frontiers | Frontiers in Marine Science

TYPE Policy and Practice Reviews
PUBLISHED 01 November 2023
DOI 10.3389/fmars.2023.1144181

OPEN ACCESS

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RECEIVED 13 January 2023
ACCEPTED 18 August 2023
PUBLISHED 01 November 2023

CITATION
Baker MR, Steins NA, Pastoors MA, Neuenfeldt S, de Boer A, Haasnoot D, Madsen S, Muller J, Post K, Sparrevohn CR and van der Meij M (2023) A new era for science-industry research collaboration – a view towards the future. *Front. Mar. Sci.* 10:1144181. doi: 10.3389/fmars.2023.1144181

A new era for science-industry research collaboration – a view towards the future

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Direct engagement of the fishing industry in the provision and co-creation of knowledge and data for research and management is increasingly prevalent. In both the North Atlantic and North Pacific, enhanced and targeted engagement is evident. More is needed. Science-Industry collaborative approaches to developing questions, collecting data, interpreting data, and sharing knowledge create opportunities for information transfer and improved understanding of ecosystem interactions, stock dynamics, economic incentives, and response to management. These collaborations require clear communication and awareness of objectives and outcomes. These initiatives also require careful attention to conditions and interactions that foster respect, trust, and communication. Respect is critical and entails acknowledging the respective skills and expertise of both scientists and fishers. Trust is needed to build confidence in the information developed and its use. Communication is essential to maintain relationships and leverage shared insights. To assess current trends and future opportunities related to this type of engagement, we convened a networking session of research scientists, industry scientists, industry leaders, and fishers at the Annual Science Meeting of the International Council for the Exploration of the Sea (ICES) to address the following questions: (1) What are scientific needs that could be addressed with industry-collected data or knowledge? And (2) How can science-industry collaboration be made sustainable? Here we identify opportunities and acknowledge challenges, outline necessary conditions for respectful and sustainable collaborative research, and highlight ways to promote stakeholder involvement in developing science. We address industry concerns and solicit industry advice. We also address challenges to scientists in ensuring standards for scientific data, conflict of interest, and applying information to advise management. The discussions in this session and subsequent correspondence have led to a set of guidelines and best practices that provide a framework to advance further collaboration between industry and research science. We identify opportunities for directed engagement. We also detail potential approaches to clarify expectations and develop avenues for iterative communication and engagement to sustain collaborative efforts over time. The intent is to improve and expand data streams and contextual understanding of ecosystem processes, stock assessment, and socio-economic dynamics to the benefits of science and industry alike.

KEYWORDS

fisheries, participatory research, collaborative research, cooperative research, stakeholder involvement, industry engagement, fisheries management

Introduction

Industry engagement with science in the context of fisheries research has waxed and waned over time and can be sensitive to the timing of prevailing issues related to management (Karp et al., 2001). Presently, there is increasing interest and initiative to promote stronger stakeholder and industry participation in the development of science and directed management of marine fisheries resources (Kaplan and McCay, 2004; Röckmann et al., 2017; Mackinson and Middleton, 2018; Baker et al., In Press). In the past few decades, documented instances of collaborative research in fisheries have grown substantially (Mackinson et al., 2011; Holm et al., 2020; Mackinson, 2022; Steins et al., 2022). Intensified collaborative research involving science and industry is motivated by the longstanding recognition and respect for the knowledge and experience of fishers operating in marine environments (Branch and Kleiber, 2017). This experiential knowledge includes recognition of patterns and processes, understanding of stock dynamics, awareness of environmental effects, and expertise in gear, equipment, and research platforms. Other driving factors include the opportunity to develop data streams with increased spatial and temporal coverage, to access remote areas or unusual conditions, to strengthen and augment existing data, and to test and improve gear or approaches. Additionally, successful management of fisheries requires improved understanding of social and economic dimensions and incentives (Berkes and Folke, 2000; Fulton et al., 2011). Fisheries science is a multidisciplinary domain that encompasses ecological processes, social dynamics, and economic drivers and interactions. At the core of fisheries, both the fishing industry and individual fishers (Figure 1) have direct and valuable knowledge not only about the environments they work in (Johannes et al., 2000), but also choices made and responses to regulation and management. This provides valuable insight to potential tradeoffs in objectives and implications for management actions (Neis et al., 1999; Neis and Felt, 2000; Gutierrez et al., 2011; De Alessi et al., 2021).

In the context of fisheries and marine science, science-industry research collaboration (SIRC) entails engaging industry partners and leveraging industry insight and infrastructure to inform scientific efforts. This might include addressing pressing fishery management needs, improving shared understanding between science and industry, and supporting marine observations. This approach encourages practicality, cost-effectiveness, and the application of results to inform fishery management (Baker and Smith, 2018). Similar to Steins et al. (2020), we define SIRC as collaborative engagement between scientists and fishers, aimed at improving knowledge for fisheries management through both fisheries-related data and fisher's experiential knowledge (Stephenson et al., 2016). As an applied approach, this entails direct industry engagement in problem identification, research design, data collection, analysis, and communication of results (Johnson and Van Densen, 2007).

There are clear direct and indirect benefits to SIRC (Johnson and Van Densen, 2007; Steins et al., 2020). These benefits have been demonstrated across multiple ecosystems and management frameworks. Direct benefits include cost-efficient data collection, enhanced temporal and spatial coverage, increased quantity and quality of the available data, and improved knowledge for fisheries management (Karp et al., 2001; Wendt and Starr, 2009; Lordan et al., 2011; Kraan et al., 2013; Stephenson et al., 2016; Mangi et al., 2018; Bleeker et al., 2021). SIRC also integrates industry knowledge in science and management (Neis et al., 1999; Kaplan and McCay, 2004) and improves the relevance of directed research, ensuring it addresses important pressing fisheries management issues (e.g., stock status, selectivity, gear technology, habitat closures; Johnson and Van Densen, 2007; Stephenson et al., 2016; Baker and Smith, 2018). SIRC also facilitates interest in and opportunities for adaptive management (Johnson and Van Densen, 2007). Indirect benefits include improved relations and engagement between fishers, scientists and managers and increased transparency and communication (Johnson and Van Densen, 2007; Steins et al., 2020). Ideally, this type of engagement, particularly when conducted in an iterative manner and over long timeframes, results in shared understanding of the data, problems, and solutions, and increased trust. Collaborative approaches to analysis and interpretation further this shared understanding and promote acceptance of results. Ultimately, this may lead to buy-in, increased investment of industry in science-based management, and increased legitimacy of the management framework (Hartley and Robertson, 2006; Dörner et al., 2015; Thompson et al., 2019; Baker et al., 2023). Finally, SIRC provides an opportunity for capacity-building and recognizes intellectual property within the fishing industry. This may lead to greater ownership in, understanding of, and appreciation for information produced through scientific research. This is particularly relevant where participatory frameworks exist to evaluate the science used in fisheries management (e.g., ICES, EU Regional Advisory

FIGURE 1
Industry vessels and gear in Dutch Harbor, Unalaska, USA (photos M.R. Baker) and Danish North Sea pelagic fisheries fleet (photo: C.R. Sparrevohn).

Committees, US Regional Fishery Management Councils, Canadian Science Advisory Secretariat, New Zealand Fisheries).

Still, SIRC has inherent challenges that may undermine successful collaboration. These hazards should be explicitly recognized and addressed (Silver and Campbell, 2005; Steins et al., 2020). Scientists and fishers may have different interests, objectives, approaches, and interpretation of results (Kraan et al., 2013; Mangi et al., 2018; De Boois et al., 2021). Absent a collaborative framework that facilitates trust and transparency, collaboration may fail (Ford and Stewart, 2021). Both scientists and fishers need to ensure that expectations are clear, and that respect and communication are maintained. Fishers must remain open to the results of research, wherever those results may lead. Scientists must show how data has been used and ensure results are presented in an acceptable and accessible format. Finally, data and analyses developed through SIRC must meet standards that enable their use and application in fisheries assessment and decision-making (Kraan et al., 2013; Mangi et al., 2018); often this entails addressing perceptions that industry-related science will reflect vested interests (Steins et al., 2020; Steins et al., 2022).

Also, SIRC is easier said than done. How to do it effectively, remains a persistent and relevant question (Reed, 2008; Kraan et al., 2014). SIRC should be, at its essence, a collaboration among equals. The involvement of industry in scientific research should include active participation of industry partners in the full scientific process, including the development of research questions, framing of hypotheses, data collection, data interpretation, and review (Johnson and Van Densen, 2007). Positive developments have been made in this direction (Steins et al., In Press). More specifically, the focus of SIRC and the role of industry in it, is increasingly shifting from passive participation towards active collaboration (Dörner et al., 2015; Mangi et al., 2018). In the former, researchers use fishery-dependent data as an input to models and analyses or use fishing vessels as a platform to collect additional data (Kaplan and McCay, 2004; Mangi et al., 2018). In the latter, industry and individual fishers actively engage in the development of research questions, design of projects, collection and interpretation of data, and communication and application of results (Johnson, 2009; Mackinson et al., 2011; Holm et al., 2020).

To explore mechanisms and foster engagement between research scientists, managers, policy makers, and fishers, we hosted a networking session at the 2021 Annual Science Conference of the International Council of the Exploration of the Sea (ICES, https://www.ices.dk). Presented here are summaries of those discussions. We intend that these discussions better direct collaborative research and cooperation between fishers and scientists. SIRC is a crucial approach to inform ecosystem interactions and change, monitor fisheries stock dynamics, understand socioeconomic drivers and impacts, and facilitate informed and participatory fisheries management. Here, we share lessons learned and best practices and, particularly in relation to ICES, present a view of future success in SIRC. Our lessons learnt are also applicable to other organizations and initiatives involved in SIRC in fisheries.

Framework for discussion on SIRC

Networking session

To further explore mechanisms and approaches to improve SIRC, a networking session (https://www.ices.dk/events/asc/ASC2021/Pages/Network_sessions.aspx; https://www.ices.dk/events/asc/ASC2021/Documents/2021_ANewEra_ASC_network_session.pdf) was hosted as part of the 2021 ICES Annual Science Conference (https://www.ices.dk/events/asc/ASC2021/Pages/science_industry_collaboration.aspx). The four conveners (first four authors of this paper) are all engaged in SIRC in a scientific capacity. Due to the COVID19 pandemic, the conference was held online. A total of 157 individuals attended this session, with 78 active participants contributing information through online polls, recorded chat, and facilitated discussion.

Our networking session actively recruited members of the fishing industry and sought participation from a broad range of experts, including: fishers involved in data collection or knowledge provision; fishing industry representatives; scientists working with fishers; scientists involved in understanding ecological and oceanographic process; scientists involved in assessment and scientific advice; policy makers who utilize scientific knowledge and advice; and non-governmental organizations (NGOs) involved in creating engagement with industry for sustainable development. Participants included researchers, policymakers, and fishers from more than 14 nations engaged in fisheries and/or fisheries research and management in the northwest Atlantic, northeast Atlantic, and northeast Pacific. Industry representatives represented pelagic trawl and bottom trawl fleets as well as at-sea and shore-based processing sectors in Europe and North America. In our first two polls, the 78 actively contributing participants identified themselves as primarily research scientists (78%), followed by fishers or fishing industry representatives (10%), policymakers (5%), NGO representatives (1%) or other (6%; Figure 2). A majority of participants (66%) had some experience in SIRC projects, ranging from occasional (35%) to full-time (5%). Approximately a third of participants (34%) had no prior experience (Figure 3). Most expressed interest in future opportunities

We anticipated addressing several topics in the networking session and set of thought-provoking statements were introduced to the participants in and prior to these discussions (Table 1). Online polls were provided in advance and at the beginning of the networking session. A short inspirational video on SIRC experiences in The Netherlands, with perspectives from fishers, scientists and NGOs, was also made available prior to the session (https://youtu.be/FsfBEBbpvck).

In addition to plenary discussions, two thematic breakout sessions were held as part of the networking session, each focused on one of the following two questions:

Breakout 1: Are there specific scientific needs that could be addressed with industry collected data or knowledge?

Breakout 2: How can science-industry collaboration be made sustainable?

For each of these two 10-minute sessions, participants were randomly divided in four subgroups, each facilitated by one of the four convenors for the session. Following each of the breakout sessions, the full set of participants reconvened for a plenary summary and discussion. A closing plenary session discussed ways forward, related to leveraging industry data and information contributions within the ICES context.

In the following sections we share ideas developed in these discussions. All quotes used in this manuscript are extracted from session discussions and reflect either the perspectives and insights provided by fishers and industry representatives (i.e., skippers, fleet managers, owners, and industry leaders) or scientists working in collaboration with the fishing industry – all are listed here as authors.

Defining terms and questions

This ICES networking session focused on science-industry research collaboration. In reviewing the outcome, it is useful to define terms

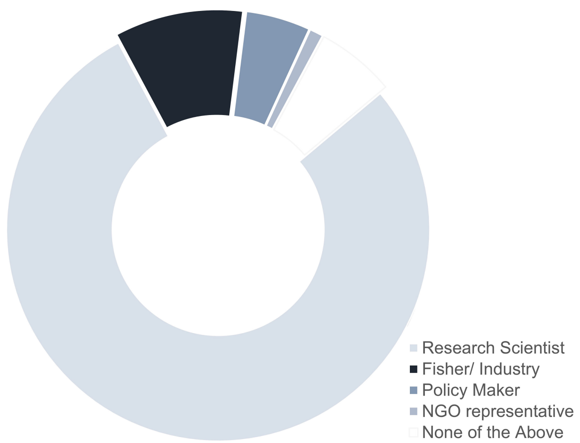

FIGURE 2
Participant affiliation. While many participants noted that multiple categories were appropriate, participants were limited to select only one (NGO – nongovernmental organization).

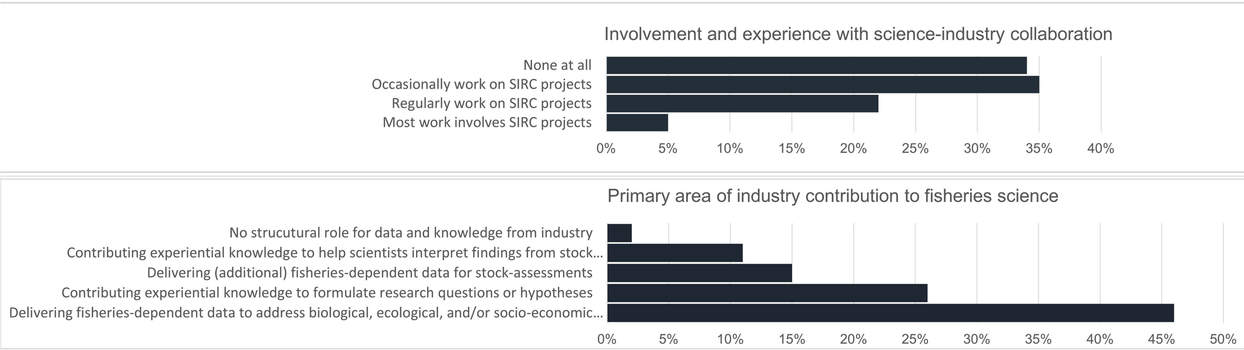

FIGURE 3
Survey poll I (SIRC – Science Industry Research Collaboration).

(Oxford English Dictionary, 2023 https://languages.oup.com/google-dictionary-en/).

net·work/netwrk/

1. a group or system of interconnected people or things.

ses·sion/seSHn/

1. a period devoted to a particular activity.

sci·ence/sīns/

1. the intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment.

in·dus·try/indstrē/

1. economic sector concerned with the development and processing of raw materials and manufacture of goods.

research/risrt/

1. a careful study of a subject, especially to discover new facts or information about it.

col·lab·o·ra·tion/klabrāSH()n/

1. the action of working with someone to produce or create something.
2. traitorous cooperation with an enemy.

As defined above, science entails systematic study, not only as an intellectual endeavor, but also as a practical exercise. Collaboration as defined here, provides useful insight to one of the challenges in this type of engagement – collaboration between science and industry may be viewed in favorable or unfavorable terms. In the first instance, it is the action of working with others to produce or create something (e.g., increased knowledge and improved fishery management). Alternatively, it may be viewed as engagement with a group inherently at odds with your own interests and objectives (e.g., conflict of interest).

In truth, there is more common ground than not between scientists and fishers. This includes not only interests, but also approaches and objectives. Scientists and fishers are both interested in learning more about marine systems, marine dynamics, fish behavior, and economic systems. Scientists and fishers are both interested in sustainability, yield, minimizing adverse effects, and maintaining natural resources.

We approach collaboration by embracing the definition in its first instance, while maintaining a sober awareness that interests may not always align. We also argue that agreement is not necessary for effective partnership. Disagreement may be a useful instance to identify where different data streams, insights, or experiences reveal gaps in knowledge and where different perspectives may offer new insights. These differences offer opportunities for more holistic understanding. Disagreement may also highlight where interests deviate and where collaboration is not useful or appropriate. This is important in setting priorities and determining the most productive areas for partnership.

Our first question (break-out 1) addressed what industry could offer to the scientific effort, related to addressing needs, presenting new possibilities, providing additional data, and improving knowledge. More specifically, we asked first whether there are

TABLE 1 Anticipated outcomes and questions posed in ICES Science-Industry Research Collaboration (SIRC) networking session.

Aims articulated in the ICES Networking Session
o Develop an inventory of scientific data needs and develop a framework outlining ways for fishing industry to meet these needs o Highlight new technologies enabling the collection and uptake of data generated by the fishing industry o Identify incentives to initiate and maintain data and information streams between industry and science o Determine how to address concerns related to validation, transparency, and accountability o Outline how to create efficient feedback mechanisms to transfer knowledge from industry to science and from science to industry o Determine how to bring in fishers' experiential knowledge into the scientific process in a consistent way
Questions posed in introduction of the discussion session
o What is the appetite and capability of industry to make meaningful contributions to scientific understanding? o How does that match needs for scientific information to address short- or long-term issues for informed fishery management? o How to build sustainable partnerships between science and industry and organize industry-science collaboration? o How to set up frameworks for industry to initiate research? o How to develop iterative collaborations? o How to develop and enforce quality control and data standards? o How to promote transparency and trust both in data collection and in evaluation of data sources? o How to evaluate the quality and reliability of the data? o How to develop criteria for the adoption of new data sources? o How to value and evaluate experiential knowledge? o How to make industry data 'count' in assessment, advice, science?

TABLE 2 Question I. ICES networking session: A new era for science-industry collaboration.

Central Question of Interest	Are there specific scientific needs that could be addressed with industry-collected data or knowledge?
Primary Discussion Point	What are unique insights and interactions that might be derived from fishery activities?
Secondary Considerations and Inferences	• How might that facilitate broader or higher resolution spatial coverage?
	• What are important differences in sampling vs fishing?
	• How might that enhance access in seasons that are not surveyed?
Primary Discussion Point	What types of acquired knowledge are informative and how might these be applied?
Secondary Considerations and Inferences	• How might those insights be used in a formal context to inform or bound quantitative statistics and models?
	• How might systems be established to collect these insights in a more regular manner?
	• How to incorporate experiential knowledge in consistent ways in the scientific process?
Primary Discussion Point	What is required for science to be able to use industry data or knowledge for scientific analyses or advice to management?
Secondary Considerations and Inferences	• What are the standards that need to be established to ensure reliability or comparability of knowledge inputs?
	• How would management processes and analytical approaches be reformed to accommodate this new information?
	• What are quantitative metrics that could be derived from fishery activities?
	• Are there new methods (e.g., qualitative network models) to integrate qualitative information in quantitative processes?
	• Are there other ways this information might be packaged to inform decision making?
Primary Discussion Point	How do we ensure validation, transparency, and accountability?
Secondary Considerations and Inferences	• What are some of the challenges and opportunities around the generation and provision of reliable data?

specific scientific needs that could be addressed with (or even only addressed with) industry collected data or knowledge. The specific sub-questions posed to discussion participants are detailed in Table 2.

Are there specific scientific needs that could be addressed with industry-collected data or knowledge?

Prior to going into breakout 1, a poll was presented to initiate discussion. In response to the question "*I see industry's contribution to fisheries science mostly in…*". The majority of the 46 participants who answered the poll see industry's role in '*delivering (additional) fisheries-dependent data to address biological, ecological and/or socio-economic research questions*' (46%). This was followed by '*contributing experiential knowledge to formulate research questions or hypothesis*' (26%), '*delivering (additional) fisheries-dependent data for stock assessments*' (15%) and '*contributing experiential knowledge to help scientists interpret findings from stock assessments*' (11%). A minority of 2% did not see a structural role for data and knowledge from industry (Figure 4).

Several themes emerged as part of our discussion on addressing scientific needs using industry-collected information: (1) use of data and knowledge; (2) ways to promote effective collaboration; (4) ways to leverage collaborations; and (4) challenges. We summarize each below.

Use of data and knowledge

Data and Information

"Collaboration leads to greater opportunity to gather data, which we are not able to gather on our own, due to constraints on finances, manpower, seasonality and spatial extent in coverage."

Fisheries science is inherently an interdisciplinary exercise (Larkin, 1978; Smith, 1994; Smith and Link, 2005). Participants noted that SIRC becomes transdisciplinary (Hessels and van Lente, 2008) when fishers become actively involved in the scientific process. Much of the science that informs management depends directly on information provided from the fleet such as statistics on catch volume, spatial maps of effort, observer data and catch samples, and logbook information (Hilborn, 2007). Fishers' knowledge is not limited to biological information, and also includes ecological, economic, social, and institutional and experiential knowledge (Stephenson et al., 2016). In this context, it is useful to adopt the Stephenson et al. (2016) distinction between fisheries observation knowledge (e.g., industry as a platform for collecting measurable data) and fishers' experiential knowledge (e.g., experience and insight on the water).

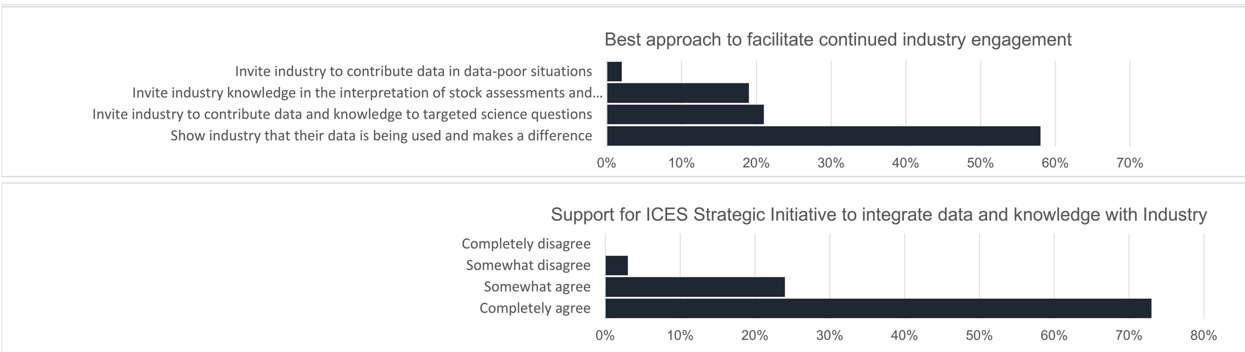

FIGURE 4
Survey poll II.

Fishers contribute information about stock structure through insight on migration and spawning dynamics (Maurstad and Sundet, 1998; Ames et al., 2000), spatial patterns related to size structure and habitat preference (Hutchings, 1996; Maurstad and Sundet, 1998; Neis et al., 1999; Ames, 2004), and effort changes in response to regulatory change (Neis and Felt, 2000).

Many challenges to effective fisheries management relate to the constraints on government-run sampling efforts that are often season-specific or otherwise limited in both duration and temporal coverage (Thorson, 2019; Bleeker et al., 2021; Gonzalez et al., 2021), constrained or influenced by gear performance (i.e., selectivity, Cadrin et al., 2016; Kotwicki et al., 2017), or otherwise unable to access all viable or relevant habitats (i.e., availability, Punt et al., 2014; Baker et al., 2019a). Many of the data needs identified in our discussions reflected these recognized limitations to scientific surveys and sampling. Discussions on where industry data might be most useful identified the need for additional information on specific habitats, broader temporal and spatial scopes, fine-scale life history detail on populations, data on nontarget species, and the better archival, use and application of opportunistic data (e.g., acoustics data, bathymetry, observational data). Vessels collect considerable observational data which can be used. Other ideas for data and information needs included opportunities to better characterize physical oceanography, mechanistic processes and marine ecosystem interactions, climate change, fleet dynamics, socio-economic data, and information on fishery priorities, culture, and way of life. A list of data and information needs identified in our session are outlined in Table 3.

TABLE 3 Data and information needs identified in discussion sections.

Information Needs
o Information on niche level habitats
o Information on non-commercial species for biodiversity metrics
o Improvements and enhancements to temporal and spatial data and sample coverage
o Self-sampling of length-at-age data and maturity data
o Assessment of impacts of fishing on society
o Understanding fisher culture and way of life
o Opportunistic data (acoustic data, climate change data)
o Socioeconomic data and information
o Information on fleet dynamics
o Threat assessment

Beyond data – knowledge, interpretation, context, and validation

"Data and interpretation are two separate things. Often fishermen are worried that the interpretation of the data is wrong because the scientist don't understand the context."

"I get the feeling that some scientists want to have everything in a model. We fishers work out in the natural world. Everything counts and everything has its effect. It is too complex for a model. At least for most models and in most fisheries. This is why working together with fishers and scientists is so important.

Participants also recognized applications for SIRC data and information (Figure 5). One is model validation. Fishery data and information have broad application relevant to testing and validating models. This includes application to fisheries models where additional sources of observational data or experiential information are used to challenge or improve confidence in existing models and insights that might lead to developing new or competing models to better characterize marine ecosystems, stock dynamics, or fisheries economics (Neis et al., 1999; Smith et al., 2007; Bentley et al., 2019). Observational and experiential knowledge are often best applied in stock assessment workshops and fisher management forums where these data and industry insights can be used to improve hindcasts and forecasts. These interactions might also be applied as a way of gaining the industry's trust in these models. Furthermore, fisheries data and information have relevance beyond exploited stocks and are also useful to ecosystem models, habitat models, and regional oceanographic models. In all these instances, fisher data and information are often available, but underutilized, and might be applied to test model skill and assumptions.

Context matters. Fishers' knowledge is often labelled as anecdotal (Pálsson et al., 1998; Neis et al., 1999). But there is value in an anecdote (Johannes and Neis, 2007) and fisheries data and fisher knowledge are critical to interpretation. Interpretation of ecological and economic data is inherently challenging. Results may reflect many underlying processes and interactions. Fishers have unique insights on what might be driving trends and what might be important underlying influences on evident observations. This can be useful in interpreting scientific results of stock assessments,

FIGURE 5
Word Diagram compiled from ICES Networking Session Discussion and Chat.

leveraging insights from ecosystem trends, and distinguishing and discriminating between data sources.

An important question that arose was *'how do we and how should we distinguish between [observational] data and [experiential] knowledge?'* And '*how should we apply each*?' Ackoff (1989) distinguishes between data (factual properties), information (processed data), knowledge (answers '*how*' to questions – analysis), understanding (answers '*why*' questions – synthesis), and wisdom (values and the exercise of judgement). Effectively integrating fishers' knowledge, be it observational or experiential, represents a fundamental challenge to established fisheries science (Hind, 2015). Despite a long history and active interest in this area, fishers' knowledge is highly qualitative and has generally failed to become integrated into the fisheries science mainstream alongside approaches that rely primarily on the knowledge of professional scientists (Stephenson et al., 2016; Steins et al., 2022). This qualitative nature, as well as the non-standard format of much fishers' knowledge, contrasts with the systematic quantitative data typically applied to inform assessments. Scientists working in fisheries have therefore found it hard to integrate this knowledge to inform better decision-making (Hind, 2015). Neis and Felt (2000) outline examples of how to move beyond 'fishery-dependent data' or 'fishery-dependent information', to more fully integrate the experiential knowledge of fishers. Comparisons between fishers' observations and data drawn from more traditional scientific sources might lead to greater consensus on stock status and management (Neis et al., 1999).

Scientific research conducted in partnership with the fishing industry not only promotes the co-production of knowledge about stock status and the marine environment, but also leverages fishers' knowledge and experience in decision-making (Wilson, 2003; NRC, National Research Council, 2004). Participants noted that science is not one thing. Multi-disciplinary approaches are needed to most effectively gather knowledge from fishers and apply it to improve fisheries sustainability and management. Moreover, discussion participants noted that experiential knowledge is built over time, and therefore might be particularly useful to understanding change over time. Systems change and baselines shift. Knowledge across generations, often embedded in the frameworks and perspectives that fishers and Indigenous and coastal communities bring to the conversation, is critical to understanding baselines, interpreting change, and providing context for data.

Technical expertise and experience

"It's not only industry providing data, but also knowledge on fishing gear technology, net performance, and external impacts on its performance. We can provide a lot of examples on how just a minor change in the application of the nets will yield much different results."

One of the most obvious areas for the application of fisher and industry contributions to science is in technical expertise and experience on the water. There are many instances of effective recruitment of industry participation in the development and execution of surveys (De Boois et al., 2021). Often these types of collaborations are crucial to resource assessment.

In the US, there are active cooperative research programs, where industry fleets are contracted to engage in research (Karp et al., 2001). This occurs through directed surveys or directed and opportunistic approaches to collect oceanographic data and monitor ecosystems. Those data are used for a variety of purposes. The effort also creates mechanisms for exchange and relationships, which further trust and long-term partnerships in project design, data collection, interpretation, and delivery of results. Similar examples exist in Europe (Bjørkan, 2011; Kraan et al., 2013; Pastoors, 2021) and New Zealand (Middleton and Guard, 2021). There are also many instances of effective collaboration towards the development and improvement of gear (Walsh et al., 2002; Harley and Robinson, 2008; Feekings et al., 2019; Merrifield et al., 2019), assessment of the selectivity of gear (Graham et al., 2007; Baker et al., 2011; Baker et al., 2014; O'Neill et al., 2019), analysis of selectivity in catch and surveys (Rose et al., 2010; Somerton et al., 2011; Veiga-Malta et al., 2019), analyses of management approaches (Smith et al., 2007; Smeltz et al., 2019) and conservation engineering solutions to mitigate fisheries impacts on marine environment (Kaiser et al., 2016; Österblom et al., 2020) or benthic substrates and communities (Rose et al., 2000; Rooper et al., 2011). Additionally, there are many examples of effective collaborative approaches to minimize or reduce bycatch and incidental mortality in protected or non-target species (Gauvin and Rose, 2001; Carruthers and Neis, 2011; Arkhipkin et al., 2021; Kroska et al., 2021; Yochum et al., 2021). There are also examples of effective science-industry collaboration to inform harvest control rules and management planning (Davis, 2008; Heller-Shipley et al., 2021). Experiential knowledge is critical here.

Promoting effective collaboration

Enhance awareness and exchange

"Scientists learn so much from fishermen. Its real-time data when they are out there, and fishermen always have something to say."

Disparities in perceptions about problems and solutions among fishers, industry, fishery managers, and scientists poses a challenge to effective management and may result in misunderstanding and distrust. Stephenson et al. (2016) note different degrees to which information from industry and fishers data and experience are integrated in fisheries assessment and management, and note that "fishers' knowledge is best implemented in a participatory process designed to receive and use it."

Session participants agreed that there is a lot of room for collaboration and that we are under-using existing opportunities. To begin, participants suggested the importance of simply getting fishers and scientists in the same room to discuss issues, mechanisms, and interactions. Another idea was to ensure room for the fishers to test and develop their ideas. Over time that investment develops trust and mutual understanding, and ultimately long-term cooperation. Time together and continuity were both recognized as critical. Participants also articulated the importance of fostering not only professional but also personal relationships.

New avenues for research

"Every day at sea is different. Every year is different. We see climate change is influencing fishing and the ecosystem. The fishermen are also scientists – we work in the ecosystem, we use echosounders, we track temperature, we observe fish behavior. Overall, fishermen are in the lead."

In addition to existing examples of SIRC, session participants noted many new opportunities for collaboration. These are outlined in Table 4.

Leveraging science-industry collaborations

Motivations and incentives

"What is the appeal of collaboration? To make it happen you need people on both sides willing to do it."

Researchers and managers increasingly recognize the importance of stakeholder engagement in fisheries research (Kaplan and McCay, 2004; Johnson and Van Densen, 2007). It can improve the quality and quantity of spatial, temporal, and ecological data, as well as promote skill transfer and provide mechanisms to identify and address differences between industry perspectives (Holm and Soma, 2016). For fishers, participation in research provides an opportunity to participate in, influence, and understand fisheries assessments (Stephenson et al., 1999). Active engagement in research also improves industry and fisher's understanding and appreciation for how information is produced in the context of scientific research and how it is used to advise management (Johnson and Van Densen, 2007; Steins et al., 2020). Incentives matter (Hilborn et al., 2005). Industry incentives for cooperative research include potential benefits of increased catch and fishing opportunities through better information, direct payment for research activities, and increased confidence in the management system (NRC, National Research Council, 2004). Participation requires both willingness and capacity (Mangi et al., 2016). The level of participation will be determined by funding, interest, and the contribution that stakeholders are willing and able to do effectively (Mackinson et al., 2011; Baker et al., 2023).

Session participants suggested that one of the main incentives for partnership is that SIRC leads to greater opportunity to gather data and to address constraints on manpower and seasonality in coverage. Scientists noted that "*we need to know more about industry motivations*". Fishers noted that "*we need to show the scientists how we work in practice*". When asked what would motivate industry to work together with science, the answer was clear: "*use our data*".

It is important to recognize that agreement is not always evident. Often times, the incentive may develop out of disagreement or management failure. A lack of consensus on the status of fish stocks may provide motivation for collaboration (Dobbs, 2000). Stock assessments often rely on spatially-coarse data collected in limited timeframes and differ from fishers' observations; one way to move towards consensus on resource status is to solicit and apply fishers' knowledge.

Insights and attitudes

"In the past, scientists have often approached fishermen as if scientists are the ones that know best. And while the fisherman is providing them information, and they don't need to know the details. It seems it is changing – scientists are approaching fishermen on an equal basis. Both sides can learn from each other."

Relationships are core to collaboration and the attitudes with which each side approaches SIRC are critical to establishing an

TABLE 4 Ideas generated in discussion sessions for new or underutilized opportunities to apply SIRC to marine science.

New opportunities to apply SIRC
o Development of study fleets supported by industry to generate continuous input or mechanisms to leverage opportunistic data collection
o Inclusion of social and economic and ecological information in reports to managers
o Research on the impact of fisheries and management on society and fishing communities, understanding fisher culture and way of life.
o Research efforts to document experiential knowledge and fishers' ecological knowledge
o Methods to identify drivers of change in stock dynamics and fishery effort and distinguish how much is driven by the environment, the fishery, and the management policies. Subtle shits in management (e.g., spatial or temporal closures) restrict effort and therefore influences catch-per-unit effort. That may have nothing to do with the stock dynamics but instead fully reflect management actions. That interaction is key and engaging with industry is the way to understand those interactions.
o Methods to gather knowledge from fishers – we need different types of science and disciplines to be involved
o Methods to integrate interdisciplinary and transdisciplinary approaches (e.g., socioeconomic information and experiential knowledge) into qualitative frameworks and models (e.g., qualitative network models).
o Processes to identify and mitigate conflict of interest

environment for trust, respect, and positive exchange. Some suggestions from network session participants included: a balanced exchange where no one side is *"dominating meetings"*, and environment where everyone feels as though *"you are at the same level"*, *"respect for expertise"*, *"curiosity"*, *"reciprocity"*, and *"trust"*.

Defining roles and responsibilities

"There is a real need for clarity in roles and outcomes. We are knowledge partners."

"When you enter a collaboration, you need to work in an agile way to determine what skills sets you have. And how to best make use of them."

In SIRC, it is important to be clear about roles (*"who will do what – and when?"*). In general, fishers have unique insights into certain areas – they know the grounds, their gear, their capabilities. Fishers are critical to assessing the technical feasibility of research and calculating costs. Fishers are also often best positioned to leverage knowledge of appropriate timing and location for directed efforts. Scientists have expertise in other areas – how a survey needs to be designed, how to collect, compile and format data to be statistically robust and to apply it towards quantitative analysis. Scientists understand the need for consistently and specified protocols and how to assess the statistical power of the observation scheme to ensure that the results will be valid statistically for use in science and management. Fishers have individual experiential knowledge; scientists know how to analyse accumulated information from many fishers together.

Benefits in SIRC arise from recognizing and leveraging these complementary sets of skills. Commercial fishers have practical experience in the marine environment, knowledge of marine organisms and processes, technical expertise, and platforms and resources to facilitate data collection. Industry perspectives and expertise may be important in survey design and gear deployment, technology development, understanding impacts of gear on habitat or nontarget species, hypothesis testing, and understanding information important to informing management. Scientists bring expertise in the scientific method, experimental design, data synthesis and statistics. Integrating complementary skills and knowledge of these two groups has the potential to improve the quality and relevance of research (Baker and Smith, 2018). Working together also furthers understanding between science and industry and promotes industry confidence in the products of the scientific research.

Session participants noted that effective collaboration starts with respect for these different areas of expertise. Participants also noted that it is important to view these collaborations as investments in an iterative relationship that might be extended across multiple projects. The intent of SIRC is to facilitate partnerships to improve and enhance data streams, inform analyses, and improve understanding of marine stocks and environments. The expertise of both fishers and scientists is crucial for making applicable rules and informing sustainable participatory management of living marine resources. Combining approaches and knowledge streams is intended to lead to more robust policy.

Challenges

"When it comes to making it for real, we always end up in the same issues. It's like this … you need a long time series, data need to be standardized and reproduced, the model is not really fit for purpose, it is difficult to combine data…"

One of the challenges articulated in network session discussions was the difficulty in combining data. Fishery-dependent data is limited to where fishery is executed. Similarly, standardized methods applied in surveys mean that gear types do not necessarily cover all areas equally well. It is very difficult to combine data collected in different ways. It is also difficult to analyze data from data sets that are not fit for purpose. One approach is to design new approaches through SIRC. Another is that fishers' surveys can be combined by many fishers putting their data together replicating the footprint of a survey.

Beyond data collection, interpretation of fisher data and information is challenging. It is often difficult to integrate experiential knowledge of fishers into a system that is dominated by models and statistics. Receiving systems will need to be reformed to deal with transdisciplinary approaches (Steins et al., 2022). Also, creating spaces for communication is hard. Timeframes do not necessarily align; funding for industry data collection schemes are often short while science needs long-term time series. Results that are developed are often slow to be integrated. Scientific processes in which fishers are involved are often dominated by scientists, with fishers often seen as a data supplier and not as a partner. Fishers also may not recognize the value in participation or have time to attend.

Additionally, there are legitimate concerns about conflict of interest. Absent a transparent framework, SIRC may be challenged by suspicions about motives of industry to contribute data. SIRC must safeguard scientific integrity and should operate within a transparent and open framework. Participants also stressed that there are legitimate concerns that the results of SIRC may have negative effects for industry. New information may lead to a shift in understanding for the ecosystem or stock. This leads to questions such as: "*What happens if/when fishers data used in stock assessment enhances negative perceptions and or results in reduced quotas? How would industry react?"* Rationalized fisheries may shift incentives for industry and allow for longer term time horizons.

History is important. Whatever is being done in the present builds on the history of interactions and engagement that preceded it. Frustration related to failed collaboration or unacknowledged results may compromise future efforts. This underscores the importance of trust building. Trust may need to be rebuilt over time, particularly if there have been negative experiences in the past.

"Don't forget that history is important. There is frustration with failed collaboration and instances where input was not implemented or incorporated into management perspectives. In many ways this

may have been as frustrating for the scientists as it was for the fishers themselves."

How can science-industry collaboration be made sustainable?

Our second question (breakout 2) aimed to identify the best mechanisms to sustain industry participation in delivering data, information, or knowledge – how do we make the collaborations last? The specific sub-questions posed to discussion participants are detailed in Table 5. Prior to going into breakout 2, a poll was presented to kick off discussions. Participants were asked to select *'the most promising mechanism that facilitates continued availability of industry data and engagement, recognizing this is not a guarantee'*. From the total of 43 respondents to this poll, 21% thought that *'inviting industry to contribute data and knowledge to targeted science questions'* was the most promising mechanism for facilitating continued availability of industry data and engagement (whilst recognising the latter is not a guarantee); 19% selected *'inviting industry knowledge in the interpretation of stock assessments and ecosystem indices'*, 2% chose *'inviting industry to contribute data in data-poor situations only'*; the majority (58%) felt that *'showing industry that their data is being used and makes a difference'* is centrally important (Figure 4).

While the principal desired outcome of industry participation in research is to improve the scientific data and knowledge available to inform effective, participatory, and transparent management and governance. The question remains- How can a deeper, more systematic, and more sustainable engagement of stakeholders be enabled (Mackinson et al., 2011)? Our results shed some light on how to best approach this. The following themes emerged in relation to making industry data contributions sustainable: (1) enabling effective collaboration, (2) promoting collaboration, and (3) facilitating engagement.

Critical components to enable effective collaboration

Relationships and trust

"What is essential? In one word, trust. It is very important for fishermen. And it is also important for scientists. When we work together, we can learn from each other. If you are able to operate on the same level, if you have a sense that scientists will also learn from you, then there is potential for understanding one another."

Trust is very important for success in SIRC. That starts with openness and honesty. Participants, both in plenary discussions and in each individual break-out, noted the importance of communication, trust, and transparency. Relationships are the core to this type of collaboration. There are benefits in building not only professional, but also personal relationships. It was noted that spending social time together is really important. Fishers noted that there is often a stiffness or distance to interactions with scientists. The solution – "*be normal*". It was also noted that scientists have often approached fishers as if they know best and that needs to be changed. This engagement has to be on an equal basis. Learn from each other. Meet on the same level. Respect as each other based on knowledge and experience. Longterm engagement is key; ultimately that leads to trust.

Expectations

"If the result of using the data means less quota, there is a risk. We are not using this data for their benefit only. And this needs to be made clear."

In SIRC, there is a need for clear expectations. All assumptions should be stated clearly, and participants need to understand what questions the research seeks to answer and how the data will be used. This is critical to ensuring realistic expectations. Participants

TABLE 5 Question II. ICES networking session: A new era for science-industry collaboration.

Central Question of Interest	How can science-industry collaboration be made sustainable?
Primary Discussion Point	o What mechanisms or approaches will increase the probability that the collaboration lasts? o What are effective ways to initiate collaborations? o What are the initial conditions necessary for active partnership? o How do we build trust? o How do we develop effective communication strategies?
Primary Discussion Point	o What are ways to effectively ensure iterative exchange and communication?
Secondary Considerations and Inferences	o How do we adapt processes to accommodate different timelines, perspectives, processes, outlooks, incentives? o What has changed in recent times that complicate or facilitate exchange and collaboration?
Primary Discussion Point	o Can science serve the needs for industry? If so, how?
Secondary Considerations and Inferences	o Often this seems to be something motivated by scientists looking to engage industry, when and how do we reverse this? o What are ways industry can highlight opportunities for increased understanding of processes that are data-poor?
Primary Discussion Point	o How do we create efficient feedback mechanisms to promote exchange of data and knowledge from industry to science and from science to industry?

should not expect the research to translate into a specific management outcome nor necessarily expect positive responses. If results of using the data means less quota, industry has to accept this; it is not only about using data to their advantage. Industry participants in this session noted that industry does not have a default expectation for positive or favorable outcomes. The interest is in understanding the reality of stock status. Industry is typically invested in the value of the resource over time; this provides a common ground and common interest to pursue and develop the best available science.

Scientists must also address industry concerns that the data will be interpreted incorrectly by people that are not fishers themselves. Context is important and industry and fishers need to be assured that the use and application of this data will be in a process that includes their input and expertise. The pace and duration of the collaboration should be negotiated and collectively understood. Clarity in expectations on both sides is crucial to positive and effective engagement.

"Data is also just one side of the conversation and interpreting this data can be just as difficult. So we are extremely worried that our data will be interpreted wrongly by people that are not fishers themselves."

Critical components to promote effective collaboration

Engagement

"Fishermen often feel there is a lot of information provided and not much in return. Feedback is essential. When data is collected, provide information on what is collected and how it is used."

SIRC is, by definition, participatory research. That should reflect active engagement on all sides, with both scientists and stakeholders involved in all stages of research planning, development, and delivery. Fishers should contribute to project planning and design. Fishers should be involved in the identification of the problem statement. Industry should also be invited to ask the questions. The development of the research question or hypothesis is an area where fishers' knowledge can contribute significantly to the scientific research process. Those on the water may have different questions and those questions often warrant further exploration. Moreover, this process fosters engagement as it reflects real interest in that research. Science is at its essence curiosity-driven. That applies to researchers and fishers alike. Active engagement in the interpretation of data may provide motivation for further engagement.

Ownership is also important. There should be open sharing of data and products. Give fishers ownership of the data they collect. This improves transparency and trust. It also provides critical information that industry can investigate and use in internal discussions and public forums (e.g., fishery council meetings). It provides industry something they can bring to the table. It gives them a voice.

Communication and transparency

"To build trust, you need communication. That's the only way. You need to meet in person."

There is a need for fishers' voices to be heard and valued. Communication is key. Continuous dialogue is essential. Keep the communication going. A common scenario described in our discussions was that that authorities approach industry and ask for data on this or that. Fishers then comply, gather the data and send it to the management authority. And that's the last they hear of it – there is no feedback on why that data is required or what it is used for. It is important that there is a dialogue at the outset. What is the purpose? What are the results? Moreover, it's important not only to share data, results, and outcomes, but also to identify what works and what doesn't work. Iterative discussions and regular feedback are critical.

Openness and honesty are important. Do not over-promise. Transparency in the process will contribute to the building of trust and confidence in the research. Ideally, in cooperative research, all participants share their findings, including the explanation of how the data have been or will be used. This entails communicating not only the results, but the significance of the results, the meaning of the outcome, the format for presenting the results, and information on how results will be communicated to industry, science agencies, and in publications, presentations, and management forums. Effective communication along these lines builds trust, which can be expected to translate into more effective management.

Critical components to facilitating effective engagement

Frameworks

"We fishers have been trying for decades to reduce discards because having unwanted fish in the trawl affects the quality of the fish we are targeting – crowding the net, removing the slime layer that keeps fish fresh, and making work to sort out unwanted fish. So, it's not that we don't want to fix it, we're just a bit stuck. To tackle it we have scientific partnerships with multiple vessels in the fleet. Fishers would like a bit of room to test and develop things themselves - for example if I'm trying a new net that might reduce discards, but which doesn't comply with the existing rules and I get stopped by the control vessel, I'm in trouble. Fishermen have been innovating on these sorts of questions for decades."

New and modified frameworks are necessary to move forward. New technology can also change how information is collected – "*automation, automation, automation*". Institutional settings that favor recurrent interaction should also be employed. Continuity is very important. Mechanisms to maintain the recurrent interactions between industry and researchers and ensure long-term engagement are key, but can be difficult to maintain with existing modes for research that are project-based. Project-based funding is limited in scope and duration; securing 20 years of funding for collaboration is unrealistic. If there are established relationships, however, the long-term outlook for partnership is often good. Institutional settings that favor recurrent interaction can help here.

One approach to consider is a shift in focus. It is often much easier to collaborate on questions of ecological understanding or ecosystem monitoring, rather than stock assessment, where there is direct economic interest and potential financial consequences. Collaboration might be viewed in this broader context. There is significant documentation of the value of fisheries observations towards ecosystem and ocean monitoring (Gawarkiewicz and Malek Mercer, 2019; Lindeberg et al., 2022). Another approach to consider is a shift in ownership and leadership. At the most basic level, give fishers ownership of the data they collect. At the extreme, give fishers ownership of regulation (e.g., New Zealand). Where fishers manage elements of the fishery, this provides strong incentive to think about what data is required and all other aspects of the management process. In between these extremes, there are frameworks for active consultation and engagement. In the US, one approach has been to engage commercial fishers directly through a steering committee. That brings fisheries scientists, managers, and fishers all in one room together to discuss what the scientists need for stock assessment, data gaps, and the feasibility collecting this information through fishers.

Actionable recommendations

Ways forward

"Roughly 10 years ago, younger scientists arrived in the Netherlands and brought a new view that we have to work together with the fishermen. And this was also what the fishermen thought themselves. And from that time, we started working together. In the past it was always fighting, and always bad results. Since started working together we have had excellent results. Our advisors work together as close as possible with the scientists."

There are both opportunities and barriers to SIRC and industry-led fisheries research (Harte, 2001; Steins et al., 2022). Both deserve further exploration. One approach is the potential for expansion of governance regimes in which fishers both contribute knowledge and actively participate in research and management. Co-management — 'the sharing of power and responsibility between government and resource users' — reflects a potential shift towards decentralization and collaborative decision-making (Berkes et al., 1991). These approaches to governance, where fishers and government managers jointly develop, implement, and enforce management measures are often viewed as a means to promote collaboration and shared stewardship (Hart, 2021; Puley and Charles, 2022) and to improve efficiency and legitimacy in the management of fisheries (Charles, 2009; Pinkerton, 2018).

Other approaches maintain distinctions between resource users and resource management, but increase engagement. Co-management is gaining increased attention worldwide and is at the core of many fishery governance discussions (Campbell and Salagrama, 2001; Linke and Bruckmeier, 2015). Engaging stakeholders in research and decision-making on European marine issues is endorsed at high levels because agreement of stakeholders is believed to be essential for any management plan to succeed (Mackinson et al., 2011). Incorporating fishers' information and knowledge generates buy-in, because the results are more likely to be viewed as practical and reasonable and therefore legitimate. These commitments and principles are also reflected in US fisheries management (Karp et al., 2001; Hare, 2020).

Until recently, the North Sea Stock Survey collected data on fishers' perceptions of the status of fish stocks through a voluntary annual survey; the aim was to provide a means for fishery scientists and managers to incorporate fishers' knowledge into their assessments (Johannesen, 2010). The Netherlands set up a dedicated multi-annual grant scheme 'Partnerships Science and Fisheries' as part of its national implementation of the European Maritime and Fisheries Fund with the specific objectives of promoting SIRC. This has led to joint development of research questions and innovative methodologies for data collection by fishers to address knowledge gaps in important data-poor commercial fisheries (Quinn et al., 2016; Cope et al., 2023), such as *nephrops* (Bleeker et al., 2021) and turbot and brill (Schram et al., 2021) in the North Sea. In Pacific Canada, governing agencies increasingly employ collaborative forms of decision-making in fisheries management to improve decision quality and legitimacy. Results indicate that an incentive to participate, consensus decision-making, and independent facilitation were key to ensuring effectiveness (Davis, 2008). These types of initiatives and this momentum towards enhanced and improved SIRC has the potential to have positive effects on resource use and sustainability, social benefits, and ecological outcomes (Sen and Nielsen, 1996; Whitehouse and Fowler, 2018).

"Industry should also be invited to ask the questions. Collaboration should not only target science. Those on the water may have different questions and those questions often warrant further exploration."

Strategic Initiative – towards a more structural approach in ICES

"Recently there have been new elements incorporated into the [ICES] stock assessment process, including ecosystem and socio-economic profiles, where ecological, economic, and social information is included in a side report. We are still trying to determine how that information will flow into the decision-making system. At the same time, there has been a profound shift in the ecological system. So we have new conditions on the water and new systems and processes in management. Those are the times where we need to focus to rebuild and strengthen trust and transparency."

Fisheries are increasingly recognized as systems with ecological, economic, social, and institutional aspects that require interdisciplinary approaches to science and participatory governance (Stephenson et al., 2016). Decision-making benefits from more holistic approach to information integration, leveraging data from fishers, scientists, management and often coastal communities and other stakeholders. Trust, communication, and a sense of partnership between stakeholders are critical to success (Johnson and Mccay, 2012; Holm and Soma, 2016).

The use of data and information from SIRC or industry-led research is an important topic of discussion within ICES (Dickey-Collas and Ballesteros, 2021). ICES is unique as a marine science organization, which also develops science and advice to support the sustainable use of marine resources. The institution serves and advises national and regional (EU) institutions and facilitates a framework within which scientists work together to provide the scientific basis for management advice. For nearly 120 years, ICES has approached fisheries management with an emphasis on integrity, transparency, and independence, but also an awareness of the need for accountability and an adaptive and flexible approach (Stange, 2010; Cvitanovic et al., 2021). Despite a history of ambiguity related to stakeholder involvement in ICES (Wilson, 2009), the current ICES mission considers stakeholder engagement to be a critical component, necessary to improve decision-making and ensure coherence and reliability in policy-relevant science (Dickey-Collas and Ballesteros, 2021). In recent decades, there has been consistent movement within ICES to open-up to stakeholders and to encourage an institutional transformation of ICES towards engagement and increased participation (ICES, 2019; ICES, 2020; Dickey-Collas and Ballesteros, 2021; ICES, 2021).

Following the breakouts, our closing plenary session discussed how to further promote to industry data and information contributions within the ICES context. ICES is currently hosting several separate workshops to develop guidelines for industry data and stakeholder engagement (e.g., Workshop on Science with Industry Initiatives 2019, Workshop on Standards and Guidelines for Fisheries Dependent Data 2021, Workshop on Stakeholder Engagement Strategy 2021, Workshop to Evaluate the Utility of Industry-derived Data 2022). Network session convenors suggested that ICES could benefit from a more structural approach, involving the stock assessment working groups and experiences from scientists and industry outside Europe. One way forward would be to set up an initiative on the integration of industry data, knowledge, and information. Participants were asked to respond to this idea through a poll and expressed their interested in participating in such an initiative. A majority of participants (73%) fully agreed with the statement that '*Setting up an ICES (Strategic) Initiative tasked with how to integrate data and knowledge from industry, involving experts from outside Europe, is much needed*' (Figure 4). Several participants also expressed their explicit interest in such initiative, including the chairs of ICES Working Groups (WG) on Maritime Systems (WGMARS), Social Indicators (WGSOCIAL), Economics (WGECON), Shipping Impacts on the Marine Environment (SHIP), Technology Integration for Fishery-Dependent Data (TIFD), and Integrated Ecosystem Assessments (IEASG).

Discussion

Several important considerations emerged from our discussions. One was how to define knowledge and understanding (Jenkins, 2004). Knowledge is more than data, but what? Another was how to best develop data quality controls to enable use in management. In defining knowledge, we draw on observations in Steins et al. (2022). Data include metrics and measurements that are products of observation, while knowledge provides context (Ackoff, 1989; Rowley, 2007). Scientific knowledge builds on systematic processes of accrued observation and experimentation and models and analysis (Hessels and van Lente, 2008). Fisher Experiential Knowledge includes the knowledge held by individuals, sectors, and communities and a process of producing and assembling that knowledge through observation, trial, and application. It includes associated socio-economic, cultural, and technological experience, often accrued over generations (Neis and Felt, 2000; Hind, 2015; Stephenson et al., 2016). Experiential knowledge also includes Traditional Ecological Knowledge, Indigenous Knowledge, and Local Ecological Knowledge with a focus on communities with histories of engagement in subsistence, recreational or commercial fisheries (Chan et al., 2019; Cooke et al., 2021). Solutions included ensuring that data or final reports follow regulatory standards and be peer-reviewed before their use in science and management. Also, interpretation was highlighted as a critical area for collaboration; including fisher knowledge here may provide insights not considered by scientists. Validation, transparency, and accountability are important to ensure the generation of reliable data. Finally, protocols and standards are necessary to identify, assess and manage potential conflict of interest in data and information provision, particularly where that data and knowledge might affect the integrity of science advice and influence management (ICES, 2023). Necessary steps include flagging possible conflict of interest at data entry points and subsequent evaluation of the potential impact.

Another important consideration was how to define collaboration. Often this requires a shared vision. Many objectives may be shared (e.g., maximize harvest, maintain healthy populations, optimize use, benefits and utility). But does the type of collaboration and framework (e.g., mandated, voluntary, compensated or contracted) matter and what is its influence the type of data and output? And what are the main incentives to initiate and maintain data and information streams between industry and science? How do we create efficient feedback mechanisms, both from industry to science and from science to industry? How do we to bring in fishers' experiential knowledge in a consistent way into the scientific process?

Many questions remain. What is the outlook for the future? How might we better leverage experiential knowledge? How do we shift the framework so that industry is positioned to ask the questions? How do we ensure industry and more importantly fishers have a voice at the table? Are there means and mechanisms to provide research funding for both industry and science? Where are the opportunities for industry to employ scientists? Fisheries organizations are increasingly hiring scientists to lead independent data-collection and research initiatives as well as represent industry perspectives and science in participatory management discussions (Peterman, 2009; Pastoors, 2016); this trend is anticipated to increase in future (Mackinson et al., 2011). Finally, under what conditions is it appropriate or even best that fishers direct and control the research and management system? What are the necessary preconditions to ensure enforcement of the regulations they propose?

Our networking session was held in the context of ongoing initiatives within ICES designed to open science to new forms of data and knowledge and improve stakeholder involvement. Its aim was to contribute to these ongoing discussions. Historically, SIRC has focused on catch sampling and surveys, gear and selectivity research, biological and catch information, and evaluation of assumptions and interpretation of results in Management Strategy Evaluations (Walsh et al., 2002; Johnson and Mccay, 2012; Kraan et al., 2013; Dörner et al., 2015; Wijermans et al., 2020; De Boois et al., 2021). New applications of Fisher Experiential Knowledge include observational knowledge of environmental effects and reporting of ecological change, perspectives on seasonality and life history (Bryan et al., 2021), species and ecological interactions (Bentley et al., 2019), alternative explanations for scientific observations (Murray et al., 2008), validation of survey data (Rand et al., 2022), enhanced assessments of habitat (Doherty et al., 2018), and informed assessments of the effects of regulatory and environmental change on fishing communities (Wijermans et al., 2020; Murphy et al., 2021). Experiential knowledge is also critical in research design, including ensuring more comprehensive and informed approaches to temporal, spatial and technological scales relevant to fisheries (Steins et al., 2022). Even when fishers' knowledge is directed towards stock assessment, experiential insights may enhance these analyses, linking stock dynamics to phenomena at a broader spatial and temporal scales, including considerations of shifting effort, ecological patchiness and change over time, historical context, and changing fish ecology.

Participants saw clear benefits but also challenges to industry contributions the scientific process. We argue that the lessons learned in SIRC may extend beyond use in applied fisheries research with relevance for industry and science engagement in the wider field of marine science (Steins et al., 2020). The discussions here are part of a broad and ongoing dialogue including other forums for coordinated exchange between scientists and fishers to determine best practices and lessons learned (Baker et al., 2019b). Such venues and opportunities should be supported to continue maintain these conversations.

We recommend the establishment of an ICES Strategic Initiative on Science Industry Research Collaboration (SISIRC) to coordinate the separate workshops on this topic, bring different expert groups together and learn from good (and bad) practices from expert groups that already have experiences in relation to collaborating with industry and using observational or experiential knowledge from fisheries. Further, coordination and learning from ongoing work is not only important in ICES, but also as part of movement towards more collaborative and transdisciplinary science more generally.

Ethics Statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

MB: Conceptualization, Data, Writing, Editing, Session Convenor, Co-lead author. NS: Conceptualization, Data, Editing, Session Convenor, Co-lead author. SN: Conceptualization, Data, Session Convenor. MP: Conceptualization, Data, Session Convenor. AB: Contributed Ideas and Content. DH: Contributed Ideas and Content. SM: Contributed Ideas and Content. JM: Contributed Ideas and Content. KP: Contributed Ideas and Content. CS: Contributed Ideas and Content. MM: Contributed Ideas and Content. All authors contributed to the article and approved the submitted version.

Funding

The inspirational video for the Networking Session (https://youtu.be/FsfBEBbpvck), the involvement of co-lead author Nathalie Steins in the session and publication fees were funded through the European Maritime and Fisheries Fund (Dutch Operational Program, Partnerships Science and Fisheries).

Acknowledgments

Insights and results emerged from a Science and Industry Research Collaboration (SIRC) Networking Session hosted as part of the International Council for the Exploration of the Sea (ICES) Annual Science Conference, convened by NS (NED), MP (NED), MB (USA), and SN (DEN). We greatly appreciate the contributions and insights of all participants of the SIRC networking session, particularly: Fanny Barz (GER), Halle Berger (USA), Katinka Bleeker (NED), Alexandra Blöcker (GER), Lisa Borges (POR), Dounia Boukaouit (DEN), Patricia Clay (USA), Dorothy Dankel (NOR), Cpt. Jacob de Boer (NED), Jochen Depestele (BEL), Antonina dos Santos (POR), Søren Eliasen (DEN), Aubrey Ellertson (USA), Tereza Fonseca (POR), Elvar Hallfredsson (NOR), Paul Hart (UK), Alan Haynie (USA/ICES), Astrid Jarre (SAF), Andrew Jones (USA), Vera Köpsel (GER), Marloes Kraan (NED), Hannah Lachance (USA), Andy Lipsky (USA), Helena McMonagle (USA), Terhi Minkkinen (FIN), Debbi Pedreschi (IRE), Pierre Petitgas (FRA), Cpt. F/V KP (NED), Jens Rasmussen (UK), Katina Roumbedakis (ESP), Amanda Schadeberg (NED), Jörn Schmidt (GER/ICES), Olivier Thébaud (FRA), Clara Ulrich (FRA), Cpt. Andreas van der Poel (NED), Alina Wieczorek (IRE), and Anna-Marie Winter (NED). We also thank the ICES Secretariat and Katla Hrund Björnsdóttir (ICES) for facilitating platforms that enabled these online discussions and ICES General Secretary Alan Haynie (ICES) for contributing to the discussions and review of the manuscript. We thank the many fishers and communities that have contributed to effective collaborative research and improved and informed sustainable fishery management practices.

Conflict of interest

Author DH was employed by the company Jaczon B.V. Author AB was employed by the company Osprey Group. Author KP was employed by the company Zeevisserijbedrijf K. Post BV. Authors JM and MM were employed by the company Cornelis Vrolijk.

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

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