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<u>Title Page</u>

Environmental (In)Justice in the Anthropocene Ocean

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Author Contribution Statement

NJB was involved in Conceptualization and Methodology Design; NJB, JJA, CEF, JB, EM, DB & IMC were involved in Literature Review; NJB, JJA, CEF, JB & EM were involved in Writing – original draft; DB & IMC were involved in Writing – review and editing; and, IMC was involved in Funding acquisition.

Highlights

- There is a substantial and growing body of literature on environmental justice.
- Yet, environmental justice issues in the oceans have received less attention.
- Issues include pollution, plastics, climate change, ecosystem services and fisheries.
- We examine the social and distributional impacts of these marine hazards and harms.
- Environmental injustices in the ocean are growing, differentiated and converging.

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Environmental (In)Justice in the Anthropocene Ocean

Abstract: Environmental justice refers broadly to the distribution of environmental benefits and burdens, and the fair treatment and meaningful involvement of all people in environmental decision-making and legal frameworks. The field of environmental justice initially developed out of a concern for the disproportionate distribution and impacts of environmental pollution and hazardous waste disposal on groups that have been historically and structurally marginalized, including Black populations and socio-economically disadvantaged communities. More recent environmental justice scholarship has expanded geographically and focused on a broader set of environmental hazards and harms, such as climate change impacts, biodiversity and habitat loss, and ecosystem service declines. Yet, the impacts and distribution of environmental hazards and harms in the marine environment on coastal populations has received less attention in the environmental justice literature. This narrative review paper starts to address this gap through a focus on five main areas of environmental injustice in the ocean: 1) pollution and toxic wastes, 2) plastics and marine debris, 3) climate change, 4) ecosystem, biodiversity and ecosystem service degradation, and 5) fisheries declines. For each, we characterize the issue and root drivers, then examine social and distributional impacts. In the discussion, we explore how these environmental injustices are converging and interacting, cumulative, differentiated, and geographically distributed, and briefly examine solutions and future research directions. In conclusion, we call for greater and more explicit attention to environmental justice in ocean research and policy.

Keywords: Environmental justice, marine justice, ocean governance, marine pollution, marine plastics, climate change, overfishing, ecosystem services

1 Environmental justice and the ocean

The concept of environmental justice emerged in the 1980s in the United States from concerns about the disproportionate burdens of pollution that were being placed on and experienced by Black communities and socio-economically disadvantaged populations [1,2]. Environmental justice research demonstrated that polluting infrastructure, such as oil refineries, mining and factories, as well as air pollution emissions and toxic waste disposal sites, were often situated near Black, Indigenous, and Latino communities [3,4]. Such environmental discrimination and racism was shown to be producing numerous negative health effects and well-being outcomes for these populations [5]. The field of environmental justice has since grown globally and expanded to focus on a broader set of environmental hazards and harms, including climate change, biodiversity and habitat loss, and declines in ecosystem services [6–11]. Environmental justice has also come to refer broadly to both the distribution of environmental burdens and access to benefits, as well as the recognition, meaningful involvement and fair treatment of people in environmental decision-making and legal frameworks [12–15].

There is a substantial and growing body of empirical evidence that has documented environmental injustices related to land, air and freshwater [4–6,16,17]. Much less attention, however, has been paid to environmental justice issues in the marine and coastal environment [18–21]. Yet, demands for marine resources have rapidly accelerated as have anthropogenic pressures on the ocean

[22–25]. Numerous environmental hazards and harms – including chemical and biological pollution, plastics, climate change, habitat modification, ecosystem service degradation, as well as biodiversity and fisheries declines – are on the rise in the ocean and exceeding the planetary boundary capacities to assimilate these anthropogenic stressors [23–28]. Such risks threaten the health and sustainability of the ocean environment, and also the health, livelihoods, human rights and well-being of the individuals, groups, communities and nations who live near or strongly rely on the ocean [18,26,29–33]. Furthermore, there is evidence that impacts of these marine environmental issues are unequally distributed geographically and produce socially differentiated impacts across racial, ethnic, gender, age and socio-economic groups [29,31,33,34].

While both substantive outcomes and procedural considerations are the purview of environmental justice research, here we primarily focus on understanding how environmental hazards and harms in the ocean are impacting coastal and marine resource dependent populations. In particular, this exploratory and narrative review examines five main environmental injustices in the ocean related to: 1) pollution and toxic wastes, 2) plastics and marine debris, 3) climate change, 4) ecosystem, biodiversity and ecosystem service degradation, and 5) fisheries declines (Figure 1). There is evidence that each of these issues is widespread, worsening, and has significant impacts on human populations that are inequitably distributed across geographies and socially differentiated among groups. In the section below, we characterize each issue, examine root drivers, explore impacts on the well-being of coastal populations and communities, and discuss how impacts are distributed and differentiated using examples from the literature. Then, in the discussion, we explore how the impacts of environmental injustices in the ocean are converging, interacting and cumulative, socially differentiated, and inequitably distributed and briefly examine solutions and future research directions.

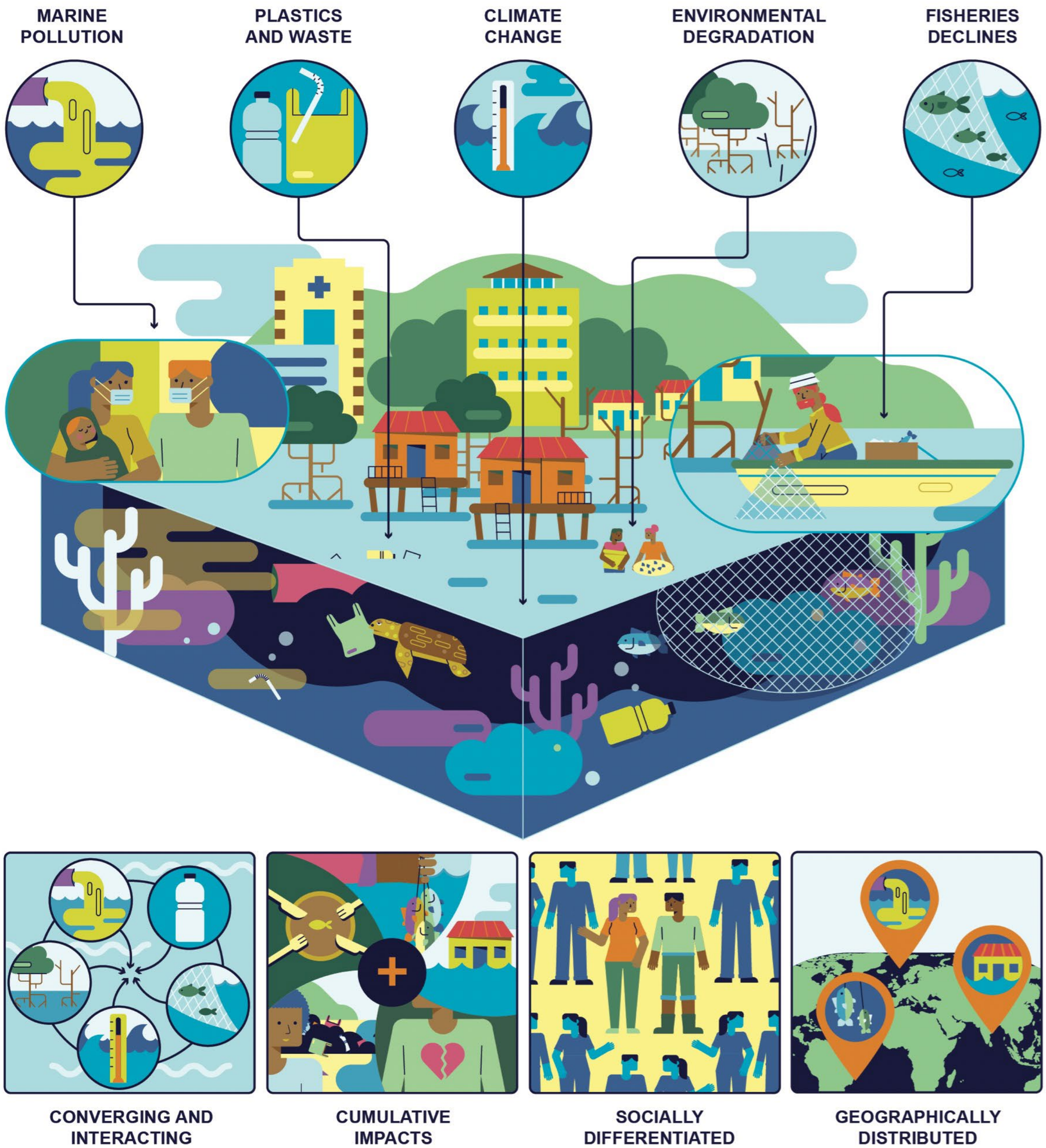

Figure 1 - Environmental injustices in the ocean, including marine pollution, plastics and waste, climate change, ecosystem degradation, and fisheries declines, impact the human well-being (e.g., health, livelihoods, economics, culture, community infrastructure, food security, and rights) of coastal populations and communities. Environmental injustices are converging and interacting, cumulative, socially differentiated, and geographically distributed which leads to varied impacts on and outcomes for different coastal communities and groups. (Credit: Estudio Relativo)

2 A review of environmental hazards and harms in the ocean

This narrative and qualitative review explores environmental injustices in the ocean and their impacts on different aspects of human well-being (e.g., health, livelihoods, economics, culture, community infrastructure, food security, and rights). We opted for a narrative and qualitative approach to allow for in-depth insights to emerge on a broad range of sub-topics related to an overarching topic and to facilitate critical reflection on the central topic and research gaps [35–37]. This approach was also taken because an initial search of the literature showed that much of the past research on oceanic/marine environmental hazards and harms does not explicitly take an environmental or social justice perspective. To understand the breadth of environmental justice issues in the ocean, we first began with a search of the Web of Science database using the search terms "environmental justice" or "social justice" and "ocean*" or "marine" or "coast*" or "sea*". The initial search yielded 358 articles, and an initial screening of the articles showed that 169 focused on the social and differentiated impacts of various environmental injustices (hererin defined as hazards and harms) in the ocean environment. We then identified five main categories of hazards and harms in the ocean and coastal environment present in the initial search and based on our own expert knowledge - i.e., marine pollution, plastics, climate change, biodiversity and ecosystem service degradation, and fisheries declines. One author who was the most knowledgeable of each issue was assigned to lead the research on and writing related to that topic. Section lead authors conducted additional targeted searches of the literature that a) characterized the nature and drivers of each issue and b) examined social and distributional impacts related to each issue. The entire authorship team also reviewed all sections, adding additional examples and references, prior to the lead author editing the final manuscript for flow and consistency.

2.1 Pollution and toxic wastes

2.1.1 Issue and Drivers

Ocean pollution has become one of the most pervasive markers of the Anthropocene. Six decades have passed since Rachel Carson's *Silent Spring* in 1962 warned the world of the negative impacts of harmful chemicals such as organochlorine pesticides (e.g., dichlorodiphenyltrichloroethane, DDT) in the environment [38]. At present, there is no corner of the world's ocean that is immune to the long-range atmospheric transport, persistence, bioaccumulative and toxic nature of pollutants, including persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs), dioxins and furans, polybrominated diphenyl ethers (PBDEs), DDTs, as well as metals, including mercury [31,39–42]. Catastrophic episodes such as the 1989 Exxon Valdez crude oil spill [43], the 2010 Deep Water Horizon oil spill [44] and the 2011 Fukushima nuclear accident [45,46] are poignant reminders of the chronic chemical assaults that impair ocean health and marine biodiversity with severe implications for the health and well-being of exposed coastal communities.

Despite command and control regulatory efforts, chemical pollution cocktails from point sources (e.g., raw sewage, wastewater treatment plant outfalls, emissions from industries, ballast water from ships, dumping at sea) and nonpoint sources (e.g., run-off of organic matter, agricultural and chemical fertilizers such as Nitrogen, and Phosphorous, current-use pesticides, emissions from artisanal and small-scale gold mining and urban environments) have continued to be discharged into the ocean environment, affecting marine biota, commercial fish and traditional seafoods [31,47–49]. These chemical mixtures include both legacy pollutants (e.g., POPs, trace metals, hydrocarbons) and new emerging contaminants of concern such as forever chemicals (Per-and Polyfluoroalkyl Substances-PFAS), flame retardants, pharmaceuticals and personal care products (PPCPs), and microplastics (see the following section) [50,51]. Excessive nutrient and fertilizer loads from agricultural lands, as well as aquaculture and mariculture, have generated hypoxic and anoxic events (i.e., 'Dead Zones' or oxygen minimum zones-OMZ), eutrophication and harmful algal blooms (HABs) or "red tides" [52]. Spillovers from sewage, livestock farms, and urbanization transport pathogenic viruses, bacteria and parasites, becoming insidious biological pollution that increasingly trigger emerging infectious diseases (EID) [53–55], and compromise coastal species, marine megafauna and subsequently human health and well-being [31].

2.1.2 Impacts and Distribution

The siege of ocean pollution impacts various aspects of human well-being in coastal populations. Human activities including oil and gas exploration and exploitation, oil pipeline construction and operation, shipping and transportation, aquaculture operations, desalination plants, and coastal cities with inadequate liquid and solid waste management generate pollution footprints (e.g., oil spills, mercury contamination, sewage emissions, plastic pollution) that jeopardize health, food security, livelihoods and human rights in coastal communities [18,23,31,56]. For example, the consumption of seafood containing high concentrations of methylmercury can damage the brain development of unborn fetuses and babies, reducing IQ and increasing risks for autism, attention deficit hyperactivity disorder (ADHD) and learning disorders [57,58]. Numerous chemical substances that are released into the ocean, including phthalates, bisphenol A, flame retardants, and PFAS, have the potential to affect the nervous system, disrupt endocrine functioning, reduce fertility, and increase cancer risk [31,58,59]. HABs produce biotoxins (e.g., domoic acid, ciguatoxin) and neurotoxins responsible for paralytic and diarrhetic shellfish poisoning, as well as ciguatera fish poisoning in marine mammals and humans [60–63]. High levels of toxic pollution or HABs in certain areas or species mean seafood cannot be harvested for either subsistence or commercial uses resulting in negative food security, recreational and economic consequences [60,64,65]. Environmental disasters - such as the Exxon Valdez or Deepwater Horizon oil spills - can also have substantial economic impacts (e.g., for the fishing and tourism industry [66–68]) while also producing serious and persistent psycho-social impacts for coastal populations who are reliant on or culturally connected to the ocean [67,69]. In the worst imaginable cases, environmental "sacrifice zones" are established in coastal and ocean areas where massive pollution is allowed to override ecosystem health, human health, and human rights [6,70–73].

Historically marginalized groups, groups that rely on subsistence harvesting or small-scale fisheries, and low-income nations tend to be disproportionately exposed to and impacted by increasing chemical and biological contamination in the ocean [58,74], a problem which perpetuates and exacerbates pre-existing inequalities. For example, the worst social-environmental impacts and public health effects of pollution are often experienced and absorbed by Indigenous people, people of color, and women [58,74]. Inuit women from the Arctic are still among the most contaminated humans with POPs such as PCB and PFAS, while struggling for food safety and security and being affected by underlying health risks due to chronic and emerging diseases such as breast cancer and endocrine disruption in the face of climate change [40,75,76]. Indigenous populations and small-scale fishers who consume high amounts of fish or mammals are exposed to the effects of methylmercury on their health

[77,78]. Afro-American communities, who have tolerated the burden of colonialism and impacts of top-down government policies for generations, have been disproportionately impacted by offshore oil and gas exploitation in coastal Louisiana where they have faced persistent industrial hazards from the myriad of old pipeline infrastructure that impair coastal marshes and produce health and livelihood impacts [72,79]. The global nature of the disposal of pollution and other wastes in the ocean reveals patterns of environmental racism, with the dumping of wastes and the breaking of ships often occurring in the lower income countries in Africa and Asia [80–82]. Oil exploration and exploitation also tends to be more polluting in lower income countries - such as Ecuador, Nigeria or Nicaragua - where corporations take advantage of environmental governance gaps and lax enforcement of standards [56,83–86].

A major reason that marginalized groups tend to experience worse impacts is because they are often not adequately consulted or included in decision-making processes. On Canada's west coast, for instance, consultation processes have tended to exclude and/or marginalize Indigenous people and local stakeholders voices and perceptions when assessing and predicting the socio-ecological risks of pollution impacts from developments (i.e., oil pipeline construction and shipping) imposed on them by the federal government [51,87]. There are countless other examples of where Black populations, Indigenous Peoples, and communities of color have been inadequately considered, consulted or provided with the opportunity to provide Free, Prior and Informed Consent (FPIC) when polluting industries and infrastructures are built [79,88,89]. These colonial and racist acts fail to recognize ancestral ocean ownership and tenure rights, inclusion of marginalized communities in decisions, respect for human rights, and consideration of social and health impacts in the formulation of pollution prevention approaches.

2.2 Plastics and marine debris

2.2.1 Issue and Drivers

The oceans are undergoing dramatic changes from the chronic and widespread impacts of escalating marine debris [90,91]. Ocean plastics are by far the largest component, contributing as much as 80-95% of global marine debris [92–94]. Plastics are ubiquitous in society, including being used in the food, health, clothing, construction, manufacturing, electrical industry and automotive and transportation sectors. The prevalence and persistence of single use plastic is particularly problematic. It is estimated that around 4.8 to 12.7 million metric tons (MMT) of plastic waste per year are discharged into the ocean [95]. The majority (~80%) of marine plastic litter comes from land-based sources [95–97]. As much as 0.8-2.7 MMT of plastic enters the ocean through rivers, with ~80% of that coming from 1656 rivers [98]. Most of this plastic enters the ocean due to improper disposal, and lack of sound solid waste management [33,95,98]. The remaining 20% of marine litter is ocean-based and comes from fisheries, nautical activities and aquaculture [94]. The fishing industry is responsible for 500,000-1 MMT of plastic fishing gear and derelict nets ("ghost nets") polluting the ocean [99,100]. Fishing gear is a particular issue as abandoned, lost and discarded nets continue to pose enormous ecological (i.e. continuing to catch valuable fish; endangered fauna e.g. sharks, sea turtles, marine mammals) and socioeconomic problems [101]. The amount of plastic waste in aquatic ecosystems is projected to nearly triple by 2040 if meaningful actions to mitigate and combat plastic pollution are not implemented [102,103].

The concerns around marine plastics stem from their persistence, accumulation and toxicity in the environment, as well as their long-term effects on ocean health, ecosystems, marine biodiversity and humans [33,92,95,97,104]. The persistence and effects of ocean plastics need to be understood in the context of different types and sizes of plastics that enter the marine environment. The most common types of plastic include polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinylchloride (PVC), polyethylene terephthalate (PET), and polyurethane (PUR) resins; and polyester, polyamide, and acrylic (PP&A) fibres [105,106]. An estimated ~40-42% of all non-fibre plastics are used in single-use packaging, which is predominantly composed of PE, PP, and PET [106]. The plastics entering the oceans are of different sizes - ranging in size from macro (e.g., plastic traps, plastic bottles and bags, styrofoam, nets) to micro (e.g., micro-beads from hygiene products, fibres from clothing). Most of the macroplastics do not degrade, but rather deteriorate, fragment and disintegrate into micro- and nano-particles, thus accumulating in the marine environment [107,108]. Much of the plastic waste that enters the marine environment also persists for a very long time. As a result, plastics are not just found in coastal regions, but also accumulate in certain areas such as the Great Pacific Garbage Patch [109], the North Atlantic subtropical gyre [110], and the deep sea [111,112]. Most (~95-99%) plastics do not remain on the surface of the ocean, but are found within the seawater column and marine bottom sediments [112–116]. Some plastic products also contain and release dangerous chemicals (e.g., plasticizers and flame retardants) into the marine environment, and plastic marine litter can also attract and absorb chemicals from the surrounding seawater [33,92,104,117]. However, the amount of chemicals contained in plastics and/or microplastics in the ocean and transferred to food webs is currently considered to be small or negligible compared to the chemical concentrations found in food, seawater and organic particles that originate from other land-based sources of pollution [118,119]. Yet, there are major gaps in our knowledge about the behavior and breakdown of plastic in the ocean, where it eventually ends up, and the quantity or concentrations entering the food web and trophic transfers to humans [116,120].

Ocean plastics affect the marine environment and life in a variety of ways. Different types, shapes and sizes of plastics can be ingested by and cause lethal and sub-lethal effects in various marine species of seabirds, fish, and mega-fauna (e.g., cetaceans, pinnipeds, large filter-feeding sharks, sea turtles), as well as in invertebrates such as corals [92,121–124]. This unfortunately is not a new phenomenon, with marine fauna collected in the mid-1970s already clearly having plastics within their stomachs [121]. In addition, microplastics and nanoplastics with associated chemical substances or additives that may well cause changes in gene and protein expression, produce inflammation, disrupt feeding behavior, decrease growth, change brain development, reduce filtration and respiration rates, and alter the reproductive success and survival of fish and other marine organisms [125–131]. Research has shown that a number of microorganisms, including pathogens, colonize plastic to form biofilms and microbial communities in the marine environment with potential negative impacts for both fish and human health [132]. For example, fish-related pathogens [133], the Cholera pathogenic bacteria *Vibrio cholerae* [134], and harmful algal species have been found hitchhiking on plastic debris [135]. There is also emerging evidence to suggest that marine plastics may reduce atmospheric oxygen production by inhibiting the growth and functioning of *Prochlorococcus* — a photosynthetic microorganism that produces around 10% of atmospheric oxygen [131]. Plastics can also interfere with the health and functioning of marine ecosystems (i.e., notably, mangroves, seagrasses, corals and salt marshes) and the production of ecosystem services [33,136].

2.2.2 *Impacts and Distribution*

Ocean plastics may impact human health and well-being in both direct and indirect ways. Human health may be affected by the negative impacts of marine plastics on marine fisheries and biodiversity - which are an essential source of food and nutrition, including a rich source of omega-3 fatty acids, selenium, iron and vitamins [137], and a well-spring of biomedical discovery [138]. In addition, the ingestion of plastics by marine species - including fish, bivalves and crustaceans - presents a food safety risk for humans when contaminated seafood enters the human food chain [139,140]. The bioaccumulation and biomagnification potential of microplastics in marine food webs is also possible depending on the residence time and elimination rate of plastic particles in organisms exposed [119,141–143]. However, the exact nature and scale of the risks posed to humans by consumption of micro- and nano-plastic contaminated seafood and associated toxic chemicals are still uncertain [140,144–147]. Evidence suggests that consumption of plastics may be particularly harmful to women's reproductive health as a source of immunotoxic and endocrine disrupting chemicals [145,148]. Furthermore, microplastics have been found in human placenta and blood [149,150] and potential risk for carcinogenesis induction in humans has been suggested [148,151]. Marine plastics can also act as vectors for pathogens, even potentially SARS-CoV2 [152], which may also have harmful consequences for human health [132,134,153]. All of the research on plastics implies potential health risks for humans - yet, the empirical evidence of actual health impacts resulting from marine plastics is still limited [154].

Another concern is the economic impacts of marine plastics. Marine plastics can produce economic costs through reducing the profitability or viability of various economic activities - for example, through the reduction in harvestable marine resources for small-scale fishers, effects on aquaculture productivity, impacts on coastal agriculture machinery and livestock, or a reduced market for marine ecotourism due to the aesthetic and ecological impacts of plastic pollution [155–157]. Broader economic losses to marine industries have been estimated at US $10.8 billion annually for the Asia-Pacific Economic Cooperation (APEC) region [158] and US $6-19 billion for 87 countries in Europe, Asia, Africa, the Middle East, the Americas and Oceania [159]. Furthermore, Beaumont et al [136] roughly estimate a loss of 1-5% in marine ecosystem services delivery due to plastics, which equates to US $500-$2500 billion annually. There are also additional and ongoing economic costs associated with waterway, beach or ocean cleanup, as well as impacts on boat engines, marinas and ports, which are often borne by coastal communities and individual businesses rather than by producers [33,117,156].

In general, plastic pollution on land disproportionately affects communities that are economically or politically marginalized - the same is likely true in the marine environment where the impacts of marine plastic pollution are felt differently across socio-economic, race, gender, age and geographical contexts [33,160]. The effects of plastics on fish and marine megafauna threatens the food security of those who are most reliant on fish including small-scale fishers and Indigenous communities [140,146,154,161,162]. Though distribution is not calculated, the effects of economic losses to industries and ecosystem services likely fall disproportionately on those whose livelihoods and well-being are most closely tied to coastal activities and resources. Children may well be more vulnerable and sensitive to plastics and associated chemicals exposure in the marine environment as they are developing both physically and mentally, and thus less resistant to lingering effects that might impact their health in the long term [163,164]. Children may also never experience and enjoy coastal areas, beaches and marine ecosystems free from plastics now and in the future.

Marine plastics also have a global dimension. Liboiron [74] challenges us to think about plastics as a form of colonialism enabled by global capitalist expansion. The amount of plastic waste generated per capita by individuals in many low- and middle-income countries is substantially less than individuals from high-income countries [165,166]. Fifteen countries account for 73.9% of the plastic waste that is exported, 11 of these countries are from the OECD [167]. However, many Low- and Middle-Income Countries are unable to adequately manage their own plastic waste let alone the burgeoning amount of plastic waste shipped from High-Income Countries [168]. The UN Special Rapporteur on Toxics underscored how this issue compounds due to the lack of adequate reception and processing facilities in lower income countries [169]. When combined with local gaps in waste management, this leads to substantially greater land-based inputs of plastics into the ocean with associated increases in environmental and societal impacts for populations in lower income countries [33,166,167].

2.3 Climatic and global environmental change

2.3.1 Issue and Drivers

Due to increased greenhouse gases (GHGs) from human activities, the concentration of carbon dioxide (CO_2) in the Earth's atmosphere has increased, the temperature has warmed, and weather patterns have changed [27,170]. The science is clear that the cause of these climate changes is human activities, including GHG emissions from combustion of fossil fuels (e.g., coal, oil, and natural gas) for industrial uses, transportation, and energy, deforestation and land conversion, agriculture and livestock, and the production and use of equipment and products containing GHGs (e.g., nitrous oxide, fluorinated gases) [170]. Furthermore, a substantial portion of GHGs are produced by nations with larger economies and higher per capita incomes [29,171].

Global climate change is producing numerous and substantial changes – both direct impacts and knock-on effects - in marine and coastal environments [27,29]. The ocean has steadily warmed and at a greater rate than the atmosphere, influencing nutrient cycling, decreasing primary production, shifting the geographic distribution of organisms, leading to range expansions of tropical species, and impacting the growth and reproduction of fish stocks [29,172–175]. Ocean warming leads to increasing sea surface and bottom temperatures displacing and removing dissolved oxygen, causing deoxygenation and hypoxia, which ultimate affect the survival and distribution of gill-ventilating organisms such as crustaceans and both small and large pelagic fish species [29, 174, 175, 198]. It is estimated that as much as 20-30% of CO_2 emitted over the last few decades has been taken up by the ocean, leading to acidification with coinciding impacts on calcification processes and growth of shellfish and coral reefs as well as loss of oxygen which contributes to hypoxic and anoxic areas ("dead zones"), exacerbating oxygen minimum zones (OMZ), and HABs [29,176–179]. Many coastal regions are experiencing "weather wilding" with increasing extreme weather events, changing seasons, and shifting rainfall patterns [180,181]. Sea level rise is leading to inundation, flooding and saltwater intrusion in coastal areas [182–184]. A higher prevalence of marine heatwaves is leading to mass mortality events and producing detrimental impacts on ecosystems, biodiversity, and ecosystem services [185–187]. Changing temperatures, rising seas, increasing salinity, deoxygenation and acidification combined are stressing coastal ecosystems, including mangroves, saltmarshes, seagrass meadows, and coral reefs, and pushing some beyond their tipping points and ability to adapt [29,188–192]. Some economically important and harmful macroalgae can benefit from elevated CO2 concentrations in the ocean and moderate increases in sea temperature, which may well trigger increasing events of harmful macroalgal blooms such as green macroalgal blooms (i.e., caused by Ulva spp.) and golden tides, generated by Sargassum spp.[Ji and Gao 2021]. This has obvious consequences for the coastal ecosystem health and local industries, including fisheries, aquaculture and mariculture (i.e., macroalgae biomass washing ashore and reduction of dissolved oxygen concentrations due to decomposition of the organic matter from harmful macroalgal blooms, leading to death of fish and other aquatic life).

2.3.2 Impacts and Distribution

The litany of climate change impacts and knock-on effects described above are having substantial but differentiated implications for coastal communities and ocean-dependent populations around the world. Extreme weather events, coastal inundation and erosion, saltwater intrusion, marine heatwaves, acidification, deoxygenation, and HABs can have detrimental effects on economic benefits from the fisheries, aquaculture, agriculture and tourism sectors [29,193–197]. Shifts in the abundance, productivity and location of fish stocks and shellfish from warming oceans and acidification are affecting fisheries jobs, revenues, and food security for many coastal populations [194,198–202]. Rising sea levels, combined with increased storm and flooding events, are harming community infrastructure, housing and health in both rural areas and urban centers [183,203–205] and leading to forced retreat or migration away from the ocean [206–210]. Climate change impacts on ecosystems can undermine provisioning, regulating, cultural and supporting ecosystem services that are fundamental for human well-being [187,188,211,212]. In short, climate change threatens the human rights of coastal populations and nations to food, livelihoods, health and physical security [213–215].

There is substantial evidence that different racial, ethnic, gender, age and socio-economic groups experience the impacts of climate related changes to a greater or lesser extent [29,216–220]. For example, pre-existing social and structural inequalities tend to situate Black populations, women and the poor in more vulnerable positions when it comes to coastal flooding, storms, and other hazards related to climate change [206,221,222]. Communities and groups (e.g., small-scale fishers or Indigenous Peoples) who have a high level of resource dependence - either for livelihoods or food security - will also be more susceptible to changes to ecosystems, ecosystem services and fisheries brought on by climate change [223–225]. Populations who have recently migrated to the coast in search of opportunities or been displaced there by inland development may be particularly subject to “coastal squeeze” from climate change impacts (***Ref). Similarly, groups with lower adaptive capacity - due to less access to financial resources, lack of alternative livelihood options, or structural barriers - will experience greater impacts of climate change [226,227]. Already marginalized groups can also be the hardest to reach and assist with recovery during and after disasters (***Ref). Climate change adaptation and mitigation programs can further marginalize local populations when their needs and voices are not taken into account (***Ref). Managed retreat, for instance, can have disruptive public health implications, including declining mental health, social capital, food security, water supply, and access to health care, that disproportionately affect Indigenous people [207]. In Bangladesh, climate adaptation projects have excluded and further marginalized women and minorities, and worsened income inequality [228].

Certain geographies, regions and countries, are also more exposed to climate change’s effects. For example, low-lying coastal areas with high populations - which are particularly prevalent in Asia

(China, India, Bangladesh, Indonesia, & Vietnam) and Africa (Egypt and sub-Saharan countries) - will be more highly exposed to sea level rise, coastal inundation, saline intrusion, flooding and landslides [195,208,229]. Sea level rise is also threatening human security and leading to outmigration from Pacific island and atoll countries [230,231]. Nations in Africa, Asia, Southeast Asia and the Pacific Islands that are near the Equator and with a high reliance on fisheries may be both more exposed and more susceptible to livelihood and food security impacts [202,224,232,233]. Many large coastal cities in low- and middle-income countries - such as Lagos (Nigeria), Manila (Philippines), and Bangkok (Thailand) - are situated in floodplains and may have lower institutional capacity to be able to adapt [234–237]. Coastal populations in Equatorial and Arctic regions may experience some of the most extreme changes in temperature and species composition [232,233,238,239]. Notably, the impacts of climate change tend to be experienced to a greater extent in lower income countries, and by those less responsible for producing carbon and causing climate change [29,171].

2.4 Ecosystem, biodiversity and ecosystem service degradation

2.4.1 Issue and Drivers

Marine ecosystem services, which describe the benefits people obtain from marine ecosystems [240], are essential for coastal communities, small-island developing states, and Indigenous communities, because they have historically provided and continue to provide food and medicine, livelihood opportunities and income, carbon sequestration, defense against extreme weather, and contributions to cultural heritage and identity, among many other benefits [241–246]. Coral reefs, for example, support the livelihoods, food and nutritional security, and well-being of hundreds of millions of people who rely both directly and indirectly on reefs [247,248]. Coastal wetlands provide global storm protection valued at $447 billion per year [249]. Seagrasses, tidal marshes, and mangroves are essential and effective carbon sinks [250]. Importantly, marine ecosystem services are neither homogeneous nor static; rather, people access a variety of ecosystem services for different reasons through diverse mechanisms that shift over time [251–253].

From pole to pole, the capacity of marine ecosystems to provide ecosystem services is declining due to pressures on ecosystems and biodiversity [24,254,255]. Over the last several decades, 50% of salt marshes, 35% of mangroves, 30% of coral reefs, and 19% of seagrasses have been lost or degraded [254,256,257]. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services' (IPBES) recent global assessment report indicates that 72% of the indicators developed and used by Indigenous peoples and local communities to monitor changes in ecosystem services showed negative trends [258]. Human activities threaten many of the world's remaining marine ecosystems and the benefits they provide [29]. These activities include overfishing [detailed in Section 2.5.1], climate change [detailed in Section 2.3.1], and various forms of ocean and coastal development and resource extraction [26,259]. Rapid coastal development is increasing demands on coastal and ocean spaces [260]. This often takes the form of building over or removing natural habitats, building out into the sea, or hardening the coast to prevent coastal erosion [259,261]. Sandy beaches, for example, which provide recreation and food, protect livelihoods, and maintain water quality, are under pressure from sand mining to support the construction industry [262], sewage input from urban, industrial, and agricultural activities [263], and sea-level rise and erosion [29]. The rapid expansion of coastal aquaculture is driving the pollution, degradation and conversion of mangroves and agricultural commons into privatized monocultures [264,265]. Seagrass dredging to expand or alter coasts for commercial use is undermining their capacity to support a variety of ecosystem services [266,267].

2.4.2 Impacts and Distribution

Globally, as marine habitats and ecosystem services decline, so too does human well-being in coastal populations and communities [242,268]. Coastal infrastructures, economies, livelihoods, food security, and public health are vulnerable to the effects of degrading ecosystems on ecosystem services [26,269]. Non-white and low- and middle-income communities bear a disproportionate share of the impacts of declining ecosystem services [34]. For example, low-income countries are more vulnerable to food insecurity resulting from degraded coral reefs [270]. Furthermore, tropical fisheries catch potential is projected to decline by 40% over the next three decades, which will create disproportionate harm for people who rely heavily on marine protein as they do in many Pacific Island Nations [271,272]. Indigenous peoples also experience disproportionately high impacts of declining marine ecosystem services that are essential for food security and cultural continuity [273]. Of particular concern, nature is declining most rapidly where nature's contributions to people are the greatest [34].

Locally, case studies demonstrate that changing or declining marine ecosystem services, and responses to these changes, are often skewed in ways that produce greater harm for marginalized groups and communities. In Kenya, female fish traders have experienced increased hardship resulting from declining fish stocks while some (male) individuals have benefited [274]. The convergence of a record-breaking oil spill and the COVID-19 pandemic created extensive damage to seagrass meadows, local livelihoods, and public health in Brazil [275]. In many cases, environmental degradation intersects with centuries of colonization to block Indigenous peoples from realizing the benefits of ecosystem services [276–278]. For example on the Central Coast of British Columbia Canada, colonial disruption of Indigenous practices has led to decreases in the size and abundance of rockfish populations, undermining food security and cultural practices of First Nations [279]. In the Canadian Arctic, climate change and ecosystem shifts are driving change in the distribution, abundance, and health of beluga, which is central to the economics, diets, and culture of Inuvialuit [280]. Migrant populations who are displaced to coastal areas, and are often heavily reliant on marine resources for food and fisheries for livelihoods, can also end up being susceptible to environmental degradation and declines in ecosystem services at the coastal margin (Ref).

Efforts to support the conservation of ecosystem services can also further marginalize certain groups while benefiting others. Marine protected areas, for example, can benefit tourism operators whereas local fishers are largely excluded [281] or fail to consider the gendered impacts of spatial enclosures on gendered access to resources [282]. Even where payments for ecosystem services programs explicitly aim to address unequal distribution of the costs and benefits of ecosystem services, local communities and Indigenous people rarely benefit from offset or conservation projects [283].

2.5 Fisheries declines

2.5.1 Issue and Drivers

At the global scale, wild fish stocks are in decline. The percentage of fish stocks that are fished at biologically unsustainable levels increased from 10% in 1974 to 34.2% in 2017 [284]. The long-term trend in global capture fisheries has been relatively stable since the mid-1990s, despite increases in fishing effort over the same period [285]. In addition, the mean trophic level of the species groups targeted has declined over time, a phenomenon described as "fishing down the food web" [286,287]. Not only does this phenomenon imply overfishing, but increased fishing at low trophic levels has particular, reverberating impacts on marine biodiversity and ecology [288]. Yet, declines are not distributed evenly across the world's oceans; the status of fisheries resources varies significantly by geography and by species and is closely related to the level of fisheries management [289].

Fisheries declines are driven by a variety of factors. Overfishing is driven by increasing global demand for seafood linked to higher incomes, urbanization, and a focus on healthier diets, as well as illegal, unreported, and unregulated (IUU) fishing [284]. Some destructive fishing methods produce downstream effects that further threaten the viability of coastal and offshore fisheries. For example, industrial bottom trawling is especially damaging to coastal habitats [290], results in high bycatch [291], and produces significant greenhouse gas emissions [292], contributing to global climate change and its associated impacts on the geographic distribution of organisms and the growth and reproduction of fish stocks [detailed above]. Bycatch products from bottom trawling are a major contributor to the fishmeal and fish oil industry [293], most of which is destined for aquaculture feed [294], in an ironic system whereby wild fish are used to rear higher-value farmed fish. Though major gains have been made in aquaculture feed efficiency in the past twenty years, the dependence on marine ingredients persists and demand continues to increase as aquaculture expands [294]. Fisheries targeting low-value fish to serve this market can considerably impact wild fish populations and marine ecosystems through the capture of juvenile fish, mesopelagic fish, and loss of biodiversity [294–296]. The use of the ocean and coasts for mining, logging, infrastructure development, coastal tourism, and aquaculture pose further threats to fish habitat and populations while also limiting access to small-scale fishers who rely on these areas and fisheries for their livelihoods and food security [297–301]. Climate change also affects fish habitats, species growth and range, and overall levels productivity and abundance (29, 174, 175). Maximum catch potential in some of the tropical countries most dependent on fisheries is projected to decline by up to 40% by the 2050s under continued high greenhouse gas emissions ().

2.5.2 Impacts and Distribution

Declines in wild fisheries, the degradation of fish habitat, and inadequate management of fish stocks directly threaten the livelihoods, food and nutritional security, and cultural practices of the millions of people who rely on fisheries daily. For example, in 2017, fish consumption accounted for 17% of the world's animal protein consumption [284]. Small-scale fisheries and aquaculture produce more than half of the global fish catch and two-thirds of aquatic foods used for human consumption, and associated value chains support over 100 million full- and part-time jobs [284]. An additional 53 million people worldwide rely on seafood for subsistence, supporting 379 million household members, or around 7% of the global population [302]. Fish is a key source of micronutrients, which are essential to human health, as micronutrient deficiencies underlie nearly half of all deaths in children under 5 years of age [161]. The depletion of fish stocks can also have devastating effects on human well-being [268], Indigenous ecological knowledge and management [303], and culturally significant harvesting practices

[304]. Marine fisheries are key contributors to national economies as well, generating US$ 80 billion dollars in export revenues for lower-income countries [305]. Yet overfishing leads to fisheries' economic underperformance, and rebuilding depleted stocks has the potential to generate long-term economic benefits that outweigh the costs [306]. Efforts to catch and export inexpensive fish to growing global markets in the face of declining stocks have also led to extreme forms of human exploitation, including human trafficking, child labour, and slavery on industrial vessels [307,308], which co-occurs with IUU fishing and overharvesting [309,310].

Impacts are not equally distributed across the planet, with small-scale fishing communities and lower income nations bearing the heaviest burdens. Small-scale fisheries produce almost half the fish consumed in low- and middle-income countries [311,312] and directly employ 90% of those working in fisheries [313], an estimated 60 million people—approximately 40% of whom are women—with a further 53 million fishing for subsistence [311,312]. Seafood is of particular importance to food and nutritional security in countries such as Bangladesh, Cambodia, Ghana, Nigeria, and in the Pacific Islands, where fish is by far the most frequently consumed animal-source food [314]. In many low-income countries, seafood is also a key source of micronutrients critical to human health [30,161], and exporting fish to supply distant markets often leads to the loss of nutritional benefits to local people [315]. Large-scale industrial fisheries, in contrast to small-scale actors, are highly subsidized and mobile, employ relatively few people, have high discard rates, and can undermine the catches of small-scale fishers [300,316,317]. Furthermore, industrial fishing is highly concentrated in higher-income nations with distant water fleets that operate in the waters around and within the economic exclusive zone (EEZ) of lower-income nations where they overharvest commercial fish and undermine local food security and livelihoods [284,318]. Higher-income countries comprise 78% of trackable industrial fishing within the national waters of lower-income countries [319]. The crisis of IUU fishing is most highly visible in western Africa, where it has been estimated that IUU fishing—mostly by foreign vessels—accounts for between one third and one half of the total regional catch [320], driving several food species toward extinction [321]. **In addition, an unknown number of vessels are not traceable, and many more use "flags of convenience"and practice "flag hopping" to avoid legal consequences of IUU fishing ( ).**

Coastal Indigenous peoples and women tend to be especially vulnerable to fisheries declines. Coastal Indigenous groups are highly dependent on marine resources for food and cultural practices yet tend to be marginalized from fisheries access and management [300,322,323]. Per capita consumption of seafood is 15 times higher in coastal Indigenous communities, on average, compared to non-Indigenous country populations [243], and fish is the primary source of food in many Indigenous communities in the Pacific [324]. Women are also more vulnerable than men to fisheries declines. As women tend to dominate lower-value, non-harvest, and informal parts of seafood supply chains, including invertebrate gleaning, processing, and marketing, they tend not to be counted in fisheries statistics [325,326], to be marginalized from fisheries management [300], and to not receive the same level of government support as men following a crisis [327]. The "invisibility" of these roles in value chains can also mask labor trafficking, peonage systems, health and sanitary issues, and unsustainable and illegal fishing, perpetuating the cycle of social and environmental abuses [328]. Furthermore, gender intersects with other social identities to produce unique relations between people and fisheries, which can increase or decrease a fisher's vulnerability and capacity to adapt to environmental change [329,330]. Recent studies have examined how gender interacts with ethnicity [331], class [332], individual decision-making [333], religious denomination and place of birth [334], nationality [335], and marital status [304] to shape fishers' access to and control of marine resources. Gender and Indigenous identity also intersect to create unique vulnerabilities to fisheries declines for Indigenous women and girls, for example, threatening the transfer and use of traditional ecological knowledge for managing fisheries sustainably [303].

Small-scale actors are frequently marginalized in fisheries management [299]. These actors often have relatively limited political power compared to industrial actors, and many policies intended to enhance the sustainability of fisheries end up targeting small-scale actors, with negative livelihood effects [299]. There has historically been insufficient representation of lower-income and previously colonized states, as well as marginalized groups (e.g., women, Indigenous peoples, people of low socioeconomic status) in decisions related to development of the coasts (e.g., energy and oil development, aquaculture, conservation) that will impact them and their fisheries [300,336,337]. International fisheries agreements have, for instance, been described as primarily commercial deals negotiated by governments behind closed doors, with few benefits accruing to local economies [300,338,339]. Capacity-enhancing and harmful subsidies by high-income nations exacerbate overfishing in the waters of other countries and in the high seas [340,341]. Meanwhile, fishing communities tend to have limited or disadvantaged access to markets, and may have poor access to health, education, and other social services [342]. Colonial legacies, lack of access to or fair allocation of resources and markets, insecure tenure rights, and a disparity of financial resources and technological capacity all act to uphold and reinforce such inequalities in fisheries [300]. Even efforts to address the high level of IUU fishing by distant water fleets in Africa have largely constrained small-scale actors, though they support millions of jobs and are better adapted to meet nutritional needs and provide socioeconomic security for local populations [343].

3 Discussion

This paper draws attention to the environmental injustices that are occurring in the ocean – through characterizing and examining the impacts and distribution of five types of environmental hazards and harms. In particular, the narrative and qualitative review examines how pollution, plastics, climate change, biodiversity and ecosystem service degradation, and fisheries declines in the ocean are impacting various aspects of human well-being in coastal populations. Below, we reflect on the converging and interacting, cumulative impacts, socially differentiated, and geographically distributed nature of these environmental injustices and impacts, and end with a brief examination of solutions and future research directions.

3.1 Converging, interacting, and cumulative environmental injustices

While this review examines the different categories of environmental hazards and harms separately, they do not exist or operate in isolation. The various hazards and harms converge, interact, and produce cumulative environmental injustices for coastal populations. As anthropogenic activities increase and pressures on the world's oceans converge [22–25], they can interact in various ways that are additive, synergistic, or antagonistic producing combined effects on ocean health, species, and ecosystems [240,344–346]. For example, nutrient run-off from agriculture or urban centers can combine with warming oceans to exacerbate HABs and increase the size of hypoxic areas or "dead zones" in the ocean [27,347]. Climate change, contaminants and fishing pressure (i.e., overfishing) can interact in ways that increase climate change susceptibility, decrease species abundance, or increase contaminant exposure in marine food webs with implications for seafood security and safety [39,348,349]. All of the environmental hazards and harms discussed in this paper converge to threaten marine biodiversity and ecosystem services [26].

The overlap and interactions of hazards and harms in the ocean and coastal environment can also lead to cumulative human exposures to environmental injustices and simultaneous, magnified impacts on different aspects of well-being (e.g., on health, mental health, livelihoods, food security) for local populations (Figure 1). Climate-related natural disasters - e.g., tropical storms, hurricanes and flooding - can lead to increased exposure to infectious diseases and chemical pollutants [350,351]. Certain regions or groups may be particularly susceptible to cumulative exposures - for example, Arctic Indigenous communities are bearing the brunt of the combined effects of climate change, accumulation of POPs and mercury, and oceanic transport of microplastics on fish and marine megafauna, food security and health [39,40,50]. Furthermore, marine hazards and harms also converge with other broader social, economic, political, governance and environmental trends and shocks, including migration and population growth, development of the blue economy, shifts in governments, or the emergence and implementation of new policy regimes or management tools [259,344,352–354]. Each of these changes can place additional pressures on resources or areas of the marine environment and can have substantive or procedural justice implications for coastal populations and communities.

3.2 Geographic distribution

This review also reveals how environmental hazards and harms are distributed geographically - in particular, highlighting both the localized and global nature of environmental justice issues in the ocean. On the one hand, local environmental injustices are rife in the marine environment - with exposures and social impacts occurring for coastal communities and populations around the world that are situated near polluting industries, urban centers, plastic laden rivers, and untreated sewage outflows [22,55,56,97,98]. Proximal environmental injustices related to different industries (e.g., oil and gas, aquaculture, shipping, ports, desalination plants) may be worse where environmental governance - laws, policies and the rule of law - are not as strong; yet, localized marine pollution and "sacrifice zones" can be found in all regions of the world [6].

On the other hand, many environmental injustices related to the ocean are global - with exposures and social impacts being experienced around the world or being produced in areas that are far from the source. The effects of climate change are felt by coastal communities globally, though levels of exposure to various biophysical changes (e.g., storms, temperatures, sea level rise, acidification and HABs) and knock-on effects (e.g., declining catches, health outcomes, migration) are greater or lesser in different regions of the ocean [27,29]. The health effects of some organic pollutants - such as methylmercury and POPs (e.g., PCBs, DDT, PFAS) - tend to be concentrated in certain regions such as the Arctic that are often far (and distant in time) from the original source due to long-range atmospheric transport and deposition [40,75,76,78]. The review also shows that high-income nations are often responsible for producing environmental injustices in low-income nations - this dynamic is present, for instance, in the production of GHGs and impacts of climate change [29,170,171], the dumping of pollution [81], the global shipment and circulation of plastic wastes [33], and fishing by distant water fleets [319,321,343]. These examples point to the role of colonialism, racism and capitalism as human-made political forces triggering and exacerbating environmental injustices at a global scale in the ocean [74,355]. These dynamics may also mean that certain geographies and lower-income countries in Africa, Asia, and Latin America are simultaneously dumping grounds for pollution and plastics and the source of critical natural resources and fish stocks for wealthier nations.

3.3 Social differentiation and intersectionality of impacts

Exposure to and impacts of environmental hazards and harms are socially differentiated across axes of identity. Numerous empirical examples in the review above show that different groups (e.g., genders, ages, ethnicities, races, classes, livelihoods), and groups at the intersections (e.g., poor women, unmarried immigrants, women from marginalized ethnic groups, poor and/or Indigenous children) are more or less exposed to, susceptible to, and impacted by the effects of all categories of environmental injustices: pollution, plastics, climate change, ecosystem service degradation, and fisheries declines. For example, Indigenous communities and racial minorities are often more exposed to ocean pollution [31,70,79,356]. Women often disproportionately bear climate change impacts, ecosystem service degradation and fisheries declines [206,217,274,303,357]. Groups that depend more on fish and seafood - e.g., small-scale fishing and coastal Indigenous communities - are more susceptible to all types of environmental harms and hazards [223–225,243]. Children are also affected more - and for the longest period of time - by the impacts of climate change, pollution, and biodiversity loss [6,358].

In particular, this review highlights how groups that are socio-economically disadvantaged or politically marginalized tend to be impacted more and experience fewer benefits. For example, women and different ethnic groups often lack legal recognition or tenure rights independent of their husbands [327,359], small-scale fishers can face physical and financial resource constraints [227], Black populations can face systemic racism [222,360] and migrants may have lower social capital, legal protection, and adaptive capacity [304,361,362] - all of which can lead to greater susceptibility to the impacts of climate change. This dynamic sets up a vicious cycle whereby pre-existing inequalities lessen a group's ability to respond to environmental change and lead to greater social impacts, thereby increasing inequality [227]. The research also shows how many responses that are designed to address environmental injustices can themselves produce socially differentiated impacts [207,228,343,363]. For example, elites often capture more of the benefits of payment for ecosystem service programs [283]. Roles in and compensation from disaster recovery work fall along gender and racial lines [364,365].

Finally, much of the literature on socially differentiated impacts focuses on a single axis of identity, such as gender or ethnicity, and we found very few intersectional analyses [366,367] that specifically address environmental injustices in the marine environment. A few notable exceptions include research by Lau & Scales [331] on how gender and ethnicity intersect to shape oyster harvesting in the Gambia, Novak-Colwell et al. [332] on how power and class operate differently for men and women adapting to fishing regulations in India, Rohe et al. [334] on how gender intersects with religious denomination and place of birth to shape participation in fisheries management in the Solomon Islands, and Ferguson [304] on how gender intersects with nationality and marital status to determine the distribution of costs and benefits of the seafood trade.

3.4 Solutions to environmental injustices in the ocean

The development and implementation of solutions to address environmental justice issues in the ocean is not an easy task. While an extended discussion of how to address each of the environmental injustices identified here is beyond the scope and focus of the paper, we would be remiss if we did not quickly touch on some overarching insights into solutions. Bold, fair and transformative actions and policies are needed at all scales - from local to national to global - to reduce pollution and plastics, mitigate climate change, stem the loss of biodiversity and ecosystem services, and address fisheries declines [26,27,368–370]. Different types of actions are necessary including policy, technological, corporate, and social changes. As a result, all manner of organizations and entities have a role in addressing each type of environmental injustice explored here - state governments and their agencies in creating and enforcing policies to address the problems, the private sector in developing new technologies and reducing harmful environmental impacts, as well as civil society in reducing consumption and demanding change. Addressing issues at the source can be more effective and efficient, while also placing the burden on producers and perpetrators rather than those affected [6]. For example, policies that ban chemical pollutants, curtail point source pollution, and reduce nutrient flows in the ocean have been successful at lessening impacts on ocean and human health [31]. Reducing plastics production, consumption, and improving waste management to turn off the tap of plastics pollution is easier than attempting to clean up ocean plastics [33,103,371]. In this respect, the recent decision to negotiate a new global treaty on plastics is a promising development [372,373]. Another promising development is the 2022 resolution adopted by the United Nations General Assembly recognizing that everyone has the right to live in a clean, healthy and sustainable environment [369]. This fundamental human right is already incorporated into the legal systems of more than 155 nations, through constitutions, legislation or regional treaties; and has been recognized, by way of interpretation, by global and regional human rights bodies. Recent court decisions from Argentina and South Africa demonstrate the utility and benefits of this right, as coastal communities and environmental organizations have won lawsuits overturning permits granted for offshore oil and gas exploration and development activities due to impacts on rights to participation, a healthy environment, livelihoods and food [374–376].

The last consideration already showss that procedural considerations are central to either the production and entrenchment, or the avoidance and remedy, of environmental injustices in the ocean. The results of our review suggest that environmental injustices in the ocean are often produced or worsened by lack of recognition of certain groups and marginalization of their voices and perspectives in coastal development, siting of infrastructure, disposal of wastes, and allocation of resources [18,79,81,88,89,300,377]. Case studies also emphasize how inadequate consideration of the social and cultural context and inappropriate approaches to consultation with local people can lead to policy solutions aiming to address biodiversity and ecosystem service degradation and fisheries declines that further marginalize already disenfranchised groups. A persistent problem in fisheries management and policy, for example, is that insufficient attention is paid to the rights and livelihoods of small-scale fishers [343,377,378] and particularly women fishers [282]. The creation of marine protected areas to protect biodiversity and ecosystem services has long been critiqued for failing to pay attention to justice and equity considerations [379–381]. Climate change adaptations and mitigation efforts without attention to social context can be maladaptations for local people [222,382,383]. International law and policy and the environmental justice literature alike underscore the need for recognition and participation of local people in environmental decision-making processes that impact their lives and well-being [4,15,384,385]. The Aarhus Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters [385] and the similar but more recent Escazú Agreement provide legal protection for the procedural rights (i.e., access to information, participation in decision-making, access to justice) of persons in more than 60 States in Europe, Asia, Africa, Latin America and the Caribbean [386]. Other countries have more general obligations to ensure public participation and access to information due to other human rights and environmental treaties.

Those who have been impacted by environmental injustices - e.g., in the form of pollution from oil, aquaculture, or coastal development activities - must also have access to justice through legitimate, independent, affordable, accessible and timely processes, and effective remedy mechanisms (***Ref).

Finally, local and place-based actions grounded in human rights are needed to mitigate community exposure, reduce vulnerability, and proactively adapt to environmental hazards and harms in the marine and coastal environment. For example, in the context of climate change this might include employing nature-based solutions **to prevent, and where not possible, to attenuate negative impacts on communities [387]** or building social adaptive capacity [226]. To reduce vulnerability of marginalized populations to disasters, it isnecessary to move beyond building local resilience to addressing the systemic issues and inequalities that make exposures and impacts worse for some populations, while also constraining their mitigation and response efforts [218,330,388]. Where ecosystem services have been undermined by past development, restoration activities might be used to rejuvenate harbors, estuaries, or shellfish beds to return ecological health and social benefits. At the very least, as has been highlighted in this paper, solutions to address environmental justice issues should not further marginalize local populations or produce additional negative social impacts [207,228,281,379]. To ensure this does not happen, attention is needed to both distributional considerations (e.g., social impacts, intersectionality) and procedural considerations (e.g., access to information, participation, respectful integration of local knowledge, transparency) with a view to co-designing solutions [15,16,384,389]. Adopting a human rights-based approach can contribute to addressing or at least not further entrenching environmental justice issues [6]. A deep engagement with different dimensions of environmental injustice and human rights can lead to te co-development of solutions with ocean-dependent communities, which has been identified as an essential precondition for the transformative change required to reverse current biodiversity loss and climate change [REF].

Finally, the literature highlights the role of local "ocean defenders" in responding to environmental injustices from development activities through a range of resistance activities (i.e., political advocacy, demonstrations, protests, communications campaigns, and legal battles) that challenge practices that endanger marine environments and threaten the human rights and well-being of coastal populations [20,390,391]. Countless examples from around the world show how local communities, small-scale fishers, Indigenous groups, women and youth have mobilized against aquaculture, oil and gas, industrial fisheries, seabed mining, coastal development, and pollution [20,392,393]. The rights of "ocean defenders" to safely gather, express their views, and peacefully protest to protect the marine and coastal environment from injustices must be safeguarded (***Ref).

3.5 Research gaps and future directions

Finally, we offer a few thoughts on research gaps and future directions. While there is a substantive body of biophysical research related to each of the environmental injustices covered in this review, there has been significantly less on the social and distributional impacts of these hazards and harms, and even less with an explicit environmental justice framing. Future research needs to build on the excellent and growing body of natural science research through bringing a more explicit environmental justice angle to research on ocean pollution, plastics, climate change, ecosystem service degradation, and fisheries declines. Similarly, environmental justice scholars need to pay more attention to the marine and coastal environment. Further exploration is needed into the specific social (e.g., health, food, economic, livelihood, social, cultural) and distributional (e.g., geographic, intersectional) impacts of all of the categories of environmental injustice in the ocean. In addition, other inter-linked dimensions of environmental justice than those covered in this article should be explored, namely epistemic justice, recognition, capabilities, as well as redistributive and restorative justice [REF].

We recommend a future systematic review of the state of the evidence on the societal impacts of each individual category of environmental injustice in the ocean to identify specific gluts and gaps in the evidence. Research on social impacts needs to be done at different scales (e.g., global, population and community level) which will necessitate diverse qualitative and quantitative approaches. Mapping of global case studies or spatial methods might be used to map and characterize the geographic distribution and social impacts of individual and cumulative hazards and harms in the marine and coastal environment [22,23,390,394]. With modern technologies and data, there is also the potential to develop and conduct more real-time monitoring and predictive modeling of environmental hazards - including levels of hazards, potential human exposures, related health impacts and outbreaks, and levels of uncertainty - which could enable early warning systems.

Future research on societal impacts should pay greater attention to social differentiation and intersectionality, including identification of the individual, social and systemic factors that lead to variation in exposures, social vulnerabilities, adaptive capacities and impacts among different groups (Ferguson, 2021; Lau & Scales, 2016; Mangubhai et al., 2021). Additional empirical studies are needed that characterize how different hazards and harms, as well as other social, economic, political and governance changes, converge, interact, and cumulatively impact local populations [259,344,345,352,353]. Further research is also needed that explores the global nature of many environmental injustices in the ocean, including understanding global drivers, flows among distant geographies, and cross-scalar interactions. A systematic review of interactions among the various injustices is recommended. There is a need for deeper examination of the root and proximal causes of environmental injustices - not just economic and physical drivers, but the underlying policy, political and normative ones as well. Such work will allow for the identification and analysis of possible viable and effective solutions, including specific actions that governments, corporate actors, and civil society can take to mitigate and address environmental injustices in the ocean. A more comprehensive exploration of solutions to address environmental justice issues in the ocean would be a useful contribution to the literature. Finally, there is a need to further document and typify local responses and resistances to environmental injustices in the ocean that are proactive, adaptive and reactive [20,390,391]. Through doing so, academics and practitioners can play an important role in supporting resistance efforts, and defending the culture, ways of life, and human rights of coastal populations.

4 Conclusion

Pollution, plastics, climate change, biodiversity loss, ecosystem service degradation, and fisheries declines are producing environmental injustices in the ocean, and threatening the world's ability to achieve the 2030 UN Sustainable Development Goals. These marine environmental justice issues are cumulatively and differentially impacting the well-being of coastal populations across geographies and axes of identity. It is projected that many of these issues will increase in the future. Rapid, systemic and transformative actions are thus urgently needed at all scales, of different types, and by all actors to address environmental justice in the ocean and fulfill the human rights of persons living in coastal communities. Yet, there are also substantial gaps in our knowledge about the social and distributional impacts of these issues across space and among groups. Filling some of these gaps in knowledge would enable us to better identify viable solutions and actions that might be taken by different actors at different scales. In conclusion, we argue for the mainstreaming of environmental justice in all realms of marine policy and practice - e.g., marine conservation, ocean-based development, ecosystem-based management and fisheries - including ensuring that attention is paid to both distributional and procedural considerations. Addressing environmental injustices in the ocean is critical to the livelihoods, health, culture, rights and well-being of global coastal populations now and in the future.

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