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### ► To cite this version:

R. Bitoun, Marc Léopold, T. Razanakoto, R. Randrianandrasana, S. Akintola, et al.. A methodological framework for capturing marine small-scale fisheries' contributions to the sustainable development goals. *Sustainability Science*, 2024, 10.1007/s11625-024-01470-0 . hal-04468704

**HAL Id: hal-04468704**

**<https://hal.science/hal-04468704>**

Submitted on 9 Apr 2024

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# A methodological framework for capturing marine small-scale fisheries' contributions to the sustainable development goals

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## Abstract

Small-scale fisheries (SSF) receive increasing international attention for landing around 40% of global marine fisheries catches and employing millions of people globally. Their contributions to food security and poverty alleviation, especially in developing countries, make it relevant to consider them when discussing Sustainable Development Goals (SDGs). Achieving SDGs by supporting SSF means understanding fisheries in their broader context, from the health of marine ecosystems to social and economic features such as employment, public health, culture, and the effects of global change. Social ecological relationships in SSF are complex and poorly understood, thus challenging the identification of policies that could improve and preserve the contributions of SSF to sustainable development. Here, we developed an expert-based rapid appraisal framework to identify and characterize the relationships between SSF and SDGs. The framework serves as a diagnostic tool for identifying strengths and gaps in SSF potential in enhancing SDG achievement in data-limited situations. Our structured approach extends beyond SDG 14 and target 14.b, offering insights into SSF's contributions to 11 other SDGs. As a proof of concept, we illustrate the approach and its potential contributions in two case studies in Madagascar. The method effectively captured the multiple dimensions of the SSF through the SDG lens, providing a contextually relevant understanding of how global UN goals can be achieved locally. Further research is needed to define mechanisms for aggregating and reporting the multiple, case-specific contributions of SSF to monitor progress toward the SDGs at national and global levels.

### Keywords

Expert knowledge; Pathways approach; SDG; Social-ecological Systems; Sustainability science.

## Introduction

The United Nations (UN) released its Agenda for 2030 in 2015, consisting of 17 interrelated Sustainable Development Goals (SDGs; UN, 2015; Fig. 2) and 169 associated targets that can be used to evaluate and promote sustainable development. This agenda, based on aspirational targets, is part of a wider shift towards governance through non-legally binding global goal-setting strategies. At the same time, global targets must be scaled down and adapted to national and local contexts to affect change (Biermann et al., 2017).

Central to the SDGs, is the concept of sustainable development, that can be defined as “meeting the social, environmental and economic needs of the present without compromising the ability of future generations to meet their needs” (UNDP 2023). The SDGs emphasize the interconnectedness between these multiple dimensions of sustainability (UN, 2014), offering a framework that allows explicating trade-offs and synergies between those dimensions (e.g., increasing agriculture can help reduce poverty and provide food while impacting biodiversity). While various frames conceptualize sustainability transformations (e.g., Blythe et al., 2018; Evans et al., 2023), we used a mixed approach based on transformation pathways of social ecological systems (SES) (Moore et al. 2014; Olsson et al. 2014; Beland Lindahl et al., 2016). Achieving sustainability, indeed, could necessitate exploring multiple ways of getting there (i.e., pathways), each with its social, economic, and environmental implications and challenges (Leach et al., 2010; Franke et al., 2020). Striving

for sustainable practices involves a dynamic political process marked by conflicts between such pathways and the transformations required (Leach et al. 2012; Blythe et al. 2021). The scope of transformative change varies, encompassing modifications in single or multiple elements of a SES, varying in depth from radical to incremental, and in speed from adaptive to abrupt changes in response to external shocks. Such approaches to conceptualize sustainability are gaining traction in research and policy discussions, especially within the context of the SDGs (Ely, 2022). To help chart new trajectories to secure a more sustainable and equitable future, the SDGs can be a valuable instrument for measuring the multifaceted aspects of sustainability and gauging the effects of different pathways across these dimensions.

Our study focuses on small-scale fisheries (SSF) and the way this sector contributes, or not, to the SDGs. This focus stems from the recognition that SSF are key stakeholders of oceans and coasts globally. Indeed, SSF account for at least 40% of the global catch of capture fisheries, employ 60.2 million people along the value chain, representing 90% of the global fisheries' workforce (FAO et al., 2023). The United Nations General Assembly declared 2022 the International Year of Artisanal Fisheries and Aquaculture (IYAF 2022) to raise awareness about the role of SSF in achieving multiple SDGs via their contributions to human well-being, healthy food systems, and environmental conditions. Indeed, SSF are generally more resource-efficient than industrial fisheries and contribute more to societal and economic SDGs, especially in least developed countries (Said and Chuenpagdee 2019). SSF can help reduce malnutrition (SDG 3: Good health and well-being) and hunger (SDG 2), especially in coastal communities, where fish is a primary source of protein and micronutrients (e.g., Arthur et al., 2022; Béné et al., 2016). For example, 50% of West African protein intake is supplied with fish resources largely harvested by SSF (Ahern et al., 2021). Moreover, consumption of fish, especially fatty fish, has shown benefits in reducing cardiovascular diseases (Li et al., 2020; SDG 3). SSF are often more resource-efficient in their production systems (SDG 12: Responsible consumption and production) when compared with large-scale fisheries, providing high nutrition levels (SDG 3) at the lowest environmental impact (Koehn et al., 2022). SSF also hold cultural importance for fishing communities (Short et al., 2021). Finally, they are the most labor-intensive oceans-related profession (SDG 8: Decent work and economic growth), providing more employment than industrial fisheries, oil and gas, shipping, and tourism combined (OECD, 2016).

Like other users of oceans and coastal areas, SSF face numerous challenges that influence their sustainability (Weeratunge et al., 2013). These include changes related to climate and environment, population and demographics, and management and governance (Chuenpagdee et al., 2005). Overfishing and pollution have significantly impacted marine biodiversity, reducing fish resources, particularly in tropical and subtropical waters (Dulvy et al., 2021). Global estimates indicate increased over-exploited stocks from 10% in 1974 to 35.4% in 2019 (FAO, 2022). Degrading environmental conditions in SSF-dependent nations could exacerbate social concerns regarding food security, employment, and social justice (Nash et al., 2020). Yet, regardless of the significance of SSF and their potential to address numerous SDGs, existing research on the ecology of SSF and their response to global changes is insufficient and scattered (Smith et al., 2021). Moreover, despite notable advancements on paper for SDG 14.b ("Provide access of small-scale artisanal fishers to marine resources and markets") globally (Our World in Data team, 2023) – with countries reporting high levels of policy implementation in favor of SSF right protection – equitable

access to resources remains unguaranteed for many SSF communities in practice. Large-scale fisheries and ocean industries operate in the same area, competing directly and indirectly with SSF for resources and space, making it difficult for SSF to maintain their livelihoods (Arias Schreiber et al., 2022). Additionally, small-scale fishers around the world face losses of fishing grounds caused by offshore wind energy and oil infrastructures (Arbo and Thủy, 2016), touristic developments (Cisneros-Montemayor et al., 2019), non-negotiated area protections (Cohen et al., 2019), coastal industrial developments, and other forms of ocean 'grabbing' (Bennett et al., 2015).

The arguments about the contributions of SSF to several SDGs highlight some of the reasons for developing the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (SSF Guidelines; FAO 2015), which closely relate to SDGs 1, 2, 5, and 14. Yet, as recognized in the SSF Guidelines, SSF contributions to the SDGs are not easy to assess and thus, are undervalued, due to the nature and the characteristics of the sector (Chuenpagdee et al., 2019). For instance, unlike large-scale fisheries, SSF are not always organized as formal business enterprises, their role in the economy may be informal. They are often embedded in communities, contributing to food security, local employment, cultural heritage, and social cohesion (Jentoft, 2019). SSF are multidimensional and diverse along a continuum spanning from low-tech artisanal fisheries to semi-industrial fleets, making them difficult to define using single metrics (Smith and Basurto, 2019). They encompass multiple activities along the value chain, including pre-harvest, harvest, and post-harvest operations (FAO, 2015). However, when assessing SSFs, technical definitions based on characteristics such as boat length, engine size, gear type, financial capital, and distance traveled from shore overlook the full scope of SSF activities such as gear mending and fish processing, a challenge being amplified by a general lack of data on SSF (Chuenpagdee et al., 2006; Smith and Basurto 2019).

Achieving sustainability in SSF requires a nuanced approach, considering the interconnectivity between environmental, economic, and social concerns, that together impinge on access. Considering sustainability as multidimensional can help steer a balanced development across SDG dimensions (Nash et al., 2020) and ensure no one is left behind (Sachs et al., 2022). Recognizing and measuring SSF contributions to SDGs could therefore provide a basis to engage in discussions about their sustainability, through a preliminary understanding of the multidimensionality of these SESs.

The contributions of the fisheries sector to the SDGs have received some attention. Singh et al. (2018) demonstrate how achieving SDG 14 (Life below water) can be synergistic with other goals. Inversely, Said and Chuenpagdee (2019) have shown that achieving target 14.b on SSF requires simultaneous progress in other SDGs relating to economic growth (SDG 8), Sustainable cities and communities (SDG 11), Peace, justice, and strong institutions (SDG 16), and Partnerships for the goals (SDG 17). Lynch et al. (2020) propose a comprehensive analysis of the contributions of inland SSF to the SDGs – virtually absent from the UN's agenda – through an ecosystem service analysis. The frameworks developed by Singh et al. (2018) and Lynch et al. (2020) share a common goal of exploring relationships between SDGs and identifying synergies and trade-offs. They draw on literature and expert knowledge, providing target-level assessments. Singh et al. (2018) use a qualitative approach, emphasizing the directionality of the relationship between SDG 14 and other SDGs (positive, negative), but lack a specific focus on SSF. Conversely, Lynch et al. (2020) focus on the relationships between

inland SSF, ecosystem services, and the SDGs. They use a two-step assessment to gauge ecosystem services' impact on SDG targets, offering insights into directionality and intensity. Both studies adopt a global conceptual framework, underscoring the need for frameworks suitable for context-specific assessments of SSF. Indeed, the diverse nature of SSF poses recurrent challenges for acquiring relevant data to monitor the sector, and hence any robust vision of this sector at a national and global level.

Data limitations make it difficult to understand underlying socio-economic processes in the SSF, limit monitoring capacity, jeopardize the sustainability of fish resources and livelihoods, and impede the achievement of development goals (Jacob, 2017). This knowledge gap calls for developing an integrated and cost-effective framework to collect and compile knowledge across the multiple dimensions of SSF, while offering sufficient flexibility to adapt to specific SSF contexts. Addressing this issue, the Illuminating Hidden Harvest project (FAO et al., 2023) is the latest systematic effort to quantify the contributions of SSF to selected SDGs through a case study approach. The case studies were carried out by national and international SSF experts who collected and compiled existing data on ecological, social, economic, and governance SSF characteristics at the national level. They also collected additional primary data (e.g., household surveys) to fill data gaps. The project leveraged available data about SSF worldwide, but confirmed that the information provided by existing initiatives is still often lacking for assessing the status and multidimensional contributions of SSF to the SDGs.

This paper introduces a rapid appraisal framework for assessing and quantifying case-specific contributions of marine SSF to achieving relevant SDG targets. The framework's rationale is threefold. First, we narrow our focus on marine and coastal fisheries (further referred to as SSF), due to a documented poor suitability of the SDG framework to assess inland fisheries (Lynch et al., 2020). Second, we employ a case-based approach to capture the heterogeneous nature of SSF contexts, addressing the challenges in characterizing SSF nationally and globally. The resulting case-based knowledge could facilitate upscaling insights for reporting on national-level SDG targets, although this goes beyond the scope of this study. Our framework aligns with the United Nations' 'localization' concept<sup>1</sup>, which encourages assessing SDGs at a scale closer to local governance to promote transformative actions at this level. Third, we argue that using multi-stakeholder and mixed methods to gather further knowledge on SSF could not only help fill data gaps but also contribute to a more nuanced and inclusive understanding of SSF dynamics. Recognizing the challenges associated with acquiring data on SSF, we underscore the pivotal role of expert knowledge and community engagement.

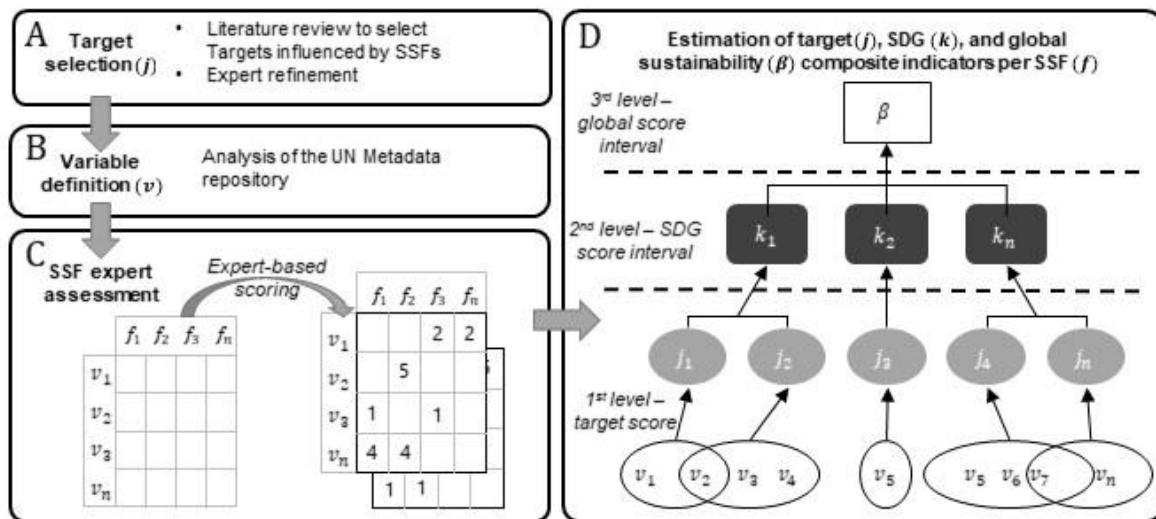
The framework was tested through a case study in Madagascar to demonstrate its applicability. Drawing on existing knowledge about SSF and expert judgments, the framework relies on a series of variables to assess the linkage between SSF and SDGs. In the following sections, we first present the framework's design (Section 1) and the application of the method to two case studies in Madagascar (Section 2). Finally, we discuss the performance of the framework, the results of the assessment in the case study and the potential for replication in other SSF contexts and countries (Section 3).

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<sup>1</sup> [www.local2030.org](http://www.local2030.org), <https://www.undp.org/governance/sdg-localization>

# 1. Rapid Appraisal Framework Design

The framework utilizes expert judgment and existing knowledge about SSF to evaluate the linkage between SSF and SDGs through a series of variables. To assess the contributions of SSF, an approach in four steps was designed: (1) Selecting the targets; (2) Defining variables; (3) Assessing SSF through expert elicitation; and (4) Creating composite indicators to measure SDG performance intervals and a global sustainability performance interval (Fig 1). Performance intervals are calculated as compensatory — non-compensatory sustainability indexes. The lower bound of the SDG index is determined by the lowest value of one of its targets, and the upper bound corresponds to the arithmetic mean of all targets per SDG.

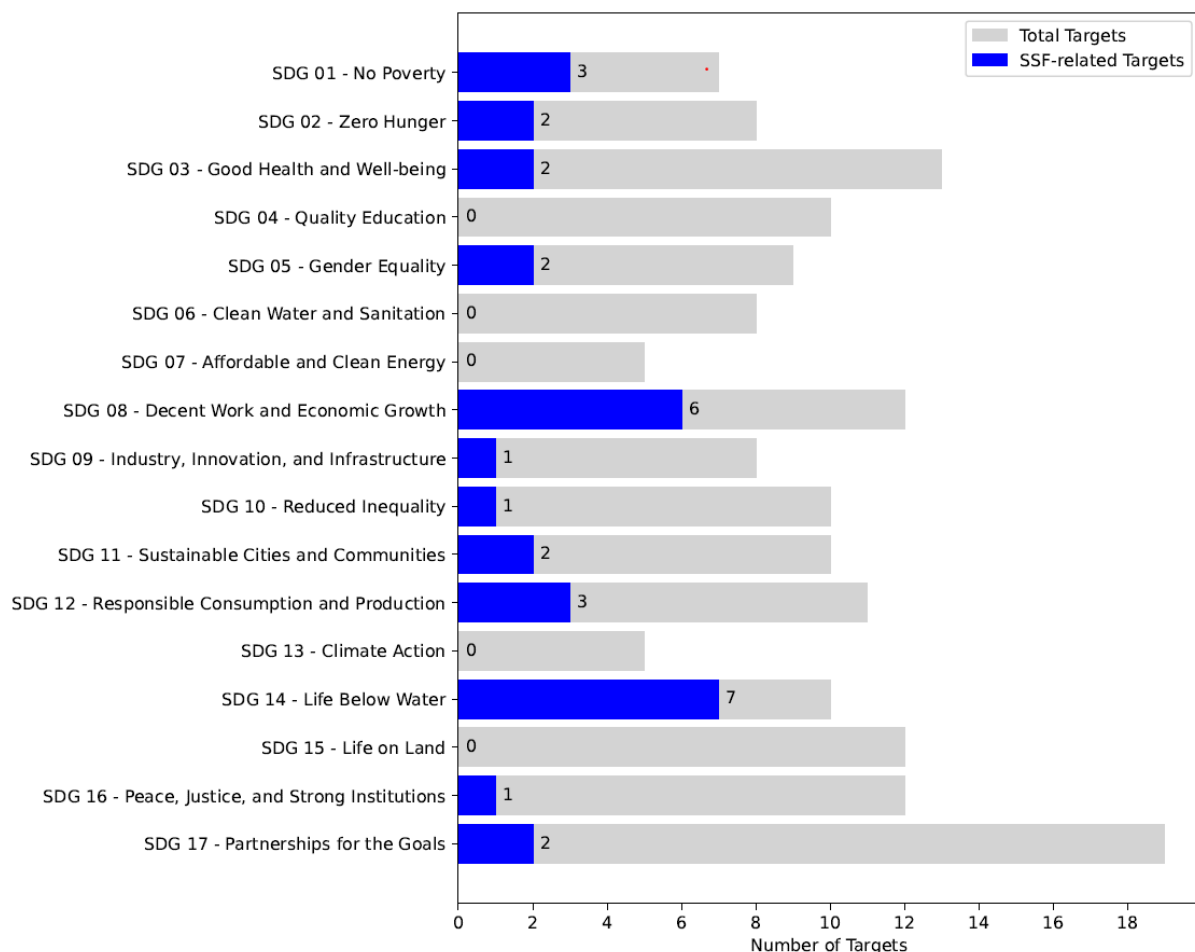


**Figure 1** Research approach used to develop the rapid appraisal framework and to evaluate small-scale fisheries' contributions to the SDGs.  $v_i$  are the variables assessed on the fishery  $f$ , used to measure the SSF contribution to targets on the  $k$ th SDG and compute the global sustainability performance indexes  $\beta$  on the fishery  $f$ . The sequential steps involve selecting targets (a), defining variables (b), scoring the SSF with expert assessment (c), and computing indicators (d).

## 1.1. Selecting targets (step 1)

This study proposes a process-based framework to characterize and identify the relationships between SSF and the SDGs. A review of the scientific literature was first conducted to identify documented relationships between SSF and SDGs (Fig. 1.a). We searched the Google Scholar database on July 11, 2022, for papers published since the release of the SDGs in 2015 and those relating to SSF sustainability and the SDGs. The search used the keywords “small-scale fisher,” “sustainability,” and “Sustainable Development Goals,” as well as variations of those terms (e.g., plural form, adjectives, abbreviations) and associated terms (e.g., artisanal fisheries, subsistence fisheries, resilience, viability, vulnerability). Abstracts of a selected sample were screened for preliminary content analysis and scanned using the United Nations LinkedSDG (<https://linkedsgd.officialstatistics.org/>), an open-source tool for extracting concepts relating to the SDGs. This tool measures the semantic similarity with the SDG taxonomy and ranks targets based on the occurrence of the topic in the paper’s content. Targets detected with the UN LinkedSDG tool were pre-selected for analysis.

An in-depth analysis of the content of the selected papers was later conducted to help refine the target selection (Expert refinement, Fig. 1.a). Results from this analysis were revised through working sessions with the research team to include only the targets *directly* influenced by SSF (Lynch et al., 2020; Singh et al., 2018). For example, fishing provides food to coastal communities, thus directly advancing progress toward SDG 2.1 on access to safe, nutritious, and sufficient food, leading to the inclusion of SDG 2.1 in the framework. Targets *not directly* influenced by the fisheries activities were considered enabling condition indicators and excluded from the assessment framework. For example, the ecological effects of SSF on marine biodiversity may affect the livelihoods of coastal populations through feedback effects on food supply and income, which may consequently lead to changes in community resilience to climate-related hazards (SDG 13.1) (Galappaththi et al., 2022). Although relevant, such indirect interactions did not result in selecting the target for inclusion in our framework.



**Figure 2** Analysis of small-scale fisheries-related targets ( $n = 32$ ) across SDGs.

Following this procedure, 32 of the 169 targets associated with 12 of the 17 SDGs were included in the framework (Fig. 2, Supplementary Materials 1, Table 1). The share of targets studied varied across SDGs, with SDG 14 (70% of targets included,  $n = 7$  targets), SDG 8 (50%,  $n = 6$ ), and SDG 1 (42.9%,  $n = 3$ ) having the highest representation, while SDG 2 (25%,  $n = 2$ ), SDG 3 (15.4%,  $n = 2$ ), and SDG 17 (10.5%,  $n = 2$ ) are moderately represented. One target is represented in SDG 9 (12.5%), SDG 10 (10%), and SDG 16 (8.3%) and are the least represented SDGs. This study did not consider SDGs 4, 7, 13, and 15, due to the limited



information to document the impacts of marine fishery-related activities on achieving these goals.

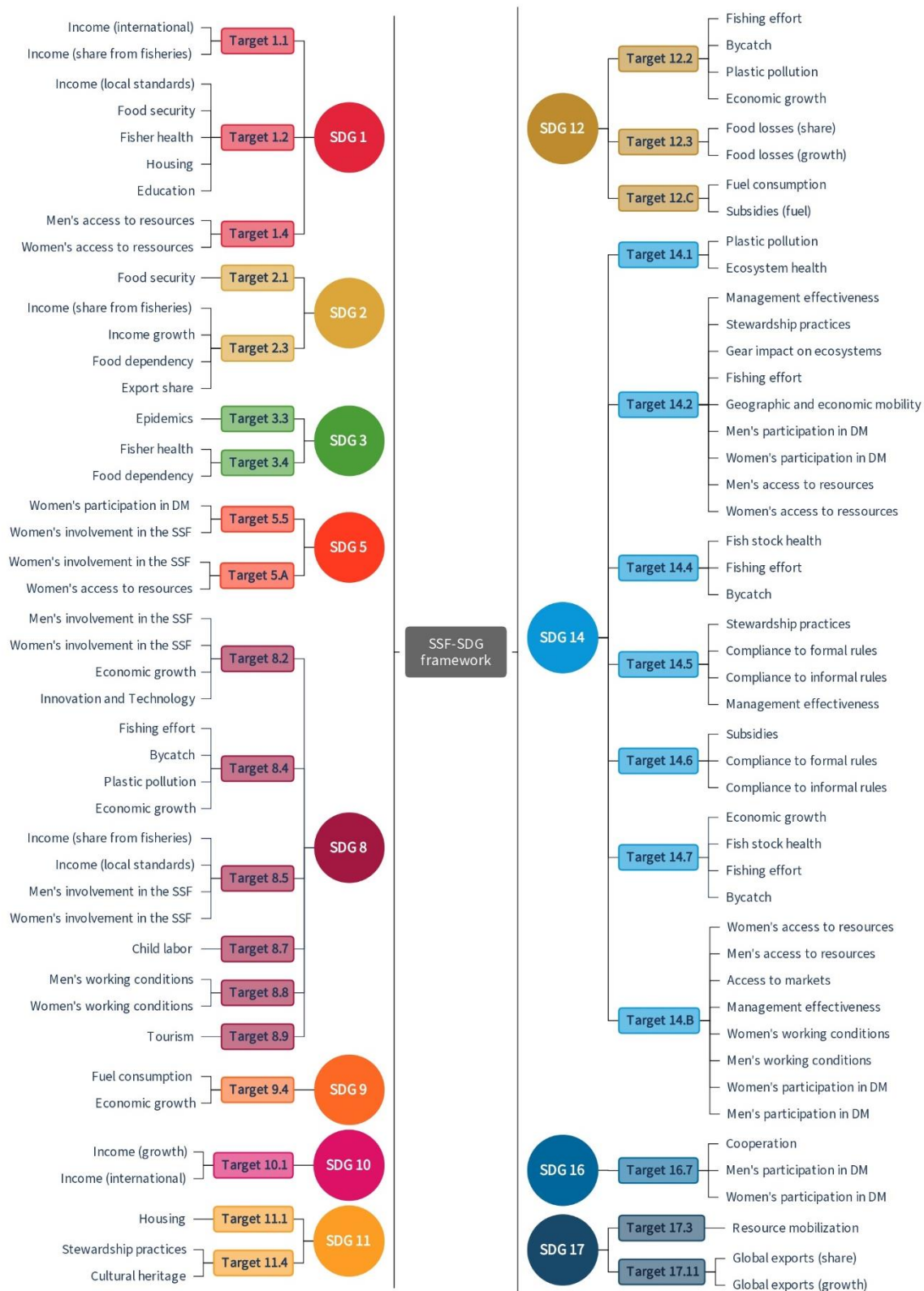
**Table 1:** Main characteristics of the case studies in Madagascar.

	<b>Octopus fishery, Andavadoaka</b>	<b>Crab fishery, Morondava</b>
<b>Number of fishers</b>	225	1,500
<b>Harvest area</b>	14 km <sup>2</sup>	200 km <sup>2</sup>
<b>Target species</b>	Reef octopus ( <i>Octopus cyanea</i> )	Mud crab ( <i>Scylla serrata</i> )
<b>Governance mode</b>	Community-based and national government management	National government management

## 1.2. Defining small-scale fishery variables (step 2)

The second step involved identifying and defining variables that could be used to assess the selected SDG targets (Variable Definition, Fig. 1.b). An in-depth review of the indicators found in the UN metadata repository was conducted to identify and group themes into higher-level indicators, consistently with Read et al. (2011). Since some SDG indicators overlap (Dang and Serajuddin, 2020), this step helped reduce the number of variables and, consequently, the knowledge base required to inform the framework. For instance, the indicator for target 14.4 measures the proportion of fish stocks within biologically sustainable levels, which requires fishing effort data, defined as the amount of a specific type of fishing gear used on the fishing grounds over time (FAO, 1997). Similarly, the indicator for target 8.4 measures the material footprint of an economic sector. In fisheries, the material footprint consists of biomass extraction (i.e., fish resources) and the exportation/importation ratio. Although biomass extraction may be estimated from landing data, these data are often largely unknown in SSF. Thus, fishing effort data was preferred as a proxy for estimating targets 8.4 and 14.4.

For policy-related targets, such as targets 5.a, 12.c, and 14.b, a thematic analysis of the UN indicator and its desired policy outcomes was performed to derive relevant variables for developing target composite indicators. For example, indicator 14.b.1 measures the degree of application of legal, regulatory, policy, and institutional frameworks recognizing and protecting access rights for SSF. The indicator also tracks ongoing initiatives to implement the SSF Guidelines and the participatory mechanisms for fishers' contribution to decision-making. The SSF Guidelines propose improvements to sustain SSF, including securing tenure, managing resources sustainably, improving work conditions, and ensuring gender equality. Therefore, target 14.b can be deconstructed into variables for each policy theme. This step resulted in developing 43 variables to measure the 32 targets selected in the previous step (Fig. 3). These variables are further described in Supplementary Materials 1, Table 2.



**Figure 3** Variables ( $n = 43$ ) used to measure fisheries' contributions to the 32 SDG targets corresponding to 12 SDGs evaluated by the framework.

### **1.3. Assessing SSF through expert elicitation (step 3)**

Variable scoring can be performed using empirical evidence and expert elicitation (SSF Expert Assessment, Fig. 1.c). Expert elicitation is a technique for collecting and synthesizing expert knowledge in data-limited situations (Riskas et al., 2018). For the SSF-SDG framework, the approach should be applied at the scale of a fishery, defined as a unit determined by an authority engaged in harvesting fish. Typically, the unit is defined in terms of people involved, species fished, area of water or seabed, method of fishing, class of boats, and purpose of the activities. Therefore, multiple fisheries may coincide in a given geographical area.

Experts are selected for their knowledge of a given fishery by the evaluators, i.e., the main investigators in the field in charge of synthesizing the expert knowledge and reporting results. Experts can be specialists in fisheries management from government agencies, academic researchers, policy-makers, representatives from non-governmental organizations (Riskas et al., 2018), or fishers and their representatives (Oliver et al., 2012). In this context, collective scoring is preferred to individual scoring. By bringing experts together to discuss and share knowledge, we can account for different viewpoints and achieve a more consensual and robust scoring outcome (Read et al., 2011). If consensus is missing, Delphi protocols could also be applied (Maini et al., 2023), involving several iterations and preserving the confidentiality of participants to limit power imbalances. Each variable is 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 5-point scale allows for nuanced answers and a good distribution of responses across Likert categories. Additionally, 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.

A concentration of medium values in survey responses could limit the ability to discriminate between SDGs, reducing data variability and the potential for meaningful insights. To mitigate this issue, a thorough cross-validation across case studies is conducted, by comparing the comments provided with the scores on each variable, using the scoring grids collectively employed by evaluators. To help standardize scoring across different contexts and by different evaluators, guiding materials provide broad definitions to refer to when allocating scores for each variable (Supplementary Materials 1, Table 2).

### **1.4. Estimating composite indicators (step 4)**

Finally, composite indicators were developed to measure the potential contributions of SSF against the selected targets (Estimation of target, SDG, and global sustainability composite indicators, Fig. 1.d). A composite indicator is an aggregate of individual indicators compiled into a single index (Nardo et al., 2005). Composite indicators are widely used to analyze complex systems by comparing disparate and multidisciplinary social and environmental variables (e.g., Munda, 2005). More recently, composite indicators have been used to monitor progress toward one or several SDGs at multiple scales, whether national (e.g., Kuc-Czarnecka et al., 2023), regional (e.g., Bie et al., 2023), local (e.g., Lo-Iacono-Ferreira et al., 2022), or at the scale of an economic sub-sector (e.g., Kynčlová et al., 2020). In this study, composite indicators were aggregates of individual variables representing different dimensions of a target being assessed. To process the data, ordinal values of the

Likert scale were converted into numerical values, where 'High' equaled 5 and 'Low' equaled 1 (Raaijmakers, 1999). Next, a three-stage aggregation procedure was carried out to measure the contributions of SSF to the SDGs, as follows (Fig. 1).

### First aggregation: from variable to target

Single or multiple variables were used to generate the indicators for target assessment. The aggregation was calculated with the arithmetic mean of the variables per target ( $t_j$ ) as follows:

$$t_j = \frac{1}{n_j} \sum v_i, \quad (1)$$

where  $n_j$  is the number of variables included in the  $j$ th target;  $v_i$  is the value of the variable  $i$ .

### Second aggregation: from target to SDG

Various approaches are proposed in the literature for aggregating indicators (e.g., Becker et al., 2017; Nardo et al., 2005; Santeramo, 2015). This research applied the most common method (i.e., using equal weights) to estimate each target and SDG (El Gibari et al., 2019; Sachs et al., 2022). In addition, a compensatory — non-compensatory SDG interval was measured, following Lo Iacono Ferreira et al. (2022) and Rickels et al. (2016), to help capture the variability amongst the aggregated indicator values. The upper bound of the interval (compensatory sustainability index,  $\alpha_k^w$ ) followed a compensability hypothesis where a high score on a given component of an SDG (i.e., a target) might compensate for a poor score in another one by computing the mean value of the targets within that SDG. The lower bound of the interval (non-compensatory sustainability index,  $\alpha_k^s$ ) followed a non-compensability hypothesis where components of an SDG are considered non-substitutable. The lower bound is defined as the lowest value of a target within an SDG. The intervals  $\alpha_k$  of the two target sustainability indexes  $\alpha_k^s$  and  $\alpha_k^w$  on the  $k$ th SDG were calculated as follows:

$$\alpha_k = [\alpha_k^s, \alpha_k^w] = \left[ \min t_j, \frac{1}{m_k} \sum t_j \right], \quad (2)$$

where  $t_j$  is the value of the target indicator  $j$ ;  $m_k$  is the number of targets in the  $k$ th SDG;  $\alpha_k^s$  is the lower bound of the interval and the non-compensatory sustainability index and  $\alpha_k^w$  the upper bound corresponding to the compensatory sustainability index with  $\alpha_k^s \leq \alpha_k^w$ .

The interval ( $\Delta_k$ ) range was calculated to analyze the variability between sustainability indexes as follows:

$$\Delta_k = \alpha_k^w - \alpha_k^s, \quad (3)$$

where  $\Delta_k$  is the range of the interval  $[\alpha_k^s, \alpha_k^w]$  on the  $k$ th SDG. Ranges close to 0 correspond to more homogenous scores between targets per SDGs, suggesting limited trade-offs between targets and better overall SDG achievements according to non-substitutable strong sustainability principles.

Missing data were handled at the target level following two Relative Mean Substitution (RMS) approaches (Downey and King, 1998; Leite and Beretvas, 2010; Raaijmakers, 1999). When

multiple variables were aggregated into a target composite indicator, the missing value was replaced by the mean of all variables in the composite indicator, provided that at least three variables were assessed for that composite indicator. For one- (e.g., target 3.4, 8.8, 11.1, and 17.3) or two-variable indicators (e.g., targets 1.1, 1.4, 2.1, and 3.3.), the missing value was calculated by computing the mean of targets within a goal (Lo Iacono Ferreira et al., 2022), if at least two targets were assessed in the goal. For example, if a given SDG is missing the value of two of the three targets assessed for this SDG (e.g., SDG 12), the condition for substituting the value of the two missing targets is unfulfilled (i.e., at least two assessed targets remaining) and SDG 12 will not be scored.

### Third aggregation: from SDGs to global sustainability index

Finally, a third aggregation of SDGs was conducted to compute a global sustainability index. The interval  $\beta_k$  of the non-compensatory and compensatory global sustainability indexes,  $\beta_k^s$  and  $\beta_k^w$  was calculated by measuring the arithmetic mean of the lower and higher bounds:

$$\beta_f = [\beta_f^s, \beta_f^w] = \left[ \frac{1}{m_f} \sum \alpha_k^s, \frac{1}{m_f} \sum \alpha_k^w \right], \quad (4)$$

where  $[\alpha_k^s, \alpha_k^w]$  are the upper and lower bound values on the  $k$ th SDG;  $m_f$  the number of SDGs studied on the  $f$ th SSF;  $\beta_f^s$  is the lower bound global index and  $\beta_f^w$  the upper bound with  $\beta_f^s \leq \beta_f^w$ .

The length of the interval  $\beta_f$  was calculated as a ratio  $\theta_f$  to analyze the balance between non-compensatory and compensatory sustainability:

$$\theta_f = \frac{\beta_f^w}{\beta_f^w - \beta_f^s}, \quad (5)$$

where  $\beta_f^s$  is the lower bound of the global interval and  $\beta_f^w$  the upper bound;  $\theta$  is the ratio of the  $f$ th SSF. The greater the length of the interval  $\beta_f$ , the lower the ratio  $\theta_f$  will be.

## 2. Applying the method: Case studies from two SSF in Madagascar

### 2.1. Case studies description

The approach was tested in two SSF from the Southwest of Madagascar, each featuring distinctive contexts in terms of targeted species, ecosystems, fishery size, and governance modes (Fig. 4, Table 1). Madagascar, confronted with severe economic challenges, stands among the world's poorest countries, with about 80% of its population living on less than \$2.15 per person and per day (Worldbank, 2012<sup>2</sup>). Over the past decade, the country has witnessed a decline in food security and an increase of its social vulnerability, attributed to structural development obstacles and environmental shocks (Fayad 2003).

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<sup>2</sup> <https://data.worldbank.org/>



**Figure 4** Location of the case studies: Andavadoaka and Morondava, Madagascar.

SSF represent over 75% of the total annual fishery catches in Madagascar, supporting the livelihoods of about 1.5 million people (Wabnitz and Harper, 2023). The demand for marine resources has grown since the 1950s due to demographic rise and with the promotion of the fishing sector by the Malagasy government and international organizations' developmental policies following the country's independence in 1960 (Grenier, 2013). Governance of Malagasy fisheries falls under the Ministry of Fisheries and Blue Economy, with decentralized regional administrations responsible for local policy implementation, aided by international non-governmental organizations (NGOs) and communities. However, governance institutions are generally poorly effective in controlling fishing pressure in coastal waters (Le Manach et al., 2012).

SSF are particularly crucial in the context of southwestern rural areas, where alternative income-generating activities are lacking, and agricultural development is hampered by climate-induced aridification, contributing to a multidimensional poverty (Nematchoua et al., 2018). Major threats to SSF sustainability in the region include overfishing, marine habitat degradation, coastal population growth, and lack of effective management (Bruggemann et al., 2012). The depletion of marine resources has exacerbated the use of non-selective fishing gears and increased the proportion of small and juvenile fish in catches over the last 30 years, which generated negative feedback (Ranaivomanana et al. 2023).

The first SSF selected targets octopus in the village of Andavadoaka (Table 1, Figure 4). This village of 1,200 inhabitants is primarily populated by the Vezo semi-nomadic fishing ethnic group. The coastal area is characterized by a shallow lagoon protected by a coral barrier reef. Octopus is typically gleaned using harpoons and spears on reef flats at low tide or beyond the reef in shallow waters around the islands of Nosy Hao and Nosy Andranombala, located

4 to 5 km offshore. The octopus fishery grew commercially in the early 2000s in the Southwest region under the impulse of private export companies (Gardner et al., 2017). In 2004, with the support of an NGO, the local community established a temporary closure of the octopus fishery in an attempt to increase catch yields. This successful experiment generated enthusiasm and a larger engagement to manage coastal resources, resulting in the establishment of a Locally Managed Marine Area (LMMA, named *Velondriake*) in 2006, including Andavadoaka and 24 other surrounding villages (Gardner et al., 2020). Two national fishing restrictions were also adopted in 2005: a 1.5-month seasonal closure during the octopus spawning season and a minimum 350-g catch weight (Raberinary and Benbow 2012). A local collective agreement called 'Dina' (Andriamalala & Gardner, 2010) was then established to better enforce the rules of the LMMA through non-compliance fines for fishing during the closure or other activities degrading vulnerable ecosystems such as mangroves and coral reefs. These efforts led to increased size of individual octopus, catch rates, and fishers' economic benefits at the lifting of the temporary reserve (Benbow et al. 2014; Oliver et al., 2015), although the sustainability of the fishery remains poorly documented. The management and decision-making process is inclusive, where multiple stakeholder types are effectively engaged through a fishery management forum. Anecdotal evidence suggests improved social capital within the community, but that the overall effects of this co-management initiative on fishery sustainability remains uncertain (Gardner et al., 2020) due to inadequate punishments for rule violations, low governance participation, and the limited ability to manage market-driven effects on fishing.

The second SSF selected is a mud crab fishery located near the city of Morondava, in the west, the regional economic capital populated by ~53,000 inhabitants (Table 1; Fig. 4). Fishing and landing sites are dispersed throughout the surrounding rivers and coastal mangrove. Fishers explore the mangroves on foot or in channels using wooden outrigger pirogues. They use a variety of gears, including a wooden hook, to extract crabs from their burrows at low tide or use hoop nets in the river channels. Crabs are mainly exported as frozen or live products or sold domestically, with fishers typically retaining smaller specimens for household consumption. Multiple factors have threatened the sustainability of this fishery in the last decade. First, international demand for live crabs in Asia has markedly increased since 2013, thus attracting fishers into the fishery and causing catches to triple between 2012 and 2017, according to official fishery statistics. Crab fishers have limited negotiating power due to a lack of institutional organization, leaving much power to buyers (Gardner et al., 2017). Second, and similarly to Andavadoaka octopus fishery, alternative incomes in coastal villages are scarce, encouraging people to enter the fishery, hence increasing the fishing pressure. Third, the regulations issued since 2014 to regulate fishing activity have had limited effectiveness in shifting this trend (Long et al., 2021). Fishers' compliance with the national seasonal closure and the minimum legal catch size (11 cm carapace width) has been limited, and harvest often exceeded the annual total allowable catch of 5,000 t established in 2014. Meanwhile, despite the national ban on mangrove wood use and sale in 2014, mangrove habitats have been increasingly deforested for timber and fuel wood extraction, placing additional ecological stress on mud crab resources (Ranaivoson 2022).

## **2.2. Data collection**

A participatory approach elicited SSF actors' expert knowledge in each case study. Following Wilkinson (1998), focus groups of 10 to 15 participants were organized at each

location (on October 5th, 2022 and December 5th, 2022, in Andavadoaka and Morondava, respectively), giving the opportunity to participants to elicit during 2.5h their knowledge and opinions. The RENAFEP-MADA Malagasy organization (Madagascar National Network of Women in Fisheries) assisted in identifying and mobilizing the participants and supporting the facilitation of workshops. Their collaboration was instrumental in achieving gender parity within the stakeholder groups. Participants included fishers, fishmongers, and members of fisher association boards. In Andavadoaka, 13 individuals from three fisher organizations were involved, namely the women fishmonger association Tsimanavake and the fisher organizations Velondriake and Milaso. In Morondava, 12 participants from six fisher organizations participated, including one organization, Mampihavana, exclusively composed of women.

Evaluators facilitated exchanges and debates among participants during the focus groups, intending to achieve collective consensus for the scoring of each variable. The guiding materials, providing generic definitions of the variables and of low and high scores on each variable, were used during the focus groups as a reference for score allocation (Supplementary Materials 1). Communication strategies were developed to make the framework easily understandable for the participants and overcome some literacy challenges. For example, workshops were held in the local languages/dialects (i.e., Vezo, Sakalava, and official Malagasy), and picture boxes were used to help identify marine ecosystems, as languages differed from one area to another. Participants were asked to comment on their views about possible developments regarding their practices (e.g., fishing gear technological evolution) and socio-economic settings (e.g., income growth, tourism) within the next 2–10 years. Participants were compensated with monetary allowances for the lost working hours and provided with rights to access their data, rectify their statements, and delete or limit the use of their statements. Complete workshop and focus group transcriptions were sent back to participants for content approval. Consultations were conducted in agreement with the ethical guidelines governing the University of Antananarivo, Madagascar, coordinating the fieldwork. The validated version of the statements was edited and translated into English and then recorded online.

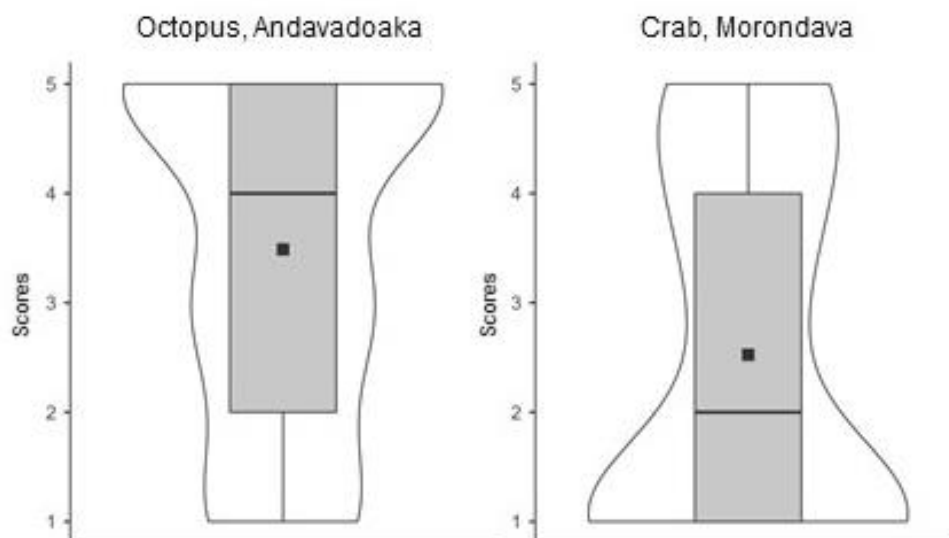
The evaluators (i.e., the lead investigators in the field) were in charge of synthesizing the expert knowledge and reporting the results. To facilitate the reporting of interview data, we used the free, open-source Kobo Toolbox form builder ([kf.kobotoolbox.org](https://kf.kobotoolbox.org)). The tool allows for collecting data in the field using mobile devices and can be used offline, facilitating data collection in remote areas. Evaluators were required to provide a short comment justifying the scores attributed to each variable by summarizing participants' conclusions and completing the justifications with literature where necessary. This helped find consensus among the experts and improved the consistency of experts' judgment across the case studies. Any potential score misinterpretations were discussed with the evaluators for resolution. A consistency validation was performed to check if missing values did not exceed a 20% threshold following Downey and King (1998)'s recommendation and that scores were properly allocated across variables. Non-conform statements were returned to evaluators for reassessment. After validation, data were pre-processed using Pycharm C.E. 2022.1.4 (<https://blog.jetbrains.com/pycharm/>) for analysis.



### 3. Results

During the workshops conducted in both case study sites, all 43 variables were scored, except for three for the crab fishery. The variable assessing compliance with informal rules (Fig. 3) was marked as 'not applicable' due to the absence of clearly defined local norms governing practices in this specific fishery. Additionally, the subsidies and resource mobilization variables were both marked as 'no data' due to a lack of available information. Consequently, targets 12.c (i.e., fossil-fuel subsidies per unit of GDP) and 17.3 (i.e., financial resources for developing countries) were not assessed for this case study. However, target 12.c is of little relevance to this fishery, as fishers use non-motorized canoes. Moreover, we did not quantify SDG 17 for this fishery, since the RMS approach used to compute missing data is applicable when evaluating a minimum of two targets per SDG. Notably, SDG 17 comprises in this framework only targets 17.3 and 17.11.

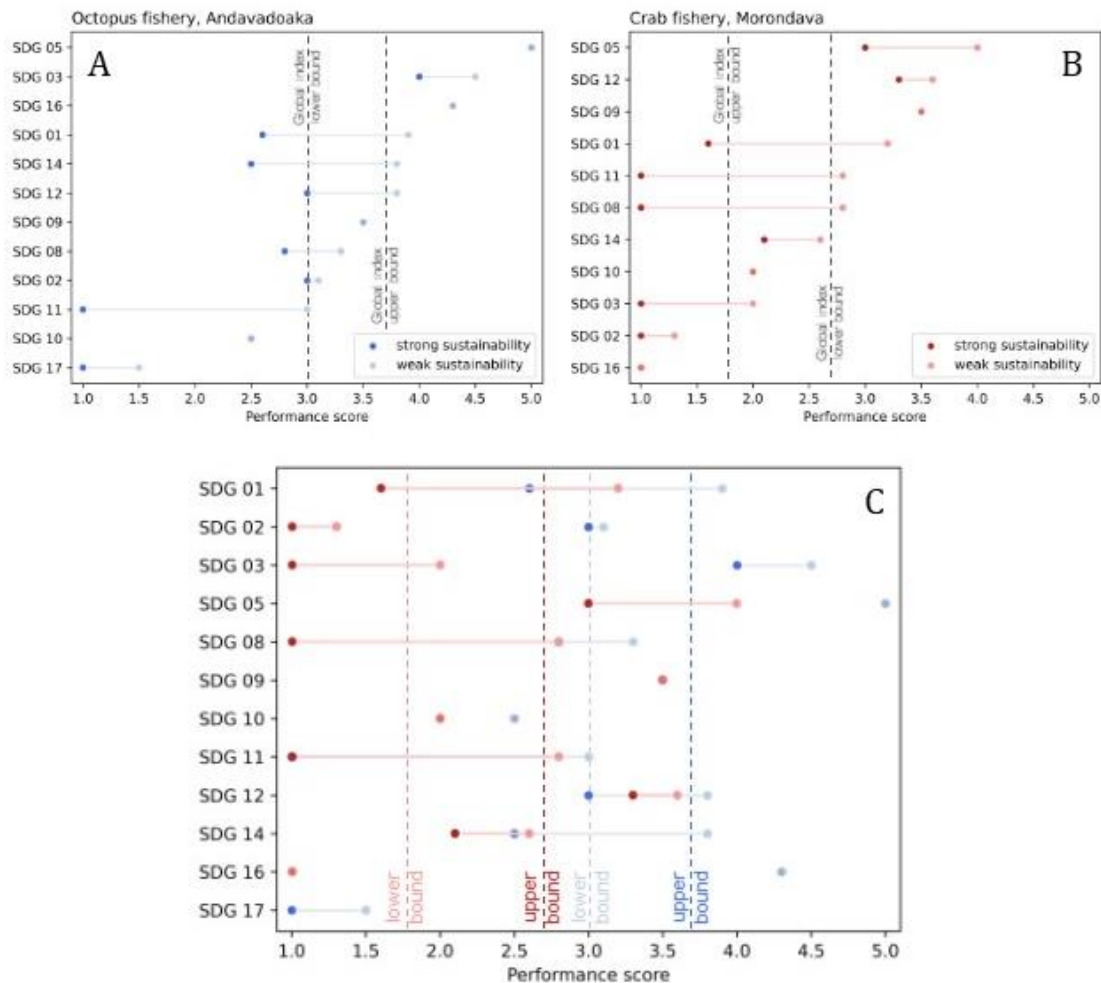
Scores varied greatly across variables in both fisheries. Specifically, variable scores for the octopus fishery were negatively skewed (-0.45), with scores concentrated toward higher values and few low values, while the skewness was positive (0.43) in the crab fishery (overall mean scores of 2.5 and 3.5, respectively; Figure 5). As a result, the octopus fishery performed better than the crab fishery on most SDG targets, with higher scores on 24 of 32 targets (see Supplementary Materials 2 for details). However, the crab fishery scored higher for other targets, such as target 8.2 (i.e., diversify, innovate, and upgrade for economic productivity) and target 8.5 (i.e., full employment and decent work).



**Figure 5** Distribution, mean (square), and median (black line) of expert-based scores across the 43 variables in the octopus fishery in Andavadoaka (left) and the crab fishery in Morondava (right), Madagascar. Descriptive statistics were analyzed and displayed using jamovi 2.3 ([www.jamovi.org](http://www.jamovi.org)).

At the SDG level, the case studies yielded contrasted outputs, suggesting possible positive and negative interactions among and within SDGs in both fisheries (Figure 6). On the one hand, higher contributions of both SSF to SDGs 1, 5, 9, and 12 and weaker contributions

to SDG 10 were observed, while the strength of the contributions to other SDGs varied between case studies. The octopus fishery showed high scores on SDGs 3 and 16 and low scores on SDG 17. Conversely, the crab fishery scored best on SDG 9 and poorly on SDGs 16, 2, and 3.



**Figure 6** Compensatory and non-compensatory sustainability performance interval (horizontal lines) per SDG and global sustainability performance index on all SDGs (vertical dotted lines) for the Andavadoaka octopus fishery (a, in blue) and the Morondava crab fishery (b, in red) with SDGs ranked by compensatory sustainability value. A comparative representation of both case studies is displayed (c) per SDGs in ascending order.

The octopus fishery displayed a somewhat better balance between global non-compensatory and compensatory sustainability ( $\theta = 5.6$ ) indices than the crab fishery ( $\theta = 3.2$ ). The intervals of most SDG scores were less dispersed and concentrated toward higher values in the octopus fishery (global interval of [3.0, 3.6]; Figure 6A) than in the crab fishery (global interval of [1.8, 2.7]; Figure 6B), except for SDG 14. For instance, in the crab fishery, target scores for SDG 8 (Decent Work and Economic Growth) were undermined by poor achievements on targets 8.7 (i.e., child labor) and 8.8 (i.e., protect labor rights and promote safe working environments) although other targets of that SDG scored high, such as 8.5 (i.e., achieve full and productive employment and decent work). Indeed, working conditions are strenuous in that fishery, with long hours, physical fatigue, children involved in fishing to

support their families, and limited capacity to bargain decent prices with fishmongers. SDG 14 indices greatly varied in the octopus fishery ([2.5, 3.8]) due to low scores of targets 14.4 (i.e., effectively regulating harvesting and ending overfishing) and 14.7 (i.e., sustainable use of marine resources) despite strong contributions to other targets (e.g., 14.5 and 14.1). Nevertheless, intra-SDG variability of some SDGs was consistently high in both fisheries, i.e., SDGs 1 and 11 (Figure 6A & 6B). This variability was due to poor achievements on targets 1.2 (i.e., reducing multidimensional poverty), and 11.1 (i.e., adequate, safe, and affordable housing) and high achievements on targets 1.4 (i.e., equal rights to economic resources) and 11.4 (i.e., safeguarding the world's cultural and natural heritage).

Overall, the octopus fishery showed a good balance across the conventional sustainability pillars: 'Economic' (SDGs 8, 9, 10, and 12), 'Social' (SDGs 1, 2, 3, 5, 11, and 16), and 'Ecological' (SDG 14), despite higher dispersion of SDG 14 indices. In the crab fishery, results highlighted stronger, although moderate and heterogeneous, contributions to economic SDGs than to other sustainability dimensions, especially in the social SDGs, suggesting that the fishery has had limited returns on the population's well-being probably as a result of growing fishing pressure during the last decade, decreasing daily harvest rates and resource abundance, habitat degradation, and ineffective management.

## 4. Discussion

### 4.1. Relevance of the framework within the global SDG discourse

In this study, we designed a rapid appraisal framework to measure the contributions of specific fisheries to SDGs and tested this method with two case studies in Madagascar. Our proposed approach is, to our knowledge, the first comprehensive method in the literature to assess specific contributions of SSF to the SDGs. It is important to remind that our method does not aim to assess if a fishery is sustainable, as commonly understood in a context of resource extraction, but aimed instead to assess how a fishery contributes to various SDGs. In this context, a given fishery could be highly overfished, and hence unsustainable from a resource management perspective, but still contribute to specific SDGs by providing food and labor to local populations for instance (at the likely cost of trade-offs with environmental SDGs). Our method is based on a structured and systematic approach to measure the multidimensionality of SSF through the SDG lens, building on insights from prior authors (e.g., Said and Chuenpagdee 2019). While SSF are often gauged through assessments of the fish resources, our approach shifts the focus on broader, and often disregarded, concerns about sustainable uses of oceans. Indeed, fish stock assessments are on their own insufficient to grasp the complexity of SSF and their ability to support human well-being, social equity (Campbell & Gray, 2019), and environmental integrity (Cochrane, 2021; Leach et al., 2010). As these models focus on maximum sustainable yield, they fail to account for the multiple states of sustainability that could coexist within a SES (Lindkvist et al., 2022). Similarly, target-based approaches, such as the SDGs, have been criticized for obscuring more complex underlying drivers of sustainability (O'Manique and Fourie 2017), such as social justice (Campbell et al., 2014) and management effectiveness (Hagerman et al., 2021). By also looking beyond the scope of SDG 14, our method helps better understand how fisheries relate to 12 SDGs, which cover a wide array of sustainability dimensions in direct relation to SSF.

By adapting the UN indicators to local contexts and performing a contextual scoring of variables, our framework also partly addresses a drawback of global target-based reporting frames such as the SDGs within the context of the global South. The SDGs received criticism for further reinforcing Western-centric notions of equity, neglecting the diverse perspectives of development, and failing to address systemic inequity and historical power dynamics (Alexander et al., 2022). Prior to SDGs, Easterly (2009) showed that the Millennium Development Goals disproportionately disadvantaged regions with high initial poverty rates. Because SSF operate in diverse and specific ecological and cultural contexts, these critiques have direct implications for SSF, particularly in less developed countries. Moreover, key aspects of multidimensional well-being of particular relevance for SSF communities are also overlooked in the UN SDGs, such as connectedness to people and places through local knowledge, skills, practice, values, and worldviews (Sterling et al., 2020). For that reason, in this study, the variables were primarily assessed using experts' knowledge in relation to the country's standard (e.g., fishers' income in comparison to minimum national wage) rather than universal, yet questionable, scales of success. Thus, the outputs of the method should be interpreted within the assessment context rather than used as absolute measures.

The participatory nature of the framework raises challenges in integrating diverse perspectives, actors, and data sources, potentially leading to data limitation, inconsistency, and bias in the assessment. The reliance on expert knowledge to assess the fisheries may limit the objectivity of the findings and increase uncertainty due to "knowledge imperfections" (Röckmann et al., 2012). Data gaps may occur in some areas as the framework analyzes a broad panel of themes and sustainability concerns. In the selected case studies for instance, disaggregated data on the local contributions of SSF to the economy were difficult to access by the local experts, as this information is monitored at the national level. Other variables, especially those concerning household welfare (i.e., housing conditions, health of household members, prevalence of some diseases in the fishing communities, and education level) remain challenging to acquire in the contexts of different fisheries and countries. Data accuracy, although not measured, should therefore be considered when interpreting the method outputs. Given these caveats, future replications of the method should evaluate these gaps, e.g., develop a quality index to indicate the reliability of output results and evaluate the impact of stakeholder types and participation on score variability. A cross-validation process based on documented information may also improve the scoring and promote agreement among experts' elicitation (Röckmann et al., 2012).

## **4.2. Usefulness of the assessment and analytical method**

Our method was designed to be flexible, allowing data collection from contexts with varying data availability while facilitating the incorporation of local knowledge. The method mostly relies on experts' and available knowledge and requires specific data inputs, which is particularly relevant for SSF where data paucity often hampers evidence-based decision-making (Chuenpagdee et al., 2019). Such a participatory research method can foster social learning (Moallemi et al., 2020), generate new knowledge (Oliver et al., 2012), and offer solutions for transformations (Saunders et al., 2016), particularly in data-poor contexts.

The use of the method can shed light on the ability (or inability) of fisheries to address multiple dimensions of sustainable development. As exemplified by the case studies, the outputs identified the dimensions where SSF performed well or lagged against the relevant

SDGs, e.g., alleviate poverty, maintain marine resources, enhance well-being, boost innovation and efficient production systems, and foster peace and justice. That information captured using the approach highlighted underlying social, economic, and environmental processes in the fisheries, similarly to SES diagnostic approaches (Kittinger et al., 2013) which is valuable information for decision-makers, fishery managers, and policy makers (Lindkvist et al., 2022). Results suggested that the crab fishery is likely confronted with resource overexploitation, inadequate working conditions, and limited economic returns to local communities, which needs to attract the attention of decision-makers. However, scores should not be considered as metrics of SSF overall sustainability per se, since unsustainable SSF practices could support the achievement of some SDGs, at least in the short term (Lynch et al., 2020). As uncertainty in the assessments can be introduced at different levels (e.g., depending on how well a fishery is documented), caution should be applied when interpreting the results.

The results further suggest that the method would be useful for investigating the interactions and trade-offs among SDGs and targets (Zhao et al., 2021). Future studies will be needed to replicate the assessment over a large set of SSF cases to capture the diversity of contexts. If applied to many case studies, the approach could also help identify patterns such as trade-offs and synergies among SDGs. Analyzing the characteristics of a large set of fisheries could also help identify potential pathways to sustainability, together with sound knowledge of the local SES (Hughes et al., 2005; Leach et al., 2010; Schlüter et al., 2022). Compiling more SSF profiles may also help generalize some interactions across SDGs in the context of SSF. This empirical knowledge could be synthesized into archetypes of SES and their dynamics (Oberlack et al., 2019; Sietz et al., 2019). Finally, additional research on optimization models (e.g., Kaim et al., 2018) could test how different measures affect SSF contributions to the SDGs and identify which solution best balances the goals.

Our approach aims to capture a complex reality into values associated with composite SDG indicators at an appropriate scale. Our results show that SDGs or global sustainability indexes, as composite indicators, raise misinterpretation risks given the high dimensionality and heterogeneity of within-SDG targets for many SDGs, as highlighted by the difference between compensatory and non-compensatory SDG indexes in the case studies (e.g., SDG 1 relating to poverty). Following other authors (e.g., Morse and Fraser, 2005), we recommend disaggregating sustainability indicators and diagnosing the contributions of SSF at the target level rather than the SDG one. Target-level indicators would also enhance output consistency, since assessing SDGs using a varying number (i.e., from one to seven; Figure 2) of SSF-relevant targets likely represented a methodological weakness of the framework.

Furthermore, we consider that assessing individually small fishing units and then aggregating them as regional case studies could help better display the variability of and the nested processes between local, regional, and national scales. Defining the limits of fisheries and what constitutes a fishing unit has been much discussed in the SES literature (Biggs et al., 2021). This task is especially challenging in tropical multi-gear and multispecies SSF with poor ports and fish landing infrastructures. We recommend, consistent with Leslie et al. (2015), assessing the smallest, most cohesive fishing unit, where fishing (e.g., species, fishing practices, gears) and social characteristics (e.g., economic status, education level) are similar. Splitting large fisheries into smaller units is likely to improve the accuracy of the assessment and avoid difficulties in assessing variables where social, economic, and environmental

dynamics varied within those fisheries (Biggs et al., 2021). Further research is needed to define suitable reporting mechanisms that could compile the specific contributions of SSF to monitor advancements toward national SDGs, in alignment with policy requirements. Indeed, models intended for policy making require large datasets (Lindkvist et al., 2022). In Madagascar for instance, overall low performance in achieving the SDGs, particularly SDGs 1, 2, 3, 5, 16, and 17, was reported (Center for Africa and Sustainable Development Solutions Network, 2020). Our case study results suggest that SSF in Madagascar could be pivotal in driving progress towards multiple SDGs, provided efforts are made to reverse declining stock trends and effectively manage the resources. Upscaling these findings holds promise for evaluating the significance of SSF at the national level in the pursuit of achieving the SDGs.

While the research provides valuable insights and findings, the framework only provides a partial image of the SSF-SDG relationships. The first limitation relates to the missing SDGs and the current inability of the framework to assess inland fisheries, something that came to light during the design of the framework. Connecting SDG 14 and SDG 15: Life on land, that is likely the most relevant SDG for inland fisheries (Lynch et al., 2020), in an integrative fishery framework remains challenging (Neumann et al., 2017), especially in coastal areas. Second, as only directly-influenced targets were selected, other SDGs that may be highly influential on SSF viability (Singh et al., 2018), such as SDG 13: Climate Action or target 8.6: Youth employment, were not considered. Youth often face some barriers when entering SSF, such as assets, finance, knowledge, and decision-making power barriers, which impacts the overall dynamics of SSF (Zurba & Trimble, 2014). Future research could extend the SDG interaction model applied to SSF to indirect relations to explore SDG dynamics in a broader context.

## Conclusions

In this study, we designed and tested a novel expert-based rapid appraisal framework that helps capture the contributions of SSF to the SDGs. This framework used 43 variables characterizing SSF activities known for their relevance to SDG targets. The method provided insights into the relative contributions of two SSF in Madagascar to 12 SDGs (SDG 1, 2, 3, 5, 8, 9, 10, 11, 12, 14, 16, and 17) and the corresponding 32 targets. We proposed a non-compensatory sustainability aggregation method as advocated in recent sustainability science research, where SDG targets are complementary but not interchangeable. This approach allowed for analyzing intra-SDG variability and understanding the interactions between targets. The research ultimately helps fill the knowledge gap on the impacts of SSF on SDGs beyond SDG 14.b. It provides a tool for rapidly acquiring baseline knowledge on data-limited SSF. Moreover, the framework is novel in connecting local challenges to the UN global SDG framework, providing a contextually relevant understanding of how global goals can be achieved locally.

The framework was instrumental in comparing two SSF within a national context rather than providing standalone SDG scores. By diagnosing how SSF develop and relate to SDGs, we provide an integrated tool that may better inform managers and policy-makers on key contributions or weaknesses to address in SSF.

## Supplemental information description

Supporting literature for SDG target definition and variable descriptions are available in Supplementary Materials 1. Additional results used for this study are available in Supplementary Materials 2.

## Declaration of interests

The authors declare no competing interests.

## Author contributions

Conceptualization, R.D, M.L.; Methodology, R.C., R.D., M.L., R.B.; Validation Verification, R.B., M.L.; Formal Analysis Application, R.B.; Investigation, R.B., T.R., R.R.; Resources Provision, T.R., R.R.; Data Curation Management, R.B.; Writing – Original Draft, R.B.; Supervision, R.D.; Project Administration Management, R.D., R.B., R.C., M.L.; Funding Acquisition, R.D. All authors participated in the revision of the manuscript.

## Acknowledgments

This work was conducted as part of the Fish2Sustainability project supported by the Belmont Forum Collaborative Research Action (CRA) Pathway 2020 on Transdisciplinary Research for Pathways to Sustainability, with funding from the French National Research Agency (ANR), the National Research Alliance for the Environment (AllEnvi), the National Research Foundation (NRF), and Future Earth. Arias Schreiber M. received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No 843165. We thank M. Arce Ibarra, M.J. Barragán-Paladines, G. David, K. Frangoudes, L. Gutierrez-Cala, and J. Guyot-Téphany for helpful discussions on the methodological development. We thank the RENAFEP-MADA network for conducting the workshops in Madagascar and the Regional Directorate of Fisheries and Blue Economy in the Menabe region for their support and availability to facilitate data collection. We thank Blue Ventures in Andavadaoka, Madagascar for help in identifying participants for the workshop. Our sincere thanks go to all the workshops' participants.

## Resource availability

Raw data generated in this study can be made available for non-commercial application on request. Further information and requests for resources should be directed to and will be fulfilled by the lead contact. All original code and survey forms have been deposited at Zenodo under <https://doi.org/10.5281/zenodo.7825253> and are publicly available as of the publication date.

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