Analysis

Illuminating the multidimensional contributions of small-scale fisheries

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Sustainable development aspires to "leave no one behind"[1]. Even so, limited attention has been paid to small-scale fisheries (SSF) and their importance in eradicating poverty, hunger and malnutrition. Through a collaborative and multidimensional data-driven approach, we have estimated that SSF provide at least 40% (37.3 million tonnes) of global fisheries catches and 2.3 billion people with, on average, 20% of their dietary intake across six key micronutrients essential for human health. Globally, the livelihood of 1 in every 12 people, nearly half of them women, depends at least partly on small-scale fishing, in total generating 44% (US$77.2 billion) of the economic value of all fisheries landed. Regionally, Asian SSF provide fish, support livelihoods and supply nutrition to the largest number of people. Relative to the total capture of the fisheries sector (comprising large-scale and small-scale fisheries), across all regions, African SSF supply the most catch and nutrition, and SSF in Oceania improve the most livelihoods. Maintaining and increasing these multidimensional SSF contributions to sustainable development requires targeted and effective actions, especially increasing the engagement of fisherfolk in shared management and governance. Without management and governance focused on the multidimensional contributions of SSF, the marginalization of millions of fishers and fishworkers will worsen.

The Sustainable Development Goals (SDGs) aspire to "leave no one behind"[1]. However, an important and culturally diverse group of economic actors and resource stewards—the global population of small-scale fishers and fishworkers—are currently lagging behind because their contributions to society remain obscure and are frequently overlooked[2]. SSF are diverse and elusive in definition but generally include pre-harvest, near-shore harvest and post-harvest activities using low-technology, low-capital and labour-intensive practices[3]. Wild-capture SSF in inland and marine waters is the most important food production system based on non-cultivated natural resources, but this small-scale subsector is often not recognized in agricultural, development and nutrition policy. Despite having a dedicated SDG target (goal 14b) aimed at securing their access to (marine) fishery resources and markets, small-scale fisherfolk were excluded, for example, from OECD blue-economy employment statistics[4] because their numbers were judged too difficult to estimate. As with some terrestrial resource-based food supplies, including hunting, foraging and pastoralism, SSF are frequently excluded from analyses of food systems[5,6]. Despite being an important source of high-quality protein and micronutrients globally[7], fish are hardly visible in strategies to achieve SDG 2 (zero hunger). Even less visible are SSF in inland water systems, which are not addressed in the SDGs[8]. A consequence of this is the marginalization of small-scale fisherfolk in national and international policy dialogue, in which they have limited influence on the governance of aquatic resources and ecosystems, including the implementation of measures against illegal, unreported and unregulated fishing[9]; marine spatial planning[10]; designation and management of marine protected areas[11]; and integrated management of freshwater systems[8]. Similarly, SSF often lose out to more-visible economic sectors, such as industrial fishing, aquaculture, tourism, agriculture, irrigation and hydropower development, in governance interventions designed to manage oceans[12] and inland waters[13]. This in turn leads to patterns of inadequate resource management,

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loss of access to fishing areas and fishery resources (including 'coastal squeeze' or 'grabbing')[14–16] or displacement from rivers and wetlands[17,18], leading to a variety of cascading effects from community-level loss of cultural heritage and economic revenue to negative effects on individuals' mental and physical health, among other issues[19].

Being invisible to national economic planners and in statistics increases the likelihood of being left out of social-protection programmes[20], climate national adaptation programmes of action[21], large debt-relief assistance programmes designed to promote growth and reduce poverty (such as poverty-reduction strategy papers)[22] and public health interventions[23]. The lack of adequate attention from governments and international development agencies[6,24] has also resulted in inadequate or inappropriate assistance after disasters[25] and has exacerbated vulnerabilities to emerging economic, social, environmental and health stressors such as COVID-19 (ref. 26). Despite this, every day this sub-sector serves as a highly important socio-economic and nutritional safety net for millions of people around the globe[27,28], often providing low-income communities with high levels of life satisfaction comparable with those of wealthy countries[29]. Coastal Indigenous populations are particularly reliant on SSF, consuming 15 times more seafood per capita than do non-Indigenous populations[30]. The international failure to better recognize the contributions of SSF and include them in sustainable development through national and international policy frameworks has consequences not only for the fisherfolk and the consumers of the fish they catch, but to the broader global society.

The historic marginalization of SSF in national and international policy and development stands in sharp contrast to case studies from around the world highlighting the important contributions small-scale fisherfolk make to sustainable development[27,31]. As such, achieving the SDGs will not be feasible in many countries without ensuring a sustainable future for SSF as key components of food systems[8], encompassing all aspects of the production, provision and consumption of food, and their interrelationships[32]. SSF provide food and nutrition security (SDG 2, zero hunger), contribute to good health and well-being (SDG 3)[33] and provide income in areas that often lack other economic opportunities (SDG 1, no poverty)[13,34]. Women participate (SDG 5, gender equality) not only in post-harvest activities but also in pre-harvest and harvesting activities, making direct inputs to household food production and monetary income[35–38]. Most species targeted by SSF are destined for direct human consumption, particularly highly nutritious and affordable small pelagic species, such as those of the clupeid family (including sardine, herring and anchovy)[39]. This constitutes one of the most energy-efficient animal-sourced food production systems, generating among the lowest environmental impacts in terms of greenhouse gas and other stressors[40–42], and they do not require feed, fertilizer or pesticide inputs or the consumptive use of fresh water[43]. With enabling policy frameworks in place, small-scale fishers and fisheries have the potential to make substantial contributions to responsible production and consumption (SDG 17) and be important environmental stewards for the maintenance of public access to healthy aquatic environments and the sustainable, equitable use of aquatic resources (SDG 14 and 14.b)[44–46], among other contributions to food systems and SDGs.

In this study, we address the demand for better global and regional multidimensional data to guide sustainable development of the sub-sector (Supplementary Section Table E1), through the first global-scale systematic data-gathering initiative of the multidimensional contributions of SSF to food provision, poverty eradication, women's employment and peoples' dietary micronutrient supply. Better data are needed to underpin and garner more economic and political support for SSF. Actions such as legal mandates, capacity building, research and other supporting initiatives by coalitions of practitioners, development partners and academics are also needed, together with participatory approaches, to enable the sustainability of SSF. Previous data-collection efforts on SSF have mostly focused on providing global estimates of marine catch and value[47,48] (such as the Sea Around Us project; Extended Data Table 2), been based on individual case studies and mostly qualitative information (including the Too Big to Ignore research network), or had a limited methodological scope[49]. Although such information has contributed to valuable policy insights[27,34], a lack of harmonized multidimensional quantitative data has probably hindered policy action[50]. Without adequate quantitative data, policy-makers may struggle to calibrate the scale of investments and priority of response, including relative to other food production systems.

Our study aims to establish the absolute and relative contributions of SSF to the multiple dimensions of sustainable development, and to determine the main policy actions needed to enhance the critical contributions of SSF. To do this, we developed global estimates for SSF catch, micronutrient supply, employment, livelihood dependency, women employed, economic value, governance participation and tenure (that is, regimes of property and access rights). We argue that improving data availability and quality for the contributions of SSF, coupled with analysis of how they are governed, can provide a firm empirical justification for recognizing them in development policies and programmes, to attain the SDGs through mechanisms that enhance this sub-sector at global, regional and national levels[6,11,51,52].

In those rare instances for which SSF data are available as part of national fisheries or demographic information systems, crucial employment data are rarely disaggregated by sex, and production data are rarely linked to national accounting of food and nutrition supply. Although scholars are starting to recognize and enumerate the importance of aquatic foods to global nutrition[53–55], the focus has been almost entirely on marine fisheries, whereas in this study we incorporate the substantial contribution from inland fisheries.

Absolute and relative contributions

Marine and inland catches

SSF provide at least 37.3 million tonnes of fish, including fin-fish and aquatic invertebrates, annually (95% confidence interval (CI), 27 million–53 million tonnes), representing at least 40% of the global capture-fisheries production reported by the Food and Agriculture Organization of the United Nations (FAO) (92.5 million tonnes, average for 2013–2017)[56] (Fig. 1a,b and Extended Data Table 1). This is equivalent to at least 31.2% of the marine (25.1 million tonnes of fish annually) and about 99.7% of inland (12.2 million tonnes; averages for 2013–2017) global fisheries capture reported by the FAO[56]. Our estimates of global SSF catch are in line with previous studies (Extended Data Table 2 and Supplementary Table C5), particularly for marine SSF. For the inland sub-sector, we acknowledge that our estimates are more conservative than those of previous modelling approaches based mostly on non-fishery data[57,58] and should be interpreted as the visible, lower end of the global estimates derived from previous studies. The limited availability of inland data is largely due to fishery agencies perceiving a lack of economic return on collecting structural and statistical data, as well as the sheer logistic constraints of covering an often vast mosaic of small water bodies, making this sub-sector particularly data deficient and thus often marginalized. Data for inland SSF should be improved, particularly at local or national levels, but we underscore the importance of including them to reverse the narrative that leads to the persistent marginalization and undervaluation of inland small-scale contributions to sustainable development. Although they are arguably small scale, recreational fisheries were not included because this study fell under the scope of the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (hereafter SSF guidelines). Recreational fisheries are estimated to contribute only 2.2% of the global fisheries catch, and about 6% of our global estimate of SSF catch[59,60] (Supplementary Section C3), but it is recognized that recreational fisheries may provide important economic, recreational and health benefits, particularly in high-income countries[61].

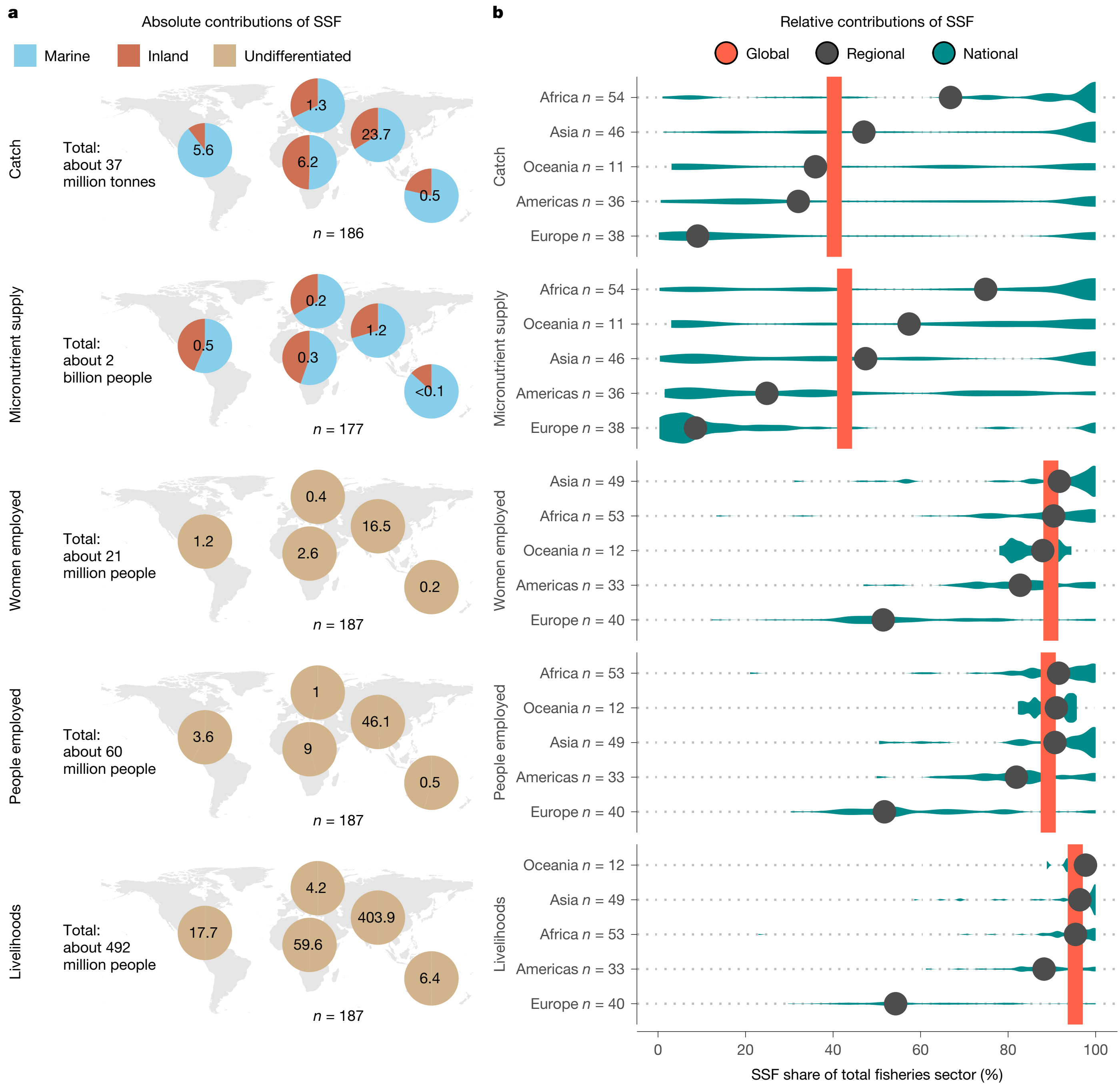

Fig. 1 | SSF multidimensional contributions to sustainable development. **a**, Global absolute contributions of SSF, including a catch of around 37 million tonnes (95% CI, 27 million–53 million), micronutrient supply for 2.3 billion people within 20 km of a coastline or large water body (10–30 km, 1.5–3.0 billion), employment for 21 million women (95% CI, 18 million–24 million), total employment for 60 million people (95% CI, 52 million–68 million) and livelihoods (part or full dependency) for 492 million people (95% CI, 447 million–535 million). Regional contributions by marine and inland sector, when possible, are shown as pie charts. Global micronutrient supply to local diets is quantified as the number of people within 20 km of a coastline or water body for whom SSF catches could contribute an average of 20% of their dietary intakes of six key micronutrients (calcium, iron, selenium, zinc, vitamin A and omega 3). Although fatty acids are not defined as micronutrients because the recommended intake for omega 3 fatty acids that are concentrated in aquatic foods (EPA and DHA) is within the micronutrient range, here we refer collectively to all six nutrients as micronutrients. Total and women's employment include pre-harvesting, harvesting and post-harvesting activities. Livelihoods include employed and subsistence fishers plus members of their households. Here *n* indicates the number of countries with data available for each metric. **b**, Proportion of SSF catch, micronutrient supply, women employed, total number of people employed and livelihoods relative to the total fisheries sector (comprising large-scale and small-scale fisheries) at global (vertical red line) and regional (black circles) scales, highlighting the distribution of proportions across countries (violin plots). Further details are found in Supplementary Section C1, including 95% CIs for catch, employment and livelihoods, maximum and minimum values for micronutrients (Extended Data Table 1), uncertainty in coastal population size (Extended Data Fig. 1) along with details per country case study, extrapolated countries, sample size and data sources (Supplementary Tables C1, C2 and C3).

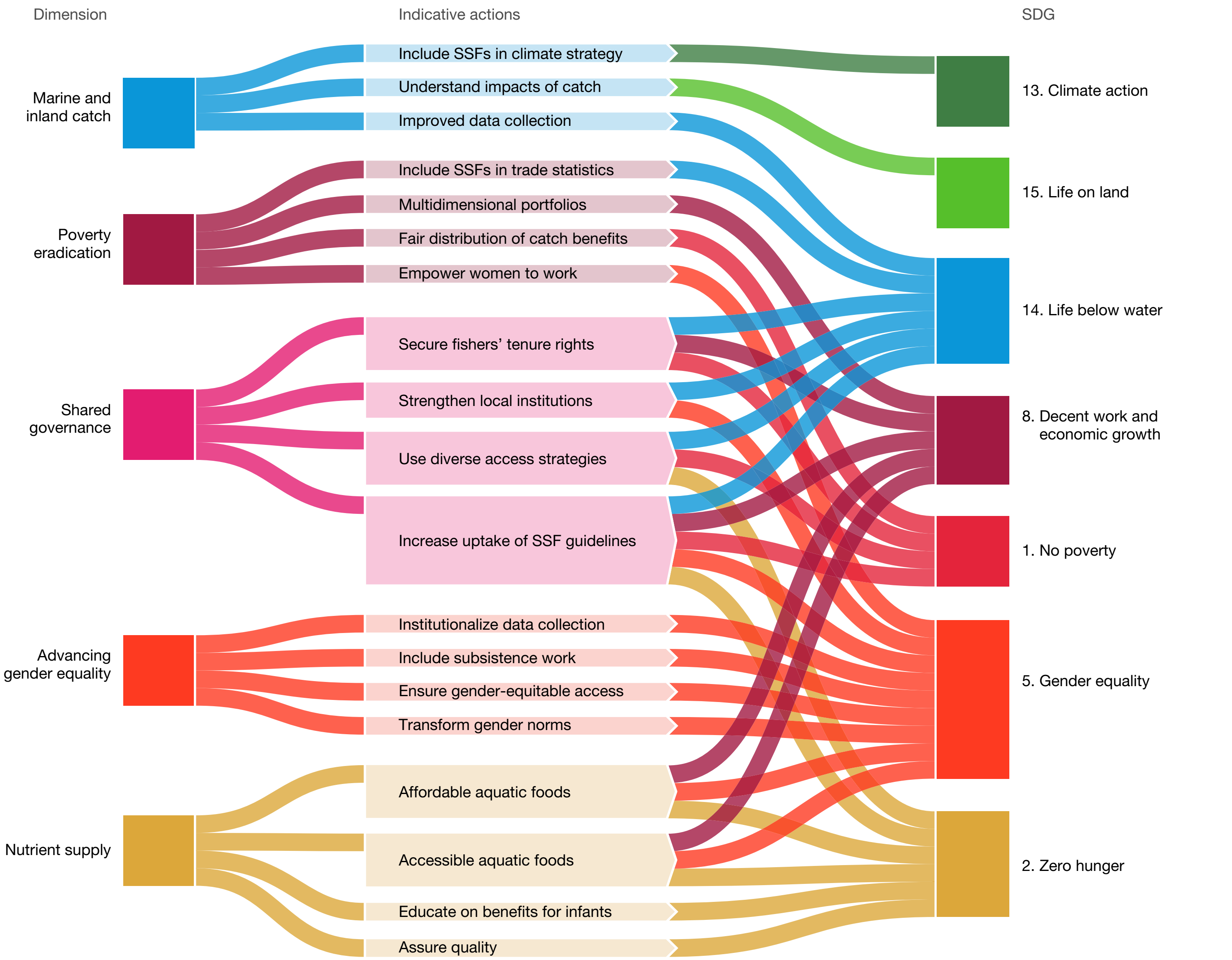

Fig. 2 | Illustration of main linkages between the various dimensions of contributions to and impacts of SSF and the SDGs. Dimensions shown are catch, poverty eradication, shared governance, advancing gender equality and nutrient supply. Identification of key actions that mediate the realization of contributions to the SDGs are mostly based on findings from the Illuminating Hidden Harvests study[74] and are synthesized in Supplementary Section D.

At the global level, marine SSF catch is more substantial than inland catch in terms of volume (67% of total small-scale catch), but the latter represents a vital contribution to food security and nutrition for households living near bodies of open water[62], particularly for the Africa region (Fig. 1a).

Most of the catch (53.0% for marine and 76.1% for inland) surveyed in our study was not identified taxonomically at species level or was recorded as "not elsewhere included". For the catch identified at the functional group level, herring, sardines and anchovies made up the largest fraction (3.8 million tonnes, 20% of the total catch), closely followed by miscellaneous pelagic fish (3.7 million tonnes, 19%) (Extended Data Fig. 2a). The category of miscellaneous freshwater fish dominated the reported inland catch (6.7 million tonnes, 63%) followed by the group of carps, barbels and other cyprinids (1.6 million tonnes, 15%) (Extended Data Fig. 2b). Overall, we found that SSF target a total of 2,104 species (1,798 marine and 488 inland, based on 58 national case studies). Increasing nations' ability to understand the species composition of their catch is important for effective management; for example, species characteristics such as life-history traits are vital to define the manner and rate at which they can be harvested and the minimum sizes to be retained. Information on catch volumes at species level, together with information on fishing intensity and ancillary information, such as size-based data, can provide information on the biological sustainability (for example, stock status) of SSF as key information in designing adequate management measures[63]. Effective management is needed to ensure that fishing activities do not cause detrimental harm to the ecosystems they depend on (for example, minimizing destructive fishing practices[64]), avoid targeting vulnerable species[65] and promote climate-resilient fisheries (for example, acknowledging the cumulative effects of climate change[16]), in accordance with SDG 14 (life under water) and SDG 10 (climate action) (Fig. 2 and Supplementary Table D1). Without effective and tailored management, many SSF will continue to overfish or move towards overfishing, compromising their long-term sustainability.

Micronutrient supply

Poor-quality diets can lead to micronutrient deficiencies that cause complications in pregnancy, impair child growth, undermine long-term health and cognitive outcomes and increase susceptibility to disease[66]. Global catches from SSF currently provide 20% of the intake of six critical but commonly lacking micronutrients[67,68] for up to 2.3 billion people

(Fig. 1a and Extended Data Table 1) living within 20 km of a coastline or large inland body of water (1.5–3.0 billion people living 10–30 km from a large body of water; Extended Data Fig. 1). This is one in four people globally and represents a large share of the estimated 3.2 billion people globally who depend on aquatic animal foods, from all sources, including large-scale fisheries and aquaculture, for 20% of their animal protein[63]. A study that focused on marine catch and coastal populations found that SSF contributes an average of 10% of dietary micronutrient intake from all foods[55]. Our estimates refine this body of evidence.

Based on global SSF catch data, the sub-sector provides the equivalent of 50% of an individual's omega-3 fatty acid (docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA)) intake, 28% of their selenium, 11–12% of their calcium and zinc, 9% of their iron and 3% of their vitamin A intake (Extended Data Table 3). SSF contributions to dietary intake were highest in Africa, Asia and Oceania, for both inland and marine systems, reflecting the high micronutrient density of these catches. Inland fisheries made the greatest contributions to dietary intake in Africa and Asia, reaching a potential 146 million people with 32% of their micronutrient intake in Africa, and 360 million people with 24% of their micronutrient intake in Asia. In Africa, however, estimates indicate that micronutrient deficiencies remain prevalent[68], with intake of micronutrients well below requirements[66,69]. Marine SSF make the greatest relative contributions to dietary intake in Oceania, providing 36% of micronutrient intake to 25 million people, and Africa, providing 23% of micronutrient intake to 181 million people (Extended Data Table 3).

For people within 20 km of a coastline or large (more than 50 km^2) inland body of water, SSF contribute the equivalent of, on average, 54% of their daily aquatic food consumption (including that from small- and large-scale fisheries and aquaculture) (Extended Data Table 3). Regionally, this can be as high as 85% and 77% in Oceania and Africa, respectively, and in 46 countries, SSF supply exceeded consumption. Indeed, in case studies of countries, an average of 79% of catch was retained for domestic use, confirming that the catch from SSF is directed primarily towards local nutrient needs (Extended Data Table 3). Many of these micronutrients are available but still lacking in diets, particularly in low- and middle-income countries with large catches from SSF[55], indicating that there is scope for developing nutrition-sensitive SSF policies to help address nutrient gaps in nutrient-deficient populations[70].

The data on available micronutrients from SSF provide evidence of the under-recognized and under-realized importance of this sub-sector in eradicating hunger and malnutrition, which is directly linked to achieving SDG 2 (zero hunger). For SSF to be part of this solution, greater coordination is needed between the actors tasked with decision-making in the fisheries, health and nutrition, and economics and trade arenas[71]. Sustainable supply and access to fish for the most vulnerable populations need to be prioritized and enhanced through evidence-based, effective fisheries management and nutrition-sensitive governance[39,70,72]. For marginalized populations in low- and middle-income nations, this means supporting vulnerable groups, including women, children and those living in poverty, to give them better access to SSF catches as an affordable source of animal food that also has a low environmental footprint (notably carp, barbel and other cyprinids from inland SSF, and herring, sardine and anchovy species from marine SSF)[39,42,73]. Other relevant actions include ensuring that information is available on appropriate handling, processing and storage protocols to ensure access to safe and high-quality aquatic foods and avoiding post-harvest losses[74], and on the benefits of fish consumption for infants, children and lactating mothers (Fig. 2 and Supplementary Table D2). National policies and appropriate incentives are required to retain an adequate proportion of SSF catches of small pelagic fish in local food markets, to help low-income consumers secure access to healthy diets. In some regions (such as West Africa), these fish are otherwise increasingly used for fish meal and other non-human-consumption purposes[75]. How much fish needs to be retained for local consumption will depend on the number of nutritionally vulnerable people and their access to alternatives with similar nutrition at a comparable cost[73]. Incentives for small-scale fishers to supply fish to domestic markets must account for the potential for fishers to earn higher incomes from exports to distant urban or export markets[76].

Poverty eradication

Although poverty is a multi-dimensional concept characterized by vulnerability[77], previous case studies have shown that SSF can support livelihoods and alleviate poverty through a range of pathways, from the provision of safety nets in times of shock or vulnerability, to increased labour productivity and incomes[27,78,79]. Our study estimated that one in every 12 people around the world (about 492 million people; 95% CI, 447 million–535 million, Extended Data Table 1) are at least partly dependent on SSF pre-harvesting, harvesting and/or post-harvesting activities through formal employment, work for self-consumption or as related household members (defined as being a member of a household in which at least one member is working in SSF for commercial employment or subsistence) in 2016.

Although data were not available to measure change over time, the snapshot provided by this study shows the global importance of SSF livelihoods that alleviate poverty through either prevention or reduction, or a combination of the two. In terms of prevention, most of those who participate in SSF live in low-income contexts marked by vulnerability, and low opportunity costs of labour in other sectors, in which the livelihoods supported may help to prevent poverty and provide safety nets that are not otherwise available in the economy. For example, 54% of those commercially employed in SSF and 57% of subsistence workers resided in countries considered to have 'high' or 'very high' vulnerability to climatic and natural hazards, according to the World Risk Index[80]. Approximately 60% of subsistence workers were located in low- or lower-middle-income countries[28], and at least 13.2% of the total population lived in a household in which one person worked in SSF for commercial employment or subsistence in 2016 in the world's 45 least-developed countries, where alternative livelihood opportunities may be limited[74]. Relative to the total capture-fisheries sector, SSF support 95% of all livelihoods at least partly dependent on fisheries, providing 89% of formal employment (Fig. 1b).

In economic terms, SSF generated 44% of the total landed value in the 58 countries surveyed (representing approximately 68% of FAO global capture-fisheries production). The estimated global landed value of the SSF catch (generated by multiplying catch and first-sale price) was US$77.2 billion (95% CI, $70.4 billion–$83.3 billion). Marine catch accounted for $58.1 billion (95%CI, $53.7 billion–$62.2 billion) and inland for $19.0 billion (95% CI, $16.7–$21.1 billion) based on the average for 2013–2017 (Extended Data Table 4). The total revenues from the first sale of the marine SSF catch exceeded the total individual revenues of some of the largest ocean-based industries in 2018, such as cruise tourism, port activities and offshore wind power[81]. Accounting for both the poverty prevention and reduction functions of SSF in assessing their potential contributions to SDG 1 (no poverty)[27,79] and SDG 8 (decent work and economic growth)[82,83], policies should aim to achieve a fair distribution of catch benefits and access to resources (SDG 14b), among other actions highlighted in Fig. 2 and Supplementary Table D3.

Advancing gender equality

A crucial step towards overcoming gender-blind policies that perpetuate the marginalization of women in the fisheries sector is the collection, use and sharing of gender-inclusive and disaggregated data. In a change from previous global studies that estimated women's participation in SSF harvesting[38,49], this study reveals approximately 21 million women (95% CI, 18 million–24 million women) employed commercially in SSF activities worldwide in pre-harvest, harvest and post-harvest activities (Fig. 1a and Extended Data Table 1), generating about 90% of all employment for women in the entire fisheries sector (Fig. 1b).

Furthermore, about 24 million women were identified in unpaid and informal activities such as subsistence fishing and processing, bringing the total participation by women to at least 44.7 million[28]. Importantly, more women engage informally in SSF activities than are commercially employed. Informal engagement (such as subsistence and other unpaid work) can limit women's inclusion in social protection programmes, exposes them to greater occupational hazards and constrains the economic benefits that can be derived from formalized fishing (for example, access to licences are often determined by ability to prove historic use)[37]. Women also participate less in governance mechanisms that shape decision-making processes, thereby directly and indirectly affecting access to nutritional and livelihood benefits[36]. Better recognizing the diverse ways in which women participate in fisheries value-chain activities, and the scale of women involved, is essential to advancing SDG 5, SDG 1 and SDG 2, among others. To increase the contributions of women in SSF to sustainable development, a summary of indicative actions is shown in Fig. 2 and Supplementary Table D4. These include the imperative of ensuring gender-equitable access to SSF through secure tenure in support of food and livelihood security[84]; and transforming dominant gender norms to promote women's leadership and governance in SSF[85,86].

Understanding regional patterns in multidimensional contributions

The magnitude of the global contribution of SSF with respect to the total fisheries sector highlights the critical importance of this sub-sector to sustainable development. Explaining regional patterns helps to contextualize it. Asia benefits from the highest absolute contributions in most dimensions (catch volume and value, people employed, livelihoods supported and women employed), producing four times as much SSF catch as Africa, which is the region with the second-highest SSF catch (Fig. 1a). Africa is where SSF were most important relative to total fisheries, contributing 67% of the total catch for the region and 75% of the total contribution to nutrition (Fig. 1b). By contrast, Europe's SSF support the lowest absolute number of livelihoods of all the regions (Fig. 1a) and make the lowest relative contributions across all dimensions (Fig. 1b). Despite this, for several countries in the region, the sub-sector represents 100% of the total fisheries sector, highlighting its importance for many national coastal communities[87]. These differences in catch share of SSF in different countries also occur in other regions, illustrating the importance of assessing these contributions at national or even local levels. The relative average contribution of SSF to overall fisheries catch in Oceania is below the global average, largely because of the high volumes of industrial tuna catches for some countries[88], but it is one of the most important regions in terms of their relative contributions to dietary intake, people employed and livelihoods supported (Fig. 1b). Moreover, marine SSF catch is four times more important in terms of kilograms of fish produced per capita in Oceania than in Asia (52.6 kg per person per year versus 14.3 kg per person per year; Extended Data Fig. 3). Our findings in Oceania serve as an important reminder that SSF are critically important to achieving SDG 2 (zero hunger) and other SDGs in those regions or countries where alternative economic and livelihood opportunities are more limited, including small island developing states and other least-developed countries.

Secure rights for fishers

Granting small-scale fishers secure rights to participate in the management and governance of their fisheries is increasingly recognized as a necessary condition for the development of locally appropriate governance systems[89] and the realization of the SDGs[90]. Devolving rights to fishers can address constraints in management capacities by fishery agencies and provide fishers with greater incentives to become stewards of their local environment[91–93]. However, we found that about two-thirds (63.8%) of the SSF catch from the 51 countries surveyed in this respect (45 for marine and 34 for inland fisheries) are not associated with formally recognized rights to participate in management and decision-making processes (that is, there are no explicit statements in written national, subnational or local fisheries policies) (Fig. 3). The remaining one-third (36.2%) of the catch is associated with different types of fishers' rights to participate in decision-making. For 12.9% of the catch in our dataset, fishers have been granted only management rights (Fig. 3), meaning they can participate in decisions about where, when and how to fish[94]. For 20.9% of the catch, fishers are increasingly empowered to manage their fisheries because, as well as management rights, fishers have been granted rights to determine who can fish through exclusion or transferability rights (Fig. 3). Full devolution of rights to fishers (as defined by granting the full suite of management, exclusion and transferability (alienation) rights in a previous classification[95]) represented only 1.7% of the catch in our dataset (Fig. 3). These general patterns are similar when the data are disaggregated by marine and inland fisheries (Extended Data Fig. 4). Our data highlight that when management or a combination of a more complete set of rights are devolved in a particular country, this typically represents only a small proportion of the national SSF catch (Supplementary Fig. C2), indicating that these arrangements are mostly localized and are not covered in national statistics, or are applied to only a subset of specific fisheries, and are not representative of national SSF policies (Supplementary Fig. C2).

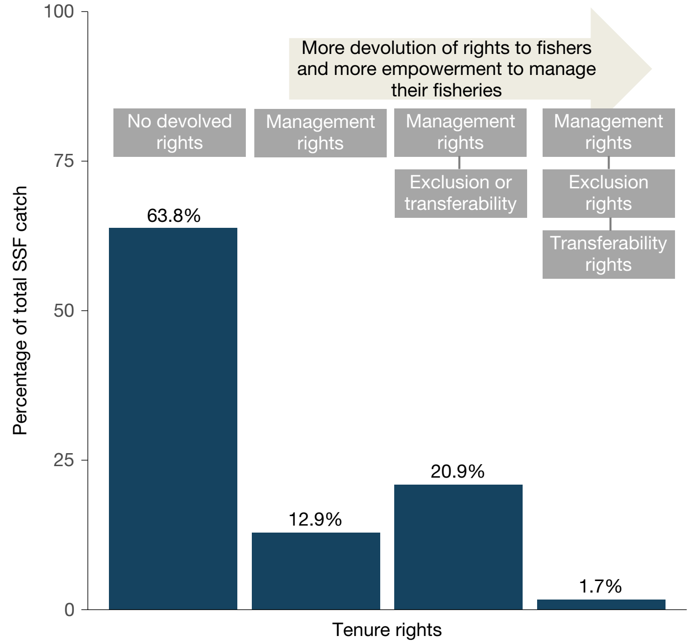

Fig. 3 | Percentage of catch with different levels of rights devolution in formally governed SSF. Data are based on analysis of policies from 51 countries that govern around 82% of their reported SSF catch. Combinations of rights that accounted for less than 1% of total SSF catch, such as devolved transferability rights, are not included in the figure.

Although two-thirds of catch is from fisheries for which small-scale fisherfolk cannot formally participate in management, this does not constitute evidence that these fisheries are mostly unmanaged or unregulated. Local, customary self-governance might be in place in the absence of formal regulations or devolved rights[96].

However, formally securing rights, either recognizing customary arrangements or developing new ones, is critical to reducing the vulnerability of small-scale fishers to exclusion or competition from more-powerful economic sectors[97] and external political, social, economic or environmental drivers of change[14,92,98]. The absence of rights to access, harvest and manage resources threatens the survival of fishers' culture, way of life and ecological sustainability, particularly among Indigenous peoples[99]. When rights are secure and there is good alignment between the rights being devolved and the circumstances fishers and managers face in localized social–ecological contexts, empowered fishing communities are more likely to develop processes that reflect local values around stewardship of the aquatic environment, sustainable fisheries and/or equitable livelihoods[93,100–102]. Actions demonstrated to secure rights to fishers include eliminating barriers to fishers' participation in fisheries management processes; creating local enabling conditions to exercise their tenure rights, including legal recognition of Indigenous rights to land and water; strengthening local supporting institutions, such as civil society organizations and decentralized fisheries agencies with clear roles and responsibilities. Stock health in SSF depends partly on fisheries- and non-fisheries-related external drivers, including climate change, pollution, infrastructure development, such as damming, and habitat degradation[18]. Measures that enhance organizational, administrative, enforcement and scientific capacity among co-management groups, ultimately leveraging secure rights, are likely to move the SSF towards sustainable practices[101,102] (Fig. 2 and Supplementary Table D5).

Discussion

Multidimensional measurement of the scale and impact of SSF has rarely been quantified, so it is unsurprising that the policy support they currently receive is not commensurate with the range and size of the different global contributions they make to sustainable development (Fig. 2). This situation is changing and there are now reasons for optimism with developments such as: the policy momentum created by the SSF Guidelines[89,103] and the International Year of Artisanal Fisheries and Aquaculture 2022; the upward trend in interest from academia, including the Too Big to Ignore research network[3,104]; increased funding by international development organizations and private philanthropists[24,52]; continued engagement of global fisher organizations and their supporters, such as the World Forum of Fish Harvesters and Fish Workers, the World Forum of Fisher Peoples and the International Collective in Support of Fishworkers, in global policy processes; and the emergence of coordinated SSF campaigns, such as the Call for Action released at the 2022 UN Ocean Conference[105].

There is evidence that improved information systems are associated with positive outcomes to several SDGs in a variety of cases and geographies (Supplementary Table D6). When such information systems are inclusive of SSF, the sub-sector experienced greater visibility and inclusion in a range of supportive policies, increased investment by governments and development partners, and improved outcomes[106]. For example, incorporation of the fisheries sector in national statistics on HIV and AIDS enabled countries where fisheries support an important number of livelihoods (Uganda, Thailand and India) to include this sector in national response strategies and development assistance programmes[107,108], contributing to the reversal of their HIV epidemic in a direct contribution to SDG 3 (good health and well-being)[109,110]. Effectively improving the inclusion of SSF in national policies will need not only increased awareness of their importance, or more technical data and information, but also better communication between government and the sub-sector (through, for example, fishers' organizations), better cooperation across governmental institutions (such as ministries of fisheries and social development), and ultimately more-effective inclusion and participation of the sub-sector in the design and implementation of inclusive policies. As demonstrated by the highly participatory process of developing the SSF Guidelines[111], purposefully designing coherent, inclusive policy frameworks with the support and participation of rights holders means they are more likely to lead to desired improvements[104].

Multidimensional SSF

Focusing on unidimensional metrics of SSF contributions (for example, only as catch or landed value, or omitting pre- and post-harvest activities) misrepresents and undervalues the importance of this sub-sector with respect to other dimensions such as employment or nutrition supply, or broader cultural values relating to sense of identity and recreation. This unidimensional production focus typically overlooks the roles of SSF in policies aimed at economic development. For instance, whereas SSF contribute to at least 40% of the total fisheries catch, when pre- and post-harvest activities are included, they contribute to 89% of the total employment, 95% of the total livelihoods and 90% of the women employed in the total fisheries sector (Fig. 1b).

What gets measured is more likely to be managed, and better accounting for the many ways SSF contribute to sustainable development induces an explicit recognition of SSF in advancing multidimensional goals[8,54,112,113] (Fig. 2). It also implies expanding current approaches in management and governance[114] focused on maximizing catch or landed value, while minimizing biological impacts on stocks (Fig. 4a), towards explicitly including other critical contributions in management objectives in line with the Ecosystem Approach to Fisheries[115], notably total employment, women employed or nutrient supply (Fig. 4b). Through multidimensional analyses, such as this study, a fuller contribution of SSF, related strengths and weaknesses in policy and management towards sustainable development of the sector can be more readily understood and acted on[13,116]. Attending to the multidimensional contributions fisheries make will require the government agencies responsible for managing fisheries to increase or better use the available human, financial and technological resources and also foster a culture of tolerance and trust for colleagues trained under different disciplinary traditions and an appreciation of types of data other than those conventionally collected on fisheries[35,117]. Redefining SSF as multidimensional activities is not entirely new[118,119]. Japan and the European Union have engaged in policy development for fisheries and agriculture within a similar framework as a means of reconciling investments in rural development[118,120] while also aligning with the principles of the ecosystem approach to fisheries. Similarly, fishing activities in other parts of the world could be valued for their role in the development of rural economies, the maintenance of rural landscapes, communities and cultural heritage, contributions to recreation and cultural values, and in managing landscapes and biodiversity, among the other diverse functions they provide to ecosystems and society. Importantly, SSF are not static and may transform or adapt in response to diverse changing ecological contexts (such as fish stock status), economic factors (such as market preferences) and social or cultural perceptions (arising demographic shifts, for example). This may take the form of economic and operational diversification of fishing and associated livelihood activities. This type of transition is most apparent for those in industrialized societies, in which there may be greater opportunities to engage in other economic activities, but how to transform is a challenge that confronts all SSF regardless of context. The allocation of rights, organizational and management capacity, development of better policies, and greater empowerment of SSF will support their ability to move towards greater self-determination and to chart a positive course for their continued development.

Evidence-based trade-offs

Obtaining sufficient multidimensional data and information about SSF in a given context, and institutionalizing the capacity to analyse and use it (Fig. 2), is necessary but not sufficient to sustain the wide range of benefits from SSF. Effective management and governance will require the evaluation of trade-offs in multidimensional management objectives and associated policies that reflect the diverse contributions of SSF to sustainable development. For instance, institutionalized collaboration between different government agencies (such as ministries of fisheries and economy) will allow the generation and analysis of multidimensional data and information that contribute to an understanding of the inherent trade-offs in management objectives for these social–ecological systems (Fig. 4b).

Fisheries in developed countries are often explicitly managed with a single goal, such as maximizing the long-term catch, based on the concept of (single species) maximum sustainable yield (enshrined in

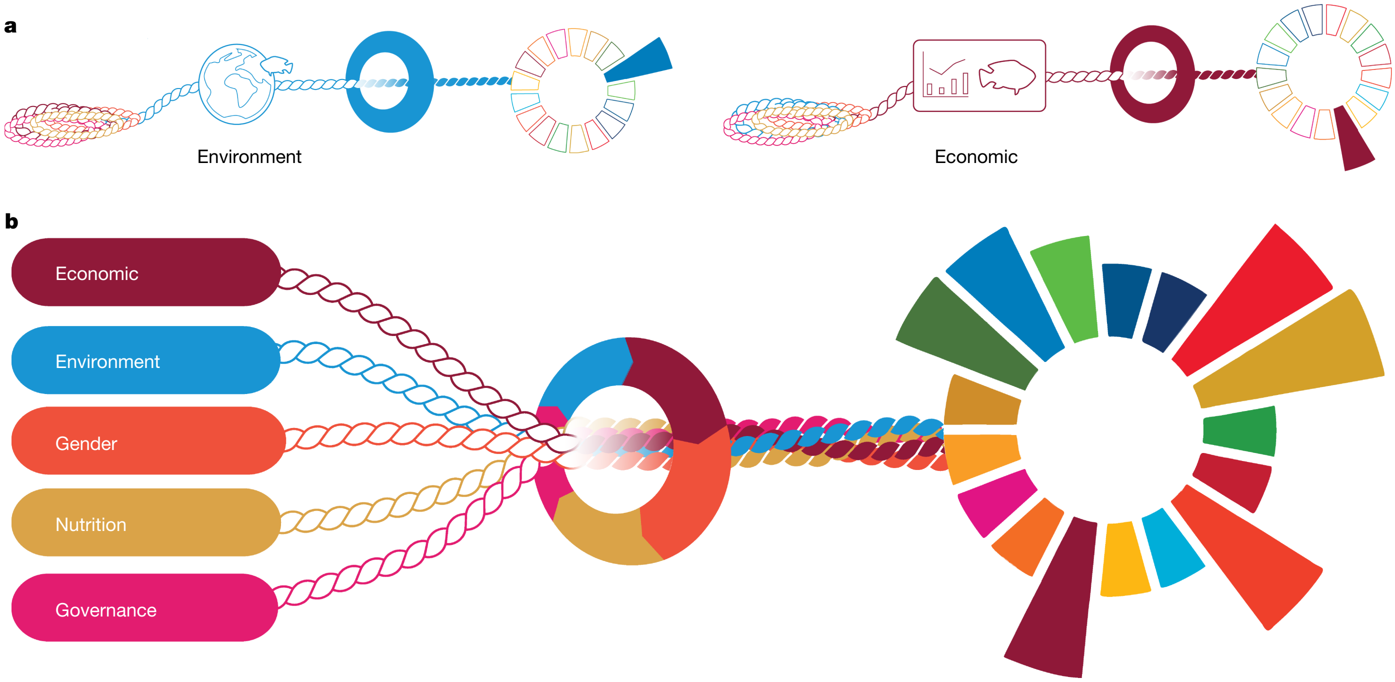

Fig. 4 | Reconceptualizing SSF as multidimensional contributors to sustainable development. a, Schematics of SSF managed for a single objective, for instance to reduce environmental impacts or to increase economic value generated from the activity, among other single-objective management choices. **b**, An alternative multidimensional approach. Managing SSF through evidence-based, participatory multidimensional analysis (such as this study) will better allow integration of SSF into a food systems approach and trade-off evaluation to inform evidence-based management, policy and governance that contributes to sustainable development.

international conventions and agreements[121,122]), maximizing economic efficiency and profitability, or maximizing the sustainability of fishing communities through employment generation[123] (Fig. 4a). The past two decades have seen an increasing trend towards the explicit inclusion of nutrition objectives in fisheries policy[124]. Policy formulation requires trade-offs between often competing objectives to be confronted, but these are often not sufficiently evaluated or explicitly articulated. Several model-based approaches to assess trade-offs between food security, economic development and biodiversity conservation exist, and these could be used in the context of operationalizing the ecosystem approach to fisheries[124]. For example, maximizing economic value while maintaining ecosystem structure would require a reduction in fishing effort, with high social cost for fishing communities with limited alternative livelihoods[125]. However, most of these approaches require specific ecological, social and economic reference points and are context and fishery specific[126,127], making them costly and data heavy. Irrespective of context, our results show that small-scale fishers make important contributions and so should be carefully considered as part of trade-off analyses when promoting transitions. Trade-off analyses also typically require a level of ecological knowledge of SSF that is often lacking in those regions where the bulk of them occur[128], limiting the local application of these approaches. We call for the development and use of simple, low-cost, data-driven and participatory approaches to understand trade-offs of multiple objectives aimed at informing the evidence-based management of SSF (Fig. 4). Standardization and coordination across data sources will facilitate the alignment of data across dimensions and enhance sound trade-off assessments[74]. Evaluation of these trade-offs should incorporate both fisher and non-fisher stakeholders, to ensure that the distribution of benefits and interest are well supported by adequate evidence and to give legitimacy to balancing difficult choices between social, nutritional, economic or environmental goals (Fig. 4b). In this respect, the involvement of small-scale fishers as co-generators and owners of data (such as traditional and local knowledge) guiding management and governance arrangements is key[129,130]. This study has synthesized data at a global level, but further actions are needed to institutionalize and support community-based data-collection programmes[131], in which fishers are trained to collect and analyse their own fishery and socio-economic data. These programmes can create financial incentives[132], enhance social cohesion, drive broader investment in SSF[133] and incentivize fishers' involvement in co-management[134]. For data-poor fisheries that are often overlooked in statistical systems, these approaches may constitute the only viable option for systematic data collection and are increasingly tested and implemented in inland fisheries in Africa[135], and in coastal fisheries in, for example, the Timor Sea[133], South Africa[132] and Mexico[136], with strong support from practitioners, donors and intergovernmental organizations[137–139]. Collaborative data collection and research among fishers, managers, practitioners and scientists may support better access to information but will not automatically result in more collaborative management, fishers' stewardship towards sustainable practices, or the effective implementation of management arrangements. Capacity development for participatory design and implementation of tailored, evidence-based approaches for collaborative legal frameworks, management, devolution of rights and SSF empowerment (Fig. 3) and resource stewardship are needed, particularly for SSF in the least-developed countries in line with the FAO Blue Transformation roadmap[140].

Conclusions

This paper illuminates the size and range of the contributions of SSF to sustainable development, supporting a more holistic understanding of what SSF are, their importance and the need to reconceptualize them for more-inclusive governance and management as part of global food systems (Fig. 4). In coastal and inland waters worldwide, particularly in lower-income contexts in which SSF form an important pillar of livelihoods, such comprehensive reconceptualization will be essential for achieving multiple policy goals for sustainable development. Moreover, we argue for a better contextualization of the importance of the SSF sector with respect to other uses of water and land, such as tourism, shipping, energy and aquaculture. Evaluating trade-offs across the multidimensional benefits provided by these sectors at local or regional levels can better inform policies aimed at ensuring broader sustainable development. In providing these multidimensional contributions and values, our study highlights the policy attention deficit that results in systemic global underinvestment in the evidence and knowledge base, and ultimately in the management and governance of SSF, perpetuating the social, economic and political marginalization of millions of fishers and fishworkers worldwide.

Online content

Any methods, additional references, Nature Portfolio reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at https://doi.org/10.1038/s41586-024-08448-z.

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Methods

The data and methodology for this paper were produced within the framework of the Illuminating Hidden Harvests (IHH) initiative conducted by the FAO, Duke University and WorldFish. Data were collated from different data sources applying specific methodologies described below and by the FAO, Duke University and WorldFish[74] for the exclusive purpose of the IHH study. Therefore, data are not to be considered official country data and do not replace the information provided in official FAO data systems.

Information on the various dimensions of contributions and impacts of SSF to sustainable development was compiled and synthesized (Extended Data Fig. 5), resulting in a database that provides estimates on catch, landed value, livelihood dependency, employment, number of women employed, contribution to dietary micronutrient intake and governance (see Supplementary Table A1 for the main indicators). In-country experts from 58 country-case studies (20 countries were strictly marine, 6 strictly inland and 32 combined marine and inland; Extended Data Fig. 6) collected secondary data on species-specific catch, ex-vessel price (as input for landed value estimations), contribution to dietary micronutrient intake and governance. For employment and livelihood dependency, microdata from national household survey instruments in 78 countries (for example, population censuses, labour-force surveys and household income expenditure surveys) were used (Supplementary Section B3.3). Primary data collection took place only when secondary sources were not available (for inland Brazil and coastal China, for example). Countries were selected on the basis of the absolute contribution to global fisheries production and employment; the relative importance of the fisheries sector in a given country (that is, production and employment per capita); the importance of fish as a source of protein in people's diet; and ensuring geographic balance (Supplementary Table A2 shows data sources, the full set of criteria and decision rules for the selection process). For this study, only capture fisheries were included in the analysis (excluding recreational fisheries and aquaculture; Supplementary Section A4). It is possible that some retained recreational fisheries catch has 'polluted' SSF catch data, particularly for inland fisheries in Europe, and to a lesser extent in North America, for which FAO data were used (Supplementary Section C3 and Annex 3 of ref. 141).

To accommodate the diversity and heterogeneity of fishing fleets considered to be 'small-scale', an a priori, standard definition was not used. Our rationale to avoid the use of technological metrics such as vessel size or gear type as cut-off points to define SSF is that, in some cases, legitimate SSF might be excluded, or large-scale operations might be included as part of the small-scale fishing fleet. Instead, experts compiled data following the most common legal or operational definition in use in each country, and comparability was assured because the same metadata about each fishery unit was collected, regardless of how each fishery unit was initially defined (Supplementary Sections A4 and A5). Case-study data were corroborated and validated by consultation with external global fisheries experts, comparison with responses to an ad hoc questionnaire that the FAO sent to all countries, and with the FAO's capture-fisheries database[56] and ref. 74 (Supplementary Sections A6 and A7). The compiled country case-study catch data (in tonnes), grouped by functional groups of species (Extended Data Fig. 2) for the years 2013–2017, were used as inputs to a regression model used to predict the catches of 152 countries using a set of suitable predictor variables (Supplementary Section B1). For marine catch, final predictors included gross domestic product, SSF jobs and region (Supplementary Section B1.1). For inland catch, final predictors included FAO landings data and world region (Supplementary Section B1.2). The FAO capture-fisheries production database is primarily based on official statistics submitted by countries, but complemented or replaced, when necessary, with data from other sources (such as fisheries regional bodies). The FAO has established a series of mechanisms to ensure that the best available information is submitted, revised and validated. However, it is acknowledged that official statistics often underestimate SSF catches, particularly those from inland fisheries, supporting the need to improve national statistical collection with the aim of better representing inland and marine SSF landings. Variances of catch estimates for case-study countries were based on qualitative confidence assignments to each country, whereas variances of catch predictions for extrapolated countries were based on regression model outputs (Supplementary Section B1). Catch estimates and variances were summed across all countries to calculate the global and regional catch contributions of SSF (Fig. 1a). Aggregate 95% confidence intervals are shown in Extended Data Table 1. Country-level predictions do not constitute empirically observed data and are no replacement for observational data for the purpose of country-level analyses. A sensitivity analysis considered an alternative set of estimates of the percentage coverage of SSF catch records in each country, which were used to expand national estimated catches (Supplementary Section B1.3). Landed economic value was estimated using species catch and annual average ex-vessel price data from country case studies as inputs and external global data on fishery-related variables driving the price and value of fisheries (for example, stock biomass or resource status, fishing technology used or fishing effort) to generate global predictions by statistical modelling and global extrapolation (Supplementary Section B2). For employment and livelihood dependency, data from national household surveys were used as inputs to produce global estimates by extrapolation (Supplementary Section B3 and ref. 28), and estimates were triangulated and validated using country case-study data and extra external datasets (such as FAO data on employment in fisheries, responses to the FAO ad hoc questionnaire, and global marine fishing fleet effort data[142]). Regional and global gender distribution was estimated by extrapolation and imputation of average gender ratios and triangulated with the ad hoc questionnaire responses and the country case studies (Supplementary Section B3.4.1 and ref. 74).

To calculate the potential contribution of SSF to local diets in Fig. 1a, fish catch data for the 58 country case studies were supplemented with extrapolated global catch data for all 186 countries, resolved to functional group level. Second, existing databases were used to extract fin-fish (www.fishbase.org) and invertebrate (INFOODS) nutrient concentrations, for six micronutrients (calcium, iron, selenium, zinc, vitamin A and omega 3). Although fatty acids are not defined as micronutrients, because the recommended intake for omega 3 fatty acids that are concentrated in aquatic foods (EPA and DHA) is within the micronutrient range, we refer collectively to all six nutrients as micronutrients important to human health, often lacking in diets but found in aquatic foods[143]. These concentrations were assigned to each species, genera, family, order and class in the reported catch, in order of descending priority[144], to estimate the catch-weighted average micronutrient concentration (for each of the six nutrients) of each functional group in each country, for the marine and inland sub-sectors. Third, catch-weighted average micronutrient concentration of each country's functional group were multiplied by the annual catch (in tonnes) and the edible portion[144,145], before summing across functional groups, to calculate, for each of the six nutrients, each country's micronutrient supply from SSF. Each country's daily micronutrient supply from SSF (average annual edible catch × nutrient concentration of catch/365) was used to calculate the per capita supply of micronutrients from SSF (daily micronutrient supply/coastal population), based on the population living within 20 km of a marine coastline or inland body of water (lakes with an area of more than 50 km^2 and reservoirs with a storage capacity of 0.5 km^3 or more). The sensitivity of these results to coastal population size was tested by estimating micronutrient intake for populations within buffers of 10 km, 20 km and 30 km. The per capita supply of micronutrients from SSF relative to each country's per capita nutrient supply was estimated from all foods using dietary intake data from the Global Dietary Database[146]. These contributions were then averaged across the six nutrients to give the average contribution of SSF catch to per capita dietary micronutrient intake. Finally, the contribution of SSF to micronutrient supply from all fisheries (Fig. 1b) was estimated relative to the total supply from global fisheries[147].

Governance analyses relied on the country case-study governance dataset containing 976 observations of diverse governance arrangements and associated catch (in tonnes), accounting for 61% of the estimated global catch in 51 countries (7 countries did not provide governance data). The fishery unit concept allowed linking catch with governance data (Supplementary Section A5). The FAO-LEX database (https://www.fao.org/faolex/en/) was also used for corroboration and gap filling. The analysis of the presence of different types of tenure rights (management, exclusion and transferability) in each governance arrangement follows ref. 95. For definitions, main assumptions and caveats, see Supplementary Section B5.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

Input files are available at Zenodo at https://zenodo.org/records/13887065 (ref. 148). All companion data, including a list of all input files (Supplementary Section F), can be found in the Supplementary Information. Source data are provided with this paper.

Code availability

Data were analysed using Microsoft Excel (Excel 2021 v.18.0), Stata (v.17) and R (v.4.2.0 and v.4.3.1). R packages: rnaturalearth (v.1.0.1.9000), simple features (unique version) and raster (v.3.6-30). To reproduce analyses, tables and figures, please refer to https://github.com/DanOvando/ihh_figs.

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Author contributions N.F. and L.W. conceived the Illuminating Hidden Harvests project. M.d.M.M.-C., X.B., S.F.-S., N.F., G.G., N.L.G., D.J.M., S.V., J.V. and L.W. designed and operationalized baseline data collection (two tiers: credit for initial effort then alphabetical). X.B., S.F.-S., S.H., D.J.M., N.L.G. and J.V. led the development and design of each thematic stream (all alphabetical). E.H.A., C.M.A., A.B., X.B., J.C., M.F., N.F., S.F.-S., G.G., N.L.G., S.H., C.C.H., J.K., M.d.M.M.-C., D.J.M., G.N., A.M.P., S.H.T., S.V., J.V. and L.W. provided feedback on project design, data collection and preliminary analysis (all alphabetical). M.d.M.M.-C., G.G., X.B., S.F.-S., N.L.G., D.J.M. and J.V. supervised data collection, screening, organization for analysis and preliminary analyses (credit then alphabetical). X.B., N.F., S.F.-S., G.G., N.L.G., M.d.M.M.-C., D.J.M., G.N., S.V. and J.V. compiled final global datasets (all alphabetical). X.B. and N.L.G. conceived the paper (alphabetical). X.B., N.L.G. and A.A. wrote the paper. A.A., X.B., N.F., S.F.-S., G.G., N.L.G., M.d.M.M.-C., D.J.M., M.C.M., G.N., D.O., A.M.P., J.P.W.R., A.T., S.V. and J.V. contributed analytical tools, statistical analyses and analysed data (alphabetical). X.B., N.L.G., A.A., N.F., E.H.A., C.M.A., A.B., J.C., M.F., S.F.-S., G.G., S.H., C.C.H., J.K., M.d.M.M.-C., D.J.M., M.C.M., G.N., D.O., A.M.P., J.P.W.R., A.T., S.H.T., S.V., J.V. and L.W. reviewed the draft and provided comments and input (credit then alphabetical).

Competing interests The authors declare no competing interests.

Additional information

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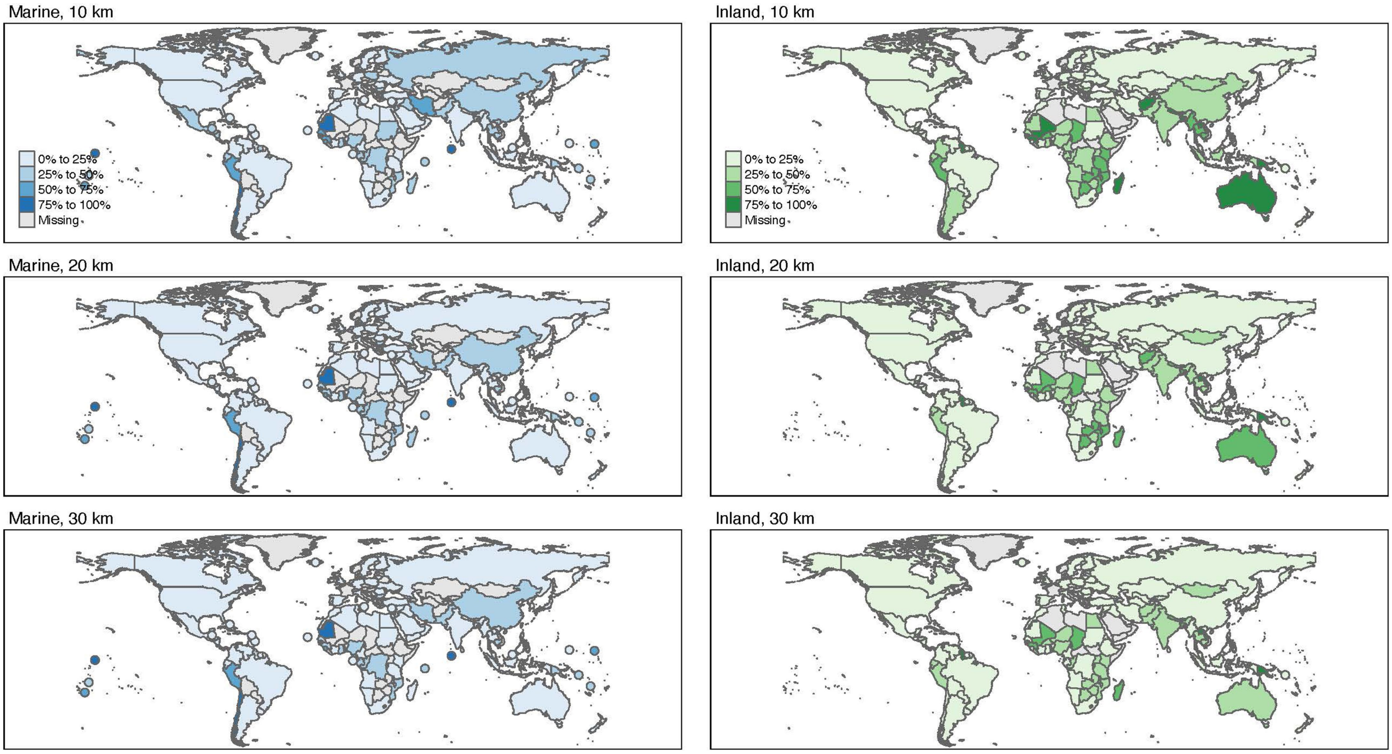
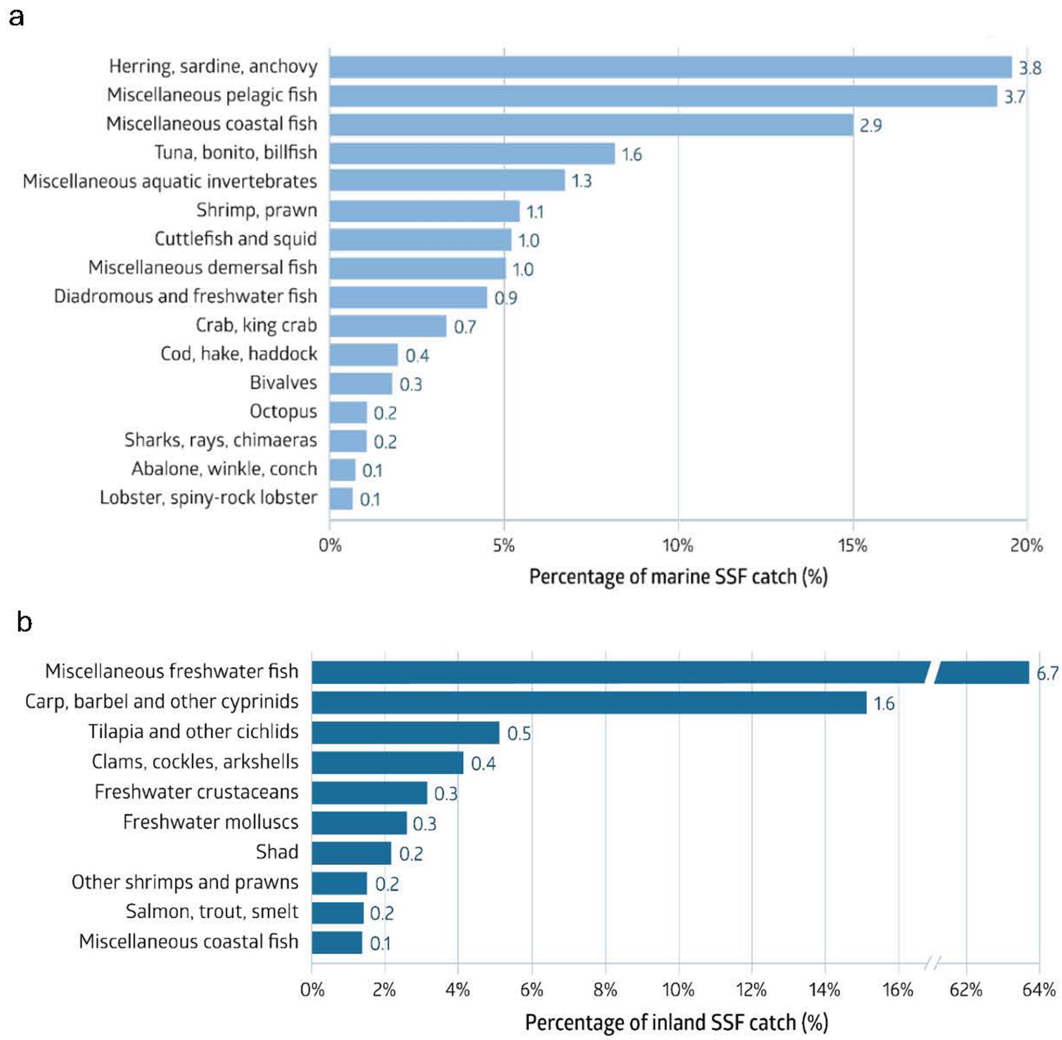
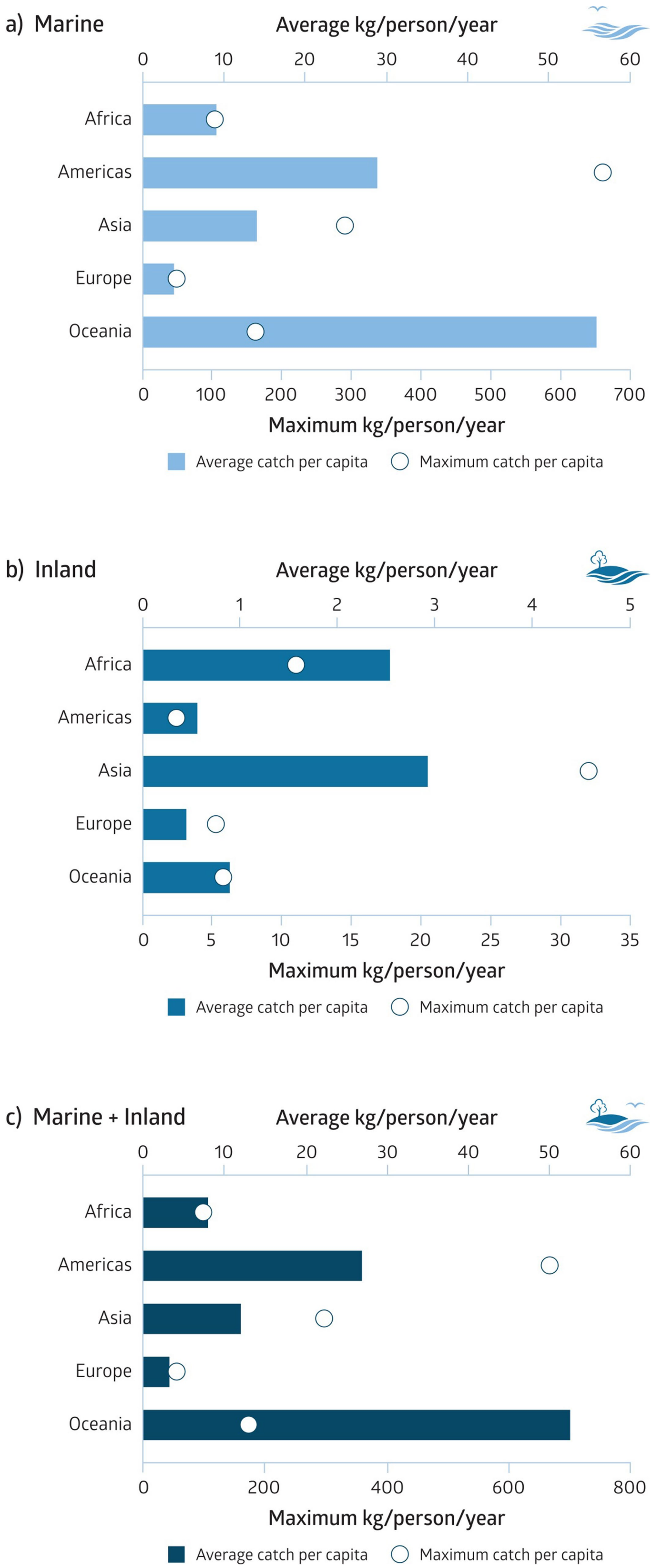


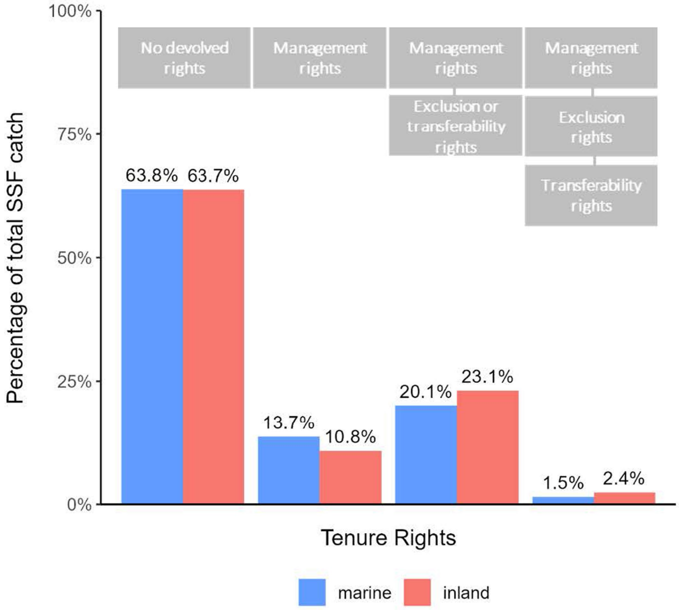
Extended Data Fig. 1 | Contribution of marine and inland small-scale fisheries to micronutrient intakes. Average per country for 10 km, 20 km, and 30 km buffers.



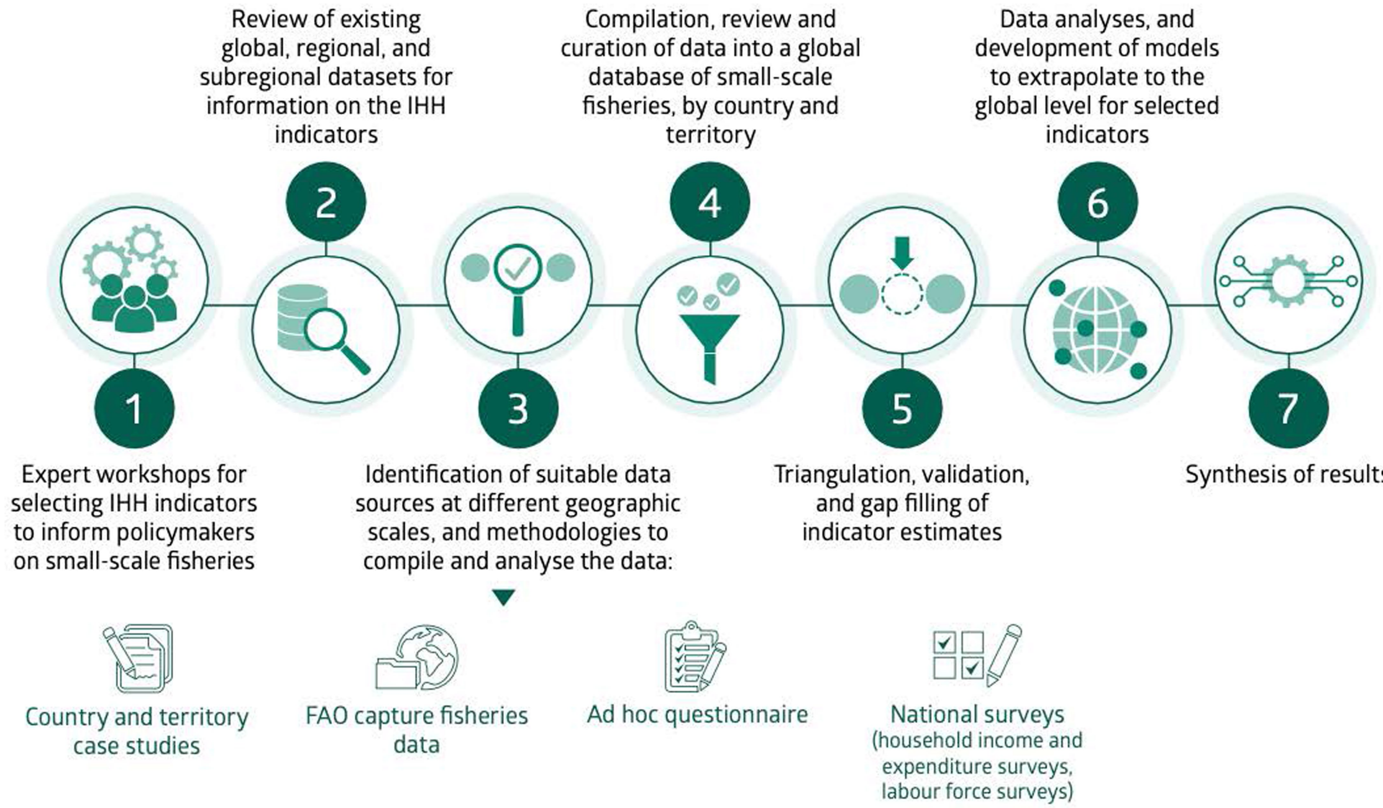
Extended Data Fig. 2 | Global estimates of percentage of small-scale fisheries catch by functional group for (a) marine and (b) inland. Numbers on bars represent catch volumes in million tonnes (averages annual values, 2013–2017). Graph represents 77% and 91% of estimated global marine and inland small-scale fisheries catch respectively. The remaining 23% and 9% was not associated to any specific functional group. Functional groups contributing <1% are not shown. Source: Gutierrez et al. 2023 in Supplementary Literature.



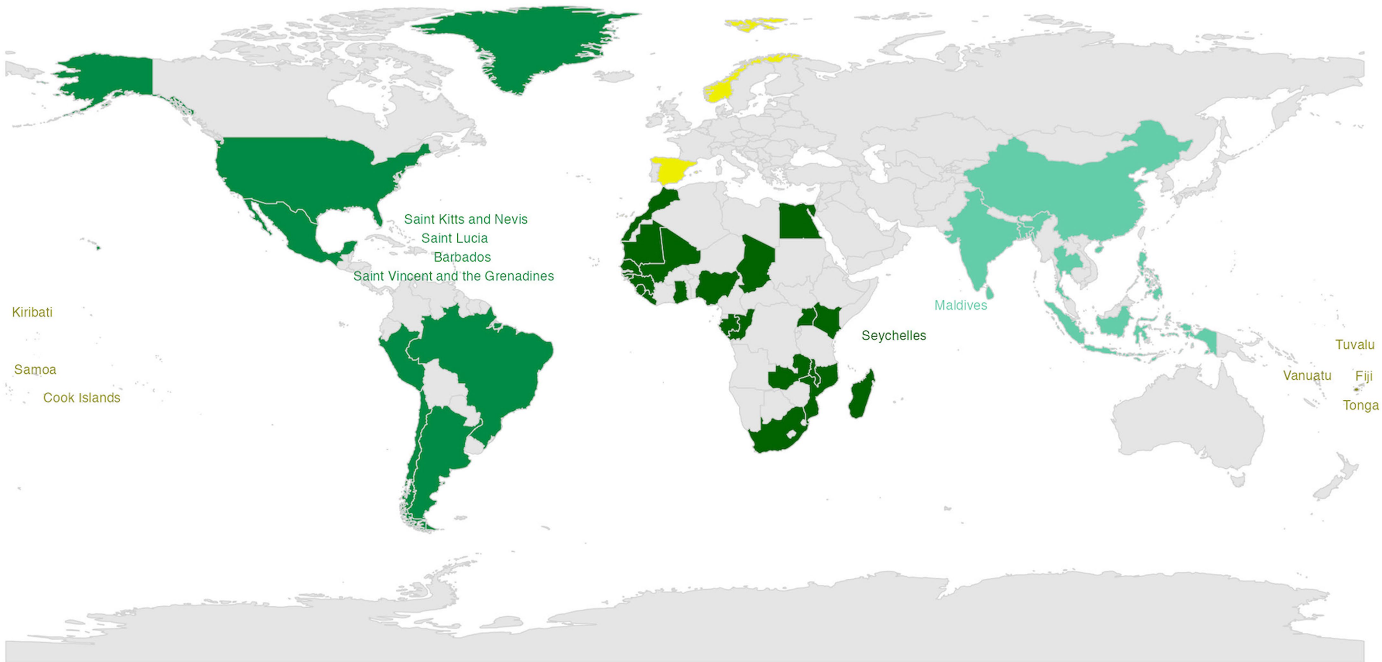
Extended Data Fig. 3 | Global estimates of small-scale fisheries catch per capita by region. Average annual values for 2013–2017 for a) marine, b) inland, and c) marine and inland. Source: Gutierrez et al. 2023 in Supplementary Literature.



Extended Data Fig. 4 | Percentage of marine and inland small-scale fisheries catch with different levels of rights devolution. Analysis based on formally governed small-scale fisheries policies from 45 marine and 34 inland countries. Combinations of rights not included in the figure: 0.9% transferability rights for marine. Source: Modified from Basurto et al. (2023) in Supplementary Literature.



Extended Data Fig. 5 | Schematic representation of the overall research process. Adapted from Mancha-Cisneros et al. (2023) in Supplementary Literature.



Extended Data Fig. 6 | Map of countries included as case studies in this study by region. Adapted from Mancha-Cisneros et al. (2023) in Supplementary Literature. Africa: Chad, Congo, Democratic Republic of the Congo, Egypt, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia (marine only), Madagascar, Malawi, Mali, Mauritania (marine only), Morocco (marine only), Mozambique, Nigeria, Senegal, Seychelles, Sierra Leone (marine only), South Africa, United Republic of Tanzania, Uganda and Zambia; Americas: Argentina, Barbados, Brazil, Chile, Greenland, Mexico, Peru, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines and United States of America (marine only); Asia: Bangladesh, China, India (marine only), Indonesia, Iran (Islamic Republic of), Lao People's Democratic Republic, Maldives, Philippines, Sri Lanka, Thailand, Türkiye and Viet Nam (marine only); Europe: Norway (marine only), Spain, and United Kingdom of Great Britain and Northern Ireland (marine only); Oceania: Cook Islands, Fiji, Kiribati, Samoa, Tonga, Tuvalu and Vanuatu.

Extended Data Table 1 | Absolute contributions of small-scale fisheries

Region	Catch (in tonnes)		Micronutrients (average contribution to dietary micronutrient intake, %)		People employed (Marine and Inland)	Women employed (Marine and Inland)	Livelihoods (Marine and Inland)
	Marine	Inland	Marine	Inland			
Africa	**3,143,100** (2,399,426 - 4,117,268)	**3,090,970** (2,611,182 - 3,658,915)	**22.9%** (0.7 - 75.6)	**32.0%** (1.8 - 80.1)	**8,960,421** (7,857,891 - 10,062,950)	**2,646,206** (2,251,226 - 3,041,187)	**59,567,680** (53,015,050 - 66,120,310)
Americas	**5,017,453** (3,601,103 - 6,990,868)	**582,341** (362,482 - 935,555)	**15.2%** (1.1 -53.1)	**13.5%** (4.5 - 43.3)	**3,600,148** (2,874,468 - 4,325,828)	**1,179,244** (906,658 - 1,451,831)	**17,685,637** (14,572,992 - 20,798,292)
Asia	**15,685,351** (11,445,697 - 21,495,437)	**7,993,883** (3,442,211 - 18,564,276)	**16.8%** (2.2 - 53.3)	**24.1%** (9.2 - 47.7)	**46,132,988** (40,471,300 - 51,794,680)	**16,516,120** (14,521,780 - 18,510,470)	**403,885,600** (370,896,300 - 436,874,900)
Europe	**861,141** (405,343 - 1,829,472)	**408,225** (50,523 - 3,298,452)	**8.1%** (0.3 - 22.2)	**3.3%** (0.1 - 12.4)	**978,383** (646,449 - 1,306,964)	**357,528** (220,627 - 494,432)	**4,241,897** (3,214,339 - 5,269,455)
Oceania	**392,693** (68,229 - 2,260,161)	**107,856** (10,672 - 1,090,091)	**35.6%** (6.5 - 67)	**41.7%** (28.9 - 51.6)	**528,788** (472,279 - 573,684)	**160,250** (138,017 - 178,889)	**6,357,078** (5,677,427 - 6,418,126)
GLOBAL	**25,099,739** (20,231,912 - 31,138,772)	**12,183,276** (6,840,205 - 21,699,965)	**17.7%** (1.5 - 53.6)	**20.0%** (4.6 - 46.5)	**60,200,729** (52,322,387 - 68,064,106)	**20,859,349** (18,038,307 - 23,676,808)	**491,737,892** (447,376,108 - 535,481,083)

Global and regional contributions of marine and inland small-scale fisheries for catch, micronutrients, employment, livelihoods and women's employment. Total and women's employment include pre-harvest, harvest and post-harvest activities. Livelihoods include employed/subsistence fishers plus partial or fully dependent household members. In parentheses 95% confidence intervals are shown for catch, employment and livelihoods. Micronutrient values are the average contribution to dietary intake of six micronutrients (calcium, iron, selenium, zinc, omega-3 fatty acids, vitamin A) for coastal populations, where uncertainty is the lowest and highest value for individual micronutrients. Although fatty acids are not defined as micronutrients, because the RI (recommended intake) for omega-3 fatty acids that are concentrated in aquatic foods (EPA and DHA) is within the micronutrient range, here we refer collectively to all six nutrients as micronutrients.

Extended Data Table 2 | Summary of other initiatives aimed at estimating global small-scale fisheries (SSF) catch

	This study		Bottom-Up, Global Estimates of Small-Scale Marine Fisheries Catches	Sea Around Us Database	Hidden Harvest		Global hidden harvest of freshwater fish revealed by household surveys	A review of major river basins and large lakes relevant to inland fisheries	Putting the fish into inland fisheries – A global allocation of historic inland fish catch
	Marine	Inland	Marine	Marine	Marine	Inland	Inland	Inland	Inland
SSF Catch	25.10 mt	12.18 mt	21 mt	27.4 mt	34 mt	14 mt	16.6 mt	15.2 mt	17.4 mt*
Year	2013-2017		2000	2013–2017	2004-2007		Range: 2008 (median year)	78% of catch (1960–2018 rivers, 1980–2018 lakes)	1960–2018
Working definition of SSF and approach used	Country and territory case study (CCS) experts used the national (legal and/or operational) definitions of SSF. Data was compiled from 58 CCS (68% of global capture production). Although most data came from official sources (68% and 88% for marine and inland respectively), other data and approaches were considered. Catches from 58 CCS were extrapolated to global levels.		Study assumed SSF activities in each country take place within "inshore fishing areas", defined as shelf area ranging from shoreline to 50 km in distance or 200 m in depth, whichever comes first	Study covered commercial SSF (named artisanal) plus subsistence fisheries. FAO FishStat global capture production database was used as a basis, with figures augmented or allocated to estimate SSF catch	Study used national definitions of SSF and compiled information from 17 case studies to derive a global picture of inland and marine capture fisheries		Study only covered inland fisheries, with all assumed to be SSF. A modeling approach built on household expenditure and consumption surveys from 42 countries was used. An extrapolation model was developed to derive a global estimate	Study only covered inland fisheries, with all assumed to be small-scale fisheries. Using a river basin approach, the reported catches for different fishery components were compiled to give a basin estimate. FAO FishStat inland fisheries catch data for countries outside of the basins were added to give a final value	Similar approach than Ainsworth et al. 2021, but including a model to calculate upper and lower range catch estimates and the literature
Input data/ information and extrapolation	CCS in 58 countries and territories and extrapolated to 196 countries and territories		~84 country case studies with catch data available; extrapolation to 140 countries using a modeling approach	204 countries and territories; based on FAO FishStat data and adjusted or reconstructed for catch not reported in official data	17 developing and 11 developed countries extrapolated to global level, using fixed assumptions		Consumption data from 42 countries extrapolated to 38 additional countries (total 80), representing 93.4% of global catch reported to FAO in 2008	Global estimate compiled from research data of fisheries within a basin for major hydrological basins; FAO FishStat data used for countries that lie outside major basins	Same than Ainsworth et al. 2021
Reference	This study		Chuenpagdee, R., Liguori, L., Palomares, M.L.D. & Pauly, D. 2006. Bottom-up, global estimates of small-scale marine fisheries catches.	Zeller, D.,et al. 2016. Still catching attention: Sea Around Us reconstructed global catch data, their spatial expression and public accessibility. Marine Policy, 70: 145–152	World Bank. 2012. Hidden harvest: the global contribution of capture fisheries. Washington, DC.		Fluet-Chouinard, E., Funge-Smith, S. & McIntyre, P.B. 2018. Global hidden harvest of freshwater fish revealed by household surveys. Proceedings of the National Academy of Sciences of the United States of America, 115(29): 7623–7628	Ainsworth, R., Cowx, I.G. & Funge-Smith, S.J. 2021. A review of major river basins and large lakes relevant to inland fisheries. FAO Fisheries and Aquaculture Circular No. 1170. Rome, FAO. https://doi.org/10.4060/cb2827en	Ainsworth, R., Cowx, I.G. & Funge-Smith, S.J. 2023. Putting the fish into inland fisheries – A global allocation of historic inland fish catch. https://doi.org/10.1111/faf.12725

*As mentioned by the authors, this figure is considered a likely maximum due to recent reductions in catches because of closures, threats, and fisheries declines in the most productive fisheries.

Extended Data Table 3 | Small-scale fisheries (SSF) supply, aquatic food consumption and contribution to daily intake of 6 micronutrients for coastal populations in 177 countries, averaged by region and marine or inland sectors

		SSF available	Aquatic food intake	SSF contribution to aquatic food intake	SSF contribution to total dietary micronutrient intake, %							Catch retained locally*	Dietary population (million)
		g/day/person	*g/day/person*	*%*	*Average*	*Calcium*	*Iron*	*Omega 3*	*Selenium*	*Vitamin A*	*Zinc*	*%*	*<20km of SSF*
Africa	Inland	97.1	32.9	76.9	32.0	22.5	12.3	80.4	56.0	1.8	18.9	84.0	146.1
	Marine	68.1	43.1	60.8	22.9	13.9	9.5	75.6	26.2	0.7	11.6	57.0	180.9
Americas	Inland	215.5	21.7	44.6	13.5	5.4	7.7	43.3	13.4	4.5	7.0	82.0	196,9
	Marine	45.1	24.8	65.1	15.2	6.2	8.1	53.1	14.7	1.1	7.7	68.0	254.9
Asia	Inland	614.1	38.6	56.9	24.1	19.7	12.0	47.7	37.7	9.2	18.4	96.0	359.6
	Marine	86.8	43.1	53.1	16.8	9.6	6.9	53.3	20.4	2.2	8.4	90.0	857.8
Europe	Inland	4.6	32.5	12.1	3.3	0.6	0.5	5.7	12.4	0.1	0.5	-	78.4
	Marine	12.8	35.2	39.0	8.1	1.8	1.9	20.2	22.2	0.3	2.0	38.0	156.4
Oceania	Inland	400.6	21.7	53.7	41.7	44.5	35.8	51.6	51.0	28.9	38.7	-	3.8
	Marine	238.0	39.1	84.9	35.6	29.8	29.9	67.0	47.5	6.5	32.7	99.0	24.9
Global mean	Inland	235	31.8	49.6	20.0	14	9.2	46.5	32.8	4.6	12.7	87.3	784.9
	Marine	69.8	37.1	57.5	17.7	10	8.6	53.6	23.1	1.5	9.7	70.4	1,474.8
	Global	**149.2**	**34.6**	**53.7**	**18.8**	**11.9**	**8.92**	**50.2**	**27.8**	**3**	**11.2**	**78.9**	**2,259.7**

Contributions to required nutrient intake (RNI) or aquatic food consumption are capped at 100% (e.g. for Oceania where small-scale fisheries supply exceeds consumption rate). Inland populations in Oceania were not detectable as there were no large water bodies in that region in our spatial analysis. Aquatic food consumption from Global Dietary Database (2018). *Catch retained locally was only available for country case studies (CCS).

Extended Data Table 4 | Global and regional landed value (in USD billion; generated by multiplying catch and first-sale price) for marine and inland small-scale fisheries including country case studies and extrapolations

Region	Landed value (USD billion)	
	Marine	Inland
Africa	**4.25** (3.99 - 4.49)	**5.66** (5.05 - 6.22)
Americas	**9.83** (9.21 - 10.41)	**0.81** (0.73 - 0.89)
Asia	**41.38** (37.98 - 44.51)	**11.97** (10.42 - 13.33)
Europe	**2.04** (1.92 - 2.15)	**0.59** (0.52 - 0.66)
Oceania	**0.61** (0.56 - 0.65)	**0.016** (0.013 -0.018)
GLOBAL	**58.11** (53.66 - 62.23)	**19.05** (16.73 - 21.11)

In parentheses 95% confidence intervals are shown.

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Reporting Summary

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For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a	Confirmed	
☐	☒	The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement
☒	☐	A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☒	☐	The statistical test(s) used AND whether they are one- or two-sided *Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
☐	☒	A description of all covariates tested
☐	☒	A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
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☒	☐	For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒	☐	For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☒	☐	Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	Data was collected using Microsoft Excel (Excel 2021 version 18.0) and Stata (version 17)
Data analysis	Data was analyzed using Microsoft Excel (Excel 2021 version 18.0), Stata (version 17) and R (version 4.2.0 and 4.3.1). R packages: rnaturalearth (version 1.0.1.9000), simple features (unique version) and raster (version 3.6-30). R codes available at https://zenodo.org/records/13887065 and https://github.com/DanOvando/ihh_figs

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Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our policy

The data used in this analysis are publicly available on zenodo (https://zenodo.org/records/13887065). The file “1_non_anon_SI_input_data.zip” is organized into folders by dimension (employment, catch, landed value, nutrition and governance), with their corresponding data described in Section F of the Supplementary

Material. Outputs from the regression analysis from each dimension are available in the "3_anon_figures.zip" in zenodo. Since we considered as input data only the observations made for 58 countries, plus the independent variables used to make predictions for the rest of the countries, country-level model based extrapolations have been anonymized. Processed data used to create figures, including absolute and relative estimates of small-scale fisheries by country and region for all dimensions, can be accessed at https://github.com/DanOvando/ihh_figs. For the nutrient analysis, the dietary intake data from the Global Dietary Database used is available at: https://globaldietarydatabase.org, and the nutrient concentration data at www.fishbase.org

Human research participants

Policy information about studies involving human research participants and Sex and Gender in Research.

Reporting on sex and gender	No human research participants were involved in the study so this is not applicable
Population characteristics	Not applicable
Recruitment	Not applicable
Ethics oversight	Not applicable

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☐ Behavioural & social sciences ☒ Ecological, evolutionary & environmental sciences

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Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	Data on the contributions of small-scale fisheries to each dimension of sustainable development was compiled and synthesized through a transdisciplinary approach resulting in a database that provides estimates on catch, landed economic value, livelihood dependency, employment, number of women employed, nutrient supply and governance per country
Research sample	Data on small-scale fisheries catch was compiled through 58 country and territory case studies (20 strictly marine, 6 strictly inland, and 32 combined marine and inland). The compiled case study data was used as inputs for extrapolation to 152 countries using a set of suitable predictor variables. Governance data uses policy information from 51 case studies. For employment and livelihoods dependency, we used existing data from 78 standardized national household-based surveys. Empirically collected data for 58 countries is provided as described above. Names of countries resulting from extrapolations have been randomized to avoid confusing them with empirically generated data.
Sampling strategy	A prioritization approach was developed to select candidate countries as case studies. Countries were selected according to different criteria, including their contributions to global fisheries catch, small-scale fisheries catch and employment in fisheries, in order to cover a representative sample, as well as the role of fisheries within countries, e.g. looking at catch per capita and the importance of fish in the diet, to select countries with low absolute contribution but with high relative importance. The selection criteria allowed the selection of both countries with high absolute contributions to global fisheries indicators and countries where, despite low global contributions, fisheries played an important role.
Data collection	Data was collected by in-country and international experts in small-scale fisheries for each of the 58 countries included in the study. The total number of experts involved was over 800
Timing and spatial scale	From 2013 to 2018
Data exclusions	Some estimates did not include data from 2018 due to patchiness
Reproducibility	Not applicable, no experiments were conducted
Randomization	Not applicable as per sampling strategy described above
Blinding	Not applicable

Did the study involve field work? ☐ Yes ☒ No

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
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☒	☐ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging