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ORIGINAL ARTICLE

Co-creating coastal sustainability goals and indicators

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Abstract

Indicators can be powerful tools to measure progress towards achieving societal goals, and many indicators have been developed for sustainability goals nationally and internationally. When indicators are developed solely through top-down approaches without engaging local knowledge, they often fall short of capturing local perceptions and concerns relevant to decision-making. The aim of this project was to co-create a Coastal Barometer and its component indicators, together with local knowledge-holders and communities, using the Ocean Health Index as a framework. As a first step, local knowledge-holders from six communities dispersed across Northern Norway were invited to articulate local sustainability goals and the required knowledge for eight broad topics pertaining to global OHI goals: small-scale fisheries, food production, sense of place, tourism, food production, clean waters, carbon storage and economy and livelihoods. In this paper, our main focus is the co-design phase of the Coastal Barometer, namely eliciting sustainability goals. We thus, present locally desired sustainability goals and sub-goals and the process of eliciting these goals. We also include suggestions from local knowledge-holders on how to reach these goals (i.e. proposed management measures), along with researchers' assessment of data availability (part of the co-production process) for developing indicators to measure progress towards these goals. Finally, we discuss the benefits and challenges of co-developing sustainability goals and indicators with local knowledge-holders. We conclude that co-design can increase the quality of sustainability assessments by enriching the view of coastal sustainability. This knowledge can subsequently be used to align indicators with local sustainability goals as well as to the local context where the indicators will be applied.

Keywords Blue growth · Ecosystem services · Public participation · Sustainability indicators · Sustainable development goals · Ocean health index

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Introduction

The UN Decade of Ocean Science for Sustainable Development was initiated by the United Nations General Assembly on January 1st 2021, calling for an ocean science to focus on sustainable use, restoration and protection of marine and coastal ecosystem in support of the 2030 Agenda for Sustainable Development (The Ocean Decade 2020). The Ocean Decade's ambition is to develop a more transformative and participatory ocean science that is "co-designed and co-delivered in a multi-stakeholder environment" (The Ocean Decade 2020). Such co-created knowledge is expected to meet the challenges identified by the Ocean Decade, including ensuring "a sustainable ocean observing system […] that delivers accessible, timely, and actionable data and information to all users" (oceandecade.org). Co-creating knowledge, i.e. the collaboration across disciplines and between

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researchers and non-academics, is at the heart of sustainability science (Kates et al. 2001; Komiyama and Takeuchi 2006) and has been defined as an "iterative and collaborative processes involving diverse types of expertise, knowledge and actors to produce context-specific knowledge and pathways towards a sustainable future." (Norström et al. 2020).

Sustainability indicators are simplifying tools helping to capture complexity about the current state and future trajectories of a system across environmental, social and economic dimensions (Bell and Morse 2018). Hence, they are essential to any knowledge and observation system that aims to measure sustainability (Bell and Morse 2003). Importantly, as noted by Meadows (1998), "indicators arise from values (we measure what we care about) and they create value (we care about what we measure)". There are several features of good indicators. They include scientific validity, time- and cost efficiency, societal relevance and public availability (Meadows 1998; Dijk et al. 2017). They should also be democratic (public participation during the development and measures should be publicly available), use existing data, be easy to understand, be clear about which direction is favourable, respond to management measures, simplify complicated phenomena and give early and clear signals of system changes (Meadows 1998; Halpern et al. 2012; Dijk et al. 2017). Co-creation of such indicators helps secure their societal relevance, but the process also requires scientific involvement to ensure that they meet the standards of good indicators.

Co-creating sustainability indicators can be summed up in three phases: (1) jointly articulating the sustainability goals and challenges and the required knowledge (co-design); (2) conducting integrated, collaborative research (co-production; e.g. selecting and operationalizing indicators); and (3) discussing the value, applicability and relevance of the results and the societal actions that could be taken based on them (co-evaluation; Fig. 1) (Prabhu 1999; Bell and Morse 2003; Reed et al. 2006; Mauser et al. 2013; Wanner et al. 2018). The transdisciplinary research process for co-creating sustainability indicators is based on collaboration across disciplines and with non-academics (Kates et al. 2001; Komiyama and Takeuchi 2006) and combines knowledge from different disciplines with experience- and place-based knowledges through an open, reflexive process, focusing on two-way learning (Reed et al. 2006; Regeer and Bunders 2009; Dijk et al. 2017; DeFries and Nagendra 2017). The three phases of co-design, co-production and co-evaluation can also be enhanced by transdisciplinary experiments for identifying ocean solutions to societal challenges, such as in real-world laboratories proposed by Franke et al. (2023) for the UN Ocean Decade. The level of involvement tends to be greatest during the first and third step, while operationalizing indicators (e.g. collecting and analysing data and formulating indicators) generally requires substantial

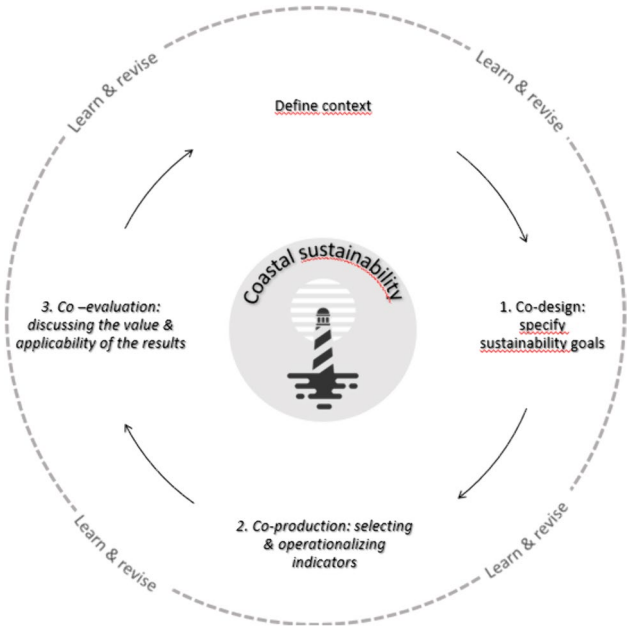

Fig. 1 Key steps to co-creating sustainability indicators based on Reed et al. (2006) and Mauser et al. 2013)

scientific involvement as a part of the co-production process. Co-creation often gives rise to new research questions, and adjustments to sustainability goals and indicators may be required along the way with new knowledge or changes in societal values and community priorities (Reed et al. 2006; Mauser et al. 2013).

In the Coastal Barometer project (kystbarometeret.no), the aim is to co-create sustainability indicators relevant for coastal communities in Northern Norway. This is a region undergoing rapid changes due to growth in the tourism, aquaculture and energy sectors (see "Study region"). Thus, knowledge about the implications of current trajectories and how they align with sustainability, as perceived at multiple levels from national to local, is needed to guide decision-making and inform and empower local communities. The Coastal Barometer follows the co-creation process illustrated in Fig. 1, starting with co-designing sustainability goals with local knowledge-holders, discussing in an interdisciplinary research team the data availability and other opportunities to operationalize relevant indicators (co-production) and then attaining feedback and discussing these indicators with society (co-evaluation) which in turn feeds back to adjustments needed.

Our focus in this paper is mainly on co-design and partly on the co-production of goals and indicators of the Coastal Barometer. We present the sustainability goals and sub-goals deemed most relevant for local people and the process of eliciting these goals. We also present an assessment of data availability for indicators measuring progress towards these goals. This assessment is carried out by the researchers in

this project (i.e. the authors of this paper). We consider this to be part of the co-production phase (i.e. the selecting and operationalizing of indicators, Fig. 1). Finally, we include local knowledge-holders' suggestions on how to reach these goals (i.e. proposed management measures) to show the broad spectrum of information provided by those involved.

In the co-design phase, we involved local knowledge-holders representing different industries and interests from six communities geographically dispersed throughout Northern Norway. Our goal was to elicit their views on what coastal sustainability is and what they consider to be important for assessing sustainability. We used the Ocean Health Index (OHI) framework (Halpern et al. 2012) and focused on eight global OHI goals that we consider relevant for this region (see "Ocean health index" section. for details on the OHI). We named the tool the Coastal Barometer to signal that we are co-creating goals and indicators of coastal sustainability and to appeal to coastal communities by using a more intuitive and lay term in Norwegian language compared to its predecessor "the Ocean Health Index". Specifically, we ask:

1. What are locally articulated sustainability goals pertaining to eight global OHI goals of relevance for coastal development in Northern Norway: small-scale fisheries, food production, sense of place, tourism, economy and livelihoods, biodiversity, carbon storage and clean waters?
2. What are locally articulated management measures (i.e. input on how to attain local sustainability goals)?
3. What data are available for assessing progress towards these goals? Are current data and monitoring programmes biased towards interests other than those articulated as important for local communities in the present study?

Ocean Health Index

The Coastal Barometer uses the OHI (Halpern et al. 2012) as a framework, which can be used to assess ocean health and sustainable coastal development from global to local scales using quantitative indicators. It has, for instance, been used to track progress towards Aichi target 10 and UN Sustainable Development Goal 14 "Life below Water" at global scales (Sachs et al. 2018; Afflerbach et al. 2019) and to assess how changes in management and human use of oceans have affected overall ocean health at regional scales (O'Hara et al. 2020; Montgomery et al. 2021). The OHI defines a healthy ocean as one that "sustainably delivers a range of benefits to people now and in the future", which is measured against 10 overarching goals (Halpern et al. 2012). The OHI goals are referred to as global OHI goals in this paper to avoid confusion with the term local sustainability goals.

The OHI was initially applied globally, but has since been widely applied at local and regional scales, so-called OHI$^+$ assessments (Elfes et al. 2014; Selig et al. 2015; OHI 2019; O'Hara et al. 2020; Exeter et al. 2021; Montgomery et al. 2021). OHI$^+$ assessments allow local priorities, local data availability and the local context to be accounted for to a greater degree (Lowndes et al. 2015) and are as such more relevant to local decision-making than the global OHI. However, to be applicable for local decision-making, there is a need to integrate different perspectives in OHI assessments, such as the voices of local and Indigenous communities (Franke et al. 2020).

Materials and methods

In this section, we first describe the study region where the sustainability indicators will be applied. We then describe the process of eliciting local sustainability goals and assessing data availability for measuring progress towards these goals.

Study region

The geographical scope of our sustainability assessment includes all the coastal municipalities in Northern Norway ($n = 81$, Fig. 2). At the regional level there are three counties in this region—i.e. Nordland, Troms and Finnmark. There is great economic value, interest and future potential in the region, especially related to industries utilizing natural resources such as hydropower, petroleum and "blue industries" such as seafood and coastal tourism (KPB 2023;

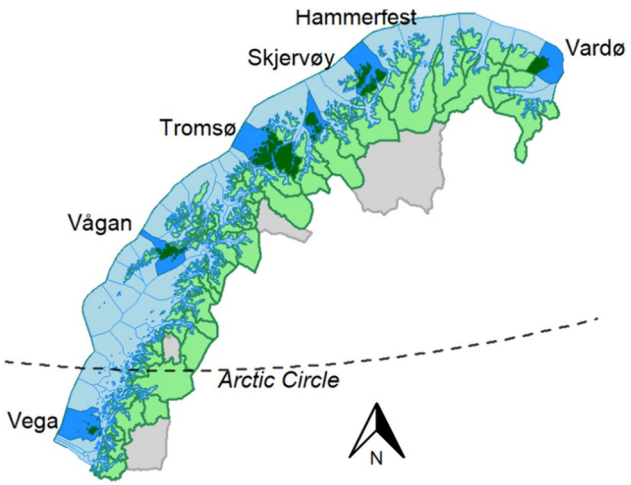

Fig. 2 Study areas. A map of the study area for the Coastal Barometer, which covers the land area (green polygons) and sea area (blue polygons) of the coastal municipalities in Northern Norway. Stakeholder involvement was carried out in the highlighted (i.e. dark blue/dark green polygons) municipalities

Business Index North). For instance, favourable environmental conditions and technological innovation have made Norway a major player on the global market for farmed salmon (Ministry of Trade, Industry and Fishery 2015), and further expansion in this industry is encouraged (Ministry of Trade, Industry and Fishery and Ministry of Petroleum and Energy 2017). The region is also a tourism hub (Ministry of Trade, Industry and Fishery 2016; NHO Tourism 2018; Runge et al. 2020). While representing a source of income, there are also sustainability concerns related to the tourism industry (Runge et al. 2020). Energy, extractive industries and transportation are also on the rise (Norwegian Ministries 2017).

Eliciting local sustainability goals and exploring data availability as a part of co-design

Case communities

Six coastal municipalities were selected where local knowledge-holders were involved in co-designing sustainability goals. These six study areas are geographically spread throughout the study region (Fig. 2) and represented a variation in population and commercial development, and environmental and natural resources (Table 1). These communities include Vardø, Hammerfest, Skjervøy, Tromsø, Vågan and Vega (Fig. 2), and are presented in detail in Engen et al. (2020).

Recruitment of local knowledge-holders

In each municipality, we invited 20–30 people to participate in the study. These included people from industries, such as seafood (aquaculture, fisheries, fish processing), maritime, tourism and petroleum; representatives from environmental, recreational, hunting and fishing organizations; individuals from protected area management, coastal administration, the State Nature Inspectorate, municipal administrations and from high schools; and representative of indigenous (Sámi) interests, including art, culture and architecture.

The selection of participants was based on our goal of capturing a wide range of perceptions and knowledge about coastal areas and sustainability. Local knowledge-holders were identified through online searches (i) in local and regional newspapers, (ii) on the municipalities' web pages and (iii) on the webpages of local organizations and businesses. We also identified local knowledge-holders involved in municipal land use and coastal zone plans, received suggestions from the municipalities and researchers in the Coastal Barometer with prior knowledge of the case municipalities and asked participants that signed up for the workshop to identify other relevant participants.

We mainly recruited participants by email and telephone. Everyone received an email with an invitation to participate in a survey and in a focus group meeting five weeks ahead of time (except for Tromsø where we scheduled the meeting 2.5 weeks after we sent the invitation). The deadline for responding to the survey and for confirming participation in the focus group meeting was 2 weeks. A reminder was sent before the deadline expired and those who did not reply within the deadline were called up to hear if they wanted to participate.

Involvement of local knowledge-holders through the nominal group technique

The method chosen for obtaining input from local knowledge-holders was based on the nominal group technique (NTG), which is a structured method for identifying, discussing and prioritizing actions, among other things. In NTG, people with different perceptions on an issue meet to individually think through ideas related to questions asked by a facilitator (step 1), share the ideas with the group (step 2) before ideas are adjusted and synthesized through a group discussion (step 3) and finally prioritized

Table 1 Population size and indicators of the size of key marine industries in the different study municipalities

	Vardø	Hammerfest	Skjervøy	Tromsø	Vågan	Vega
Population size (2022)[a]	1900	11,283	2780	77,765	9714	1195
Expected population size in 2050[a]	1982	11,303	2555	84,846	10,219	1099
Tonnes of farmed salmon produced in 2019[b]	0	20,862	24,537	15,631	1106	4800
Number of fishers in the municipality in 2019	118	92	83	378	223	30
Number of people employed in tourism in 2019[c]	96	514	58	5855	739	65
Tax incomes to the municipalities from people employed in tourism[c]	2,054,000	17,762,000	760,000	200,000,000	15,684,000	554,000

[a]Data from Statistics Norway

[b]Data from The Norwegian Fisheries Directorate

[c]Data from the Confederation of Norwegian Enterprise

through ranking (step 4) (Delbecq and Van de Ven 1971; Hugé and Mukherjee 2018).

There are several benefits to NTG, along with some limitations that need to be considered. Individually generating ideas is thought to make the process more efficient because people are able to think freely without having to concentrate on others talking at the same time (Hugé and Mukherjee 2018), while group discussions can enable more rational decision-making by, for instance, reducing people's tendency to be overconfident in their own assessments (Mukherjee et al. 2018). Another strength of the method is that it ensures that every voice in the group is heard and it limits domination by just a few. NTG works best when the issue raised is not very contentious (Hugé and Mukherjee 2018; Mukherjee et al. 2018). The aim of this study was to elicit locally relevant coastal sustainability goals, something we consider less contentious than identifying the indicators and weighing different interests in specific cases.

We adjusted the method to accommodate our need for input on eight global OHI goals, since NTG is designed for input on few topics/questions at a time (Hugé and Mukherjee 2018). The local knowledge-holders were introduced to the eight global OHI goals through a survey sent out prior to the focus groups (step 1), and the same global OHI goals with related questions were discussed during the focus group (step 2). Project researchers synthesized local knowledge-holders' input (step 3), which was presented to them through a report (Engen et al. 2020) (step 4). The local knowledge-holders were able to comment and suggest amendments to the report. Capacity constraints did not allow our synthesis of local knowledge-holders' input to be subject to rigorous group discussion among those involved.

Figure 3 shows the introduction to each global OHI goal given to the participants. The adjusted NTG process is described in detail in supplementary material 1 (S1). The full version of the survey in Norwegian can be found in supplementary material 2 (S2). The survey was developed by a few members of the project team. It was designed to be open ended and allow for rich descriptions related to each topic, while also providing participants with some information regarding each topic. The survey followed the structure of the Ocean Health Index topics and encouraged participants to elicit what they think is important to consider when assessing the state and sustainability relating to each topic (e.g. state and sustainability of food provisioning from aquaculture and fisheries, the economy, tourism, etc.). The survey also included a few background questions to allow us to roughly assess the representativity of our survey according to common parameters (age, gender, occupation, education).

Qualitative coding of local knowledge-holders' input

When synthesizing local knowledge-holders' input, we focused on statements reflecting normative views (i.e. statements reflecting what is good or bad) about the state or development of the coastal socioecological system for the different topics. We organized these perceptions into overarching local sustainability goals and local sub-goals. We also coded what we considered suggestions of measures for achieving a desired state or development. This input was not analyzed further (i.e. we did not assess data availability), but it is included in the supplementary material.

This work was guided by the distinction between principles and criteria. Principles are fundamental ideas or guidelines about what sustainability is (here: local sustainability goals) (Prabhu 1999). Criteria refer to standards that say something about when the principle is realized (here: local sub-goals) without directly measuring condition which is what indicators do (Prabhu 1999; Mendoza and Prabhu 2000; Hák et al. 2007). Mendoza and Prabhu (2000) describe this as a way to "collect and organize information in a manner that is useful in conceptualizing, evaluating, implementing, and communicating" sustainability. Thus, throughout this paper we refer to local sustainability goals as overarching ideas and fundamental principles about sustainability, local sub-goals as criteria that specify what sustainability goals mean in practice at local level, while indicators refer to the quantitative and qualitative data that we synthesize as the product of the Coastal Barometer aimed at measuring progress towards local sustainability goals and sub-goals. The indicators themselves are not presented in this paper.

Researchers' evaluation of data availability

Based on relevant local knowledge-holder's input, an interdisciplinary team of scientists with a background in ecology (e.g. research related to marine spatial ecology, fisheries and aquaculture, marine and coastal biodiversity, carbon storage and sequestration), environmental social sciences (sustainability science, political science) and socioeconomics assessed the availability of data to create indicators that could measure the locally defined sustainability goals. Additional researchers were involved in developing the Coastal Barometer other than those listed as co-authors. Some are mentioned in acknowledgements. Data availability was rated according to a traffic light system based on whether data that captured the sub-goal were available at the local level (municipality) and over time (Fig. 4). Green colour was assigned to sub-goals that met these two requirements. Data with restricted access (e.g. a permit is needed to access the data) were also marked as green if they otherwise met the requirements, though they were not readily available for download. Yellow was used

Fig. 3 Introduction to the eight global OHI goals relevant for Arctic Norway

on sub-goals where data were only partly available. This included cases where data were available (i) that captured a proxy measure for indicating the criteria envisioned by participants, (ii) at the national or regional levels, (iii) were available but not as an annual time series or (iv) required analysis or further processing. Red means that data were not available to measure the sub-goal. The process of rating was based on the input from researchers that had prior knowledge on data availability for a given sub-goal and through Internet searchers of public databases

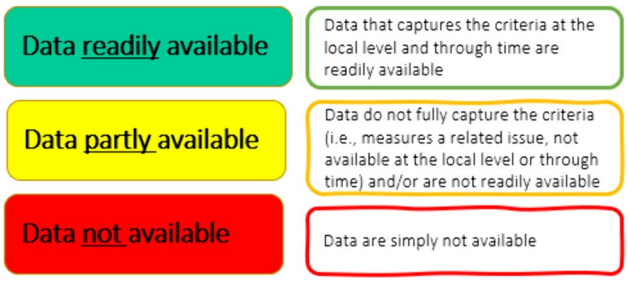

Fig. 4 Traffic light system for data availability. Colour coding that stipulates data availability for measuring local sustainability goals

and reports, along with inquiries to public authorities such as the Norwegian Fisheries Directorate and Statistics Norway.

Results

Local knowledge-holders

A total of 54 people participated in the co-design process either by answering a survey and/or participating in a focus group meeting. In each focus group meeting, 7–11 people attended. A pilot meeting was conducted in Tromsø. However, we were a bit pressed for time and the deadline from the time we sent the invitation to when we scheduled the meeting was short (2.5 weeks) and only one person attended. This person, nevertheless, contributed substantially to both the content and the process. Nature conservation, outdoor recreation and tourism were represented in the highest number of municipalities ($n = 5$; Table 2), followed by local fisheries, aquaculture, the seafood industry, the coastal administration and research ($n = 3$–4), and finally education, petroleum, deep-sea fishing, waste management, hunting and fishing, cultural and natural heritage and other local residents ($n = 1$–2; Table 2). Interest groups that we invited, but who did not participate were young people (i.e. high school students, local municipal youth council members), people representing Sea Sámi (Indigenous) interests and the maritime industry. The gender distribution was relatively balanced with 25 women and 29 men. The average age among those who reported this through the questionnaire ($n = 16$) was 57 years. This is above the average for Northern Norway, which was 42 in 2023 (Statistics Norway 2024).

Those who chose not to participate gave different reasons. Some felt that the questionnaire was too comprehensive, while others said that they did not find the topics that were relevant to their interests and activities. In some cases, the survey and the meetings coincided with fishery activity, political meetings, board meetings, stocktaking, public

Table 2 Local knowledge-holders involved in the co-design divided by the interest group

	Vardø	Hammerfest	Skjervøy	Tromsø	Svolvær	Vega
Nature conservation	X	X		X	X	X
Tourism	X		X	X	X	X
Outdoor recreation	X	X	X	X		X
The municipality		X[a]	X[a]		X	X
Aquaculture		X			X	X
Research	X				X	X
The seafood industry		X		X		X
Small-scale fisheries	X			X	X	
Coastal administration	X	X			X	
Cultural and natural heritage	X					X
Education (seafood industry)	X		X			
Local inhabitants	X		X			
Oil and gas		X				
Hunting and fishing		X				
Deep-sea fishing		X				
Pollution, waste management					X	
Focus group meetings (no. of participants)	11	7	7	1	7	9
Questionnaire (no. of replies)	3	2	1	5	1	0
Total no. of participants	14	9	8	6	8	9

The table shows interest groups that provided input to the Coastal Barometer through the questionnaire, interviews or focus group meetings by municipality

[a]Separate meeting with the municipal administration

events and a period where high school kids worked as interns away from school. Long travel distance to the meetings and infrequent ferry services also affected the turnout. Participation fatigue was a factor for the so-called "local champions" that are often asked to participate in local events. Lack of financial compensation for traveling and time spent at the meeting was also mentioned as a reason for not participating. An ongoing conflict between different interest groups also acted as a barrier to participation in at least one case.

Local sustainability goals and sub-goals

Below follows a description of the local sustainability goals and sub-goals for each of the eight global OHI goals, in addition to the assessment of the scientists of data availability for indicator development to measure progress towards these goals. Proposed management measures are also mentioned. A complete list of goals, sub-goals, proposed management measures and project researchers' evaluation of data availability can be found in supplementary material 3 (S3). Goals, sub-goals and researchers' data availably assessment are summarized in Fig. 5.

Local fisheries

Participants identified several issues tied to whether local fisheries are being sustained into the future. These were recruitment of fishers to the sector (e.g. number of fishers and vessels, age of fishers, age of vessels); gender balance; resource access (e.g. stock status, year-round resource access, quota size); opportunities for landing, transporting and exporting fish (e.g. fish landing sites and harbours); and diversity of species harvested.

Participants also made a number of suggestions on how to achieve these goals, such as simplifying fishery regulations, easier access to recruitment quotas (i.e. special quotas awarded younger people so they can enter the fishery), greater opportunities for financing the purchase of fishing vessel and quotas, reducing start and operating costs of small-scale fisheries, improved educational opportunities and providing an overview over the harvestable resources that exist locally and at the time of year these are available for harvest.

For recruitment of fishers, the data necessary for indicator development are available from the Norwegian Fisheries Directorate. For the other goals, data are partly available or lacking (Fig. 5). For instance, catch statistics and stock status for assessing whether fisheries are carried out sustainable (according to MSY) are only available for the most important commercial species. Fishers' income can be obtained through the tax registry, but data are not readily available. The number of fish landing sites and fishery harbours can be used as an indicator of landing and transport, but do not necessarily reflect access to infrastructure for individual fishers. Species diversity in catch statistics compared with stock statistics can capture the degree to which fishers fully utilize the resources available. These data do not fully capture whether they have the opportunity to diversify if the need is present.

Food production

Participants identified good governance (e.g. competent decision-making, no illegal activity, opportunities for local entrepreneurship); access to infrastructure and communication (e.g. effective means of transportation); little or no pollution; positive attitudes and few area-use conflicts; safeguarding biodiversity (e.g. low bycatch in fisheries, low impact of mariculture on wild fish); resource efficiency and quality products (e.g. low feed conversion ratio in mariculture); small-scale and local food production; utilizing a range of different species; and well-marketed seafood products as key aspects of sustainable food production.

The participants suggested a range of measures for reaching these goals such as using closed pens for fish farming, tagging farmed fish so that they are easily identified as escapees, increasing the protection of fjords to safeguard the smolt of wild salmon and redistributing fish quotas so that more people are granted access to small-scale fisheries to reduce CO_2 emissions.

The feed conversion ratio in mariculture was the only indicator that could be fully covered by existing data, because data on the amount of feed used and fish produced are available on request (need permission to access the data from the Norwegian Fisheries Directorate). Other data are available to cover many aspects of the environmental impact of mariculture, such as results from bottom sediment environmental survey, medical treatment, emissions of nitrogen and phosphorus, disease outbreaks and use of chemical agents to remove salmon lice. Catch statistics and stock status for the most important commercial species are available for assessing whether fisheries are sustainable (e.g. according to maximum sustainable yield) and the Norwegian Institute of Marine Research assesses the environmental impact of different fisheries with regard to size selectivity, discard issues and impact on bottom habitat, though information is not available at the local level.

Sense of place

Coastal areas were important for the participants for many reasons, such as for outdoor recreation (e.g. walks along the shoreline, spending time with family and friends, boating, kayaking, recreational fishing and diving); experiencing untouched, quiet or beautiful areas; for cultural history and cultural landscapes; and to carry out motorized vehicle use.

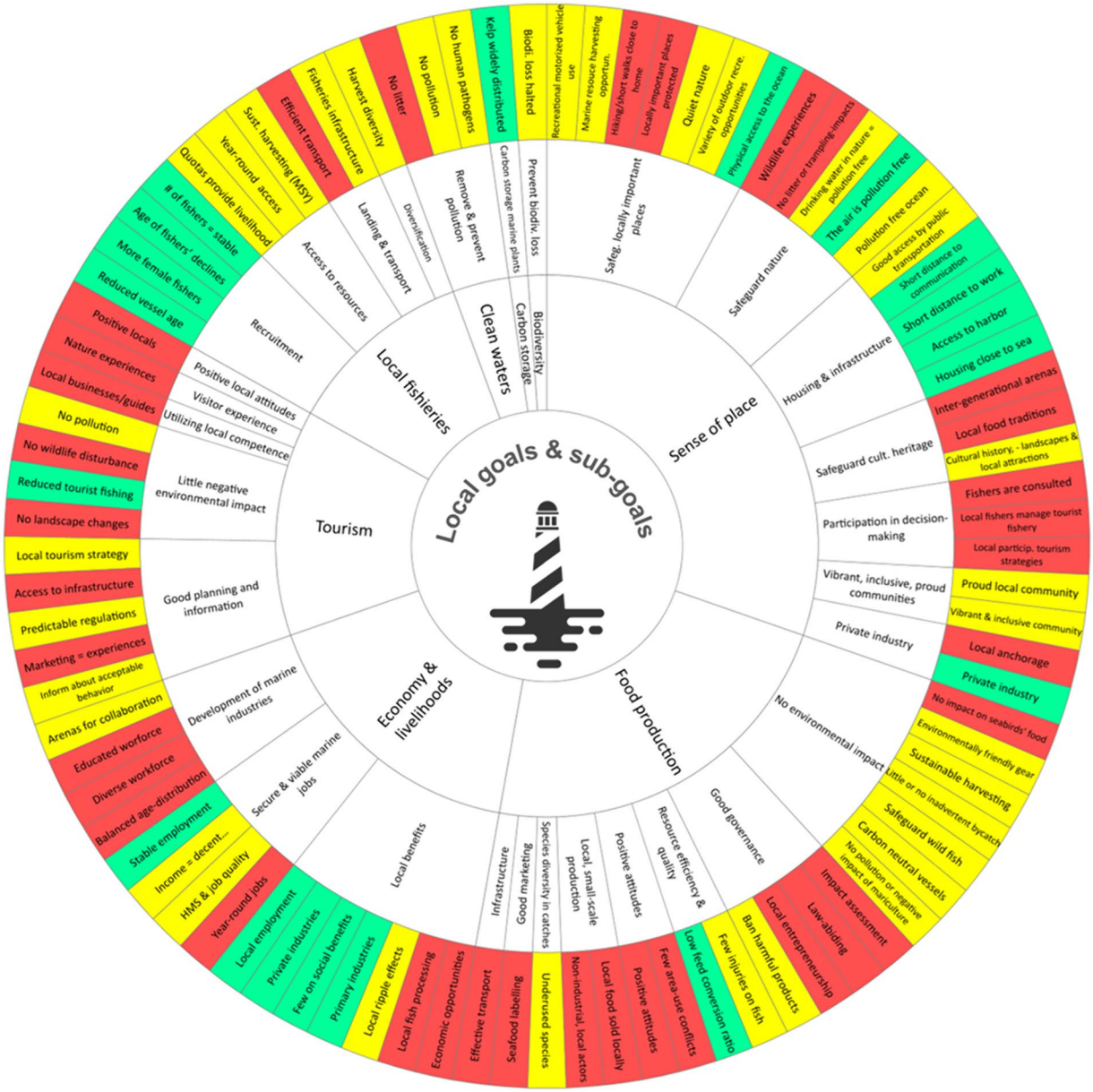

Fig. 5 Sustainability topics (inner ring), local sustainability goals (middle ring) and local sustainability sub-goals colour-coded according to project researchers' evaluation of data availability (outer ring). Sustainability goals and sub-goals were elicited through focus groups and surveys with local knowledge-holders in six coastal communities in Northern Norway in 2019. The colour coding describes data availability, as in Fig. 4

To assess whether opportunities for recreation and attributes of marine environments associated with sense of place are being sustained, the participants believed it was necessary to consider locally important places; safeguard nature, high quality places of residence and local traditions; have good infrastructure and communication; have private business; utilize locally anchored resource; have vibrant and inclusive communities; and participate in decision-making.

The participants also suggested several measures to follow up these sub-goals, such as avoiding establishing fish pens in areas that are important for recreational fishing, public ownership of outdoor recreation areas, map the use of outdoor recreation areas, limit land development, promote the uniqueness of different places, limit, facilitate and channel traffic and maintain trails.

Availability of the data necessary for indicator development was variable. Data were available for housing and infrastructure, air quality, private industry and access to the shoreline, but otherwise partly or fully lacking. The reason for the lack of data is likely a reflection of the

intangible nature of these issues (e.g. opportunities for intergenerational knowledge transmission, preservation of local food traditions, opportunities for wildlife experiences and quiet nature) and a view of these issues as less important than more easily quantifiable and economically rewarding (tradable) commodities such as seafood, overnight stays in tourism and employment rates. An online participatory mapping platform (www.mpt.link/kyst) along with industry-specific surveys (Engen et al. 2021) have been developed by the project to collect information related to goals identified by participants as important, including capturing locally important places and participation in decision-making, respectively.

Tourism

The coast and the ocean provide numerous opportunities for quality experiences for tourists, according to the local participants. These include, for instance, opportunities to experience wildlife; participating in fishing, hunting and other types of harvesting; boating; experiencing nature with little forms of facilitation (simple nature experiences); and experiencing culture and authentic communities. Sustainable tourism, according to the local participants, is characterized by maintaining quality experiences for tourists; little or no negative environmental impact; positive attitudes in the local population; good planning and facilitation; good information to tourists; and use of local competence (e.g. use of local guides).

The participants also suggested several measures to reach sustainability goals, such as improving safety for tourists, prioritizing small tourist businesses/actors/niche tourism and nature-based tourism, increasing restrictions on tourist fishing, improving control of tourist businesses, increasing certification of tourist destinations, and limiting the number of tourists.

Data for indicator development about tourism are not officially available for all 81 municipalities. The economic impact of tourism relating to overnight stays and employment is available, but what is perceived as high-quality experiences by tourists are better represented by reviews in social media platforms such as Flickr (Mul et al. 2022) or tripadvisor. A PPGIS survey carried out by the Coastal Barometer captures residents' attitudes to tourism in their municipalities (www.mpt.link/kyst), but there are no good monitoring data on environmental impacts or the degree of involvement of local expertise in tourism development. The state-owned development bank Innovation Norway has made its own sustainable destination label reflecting that a plan is in place for minimizing environmental impacts and to involve host communities (Innovation Norway 2022), but there are no monitoring data measuring the progress towards these goals.

Economy and livelihoods

An assessment of the economy and livelihood related to ocean and coastal industries should, according to the participants, consider if jobs in marine industries are viable and secure (i.e. that the number of jobs is stable, gives year-round employment and good job quality). In addition, attention should be paid to whether further development of these industries is prioritized by public authorities, for instance, by facilitating innovation and collaboration among different industries and making businesses attractive for people with higher education. Lastly, marine industries should contribute to settlement in coastal communities for instance through providing ripple effects locally such as jobs in other industries and income to the municipality.

Data on employment in marine industries are available on the municipal level for fisheries and aquaculture, but not for other sectors, as the marine component of sectors like tourism cannot be separated out. Such data are available for a few sectors, including fish and seafood processing at the county level, but not at the resolution of municipality. Data on wages, income and value added, including through economic ripple effects, are also available at this resolution. Data on job quality, development and collaboration in marine industries are not available.

Biodiversity

Halting biodiversity loss was mentioned by some participants, and we coded this as a local goal, in line with global goals. Additionally, the participants focused on the need for increased knowledge about changes in biodiversity over time as well as the need for greater knowledge about the causes of biodiversity loss.

Participants pointed to several factors that they believed were important to deal with to safeguard marine life, such as ocean acidification, pollution, alien species, reflection seismology and harvesting. Some also felt that a fundamental value change is necessary and that it is important to focus on awareness raising and to assess the values of decision-makers. Increased biodiversity conservation and exporting technology and management expertise were also mentioned as explicit management measures.

Data availability on biodiversity in coastal Arctic Norway was assessed by Arneberg (2021). Good datasets are available for seabirds (species diversity and abundance/number of breeding pairs) and demersal fish (number of species standardized to 10 trawl hauls), which are the two most important groups in coastal ecosystems. For the subgoal "habitat", five habitats were identified: coral reefs, kelp forests, eelgrass meadows, soft bottom shoreline and spawning grounds important to fish, shrimp or crabs. Important areas for breeding and moulting by grey- and harbor seals,

and the abundance of the key commercial species cod, haddock and shrimp, have also been identified as indicators of biodiversity (Arneberg 2021).

Carbon storage

Carbon storage seemed to be a topic that few people focus on or have knowledge about, as the input from the participants through the questionnaire on this topic was limited. As a result, we did not focus on carbon storage during the focus group meetings. Nevertheless, we received input through the questionnaire saying that to take advantage of the opportunities of carbon storage in marine plants, we must ensure that the kelp forests have a large distribution and are in a good condition.

Several measures to realize this goal were mentioned, such as removing the negative effects on kelp forests such as sea urchin grazing and kelp harvesting. It is also important to make management plans that ensure sustainable harvesting of marine plants, but also to prioritize kelp farming which has the possibility to bind CO_2 that can subsequently be sequestered using new technology.

Data on kelp distribution is available through a statistical model developed by NIVA (Frigstad et al. 2021) based on a large dataset from the Norwegian program for mapping of marine habitats (Bekkby et al. 2013). Older (and not statistical) models elucidate the presence and also the extensive loss of kelp forests in Northern Norway (Gundersen et al. 2011), while later Christie et al. (2019) explained the negative effects of climate change and crab predation on sea urchins. As sea urchins are an important predator of kelp, their population decline has resulted in the recovery of parts of the kelp forests, thus benefiting CO_2 binding and biodiversity (Christie et al. 2019).

Clean waters

An assessment of clean waters should, according to the participants, look at whether coastal waters are pollution free (e.g. free of litter, human pathogens from sewage for instance or other pollutants such as organic and inorganic substances).

The participants also mentioned several measures to achieve clean waters, such as sufficient opportunities for waste management for fishers and industry, awareness raising, stricter regulations (for instance prohibiting dumping of mine tailings in the fjord), prohibition of the use of heavy oil, reduction of the use of plastic and improvement of management (e.g. authorities map and clean up plastic pollution).

While visual surface, midwater and bottom trawl surveys have been established in the Barents Sea to monitor marine litter (Grøsvik et al. 2018), there are no litter surveys off the shore in coastal areas in Norway. Thus, the only data available are on beach litter as monitored through the OSPAR protocol and through citizen science protocols (Falk-Andersson et al. 2019). Data are not available at the level of municipality, and the amount of data available through the citizen science protocol, which is the protocol with the highest coverage, is low in this region (Falk-Andersson et al. 2019). The ecological and chemical state of coastal waters in Norway are classified through the EU Water Framework Directive. The chemical state reflects pollution due to environmental contaminants. The ecological state is determined by release of nutrients, thus mainly reflecting organic pollution, but also the degree of sedimentation which affect benthic communities. The coast of Arctic Norway is divided into 985 water bodies. By 2021, classification of the ecological state was conducted in 91% of these, but only 20% of the water bodies were assessed for chemical state. Classification should be based on measurements conducted in the past 3 years, but often a limited number of parameters are measured and the number of measurements in each water body is few. Classification is therefore often based on expert opinion.

Local knowledge-holders' feedback

A report was produced where we presented our synthesis of the local sustainability goals, sub-goals and management measures (Engen et al. 2020). Here, we also presented a preliminary suggestion of indicators that we could use to measure the degree to which the local sustainability goals were realized in practice. We sent this report to all the participants and gave them the opportunity to make amendments. Only a few people had comments on the report and none suggested changes to the principles, criteria or proposed indicators.

Data availability and gaps

Overall, we see that many local sustainability sub-goals are not captured by current data collection efforts organized by public authorities nor by other data that are readily available for the public. For 19 out of 89 sub-goals, readily available data exist (green colour, Fig. 5), while data are partly available for 35 sub-goals (yellow colour, Fig. 5) and not available for 35 sub-goals (red colour, Fig. 5).

Statistics Norway and the Norwegian Fisheries Directorate were the source of data in many cases (S3). Other actors that provide data according to our mapping include the Norwegian Mapping Authority, the Norwegian Institute for Air Research, the Norwegian Institute for Water research, the Norwegian Environmental Agency, the Norwegian Food Research Institute, BarentsWatch, the Norwegian Digitalization Agency, the Norwegian Institute of Public Health and Innovation Norway (S3).

There does not seem to be a clear-cut pattern in the type of sustainability goals that are captured by ongoing data collection efforts. Data availability seems to be relatively good for aspects of employment (including within fisheries), private/local industry and housing and infrastructure, air pollution and kelp distribution. The more intangible issues such as local attitudes, area-use conflicts, nature and cultural experiences and local anchorage, participation and entrepreneurship seem to be less well captured.

Discussion

Integrated assessments of coastal sustainability that capture the complexity of coastal socioecological systems can be used to guide decision-making along sustainable trajectories (Kates et al. 2001; Borja et al. 2016; Halpern 2020). However, defining what constitutes a healthy ocean (desired state/"what ought to be") is no easy task, let alone understanding how to move from the existing state ("what is") towards sustainability (Hisschemöller and Hoppe 1995; Dietz 2013; Hoppe 2018; Halpern 2020). Value differences, trade-offs between sustainability goals, different needs and governance create uncertainty about *which* goals should be pursued, while incomplete understanding about how complex socioecological systems respond to management create uncertainty about *how* sustainability goals should be pursued. The choice of scale also has implications on how sustainability is understood and measured, where assessments developed for larger scales without local involvement may miss socioecological changes critical for locals (Sterling et al. 2017) and fail to resonate with local actors and decision-makers, while assessments at very small scales may miss connections to and influences from regional and larger-scale drivers.

Our study shows that there is a diverse set of goals and criteria that locals find relevant to measure to reflect coastal sustainability. We also find that most of these goals and criteria are difficult to measure using existing data or need further specification or in-depth assessments to compare to indicators normally used in sustainability assessments. Unsurprisingly, there is a lack of data available to measure the importance of local culture, traditions and heritage, but there is also knowledge and data gaps relating to sustainable tourism and food production from a local perspective. Our ambition with the Coastal Barometer is to contribute with transparent and informed open discussion for learning about what matters to people and to stimulate to deliberations about the principles and criteria relevant to desirable sustainable future conditions that is supported by information available (IPBES 2024). To enhance deliberations there is also a need to generate information that reflects the goals and criteria that local people define as relevant for measuring sustainability.

Co-creation may help resolve issues of scale, i.e. allow for results to be scaled up or down depending on the situation, while maintaining legitimacy and relevance for decision-makers at different levels. Involving non-academics in research may also inspire society at large to act on the basis of new research and results (Komiyama and Takeuchi 2006), as well as inspire other researchers to work collaboratively with non-academics. Through such a collaborative process all involved parties learn from each other—i.e. there is a knowledge exchange. Thus, potential outcomes of co-creation include socially robust and scientifically credible knowledge, empowerment, learning and transformative change (Gibbons 1999; Regeer and Bunders 2009; Lang et al. 2012).

In this study, local knowledge-holders from Northern Norway contributed to defining locally important sustainability goals as an initial step termed the co-design phase, towards co-creating a coastal barometer (i.e. sustainability indicators). We also received rich input on how these goals should be pursued (i.e. management measures).

We identified two main challenges to knowledge co-creation in our co-design and co-production phase, namely representation and data availability. While we reached out to a broad range of local knowledge-holders, we experienced some challenges with lack of representation of a few groups. Data are available for many of the sub-goals identified as important by local people knowledge-holders. While there was not a clear bias in data and monitoring programmes to measure the eight global OHI goals, some areas need strengthening to capture local concerns. In the following, we discuss these two challenges ("Securing representativity of local knowledge-holders" and "Biases in data availability and monitoring programmes"), along with other potential sources of bias ("Other sources of bias") and the way forward for co-creating coastal sustainability indicators ("The way forward"). We also reflect on the co-creation process and how local input and data availability influenced indicator development ("Constructing a coastal barometer based on the OHI framework").

Securing representativity of local knowledge-holders

In line with the vision of the UN Decade of Ocean Science, we aim to develop an inclusive barometer by inviting people to define sustainability and co-produce knowledge about a sustainable and healthy ocean seen from the perspective of coastal communities. Our study illustrates how local knowledge and values are essential for an enriched picture of coastal sustainability. This enriched picture can "serve as a legitimate starting point for further analysis and knowledge generation" (Tengö et al. 2014). However, this also requires

that the local knowledge-holders involved are representative for the issue at hand. We reached out broadly when inviting relevant local people to give input in this study; however, three key stakeholders and rights holders were not represented: young people (ages 14–19), people representing Sea Sámi (Indigenous) interests and the maritime industry.

Indigenous communities are particularly vulnerable to anthropogenic actions due to their close links to and reliance on the natural environment (Kosanic and Petzold 2020), and ensuring that the voices of Indigenous communities are heard is essential for equitable sustainability transitions. In Norway, securing the material basis for Sámi livelihoods and culture is a key concern, such as the access to coastal pastures and migration routes for Indigenous Sámi reindeer herding, along with providing opportunities for small-scale fishing (Broderstad and Eythórsson 2014; Johnsen and Søreng 2018; Hausner et al. 2019; Engen et al. 2021). A key challenge with Indigenous Sámi participation is research fatigue (Engen et al. 2023), which could partly explain the lack of Sea Sámi participation in our case. Another factor was the lack of compensation for travelling to the venue. Going forward, Sea Sámi concerns and participation will receive much more attention through the work with incorporating the Indigenous perspectives into the barometer.

Unsustainable resource use and the degradation of ecosystems deprive younger generations of future opportunities and create intergenerational injustices (Knappe and Renn 2022) Thus, involving younger people in defining sustainability is important. This is recently recognized in the Global Biodiversity Framework, which stresses that intergenerational justice and the meaningful participation of younger generations should be a guiding principle for implementation of the framework (CBD 2022). Younger people however seemed reluctant to participate in our study. We suspect that the workshop format might have seemed a bit overwhelming, seeing as they were asked to participate together with adult stakeholders. They did not take the opportunity to give input through the questionnaire, which suggests that the framing of the study may have failed to resonate with them. Going forward, young representatives may require a tailored format for increased participation. Young people are also a key target group for the outputs from the barometer, which we envision can be used in schools and elsewhere for educational purposes.

The shipyard industry is a key industry within the maritime segment (i.e. businesses that own, operate, design, construct deliver equipment or specialized services to all kinds of ships and other floating devices (Haugland et al. 2021). In Norway, shipyards are often cornerstone companies that contribute to local employment and value creation, and in Northern Norway the shipyard industry is mainly smaller with new building and repair with aquaculture and fishing as the main markets (Haugland et al. 2021). The lack of participation of shipyards could be due to a lack of resonance—e.g. coastal sustainability may not seem directly relevant for these actors compared with, for instance, industries that more directly rely on and impact the environment such as fisheries and aquaculture.

Poor, elderly and disabled have also been identified as an often-marginalized social groups particularly vulnerable to anthropogenic actions (Kosanic and Petzold 2020). Capturing the perspectives of these groups may give additional perspectives, for example related to the importance of proximity to natural resources (Kosanic and Petzold 2020). We did not explicitly focus on the participation of these groups. This is also something to keep in mind for future stakeholder involvement in the barometer.

Biases in data availability and monitoring programmes

While there does not seem to be a strong bias in data collection and monitoring programmes, we do find gaps in data availability that limits opportunities for assessing progress towards locally defined sustainability goals. Our results show that the local people were highly engaged when discussing sociocultural values relating to sense of place, fisheries and environmentally and culturally sensitive tourism, but that data seems to be especially scarce when it comes to social and cultural aspects such as governance, attitudes, experiences, cultural history, traditions and local anchorage. Many of these aspects fall within the concept of "cultural ecosystem services". These are non-material benefits people obtain from nature in terms of spiritual, esthetic, educational and recreational values. While supporting, provisioning and regulating services often provide more tangible benefits to human well-being, the ecosystem service concept also recognizes the importance of the ecosystem in providing cultural services (Millennium Ecosystem Assessment 2005).

A lack of data and analysis of cultural ecosystem services (CES), as well as structures for including qualitative data on CES in management decisions, have been identified as a hindrance of their uptake in policymaking and management practices (Hernández-Morcillo et al. 2013; Martin et al. 2016; Kosanic and Petzold 2020). A review by Martin et al. (2016) found little information on CES in specific coastal and marine habitats and ecosystems, which was linked to the lack of disaggregated data for these ecosystems (Martin et al. 2016). They argued that the risk of this is that our understanding of CES values associated with various habitat types may be poorly understood and therefore undervalued. This issue of scale is also a limitation of our study as the sustainability goals is generalized to the level of coastal municipalities.

Studies on CES have been dominated by recreation and tourism, which may be due to these services being more

tangible and easier to quantify using monetary valuation methods (Hernández-Morcillo et al. 2013; Martin et al. 2016). Still, qualitative and quantitative methods are both used in CES research to identify a range of CES (Hernández-Morcillo et al. 2013; Martin et al. 2016; Kosanic and Petzold 2020). Addressing research gaps on CES does not only require quantification, but also in-depth understanding of the specific CES and the qualitative benefits they represent to individuals and groups. For example, while quantitative data is important for building maps, classification and ranking of CES, qualitative information gives insights into the ranking and understanding links between cultural practices and nature. Mixed-method approaches using multidisciplinary integrated frameworks have therefore been recommended for capturing CES (Cabana et al. 2020; Kosanic and Petzold 2020).

A topic that was not explicitly raised by the local knowledge-holders in this study was the connection between nature and physical and mental well-being, which has been identified as an important area of research on CES (Hernández-Morcillo et al 2013; Kosanic and Petzold 2020). This could be due to the framing of the workshops around the sustainability goals. The local knowledge-holders did identify related factors such as "vibrant, inclusive, and proud communities", "hiking/short walks close to home", and "physical access to the ocean". Closer collaboration with the health sciences can contribute to improving our understanding of the link between the sustainability goals and physical and mental well-being.

Filling these gaps will be a key step in being able to complete a comprehensive assessment of the health of the ocean and its significance regarding human health in Northern Norway. More effort is therefore needed to integrate these aspects in the coastal barometer.

Other sources of bias

There are other sources of bias that could have affected the local input we collected. This includes group dynamics during the workshops, where vocal and powerful individuals may have affected what participants felt comfortable sharing. We attempted to remedy this with individual dialogues with participants after the workshop, in some cases. Moreover, our choice of a mixed-methods approach allowed participants to express themselves through surveys as well as in groups. In "Local knowledge-holders" we also reflected on other barriers to participation expressed by our participants (including seasonal activities that collide with the workshops, along with other commitments, capacity and travel distances, participation fatigue).

The way we researchers organize the co-creation process, including how we interpret and understand participants' input is affected by our knowledge, background and values, and also has an effect on the results. For instance, our grouping of the local input for the ecological sustainability topics was influenced by a natural science perspective focusing on input explicitly referring to the environmental state (i.e. how good or bad the situation is for biodiversity, clean waters and carbon storage). We also found that the ecological goals were more challenging to discuss with local knowledge-holders, in some cases, than the social and economic topics, and quite a few participants referred to ecological sustainability as a scientific and public management responsibility. In retrospect, we could have lifted other aspects mentioned by the participants from management measures to sub-goals, such as fundamental value change, preventing negative effects of harvesting, increased marine protected area and reduced ocean acidification. The iterative nature of the co-creation process is in place so that we can be reflexive about and articulate these different understandings and ways of interpreting sustainability so that these are brought to the fore and discussed.

Constructing a coastal barometer based on the OHI framework

Albeit data were lacking for several of the sustainability issues brought forward by local knowledge-holders, we were able to combine local input and concerns with the datasets available to construct sub-indicators for eight of the ten OHI indicators for 81 coastal communities (kystbarometeret.no). In this process, we gave priority to local concerns and although we kept the original formulation of the goals given by the OHI framework, the sub-goals were re-formulated to match local context and data availability. For example, local fisheries (named Artisanal Fisheries Opportunities in the original OHI framework) was given high priority by local knowledge-holders. In the OHI framework, the goal ensures the access to artisanal fishing for local fishing communities and measures whether people who need to fish on a small, local scale have the opportunity to do so (oceanhealthindex.org). Our local knowledge-holders were especially concerned about the recruitment of local fishers, the local access to resources and the opportunities for landing and processing the catch in the community (see "Local fisheries"). To accommodate these concerns, we developed three sub-goals measuring the change in the number of local fishers and small fishing vessels as indicators of recruitment to local fisheries and the proportion of the value of fish harvested within the community that was fished by local fishers and delivered locally, measuring a combination of local access to the resources and local opportunities for landing of catches. Similar adjustments were made for all of the nine OHI goals, and the formulation of goals and sub-goals together with the statistics are shown on the web platform.

The way forward

Securing representativity is important in co-development of knowledge. Exploring new methods to secure broad stakeholder involvement can increase the legitimacy of the process. This inclusivity will also contribute to understanding the different types of CES affecting human well-being, including the impact of the resolution of data collected, and the trade-offs involved (Martin et al. 2016; Kosanic and Petzold 2020). Such studies of CES are crucially needed for further insight into how sociocultural aspects can be better accounted for in the development of indicators in the Coastal Barometer.

The Coastal Barometer project is novel in its strong emphasis on social and cultural sustainability, and we have collected additional social data to fill some of the gaps identified in this study. For instance, we have invited 17,000 residents in the 81 coastal communities in Northern Norway to share their observations and perceptions on coastal sustainability and map locally important areas through a web-based public participation GIS survey. We have carried out big data analyses of social media data (Runge et al. 2020; Mul et al. 2022) and developed a survey instrument for eliciting local knowledge-holders' perceptions of justice and inclusivity in light of the blue economy (Engen et al. 2021), which will be used to survey representatives of blue industries. We are also working extensively with Indigenous perspectives related to our sustainability topics. The plan is to incorporate all these efforts into the Coastal Barometer.

The Coastal Barometer is currently being launched to the public. Our ambition is that this knowledge platform will function as a democratic tool for the local population of coastal communities in the region, as well as a source of information for planning and management, ultimately benefitting North Norwegian ocean health. The launch also includes reaching out to local decision-makers and knowledge-holders for feedback on the indicators now that they have been developed. This brings us to phase 3 of the co-creation process—namely, co-evaluation.

During the co-evaluation phase, we will present the local input (i.e. the goals, sub-goals, management measures) and the resulting indicators. We will discuss how well the indicators resonate with local perspectives on sustainability and facilitate dialogue on suggested revisions, potential applications of the tool, as well as different ways of disseminating this work.

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Data availability Data supporting this study are included within the article and/or supporting materials.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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