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Mechanisms and models for industry engagement in collaborative research in commercial fisheries

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Data and insights from fishers are essential sources of information to advance understanding of fishery and ecosystem dynamics. Incorporating fisher and industry knowledge holds prospects for improving marine science and fisheries management. We address cooperative research in the context of collaboration between fishers, scientists, industries, universities, and agencies to develop applied research to understand marine ecosystems, inform fishery management, enhance sustainability, govern resource use, and investigate social-economic dynamics. We leverage the insights of more than 100 research scientists, fisheries managers, industry representatives, and fishers to outline actionable recommendations for effective approaches and mechanisms to integrate industry data, perspectives, and insights in fisheries science. We also highlight opportunities and address challenges and limitations to such collaboration.

KEYWORDS

fisheries management, fisheries science, fishing industry, cooperative research, science-industry research collaboration

1 Introduction

"You can't look at a problem with knowledge of only one aspect of it. The best group to solve problems will have experience from different perspectives."

Cooperative research (CR) in fisheries and marine science refers to scientific research conducted in partnership with communities, fishers, or the fishing industry (NRC, National Research Council, 2004). In the latter instance, this integration of industry perspectives, equipment, and skills with scientific approaches, applications, and processes has proven effective for compiling fisheries data (Johnson and van Densen, 2007; Hind, 2015), addressing data gaps (Heimann et al., 2023), generating knowledge (Hartley and Robertson, 2008; Jones et al., 2022), monitoring ecosystems (Olsen et al., 2023), engaging stakeholders (Mackinson et al., 2011 Calderwood et al., 2023), and informing management (Wilson, 2003; Baker et al., 2014; Gray and Catchpole, 2021; Mackinson et al., 2023). Science-industry collaboration in fisheries research is gaining further momentum (Steins et al., 2022) and there is increased effort to provide policy recommendations toward facilitating industry contributions to science and management (Murphy et al., 2022; Baker et al., In Press; Steins et al., In Press).

Here we present findings and recommendations from more than 100 fishermen, industry representatives and research scientists participating in panel discussions at the Lowell Wakefield Fisheries Symposium on Cooperative Research – strategies for integrating industry perspectives and insights into fisheries science (Baker et al., 2019a; https://alaskaseagrant.org/events/wakefield-fisheries-symposium). Symposium participants included scientists from government agencies, academics, research institutes, and industry, as well as fishermen and fishing industry representatives from 17 industries in 11 large marine ecosystems. These industries include large-scale fisheries in the commercial sector and collectively represent 26% of global commercial landings and 14% of global commercial fishing landings value (2.45 million metric tonnes and $2.77 billion USD; DDPO, 2023; FAO, 2022; NOAA, 2023; NZRLIC, 2023). Case studies that highlighted industry-led presentations and science-industry teams provided concrete examples of effective collaboration and identified best practices and lessons learned (Figure 1). This symposium aimed to identify challenges, highlight opportunities, and outline actionable recommendations for facilitating effective CR to inform fishery science and management.

In the following sections, we define challenges and opportunities to effective CR in industrialized commercial fisheries and outline actionable recommendations. All quotes are from the scientists, fishers, and industry leads listed here as authors, extracted from discussions at the symposium.

2 Policy options and implications

2.1 Outlining frameworks for finances and funding

"It's incumbent upon everyone who uses the resource, to pay to play. In some cases, that's funding, in some cases that's just participating in the research."

One of the challenges in navigating effective CR is establishing processes for funding and resources. Investment, either by government or industry, raises questions related to responsibilities, priorities, and mechanisms. Most governments with jurisdiction to manage fisheries invest in science. There is often a legal obligation on the government to invest in research to inform decisions related to the use and disposition of a public trust resource (Criddle, 2008). Important questions emerge – How does supplemental funding or financing by industry collaboratives complement government-supported science? To what extent does the funding source help or get in the way? When does it replace it? What are the frameworks that reduce barriers to investment?

2.2 Responsibilities for investment

"The public contribution is the baseline. The money from the industry is designed to enhance that investment. But it's really hard to push back on that tendency to take that additional funding for granted, to rely on that funding, and put any new funding in some other area that doesn't have organizational capacity to provide supplemental private funding. All of a sudden, now we're funding what used to be a government mandate. How do you go backwards?"

Engaging stakeholders in informing management for the sustainable use of living marine resources is critical. Sometimes, that may mean directly financing the science that informs management. However, the caveats are numerous. A common concern for the industry is ambiguity in whether they are getting involved or taking over. Finding the line where government responsibilities end and opportunities for external investment start may be challenging. In the context of management, a core mission of government science should be funding the minimum information needed to manage stocks and set fishing at levels that maintain a fishery into the future. Beyond that, the industry may be well positioned to refine biomass estimates, improve understanding of stock distribution, or inform of how environmental conditions or market variability may influence stocks and markets. There are also devolved approaches to achieving these objectives. In New Zealand, the approach is to specify performance metrics for research and open a process for bids on contracts to conduct the research. A related example would be when agencies contract with Tribes, communities, consulting firms, or university research institutes to undertake studies or maintain data monitoring programs that provide information needed for management. Devolved approaches may be particularly important in regions where government capacity is limited or is costly or impractical for centralized research programs.

Another common concern is that industry investments in CR will result in government funds being re-allocated to other areas. In that case, the industry may be burdened with continuing to support research that was formerly the responsibility of the management agency. The risk is that, when the industry steps in to provide the funding, it will later be difficult to get the government to resume funding in the future.

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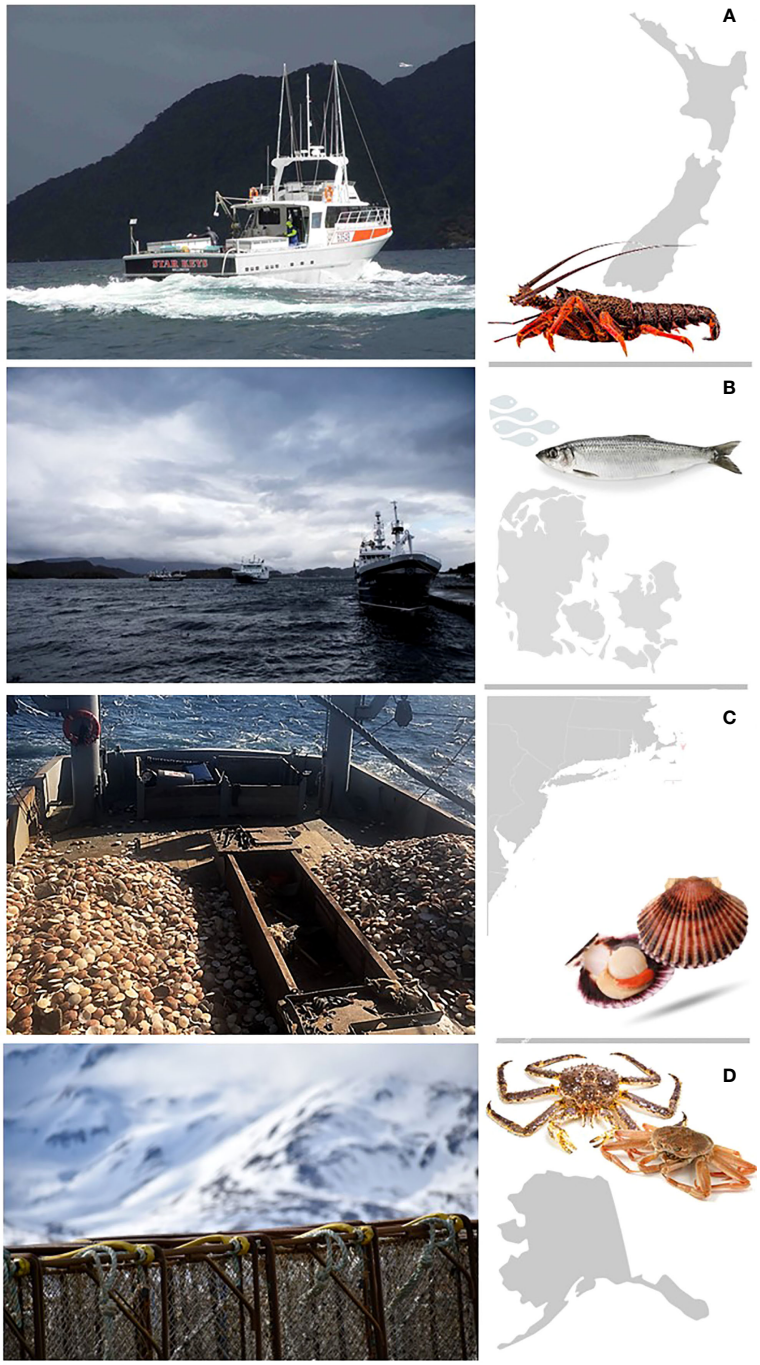

FIGURE 1
Cooperative research efforts in fisheries detailed in case studies in the Lowell Wakefield Symposium, including **(A)** New Zealand rock lobster fisheries, **(B)** North Sea small pelagic fisheries for herring, smelt and sandeel, **(C)** Northwest Atlantic scallop fisheries, and **(D)** Alaska groundfish and crab fisheries. Photo credits: D.R. Sykes, C.R. Sparrevohn, B. Eilertsen, and M.R. Baker.

2.3 Managing conflict of interest

"There are always external influences and internal biases. If the optics look bad, extra time should be devoted to ensure the process is rigorous, the science is sound, that we're following first principles.

There are inherent dilemmas in industry participation in fisheries science (Jacobsen et al., 2012; Sparrevohn et al., 2019). The aim is to enhance science and increase legitimacy without jeopardizing credibility (de Boois et al., 2021). Questions arise as to whether joint efforts represent collaboration or collusion (Sykes, 2019). These challenges may be recognized and explicitly addressed through contracts, performance metrics, quality-control processes and other mechanisms to ensure transparency and oversight. In many regions, including New Zealand, Europe, Canada, the northwest Atlantic, the northeast Pacific, and Alaska, there appears to be evidence of a paradigm change in how fishery,

science and advice are interacting (Ma et al., 2019; Mercer et al., 2019; Sheridan and Templin, 2019; Sparrevohn et al., 2019; Sykes, 2019). Challenges include – how to increase industry confidence in the research and how to adapt scientific processes to incorporate the knowledge and insights of fishers. To maintain stakeholder support, research processes must be clearly articulated, well-substantiated, impartially applied, and respectful of sources of knowledge and ways of knowing. Core components to success have been clear protocols for information sharing (early and often), strong frameworks for coordination, communication and response, and a priority on increasing stakeholder trust in processes and outcomes. Transparency in the engagement process is critical to internal and external audiences, and effective implementation and application to management requires a thorough understanding of stakeholder motivations for participation. Finally, submitting the research to rigorous external peer-review will often address perceptions of bias or concerns about conflicts of interest.

"There's a number of people who have said, 'we shouldn't have industry involved at all.' Why are we not conducting science in a manner that allows us to follow the math, identify the biases, spot flaws in the process, and identify where the outcome has been driven by a particular input?"

3 Actionable recommendations

"OK, we've got to do something."

CR is often conducted on a large scale through organized mechanisms that incentivize involvement. Successful examples include research set-aside programs, cost recovery, fisheries collaboratives, and cooperative research institutes and programs. We discuss each in the following sections.

3.1 Models for industry-financed science

"Government investments change over time, and we may be left with data gaps that hurt industry. There are risks with industry taking over the funding, but there are also huge benefits to ensuring that we have the information and data that we need."

In the New Zealand Rock lobster fishery, where industry leads research, industry stakeholders gain confidence that funding will be directed toward issues most critical to the fishery (Sykes, 2019). Similar results have been noted in fisheries collaboratives in Alaska (Behnken and Sylvester, 2019; Oliver et al., 2019) and New England (Mercer et al., 2019; Stokesbury and Eilertsen, 2019), where formal agreements between industry, scientists, community stakeholders, research institutes, and management authorities result in collaboratives able to address budget shortfalls and ensure sufficient resources to manage fisheries in an informed manner.

3.2 Research set-aside programs

"We started out with 1% of our total allocation. And that 1% would go out for bids. Science organizations could write proposals. There was a panel to review proposals and award bids to support research. The captain, the crew, the owner – would get a smaller percentage, but with a return. And now we've increased it to 2%. The industry drove that, the industry wanted it."

Research Set-Aside (RSA) programs provide a mechanism to fund research and compensate vessel owners participating in research through the sale of fish harvested under a research quota. The New England Council (and until recently, also the Mid-Atlantic Fishery Management Council) set-aside is awarded through a competitive grant process managed by the National Oceanic and Atmospheric Association (NOAA), with priorities established by the Councils. Solicitations for RSA proposals are posted at www.grants.gov and distributed widely through the Councils and NOAA Fisheries public relations channels. In New England and the western Atlantic region, RSA programs have a demonstrated track record for supporting applied research that informs fishery management decisions and improves stock assessments. RSA programs have been applied to the Atlantic Sea Scallop, Atlantic Herring, and Monkfish Fishery Management Plans. Examples of research include habitat analyses and evaluation of fishing impacts (Stokesbury and Harris, 2006).

3.3 Cost recovery

"The investment in rock lobster fishery science has partial cost recovery. The rough rule of thumb is 75% of the cost of research has to be recovered by the industry. And because we are paying, we have a say in what is funded."

Another approach is cost recovery. While most countries use general tax revenues to fund fisheries research, others levy the commercial fishing industry to recover research costs. In this context, research costs are shared between the sector and taxpayers. A more direct relationship between the primary beneficiaries of fisheries management (i.e., fishermen) may lead to more efficient interventions. Fishers may be more incentivized to pressure governments for services that meet needs in an efficient manner (e.g., Organization for Economic Co-operation and Development, Wallis and Flaaten, 2000). Cost recovery is applied in Canadian and New Zealand fisheries (Dewees, 1998). In British Columbia, this occurs through community-based self-management and government-community co-management cost-sharing arrangements (Thompson et al., 2019). In New Zealand, quota owners pay resource rents on the quota through a cost-recovery regime. The rationale is to (1) secure revenue to offset fisheries management costs; (2) encourage greater industry responsibility to reduce regulation and costs; (3) provide industry voice in the development and delivery of fisheries management; and (4) match levies to resource rent (Harte, 2007).

3.4 Fisheries collaboratives

"Institutions enable cooperative research, but people conduct cooperative research."

Fisheries collaboratives are agreements between industry, communities, agencies, and other actors with vested interest in a particular fishery. In Alaska, the Bristol Bay fisheries collaborative (https://www.bbsri.org/bbfc) includes the state management agency and a federally-authorized regional community development quota program, representing local fishermen, villages, and municipalities. The formal agreement commits the signatories to contribute and raise funding from the fishing industry and other stakeholders to ensure that fishery managers have sufficient resources to manage salmon for the benefit of all users. Benefits include a consolidated and reliable funding mechanism and a more coordinated research approach, that simultaneously examines multiple projects and their potential to maximize benefits to the fishery.

3.5 Industry-led cooperative research institutes and foundations

"In collaborative research, sometimes it is stakeholders who lead the way."

There are many examples of industry-led research cooperatives that advance CR. The Pollock Conservation Cooperative Research Center is industry-funded, but managed through an academic partner, the University of Alaska Fairbanks, which supports peer-reviewed competitive research grants. Research priorities are recommended by an advisory board that includes industry representatives, university leads, and representatives from a federal or state management agency. Priorities include research to improve biological data and statistical models of stock status, analyses of incidental catch and discard mortality, ecosystem considerations, management strategy, and sustainability of protected species (Criddle, 2019). The Bering Sea Fisheries Research Foundation (BSFRF) is another industry group representing commercial fishing interests, particularly crab. BSFRF has partnered with NOAA in CR related to king, snow, and Tanner crab surveys assessments, and estimates of crab handling mortality (Foy and Goodman, 2019). Research projects are prioritized by a joint agreement between BSFRF and NOAA within a framework set by the North Pacific Fishery Management Council. Cooperative projects include analyses on trawl efficiency in the NOAA bottom trawl survey. Other examples include the Aleutian Longline Fishermen's Association Fishery Conservation Network (Behnken and Sylvester, 2019).

3.6 Cooperative research programs and development agreements

"It came from talking to each other and then working together. Now, the average fisherman is in direct collaboration with enforcement – the guys who were there to shut us down with regulations that we just couldn't follow. We went from complete breakdown to being able to work together."

Several research-based institutions have also developed CR programs to foster direct engagement and collaboration between industry and scientists (Table 1). Examples in the US include North Pacific Research Board (NPRB) and NOAA science center initiatives (Baker et al., 2019b; Chandler, 2019; Foy, 2019). Partnerships between fishing fleets and the science community can bring many benefits, including enhanced data access, information sharing, economic efficiency, and societal empowerment.

NPRB strongly encourages CR with industry (Baker and Smith, 2018; Baker et al., 2019b) and funds research in the North Pacific that addresses stock assessment, gear modification, electronic monitoring of fleet activity, monitoring for marine disturbance, tracking and movement studies, marine mammal depredation on fishing gear, and bycatch reduction. These efforts not only support marine observations, but often address pressing management needs and improve understanding between the research community, management agencies, and industry.

NOAA Fisheries' Cooperative Research Program involves regional partnerships with a broad range of external stakeholders, including state and tribal managers and scientists, fishing industry participants, and academic institutions (Chandler, 2019). Benefits include increased quantity and quality of data, inclusion of stakeholder knowledge in science and management, improved relevance of research to fisheries management, and reduced costs. Other benefits include shared understanding of science, stakeholder buy-in, improved relationships with constituents, and incorporation of industry knowledge, local knowledge, and traditional knowledge in a representative framework (Foy, 2019).

In New England, the Commercial Fisheries Research Foundation was founded and led by members of the fishing community to provide fishermen with opportunities to contribute to the science and management of key fisheries resources (Mercer et al., 2019). The CFRF develops practical solutions to scientific and supply chain challenges, providing fishermen with specialized apps to collect biological and environmental data and developing scientific products (e.g., digital maps of the seafloor) to inform fishery management. CFRF initiatives have been successful in reducing bycatch through conservation engineering, improving data for stock assessments, and growing markets and consumer awareness of underutilized species (Mercer et al., 2019). Research includes fisheries-based research fleets for lobster (*Homarus americanus*), Jonah crab (*Cancer borealis*), quahog (*Mercenaria mercenaria*) and black sea bass (*Centropristis striata*).

3.7 Forums for discussion and engagement

"What I've seen is, you get people in the same room. At the outset, you have a dialogue. Over time, you're exposed to information through some of the same people. And eventually you realize, 'wait a minute, they're actually doing something that makes sense.' Also, 'here's how to improve that.'"

Much of fisheries management occurs in public forums such as local, regional, or national fishery management council meetings (e.g., US regional fishery management councils http://www.fisherycouncils.org/; ICES regional and advisory areas, https://www.ices.dk/) or commissions developed to focus on specific target

TABLE 1 Established platforms for Cooperative Research and Industry-led initiatives in North America.

Framework for Collaborative Research	Description of Collaboration	Relevant References
Alaska Longline Fisheries Association Fishery Conservation Network	ALF-AFCN engages fishers in research and conservation including more than 100 fishermen, 100 vessels, and has successfully implemented 7 fisher-led projects.	Behnken and Sylvester, 2019
Alaska Hatchery Research Project	AHRP aims to ensure hatchery programs are not detrimental to wild salmon and develop trust among stakeholders, including the Alaska Department of Fish and Game, University of Alaska, salmon hatchery operators, and National Marine Fisheries Service.	Sheridan and Templin, 2019
Alaska Seafood Cooperative	ASC launches collaborative initiatives with management agencies to reduce bycatch mortality, including in Pacific halibut, using exempted fishing permits to sort halibut from target catch and expedite release. Processes are refined iteratively, with industry and agencies collaborating to problem solve and improve design.	Oliver et al., 2019
The Commercial Fisheries Research Foundation	CFRF was founded by Rhode Island's fishing community to develop practical solutions to scientific and supply chain challenges (e.g., collect biological and environmental data, digital maps) and implement initiatives to reduce bycatch, improve stock assessment data, and promote consumer awareness.	Mercer et al., 2019
Bering Sea Fisheries Research Foundation	BSFRF is an industry group representing commercial fishing interests and has partnered with management agencies on research relevant to king, snow, and tanner crab surveys, trawl efficiencies in agency surveys and estimates of crab handling mortality.	Foy and Goodman, 2019
International Pacific Halibut Commission	IPHC engages in multiple CR programs, building on interest from industry for data collection, dockside collection programs, and confidentiality agreements. Programs include at-sea sex-marking protocols for commercial vessels, testing of sex-marking methods, and genetic assays to monitor landed commercial catch. CR programs also estimate discard mortality rates in the longline fishery to estimate injury and vitality.	Stewart et al., 2019; Dykstra et al., 2019
NOAA Fisheries Cooperative Research Program	NOAA-FCRP is a nationwide network coordinating regional partnerships with a broad range of external stakeholders, including state and tribal managers and scientists, fishing industry, and universities. Benefits include increased quantity and quality of data, inclusion of stakeholder knowledge, improved relevance of research to fisheries management, and reduced costs.	Chandler, 2019
NOAA Fisheries Cooperative Research Program, Alaska Fisheries Science Center	NOAA-AFSC is engaged in multi-agency research, collaboration with industry sectors and co-production of research with coastal communities. Specific collaborative research includes longline surveys (Malecha and Lunsford, 2019), biometric data collection (Lang and Foy, 2019), tagging and recovery studies (McDermott et al., 2019), logbook programs (Rodgveller and Lunsford, 2019), and collection of opportunistic acoustic data (Barbeaux et al., 2019).	Foy, 2019
North Pacific Fisheries Research Foundation	NPFRF builds collaborations to develop and implement salmon excluders in the pollock fishery to reduce incidental catch. To mitigate bycatch caps and time and area closures, fishermen have developed gear modifications to enable salmon escapement. Funding is provided through industry donations and in-kind support from industry and management agencies.	Gauvin et al., 2019
North Pacific Research Board Investments in Cooperative Research with Industry	NPRB encourages and funds competitive grants for cooperative research with industry as well as community engagement projects. Research in CR has included stock assessment, gear modification, electronic monitoring of fleet activity, monitoring for marine disturbance, tracking and movement studies, marine mammal depredation on fishing gear, and bycatch reduction.	Baker et al., 2019b; Baker and Smith, 2018
Pollock Conservation Cooperative Research Center	PCCRC is an industry-funded research center managed at the University of Alaska that supports competitive research grants and fellowships. Research priorities are recommended by industry and include: improved biological data and statistical models; estimates of discard mortality; habitat and ecosystem considerations; fisheries management strategy and regulatory flexibility; sustainability of protected species; and product value.	Criddle, 2019

species (e.g., International Halibut Commission, https://iphc.int/, Pacific Salmon Commission, https://www.psc.org/). These forums provide a framework for regular meetings including research scientists, fishery managers, fishermen, and community members and representatives. This is intended to 'allow regional, participatory governance by knowledgeable people with a stake in fishery management' (http://www.fisherycouncils.org/). Plans and management measures (e.g., fishing seasons, quotas, bycatch regulations, closed areas) are constituted following public review and discussion of scientific advice.

At the International Council for the Exploration of the Sea (ICES), stakeholders 'sense test' the science, develop ideas for process reform, solicit priorities for the strategic plans, participate in advisory forums, and engage in meetings to guide research programs (Ballesteros and Dickey-Collas, 2021). ICES principles, policies, and strategic plan require stakeholder engagement and identified pathways for participation include expert groups and workshops, consultation or scoping exercises, and participatory research and co-creation of knowledge (Dankel et al., 2016; ICES, 2023).

While these meetings and associated workshops create platforms for fishermen to contribute to management processes, Councils and regulatory authorities determine allocation and limits; other more targeted forums may be more successful in fostering and

incentivizing CR projects and innovation. Many other institutions integrate perspectives of fishermen, fishery managers and scientists (Table 1) to determine priorities for research, identify mechanisms for collaboration, discuss ideas on how to improve what is known about fish stocks and marine systems, and determine how to conserve the resource and optimize management.

"In the North Pacific, fishery management and the annual development of stock assessment plans has processes that directly engage industry through plan teams and other processes that enable a back-and-forth with the scientists. This is one avenue for increased engagement. The data are often straightforward but the interpretation is challenging"

4 Discussion – best practices and principles of cooperative research

"So what's the best way forward?"

Initial success is often achieved through finding common ground and staying simple. Longterm success is often achieved by maintaining momentum, carefully examining processes, and repeating what works. Continued collaboration means constantly refreshing and revisiting aims and objectives, and refining the approach. Best practices distilled from multiple regions resulted in a set of principles for effective and sustainable CR (Table 2). Crucial elements focus on how CR should be collaborative, robust, relevant, cost-effective, timely, directed, and involve dedicated and engaged partners. Recognizing expertise and integrating disciplines and perspectives can provide opportunities to build trust. Open communication and exchange maintain integrity and focus. Clarifying roles and responsibilities confirm commitments and mitigate potential conflict. Sharing data and publishing together strengthen relationships, promote transparency, and ensure results are well-positioned to inform management.

"Find success, and from that, benefits flow. Early on, find projects that are small, tractable, maybe pilot work that has a high chance of success. Get a win and get momentum. Over the years, you form relationships; it helps to have that trust."

TABLE 2 Guidelines and Best Practices.

o Understand the management process and its timing
o Avoid conflicts of interests among stakeholders and researchers
o Prepare for people issues and potential conflict
o Identify and recruit strong leaders
o Anticipate unexpected results and new questions
o Develop large sample sizes to ensure robust research results
o Avoid sensationalized reporting of research results
o Strive for transparency
o Acknowledge disagreement early and often
o Share all data and results openly
o Publish results collaboratively

These guidelines and best practices were distilled from multiple sources and presentations throughout the week-long symposium and subsequent discussions. Information is distilled and sequenced here to highlight some of the most important takeaways from professionals and experts with experience designing and implementing cooperative research in fisheries from both science and industry perspectives.

Author contributions

MB: Symposium Convenor, Steering Committee, Presenter, Conceptualization, Writing, Editing. RA: Panel. RC: Panel. KC: Presenter. DE: Keynote Speaker, Panel. RF: Keynote Speaker, Panel. JG: Steering Committee. SG: Keynote Speaker, Panel. LH: Panel. BH: Symposium Convenor. NK: Keynote Speaker, Panel. AM: Presenter. EP: Panel Moderator. MR: Panel Moderator. JR: Panel. RS: Panel. CS: Keynote Speaker, Panel. KS: Keynote Speaker, Panel, Editing. DS: Keynote Speaker, Panel. All authors contributed to the ideas presented here. All authors were invited speakers, panelists, and/or symposium convenors at the 2019 Lowell Wakefield Fisheries Symposium on cooperative research. This manuscript was organized and developed by the lead author (Symposium Chair) and reflects insights and perspectives of listed contributing authors, developed in panel discussions, invited presentations, and subsequent correspondence and exchange. All authors contributed to the article and approved the submitted version.

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Conflict of interest

Author DE was employed by Liberty, Nordic Inc. Author MR was employed by the company Bristol Bay Economic Development Corporation.

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