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Exploring cross-country externalities, viable resilience, and sustainability options for small-scale fishing communities in the tropics

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Introduction: Small-scale fishing communities are important for the development of emerging economies, sustaining livelihoods, and global food systems. However, the increasing human-environmental pressures are threatening the provision of these sustainability benefits. Unfortunately, limited research has been undertaken to comparatively explore the increasing vulnerabilities among fisherfolk and how sustainable transformations could be achieved.

Methods: A mixed methods approach involving participatory interactions with coastal fisherfolk and sourcing/analysis of data on ocean circulation patterns and sea surface temperature from 2000 to 2020 was utilized. Participatory interactions were conducted with 230 and 209 fisherfolk in India and Papua New Guinea, respectively, to understand the level of vulnerability and possible viable options that could foster coastal fisherfolk sustainability and sustainable development.

Results and discussion: Small-scale fisherfolk reported shared commonalities, especially in the fisheries systems, activities, and vulnerabilities. There is gender-specific specialization in fishing activities. Fishing is a job that embodies unique socio-cultural identities. Fisherfolk's identity is protected using century-long fishing methods. Most fisherfolk, especially in Papua New Guinea, predominantly possess low formal education and utilize semi-modern fish preservation techniques. Social-demographic vulnerabilities are increasing, such as the aging population. The declining fishing population leads to unsustainable livelihood futures. The burden of securing household livelihood often falls on a single individual. Increased vulnerability has increased the use of unsustainable fishing practices. Ocean circulation patterns are becoming extreme in all locations. Ocean temperatures have increased by 2 OC from 2000. From 2018-2020, the Indian Ocean Dipole increased to almost 1. Sea surface temperatures are increasing along the northwest fishing coast of India. Sea surface temperatures in northern fishing zones of Papua New Guinea are reducing. Additionally, increasing illegal and exploitative fishing by distant fleets was reported. Fisherfolk are experiencing a socioeconomic identity crisis. Hard and soft measures, including community-based fisheries rights and licensing of fishing operations, are reported, although with mixed results. This calls for collaborative governance mechanisms that are flexible and integrate the fisherfolk communities. Six sustainable leverage points are co-identified and co-created that can enhance sustainable marine fisheries transformations. The leverage points incorporate critical marine social science and fisheries science theoretical and conceptual perspectives and narratives. By incorporating the key components of the leverage points, the possibilities of aligning sustainable fisheries targets to regional and global blue transformation programs in Indian and Papua New Guinea could be initiated. In regions with small-scale fishing communities, findings revealed that although building resilience is complex, due to increasing human-environmental pressures in fishing zones, collaborative actions, including the recognition of the value of conventional fisherfolk, indigenous communities, and fisherwomen inclusion are critical. This helps in creating voluntary actions on sustainable fishing practices, governance, and management. To further drive social-natural science sustainability research in vulnerable tropical fishing regions, emphasis should be placed on conducting research that engages/captures the perspectives of the vulnerable fisherfolk.

KEYWORDS

small-scale fisheries, small-scale fisherfolk, ocean sustainability, sustainable development goals, sustainability leverage points, India, Papua New Guinea

1 Introduction

Small-scale fisherfolk (SSF) (commonly referred to as artisanal fishers) are key drivers of fisheries operations, mostly in emerging economies (FAO, 2021, 2024a). This implies that SSFs could drive sustainable global fisheries value chains, food systems, and livelihoods (FAO, 2021, 2024a,b; Simard, 2024; Tacon and Shumway, 2024). The contribution of SSFs (including fisherwomen empowerment) is well-documented in most coastal communities, notably among tropical fishing countries (Spalding et al., 2023; Matovu et al., 2024a). Depending on the country, SSF contribute 40 to 90 percent of the capture fisheries fish landings, notably in tropical fishing regions (de Juan et al., 2024; Nomura et al., 2022; FAO, 2024b). Critically, most of the micro-level fishing value chains are managed by fisherwomen (FAO, 2021, 2024a,b). This further highlights several sustainability benefits associated with SSF, emphasizing their role in reducing bycatch and discards, preserving socioecological knowledge, utilizing less exploitative fishing gear, and optimal fish harvesting (Lee et al., 2022; Mammel et al., 2022; Lee et al., 2023; Partelow et al., 2023; Spalding et al., 2023). These benefits align with the blue economy (BE) targets and are critical to the balancing of threatened socioecological systems (Villasante et al., 2022; Matovu et al., 2024,b).

Unfortunately, in most jurisdictions and policy discourses, the contribution of SSF toward sustainability and sustainable livelihoods is undervalued (Spalding et al., 2023; FAO, 2024b). Part of this is due to the conceptual disregard for the nested interactions in socioecological systems and the interdependent nature of SSF (including shared vulnerabilities, histories, visions, and socioecological grief), in most coastal zones, across geographies (Villasante et al., 2022; Partelow et al., 2023; Lee et al., 2023; Nomura et al., 2024; Matovu et al., 2024a). To effectively and collaboratively manage and govern the declining and vulnerable fisheries resources, it is essential to explore the complex interactions within micro-level coastal systems, the intricate dynamics at play, and the narratives of small-scale fisheries that can enhance resilience or shed light on vulnerabilities (Dias et al., 2023). This can concurrently help identify the situational proximate and distal indicators or drivers of vulnerability, how SSF and socioecological systems are embedded, and what narratives of positive transformative change are needed to holistically respond to current vulnerabilities to build sustainable futures (Matovu, 2024; Wang et al., 2024; Li et al., 2024; Harding et al., 2022; Fabinyi et al., 2022).

In this paper, we analyzed two case studies of India and Papua New Guinea (PNG) to gain an in-depth understanding of the spatial and temporal dynamics of the SSF landscape. This study focuses on (i) understanding the situational indicators of SSFs' livelihoods and their vulnerabilities; (ii) obtaining micro-level narratives and perspectives of SSF on how to build viable resilience options, co-create ocean sustainability measures/actions; and (iii) mapping sustainable development targets that are aligned with coastal communities' narratives of transformation and resilience. The perspectives targeted in this study have been highlighted in several socio-ecological systems studies and transdisciplinary (TD) research approaches (Nomura et al., 2022; Fabinyi et al., 2022; Dias et al., 2023; Matovu et al., 2024a). TD research approaches have been envisioned as key in understanding complex socio-ecological shifts and drivers, documenting anthropogenic-environmental system vulnerabilities, and charting ocean sustainability interventions (Karantoni et al., 2023; Croft et al., 2024). Using this emerging discourse in marine social science research, possibilities for identifying micro-level complex impediments to equity, social justice, and access to commons are possible (Matovu et al., 2024a; Croft et al., 2024). The co-generation of ideas from the perspectives of micro-level communities, as used in this study, further contributes to the co-ideation of transformative narratives on the viable options needed to drive sustainable livelihoods and ecosystem co-management (WorldFish, 2023). This can help in creating socioecological safety nets as SSF in the tropics brace for unsustainable socioecological shifts (Nayak, 2017; Dias et al., 2023). The main aims of this paper are to:

- Gain a comparative understanding of the situational indicators of SSF socioecological systems (i.e., demographic shifts/indicators, nature of the fishery, and fisheries characteristics) between India and PNG.
- Explore the perspectives of SSF on the viable practices and principles (modern or indigenous) and their ramifications toward sustainable fisheries.
- Document the comparative human-environmental drivers of vulnerability among SSF and coastal fishing zones in India and PNG.
- Co-create and co-design multi-country leverage points that could drive sustainable futures based on the narratives and perspectives of vulnerable SSF in tropical fishing zones.

2 Methods and materials utilized

2.1 Case studies

Case studies of SSF in India and PNG were utilized to understand coastal fisheries vulnerabilities and generate sustainability narratives to drive sustainable development, co-management, and co-governance (Figure 1).

2.1.1 Overview of small-scale fisheries in PNG

PNG is in the Pacific Ocean (See Figure 1) and is the largest and most populous member of the Pacific Island Countries (PIC; 3.1 million square kilometers of ocean jurisdiction) (Havice and Reed, 2012; Smith, 2013; Simard, 2024). PNG is endowed with unique and abundant marine fisheries resources (including sovereign rights over valuable tuna fisheries) (Havice and Reed, 2012). Over 85 percent of rural and 30 percent of the coastal communities have directly or indirectly engaged in fishing or fish-related activities for their livelihoods (Smith, 2013; Simard, 2024). To alleviate the worsening demographic indicators (including malnutrition and poverty), small-scale fishing has been envisioned as a critical component of the Food Security Program of PNG, Roadmap for Coastal Fisheries and Marine Aquaculture, and the Fisheries Strategic Plan 2021–2030 (Smith, 2013; Simard, 2024).

2.1.2 Overview of small-scale fisheries in India

India has a long coastline covering 8,118 kilometers, and fishing (mostly small-scale) is one of the oldest occupations of coastal communities (Bapat and Kurian, 1981; Matovu et al., 2024,b). Fishing serves as a key aspect of social identity, with small-scale fisheries activities closely linked to water resources that encompass the sea, backwaters, coastal lagoons, estuaries, floodplains, and rivers (Nayak, 2017; Pradhan et al., 2023). According to the Central Marine Fisheries Research Institute (CMFRI), over 3,461 marine fishing villages with 1,457 marine fish landing sites are spread all over the coastal regions of India (http://www.cmfri.org.in). About 75 percent of the 28 million fisherfolk workforce is engaged in small-scale fishing (Jena and George, 2018). About 75 percent of India's fish consumption demand is satisfied by SSF (http://www.cmfri.org). Most SSF work along river basins (29,000 km); estuaries (300,000 hectares); floodplain wetlands (525,000 hectares); and reservoirs (3.15 million hectares) (Singh, 2020). User rights are complex due to a hierarchical and self-governance model; for instance, the access rights of SSF to the resources depend on the state fisheries law (Singh, 2020). Some states have given exclusive rights to individuals or cooperatives of fishermen communities, while other states still give the right to the highest bidders (Jena and George, 2018).

2.2 Data collection/sourcing procedure

A mixed-methods research approach that combined qualitative and quantitative data collection and analysis techniques within two related case studies was utilized (Kumar, 2018). According to Bhattacherjee (2012), mixed methods research enables the gaining of more nuanced data that comprehensively captures key research questions and yields robust findings on a given topic or study area (Bhattacherjee, 2012; Kumar, 2018; Matovu et al., 2024). In this study, the mixed methods utilized involved participatory field interactions (interviews) with coastal fisherfolk, and sourcing/analysis of data on ocean circulation patterns (e.g., sea surface temperature from 2000 to 2020) was utilized. This is explained below.

2.2.1 Field data collection

A phased process, that could be replicable in other coastal settings, was utilized to conduct field data collection among the coastal fisherfolk, as guided by previous studies in coastal fishing zones (Matovu et al., 2024,b,a). The entire process involved three steps, including (1) the research preparation stage, (2) the research action stage, and (3) the research dissemination stage (Kumar, 2018). In the preparation stage, the activities conducted included conceptualization of the idea by the author 1 institute to comparatively understand the state of small-scale fisheries, and reviewing literature on the state of small-scale fishing and fisherfolk in India and Papua New Guinea (PNG). India and PNG were selected because the project team had researchers who knew the targeted areas. This was followed by the development of field data collection tools, especially the questionnaire and interview guides, and the pre-testing of the questionnaire to be utilized during field data collection, utilizing the guidelines by Kumar (2018). The questionnaire had four parts, each focusing on understanding the SSF landscape in India and PNG (https://docs.google.com/document/d/1sIpTP6NYBHYBCpvt1fpzFpvJkYn62NAs/edit?usp=sharing&ouid=103348425065177968004&rtpof=true&sd=true). To capture comparative field data on the state of small-scale fishing and SSFs, that could be well-represented and reported in the findings, a Likert scale incorporated into the questionnaire (Bhattacherjee, 2012; Kumar, 2018) (see parts 2 and 4 in the questionnaire).

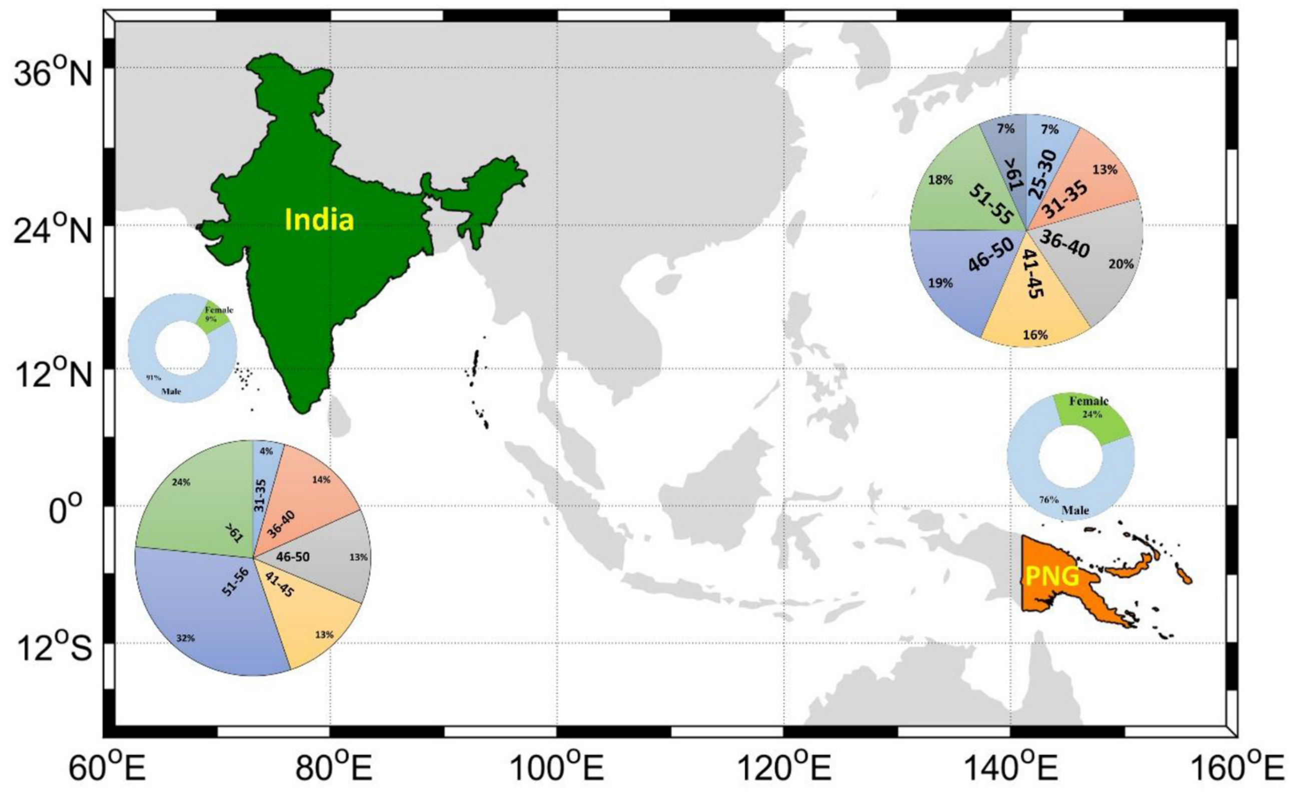

FIGURE 1
Geographical locations of India and PNG. The donut charts indicate the distribution of study participants (based on sex-female and male), and the pie charts indicate the age distribution of the sampled fisherfolk (Authors' creation).

The second phase involved actual field data collection. In India, field data were collected from *Kochi* in Kerala and *Digha* in Calcutta in West Bengal. Data collection in Kochi was conducted in October 2023, and in Digha, data was collected in September 2023. Before actual data collection in Kochi and Digha, a local contact was utilized in all locations to help interact with and identify the target sample population for interview/interaction. In Digha, through simple random sampling, 124 individual fisherfolk agreed to participate in face-to-face interviews. The interviews lasted for 4 days, and each interview was conducted at the fish stall or workplace of the interviewee. In Kochi, a research assistant from the Central Marine Research Fisheries Institute helped in planning and scheduling appointments with prospective fisherfolk for interviews. A total of 106 fisherfolk agreed to participate in the study, and the interviews/interactions lasted for 3 days. Most interviews lasted between 30–60 min, or until the data saturation point (where responses had become repetitive), as emphasized by Matovu et al. (2024a). Interviews were mainly organized during days when fisherfolk were free from work. The first interviews were conducted in the Fort Kochi area near the Cochin backwater, situated near the Chinese gillnet fisheries. Before conducting interviews, a transect walks along Fort Kochi area was conducted to acclimatize and obtain background information "know the fisheries and community resources or assets" (transect walks are a participatory field data collection technique where a researcher walks along a given area/section of the field to observe and capture critical field findings or observations). To obtain more qualitative data and avoid the collection of data from a single fisherfolk community or group, interviews were conducted with local fisherfolk in the Kannamali fishing community. Snowball sampling was employed among Kannamali fisherfolk (i.e., snowball sampling is done where interviewees direct a researcher to a given respondent(s) with factual or more in-depth knowledge on a given topic) (Neumann, 2014). Thus, the choice of Kannamali fisherfolk in this study was based on local qualitative reports that Kannamali fisherfolk have a long history of engagement in small-scale fishing activities. Thus, a total of 230 fisherfolk participated in interviews in the two sampled fishing communities in India.

Similarly, in PNG, a phased field data collection procedure was employed. First, ethical clearance was obtained from the National Capital District (NCD), the capital of PNG. This was followed by the conducting of initial purposive interviews with 1 key official involved in small-scale fisheries governance. Through the key informant from the NCD, there was mapping of the dominant SSF communities that could help capture critical data on small-scale fishing and fisherfolk livelihoods in PNG. With this, three different coastal provinces were purposively selected for conducting participant interviews with fisherfolk. These were: Central (southern region), Madang (Momase region), and East New Britain (Islands region). In the Southern region, interviews were conducted in Tubuseria fishing village and Koki main fish market. In Momase, engagements were conducted in Iduwan, Badup, and Nulairu fishing villages. In the Islands, fisherfolk in *Kabakaul*, *Vunamami*, and *Tokunar* fishing villages participated. A total of 209 fisherfolk participated in the interviews, and the interviews lasted for 2 weeks. Most interviews lasted between

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30–60 min, depending on the willingness of the interviewees to continue participating. During data collection, especially at Koki fish market, transect walks were conducted to randomly sample and interact with fisherfolk, and capture key assets or resources utilized by the fisherfolk in the community for their fishing operations. In some communities, e.g., Tubuseria, house-to-house interviews and interactions (based on the request by the interviewees) were conducted to obtain qualitative stories, perspectives, views, and ideas of fisherfolk. Some interviews were conducted along the beachfront. This was done in scenarios where fisherfolk (including fisherwomen) were returning from fishing expeditions or fish-related businesses.

2.2.2 Ocean circulation data sourcing

To explicitly understand the dynamics of the ocean circulation patterns in the context of coastal fishing zones in the Pacific (for PNG) and the Indian Ocean (for India), an analysis of ocean environmental parameter: sea surface temperatures (SST) in the Pacific and Indian Ocean regions, covering 2000–2020, was conducted. SST data from the years 2000 to 2020 were sourced from the Copernicus Marine Environment Monitoring Service (CMEMS; https://marine.copernicus.eu) via the Global Ocean Physics Reanalysis product (ID: GLOBAL_MULTIYEAR_PHY_001_030) to provide monthly composite SST fields with a spatial resolution of 0.083° × 0.083°. Through this, it is possible to understand the changes in ocean surface temperatures over time. To create a spatial resolution that can bring out clear visualizations and computations of remotely sensed ocean environmental data, monthly averages were computed using the MATLAB software package, ensuring consistency in spatial representation across the dataset. Additionally, a suite of climatic indices was inserted into the MATLAB software to capture large-scale oceanic and atmospheric interactions. The Indian Ocean Dipole (IOD) index was downloaded from the NOAA Physics Sciences Laboratory (https://psl.noaa.gov/gcos_wgsp/Timeseries/Data/dmi.had.long.data). Pacific Decadal Oscillation (PDO) data were obtained from the National Centers for Environmental Information (NCEI) (https://www.ncei.noaa.gov/pub/data/cmb/ersst/v5/index/ersst.v5.pdo.dat). To represent the El Niño-Southern Oscillation (ENSO), data from the Multivariate ENSO Index (MEI) were sourced from NOAA's Physical Sciences Laboratory (https://www.psl.noaa.gov/enso/mei/data/meiv2.data). Furthermore, the Oceanic Niño Index (ONI) was accessed from the NOAA database (https://psl.noaa.gov/data/correlation/oni.data), and the Southern Oscillation Index (SOI) was downloaded from the same NOAA platform (https://psl.noaa.gov/data/correlation/soi.data). This data was sourced to (i) relate field data findings on SSF environmental vulnerabilities with the local knowledge, and (ii) contribute to scholarship by visualizing the most vulnerable areas affected by the changing ocean circulation patterns in India and PNG.

2.3 Data analysis procedure

2.3.1 Field data

A step-by-step criterion for systematically analyzing, interpreting, and reporting field data was utilized (Neumann, 2014; Matovu et al., 2024a). First, the collected data was translated from the respective state or regional languages (i.e., *Malayalam* for the field data collected from fisherfolk in Kochi, Kerala, *Bengali/Hindi* for the data from West Bengal, and *Pidgin* for PNG) to English. Second, the data from the different questionnaires was entered into separate Microsoft Word Excel sheets (India: https://docs.google.com/spreadsheets/d/1v_SoVQOwGF2CGQm4fVM0ysAlCT_jXsQt/edit?usp=sharing&ouid=103348425065177968004&rtpof=true&sd=true and PNG: https://docs.google.com/spreadsheets/d/1rmKY4lZ_q8kM-24UmcHhyiN18j3BVcAg/edit?usp=sharing&ouid=103348425065177968004&rtpof=true&sd=true). In each Excel sheet, the responses were coded with numbers that aligned with the responses in the questionnaire. According to Kumar (2018), the coding of responses from the study participants enables the interpretation, description, and reporting of the results in different formats. In this study, the coded responses were reported using tabulation, visualization (figures), and descriptive analysis. Tabulated data represented the frequency and percentage of given responses. Descriptive analyses were utilized to elaborate on the tabulated and visualized data.

2.3.2 Ocean circulation patterns

Ocean circulation data serve as critical indicators for the comprehension of atmospheric/environmental variability and vulnerabilities over swathes of ocean and coastal zones (Lee et al., 2022; Mammel et al., 2023). In this study, SST data were analyzed. The analysis focused on assessing the fluctuations in SST across the ocean and coastal regions of PNG and India, where SSF operates. To analyze the remotely sensed data, the MATLAB software package was used to plot the temperature indices over time. This allowed for the visual representation and trend analysis of SST over the years and across seasons. These are essential for understanding the influence of SST variability on marine resources (fish) and coastal communities. This further enabled a comprehensive assessment of the climatic forces driving SST variability and their broader implications for the regional marine environment and fisherfolk.

3 Results

3.1 Comparative demographic characteristics of the fisherfolk

Insightful demographic indicators are revealed in Table 1. First, in both locations, fishing activities are dominated by men (91 percent in India, 76 percent in PNG). Most fisherfolk are either illiterate or semi-literate (75 percent in PNG; 63 percent in India) and only have primary-level education. The fisherfolk population is aging and declining (69 percent in India and 44 percent in PNG are above 46 years of age). This is partly due to the increasing migration to urban centers for other livelihoods and low interest by youths in engaging in fishing. In India, for instance, 78 percent of respondents agreed that young people prefer emigrating to towns for other livelihoods, such as business and formal employment.

TABLE 1 Comparative demographic indicators of fisherfolk and fishery activities in India and Papua New Guinea (PNG) (source: field data).

Demographic indicator	India		Demographic indicator	PNG	
	Frequency	Percentage (%)		Frequency	(%)
Gender					
Male	210	91		159	76
Female	20	9		50	**24**
Level of education					
No formal education	7	3		1	1
Primary	144	63		157	75
High school (Vocational and secondary)	75	33		50	24
Above college (incl. undergraduate or graduate degree)	4	2		1	1
Age					
Below 30	0	0		16	8
31–45	72	31		102	49
46 and above	158	69		91	44
Monthly earnings (In USD)					
Less than 240	68	30		17	8
241–720	162	70		191	91
Above 721	0	0		1	1
Contribution to household livelihood					
Single	140	61		127	61
More than one	90	39		82	39
Ancestry					
Indian	223	97	Micronesian	28	13
Bangladeshi	5	2	Melanesian	161	77
Burmese	2	1	Polynesian	20	10
Dominant fishery type					
Fixed net	68	30		16	8
Gill net	87	38		4	2
Long line	75	32		0	0
Pole and Line	0	0		88	42
Others (i.e., Indigenous types)				101	48

A similar finding observed is the gender-specific specialization in fisheries activities. For instance, in Kochi, fishermen are the dominant primary fisherfolk who go fishing in the high seas. Fisherwomen mostly deal in secondary value chain activities, such as fish selling. Nevertheless, among some communities, such as in PNG, some coastal women are part and parcel of the primary value chain activities, such as harvesting of shells, and monitoring of the community's primary fishing sites, due to their knowledge in sustainable conservation. In Kochi, stories of fisherwomen's engagement in the harvesting of clams were reported. These are insightful findings that could determine the future of sustainable blue foods provision, community food security, nutrition, and the underlying complexity of the socioeconomic aspects of blue food production across value chains.

Of concern is the declining economic returns accrued from fishing. For instance, 81 percent of fisherfolk, especially in India, reported a decrease in the economic value (profits) (see: shared link of analyzed data on India). This might be unsustainable as household livelihood contributions are made by a single person, and yet 70 percent of fisherfolk earn between 241–720 USD per month. Ancestral links to fishing determine a fishery type, especially in PNG, where Indigenous communities, such as in Melanesia, were reported to have been using the pole and line method to catch fish for centuries. The predominance

FIGURE 2
Visual representation of the fishing gear and nets utilized by SSF in PNG (Source: Field photo captured in Vanamami fishing community). **(a)** represents a handmade conventional fishing trap soon to be launched into the sea, and **(b)** shows a wooden canoe, i.e., locally known as *dingies*, utilized by SSF to capture catch (mostly for subsistence consumption).

of conventional fishing gears was observed among fisherfolk, especially in PNG (Figure 2).

3.2 Comparative situational indicators of SSF socioecological systems

The situational indicators of the SSFs and fishing activities are highlighted in Figure 3.

Comparatively distinct indicators were reported. For instance, in India, 86 percent of SSFs were engaged in commercial fisheries. On the contrary, SSF in PNG are either indigenous or subsistence fishers, mainly extracting fish for household consumption. The increased engagement in commercial fishing activities by SSF in India was reported to be a result of the change in the type of fishing vessel and gear utilized in fishing. In India, 46 percent of the fisherfolk used gill nets as compared to 14 percent in PNG. Most SSF in PNG utilized simple gears, such as harvesting machines (15 percent), hook and line (23 percent), and cast net (31 percent). In PNG, small-scale fishers primarily rely on dinghies for harvesting their catch, accounting for 64 percent of their activities, while canoes make up the remaining 36 percent. On the contrary, Fiberglass (40 percent) and decked vessels (32 percent) were utilized in India. The comparative divide in the type of fishing is evident in the tonnage of the vessels. Sixty-three percent of SSFs in India have shifted to outboard engine boats or vessels that have a tonnage of 20–50 tons and above 50 tons, respectively.

Two dominant ecosystems were utilized in small-scale fishing activities: marine and brackish. In India, 91 percent of SSFs in India extract the catch from the marine ecosystem zones, as compared to 52 percent in PNG. SSFs in PNG comparatively operate around brackish ecosystems (48 percent), as compared to 9 percent in India. To further extract fish, 39 percent of SSF in India have ventured into the deep/open seas. In PNG, 100 percent of the SSFs operate in nearshore coastal zones (i.e., beach, inland coast, estuary, and lagoon). From the participant's field observations in both locations, the variation in the fish catch is primarily influenced by the type of gear and vessel employed by SSF.

Regarding post-harvest activities, most SSF were engaged in the following four main categories: low-tech processing (such as fish sun drying, smoking, and cooking), marketing/trading, transportation, and medium-tech value addition. The dominant post-harvest activity was marketing (77 percent in India and 69 percent in PNG). A comparatively higher proportion of SSFs in PNG (31 percent) than in India (9 percent) use low-tech

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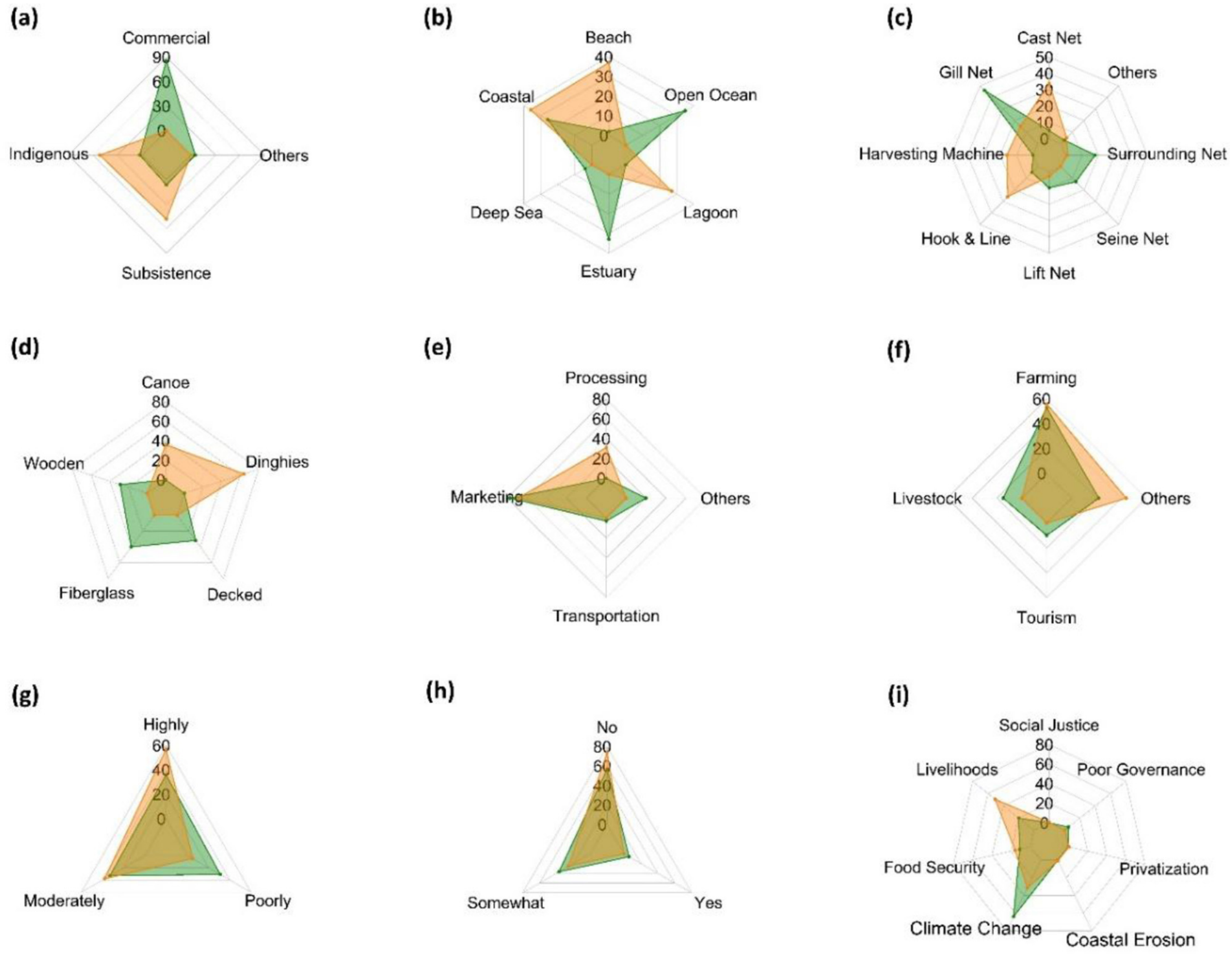

FIGURE 3
A comprehensive comparison of coastal SSF between India (represented in green) and PNG (represented in orange) across several key dimensions (Source: Field data). The categories in Figure 3 represent: **(a)** comparative types and classification of small-scale fisherfolk (SSF); **(b)** ecosystem where the SSF operate; **(c)** different fishing gear utilized by SSF; **(d)** vessel types employed in fishing operations; **(e)** nature of post-harvest activities; **(f)** alternative livelihood activities; **(g)** community perceptions on the value of SSF and fishing; **(h)** perception of SSF as an occupation; and **(i)** major governance concerns among SSF.

processing activities. Eleven percent of SSFs in India were getting involved in medium-tech harvested fish value addition practices, such as packaging. This has been mainly done through micro-level fisherfolk cooperatives, such as in Kochi.

To boost the economic situation and livelihoods, SSFs have ventured into alternative livelihoods. The following four dominant alternative livelihoods were reported: farming, animal husbandry, small trade and business, and tourism-related jobs. The dominant alternative livelihood is farming in both case studies (India: 53 percent and PNG: 56 percent). Forty-four percent and 22 percent in PNG and India, respectively, have ventured into small businesses (mostly fisherwomen). In India, 10 and 15 percent of fisherfolk have shifted to tourism-related jobs and animal husbandry, respectively.

Different governance mechanisms were reported in PNG and India. In India, fisherfolk reported that the emphasis has been on setting up or enforcing hard-law governance mechanisms, such as licensing of vessels and use of permits. (un)Surprisingly, in PNG, fisherfolk prefer the use of governance mechanisms that spur community-based rights for SSFs. Accordingly, 100 percent of SSF in India and 66 percent in PNG concurred that by streamlining governance mechanisms, access rights (for fishermen and fisherwomen) to fishing zones and fishing sites could be enhanced.

SSF reported increasing human threats, such as overfishing (India: 81 percent, PNG: 52 percent), increased cross-country illegal fishing (India: 69 percent, PNG: 20 percent), declining marine fish resources (India: 80 percent, PNG: 29 percent), and thus, two critical governance mechanisms were recommended. Seventy-two percent of fisherfolk in India argued that functioning governance mechanisms require marine zoning using marine protected areas (MPAs). In PNG, 49 percent of fisherfolk recommended the creation of unique community-managed MPAs and fish zones. Second, prohibitive regulations, especially for commercial fleets, should be set up in critically endangered and over-exploited fishing zones (India: 81 percent, PNG: 40 percent).

3.3 Comparative vulnerability drivers among SSF

During the interactions and interviews with fisherfolk, complex anthropogenic-environmental drivers of vulnerability were reported. Ten narratives of vulnerability were revealed by the fisherfolk in India and PNG (Table 2). A dominant and comparatively higher vulnerability narrative is related to climate and ocean environment changes. For instance, in PNG, 94 percent of fisherfolk reported acute climate change (CC) complexities and worsening ocean environment conditions, such as sea waves.

Accordingly, SSF reported increasing vulnerabilities. For instance, during participant interviews in Tokunar Fishing Village in PNG, it was reported that for the last few years, the sea has been changing. The changes reported included sea waves, declining fish, and changes in the ocean waters (a sign of either marine pollution or eutrophication). Additionally, an account of the causal drivers of the increasing vulnerability of SSF was reported (Figure 4). Generally, eight dominant vulnerability drivers were reported. Most of the drivers are environmental vulnerabilities, especially climate change-induced ocean changes. The causes of SSF vulnerabilities are more pronounced among SSF in India. For instance, 81 study participants in India reported overfishing, as compared to 52 in PNG. Nevertheless, changing and worsening ocean environmental/CC indicators are creating uncertain futures for SSF. For instance, in all regions, SSF reported that since CC indicators have become prevalent, fish stocks and catch have declined (India: 88 percent, PNG: 35 percent).

To situate the dimensions of environmental vulnerabilities and their causation, an analysis of the SST, SST trends, and ocean circulation patterns in the Indian and Pacific oceans was conducted. As represented in Figure 5, the SST of the marine fishing zones in India and PNG has increased from 2000 to 2020. Across India's and PNG's waters, the average increase in SST from 2000 to 2020 is 2°C. The seasonal and monthly variations in SST over the same period have been worse (Appendices 1–6). For instance, in southern India, from 2000 to 2020, the monthly mean SST is observed at 26 to 32°C (Appendix 1). The increasing temperatures could affect fish abundance and SSF in the south Indian states of Kerala and Tamil Nadu. In PNG, warmer/hotter SSTs are shifting toward the eastern coastal zones, representing additional vulnerabilities to SSF sedentary along the eastern coast (See Appendix 6).

As the SSTs are changing sporadically in all regions, understanding their correlation becomes critical. Hence, a trendline of SST for India and PNG has been visualized (Figure 6). A critical revelation from the SST trend reveals that different coastal regions in India and PNG have/are experiencing variations in SST. Most of the coastal regions, especially in West Bengal, northwestern and southern India, have experienced increased SST for the last two decades. In PNG, relatively low ocean temperatures are observed in the Pacific high seas. However, coastal regions (where most fisherfolk operate), such as the southern and eastern parts of PNG, reveal hot SST.

Additionally, ocean circulation patterns are attaining more extreme values in all locations (Figure 7). For instance, from 2018–2020, the IOD almost scaled up to 1. For instance, the observed ENSO-related indices are critically worrying indicators that might influence or impact fish biodiversity interactions (Mammel et al., 2023). As reported by SSF, for the last decade, migratory and sedentary species have no longer been seen. This perspective partly reveals the negative ramifications of climate variability and changing ocean circulation patterns on fisherfolk's livelihoods in all regions.

3.4 Vulnerability mitigation and resilience strategies among SSF

Recognizing the fragility of small-scale fisheries and SSF livelihoods, several mitigation measures were reported. In India, especially in Kochi, respondents reported that the prominent measure is the issuance of fishing licenses or permits (230 responses). In PNG, the dominant measure is community-based rights (209 responses). Community-based rights have involved community leadership in fisheries value chains, emphasis on the utilization of locally made fishing gears and traps, and utilization of community/fisherfolk knowledge in identifying nearshore areas with the most fish sightings (Figure 8).

Additionally, fisherfolk agreed that institutional mechanisms for sustainable fishing are needed. For instance, in India, 43 percent of the respondents reported that if the government sets up marine protected areas (MPAs), most governance policies on sustainable fishing in nearshore areas will be achieved. Additionally, 49 percent of the respondents in India revealed that, with the increasing marine natural resource contestation and cross-border illegal fishing activities, the formulation of prohibitive regulations in fishing areas operated by SSF is critical. This can limit overfishing caused by commercial fishing fleets. To sustain regulatory mechanisms and enhance community engagement in fisheries resource management, 74 percent of participants in PNG recommended that this should be done by engaging fisherfolk households or their families in setting up guidelines on who to license, when, where, how, and at what cost. It was argued that if SSF can secure operational licenses at reasonable fees, illegal and destructive fishing practices might be minimized. In other words, fisherfolk recognize the need for soft and hard laws in promoting fisherfolk resilience and adaptation to the increasing vulnerabilities in the fishing zones. Additionally, as SSF reported the existence of possible alternative livelihoods, such as small-scale fish processing and the making of nature-based products, such as handmade fish traps, this could be explored as a socioeconomic empowerment prospect.

4 Discussion

This study revealed critical, nuanced, and surprisingly interlinked dynamics of the marine fisheries and SSF landscapes. From the ethnographic and sociological perspective, fisheries are not only a job, but rather, it is a familial and community identity that has been passed onto generations, as highlighted in previous studies (Nayak, 2017; Grant et al., 2021; Matovu et al., 2024a). Most fisherfolk revealed that engagement in fishing has been around for over 100 years. Most often, the social identity

TABLE 2 Comparative summary of key vulnerability indicators among small-scale fisherfolk (SSF) (source: field data).

Vulnerability driver/narrative	India		PNG	
	Frequency of responses	(%)	Frequency of responses	(%)
Declining ecosystem health	200	87	198	95
Social injustice	184	80	121	58
Livelihood insecurity	186	81	166	79
Food insecurity	126	55	133	64
Complex and competitive markets	150	65	190	91
Climate/ocean environment changes	205	89	197	94
Ocean and coastal pollution, erosion	200	87	80	38
Ocean grabbing and privatization	167	73	145	69
Mal-governance	189	82	125	60
Stakeholder conflicts	190	83	150	72

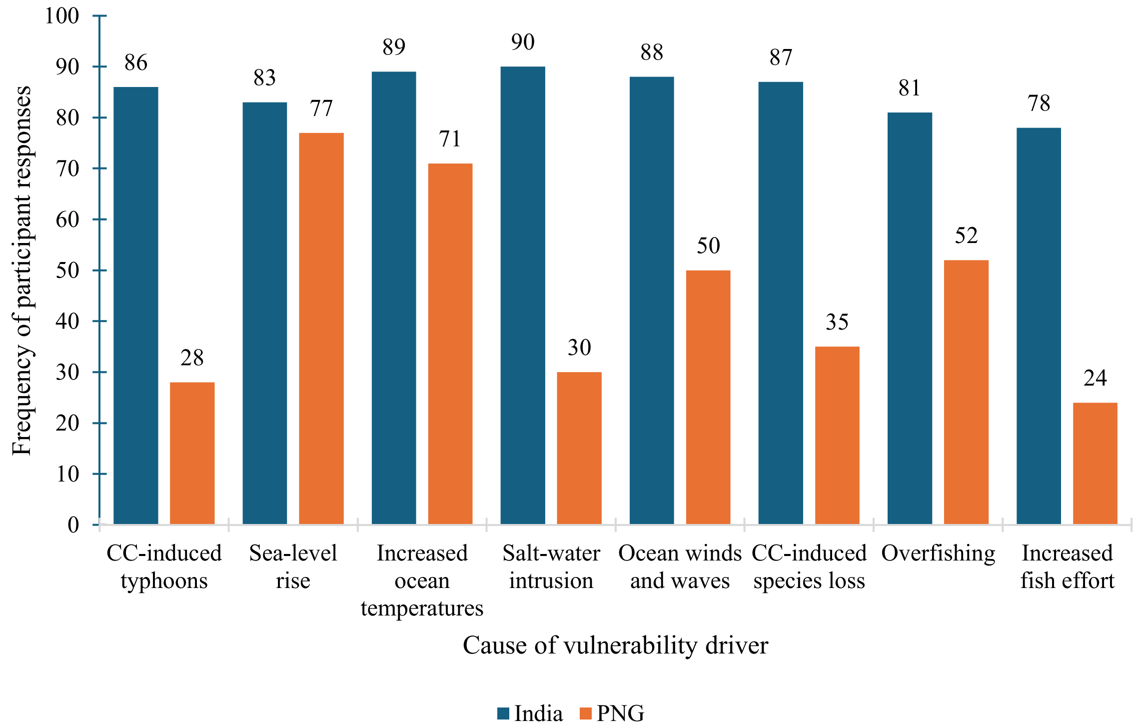

FIGURE 4
Breakdown of the drivers of the increasing vulnerability of SSF in India and PNG (source: field data).

of a community/individuals as fishers is viewed with pride. For instance, in PNG, the fisherfolk and community have high esteem for fishing as a profession. Thus, fishing is not a last-resort livelihood activity among SSF. Rather, it is a way of life mode of social belonging, and an ecological identity.

Several studies in Asia, India, and PNG have succinctly revealed the value of fish, and fishing as a community common, shared resource, and socioeconomic identity, that needs to be urgently safeguarded (Adams, 2012; Nayak, 2017; Diedrich et al., 2019; Fabinyi et al., 2022; Dias et al., 2023). The social identity perspective of fishing/SSF has created robust social capital safeguards, including trans-generational deciphering of sustainable fisheries knowledge (Diedrich et al., 2019). For instance, among the Melanesian Indigenous communities in PNG, critical socio-cultural knowledge has promoted the use of dingies, hand-rowed canoes, and indigenous fishing methods, such as poles and lines, to safeguard the fishery and community pride (Adams, 2012; Grant et al., 2021). Unique fisherfolk identities have been further reported in studies around Chilika Lagoon and West Bengal in India (Nayak, 2017; Pradhan et al., 2022, 2023; Nair and Nayak, 2023).

In the context of blue food sustainability, key insights concerning inclusion in the value chain activities and food

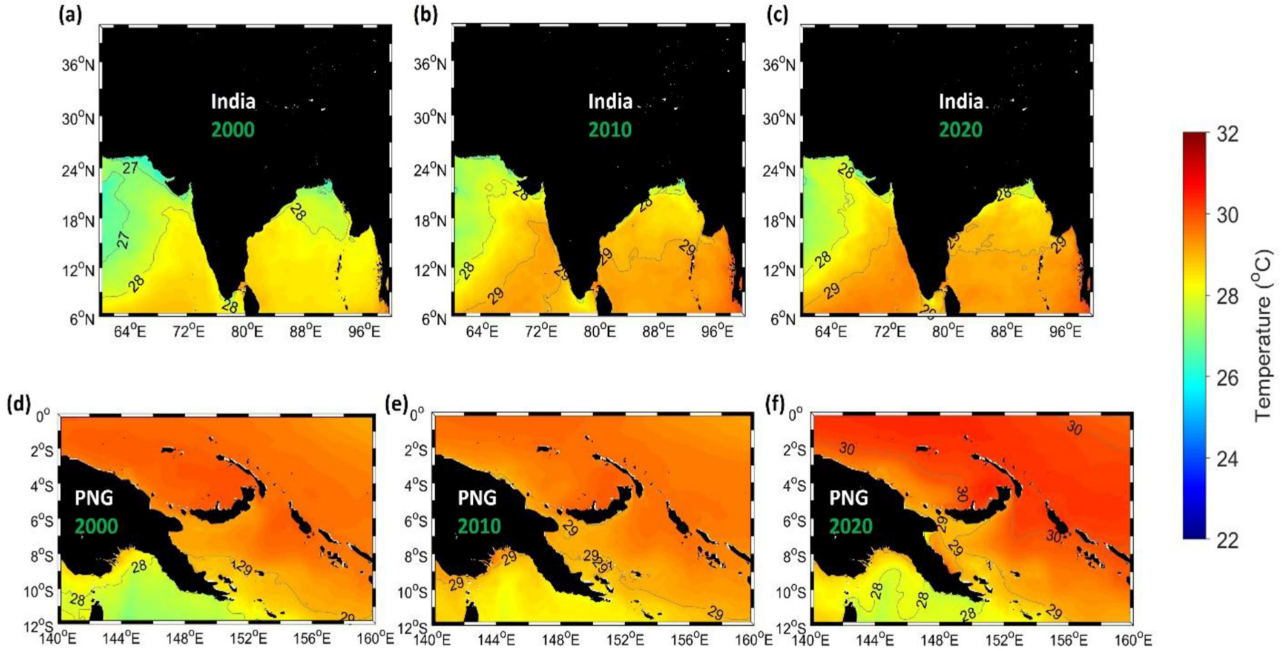

FIGURE 5
Inter-decadal changes in the SST around the marine fishing zones of India and PNG: **(a)** 2000, **(b)** 2010, **(c)** 2020, for India and **(d)** 2000, **(e)** 2010, **(f)** 2020, for PNG, respectively.

security were reported. As women are drivers of fisheries value chains, it is plausible that sustainable blue food transformations will only be successful through fisherwomen's empowerment. This is because women have untapped knowledge on fisheries conservation, governance, and sustaining value chain activities. The insights have been reported in several studies in the tropical regions, especially in Kerala, India (Pradhan et al., 2022; Matovu et al., 2024c). However, the success of the possibilities of creating transformative cultures in blue foods provision will depend on how well coastal fisherfolk remain attached to their vocation. In the current state, worrisome demographic trends in India and PNG are likely to compromise these benefits and women's ability in SSF, as the fisherfolk population is graying and declining. The decline has been partly due to the following factors: (i) emigration by youths, (ii) preference for alternative livelihoods by fisherwomen, and (iii) increasing socio-ecological vulnerability of the fisherfolk and fish stocks. These concerns could scale up the vulnerability and collapse of SSF in the increasingly competitive fishing sector, thus posing bleak futures to blue food provision or the socioeconomic livelihood benefits of fisherfolk. The negative trade-offs of declining fisherfolk populations have been succinctly reported in Japan, where a 68 percent decline in the fisherfolk population in Japan from 1975–2018 led to a decline in household self-sufficiency from 113% in 1964 to 55% in 2017 (Teh et al., 2020). In the context of the current study, it unravels worrisome vulnerability indicators, and the SSF might be braced for tougher times unless sustainable livelihood measures are promoted (Spalding et al., 2023; Matovu et al., 2024c).

To navigate the challenging socioeconomic landscape, SSF, especially in India, are transitioning to commercial fishing practices, utilizing high-tonnage vessels, gill nets, and exploring alternative livelihoods. This shift, although it might increase their income in the short run, research and field narratives show a gloomy situation in the context of social livelihood welfare. Most often, socioecological systems, including artisanal fisherfolk, are increasingly exposed to uncharted vulnerabilities. For instance, fisherfolk are risking their lives by venturing into the open sea with less fit vessels, such as Fiber boats. The increasing commercialization of SSF activities has opened avenues for elite capture (by well-connected fisherfolk), inequalities, and injustices regarding access to fishing zones and markets (Nayak, 2017; Fabinyi et al., 2015). Furthermore, the profits accrued from the alternative livelihoods are insufficient to sustain the bulging fisherfolk household population. These concerns are emblematic of the micro-level system complexities and vulnerabilities among SSF (including industrial fisheries shifts) (Havice and Reed, 2012; Fabinyi et al., 2015; Matovu et al., 2024a; Simard, 2024). This perspective partly reveals that the provision of blue foods is becoming more complex, socio-ecologically expensive, and economically costly. This is worsened by the escalating trend of environmental vulnerability. Coastal India and PNG have experienced an increase in SST of 2^0C since 2000. This might compromise the catches and stocks harvested by SSF. This is because most SSF, as reported in PNG, operate in nearshore areas, such as estuaries. Yet, most of these areas are being decimated by CC-induced impacts, such as coastal flooding, typhoons, and saltwater intrusion, among others. The reported CC-induced vulnerabilities are synonymously reported in several

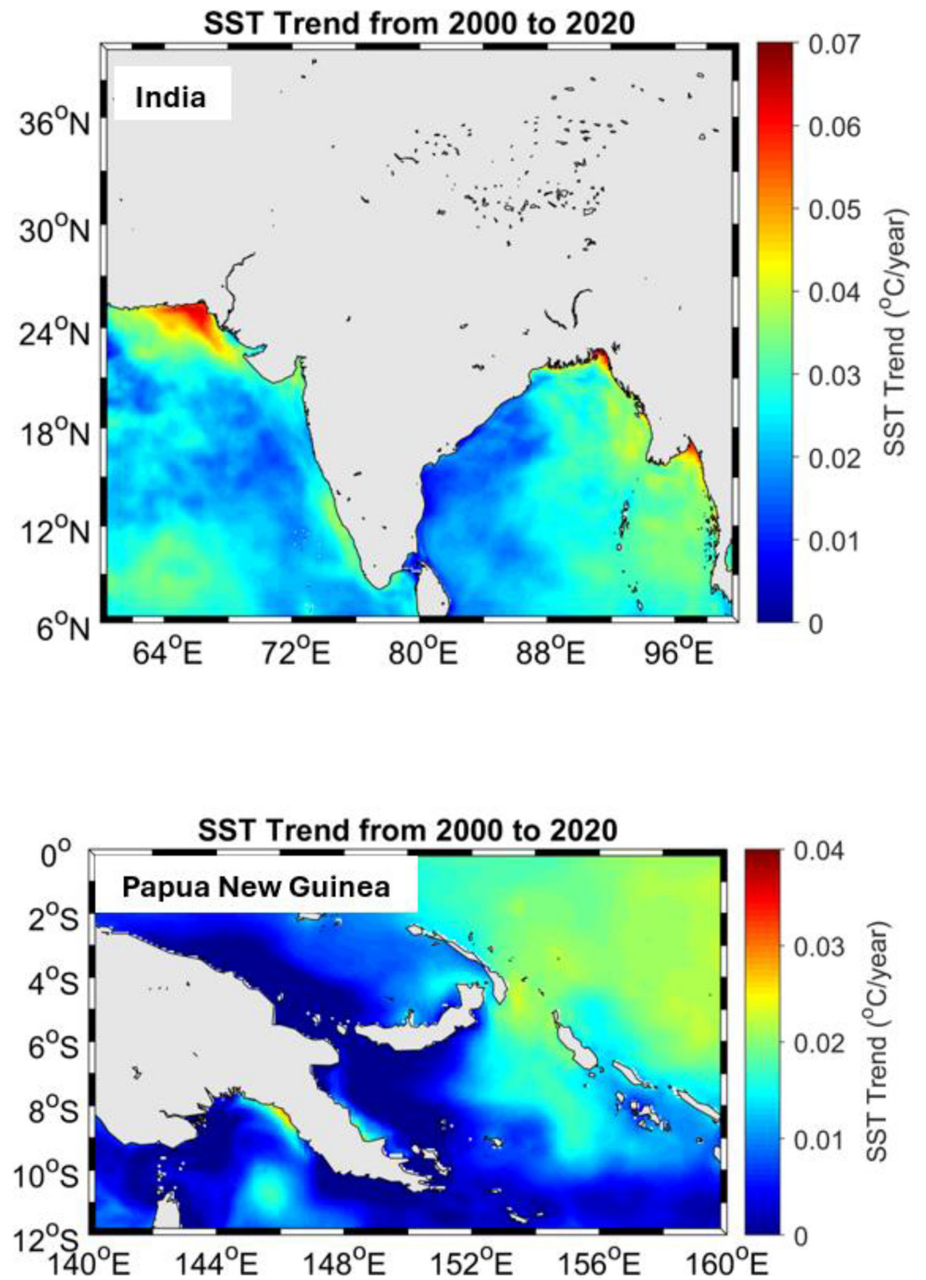

FIGURE 6
Sea surface temperature trend of India and Papua New Guinea from 2000 to 2020 (Source: Remotely sensed data from https://marine.copernicus.eu).

studies, such as in West Bengal in India (Pradhan et al., 2022, 2023) and in the Pacific region (Le Cornu et al., 2018; Lee et al., 2022). The increased prevalence of CC-induced vulnerabilities and negative ocean environmental indicators might scavenge pristine coastal fishing zones, and compromise ecosystem health and livelihoods of coastal communities in India and PNG. This concern has been reported in tropical regions where increasing climate variability for the last 20 years is affecting migratory and sedentary species in these two regions (Barclay et al., 2019; Dias et al., 2023). This narrative is supported by recent evidence that most SSFs have a limited comprehension of CC-driven changes and critical resilience options (Le Cornu et al., 2018; Pradhan et al., 2023; Matovu et al., 2024,b).

Additionally, although SSF in India and PNG demonstrated the need for collaborative governance mechanisms and support for micro-level governance options, such as community-managed MPAs, implementation mechanisms are still inadequate. Reflecting on this, there is evidence of limited knowledge, collaborative design of inclusive policy mechanisms, and implementation of

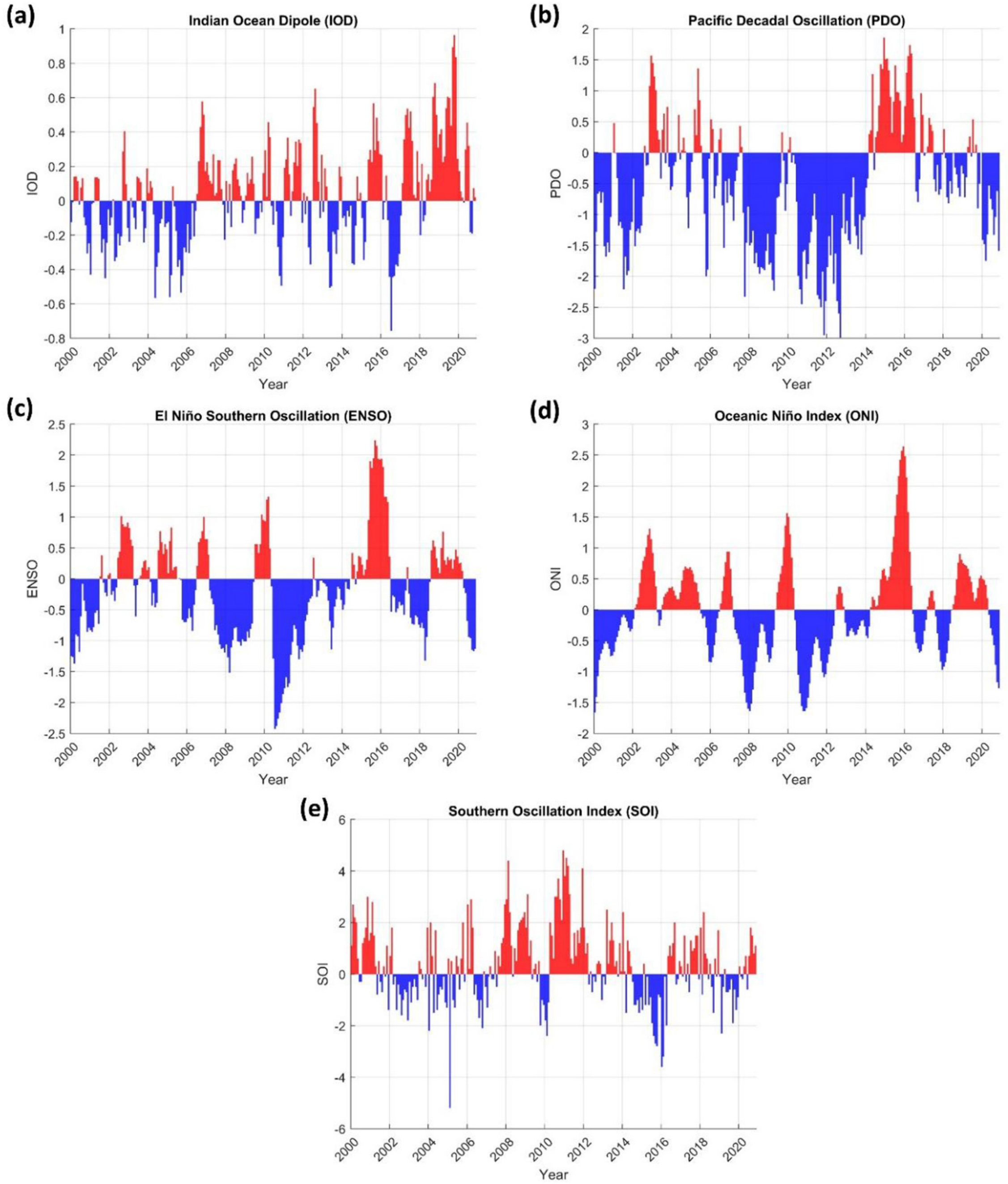

FIGURE 7
The annual trends of various climate indices over the Indian and Pacific Oceans from 2000–2020. The categories in figure represent the **(a)** Indian Ocean Dipole (IOD), **(b)** Pacific Decadal Oscillation (PDO), **(c)** El Niño-Southern Oscillation (ENSO), **(d)** Oceanic Niño Index (ONI), and **(e)** Southern Oscillation Index (SOI).

sustainable policy and regulatory mechanisms that could gravitate toward micro-level blue foods sustainability. Additionally, as reported in coastal zones of India, such as in West Bengal, strict institutional governance mechanisms might not be sustainable, as they are mostly restrictive and prohibitive governance mechanisms that curtail access to historically community-managed fishing zones (Pradhan et al., 2022, 2023; Kanyagui et al., 2024). This might compromise fisherfolk's livelihoods, lead to socioeconomic livelihood shifts, and increase competition for resources and resentment of institutional regulations (Kanyagui et al., 2024). Several studies have reported the mal-implementation gaps of most top-down governance mechanisms among SSF in India and PNG (Barratt and Allison, 2014; Valmonte-Santos et al., 2016; Barclay et al., 2019; Pradhan et al., 2022; Harding et al., 2022; Dias et al., 2023). The creation of resilient mechanisms and entry points that entrench SSF in blue foods sustainability amidst increasing shocks is an urgent necessity (Smith, 2013; Singh, 2020; FAO, 2021). This can help identify

FIGURE 8
Some of the prominent nature-based practices for sustainable fishing among coastal fishing communities in PNG (source: field photo). Photo **(a)** represents a community-managed fishing zone in Kabakaul fishing village in the East New Britain Province, Islands Region. Photo **(b)** indicates the sticks inserted in the nearshore to reveal the fishing grounds where the fish were most sighted in the Vunamami fishing area. Fisherfolk revealed that sustainability does not necessarily mean more earnings but focuses on managing key community assets for generations.

critical entry points for enhancing SSF resilience and promoting ocean sustainability.

5 Swimming toward sustainable narratives for SSF resilience, ocean sustainability, and sustainable development

Owing to the immense contribution of SSF to food security and livelihoods and their vulnerabilities, across regions, urgent resilient safeguards are needed (Valmonte-Santos et al., 2016; Harding et al., 2022; FAO, 2021, 2024a,b). To contribute to this (answers to *aim 4 of the study*), six key entry points to reverberate and aid sustainable SSF were co-ideated and co-developed (Figure 9). In this study, the co-created key entry points are called "*Sustainable Fisheries Leverage Points* (SFLP)" and are described in Section 5.1.

5.1 Viability of the SFLP in the domain of ocean sustainability and sustainability of SSF

The significance of the identified leverage points becomes clear when viewed through a critical lens within the context of emerging ocean sustainability narratives and the blue transformation roadmap (Partelow et al., 2023; FAO, 2024b) (Also see Figure 5). The emphasis on situational profiling of the state of SSF (*LP 1*), especially in vulnerable tropical regions, has been well-documented in recent studies (Spalding et al., 2023; Partelow et al., 2023; Matovu et al., 2024a,b). In data-limited tropical fishing zones, the benefits of situational profiling are two-fold. First, it gives an overview of the complex socio-ecological landscape that SSF operates in, and second, it helps in understanding the intrinsic and extrinsic micro-level interactions and feedback in the fisheries landscape (Nayak, 2017; Croft et al., 2024; Matovu et al., 2024b). In the global research and policy discourse, co-creating baseline inventories has been envisioned as critical in refining national action plans for SSF, notably on food rights (FAO, 2021). By twinning food rights to planning mechanisms, avenues for minimizing poverty (SDG 1) and food insecurity (SDG 2) are developed.

Under *LP 2*, a critical narrative identified is the value of datafication in fisheries to inform sustainable management or governance actions. The fact that just 16 percent of marine social science research is known is a serious concern in the field of marine sustainability research (Partelow et al., 2023). Given that the majority of tropical SSF are growing more fragile, this is quite concerning (Spalding et al., 2023; FAO, 2024a). Global fisheries studies have long noted the lack of evidence-based data, especially when it comes to the social dynamics of fishermen, particularly concerning fisherwomen (FAO, 2024b,a). Social inequality, unjust support system implementation, and improper livelihood safeguard implementation could result from this (Harding et al., 2022; Riechers et al., 2024). Studies carried out in the Pacific Coral Triangle have extensively shown the consequences of having little evidence-based data to develop resilience to shocks and sustainable transitions (Valmonte-Santos et al., 2016; Riechers et al., 2024). When properly explained, as in the case of PNG, datafication can assist in revealing the inherent knowledge and science of the populace on the conservation of fisheries and voluntary guidelines for the management of coastal resources (Le Cornu et al., 2018; Barclay et al., 2019; Simard, 2024). The identification of entry sites for support programs, such as those on fisherwomen's empowerment in fisheries value chains, is also aided by such data (Smith, 2013; FAO, 2024b).

The emphasis on strengthening community-based rights (*LP 3*) is a novel narrative, especially among micro-level SSFs. Under the FAO's blue transformation roadmap, securing fisheries rights has

• Leverage Point (LP)	• Small-scale fisherfolk narrative(s) co-created envisioned to drive sustainability and sustainable development
LP 1: Situational Profiling of the socioecological dynamics of a fishery system	• Baseline profiling of vulnerability concerns of SSFs based on their perspectives. Encompasses the creation of inventories for coastal fisher communities. Focus on identifiction of key demographic indicators, ecological indicators, and environmental threats. Intangible aspects (including indigenous knowledge and people's needs), socioecological pain points
• **LP 2: Datafication of the key drivers in the system, such as stakeholder, nature of activities, value chain dynamics**	• Qualitative and quantitative creation of data repositories. Here, the focus needed is on identifying the nature of interactions (human-ecological), mapping coastal ecosystems, key stakeholders and their interactions in a system, indicators of vulnerability/viability, economic and social benefit indicators, mapping of dominant threat factors/drivers
• **LP 3: Strengthening of micro-level fisherfolk community-based rights, and livelihood safeguards**	• Protection of social identities, visions, histories, and communities driving sustainable value chain practices. Minimising fishery practices that increase environmental harm. Allow for the regeneration of marine life and habitats, and adapt to climate change using local knowledge perspectives, and evidence-based fisheries science indicators. Community training and capacity building especially for youth, women, and local leaders.
• **LP 4:Transitional and transformative shifts towards nature-based fisheries and value-chain practices (at micro and national levels)**	• Professional recognition of the viable nature-based solutions and alternatives in a given fisherfolk community. Harnessing key local knowledge keepers and documenting success stories on the use of nature-based solutions. Green/blue financial/support schemes for sustainable fisheries. Regulatory safeguards on indigenous conservation practices.
• **LP 5: Incentivization of the transformative narratives, cultures, and communities fostering sustainable small-scale fisheries practices/value chains**	• Increased avenues for financial mechanisms, including international aid and incentives for climate change adaptation. Encouraging voluntary and non-monetary transformative practices, such as community-managed fishery zones, Resolving the economic and institutional concerns that influence fisheries, and fostering relationships to maximize benefits and avoid potential areas of conflict (e.g. with the no-take zones). Promote the sustainable growth of coastal fisheries, the most accessible resource, with the full participation of subsistence fishers. Providing subsistence fishers with technical assistance and other means of support to ensure and sustain traditional management and enable to cope with growing commercial pressure
• **LP 6: Enhancement of avenues for co-governance, co-management, co-design, and co-ideation of sustainability practices (in the short and long-run)**	• Promoting fair and transparent partnerships. Recognition of past injustices. Recognition and respect of diverse stakeholder perspectives, narratives and visions on sustainable fisheries. Simplifying the sustainability projects initiation and implementation process. Perspective change at all levels using different transdisciplinary approaches. Creation of platforms/mechanisms for holistic knowledge exchange and co-learning. Avioding of generalizability of vulnerability/viability. Transferability by learning from other success stories, change-agents, or case studies

FIGURE 9
Co-created leverage points (LP) to drive ocean sustainability and viable transitions among SSF (source: authors' development).

been emphasized (FAO, 2024b). However, how to do this has largely remained subjective, due to limited data or previous research on co-designing SSF narratives (Nomura et al., 2022; Spalding et al., 2023; Matovu et al., 2024a). Fisherfolk gave insights on how this could be done. In PNG, for instance, a community-based approach that cements the social identities, knowledge, and sustainability knowledge in historically utilized fishing zones was recommended. This can reduce social vulnerability and aid livelihood security (SDG 8) (Harding et al., 2022). In India, fisherfolk emphasized the use of both soft and hard management regulations, depending on the level of vulnerability. These insights are soundly situated in the global governance targets. For instance, the community rights approach is key to the SSF guidelines on sustainable SSF, the Territorial User Right for Fisheries (TURF), and the right to food (FAO, 2024b,a). By creating community-led management zones, avenues for the sustainable governance of locally managed marine zones (including local cultures/social capitals) are enhanced (Le Cornu et al., 2018; Riechers et al., 2024).

LP 4 crucially embeds a new dimension of ocean sustainability coiled around nature-based transitions in the fisheries value chain. These are critically important in the drive toward the blue transformation roadmap (FAO, 2024b). As SSFs already possess inter-generational knowledge of nature-based solutions, such as the use of pole nets and dingies, as an alternative to commercial fishing fleets or activities, sustainability transitions are possible (Harding et al., 2022; WorldFish, 2023; Dias et al., 2023). Depending on the targeted sustainability intervention, this can be done using different interventions/approaches. In India, mechanisms, such as the use of a socioecological perspective to understand the synergies and trade-offs of value chains, have been emphasized (Pradhan et al., 2022). This can be done through the mapping of commons, tangible and intangible capitals, and interactions of actors in the value chains (Nayak, 2017; Dias et al., 2023; Pradhan et al., 2023). Among Indigenous fisherfolk, such as in Melanesia, safety nets can include the use of transdisciplinary approaches, including citizens' science, knowledge co-creation, and safeguarding of zones/communities with critical nature-based sustainability knowledge (Harding et al., 2022; Riechers et al., 2024).

To increase collaborative efforts in driving SSF sustainability, incentivization of small-scale fisheries is critical (FAO, 2021, 2024a) (*Part of LP5*). Incentivization should be embedded in monetary and non-monetary inducements for sustainability shifts (Riechers et al., 2024; Spalding et al., 2023; Partelow et al., 2023). Monetary incentives can help identify and create funding opportunities for disempowered fisherfolk, particularly fisherwomen (Matovu et al., 2024a; FAO, 2024a). Unique and affirmative forms of compensation, such as carbon credit funding for fisherfolk driving toward climate change adaptation and sustainability measures, can be charted (Riechers et al., 2024). Non-monetary inducements, such as upholding and recognizing the rights of Indigenous communities, are being emphasized (Le Cornu et al., 2018; Harding et al., 2022). A study by Partelow et al. (2023) revealed that non-monetary incentives help in the creation of five key social intervention arenas for ocean sustainability. Some of the benefits of this include enshrining ethical dimensions in decision-making, collaborative voluntary co-governance, transformative shifts in human behavior, goals, and values (regarding unsustainable practices), impactful responses to vulnerability threats on fisherfolk, and co-production of transformative sustainability pathways hinged on transparent and inclusive transdisciplinary partnerships (Partelow et al., 2023; Spalding et al., 2023; Matovu et al., 2024a).

The role of the co-governance, co-design, co-management, and co-creation narrative in charting ocean sustainability and global sustainable development futures cannot be understated (*LP6*). Sustainable futures are hinged on co-design and co-management in both policy and scholarly research (Matovu, 2024; Croft et al., 2024; Riechers et al., 2024). Although divergent methods on how to do this, especially in the marine fisheries domain, are reported, the benchmark is that, through co-design, novel narratives for transitioning from vulnerability to viability among vulnerable fisherfolk have been evident (Dias et al., 2023; Pradhan et al., 2023). Studies by Matovu et al. (2024a), Nomura et al. (2022), and Breckwoldt et al. (2021) revealed four critical steps on how this could be done. Sustainable co-design requires (i) being immersed in the social fabric of the community (community live-in-labs) to create rapport with vulnerable communities, (ii) openness to all threads of community knowledge obtained or deciphered (including community networking to build trust), (iii) being accommodative, professional recognition, fair, and just to create a leveled ground for all stakeholders and (iv) ideating and implementing simple, but feasible interventions that respect the targeted community fabric.

These perspectives are emphasized, for instance, under SSF Right to Food Guideline 8 on "access to resources and assets," while building on the premises of Guidelines 2, 3, 9, 10, 11, and 13 (FAO, 2024b). Additionally, the co-governance and co-creation narrative is critical to the four marine fisheries and five fisheries value chain targets envisioned under the FAO's blue transformation roadmap (FAO, 2024b). The roadmap envisions leveraging sustainable fisheries and aquaculture technologies and practices and strengthening the value or role of SSF in blue foods provision, among others. Through this, a typology of sustainability benefits among SSFs could be realized. These are (i) the co-creation of effective fisheries management systems that address ecological, social, and economic objectives while considering trade-offs (ii) re-affirming the human rights-based approach among SSFs and the application of human rights principles as integral to the process of ensuring the progressive realization of the right to food in the context of national food security and (iii) collaborative identification and guidance for coastal communities/economies on the right to food over different policy arenas with an emphasis on participation, including access and sustainable management of natural resources or livelihood capitals (FAO, 2021, 2024a,b; Matovu et al., 2024a). Co-creation, as emphasized by the fisherfolk, correlates with the emerging sustainability perspectives on SSFs (Roberts et al., 2024; Matovu et al., 2024c). Future perspectives emphasize that fisheries must function according to principles that (i) limit trade-offs on marine life, (ii) adjust to climate change, (iii) permit the regeneration/recovery of diminished biodiversity, and (iv) support and improve the resilience, wellbeing, and general health of vulnerable coastal people and communities (Breckwoldt et al., 2021; Nomura et al., 2022; Spalding et al., 2023; Partelow et al., 2023; Roberts et al., 2024; Matovu et al., 2024a,c,b; Matovu, 2024).

6 Conclusion: key lessons and future directions for research and policy

Insights from the fisherfolk reveal that irrespective of the geography, SSF in the tropics seem to have shared commonalities, especially in the fisheries systems, activities, and vulnerabilities. First, among SSF, fishing is not just a job; it embodies a social identity. In PNG, this identity is protected using *dingies*, hand-rowed canoes, and century-long fishing methods, such as pole and line. Most fisherfolk are semi-literate and illiterate. The impact of this could partly explain the use of low-tech fish processing methods, such as in PNG. Fisheries employment is mainly dominated by males, but the masculine dominance is slightly changing among fisher communities, such as Melanesia in PNG. In Melanesia, fisherwomen are increasing, and this has created better sustainable livelihood security. Social-demographic vulnerabilities are increasing. Fisherfolk are decreasing and aging, especially in India. This is exacerbated by youth emigration or their preference for urban life and better-paying jobs. Declining fisherfolk labor force is leading to unsustainable livelihood futures, such as in food provisioning and encroachment of communal fishing grounds by external or commercial fishers. In many communities, like Digha, the burden of securing household livelihood often falls on a single individual. The high number of household family members and declining economic returns from fisherfolk are creating a vicious cycle of poverty.

To sustain their fragile livelihoods, SSF, such as those in India, have resorted to the use of commercial vessels with over 20 tons and gill nets. The increasing commercialization of SSF activities could ruin fish spawning grounds and fish availability, as fisherfolk mainly fish in nearshore areas. The declining fish stock and catches have made fisherfolk, such as those in India, risk their lives by venturing into the high seas. An increasing concern is the rise in illegal fishing activities, particularly cross-border and distant fishing vessels in PNG. Distant or illegal fishing fleets frequently employ exploitative and unsustainable methods, resulting in the decline of commercially valuable fish species. As fish catches decline, competition for natural resources has intensified as fisherfolk seek alternative livelihoods. The need for sustainable livelihood and household welfare security has created a socioeconomic identity crisis. This is because fisherfolk and fisher communities are resorting to alien jobs, where they have less experience, such as tourism and farming. To avoid the fisher community system and livelihood collapse, the urge for the co-creation of governance mechanisms is needed. In PNG, a community-based rights approach was emphasized. In India, fisherfolk argued that soft and hard laws (including zoning of pristine fishing sites and setting up of MPAs) could be key.

From a policy perspective, fisherfolk advocated for the co-creation of spatially explicit management approaches that foster adaptation to anthropogenic-environmental vulnerabilities.

To foster community acceptance and encourage voluntary participation, co-management can be leveraged, including community-based co-management and shared resource rights approaches. Co-management can be streamlined by integrating emerging indigenous/coastal fisherfolk community governance approaches (citizen science) with new marine governance mechanisms, such as MPAs and coastal zoning. This flexible and integrated approach can aid the creation of phased responses to coastal vulnerabilities over various time scales and longer time frames. Further benefits can include the intertwining of micro-level demographic shifts in real time with changing fisheries value chains or environmental variabilities. This will help to ensure a match between the multiple kinds of boundaries (i.e., social, ecological, economic, and institutional) in a continuous, adaptive, and collective way that considers the perpetually shifting and socially-ecologically linked nature of small-scale fisheries systems, blue foods sustainability requirements, and the complex climate change dynamics.

Although this study documents new insights concerning the plight of SSF in India and PNG, two limitations are revealed (i) the questionnaire was close-ended and this somehow conditioned fisherfolk to mostly give answers that captured the questions in the questionnaire, and (ii) a small sample population were utilized, which might limit the capturing of diverse fisherfolk perspectives. Further research that utilizes diverse participatory methods and narrative engagements can be conducted, with a larger or comparable sample population. This can complement the current study findings by bringing forward more ground-truth evidence-based stories, perspectives, and ideas on SSF vulnerabilities and adaptation strategies that are replicable in other tropical regions. By capturing social/qualitative data of fisherfolk, socioecological sustainability narratives, and best options for sustainable blue foods provision, which include marine farmed species, can be identified. These narratives can help align the leverage points co-developed with fisherfolk in this study to develop robust policy insights on SSF inclusion in fisheries and ocean socioecological management discourses. To further drive social-natural science sustainability research in vulnerable tropical regions, emphasis must be placed on (i) invigorating micro-level perspectives of different social groups of SSF and (ii) aligning them with evidence-based marine environment vulnerability indicators. This can help identify key entry points for co-creating resilience and profiling guidelines for sustainable SSF livelihoods across regions.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding authors.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the [patients/ participants OR patients/participants legal guardian/next of kin] was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

M-AL: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Software, Supervision, Validation, Writing – original draft, Writing – review & editing. MM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. BMa: Data curation, Formal analysis, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. LK: Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. BMo: Supervision, Validation, Writing – original draft, Writing – review & editing. IM: Formal analysis, Validation, Writing – original draft, Writing – review & editing. SM: Data curation, Writing – original draft, Writing – review & editing. MS: Formal analysis, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/focsu.2025.1541847/full#supplementary-material

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