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The contributions of coastal small-scale fisheries toward the sustainable development goals: a Kenyan Case Study

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Small-scale fisheries (SSFs) contribute significantly to the economies of coastal developing nations, offering employment and food, and supporting sustainable development goals (SDGs). Despite increasing focus on SSFs, data, and knowledge gaps persist in SSFs research and their contribution to SDGs. Ten fisheries were assessed in Kenya for their contributions to 12 SDGs, highlighting different levels of contributions. Small pelagic and shrimp fisheries display higher overall contributions to SDGs, appearing to perform strongly in more SDGs, while handline and octopus fisheries display lower contributions to SDGs. Specific contributions can vary depending on the characteristics of individual fisheries, such as their structures and markets. This study provides valuable insights from an under-represented part of the world on the under-researched topic of SSFs and SDGs. It also contributes significantly to research on sustainable development in developing coastal nations and highlights gaps and areas for improvement in achieving the SDGs within the context of SSFs.

Small-scale fisheries (SSFs), which mainly include artisanal, inshore, traditional, and subsistence fisheries, contribute to the economies of coastal countries, supporting livelihoods, especially in the least developed countries[1]. SSFs offer key solutions to development issues and are pivotal for hunger and poverty reduction[2,3]. They promote economic growth through employment and trade[4]. In addition, they provide affordable and nutritious food for communities[5]. SSFs provide societal benefits and support local cultures[6].

Fishing is a major source of livelihood for communities along the Kenyan coast. The sector supports small-scale fishers, traders, and processors, including women, who play a key role in the value chain of landed fish and fishery products[7]. Kenya's SSFs are characterized by traditional fishing practices using small boats (i.e., fishing close to shore) or no boats (i.e., foot fishers)[7,8]. Kenya's coastal and marine SSFs generate approximately USD 7.95 million per year[9] and produce 80% of the 24,000 Mt total annual coastal and marine landings[7]. Over 14,000 fishers are involved, using 3,174 small-scale fishing vessels operating from 213 landing sites[10]. The sector provides income and animal protein for up to 80% of rural coastal households[11].

Most small-scale fishing activities occur in the inshore waters and lagoons characterized by coral reefs, mangrove creeks, and seagrass beds[12]. Fishing is concentrated in these nearshore areas. Catches fluctuate significantly between months, with the highest catches each year occurring between January and March during the northeast monsoon season[13–15]. Total monthly catches range from 1200 to 3400 Mt, with an average catch of 2000 Mt per month[14].

Suitable and salient information on SSFs is considered key for the sustainability of these fisheries[16]. However, information about SSFs remains scarce due to their diversity and complex social-spatial structures within the fishery[17]. SSFs are mostly open-access, using diverse methods and vessels and targeting diverse coastal and marine resources[3]. These characteristics challenge an evaluation of these activities that could help inform policies, as is done for large-scale/industrial fisheries (LSFs). Consequently, there is a poor representation of SSFs in policies and implementing agencies, resulting in poor support for those fisheries[18].

The Sustainable Development Goals (SDGs) that were agreed upon in 2015 by United Nations member states were set to be achieved by 2030. Those 17 SDGs cover various areas of focus, such as human health, wealth and well-being, gender, equality, environment, and justice. The 17 SDGs set 169 targets that help track progress (or lack of) toward those goals. According to the sustainable development report of 2023, none of the goals and only around 18 percent of the SDG targets are on track to be achieved globally by 2030[19]. There are large variations in progress amongst regions and income groups. Most countries of the sub-Saharan region, including

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Table 1 | Status of Kenya's progress on SDGs implementation[19]

SDG/Status	Achieved	On track	Stagnating	Decreasing
1- No poverty			✓	
2 - Zero Hunger			✓	
3 - Good health & wellbeing			✓	
4 - Quality education		✓		
5 - Gender equality		✓		
6 - Clean water and sanitation			✓	
7- Affordable and clean energy		✓		
8 - Decent work & economic growth			✓	
9 - Industry, Innovation and Infrastructure		✓		
10 - Reduced inequalities		✓		
11 - Sustainable cities & Communities				✓
12 - Responsible Consumption & Production	✓			
13 - Climate action	✓			
14 - Life below water			✓	
15 - Life on land				✓
16 - Peace, justice & strong institutions			✓	
17 - Partnerships for the Goals			✓	

Kenya, have achieved or are on track to achieving SDG 12 (Responsible consumption and production) and SDG 13 (Climate action) but are stagnating or lagging in achieving the other SDGs. Kenya's performance on the SDGs places it 123 out of the 166 countries evaluated[19]. The report assesses each country's progress on individual SDGs using four categories: achieved, on track, stagnating, or decreasing. Table 1 summarizes Kenya's progress according to this ranking system.

SSFs are explicitly addressed by SDGs Target 14.b (Provide access of small-scale artisanal fishers to marine resources and markets) to account for global change in coastal and marine resources, technology, and fishery value chains, which have been jeopardizing the sustainability of SSFs around the world, threatening the livelihood of many coastal communities[20].

Coastal and marine SSFs practiced in many coastal communities worldwide could play a bigger role in achieving the UN SDGs than LSFs[4,21]. Evidence shows that SSFs contribute to food security (SDG 2), provide income (SDG 1), and employ more women (SDG 5) than other forms of fisheries[22]. In Kenya, SSFs have the potential to advance the achievement of these SDGs, some of which are currently stagnating (see Table 1; e.g., SDGs 1 and 2). Small-scale coastal and marine fisheries provide valuable food security and livelihoods for about 20 million coastal people living in eastern Africa[23]. Given this context, SSFs should be more present in SDG discussions. Unfortunately, SSFs are often wrongly considered a sustainability problem rather than an asset[24–26]. As we approach 2030, understanding the interactions between SSFs and environmental, social, and economic SDGs is crucial for recommending approaches for sustainable SSFs. The interactions may vary depending on fishery seasonal patterns, the socio-ecological context, and the spatio-temporal scale of the fishery.

Despite the growing global focus on SSFs and increasing data collection efforts (e.g., the Illuminating Hidden Harvest initiative[27]), large data and knowledge gaps persist in most countries[28,29]. These gaps hinder our understanding of SSFs' impact and potential. A critical challenge lies in improving information sharing and collaboration among diverse SSFs stakeholders, including fishers, non-governmental organizations, scientists, fisheries administration, and policymakers[5,30].

Scaling up locally collected data will be required to inform national policies and interventions, e.g., for a better understanding of the contribution of SSFs to sustainable development, including inherent trade-offs between SDGs[31,32]. The transdisciplinary research approach can provide a comprehensive outcome of SSFs in relation to SDGs[33,34], offering tools and methods to look at problems and inform policies through a more holistic lens[35]. Such an approach allows scientists, practitioners, fishers, and many other stakeholders to identify the problems and opportunities through an interactive and iterative process, helping align actors' perspectives across scales, from local management to national policy levels. To address the need for comprehensive data and analysis in SSFs, particularly in relation to their contribution to the SDGs, there is a clear need for a specialized assessment tool. Such a tool would not only help bridge the existing data gaps but also provide a standardized method for evaluating SSFs' impact on SDGs across different contexts and regions.

Building on this need, the Fish2Sustainability (F2S) project aimed to address these data gaps and evaluate the contributions of SSFs to the SDGs. A key feature of this research is its reliance on a novel methodological framework developed by Bitoun et al.[36]. This method provides a structured approach to assessing the multifaceted contributions of SSFs to the SDGs, allowing for a comprehensive and standardized evaluation across different contexts. The Kenyan case study focused on coastal and marine SSFs, encompassing a diverse range of SSFs which included estuarine catfish, basket trap, octopus, gillnet, lobster, handline, ring net, shrimp, sea cucumber, and small pelagic fisheries. These SSFs were selected based on their national representativeness, economic importance, location, and scale.

Multi-stakeholder and mixed methods were used to gather knowledge on SSFs to help fill data gaps and contribute to a more inclusive understanding of SSFs dynamics. As acquiring data on SSFs is challenging, expert knowledge and community engagement helped evaluate the linkage between SSFs and SDGs through a series of variables identified in the rapid appraisal framework (ref. 36, see "Methods"). The framework involved four steps. In the first step, a literature review was conducted to identify documented relationships between SSFs and SDGs. This resulted in the selection of 32 targets associated with 12 of the 17 SDGs. In the second step, 43 variables were defined to measure the 32 targets selected. The third step involved assessing SSFs through expert elicitation. The framework was applied at the scale of a fishery, defined as a unit based on gear or target species. The fourth step involved creating composite indicators to measure SDGs performance intervals and a global sustainability index. This process included a three-stage aggregation procedure: from variable to target, from target to SDGs, and from SDGs to a global sustainability index.

While this study is not the first attempt to assess the contribution of SSFs towards the SDGs—with notable previous efforts by Singh et al.[32,37], and Basurto et al.[4]—it represents a significant contribution to the field, particularly for Kenya and the broader sub-Saharan region. Indeed, this study provides valuable insights from an under-represented part of the world on the under-researched topic of SSFs and SDGs. Furthermore, this study contributes to research on sustainable development in developing coastal nations and highlights gaps and areas for improvement in achieving the SDGs within the context of SSFs.

Results

Change in variables across SSFs

A 5-point Likert scale, converted into numerical values (5 = most desirable; 1 = least desirable situation) for each variable, was used for scoring. Figure 1 presents the scores across the variables in the SSFs. Lobster, sea cucumber, shrimp, and small pelagic fisheries are high in many variables. Even though information for some variables was missing in the lobster fishery, variables with the most desirable situation were related to involvement, access to resources, markets, and income. For the sea cucumber fishery, scores were high for gear, involvement and access to resources and markets, and income.

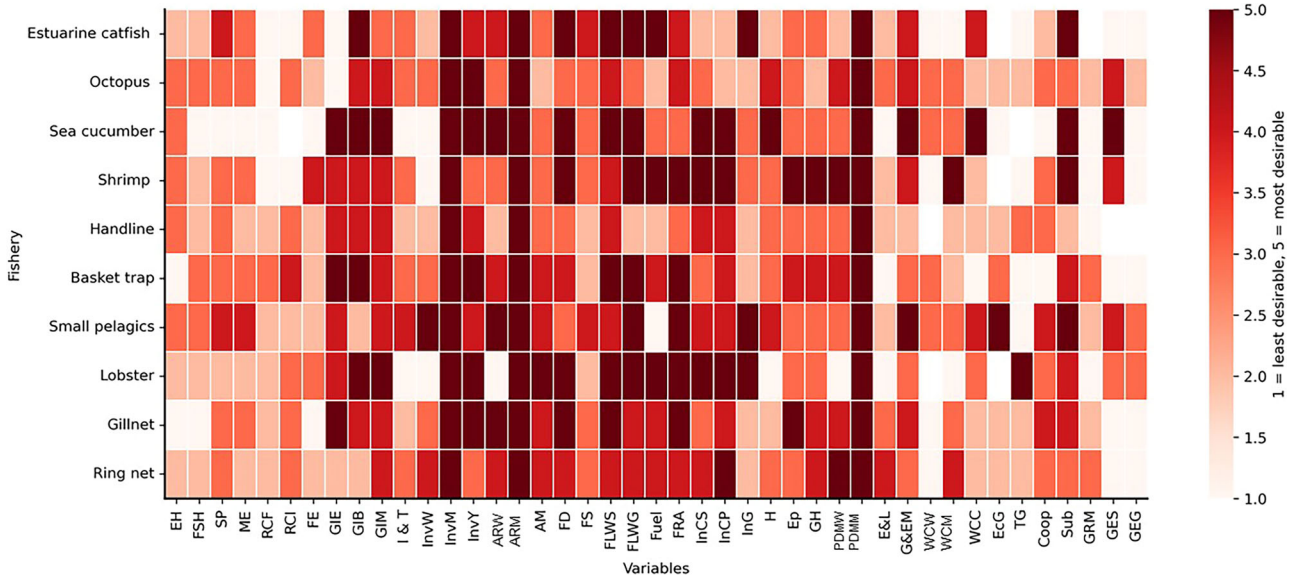

Fig. 1 | Levels of contribution (scores) of fisheries to SDG variables. Scores: 1 = least desirable situation for the variable; 5 = most desirable situation for the variable. EH ecosystem health, FSH fish stock health, SP stewardship practices, ME management effectiveness, RCF rule compliance (formal), RCI rule compliance (informal), FE fishing effort, GIE gear impact on ecosystem, GIB gear impact on bycatch, GIM gear impact on marine debris, I&T innovation and technology, InvW involvement in the SSF (women), InvM involvement in the SSF (men), InvY involvement in the SSF (youth), ARW access to resources (women), ARM access to resources (men), AM access to markets, FD food dependency, FS food security, FLWS food losses and waste (share), FLWG food losses and waste (growth), Fuel fuel, FRA share from fisheries-related activities, InCS income compared to local standards, InCP income compared to international poverty, InG income growth, H housing, Ep epidemics; GH global health, SC social cohesion, PDMW participation in decision-making (women), PDMM participation in decision-making (men), E&L education and literacy, G&EM geographic and economic mobility, WCW working conditions (women), WCM working conditions (men), WCC working conditions (children), EcG economic growth, TG tourism growth, Coop cooperation with other economic sectors, Sub subsidies, GRM global resource mobilization, GES global exports (share), GEG global exports (growth).

For the small pelagic fishery, variables with high scores were spread across from involvement and access to resources and markets, fuel, income, well-being, and economy. On the other hand, the shrimp fishery had the most desirable situations for variables related to income and well-being. Handline fishery had the least desirable situation for many variables.

Overall, variables related to ecosystem, stock health and stewardship practices scored low for most SSFs. Management effectiveness and compliance scores were also generally low for most SSFs, particularly compliance with formal rules. In contrast, aspects related to fishing gear scored medium to high for most SSFs, suggesting SSFs with mainly low impact gear.

Men's involvement in the fisheries, their access to resources, and their participation in decision-making consistently scored high across SSFs. Women's involvement in the fishery and their access to resources is also high for gillnet, small pelagic and sea cucumber fisheries, and women's participation in decision-making was high for shrimp and ring net fisheries. Children's involvement scored high for most SSFs, suggesting that children are not tasked with fishing activities.

Regarding economic factors, income levels ranged from medium to high score for most SSFs. The case studies generally have a limited impact on tourism, except for the lobster fishery, which supplies tourist hotels (high score). The SSFs have a limited impact on global resource mobilization, i.e., low contribution to mobilizing funds that could help support small-scale fisheries (e.g., grants, loans, or investments aimed at improving fishing practices, equipment, and infrastructure). Also, the SSFs have a limited impact on global exports, i.e., SSFs do not have access to international markets. Other variables relating to social considerations showed mixed results. Fisher's health is generally good, while their educational level remains low. SSFs actor dependency on their catch for nutrition was scored high for gillnet, lobster, and sea cucumber fisheries. Food security varied from low to medium for most of the SSFs. Food waste scored high, suggesting minimal losses due to waste. Occupational flexibility, measured by a Fisher's capacity to move to other fisheries or occupations, scored high to medium. However, work conditions are generally limited in these fisheries.

Change in targets across SSFs

Figure 2 illustrates the scores of SDG targets for the selected SSFs by aggregating the variables according to the method proposed by Bitoun et al.[36]. The analysis shows varying levels of SSFs contributions across different targets and fisheries. Overall, the lobster fishery had the most desirable situation for more targets, even though information on some targets was lacking. The fishery performed well on targets 1.1 (Eradicate extreme poverty); 8.7 (Eradicate forced labor and child labor); 8.9 (Promote sustainable tourism); 10.1 (Income growth), and 12.3 (Mobilize financial resources).

The shrimp fishery performed well on targets 1.1 (Eradicate extreme poverty); 3.3 (End epidemics); 3.4 (Reduce premature mortality); and 12 C (Rationalize inefficient fossil fuel). On the other hand, the sea cucumber fishery performance was spread across the targets from target 1.4 (Equal rights to economic resources); 8.7 (Economic productivity); to 11.1 (Affordable housing) and 12.3 (Mobilize financial resources). While small pelagic fishery performed well on targets 1.4 (Equal rights to economic resources); 5.A (Women's equal rights); 8.2 (Higher economic productivity) and 8.5 (Employment and decent work for all).

The Kenyan SSFs reveal a good contribution to Targets 1.4 (Equal rights to economic resources), 12.3 (Reduce food losses) and 8.7 (Eradicate forced labor and child labor) (Fig. 2). Conversely, the SSFs show limited contributions to targets 8.8 (Protect labor rights), 17.3 (Mobilize financial resources) and 17.11 (Increase exports from developing countries), consistently scoring poorly across the majority of SSFs (Fig. 2). Most SSFs scored high for T1.1 (Eradicate extreme poverty), especially the shrimp and lobster fishery (Fig. 2). The scores were mixed for T 1.2 (Reduce the proportion of people living in poverty) with scores between 2 (low) and 4 (medium-high) for the SSFs.

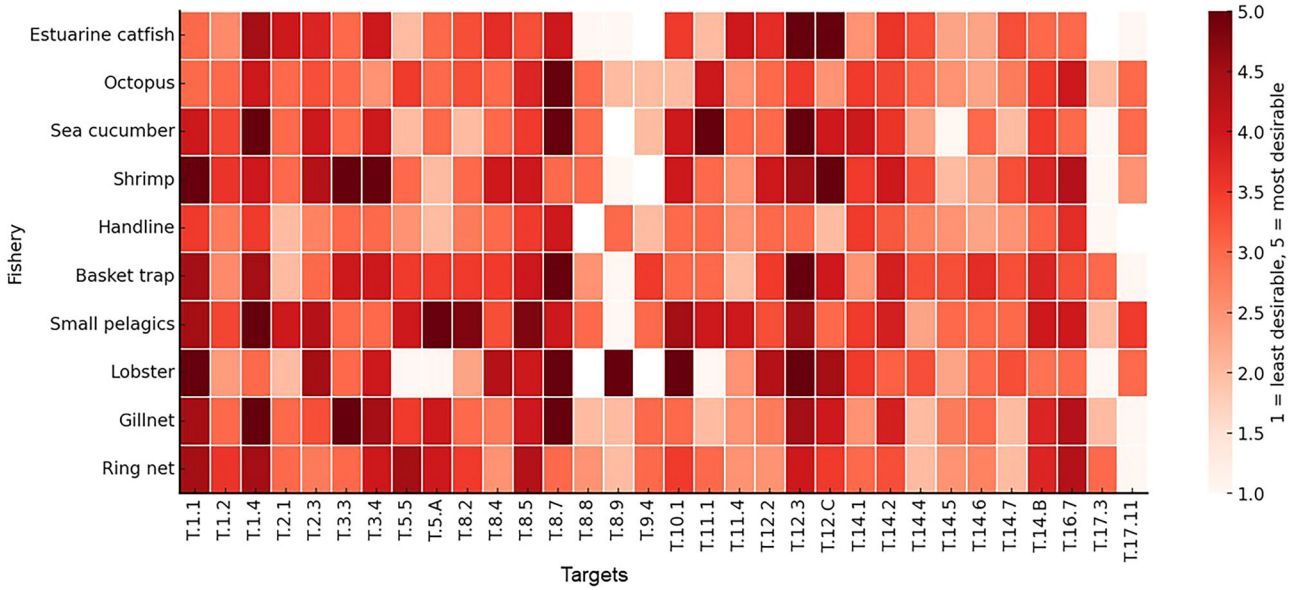

Fig. 2 | Levels of contribution (scores) of fisheries to each SDG target. Score: 1 = least desirable situation for the target; 5 = most desirable situation for the target. Target 1.1—Eradicate poverty. Target 1.2—Reduce poverty. Target 1.4—Equal rights to economic resources. Target 2.1—End hunger. Target 2.3—Double productivity and income. Target 3.3—End epidemics. Target 3.4—Reduce premature mortality and promote well-being. Target 5.5—Women's participation and leadership. Target 5.A—Women's equal rights. Target 8.2—Higher economic productivity. Target 8.4—Efficiency in consumption and production. Target 8.5—Employment and decent work for all. Target 8.7—Eradicate forced labor. Target 8.8—Protect labor rights. Target 8.9—Promote sustainable tourism. Target 9.4—Upgrade infrastructure and retrofit industries to make them sustainable. Target 10.1—Achieve and sustain income growth. Target 11.1—Adequate and affordable housing. Target 11.4—Protect cultural and natural heritage. Target 12.2—Sustainable management and efficient use of natural resources. Target 12.3—Reduce food waste and food losses. Target 12.C—Rationalize inefficient fossil-fuel. Target 14.1—Prevent marine pollution. Target 14.2—Sustainably manage and protect marine and coastal ecosystems. Target 14.4—Regulate harvesting, end overfishing, and restore fish stocks. Target 14.5—Conserve at least 10% of coastal and marine areas. Target 14.6—Prohibit fisheries subsidies. Target 14.7—Increase the economic benefits to SIDS and LDCs. Target 14.B— Provide access to marine resources and markets. Target 16.7—Participatory and representative decision-making. Target 17.3—Mobilize financial resources for developing countries. Target 17.11—Increase exports of developing countries.

SSFs contributions to SDGs

The contributions of SSFs to the SDGs varied highly amongst fisheries and goals. Several SSFs demonstrated substantial contributions towards various SDGs, particularly SDG 1 (No poverty) and SDG 16 (Peace, justice, and strong institutions), except for estuarine catfish, octopus, handline, basket trap, and lobster fisheries (Fig. 3). SDGs 10 (Reduced inequalities) and 12 received significant contributions from four SSFs each. Sea cucumber, shrimp, small pelagic, and lobster fisheries contributed most to SDG 10. In contrast, estuarine catfish, sea cucumber, shrimp, and lobster fisheries contributed most to SDG 12. Three SSFs had high contributions towards SDG 3 (Good health and well-being) i.e., shrimp, basket trap, and gillnet fisheries.

Small pelagic, shrimp, sea cucumber, ring net, basket trap, and gillnet fisheries are SSFs with high overall achievement of SDGs. Handline and estuarine catfish fisheries are low-performing SSFs. Some SSFs have unbalanced contributions to the SDGs: lobster, estuarine catfish, sea cucumber, and gillnet fisheries.

An analysis of all the assessed fisheries indicates that the overall contribution of Kenya's coastal SSFs towards the SDGs shows potential for advancement. Six of the 17 SDGs assessed, i.e., SDGs 1, 3, 8, 10, 12, and 16, demonstrated good contributions of the SSFs. Contributions to SDGs 2, 5, 11, and 14 indicate a moderate contribution. However, contributions towards SDGs 17 and 9, on partnerships for the goals and industry, innovation, and infrastructure, respectively, were more limited.

Discussion

When studied in the context of SDGs, SSFs are often discussed primarily in light of SDG 14 (i.e., the "Ocean SDG"), the SDG capturing SSF and fisheries resources more generally. Here, we applied the recent method from Bitoun et al.[36] at the scale of an entire country, Kenya, to assess the contributions ten key SSFs make to 12 SDGs and 32 associated targets. It is important to note that a fishery contributing strongly to sustainable development goals is not necessarily the same as a sustainable fishery, as commonly understood (i.e., one whose fish resources are managed sustainably). The analysis highlighted an overall strong contribution of Kenya SSFs to SDGs, with scores over 3 out of 5 for 9 of the 12 SDGs. Contributions are specifically high for SDG 1, 3, 10, 12, and 16. Large differences among the ten fisheries were observed, with some SSFs demonstrating strong contributions to many SDGs, while others appear to have limited contributions to those goals. We discuss these contributions, acknowledge some study limitations, and provide recommendations for better aligning Kenya's SSFs with SDGs.

The SSFs studied offer very contrasting results, both among fisheries and also among targets and goals of the same fishery. Overall, the 'small pelagic' and 'shrimp' fisheries contribute the most to SDGs, while the 'handline' and 'octopus' fisheries contribute the least.

The small pelagic fishery displayed high contributions to SDGs 1, 2, 5, 10, 11, and 16, and was the most balanced case study across all SDGs. It performs well, for instance, in eradicating poverty (SDG 1) and providing food security (SDG 2). This probably reflects that the fishery is known to provide nutritious and affordable fish[38,39]. The small pelagic fishery also contributes to SDGs 5 and 10, as gender equality and reduced inequalities are reflected by a considerable involvement of women in the fishery value chain, particularly in the post-harvest activities. Further, the contribution of the small pelagic fishery to these SDGs has had positive effects that support the contribution to SDGs 11 and 16, sustainable communities, and peace. Generally, such a fishery contributing more broadly to a range of SDGs could offer a more diverse 'portfolio' of benefits for the communities involved in those fisheries.

The shrimp fishery demonstrated strong but very uneven performances across SDGs, with its strongest performance in SDG 3, achieving the highest contribution among all studied fisheries on any SDG. It also performed well in SDGs 12 and 16, and in lower extents to SDGs 1 and 10. It,

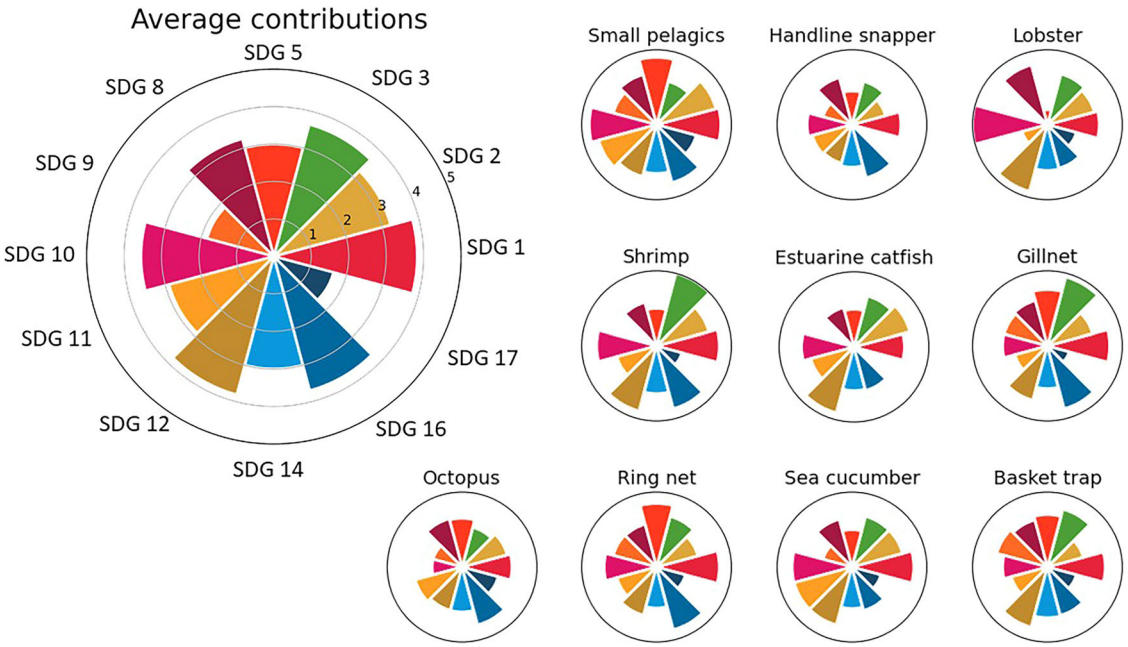

Fig. 3 | Contributions of ten Kenyan small-scale fisheries to the 12 SDGs (right), with a summary plot (left). Scale: 1 = least desirable situation; 5 = most desirable situation. Certain fisheries demonstrated particular strengths in specific SDGs. The estuarine catfish and small pelagic contributed significantly to SDG 2 (Zero hunger), while small pelagic and ring nets advanced SDG 5 (Gender equality). Sea cucumber and small pelagic fisheries had high contributions towards SDG 11 (Sustainable cities and communities). The Lobster fishery also had a high contribution towards SDG 8 (Decent work and economic growth). In contrast, handline fishery performed poorly across SDGs. The contributions of SSFs to SDGs 9 (Industry, innovation, and infrastructure) and 17 (Partnerships for the goals) were limited. For some fisheries, such as estuarine catfish, shrimp, and lobster, information regarding SDG 9 was not documented. Similarly, data on SDG 17 were lacking for estuarine catfish and handline fisheries.

however, suggests more modest contributions to SDG 2 and low contributions to SDGs 5, 8, and 17, but also to SDG 14. Gender roles in the fishery are clearly delineated, with women predominantly involved in post-harvest activities. In contrast, fishing activities remain dominated by men, based on the assumption of technical expertize and physical strength required for handling boats and fishing nets. This gender disparity is reflected in the moderate contributions of the fishery to SDGs 5 and 8. The fishery capitalizes on the local and regional markets, as accessing the international markets has not been harnessed due to high market standards, low catch volumes, and technological constraints, thus limiting contribution towards SDG 17.

The basket trap fishery represents one of the most common traditional fishing practices along Kenya's coastal region[10]. The fishery, along with the shrimp fishery, demonstrates strong performances overall, with higher contributions towards SDGs 1, 3, and 12. Such a success may be attributed to its sustainable characteristics: basket trap fishers primarily utilize non-motorized boats or operate as foot fishers, employ selective fishing gear that minimizes bycatch, and distribute their harvest through local consumption and sales networks[12,40–42]. The fishery also advances SDG 5 through women's multifaceted involvement, including bait collection, gathering trap-weaving materials, and ownership of basket traps and fishing vessels.

The analysis of other SSFs, particularly the lobster and estuarine catfish fisheries, showed lower and often uneven contributions across SDGs. The lobster fishery is particularly uneven in its contributions. It performs well in SDG 10 by serving as a key economic driver for coastal fishing communities but with the lowest score amongst all the fisheries for SDG 5. Lobster is a high-value product that contributes to sustained income growth (Target 10.1) while generating foreign exchange earnings for the country[7]. The estuarine catfish fishery performed well in SDGs 12 and 2 but low on SDGs 5 and 8. The fishery employs diverse fishing gears and predominantly non-motorized vessels while implementing effective post-harvest practices such as smoking to prevent spoilage[7,43]. The high market demand for catfish products, both locally and regionally[7], coupled with these sustainable practices, supports the reduction of food waste (Target 12.3) and promotes fuel efficiency (Target 12C).

The results also show that most fisheries performed well for SDG1, but handline, basket trap, gill net, and ring net performed better for SDG1 than SDG 2. SSF plays a key role in providing income for fisher communities, thus supporting SDG 1 in poverty reduction. However, in many cases, fishers may sell the high-value catch for income rather than consumption[38,39]. This situation may have contributed to this pattern observed in the handline, basket trap, gill net, and ring net. Most SSF performed poorly on SDG 17 as most of the catches are consumed locally and very few for export due to limited access and challenges in meeting the standards for international export markets[7,44]. The lobster fishery had a poor performance for SDGs 5 and 11, and this could suggest that although lobster is a high-income fishery, it has not yet been reflected in an improved lifestyle for fishers and their family. The SSF contributions towards SDG 14 were limited in most fisheries. This may be due to challenges in managing and regulating harvest and overfishing fishery resources. Even though regulations and conservation efforts are in place in most BMUs, financial resources may be limited for implementation. Handline and Octopus fisheries performed poorly in most SDGs; this may be attributed to several factors, such as the seasonality of the fisheries, limited financial resources to support the fishery, access to markets, and low market prices[44–46].

Kenya generally did not improve much nationally towards SDGs 1, 2, and 3 (see Table 1), goals often seen as being central to SSF contributions due to their key roles in ensuring employment, food security, and well-being in coastal communities. As shown by our results, Kenya's SSFs demonstrate significant potential to contribute to SDG 1, as documented by numerous studies highlighting their role in eradicating poverty[2–4]. Additionally, these fisheries show strong contributions toward SDG 16, particularly evident in six SSFs: ring net, gill net, small pelagic, shrimp, octopus, and handline

fisheries. Such a result could stem from the high social ties within fishing communities, which facilitates the effective implementation of common policies and practices[47].

Similarly to most other African countries, the gender dynamics in Kenya's fishery reveal persistent male dominance along the value chain, including fishing, trap-weaving, vessel ownership, and fish trading, while women tend to be more involved in post-processing[48]. Additionally, a critical power structure exists through fishing vessel owners, predominantly men, who provide essential resources such as vessels, gear, and financial support during hardships[44,49]. However, this creates a dependency where vessel owners control both pricing and payment systems[49]. This power imbalance may hinder economic growth and progress toward SDG 8. Previous studies suggest that empowering fishers through direct ownership of fishing gear and vessels could help address exploitation issues and promote economic independence[50].

This study shows that Kenya's SSF contributions towards SDGs reveal consistently high performance across five areas. First, SSFs clearly contribute to reducing poverty and promoting health and well-being (SDGs 1 and 3) due to their role in coastal Kenyan communities as a source of income and livelihood support[38,41,51]. Second, they help reduce inequalities (SDG 10) by assisting fishers to achieve and maintain daily incomes above 2.15 USD. Third, these fisheries support responsible consumption and production (SDG 12) through minimal bycatch and effective local marketing systems, including preservation methods like boiling, salting, and drying[7,12,41]. Finally, they strengthen community institutions (SDG 16) through collaborative decision-making processes that foster social cohesion[47].

Overall, the contributions of SSFs to SDG 9 appear lacking for some SSFs. This could suggest that infrastructure and sustainable retrofit industries need to be upgraded, as most SSFs have low capital investment and technology[12,41,52]. Most fisheries exhibit a low contribution towards SDG 17. Most products are locally consumed, with export markets limited to a few groups like sea cucumber, lobster, and octopus[7]. In addition, there is limited resource mobilization to the fisheries.

Some limitations may have influenced the findings of our study. Stakeholder bias may have impacted responses due to varying views, social dynamics, and differences in participants' level of understanding and experience[53,54]. The concepts of SDG were far from being intuitive to some participants, and the technical terms used in the surveys may have been challenging to convey or understand, potentially affecting the scoring of some targets. Some variables, especially those concerning household welfare (i.e., housing conditions, household health, disease prevalence in fishing communities, and education levels), are sensitive and challenging to collect in specific contexts. Furthermore, the assessment was focused on global SDG standards, which may not fully capture local realities, leading to potential biases or the exclusion of certain local contributions. There is a need to refine and adapt the assessment tool to better reflect local contexts.

The contribution of SSFs to the SDGs is rarely accounted for due to the sector's complexity and multidimensional nature. This study was the first attempt to assess the contribution of SSFs towards the SDGs in Kenya. SSFs were assessed using a simple tool that involved SSF's stakeholders. The findings suggest that Kenya's SSFs contribute to multiple SDGs (notably SDGs 1, 2, 3, 5, and 8), while their impact on SDGs 9 and 17 remains limited. Due to some unavoidable sensitivity of the scoring to the method used, results should be analyzed for general trends, as detailed interpretations of individual scores could be misleading. The framework served as a diagnostic tool to identify strengths and gaps in SSF's contribution to the SDGs. It was also helpful to raise participants' attention to SDGs, concepts often used at the political levels but detached from other parts of the societies.

Additional case studies could provide a more comprehensive account of Kenya's SSFs' progress toward the SDGs. Expanding SSF's access to export markets is also a priority for their development. In addition, raising awareness among SSF actors about the SDGs could further enhance their engagement in sustainable development efforts.

In conclusion, the study helped better understand SSFs' role in contributing to the SDGs in Kenya. Among the fisheries assessed, the small pelagic, shrimp, and basket trap fisheries performed better than the others in key SDG-related indicators. Notably, the small pelagic fishery supported the involvement of women and improved access to resources and markets. Overall, while SSFs make notable contributions to multiple SDGs, their impact on SDGs 17 and 9 appears limited.

Methods

Approach

This study assessed the contribution of a selected group of SSFs to relevant SDGs. The framework was developed as part of the Fish2Sustainability project, and details on the methodology can be found in Bitoun et al.[36]. The framework included 32 of the 169 SDG targets, belonging to 12 of the 17 SDGs, that SSFs could directly influence. Forty-four variables were used to measure fisheries' contributions to the 32 SDG targets. A participatory approach was used to collect information from SSF actors' experts in each case study. We then used the expert-based rapid appraisal framework to identify and characterize the relationships between SSFs and the SDGs. Scoring involved assessing the different SSF variables related to selected SDG targets. The scores ranged from 5 (most desirable) to 1 (least desirable). The qualitative assessments of SSF variables were then computed into composite indicators, allowing for an estimation of the contribution of these fisheries to a diversity of SDGs.

Case studies

SSFs' selection was based on several factors. First, attention was paid to the commercial importance of the fishery, with an emphasis placed on dominant fisheries that significantly contribute to local economies. Geographical location was also considered to ensure a representative sample across different coastal areas. Finally, the selection was refined by fisheries researchers and informed by data from the Frame survey - a national census of the fishers, fishing vessels, gears, and related facilities[55]. The selected SSFs were categorized based on either the fishing gear employed or the target species, as follows:

1. The estuarine catfish fishery was selected because it ensures food security for both inland and coastal communities and has attracted a lot of fishers and traders. The fishery targets marine and freshwater catfishes of the Tana River mouth and the river channel, delta, and mangrove areas. About 200 fishers operate in this fishery. The fishing gears used include set gillnet (multi- and mono-filament), longline, *mgono* traps (conical fish-trap used mostly in rivers and creeks), and use bait like an octopus. Gear is set from 4 pm to 6 am and retrieved after 2–4 h. Fishers use dugout canoes with a crew of two per canoe. The processed fish products include salted, sun-dried, smoked, and fried fish. The fishery is co-managed, following the Fisheries Management and Development Act of 2016 regulations and the Fisheries Beach Management Unit (BMU) Regulations of 2021. The fishery is threatened by environmental degradation, pollution, and climate change.
2. The octopus fishery mostly targets *Octopus vulgaris* and *Octopus cyanea* and takes place mainly in coral areas, rocky bottoms, and lagoons of the Kwale, Kilifi, and Lamu counties. It attracts women and youth, does well in the local and export markets, and provides food security to the coastal people. The fishing gear used are spear guns, hooks, and sticks. Octopus fishing can be done by diving or walking, searching for the target, and capturing using hooks and sticks.
3. The sea cucumber fishery is commercially important due to its export market to China. It occurs along the entire coast of Kenya, concentrated in Lamu and Kwale Counties, in seagrass, sandy areas, hard rocks, and coral areas. The highest diversity is reported in reef lagoons, and the lowest in seagrass beds. The main species targeted are *Holothuria* spp., *Thelenota bananas,* and *Actinopyga mauritiana*. Harvesting is performed using scoop nets or handpicking by foot fishers and divers.
4. The shrimp fishery is locally and commercially important, providing food security for the coastal people. It occurs in the Kwale, Mombasa,

Kilifi, Tana River, and Lamu counties, in river estuaries, in mangrove creeks, sandy and muddy bottoms. The main species caught are *Penaeus monodon*, *Metapenaeus monoceros*, *P. indicus*, *P. semisulcatus*, and *P. japonicus*. The fishing gear used is shrimp seine, cast net, monofilament net, and conical traps. Fishing occurs throughout the year, but shrimps are more abundant during the rainy season.

5. The handline fishery is locally and commercially important. It occurs along the entire coastline, mostly in nearshore areas, in the reef ecosystem, in seagrass meadows, and in the Northern Kenyan Banks' mangroves, a new fishing ground with high potential. The main species are *Lutjanus argentimaculatus*, *L. fulviflamma*, *L. bengalensis*, *L. bohar*, *L. gibbus*, Serranidae, Trevallies, Barracuda, Tuna, Wahoo, and Sailfish. Fishing gears used are handlines, trolling lines, long lines, and droplines. Fishers use either motorized or non-motorized boats to get to the fishing grounds, with ice and cool boxes and can stay out at sea for up to 3 days. Fishing takes place both at night and daytime and uses artificial baits (Rapala).
6. The basket trap fishery was selected because it is the most commonly used traditional gear on the Kenyan coast, catches more commercial species, and has low by-catch. It operates along the entire Kenyan coastline, at a national scale, in seagrass beds, sand bottom, off coral reefs, and rocky shores. The main species caught are *Siganus sutor*, *Leptoscarus vaigiensis*, *Scarus ghobban*, *Lutjanus fulviflamma*, and *Lethrinus lentijan*. The fishing gear used is a basket trap. Fishers use non-motorized canoes propelled by sail power or paddles. Deployment of traps is done during the day. The traps are left overnight, and the catch is removed the next day. A combination of algae, crushed sea urchins, brittle stars, mollusks, or even cabbage is used as bait.
7. The small pelagic fishery is locally and commercially important for regional export. The fishery has a shared transboundary resource and provides the best nutrition and potential for research on small pelagic species. It operates at a local scale on the south coast of Kenya, in the Kwale County in Vanga, Jimbo, Gazi, and Shimoni, within seagrass beds, open waters, and off coral reefs. The species caught in this fishery include anchovy (*Engraulis* sp., *Stolephorus* sp.), round herring (*Etrumeus teres*), spotted herring (*Herklotsichthys* sp.), and *Sardinella* spp. The fishing gear used is surrounding nets (Ring nets). Fishing is mostly done during the night. The vessels used in the fishery are motorized *Mashua* (locally made boats) and lamps to provide light attracting the fish. The fishery is highly seasonal.
8. The lobster fishery was selected because it does well in the local and export markets. This is a national fishery occurring in the Kwale, Mombasa, Kilifi, Tana River, and Lamu counties. The main fishing grounds include the waters off Kiunga, Kizingitini, Kipini, and Ngomeni in the north of Kenya and Msambweni and Shimoni in the south of Kenya's coast. About 70% of catches come from the Lamu archipelago, specifically from Kizingitini, Kiunga, and Kiwayu[7]. The fishery operates in inshore areas located near shallow reefs and lagoons, with the main habitats being coral reefs, rocky bottoms, and seagrass beds. The five species caught (*Panulirus ornatus*, *P. homarus*, *P. longipes*, *P. versicolor, P. penicillatus*, and *P. ornatus)* comprise the bulk (70%) of the catch. The main fishing methods used by artisanal fishers are skin diving and snorkeling gears. Other legal methods of lobster fishing include multifilament gillnets and traps. Prohibited fishing methods include monofilament gillnets, spear guns, and SCUBA gear.
9. The gillnet fishery is another commonly used gear that catches a high diversity of species but also results in high bycatch. It occurs all along the Kenya coastline in areas of coral reefs, open waters, mangroves, seagrasses, and lagoons. Various species are caught, including *Istiophorus* spp, *Thunnus* spp, *Scarus* spp, *Lutjanus* spp, *Lethrinus* spp, *Caranx* spp, and *Siganus* spp. The main fishing gear used are multifilament and monofilament gillnets. Drifting gillnet is mostly used at night, and set gillnet is used both day and night.
10. The ring net fishery is locally and commercially important and catches a high diversity of pelagic species. It occurs especially in the Kwale and Kilifi counties, within seagrass, bare sand, and patchy areas, beyond the reefs, at 15 m to 20 m depth. Various species are caught, including *Sardinella* spp, *Thunnus* spp, *Selar crumnepholus*, *Rastelliger kanagurta*, and *Sphyraena* spp. The gear used is a surrounding ring net (small purse seine). Ring net was introduced into Kenyan waters from Pemba, Tanzania, in the late 1990s. The fishery mainly operates 30–40 km from landing sites. The fishing operation includes the use of SCUBA divers to locate schooling fish and guide them toward the ring net. They use motorized boats, with each fisher having a responsibility during the fishing operation. Ring net fishing is done during the day.

Data collection

A stakeholders' workshop was held at the Pwani University, Kilifi, on November 22nd, 2022, where 50 stakeholders were invited. The stakeholders were from research, academia, government, and non-government organizations, representatives of the fisher community (BMUs, which comprise local fishers, dealers, fishmongers, and all those related to fishing or coastal activities), and graduate students. The workshop was organized around group and plenary discussions on the selected fisheries. In this workshop, the rapid appraisal framework was applied for each of the ten fisheries in group discussions involving experts of each fishery. Interviews' sites were selected based on the locations of the fishery, and taking security into consideration. For example, small pelagic fishery takes place only in some areas in south Kenya, in Kwale County; Lamu County was not visited due to security issues.

The research team had 10 multidisciplinary members, and fishers were randomly selected from the representatives and respective fisheries. Interviews were held by teams of researchers from January 16th to 21st, 2023, with BMU representatives and fisheries managers in field visits. Interviews were conducted in 16 BMUs along the Kenyan coast from Tana River, Kilifi, Mombasa, and Kwale Counties. The BMUs were in Kipini, Malindi, Watamu, Kilifi, Takaungu, Mtwapa, Nyali, Timbwani, Mwaepe, Gazi, Mkunguni, Shimoni, Kibuyuni, Majoreni, Jimbo, and Vanga. The Interviews were conducted with 3–5 BMU officials/members (with at least one woman) for one or more of the selected SSFs. The BMU members were experienced fishers in the selected fisheries and fishmongers, most of whom were women. Each interview took between one and a half to three hours and consisted of open-ended questions (provided in Supplementary Note 1), to which interviewees provided ratings from 1 (low) to 5 (high). Secondary data was sourced from published and gray literature.

The rapid appraisal framework for assessing SSF contributions

The study employed an expert-based rapid appraisal framework to assess and quantify case-specific contributions of marine SSFs to achieving relevant SDG targets. Indeed, each SDG Goal has specific targets—169 in total—that outline measurable objectives to achieve the SDGs. The framework (detailed in ref. 36) followed a four-step approach. In step 1, a review of scientific literature was conducted to identify documented relationships between SSFs and SDGs. This resulted in the selection of 32 targets associated with 12 of the 17 SDGs. Those 12 SDGs are SDGs 1,2, 3, 5, 8 (Decent work and economic growth), 9, 10, 11, 12, 14, 16, and 17. SDGs 4 (Quality education), 6 (Clean water and sanitation), 7 (Affordable and clean energy), 13, and 15 (Life on land) were not considered due to the limited documented evidence on the direct impacts of marine fishery-related activities on these goals. In step 2, variables that can help assess each SDG target were identified. This involved reviewing indicators from the UN metadata repository and grouping them into higher-level indicators. This step resulted in 43 variables used to measure the 32 selected targets. The variables are provided in Supplementary Note 2, and the relationships between the SDGs and SSF variables are presented in Fig. 4.

The third step involved assessing SSF through expert elicitation. The framework was applied at the scale of a fishery, defined as a unit based on gear or target species. Experts are selected for their knowledge of a given fishery by the investigators. For the case study, experts included specialists in fisheries management from government agencies, academic researchers,

Fig. 4 | SSF variables and their respective SDG targets and goals.

and representatives from non-governmental organizations. Collective scoring (as a group) sessions were conducted to encourage knowledge sharing and achieve consensual outcomes. Each variable identified in step 2 was scored on a 5-point Likert scale, with 'High' representing the most desirable situations (e.g., good environmental conditions, high social welfare) and 'Low' representing the least desirable situations (e.g., depleted fish stocks, poor working conditions). The method allows 'Not applicable' and 'No data' options to account for the variables that do not apply or that cannot be evaluated when no data is available. Guiding materials were provided to help standardize scoring across different contexts and by different evaluators when allocating scores for each variable (Supplementary Note 2).

The final step involved creating composite indicators to measure SDG performance intervals and a global sustainability index. This process included a three-stage aggregation procedure: from variable to target, from target to SDG, and from SDGs to a global sustainability index. The study employs compensatory and non-compensatory methods to provide a nuanced assessment of SSFs' contributions to SDGs. These methods, rooted in recent sustainability literature, offer complementary perspectives on SSF performance across various SDG targets. The compensatory method allows for trade-offs between different targets within an SDG. It calculates the arithmetic mean of all target scores for each SDG, reflecting an optimistic view where strong performance in one area can offset weaker performance in another. For instance, if an SDG has three targets with scores of 5, 3, and 1, the compensatory index would be 3 $((5+3+1)/3)$. This approach, aligned with work by El Gibari et al.[56], provides an upper bound for SDG performance and acknowledges the potential for positive aspects to balance out negatives. In contrast, the non-compensatory method, drawing on principles discussed by Rickels et al.[57] does not allow high scores to offset low ones. It uses the lowest score among all targets for an SDG, considering all components as essential and non-substitutable. Using the same example, the non-compensatory index would be 1 (the lowest score). This conservative approach ensures that weaknesses are not overlooked and provides a lower bound for SDG performance. By utilizing both methods, the study creates an interval, similar to the approach introduced by Lo-Iacono Ferreira et al.[58]. The interval between the upper (compensatory) and lower (non-compensatory) bounds indicates the variability or balance in performance across different targets within an SDG. Finally, the global sustainability index is calculated as a ratio of the length of the interval, where the greater the length of the interval, the lower the ratio. A narrow interval, represented by a higher ratio, suggests consistent performance across targets, while a wide interval indicates significant disparities, potentially highlighting areas requiring targeted interventions.

A participatory approach was used to collect information from SSF actors' experts in each case study. These actors (stakeholders) included SSF participants (e.g., fishers, community representatives, actors within the value chains, and local organizations) and other stakeholders of the fishery sector (e.g., fishery administration agencies, research institutions, international NGOs, and fishing consultants). The scoring exercise was flexible, allowing group (score by consensus) or individual (scores averaged per SSF) scoring. The activity applies to any SSF scale: community, province/state, or region.

Scoring the SSF variables involved assessing the SSF variables related to SDG targets (Table 2). Scores were: High, Medium high, Medium, Medium low, Low, No data, and Not applicable. The variables were scored on a 5-point Likert scale, with 'High' or most desirable = 5 and 'Low' or least desirable = 1.

Ethics review

This research involved the participation of stakeholders and was approved by the Technical University of Mombasa Scientific Ethics Review Committee (TUM-SERC) with the approval number TUM SERC EXT/001/2023. Informed consent to participate in the study was obtained from participants as part of the requirements of the Ethics Review.

Table 2 | Categories and SSF variables used in the scoring

Category	SSF Variables
1. Environmental condition	1.1. Ecosystem health 1.2. Fish stock health
2. Practices	2.1. Stewardship practices 2.2. Management effectiveness 2.3. Rule compliance (formal and informal) 2.4. Fishing effort 2.5. Gear impact 2.6. Innovation and Technology
3. Access	3.1. Involvement in the SSF (women, men, and youth) 3.2. Access to resources (men and women) 3.3. Access to markets (men and women)
4. Food	4.1. Food dependency 4.2. Food security 4.3. Food losses and waste
5. Income	5.1. Share from fisheries-related activities 5.2. Income compared to local standards 5.3. Income compared to international poverty 5.4. Income growth
6. Well-being	6.1. Housing 6.2. Epidemics 6.3. Global Health 6.4. Social cohesion 6.5. Participation in decision-making 6.6. Education and literacy 6.7. Geographic and economic mobility 6.8. Working conditions
7. Economy	7.1. Economic growth 7.2. Tourism growth 7.3. Cooperation with other economic sectors
8. Global exchanges and Finance	8.1. Subsidies 8.2. Global resource mobilization 8.3. Global exports (share and growth)

Data analysis

Scores from the stakeholders' workshop and BMUs were compiled for each SSF and aggregated to obtain the variables' scores using the framework described by Bitoun et al.[36]. The forms were collected using Kobo Toolbox and further analyzed with Pycharm (Anaconda3 version 2023.03-1) to provide polar charts showing each SSF contribution towards the SDGs[59].

Data availability

The raw data and other resources are publicly available to facilitate the replication and extension of this study to other contexts. This includes the original data collection forms and the code used for data pre-processing. These resources are accessible in Zenodo under the following: https://doi.org/10.5281/zenodo.7825253.

Code availability

The code used to run the analyses is available in Zenodo under the following: https://doi.org/10.5281/zenodo.7825253.

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Competing interests

The authors declare no competing interests.

Additional information

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