A Global Analysis of the Climate Risk of Women in Small-Scale Fisheries

By

Claudia Suzanne Deeg

John Virdin, PhD, Advisor

Xavier Basurto Guillermo, PhD, Advisor

April 28, 2023

Master's project submitted in partial fulfillment of the requirements for the
Master of Environmental Management degree in the
Nicholas School of the Environment, Duke University

Duke

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EXECUTIVE SUMMARY

In recent years, researchers have increasingly acknowledged that women make significant contributions to small-scale fisheries (SSF) globally and that a gap in the availability of gender-disaggregated data exists, yet the gap and the prevalence of sexist data persist. Small-scale fishers make outsized contributions to livelihoods, food, and nutrition security around the world. Women most often participate in fisheries through gleaning (gathering bivalves and other target species in shallow water by foot, also called foot fisheries) and in the post-harvest segment of the value chain (such as processing and trading). However, definitions of SSF often focus on harvesting activities by boat. This limited understanding of fisheries, in conjunction with the common perception that women's fisheries work is simply an extension of household duties and not real fishing, makes women largely invisible in the sector. Accordingly, women's contributions to SSF are often undervalued. Climate change poses a significant threat to SSF livelihoods worldwide and women, on average, are likely to be disproportionately impacted by a warming planet.

In this study, I use gender-disaggregated data on women's employment in small-scale fisheries to examine the risk and vulnerability of women fishers to climate change. I use a global database of national labor and employment data and two published climate risk indices to analyze the geospatial distribution of women fishers in contexts of high-risk as well as the statistical correlations between populations of women fishers and current and projected climate risk. The data for this project is sourced from the "Illuminating Hidden Harvests" study, a collaboration between Duke University, the United Nations Food and Agriculture Organization (FAO), and WorldFish. I conducted a pre-analysis literature review using the databases Web of Science and Scopus in which I found no articles addressing the intersection of SSF, climate change and gender.

My results show that women working in SSF are broadly distributed around the world but are most populous in Asia and comprise the biggest percentage of the regional and sub-regional populations in Oceania and the Pacific Islands. While women represent over a

third of SSF workers worldwide, the proportion of women in national SSF sectors varies widely from 8% to 61%. I estimate that up to 19 million women fishers (92.18% of total) live in countries with high- or very high-risk to climate change. The actual number predicted varies between climate risk indices, showing the need to review multiple sources for policy development. The proportion of women in relation to men across categories of climate risk is relatively stable, suggesting that women are not necessarily more likely than men to live in contexts of high climate risk. However, women may still be disproportionately impacted by climate change impacts. Assuming a stable population and global distribution, the number of women fishers at risk is projected to increase as climate change worsens, affecting up to 1.6 million additional women under a 'pessimistic' climate scenario. There is a statistically significant relationship between worsening gender inequality and an increasing number of women small-scale fishers, as well as between gender inequality and increasing risk and vulnerability to climate change. It is likely that the data used in this study underestimate the true number of women working in SSF, so it is very possible that the number of women small-scale fishers at high-risk to climate change is even higher.

This study shows that many women small-scale fishers live in contexts of high climate risk, vulnerability, and gender inequality. Fisheries scientists and policymakers must prioritize collecting gender-disaggregated data and countering social-cultural barriers to valuing women's contributions. It is critical for countries to develop gender-sensitive fisheries and climate policies to support this oft-marginalized population and to empower women to contribute to SSF provisioning and climate adaptation. A number of countries still do not address gender in national climate policy, and many past gender fisheries policies have been narrowly focused and failed to address systemic barriers. The results of my research provide a broad overview of this issue and further research should look at variations across segments of the value chain and include women engaged in subsistence fishing.

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1. INTRODUCTION

In the English language, we commonly use the term “fisherman” to refer to a person who captures fish from the water for a living. In the United States, this word typically invokes an image of a man on a boat using a rod or net to obtain his catch. While the non-gendered term ‘fisher’ has recently become more popular in scientific literature, the gendered understanding of fisheries persists around the world (Harper et al., 2013; Kleiber et al., 2015; Smith & Basurto, 2019). As a result, women’s work in fishing is chronically overlooked and underreported in fisheries data (FAO et al., 2023; Harper et al., 2013). This may be especially true in the small-scale fisheries (SSF) sector, which is often undervalued compared to the large-scale fisheries (LSF) sector (Smith & Basurto, 2019). In fact, marginalization is the second-most important driver of vulnerability in the SSF sector as it is frequently deprioritized relative to LSF and other sectors such as tourism (Cánovas-Molina & García-Frapolli, 2022). Women fish workers are typically further marginalized within the SSF sector and excluded from decision-making, thereby exacerbating vulnerability and marginalization despite the high importance of both the SSF sector and women’s contributions to it (Cánovas-Molina & García-Frapolli, 2022).

SSF, while “small” in scale compared to the LSF sector, are by no means insignificant in terms of environmental, economic, and nutritional impacts. According to the recent study “Illuminating Hidden Harvests: The contributions of small-scale fisheries to sustainable development” (IHH), 90% of all people working in capture fisheries are in the small-scale sector and they are responsible for 40% of the total global catch (FAO et al., 2023). The sale of fish catch provides an important source of income for the 60 million people employed in the sector and the personal consumption of fish is critical for food and nutritional security to the 53 million subsistence fishers around the world. Of course, these categories are not mutually exclusive, and an employed fisher may consume some of their catch, and vice versa (FAO et al., 2023). Work in SSF also serves an important buffer and safety net role for people employed in other sectors, such as agriculture, to supplement their income or to fall back on when their primary livelihood source is insufficient or inaccessible (Virdin et al., in review). SSF are found in every country of the world and vary widely such that it is all but impossible to determine a single definition (FAO, 2015). Yet despite their diversity, SSF are often defined in ways that over-emphasize the harvest

segment of the value chain, such as gear type or vessel length/motorization, which can bias SSF research towards male-dominated fishing activities (Smith & Basurto, 2019).

The lack of gender-disaggregated data in small-scale fisheries has long been acknowledged, but the issue persists in fisheries science (FAO et al., 2023; Harper et al., 2013; Kleiber et al., 2015; Weeratunge et al., 2010). This issue is known as the "gender data gap" and continues through a self-reinforcing cycle in which women are assumed to make no or minimal contributions to fisheries, so fisheries data is collected only about men or male-dominated fishing activities, and the original assumption is reinforced (FAO et al., 2023). Yet fisheries are more than just fishing, and attention to all types of fisheries labor is critical to accurately understanding the impacts of SSF and women's contributions to it (Harper et al., 2013; Kleiber et al., 2015; Smith & Basurto, 2019). The IHH study showed that more than a third (34.6%) of employed SSF actors are women, and this number may well be an underestimate due to the barriers to gender-inclusive data enumerated above (FAO et al., 2023). The rate of women's participation varies greatly across the value chain, from 15.4% in the pre-harvest segment (e.g., net repair) to 49.8% in the post-harvest segment (e.g., processing and selling) (FAO et al., 2023). Within the harvest segment, women often, though not always, engage in foot fisheries or gleaning, whereby actors search for target species like shellfish and octopus in intertidal environments with little or no gear (Harper et al., 2013; Kleiber et al., 2015). Women's catch is often directed towards household food consumption, while men's catch may be more often high-value target species sold on the market. Thus, women's catch is key source of food security and the high nutrient density of fish is greatly beneficial to household health and development (FAO et al., 2023; Harper et al., 2013; Kleiber et al., 2015). Foot fisheries are often overlooked in official data collection and non-harvest activities can be deprioritized in research and data. This may be partially because women's fishing work is often considered part of household duties and may be informal or unpaid and thereby largely invisible to researchers and decision-makers. These systematic data exclusions of women's fishing work can lead to misrepresentation of the environmental impact of fisheries, undervaluation of the food and economic importance of SSF, and entrenched barriers to women's participation in fisheries management (FAO et al., 2023; Harper et al., 2013; Kleiber et al., 2015; Smith & Basurto, 2019).

Climate change is already having adverse impacts on SSF, and women are likely to be disproportionately impacted by a warming planet. For marine fisheries, as sea surface temperature increases, both fish and invertebrates respond by generally shifting to higher latitudes and deeper waters (Cheung et al., 2013; Ojea et al., 2020). These shifts are concerning for all SSF workers who likely have less ability to 'follow the fish' than LSF but could be particularly harmful for foot fishers who depend on accessing target species in shallow waters close to home (Ojea et al., 2020). Fish stocks have been shifting in response to changing sea surface temperature since the 1970s, and significant range shifts are predicted as climate change worsens in the coming decades (Cheung et al., 2013). The accompanying redistribution of catch species is likely to benefit some areas but decrease catch in others, with tropical coastal communities being the most vulnerable; for example, the Indo-Pacific region could experience up to a 50% decrease in maximum catch potential under a high-emissions scenario (Cheung et al., 2010). Declining fish catch is the most important driver of vulnerability in the SSF sector (Cánovas-Molina & García-Frapolli, 2022). Movement of fish and other impacts of climate change are predicted to increase food insecurity, transboundary conflicts, and decrease public health (Blasiak et al., 2017). Moreover, these impacts are happening in a context of worsening gender inequality around the world. The COVID-19 pandemic has reversed positive trends in several metrics of gender inequality, and the United Nations estimates that it will take an additional 286 years to achieve gender equality at the current rate of progress (Azcona et al., 2022). Research suggests that women are, on average, more likely to suffer negative impacts of climate change than men due to lesser access to and control of assets, social-cultural gender roles, and limited decision-making power (Goh, 2012; Terry, 2009). This is not limited to rural or developing contexts; for example, women are more likely to be severely impacted by climate-related 'urban heat island effects' in cities (Terry, 2009). However, in some contexts, men may be more vulnerable to the impacts of climate change because their livelihoods are tied to land or cultural responsibility for food provisioning (Goh, 2012; Terry, 2009). It is important to recognize that considering gendered differences is critical for reducing the vulnerability of individuals of all genders, and that while women are generally more marginalized in SSF and climate contexts, there is substantial contextual variation and other relevant factors that should be considered in policy and management.

This study provides a global overview of the current and projected context of climate risk for women small-scale fishers. I present both the global distribution of women SSF workers across various dimensions as well as the climate risk using national-level estimations. I focus specifically on women employed in the SSF sector aggregated across inland and marine fisheries and across the value chain. It is my hope that this study serves as a starting point for future discussion and analysis to inform gender-sensitive climate and fisheries policy.

2. METHODS

I sourced the data used for analysis from the "Illuminating Hidden Harvests" (IHH) project (FAO et al., 2023). The IHH team compiled secondary livelihoods and employment data from countries around the world collected by national labor force surveys (LFS) and household income expenditure surveys (HIES) from the International Labor Organization. The data are from the year 2016 and include gender-disaggregated employment, subsistence, and dependency data across the value chain and for inland and marine fisheries. Employment data were available for 187 countries. It is important to note that gender is not a binary and there are non-binary fishers who contribute to SSF around the world, but there is a significant gap in the literature on non-binary fishers. My dataset only contained data on men and women and therefore my discussion of gendered differences in SSF employment and climate risk is confined to these two genders, a limitation of this study. I obtained additional data from various sources as needed: 2016 country population data came from the World Bank (World Bank Group, 2016) except for the Channel Islands from the UN Statistics Division (UN Data, n.d.) and Taiwan from the Population Reference Bureau (Population Reference Bureau, 2016). Data on gender inequality came from the Gender Inequality Index (UN Development Programme, 2023). Climate data and projections are from the WorldRisk Index (Mucke et al., 2022), INFORM Risk Index (Inter-Agency Standing Committee and the European Commission, 2022), and INFORM Climate Index (Poljansek et al., 2022). The climate analyses using INFORM Risk and Climate included 179 countries and the WorldRisk analysis included 178 countries. Microsoft Excel was used to clean and process data, calculate descriptive statistics, and create tables and graphs (*Microsoft*

Excel, 2023). RStudio was used to calculate statistical significance using Spearman's rank correlation test. This test measures statistical significance using critical probability ($p \leq 0.05$) and a rank correlation coefficient (rho or ρ) to measure the strength and direction of the correlation (R Core Team, 2021). Maps and other figures were created using ArcGIS Pro (*ArcGIS Pro*, 2023).

These two climate indices, INFORM and WorldRisk, were chosen for this study as they are widely used and well-regarded within the scientific community and were included in the recent Intergovernmental Panel on Climate Change (IPCC) report (Birkmann et al., 2022). Both indices characterize a country's risk with a numerical score and a categorical rank from 'very low' to 'very high' (Inter-Agency Standing Committee and the European Commission, 2022; Mucke et al., 2022). INFORM Risk defines a country's level of risk as a product of three dimensions: hazard and exposure, vulnerability, and lack of coping capacity. WorldRisk's top-level dimensions of risk are exposure and vulnerability. The dimensions for both indices include numerous sub-dimensions and indicators, which differ from each other. The WorldRisk Index was substantially redesigned for its 2022 update, including a new calculation method and a near quadrupling of the number of included indicators (Garschagen et al., 2021; Mucke et al., 2022). While previous studies have found high levels of agreement in risk and vulnerability estimations between the WorldRisk and INFORM Risk Indices, the results varied notably in this study (Appendix 1) (Birkmann et al., 2022; Garschagen et al., 2021). The INFORM Climate Change Risk Index is a new INFORM product released in 2022 that includes future climate projects under different emissions and population scenarios with the goal of informing disaster planning and adaptation efforts (Poljansek et al., 2022). For this study, I compared the 'pessimistic' scenario (characterized by 'high emissions,' 'high challenges' to mitigation and adaptation, and high population growth) with the 'optimistic' scenario (characterized by 'moderate emissions,' 'low challenges' to mitigation and adaptation, and low population growth) (Thow et al., 2022).

3. RESULTS

Prior to commencing data analysis, I conducted a review of relevant literature using Web of Science and Scopus. I searched for articles mentioning small-scale fisheries, livelihoods, and climate change plus an additional criterion of vulnerability, subsistence, or gender. This search returned 52 unique results across the two databases of which six mentioned gender, two mentioned subsistence, and nine were global-level studies. No studies identified in this search specifically addressed the intersection of gender, SSF, and climate change.

3.1 Global Distribution of Women in Small-scale Fisheries

To develop appropriate gender-sensitive fisheries and climate policy at the regional and global level, it is critical for governments to understand the number and distribution of women in the SSF sector. The vast majority, over 95%, of women SSF workers live in developing countries (Figure 1A). Most (88%) women SSF workers live in lower- or upper-middle income countries (Figure 1B). China accounts for the majority of women SSF workers in the upper-middle income category. Both high (6.3%) and low income (5.7%) countries have much lower total

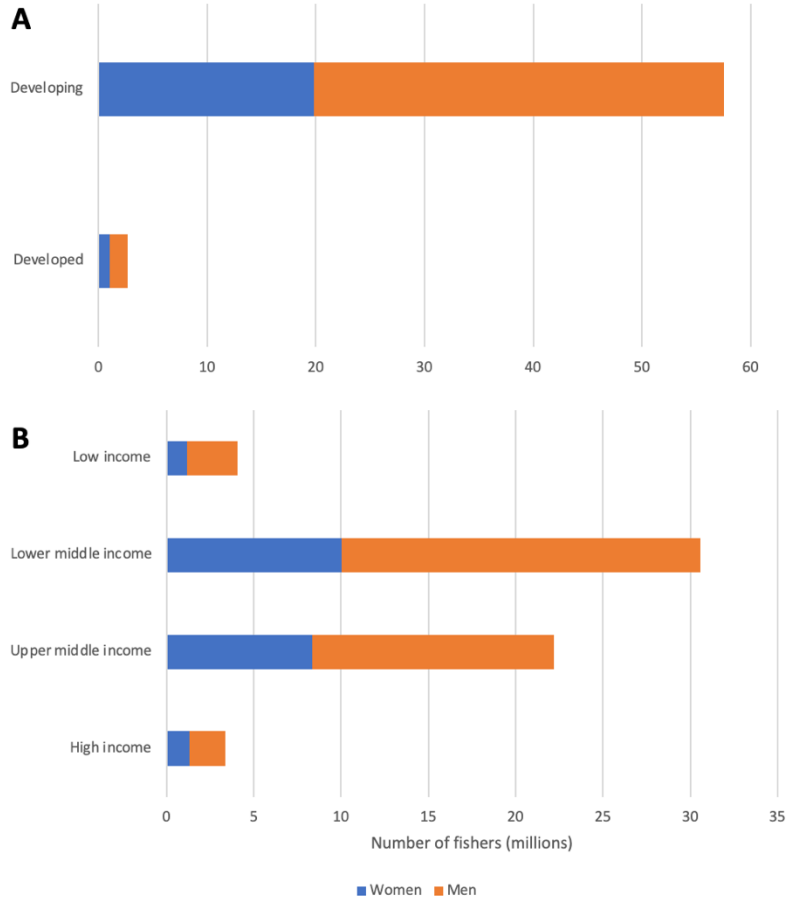

Figure 1. Distribution of small-scale fishers across development and income categories, disaggregated by gender. Panel A shows the number of fishers in countries with different World Bank income levels. Panel B shows the number of fishers in developing versus developed countries. The labels at the right of each bar show women as a percent of the total small-scale fishers in each category. Data source: FAO et al., 2023.

numbers of women SSF workers, and the number of women workers in a country both as a total number and percent of population is negatively correlated with increasing gross domestic product ($p<0.001$, $rho<-0.3$ for both). The proportion of women working in SSF increases as national income increases, with more than a 10% difference between low- and high-income countries (29.0-39.2%; Figure 1B). This trend could be due to additional economic opportunities for women in higher-income countries, but it is not statistically significant ($p=0.64$).

The geographic regions where women make the greatest contributions to SSF vary based on the metric used. Most women SSF workers live in Asia and Africa, following the distribution trend for all SSF workers (Figure 2A,C; dominant sub-regions: Eastern/Southern/South-eastern Asia and Sub-Saharan Africa) (FAO et al., 2023). The proportion of women working in the regional SSF workforce relative to men ranges from 29.53% in Africa to 36.55% in Europe. The range is much wider at the sub-regional level, from 12.18% in Northern Africa to 41.45% in Western Europe, possibly reflecting greater variation at the sub-regional level in gender equality and fisheries data collection methods (Smith & Basurto, 2019; UN Development Programme, 2023). While Oceania has the lowest number of total and women small-scale fishers according to the IHH dataset, SSF workers represent the highest percentage of the regional population in Oceania compared to other regions (SSF workers are 1.3% of the total regional population; women SSF workers are 0.39% of the total population; Figure 2B). Polynesia, Micronesia, and Melanesia have the highest percentages of women SSF workers relative to the total sub-regional population, while Western Europe, Northern Europe, and Central Asia have the lowest (Figure 2D). The size of the SSF sector in comparison to the total population can serve as a proxy for the relative importance of the sector in these sub-regions and throughout Oceania. Clearly, it is important to know the numbers of women working in SSF in terms of the total population, percent of population, and proportion of the SSF workforce to inform policy and to measure progress towards related gender equity, sustainability, and resiliency goals.

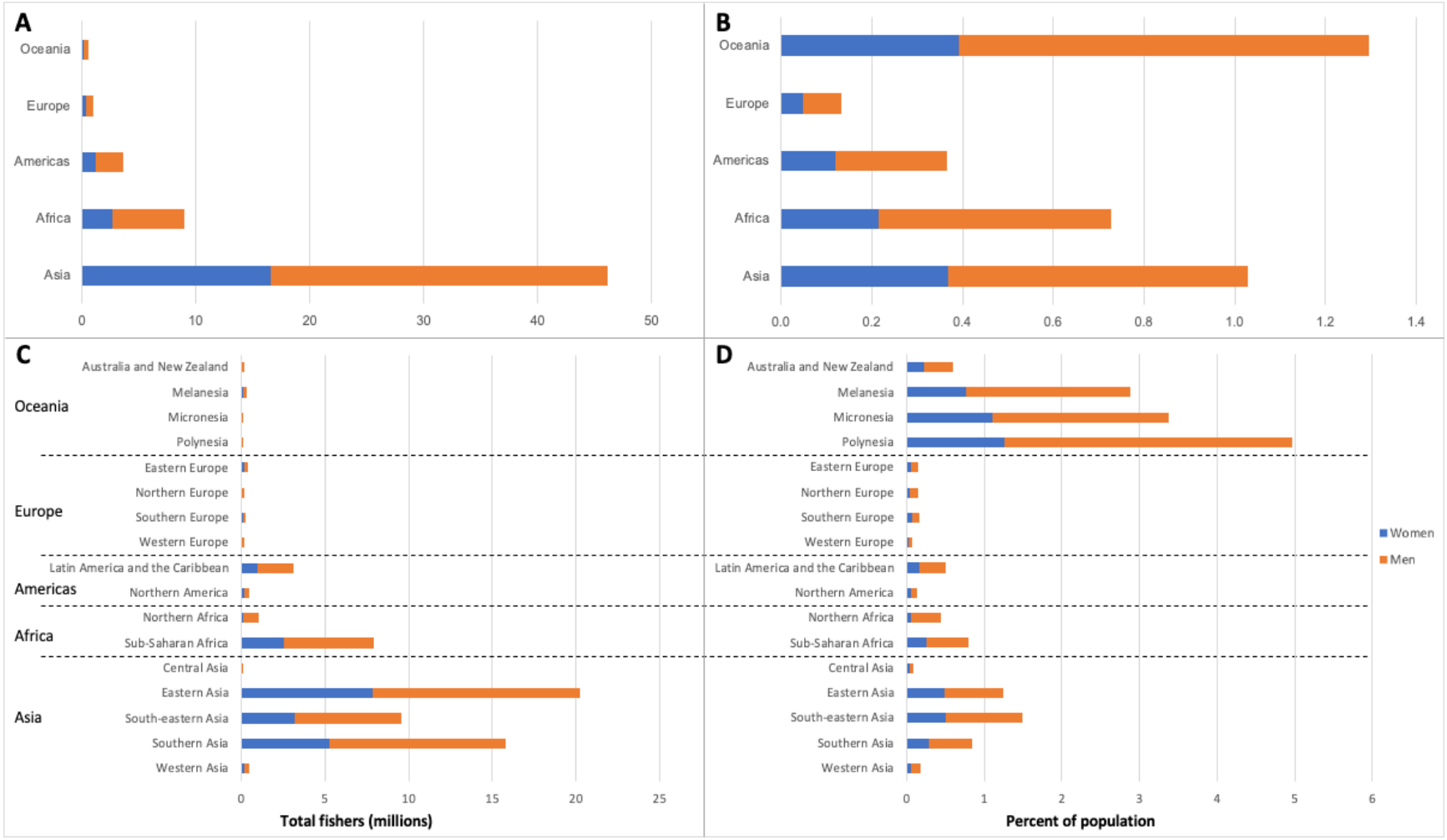

Figure 2. Regional and sub-regional distribution of small-scale fish workers, disaggregated by gender. Panels A and B show the distribution across United Nations classified regions by total number of fishers (A) and percent of regional population (B). Panels C and D show the distribution across the 17 United Nations classified sub-regions by total fishers (C) and percent of sub-regional population (D). Note that each panel has a different scale. Data source: FAO et al., 2023.

While women represent more than a third of all employed SSF workers globally (34.6%; FAO et al., 2023), the proportion of women in the SSF workforce compared to men varies significantly at the national level. Women as a percent of the SSF workforce ranges from as low as 8.2% (Luxembourg) to well over half of the national workforce at 61.2% (Cambodia; Tables 1 and 2). The low rate in Luxembourg, a Western European country, is surprising given that the sub-region ranks highest overall for women's participation (Figure 3). There is not a clear regional trend associated with greater proportions of women in the national SSF workforce, as the top ten countries range four continents (Table 1; Figure 3). The top countries range from lower-middle to high income, seven are developing, and five are classified as a net food-importing developing country (NFIDCs). One country, São Tomé and Príncipe, is a small-island developing state (SIDS) and considered a least developed country (LDC). The diversity of countries with high representation of women in SSF is interesting and could be influenced by official recognition of women's labor in fisheries data collection. For example, in the IHH study the Mexican research team's definition of SSF in Mexico explicitly mentioned women's participation, predominantly in the pre- and post-harvesting sectors (FAO et al., 2023). Additionally, the Spanish research team provided a broad national definition of SSF and stated that each region uses its own definition, possibly allowing for regions with a high prevalence of foot fisheries to define their SSF sector accordingly (FAO et al., 2023). Interestingly, the countries with the lowest proportions of women employed in SSF do not have the same geographic diversity as the top ten; eight of the bottom ten countries are in Africa (6 Northern Africa, 2 Sub-Saharan Africa) while the other two are in Europe (Table 2; Figure 3). The countries range low to high income, eight are developing, six are NFIDCs, and two are LDCs. In contrast to the countries with high rates of women's participation, the lowest countries may reflect limited official definitions of SSF, as has been previously documented in North Africa and the Middle East (FAO et al., 2023; Smith & Basurto, 2019). These results show that greater representation of women in the national SSF workforce cannot be assumed by geography alone.

Both the highest and lowest countries vary broadly in the level of national gender inequality, suggesting that women's empowerment does not necessarily lead to higher rates of participation in fisheries (Tables 1 and 2). The Gender Inequality Index (GII)

produces a measure of national gender inequality based on reproductive health, empowerment and the labor market measured from 0-1, where low scores represent low inequality and vice versa (UN Development Programme, 2023). There is a statistically significant correlation between increasing gender inequality and increasing numbers of women fishers in a country (total women fishers: $p<0.001$, rho=0.38; percent of national population: $p<0.001$, rho=0.45). Limited participation in the labor force is a common characteristic of countries with high gender inequality, but it is possible that in these countries women are more likely to be employing doing traditional 'women's work', which often includes gleaning, net-making and other fishing activities (Kleiber et al., 2015; UN Development Programme, 2023). Interestingly, there is not a significant correlation between increasing inequality and a higher proportion of women working in the national SSF sector ($p=0.59$). Of the countries with the highest proportions of women working in SSF, Cambodia, Botswana, and São Tomé and Príncipe are ranked in the bottom third globally for gender equality (169 countries in GII 2016 ranking; Table 1). Thus, despite the importance and contributions of women in these countries to SSF, inequality is high compared to the rest of the world. Only two countries, Spain and Slovenia, are in the global top third for gender equality. The pattern is repeated in the countries with the lowest proportions of women in SSF (Table 2); three countries are in the bottom third for gender equality (Mauritania, Sudan, and Côte d'Ivoire) while four are in the top third (Luxembourg, Morocco, Norway, Tunisia). Other cultural or biological factors are likely more influential than gender inequality in influencing the proportion of women in a country's SSF workforce, though it is possible that correlations exist within specific segments of the value chain (e.g., how does changing gender inequality impact women's participation in harvesting).

Table 1. Top ten countries with the highest proportion of women working in the small-scale fisheries sector. The rightmost column lists the country's 2016 Gender Inequality Index score and world ranking.

Country	Region	Sub-Region	Total women small-scale fishers	Percent of women working in the SSF sector	Gender Inequality Index score (rank)
Cambodia	Asia	South-eastern Asia	536991.11	61.21%	0.475 (115)
Spain	Europe	Southern Europe	37230.41	51.04%	0.07 (12)
Costa Rica	Americas	Latin America and the Caribbean	8234.53	50.66%	0.312 (67)
Slovenia	Europe	Southern Europe	1361.36	49.08%	0.057 (9)
Botswana	Africa	Sub-Saharan Africa	4091.46	48.87%	0.48 (118)
Honduras	Americas	Latin America and the Caribbean	20754.75	47.67%	0.423 (96)
São Tomé and Príncipe	Africa	Sub-Saharan Africa	825.65	47.15%	0.523 (126)
Mexico	Americas	Latin America and the Caribbean	171758.52	45.91%	0.341 (75)
El Salvador	Americas	Latin America and the Caribbean	15686.91	45.89%	0.377 (82)
Italy	Europe	Southern Europe	32235.71	45.72%	0.075 (13)

Table 2. Bottom ten countries with the lowest proportion of women working in the small-scale fisheries sector. The rightmost column lists the country's 2016 Gender Inequality Index score and world ranking.

Country	Region	Sub-Region	Total women small-scale fishers	Percent of women working in the SSF sector	Gender Inequality Index score (rank)
Luxembourg	Europe	Western Europe	0.33	8.19%	0.063 (11)
Egypt	Africa	Northern Africa	29864.22	8.97%	0.443 (106)
Mauritania	Africa	Sub-Saharan Africa	3417.90	11.40%	0.633 (157)
Sudan	Africa	Northern Africa	19406.13	12.26%	0.567 (143)
Morocco	Africa	Northern Africa	37862.99	12.56%	0.44 (103)
Libya	Africa	Northern Africa	5381.06	13.11%	0.268 (54)
Côte d'Ivoire	Africa	Sub-Saharan Africa	12981.14	15.27%	0.645 (160)
Norway	Europe	Northern Europe	3732.21	15.95%	0.033 (2)
Algeria	Africa	Northern Africa	20476.66	16.33%	0.428 (99)
Tunisia	Africa	Northern Africa	12588.79	17.44%	0.273 (55)

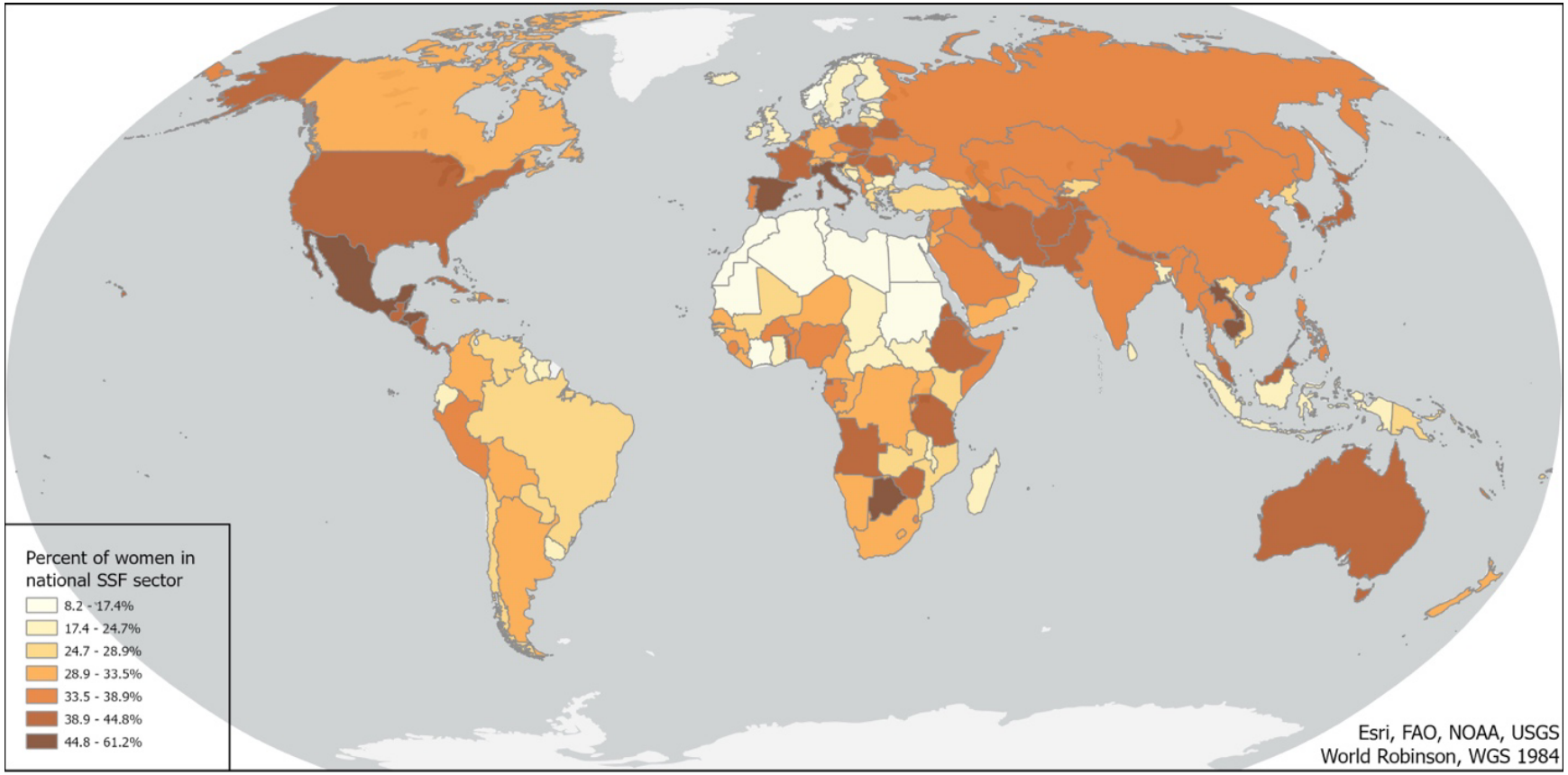

Figure 3. Proportion of women in the small-scale fisheries sector by country. National estimates range from a low of 8.2% of small-scale fishers in Luxembourg being women to 61.2% of small-scale fishers being women in Cambodia. Data source: FAO et al., 2023.

3.2 Context of Climate Risk for Women in Small-scale Fisheries

There is a significant positive relationship between the number of women small-scale fishers and national risk and vulnerability to climate change. According to both climate indices used, WorldRisk and INFORM Risk, as the number of women small-scale fishers in the country increases either as a total number or as a percent of the national population, the national level of risk and vulnerability

also increases ($p<0.05$ for all). The relationship is stronger between women SSF workers and overall climate risk than vulnerability (rho for total women SSF workers: 0.53-0.68 for risk; 0.36-0.55 for vulnerability). The magnitude of the statistical relationships is stronger for the WorldRisk Index than the INFORM Index.

WorldRisk and INFORM differ notably from each other in how they estimate national-level risk and vulnerability, but both indices estimate that a substantial number of women small-scale fishers face high risk to climate change (Figure 4). When compared against the INFORM Risk Index, I estimate that 8.92 million women (42.98% of total) live in high or very high-risk countries. Using the WorldRisk Index, I estimate that the majority of women small-scale fishers, 19.35 million or 93.25% of total, live in high or very high-risk contexts (Figure 4, panel A). China, home to more than 18 million small-scale fishers, largely drives the distribution of the trend and the disparity between the two indices. Though it is considered to have 'low' vulnerability by both indices, the INFORM Index rates its overall risk as

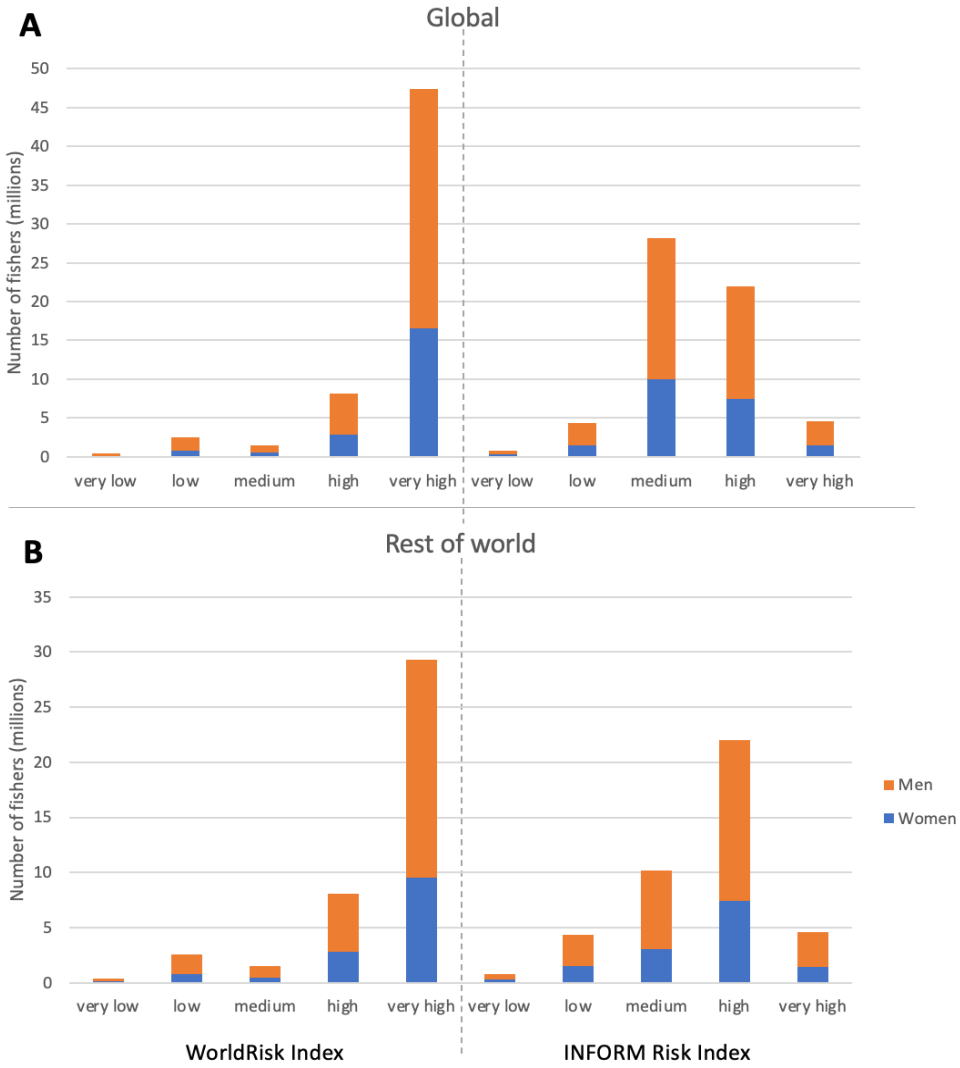

Figure 4. Climate risk exposure of small-scale fisheries livelihoods. Panel A shows gender-disaggregated results for all countries for which data was available. Panel B removes China as roughly 30% of all fishers to see the distribution for the rest of the world. Note that panels have different scales. Data sources: FAO et al., 2023; Inter-Agency Standing Committee and European Commission, 2022; Mucke et al., 2022.

'medium' while WorldRisk rates it as 'very high' risk. Removing China to look at the rest of the world, risk distribution of women fishers stays largely similar under the WorldRisk Index, but the INFORM risk distribution shifts so that the largest proportion of livelihoods are found in the high-risk category (Figure 4, panel B). The disparity between the indices decreases as well; with China removed as an outlier, I estimate that 64.80% (INFORM) to 89.83% (WorldRisk) of women small-scale fishers live in high or very high-risk contexts. Furthermore, 59.43% (INFORM) to 84.60% (WorldRisk) of women SSF workers are in countries with high or very high vulnerability to climate change, excluding China (Figure 4, panel D).

Interestingly, the WorldRisk Index estimates that a higher percentage of women than men SSF workers are in high or very high-risk contexts, but the INFORM Index estimates the opposite trend. Both indices estimate more men than women SSF workers live in countries with high or very high vulnerability to climate change, by a difference of roughly 3-5%. It is possible that countries with higher risk and vulnerability also have more women whose fishing work is considered informal or is unpaid, and that the true extent of women's work in these countries is underestimated (Kleiber et al., 2015; Smith & Basurto, 2019). The proportion of women to men in each category of national risk is relatively stable, ranging from 29.9% (low) to 34.9% (very high) for the WorldRisk Index and from 31.2% (medium) to 38.6% (very low) for INFORM Risk. There is no significant correlation between women as a proportion of the SSF workforce and national risk or vulnerability ($p>0.46$ for all).

The impacts of climate change are expected to worsen in the next centuries but will vary widely based on global response (Figure 5A). The global mean climate risk for women fishers (baseline risk score: 3.66, classified as "medium") will continue to increase due to climate change under both an optimistic and a pessimistic scenario, peaking at 3.82 under the former and 4.00 under the latter scenario (Figure 5A). Of course, the global mean risk is a coarse metric, and the severity of risk and impacts of climate change are not evenly

distributed around the world. Assuming stable national populations of fishers, the number of women small-scale fishers living in contexts of high- or very high-climate risk will increase by 18.16% by 2080 under a pessimistic climate scenario, affecting an additional 1.6 million women (Figure 5B). The number of livelihoods in very low- to medium-risk contexts will decrease progressively from the baseline (2020) to 2080, the number in high and very high-risk contexts will increase (Figure 5C). Even under an optimistic climate scenario, the number of women fishers at risk will peak in 2050 and, despite a small decrease, increase overall by 2.95% over the next fifty years, impacting 260,000 additional women. The projected increase in climate risk for women SSF workers is greatly concerning, especially given the vulnerability of both the SSF sector as a whole and women more so than men to the negative impacts of climate change.

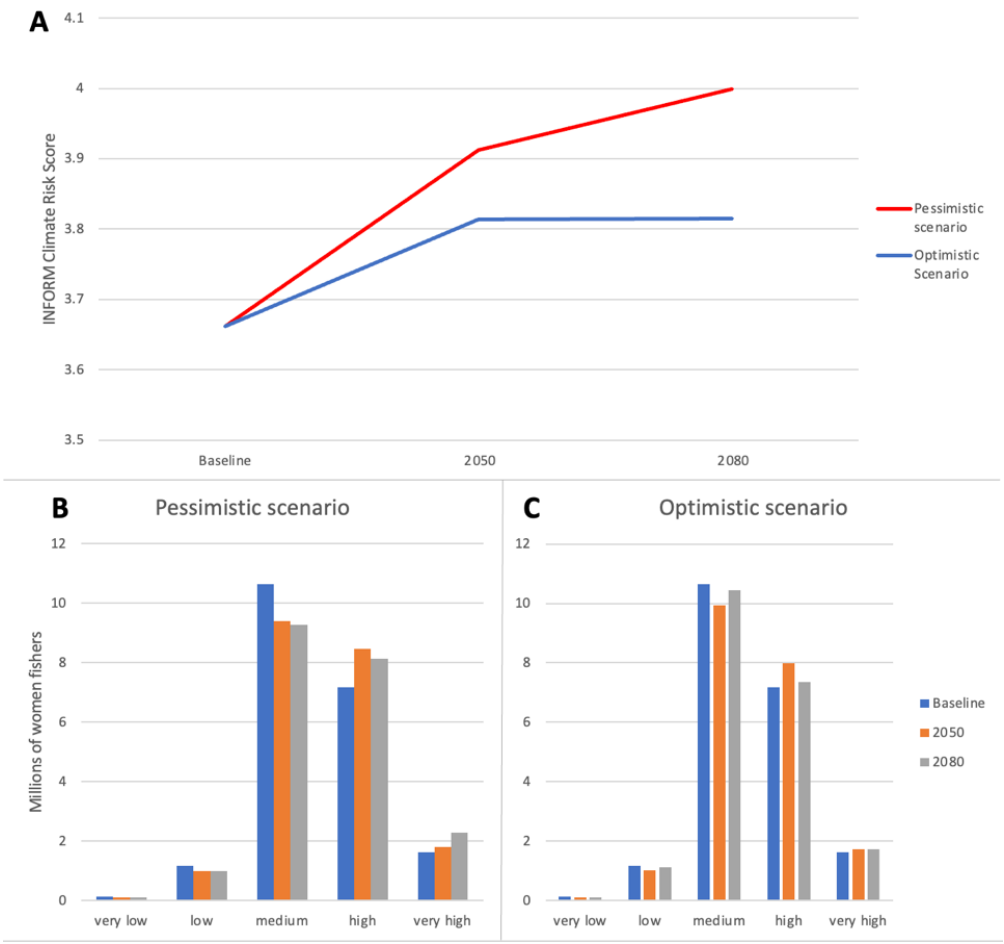

Figure 5. Projected future risk of women small-scale fishers under a pessimistic and an optimistic climate change scenario in the baseline year (2020) and projections to 2050 and 2080. Panel A shows the change in mean climate risk for all women fishers. Panels B and C compare the distribution of women fishers across categories of climate risk. Data sources: FAO et al., 2023; Inter-Agency Standing Committee and European Commission, 2022.

4. DISCUSSION

4.1 Gender must be considered in national climate policy

This analysis showed that high numbers of women small-scale fishers are at high or very high risk and vulnerability to climate change and are found in countries with high levels of gender inequality. There are significant positive correlations between gender inequality and national risk and vulnerability, and the relationship is quite strong for most correlations ($p<0.001$ for all; WorldRisk: risk – rho=0.19, vulnerability – rho=0.76; INFORM: risk – rho=0.78, vulnerability – rho=0.77). This underscores the compounding marginalities for women small-scale fishers between gender discrimination, climate risk and vulnerability, and deprioritization of SSF at the national level. There is significant progress to be made in developing gender-sensitive climate policy. According to the Gender Climate Tracker, only two countries in the world, Liberia and Peru, have legislation addressing the interaction of climate change and gender mentioned in the Nationally Determined Contributions (NDCs) to the Paris Agreement, and one country's legislation is still unfinished (Women's Environment and Development Organization, 2023). Of the ten countries with the highest proportions of women in the SSF sector, two (Botswana and El Salvador) do not mention gender in their NDCs. Of the other eight countries, only one (Honduras) positions women as agents of change. Three (Costa Rica, Honduras, and Mexico) position women as stakeholders. Four of the ten did not reference gender in their original NDCs but have added them in the updated NDCs, which is a positive sign of increasing awareness of gendered differences in climate change (Women's Environment and Development Organization, 2023). As discussed above, China is home to the largest number of small-scale fishers, both in total and for men and women. China is estimated to have one of the biggest losses in maximum catch potential (Cheung et al., 2010) under a high-emissions scenario and is one of the top three countries with the "most potential for improvement in fisheries management" (Blasiak et al., 2017). China did not include any reference to gender in its original NDC, and policies implemented or omitted in this country will have significant implications for women in small-scale fisheries around the world (Women's Environment and Development Organization, 2023).

While there does not appear to be substantial differences in the context of climate risk and vulnerability between women and men SSF workers, it is still vital to have gender-disaggregated data because climate change has and will continue to have differential impacts on fishers by gender (Goh, 2012; Terry, 2009). The small-scale fisheries sector, due to its outsized importance for livelihoods and food and nutrition security, presents an opportunity for decision-makers to target the sector for climate change resiliency and gender equality goals. By targeting women in SSF, governments would not only be directly assisting this often marginalized population but would have broader benefits given that women's fisheries work is often directed towards food provisioning and that many people rely on SSF beyond those directly employed in the sector (FAO et al., 2023; Harper et al., 2013; Kleiber et al., 2015). At the global level, 379 million additional people rely on SSF for their livelihoods beyond those working directly in SSF or subsistence fisheries (FAO et al., 2023). Policy interventions could be targeted on subsectors where women are more often employed, such as foot fisheries and the post-harvest sector, but should always be adapted to national and local contexts (Smith & Basurto, 2019). To date, much policy on gender in fisheries has followed an outdated approach that can unintentionally continue or exacerbate inequalities and future policies must be carefully crafted to avoid these pitfalls (Call & Sellers, 2019; Lawless et al., 2021). In the Pacific Islands, where SSF are highly important and women represent a notable segment of the overall population, gender commitments in fisheries policy focus narrowly on "women's issues" rather than on broader gender equality and the need to address systemic issues and barriers (Lawless et al., 2021). If not properly designed, policies that seek to engage women in interventions may unintentionally increase their labor burdens without a commensurate increase in income (Call & Sellers, 2019). To achieve gender goals, policies must recognize the breadth and complexity of gender, center gender work in projects from the beginning, and work to address systemic inequalities by partnering with actors across sectors and scales (Call & Sellers, 2019; Kleiber et al., 2015; Lawless et al., 2021).

4.2 Systemic barriers to women's recognition and representation in SSF

The significant correlation between increasing gender inequality and increasing women SSF workers in a country is concerning, and the strength of the relationship is notable (rho: 0.38 for total women, 0.45 for percent of population). Women face barriers to equality

all over the world, and no country has yet achieved full gender equality (UN Development Programme, 2023). This correlation suggests that more women small-scale fishers live in contexts of high gender inequality where they may face systemic, social, and cultural barriers to full recognition of their labor and to empowerment in decision-making contexts. It has been well established that women's work in fisheries is often informal and under- or unpaid, and working to properly assess and value this labor could be an opportunity for countries to reduce gender inequality via governance mechanisms such as Cambodia's gender-mainstreaming policy (FAO et al., 2023; Fisheries Administration, 2015; Lentisco & Lee, 2015).

Notably, there is no correlation between gender inequality and a proportion of women in the SSF workforce. This result is initially surprising as one might assume that increasing equality would allow more women to participate in or have their contributions recognized in the SSF sector. It is possible that the lack of correlation aggregated across the value chain masks more nuanced trends at the subsector level. For example, women are most often employed in the post-harvest sector which is generally low paid. As equality and empowerment increase, women small-scale fishers may transition from the post-harvest to the harvest sector where there is generally more economic opportunity, potentially increasing livelihoods outcomes without increasing women's representation in SSF (S. Harper, personal communication, 2023). A high proportion of women in the SSF workforce does not guarantee equal rights or representation. In Spain's Galicia region, net-weavers are a critical part of pre-harvest fisheries work and are predominantly women, but they do not have recognized labor rights or representation in fisher guilds (FAO et al., 2013). As described above, Spain has the second-highest national proportion of women in the SSF workforce but fisheries work is highly gender-segregated and women are primarily employed in the "most precarious and worst paid activities" (Piñeiro-Antelo & Santos, 2021). Furthermore, a smaller proportion of women SSF workers does not mean that the women working in the sector are not making valuable contributions and it is quite possible that these numbers are an underestimate. It could be even more important in these contexts to ensure that women SSF workers in these countries are not further marginalized by the proliferation of gender-blind climate and fisheries policies.

4.3 Necessity of considering relative importance of women in SSF by geographic scale

While it is critical to understand the distribution of women small-scale fishers by total number, it is equally important to know the relative strength of the sector at different geographic scales in order to determine where women's fisheries contributions are most important to livelihoods and food security. For example, Oceania ranked lowest in terms of the overall population of women small-scale fishers but highest when considered as a percentage of the total population. SSF are culturally and economically important throughout Oceania and women traditionally work in shallow water foot fisheries from the Pacific islands to Indigenous communities in Australia and New Zealand (Lambeth et al., 2002). Within Oceania, there is still substantial variation. The 'Australia and New Zealand' sub-region is still in the top half of sub-regions with higher percentages of women SSF workers in the population but is notably lower than the three Pacific Island sub-regions within Oceania, which occupy the top three spots. Women's contributions to food provisioning in the Pacific Islands are significant; in Samoa for example, women provide an estimated 20% of the per capita seafood consumption (Lambeth et al., 2002). Therefore, while global overviews of women in SSF can be helpful in developing international policy and strategic planning, it is critical not to overlook areas where women small-scale fishers are less populous but make essential contributions to livelihoods and food security.

4.4 Not by geography alone: Trends in the proportion of women in national SSF workforces

The wide range of women as a percent of national SSF workforce is an interesting result and the global variability does not have a clear driver amongst the demographic variables studied here. As previously mentioned, Oceania and its sub-regions Polynesia, Melanesia and Micronesia have the highest percent populations of women SSF workers, yet they do not have the highest proportions of women in the workforce. In fact, Polynesia has the third-lowest proportion of women in the sub-regional workforce (25%), while Western Europe, home to the country with the lowest national proportion (Luxembourg, 8.2%), has the highest sub-regional proportion at 41.5%. Clearly, geography alone is insufficient to explain trends in women's representation in the SSF workforce.

Countries with greater proportions of women in the sector could be driven by positive social-cultural associations, supportive governance policies, and the prevalence of foot fisheries. As previously discussed, in many places around the world women's fishing work is not considered 'real fishing' or women may hesitate to self-identify as fishers for various reasons, such as considering their labor part of household chores or shame in needing to fish perhaps due to poverty (Kleiber et al., 2015). Notably, a recent study in Cambodia's Pursat province found that most female fishers surveyed actively identified fishing as part of their work, although few men did (Kwok et al., 2020). This cultural acceptance, at least amongst fisherwomen, and the use of data collected via self-reporting surveys may have allowed the true extent of women's contributions in Cambodia to be more accurately captured, whereas some countries with lower proportions of women in SSF may represent an undercount due to negative associations. This positive identity may have been partially enabled by the country's "Gender Mainstreaming Policy and Strategy" for agriculture (including fisheries), first implemented in 2006 and revised in 2015 (Fisheries Administration, 2015; Lentisco & Lee, 2015). This policy and the related "Action plan for gender equality promotion and child labor elimination in the fisheries sector 2016-2020" aim to build stakeholder capacity on gender equality and promote women's economic empowerment through fisheries. The initial 2008-2012 action plan increased gender awareness and knowledge among fisheries managers and increased the numbers of women employed in management (Fisheries Administration, 2015). Studies have shown that the Cambodian gender mainstreaming effort, one of the first such policies for fisheries in a developing country, enabled women's participation in community-based fisheries management (Weeratunge et al., 2010). Furthermore, in Spain, foot fisheries are a dominant subsector of SSF, and women are the primary actors (Piñeiro-Antelo & Santos, 2021). The Spanish northwest region of Galicia is one of the top fishing regions in the European Union and has the highest proportion of women in the fisheries sector. Shellfish gleaning by foot represents 17% of employment in Galician fisheries and while women in Galicia are very rarely present on fishing boats, more than 95% of bivalve gleaning is conducted by women (Piñeiro-Antelo & Santos, 2021). Gleaning in Galicia, as in many places around the world, is a traditional practice for women and the scale of this subsector in Spain likely drives the high proportion of women working in SSF (Piñeiro-Antelo & Santos, 2021). It is quite possible that social acceptance, gender-mainstreaming governance

mechanisms and strong foot fishery subsectors such as those found in Cambodia and Spain strongly influence higher representation of women in the SSF sector, but more research is required.

In contrast to the high geographic diversity of countries with highly female SSF sectors, the low proportion of women in Africa, particularly Northern Africa, is striking. As a sub-region, Northern Africa has the lowest proportion of women in SSF at only 12.18% and it is home to six of the lowest ten countries. Two more of the bottom ten countries are in Sub-Saharan Africa (Mauritania and Côte D'Ivoire in West Africa). The low proportions in Northern Africa could be due to an undercounting of women's work and narrow definitions of small-scale fisheries. A systematic review of national SSF definitions around the world determined that 100% of SSF definitions in North Africa and the Middle East used fishing gear as a defining factor, which could bias data towards primarily counting harvest sector workers (the value chain segment with the lowest proportion of women) and omitting fisheries in which women most often participate, i.e., foot fisheries (Smith & Basurto, 2019). In Nigeria in West Africa, women primarily make nets for fishing, a job essential for any harvesting to take place, but this task is considered part of women's "reproductive or household duties" and therefore not counted as fisheries work in national censuses (FAO et al., 2023). Additionally, the low representation of women in SSF could be influenced by limited formal fisheries employment activities throughout Africa. In this case, women may be participating in subsistence fishing at a much higher rate than commercial fishing and a forthcoming study has established that women's participation in subsistence fishing in Africa is much higher than in other world regions (Virdin et al., in review).

4.5 Economic influences on women in SSF

The negative correlation between the number of women small-scale fishers and national GDP could be influenced by the availability of other economic opportunities which employ women outside the fisheries sector in higher income countries. Organization for Economic Co-operation and Development (OECD) countries have had an overall decrease in fisheries employment over the past few decades as the sector has become less economically important (Blasiak et al., 2017). Moreover, increasing modernization and

professionalization of fisheries in high-income countries can result in fisheries "masculinization," particularly of harvest-sector jobs (Piñeiro-Antelo & Santos, 2021). While the professionalization process in some cases may lead to increasing feelings of empowerment among women at the individual level (but not necessarily the collective), it can also reduce the number of women employed in the sector (Piñeiro-Antelo & Santos, 2021). The small number of women SSF workers in low-income countries, despite the overall negative correlation, could be due to few opportunities for formal, paid employment. It is likely that many women in low-income countries engage in subsistence fishing; the majority of subsistence fishers live in low or lower-middle income countries, and women represent 45.2% of all subsistence fishers globally (FAO et al., 2023; Virdin et al., in review). SSF are generally less formal and more difficult to capture data from than LSF, and these challenges are likely exacerbated in low-income contexts (FAO, 2015).

4.6 Limitations and future research

This study attempts to tackle the complex interactions between small-scale fisheries, gender, and climate change. The results are limited by a lack of gendered data beyond the women/men binary. It is quite possible that the data used in this study in some or all countries underestimate the true scale of women's work in the sector for the various systemic reasons described above (FAO et al., 2023). Furthermore, by aggregating employment across the value chain and employing national-level estimations of risk and vulnerability, my research provides only a broad overview of these issues which, while informative, should be further researched to inform gender, climate, and fisheries policy. My study focused on women employed in SSF, but subsistence fishing is a critical sector for women in terms of livelihoods and food security. I intend to look specifically at women's engagement in the subsistence sector in future research for publication.

5. CONCLUSION

Women make significant contributions to small-scale fisheries around the world, but their representation by country in terms of total and percent population and proportion of the SSF workforce varies widely and has complex, interacting drivers. Up to 20 million women small-scale fishers live in high- or very high-risk countries and the climate risk of women in small-scale fisheries is projected to increase over the next 60 years. While the exact number of women fishers at risk varies based on the index used and projected scenario, the risk is significant and underscores the need to consider gender in national climate policy. Recognition of women's fisheries labor, including informal or unpaid activities, is critical for understanding the sector and informing fisheries and climate planning. It is crucial to remember that a gender-blind policy is not gender-neutral; that is, a climate or fisheries policy which does not center gender issues and impacts can still have harmful and disproportionate impacts on women and people of all genders (Lawless et al., 2021; Smith & Basurto, 2019). Future research should continue to examine the links between gender, fisheries, and climate change at different segments of the value chain and in different regional and national contexts. Researchers and policymakers should prioritize collecting gender-disaggregated fisheries data and use this data to inform climate and fisheries policy (FAO et al., 2023).

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Appendix 1. Additional figures.

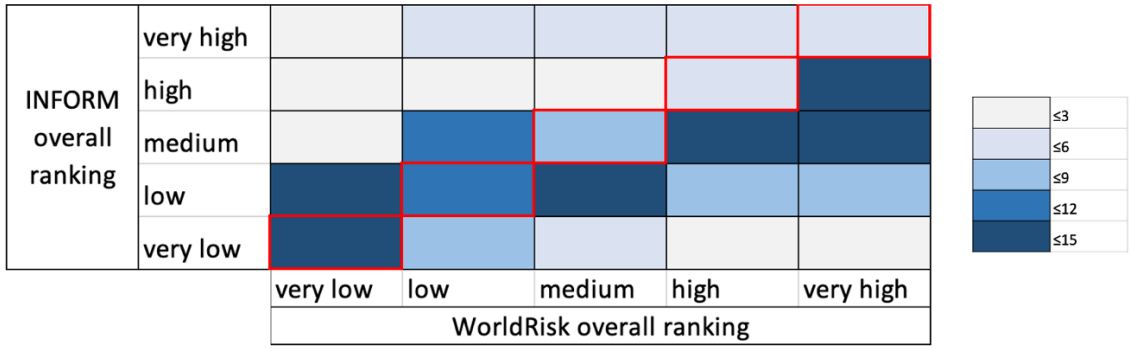

Figure 6. Agreement between the INFORM and WorldRisk overall national climate risk rankings. The 'agreement' cells are outlined in red. For perfect agreement, the darkest colors would all fall in the red-outlined boxes.

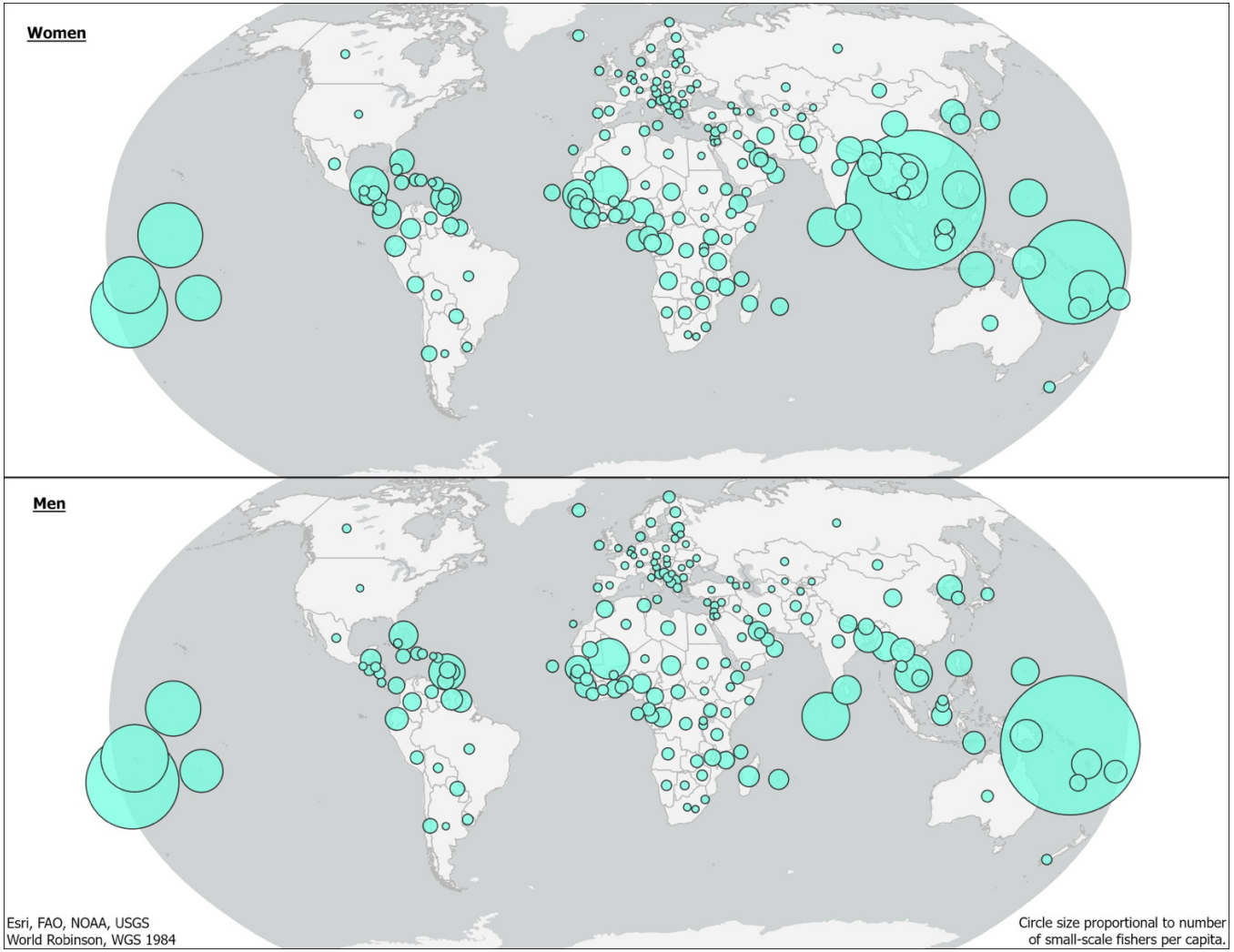

Figure 7. Comparison of the representation of women and men small-scale fishers by country. Each country included in the study has a circle centered over its geographic center which is scaled in relation to other countries to show the relative size of the national small-scale fisheries population. The top panel shows women small-scale fishers per capita, and the bottom panel shows men small-scale fishers per capita. E.g., a smaller circle in the top panel represents a relatively low population of women-small scale fishers in the country, while a larger circle represents a relatively high population.