EU research/academic careers in marine sciences and conservation. The global survey results are consistent with the patterns shown by the data, highlight perceptions held in and beyond Europe, and suggest broad implications of this persistent and widespread under-representation of women in marine science and conservation. Overall, more women than men perceive that men fill more senior positions, publish more in top journals, and lead more science and policy fora than women. Differences in perceptions between men and women may be partly explained by a relative reluctance among STEM faculty men to accept evidence of gender biases in science (Handley et al., 2015).

Two thirds of respondents perceive that gender balance would influence positively marine conservation outcomes, perhaps related to evidence demonstrating that gender diversity leads to solving problems more efficiently (Nielsen et al., 2017), especially regarding environmental issues (Wang et al., 2019). There is evidence that women exhibit higher levels of social sensitivity, and teams with a high proportion of women boost the collective intelligence in scientific teamwork (Joshi, 2014) and cooperation in natural resource conservation (Revollo-Fernández et al., 2016). Moreover, women researchers have raised important, and often neglected, concerns in marine conservation (Gissi et al., 2018) and their increased participation in editorial boards of conservation journals, which are currently male-dominated, could contribute in finding innovative solutions to conservation problems (Liévano-Latorre et al., 2020).

While measures have been identified to address gender biases in science and promote gender equity (Kapareliotis and Miliopoulou, 2019), to the best of our knowledge, support for different measures has not been comprehensively assessed. Results of our survey highlight consistent support for measures that increase fairness and transparency in competitions and evaluations, and that support balance between

Table 1
Total number of men and women in leading positions in EU research institutes. All women presidents and general directors were appointed after 1990; the year of their first appointment is provided in parentheses.

Period	Institute	President		Gen. director	
		M	W	M	W
1923–2019	Italian National Research Council (CNR)	21	0	N/A	N/A
1958–2019	Italian National Institute of Oceanography and Applied Geophysics (OGS)	6	1 (2011)	14	2 (1991 & 2000)
1986–2019	Italian Institute for Environmental Protection and Research (ISPRA)	8	0	N/A	N/A
1994–2019	Italian National Inter-University Consortium for Marine Sciences (CONISMA)	4	0	2	0
1981–2019	French National Centre for Scientific Research (CNRS)	7	1 (2006)	7	2 (1997 & 2000)
1939–2019	Spanish National Research Council (CSIC)	18	1 (2017)	N/A	N/A
1917–2019	Spanish Oceanographic Center of Vigo	N/A	N/A	13	2 (1991 & 2015)

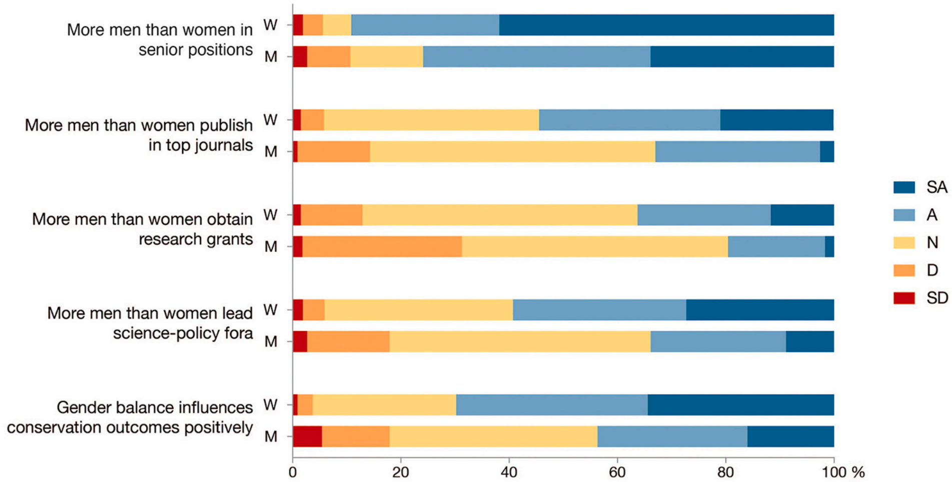

Fig. 2. Stacked bar chart showing the frequency distribution of the level of agreement of women (W; n = 576) and men (M; n = 188) respondents with five statements. SA = strongly agree, A = agree, N = neither agree nor disagree, D = disagree, SD = strongly disagree.

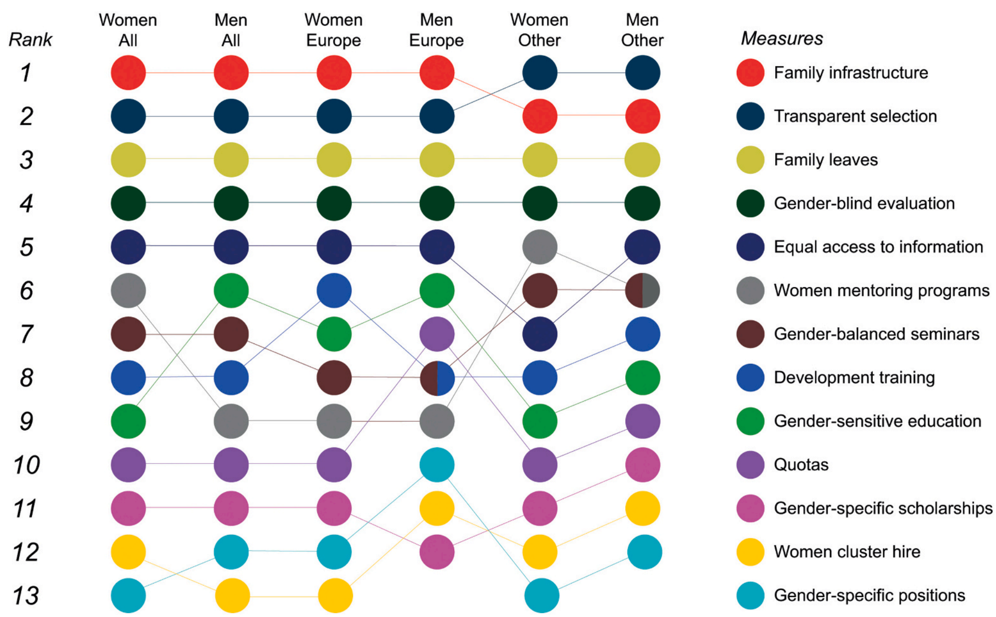

Fig. 3. Bump chart presenting the ranking of 13 mitigation measures for the improvement of gender balance in marine sciences and conservation across different groups of respondents: all women (n = 576), all men (n = 188), women in Europe (n = 325), men in Europe (n = 112), women in other continents (n = 251), and men in other continents (n = 76).

family and work life. In contrast, our survey shows that gender-oriented measures, such as gender-specific scholarships and cluster hires, are a lower priority. This finding challenges some common practices applied to achieve gender equity. For instance, in 2016, the European Institute for Gender Equality produced a toolkit (EIGE, 2016) that proposes a series of best practices for research institutes that are all gender-oriented, such as women targeted recruitment in STEM. Gender quota are also broadly applied in EU policies across sectors including research. However, the survey respondents showed reluctance towards gender-oriented measures and, interestingly, European women ranked gender quota as a lower priority than men did. Implementing gender-oriented policies cannot automatically reshape institutions (Kapareliotis and Miliopoulou, 2019). Instead, promoting critical gender awareness in institutions considering contextual (institutional and family-related) factors and non-contextual factors (including individuals' attitudes and beliefs) should be prioritized (Mitchneck et al., 2016; Kapareliotis and Miliopoulou, 2019).

Many respondents highlighted the unequal sharing of childcare responsibilities within the family and its impact on women's research careers. Support and empowerment of women caregivers at an organizational and structural level, through reinforcement of relevant infrastructures, is needed to facilitate balancing family and work life. This issue is currently of utmost importance as the COVID-19 pandemic is disproportionally affecting women's working hours and consequently their careers (Minello, 2020). Accordingly, the period of partial inactivity for women and men caregivers during the pandemic crisis should be considered in future job applications, tenure track positions, and scientific production evaluations, e.g. for obtaining grants or competitive projects. For example, the EU Marie Skłodowska-Curie Individual Fellowships aim to facilitate people coming back to their career after a break (e.g. due to parental or long-term sick leave), factoring such periods of research inactivity into the evaluation. This fact may partly explain why our results suggest that this type of fellowship is one of the most successful EU funding mechanism for promoting gender equity in research.

Despite reaching out to scientists of all genders via social media, 75% of survey respondents were women. We therefore acknowledge that our results may represent a partial view of the marine science and conservation community. Nevertheless, this gender bias in survey participation alone suggests that women are perhaps more interested in gender equity, and thus are more willing to dedicate time to a relevant survey than men. Moreover, survey response and non-response studies have shown significant response bias and particularly that women are more likely to participate than men regardless of the survey's subject (Smith, 2008). Such studies have also demonstrated that participation decreases with age (Smith, 2008). In contrast with these results, senior scientists showed greater response rates to our survey, maybe because they have experienced more gender inequality throughout their careers than students and early-career scientists, as demonstrated herein and elsewhere (e.g. Hechtman et al., 2018).

Besides having deep social, economic, and wellbeing implications (Deininger et al., 2019; Klasen, 2007), gender biases influence our interaction with the ocean (Gissi et al., 2018), its resource management (Kleiber et al., 2015) and conservation (Tallis et al., 2014). Ram-Bidesi (2015) highlights women's direct and indirect role in fisheries management and argues that the recognition of their role and empowerment can increase the use of sustainable fishing practices. Moreover, studies conducted across the world, have demonstrated that gender inclusive management is critical for the effective creation, use and adoption of environmental governance (Di Ciommo and Schiavetti, 2012; Michalena et al., 2020). Therefore, empowering women may substantially advance marine conservation and the sustainable use of the ocean and its resources.

By analyzing and publishing data on differences in representation of women and men in marine sciences and conservation, we highlight issues of gender diversity and equity with the goal of informing policies aiming to remove gender biases. Sustainable Development Goal 5 has set the specific target to ensure women's full and effective participation and equal opportunities for leadership at all levels of decision making. Empowering women in science by securing transparent and gender-blind processes in hiring and evaluation in academia, as well as better share of family responsibilities, would allow their more balanced participation in leadership and ability to influence strategic decisions in marine sciences and conservation. These issues go well beyond the disparity between men and women in science and conservation practice. We explicitly focused our study on the exploration of gender inequality between women and men and did not investigate biases regarding other genders, cultural, or racial biases. Future studies should expand to address inequalities across different dimensions of human diversity and their intersections.

CRediT authorship contribution statement

Sylvaine Giakoumi: Conceptualization, Methodology, Investigation, Formal analysis, Visualization, Writing – Original draft.

Cristina Pita: Conceptualization, Methodology, Investigation, Formal analysis, Data Curation, Visualization, Writing – Review & Editing.

Marta Coll: Conceptualization, Methodology, Investigation, Writing – Review & Editing.

Simonetta Fraschetti: Conceptualization, Methodology, Investigation, Writing – Review & Editing.

Elena Gissi: Conceptualization, Methodology, Investigation, Visualization, Writing – Review & Editing.

Isidora Katara: Formal analysis, Data Curation, Visualization.

Elena Lloret-Lloret: Conceptualization, Methodology, Investigation, Writing – Review & Editing.

Francesca Rossi: Conceptualization, Methodology, Investigation, Writing – Review & Editing.

Michelle Portman: Conceptualization, Methodology, Writing – Review & Editing.

Vanessa Stelzenmüller: Conceptualization, Methodology, Writing – Review & Editing.

Fiorenza Micheli: Conceptualization, Methodology, Writing – Review & Editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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