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PERSPECTIVE

Integrating diverse objectives for sustainable fisheries in Canada[1]

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Abstract: An interdisciplinary team of academics and representatives of fishing fleets and government collaborated to study the emerging requirements for sustainability in Canada's fisheries. Fisheries assessment and management has focused on biological productivity with insufficient consideration of social (including cultural), economic, and institutional (governance) aspects. Further, there has been little discussion or formal evaluation of the effectiveness of fisheries management. The team of over 50 people (*i*) identified a comprehensive set of management objectives for a sustainable fishery system based on Canadian policy statements, (*ii*) combined objectives into an operational framework with relevant performance indicators for use in management planning, and (*iii*) undertook case studies that investigated some social, economic, and governance aspects in greater detail. The resulting framework extends the suite of widely accepted ecological aspects (productivity and trophic structure, biodiversity, and habitat–ecosystem integrity) to include comparable economic (viability and prosperity, sustainable livelihoods, distribution of access and benefits, regional–community benefits), social (health and well-being, sustainable communities, ethical fisheries), and institutional (legal obligations, good governance structure, effective decision-making) aspects of sustainability. This work provides a practical framework for implementation of a comprehensive approach to sustainability in Canadian fisheries. The project also demonstrates the value of co-construction of collaborative research and co-production of knowledge that combines and builds on the strengths of academics, industry, and government.

Résumé : Une équipe interdisciplinaire d'universitaires et de représentants gouvernementaux et de flottes de pêche a collaboré à l'étude des nouvelles exigences en matière de pérennité des ressources halieutiques canadiennes. L'évaluation et la gestion de ces ressources ont mis l'accent sur la productivité biologique en ne tenant pas suffisamment compte d'aspects sociaux (y compris des aspects culturels), économiques et institutionnels (de gouvernance). L'efficacité de la gestion des pêches a en outre fait l'objet de très peu de discussions ou d'évaluations formelles. L'équipe composée de plus de 50 membres a (*i*) cerné un ensemble exhaustif d'objectifs de gestion pour un système de pêches pérenne reposant sur des énoncés de principes canadiens, (*ii*) regroupé ces objectifs en un cadre opérationnel comptant des indicateurs de rendement pertinents à utiliser dans la planification de la gestion et (*iii*) réalisé des études de cas pour examiner plus en détail certains aspects sociaux, économiques et de gouvernance. Le cadre en découlant élargit l'ensemble des aspects écologiques (productivité et structure trophique, biodiversité et intégrité des habitats et écosystèmes) largement acceptés pour y inclure des aspects économiques (viabilité et pros-

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Authorship reflects the contribution of a subset of the project members in development of this specific paper. A full list of project participants is presented in Appendix A. The first three authors contributed to the day-to-day leadership of the project and to the primary shape of the paper. The other authors are listed alphabetically.

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périté, moyens de subsistance durables, répartition de l'accès et des bénéfices, avantages pour les régions–collectivités), sociaux (santé et bien-être, collectivités durables, pêches éthiques) et institutionnels (obligations légales, structure de bonne gouvernance, processus décisionnel efficace) comparables de la pérennité. Ces travaux fournissent un cadre pratique pour la mise en œuvre d'une approche intégrée visant la pérennité des ressources halieutiques canadiennes. Le projet démontre également la valeur de la construction collective de recherches collaboratives et de la production collective de connaissances qui mettent en commun les forces des universitaires, de l'industrie et des gouvernements. [Traduit par la Rédaction]

Introduction

Canada's legislation and international commitments require attention to ecological, social (including cultural), economic, and institutional (governance) aspects of fisheries. The Federal Sustainable Development Strategy (ECCC 2016), which, along with the Fisheries Act, is the basis for the management of fisheries and specifies "that sustainable development encompasses and requires thorough consideration of economic, social and environmental factors". The 2011 Report of the Commissioner of the Environment and Sustainable Development (Office of the Auditor General 2011) explicitly points out that "the Federal Sustainable Development Act … acknowledges the need to integrate environmental, economic and social factors when making all … decisions. A fourth category, organizational properties, includes ways of integrating and managing the first three" (Office of the Auditor General 2011: p. 21). Fisheries and Oceans Canada's (DFO) Sustainable Fisheries Framework, which guides Integrated Fisheries Management Planning, also requires integration of social and economic considerations (DFO 2016*a*). Further, the guidance documents on Integrated Fisheries Management Planning (DFO 2010) refer to the need to incorporate economic, social, and cultural aspects, but without instructions on how to do so.

Canada has an extensive system of analysis (including peer review) for biological advice, especially productivity of the target stock, but no formal system for analysis or consideration of other aspects of fisheries systems (Stephenson et al. 2018; Benson and Stephenson 2018). While much has been done by DFO to develop an expanded set of conservation objectives, these have not been applied comprehensively to all fisheries, and key properties have not been placed in a practical framework for implementation. Further, while the list of conservation objectives is growing, the social (including cultural), economic, and institutional objectives and related performance indicators have generally not been articulated, and there is no agreed framework for practical integration of these aspects in management decision-making. The result is that although Canada has broad objectives for fisheries management, several aspects are not currently being tracked in most fisheries. Economic, social, and institutional aspects, including trade-offs, are considered later in the process or as political decisions (Lane and Stephenson 1998; Parlee 2016; Benson and Stephenson 2018). This approach has been criticized for a lack of transparency, prevalence of short-term considerations, and resulting in unintended consequences (Stephenson 2012; Bavington 2010; Pinkerton 2013).

These points collectively highlight the need for research that will help Canadian fisheries management move from an approach that has been based largely on the consideration of biological aspects of conservation (e.g., Gavaris 2009) to a practical framework that appropriately incorporates additional social (including cultural), economic, and institutional aspects that make up the four pillars of sustainability (e.g., Boyd and Charles 2006; Stephenson et al. 2017). This is not only an issue in Canada, but internationally as many nations move to implement a more holistic approach to management and a broader perspective towards sustainability (Charles 1994, 2001; FAO 1999, 2003*a*, 2003*b*; Fletcher et al. 2010; Rametsteiner et al. 2011).

The widespread failure to integrate all four pillars of sustainability (ecological, social, economic, and institutional or governance) has arguably contributed to the inability of nations to achieve the aspirations of ecosystem-based and integrated management (Begg et al. 2015; Garcia et al. 2014). Stephenson et al. (2017) point to three major impediments identified in the literature: (*i*) a relative lack of explicit social, economic, and institutional objectives, (*ii*) a general lack of process (frameworks, governance) for routine integration of all four pillars of sustainability, and (*iii*) a bias in assessment and management processes towards biological considerations. They call for a "systems" approach with explicit consideration of strategic and operational aspects of management: multidisciplinary or transdisciplinary evaluations, practical objectives for the four pillars of sustainability, appropriate participation, and a governance system that is able to integrate these diverse considerations in management. There is a need to expand governance to include more diverse players in the science advisory and management processes and for a framework in which specific objectives can be established and used in practical management.

In this paper, we first describe the methodological approach taken in our collaborative work. We then describe the iterative development of a framework for sustainability objectives related to Canadian policy, which includes (1) a broad set of objectives reflective of the four pillars of sustainability relevant to Canadian fisheries policies and (2) an operational framework for use in management planning. There follows a description of the case studies undertaken within the project to specifically evaluate and apply those aspects of the framework that have not been well addressed to date, including distribution of benefits, well-being, and governance. Our discussion then focuses on the framework of sustainability objectives, requirements for new information–processes, and the process of interdisciplinary collaboration.

Methodological approach

There is a need to prepare Canadian fisheries to be more sustainable and to participate effectively in emerging management regimes. This project (Project 1.1) of the Canadian Fisheries Research Network (CFRN; Thompson et al., in press) anticipated this critical need and thus undertook interdisciplinary research into an expanded perspective on sustainability. As in all projects of the CFRN, this research was based on questions identified by industry, of importance to fisheries management, and requiring collaboration among industry, academia, and government. The project, which began in 2010 and extended through 2016, involved a collaborative, participatory, and interdisciplinary engagement process that also represents the methodology used to develop the framework.

The overall context of the research was to provide support for "ecosystem-based" and "integrated" management, which demands new knowledge requirements with emphasis on a broader view of sustainability that goes beyond biological considerations. Insights from diverse knowledge systems, when brought together, allowed us to build a common understanding about the needs of future management and how to evaluate progress towards meeting those needs.

The project was deliberately focused on co-construction of new knowledge and included over 35 academics (including students) from several disciplines working with members of the harvesting sector of industry and government (science and policy–management) representatives (listed in Appendix A, Table A1). The team was not static over the 6 years, but expanded in 2014 to include interested

members of other CFRN projects, including several working on management strategy evaluation and on adaptive management.

The primary mechanism through which the framework was developed was a series of workshops, working groups, and project conference calls designed to

- develop a definition of sustainable fisheries, rooted in Canadian policy
- develop a logic frame and comprehensive framework for evaluating fisheries against the principles and objectives identified in the definition of sustainable fisheries, and
- design and conduct a series of case studies in which we investigated aspects and attempted to apply the framework.

In the context of an ecosystem approach, we drew on Integrated Fisheries Management Plan (IFMP) guidance documents (DFO 2010), a report of the Commissioner for Sustainable Development (Office of the Auditor General 2011), and international literature to expand applied IFMP to a more comprehensive consideration of the "human dimension". A management committee organized working groups to address specific aspects of the framework, which were then workshopped in 10 face-to-face meetings and more than 19 conference calls for the entire research team. In addition, student working groups, who were developing case studies, collaborated on refining indicators for under-theorized aspects of the framework (see later sections on case studies). We took an "incremental" approach, asking how little we need to change existing management planning to make the required improvements. The team worked around a logic frame, aimed at matching the suite of common ecological aspects (productivity, biodiversity, and habitat) with comparable social (including cultural), economic, and institutional (governance) aspects to form a "report card" with a comprehensive set of objectives. We benefitted directly from perspectives articulated by fish harvesters, mostly representatives of the independent owner–operator fishing fleets. The collaborative approach allowed us to place this research firmly in a context of theory development, public policy, legislation, and relevant case studies to arrive at credible, salient, and legitimate results (Cash et al. 2003).

Throughout the process, the general approach was to engage in discussion to achieve consensus on project objectives. This was considered important because we wanted to integrate the insights from different disciplines, research approaches, perspectives, and experiences. Consensus was interpreted as general agreement that an aspect was "good enough" to move forward (Star 2010). Achieving consensus around each of the objectives was a challenging process that took substantial time and effort. In retrospect, the success of this approach depended on several conditions. One key condition for success was building a common set of concepts and principles, which required learning to work across disciplines and experiential knowledge and to understand perspectives and experiences outside one's own field or area of work. Progress was slow to start because it took several meetings to develop trust in the collaboration and in a common approach. For example, should we work from international aspirational goals or instead focus on solving practical problems specific to local fisheries? It was a particular challenge to connect those from social science and natural science backgrounds into a common approach, which sometimes required mini-workshops to clarify methods or theoretical orientations. This is typical of efforts to collaborate within interdisciplinary and participatory science groups (Star 2010; Chilvers and Kearns 2016).

Compounding this challenge were the unique demands of linking the "human dimensions" of fisheries (e.g., social (including cultural), economic, and institutional aspects) with each other and with the biological aspects throughout the process. While the aspects that form the human dimensions feature in international agreements, and even in Canadian policy, they have been relatively neglected in comparison with biological aspects of fisheries in the past (Stephenson et al. 2017). Fishery biologists and managers have a long history of working together and have had an opportunity to achieve consensus on many relevant aspects of the biological basis for management. The relevant literature for the human dimensions is less known among managers and by biological scientists and less prescriptive, and there generally is less agreement on performance indicators. Building these aspects had to start from the bottom up, and developing a consensus on these aspects of fisheries management required far more discussion relative to ecological aspects.

A second, related key methodological condition for success was the highly iterative nature of the engagement process. We deliberated on the concepts of sustainability, especially as reflected in Canadian legislation and policies and in relevant international agreements. We discussed the structure of frameworks that would be most useful to current and future management, and we undertook extensive research to propose, review, discuss, and validate the dimensions, goals, indicators, and attributes of a comprehensive framework. Specific issues that had to be worked out included discussion of inductive versus deductive approaches to the development of evaluation frameworks. The number and range of objectives or elements and indicators received considerable discussion in the early workshops. Issues of scale, potentially conflicting objectives, and the relative weight given to various objectives were areas of extensive iteration and discussion.

A third and perhaps unexpected methodological condition for success was the interaction between framework development and case study research. Students of this project collaborated with those of other projects in a "student indicator working group" (E. Angel, D. Edwards, S. Hawkshaw, C. Wor, and C. Parlee, unpublished data). With the framework development moving more slowly than expected, student research proceeded by integrating partial insights from the draft framework. Framework development benefited from the results emerging from case studies, with discussions drawing on concrete evidence from field experiences to inform priorities around objectives, criteria, and indicators. In this sense, early drafts of the evaluation framework impacted the design of research projects, and the early research results from the field affected discussions and later iterations of the framework.

The development of a comprehensive framework formed the core theme for a sequence of research activities and meetings that included evaluation of Canadian policy objectives, development of candidate objectives related to policies, development of performance indicators, and study of select aspects in case studies.

A framework for sustainability objectives related to Canadian policy

The project team reviewed Canadian fisheries policies (Table 1) and international agreements to compile a list of objectives or aspirations related to the four pillars of sustainability. We discussed the spectrum of aspects of sustainability and agreed on a working definition of a sustainable fishery:

> A sustainable fishery respects the ecological integrity of the ocean and its resources; is ethical, responsibly governed, economically viable and technologically appropriate; supports communities; draws on local culture, heritage, and diverse knowledge systems; and enhances health, well-being and the public good (Project meeting, April 2012)

We deliberated on these diverse aspects of sustainability in workshops to develop a list of elements for social, economic, and institutional or governance aspects that were analogous to the widely accepted ecological elements concerning productivity, biodiversity, and habitat. We sought to extend the framework for incorporation of ecological aspects of an ecosystem approach to management currently in use in fisheries in Canada (summarized

Table 1. Canadian policies and international commitments used to define the scope of objectives for the Canadian Fisheries Research Network framework.

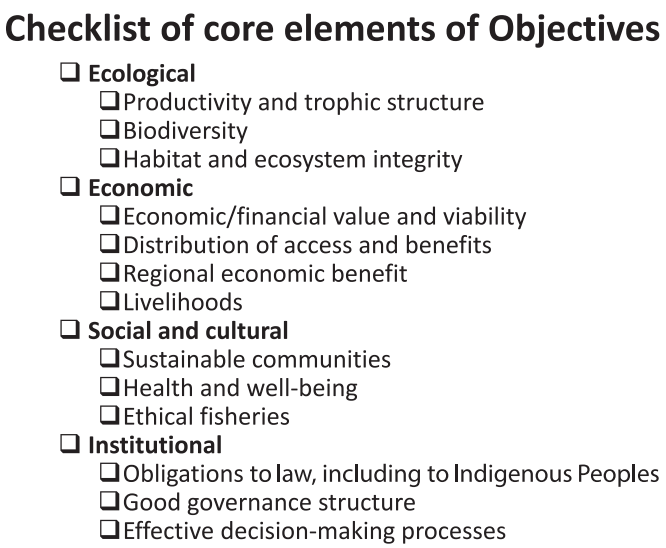
	Policy–agreement	Reference
Aichi	UN Decade on Biodiversity: Strategic Plan 2011–2020. Aichi Biodiversity Targets	Convention on Biological Diversity 2010
AFPR	Atlantic Fisheries Policy review: Framework for the Management of Fisheries on Canada's Atlantic Coast	DFO 2004
CLoS	Convention on the Law of the Sea	United Nations General Assembly 1995
Code	Canadian Code of Conduct for Responsible Fishing	DFO 1998
COS	Canada's Oceans Strategy	DFO 2002*a*
FAO Code	FAO Code of Conduct for Responsible Fisheries	FAO 1995
FAO Tech4:2	FAO Technical Guidelines for the ecosystem approach to fisheries	FAO 2003*a*
FAO Tech8	FAO Technical Guidelines for Indicators of sustainable development of marine fisheries	FAO 1999
IAPF	DFO Integrated Aboriginal Policy Framework	DFO 2006
MPA	National Framework for Canada's Network of Marine Protected Areas	DFO 2011
PIIFCAF	Policy for Preserving the Independence of the Inshore Fleet in Canada's Atlantic Fisheries	DFO 2007
POF	Policy and Operational Framework for Integrated Management of Estuarine, Coastal and Marine Environments in Canada	DFO 2002*b*
SDS	Canada's Sustainable Development Strategy	Canada 2018
SFF	DFO Sustainable Fisheries Framework	DFO 2016
Socio-Eco Frame	A framework for socio-economic analysis to inform integrated fisheries management planning and fish harvest decisions	DFO 2008
WPS	Policy for Conservation of Wild Pacific Salmon	DFO 2005

by Gavaris 2009) to include social, economic, and institutional aspects. While it is not the role of a research group to dictate objectives, we defined a spectrum of candidate objectives we suggest is relevant to Canadian fisheries management (Fig. 1). These candidate objectives, with associated policy statements, are presented in Table 2.

The project focused on developing a comprehensive framework that would link the candidate objectives with relevant performance indicators so as to be useful in management decision support. Several major iterations of the framework, which differed in emphasis, took place over the life of the project (refer to online Supplementary Material[2]). An initial "scoping framework" (Supplementary Material #1[2]) was developed early in the project from a scan of Canadian policies and international literature and deliberations of the project team. We sought to find social, economic, and institutional equivalents to the productivity, biodiversity, and habitat elements of the ecological domain. A second, "indicator framework" (Supplementary Material #2[2]) was a more academic treatment in which elements are linked explicitly to a thorough literature review related to performance indicators undertaken by the student working group. A third "policy framework" (Supplementary Material #3[2]) blended the elements of two previous versions around the practical needs of Canadian policy and decision-making. While there was some variation in the wording and specific structure of the framework during this evolution, the basic scope remained the same.

The resulting CFRN Comprehensive Fisheries Sustainability Framework (Table 2) includes a list of ecological, social, economic, and institutional aspects (elements for candidate objectives) that logically flowed from Canadian policy and the literature to be considered in Canadian fishery planning, management, and evaluation. It also lists candidate performance indicators that allow practical implementation. The framework's three ecological objectives of productivity and trophic structure, biodiversity, and habitat and ecosystem integrity are well recognized in Canadian fisheries management planning (e.g., Gavaris 2009) and are based on reasonable international consensus (e.g., Sinclair and Valdimarsson 2003). These objectives are well described in Canadian polices, including the Sustainable Fisheries Framework (DFO 2016*a*).

Fig. 1. Spectrum of core elements of objectives for a sustainable fishery as determined by the Canadian Fisheries Research Network.



We have proposed four economic elements. "Economic viability and prosperity" emphasizes the performance of individual or private operations. "Sustainable livelihoods" focuses on ongoing continuity of employment within the fishing sector. "Distribution of access and benefits" includes allocation, equitable trading relationships, equity and fairness in distribution of access and benefits, and intergenerational equity. "Regional economic benefits to community" reflects the role of fishing within regional economic development (employment, income, human capital, labour) as well as synergies with other sectors, such as tourism, through the

[2]Supplementary data are available with the article through the journal Web site at http://nrcresearchpress.com/doi/suppl/10.1139/cjfas-2017-0345.

Table 2. The Canadian Fisheries Research Network comprehensive fisheries sustainability framework, including reference to relevant policies and candidate performance indicators (abbreviations are explained in Table 1).

Objective topic	Examples of objectives from policy statements	Candidate performance indicators
ECOLOGICAL		
Productivity and trophic structure (productivity regimes)	• Ensure continued **health and productivity** of Canada's fisheries and healthy fish stocks (SFF) • **Long-term sustainability** (SFF; WPS); sustainable use of the biological resource in a way and at a rate that does not lead to their long-term decline, thereby **maintaining the potential** for future generations (WPS) • "**Maintenance of target, bycatch, and ecologically dependent species** and their **ecological relationships** within the bounds of natural fluctuations in abundance" (SFF) • "Minimization of the risk of changes to species' **abundances** or **relationships,** which are difficult or impossible to reverse" (SFF) • "Exploitation of any stock should take account of both the **productivity** of the stock and its **trophic role** in the ecosystem" (SFF) • "**Forage species** should be managed in ways that ensure local depletion of **population components** does not occur" (SFF) • "Principles of Precautionary Approach … management of forage fisheries … future **recruitment** of the target species is not impaired, and **food supply for predators** is not depleted" (SFF) • No tolerance for preventable decline rebuilding plan must be in place to promote **stock growth** (SFF)	• Productivity (e.g., yield potential, rate of generated biomass, rate of generated abundance) • Recruitment dynamics (e.g., compensation or depensation, changes in average recruitment) • Target fishing mortality • Escapement • Incidental–bycatch mortality • Gear modifications designed to reduce incidental mortality • State of species (e.g., population, stock, sex) • Changes to species' abundance • Index of abundance (e.g., catch per unit effort, stock assessment biomass) • Regime shift indicators (e.g., average trophic level, length of fish, changes in sea surface temperature, water acidification)
Biodiversity (within population, food web persistence, community-level, non-native species)	• "**Multispecies interactions** are important factors to consider in defining rebuilding objectives and management measures…" (SFF) • Provide long-term **protection of marine biodiversity**, **ecosystem function**, and **special natural features**… Protecting examples of all types of **biodiversity** (genetic, species, and ecosystem level) (MPA) • "Maintenance of **full reproductive potential** of the forage species, including **genetic diversity** and **geographic population structure**" (SFF; WPS; Aichi) • Reduce direct pressures on **biodiversity** and promote sustainable use (Aichi) • Promote responsible fishing that helps **reduce bycatch** and **mitigate impacts to habitat** anywhere it is biologically justified and cost-effective (SFF; Code)	• Species assemblage structure (e.g., species richness, Shannon diversity index) • Genetic diversity (e.g., genetic variation using microsatellites and mitochondrial DNA, genetic mixing, phenotypic sex ratio) • Phenotypic diversity (e.g., maturation at age, size at age, phenotypic sex ratio) • Metapopulation structure • Proportion of rare species subject to anthropogenic activities • Food web interactions (e.g., stability, probability of change) • Biogenic structures (proportion surveyed, degree of impact from anthropogenic activity) • Non-native species (e.g., abundance, degree of impact, probability of introduction)
Habitat and ecosystem integrity (physical and chemical, including substrate and ecosystem services)	• Healthy environment (SDS; COS) • Protect and conserve fisheries **habitat** (SFF; WPS; AFPR; MPA) • Maintain **habitat** and **ecosystem** integrity (WPS) • "…mitigate impacts of fishing on **sensitive benthic areas**…" (SFF) • "Conservation of fisheries resources and fish **habitat** … is a key priority of fisheries management decision making" (SFF; AFPR; POF; WPS; Code)	• Substrate characteristics • Proportion of gear modified to reduce impact on substrate species • Proportion of nursery, spawning, or sensitive areas • Pollution (e.g., proportion of anoxic zones, eutrophication risk, potential for catastrophic events) • Proportion of migration pathways and pelagic pathways • Probability of climate-change-induced regime shift • Presence–abundance of biogenic species • Introduction and proliferation of disease–pathogens

Table 2 (*continued*).

Objective topic	Examples of objectives from policy statements	Candidate performance indicators
ECONOMIC		
Economic viability and prosperity (sustainable wealth)	• **Economic prosperity** for commercial, Aboriginal, and recreational fish harvesters and **communities** with the common goal of a sustainable, **economically viable**, internationally competitive industry (SFF, SDS) • Fisheries will become a biologically sustainable resource supporting fisheries that are sustainable and **economically viable**, contributing to the economic base of coastal **communities** (AFPR) • Support sustainable **economic opportunities**, which requires the development of a scientific knowledge base of oceans resources and development impacts… Sustainable economic activities depend on the provision of a safe and secure operating marine environment (COS) • Maintain an independent and **economically viable** inshore fleet… (through the creation of circumstances for resource users to be more self-reliant, **economically viable**, and self-sustaining on a long-term basis) (PIIFCAF) • "Where resources allow, the inclusion of a **cost-benefit analysis** … valuable instrument in development and implementation of rebuilding plans" (SFF) • An **economically viable** and internationally competitive industry that is adaptable to changing markets… Pursuing this vision requires the integration of economic analysis into departmental decision-making, into the design and evaluation of policies and programs (Socio-Eco Frame; SFF)	• Human demographics (e.g., age, sex, education, income level) • Historical fishing levels (e.g., amount of time in industry, number of generations of fishing history) • Number of employees meeting certification standards (e.g., first aid, marine emergency duties, master's ticket) • Social mobility • Technological impacts (e.g., job losses, deskilling, loss of customary or traditional knowledge) • Realized catch relative to potential target harvest • Discard waste • Market price relative to private marginal cost of production • Output (e.g., cost relative to the lowest possible average total cost, output obtained from given quantity of inputs relative to the maximum output obtainable from that given quantity of inputs) • Number of fisheries that fishing enterprises participate in • Net profit of enterprises • Bankruptcy rates • Investment, stock–flow in fishery • Availability of capital–debt financing • Number of enterprises dependent on one fishery • Proportion of investment stock–flow in depreciating assets versus access by operator • Experience and education of fishermen • Availability of fishermen with the required education and certification • Distribution and means of compensation for fishermen • Amount of labour force represented by an industry organization • Presence or absence of oligopsony or monopsony • Percent control of each stage of the value chain by a single entity • Presence or absence of legislation to restrict market failure • Economic sustainability index
Sustainable livelihoods (employment, income, human capital, labour)	• Provide attractive **incomes** to industry participants (Socio-Eco Frame) • **Attract and retain skilled workers** (Socio-Eco Frame)	• Livelihood index (Sustainable Livelihood Security Index, Economic Security Index) • Unemployment rate • Employments gains versus losses • Evidence of subjective perception of the viability of livelihoods • Reallocation (e.g., reallocations of stakeholders without compensation, compensation relative to fair market value, proportion of realized allocation relative to potential allowed allocation, loss of income from reallocation of access rights) • Amount of harvest being contested by one or more stakeholders groups • Distribution of catch

Table 2 (*continued*).

Objective topic	Examples of objectives from policy statements	Candidate performance indicators
Distribution of access and benefits (distributed benefits (including equity and fairness and distribution of access and benefits), allocation, equitable trading relationships, intergenerational equity)	• Strengthen the application of the **Owner–Operator and Fleet Separation policies** (PIIFCAF) • Ensure that inshore fish harvesters remain independent and that the benefits of fishing licences flow to the fish harvester and the **coastal community** (PIIFCAF) • Assist fish harvesters to retain control of their fishing enterprises, **enhance access to capital** from traditional lending institutions, and **maintain the wealth** generated from fish harvesting in **coastal communitie**s (PIIFCAF) • Access and allocation of fisheries resources will be more stable and predictable, and decisions will be made and conflicts resolved through fair, transparent, and rules-based processes (AFPR) • Consider aquaculture to promote **diversification of income** and diet (FAO Code)	• Number of reallocations across stakeholder groups without compensation • Proportion of realized compensation relative to fair market value of reallocated workers across stakeholder groups • Proportion of realized allocation relative to potential allowed allocation • Loss of income from reallocation of access rights • Sum of seafood harvest being contested by one or more stakeholder groups
Regional economic benefits to community (through the creation of synergies through the integration of regional community resources, including fishing)	• Provide an economic driver for **communities** in coastal regions (Socio-Eco Frame) • "The fishery is common property resource to be managed for the benefit of all Canadians, consistent with…, including socio-economic benefits to **communities**" (SFF) • Ensure that the benefits of fishing licences flow to the fish harvester and the coastal **community** (PIIFCAF)	• Distribution of catch income by sector • Distribution of access by fisheries participants • Number of major changes to access conditions over time • Value of fisheries related public infrastructure (e.g., wharves, docks, piers, coast guard facilities) • Value of fisheries related fisheries-related private infrastructure (e.g., vessels, processing plants, service providers) • Natural capital (amount, rate of depletion)
SOCIAL		
Health and well-being (occupational safety, food security	• "States should ensure that … all fisheries activities allow for **safe, healthy, and fair working and living conditions**" (FAO Code) • Harvesting, handling, processing, and distribution should maintain the nutritional value, quality, **safety**, **and security of food** (FAO Code) • "Governance should ensure … **human … well-being and equity**" (FAO Tech4:2) • "…objective to consider under … fisheries sustainable development… Cater for the **well-being of a fishery workforce within a wider community** and broader economic context" (FAO Tech8) • Support sustainable economic opportunities, which requires the development of a scientific knowledge base of oceans resources and development impacts… Sustainable economic activities depend on the provision of a **safe and secure operating marine environment** (COS) • Management processes and decisions will honour obligations to First Nations and their treaties (WSP; AFPR; SFF)	• Social factors (e.g., suicide rate, infant mortality rate, unemployment rate, migration rate) • Proportion of population below the poverty line • Income disparity (e.g., Gini coefficient, ratio of highest wage to average wage) • Availability of affordable services (education housing, daycare, medical care) to population • Proportion of seafood caught within the community that is consumed by the local population • Sum of seafood caught by local population • Self-determination (subjective perception of self-efficacy, attachment to place, social mobility) • Food safety (e.g., number of seafood establishments regulated for food safety, number of recent inspections, number of establishments in compliance with regulations, reported cases of food-borne illness from seafood) • Occupational safety (e.g., number of deaths at-sea, number of injuries over time, ranking of job safety, proportion of fisheries work force subject to Canadian labour laws, proportion of fisheries workforce that meets certification standards)

Table 2 (*continued*).

Objective topic	Examples of objectives from policy statements	Candidate performance indicators
Sustainable communities (community well-being, social capital, informed citizenry, heritage)	• "The WSP … is intended to foster a more robust resource that supports sustainable fisheries and recognizes the **intrinsic value to society**" (WSP) • **Vibrant society** for current and future generations (SDS) • **Self-reliant fisheries** and collaboration among all orders of government will contribute to the **well-being of coastal communities**. To be more self-reliant, resource users will have more flexibility to make decisions about their own economic and social objectives (AFPR) • **Sustainable communities** is a priority (SDS) • One goal of national network of MPA is "to enhance **public awareness and appreciation** of Canada's marine environments and rich maritime history and culture" (MPA) • Ensure that inshore fish harvesters remain independent and that **the benefits of fishing licences flow to the fish harvester and the coastal community** (PIIFCAF)	• Social capital (e.g., subjective perception of shared values and norms within a local population, participation in social institutions within local population, social networks) • Informed citizenry (e.g., rating of importance of fisheries, preference valuation for the existence of fisheries dependent communities, willingness to pay for local seafood, readily accessible data, number of visits to fisheries websites, organization of seafood community events) • Vital civic culture (e.g., condition of social institutions, voter turnout in local elections, quality of local education) • Individual and collective well-being (e.g., evidence of subjective perception of well-being within local area, well-being indices within local population)
Ethical fisheries (equity, rights)	• Improve **human well-being and equity** (FAO Tech4:2) • "Objectives of the code are to provide **standard of conduct for all persons** involved in the fisheries sector" (FAO Code) • **Allocate user rights** (FAO Tech4:2) • Recognize important contributions and protect **rights of artisanal and small-scale fisheries** (FAO Code; CLoS) • "Ethical" issues in fisheries include the basic human interests in welfare, freedom, and justice (FAO 2005) and include aspects ranging from ecosystem well-being and conservation through well-being and just access to equity, social efficiency, right to food, and food safety (FAO 2005)	• Specific attention to well-being and equity, including allocations and access • Adherence to standards of conduct in code of conduct and management plans • Occupational safety (e.g., number of deaths at sea, number of injuries over time, ranking of job safety, proportion of fisheries workforce subject to Canadian labour laws, proportion of fisheries workforce that meets certification standards) • Individual and collective well-being (e.g., evidence of subjective perception of well-being within local area, well-being indices within local population)
INSTITUTIONAL		
Legal obligations, including to Indigenous Peoples	• "Management processes and decisions will honour **obligations to First Nations and their treaties**" (WPS; AFPR, SFF)	• Explicit reference to and adherence to First Nations obligations • Record of accountability with respect to laws and policies
Good governance structure (collaboration, shared stewardship, participation, roles and responsibilities of participants, policies, agreements)	• "involving fishing **participants** as partners and involving others through engagement facilitates **co-management** interactions and **shared stewardship**" (SFF) • "**Shared stewardship** is an important part of managing Canada's fisheries … promote **collaboration, participatory decision-making and shared responsibility** with resource users" (SFF; AFPR) • **Self-reliant** fisheries and **collaboration** among all orders of government and other stakeholders (AFPR; SFF) • "Objectives of COS is international leadership … influencing international priorities, **decisions, and process**" (COS) • "Commitment of COS is to **work collaboratively** within the federal government and among levels of government" (COS) • "Commitment of COS is to share responsibility for achieving **common objectives**" (COS)	• Rules (e.g., commercial activities covered by institutional processes, evidence of support for institutional processes, evidence of consistency among institutional processes, local population norms and values, evidence of consistency in institutional processes between stakeholder groups) • Resources (e.g., level and duration of support for management activities among stakeholder groups, types of conflict resolution processes available to deal with disputes) • Agreement (e.g., agreements involving stakeholder groups and local population, agreements supported by institutional processes or legislation, evidence of distribution of authority in agreements)

Table 2 (*continued*).

Objective topic	Examples of objectives from policy statements	Candidate performance indicators
	• "Fish **harvesters will address problems of fisheries in Canada**, adopting specific mechanisms and regulations as required" (Code) • "Producing a workable **decision framework** for a fishery will require the **participation** of fishery interests **in all aspects of the process** to develop the framework." (SFF) • Objective of "**improved governance** by increasing sustainability, transparency, and accountability in fisheries management and by promoting shared stewardship" (SFF; AFPR) • **Manage** fisheries for sustainable benefits (responsibility to provide sustainable harvesting opportunities that will best meet its obligations to First Nations, contribute to social well-being, and provide employment and other economic benefits to individuals and fisheries-dependent communities) (WPS) • "The fishing industry must be **responsible** for sharing costs of, and **participating** in, monitoring of ecosystem properties used in **management** of fisheries on forage species." (SFF) • "Fish harvesters will develop, maintain, and **promote public awareness** and understanding of the issues surrounding **responsible fishing** and the measures taken by fishers to conserve stocks and protect the environment." (Code) • "Fish harvesters will **conduct harvesting operations** in accordance with Canadian **fisheries' laws and regulations; international laws, regulations**, conventions, declarations and protocols adopted by Canada; and harvesting plans adopted by each fishery" (Code)	
Effective decision-making processes (democratic, participatory, transparent, openly communicated, integrated, structured decision-making, collaborative, cooperative, responsible and effective management, compliance, accountability, adaptive management)	• "Governments, Aboriginal groups, coastal communities, industries, and other persons and bodies affected by or affecting marine resources have **a duty and shared responsibility for supporting the sustainable development of marine resources**" (POF; Code) • **"Integrated management** is an essential aspect of ensuring commercial and non-commercial interests are considered in the planning and managing of ocean activities, such as fishing." (SFF; COS) • **Ecosystem approach** is fundamental to the conservation and sustainable use of Canada's fisheries (SFF) • Ecosystem sustainability and function is of primary importance. The identification of **ecosystem-based management** objectives and reference levels will guide the development and implementation of management to achieve sustainable development (POF) • "The **precautionary approach** is a fundamental component of an effective risk management strategy." (SFF; POF; COS) • **Flexible management**: The implementation and monitoring efforts of many different authorities, organizations, and interests are brought together and focussed on a jointly defined set of issues and objectives (POF)	• Existence of management plan (e.g., IFMP; marine use plan) with specified decision-making process • Documentation of changes (improvements) to plan in relation to effective decision-making • Evidence of stakeholder group collaboration in processes of decision-making • Evidence of accountability (documented roles and responsibilities, explicit consequences for nonperformance of duties, binding commitments to third party standards) as part of general management activities • Evidence of accountability legislation–regulation and institutions and fisheries management activities • Degree to which assessment exists (performance-based audit, program evaluation, fishery management plan evaluation) • Evidence of process for addressing trade-offs and degree to which processes are implemented • Attention to mechanism for power sharing and dispute resolution • Attention to inclusivity and appropriate representation in composition of planning team • Processes to ensure that participants are informed and that processes are transparent • Stakeholder perception of collaboration, cooperation, inclusivity, flexibility, and transparency

Table 2 (*concluded*).

Objective topic	Examples of objectives from policy statements	Candidate performance indicators
	• **Self-reliant fisheries** and **collaboration** among all orders of government will contribute to the **well-being of coastal communities**. To be more self-reliant, resource users will have more flexibility to make **decisions** about their own economic and social objectives. (AFPR) • The principles of sustainable development maintain that social, economic, and environmental issues are interconnected and must be integrated into the **decision-making process**. (SDS; WPS; COS; POF; SFF) • Open and transparent **decision-making** and governed by clear and consistent **rules and procedures** (WPS; SDS) • Make environmental **decision-making** more **transparent** and ensure that the government's environmental goals are taken into account when pursuing social and economic goals (SDS) • **Decisions** on protection and sustainable use will be based on meaningful public input to ensure they **reflect society's values** (WPS) • Participants will be effectively involved in fisheries management **decision-making processes** at appropriate levels; they will contribute specialized knowledge and experience and share in accountability for outcomes (AFPR; SFF; COS; POF; Code; Aichi) • "Whenever appropriate, **management decisions** and actions will take into account **socio-economic factors** as well as biological." (SFF; WSP) • "**Managing decisions** should take into consideration Aboriginal traditional knowledge and other local and **traditional knowledge**." (SFF) • Fish harvesters will work to balance the level of fishing effort with the sustainable supply of fisheries' resources to ensure **responsible management** and responsible professional harvesting (Code; SFF) • "MSE … provides users with the information to evaluate trade-offs among performance measures arising from conflicting objectives." (SFF) • Reflect the best science as well as traditional knowledge (WPS)	

integration of regional community resources. These objectives are best articulated in the 2007 Policy for Preserving the Independence of the Inshore Fleet in Canada's Atlantic Fisheries (DFO 2007) and the 2004 Policy Framework for the Management of Fisheries on Canada's Atlantic Coast (DFO 2004).

We suggest three social and cultural objectives. "Health and well-being" includes working conditions, occupational safety, and general health within a wider community and broad economic context. "Sustainable communities" emphasizes the importance of the contribution of fishing to the well-being of dependent communities, social capital, informed citizenry, and heritage. "Ethical" issues in fisheries include basic human interests in welfare, freedom, and justice. While less well-articulated, these objectives appear in aspirational terms in several policies, including the Sustainable Development Strategy (Canada 2018), and are certainly prominent in international agreements such as the Guidelines for Responsible Fisheries (FAO 1999).

Institutional elements include legal obligations, good governance structures, and effective decision-making processes. "Legal obligations, including to indigenous peoples" recognizes the close and traditional dependence of many indigenous and local communities on fishing (DFO 2006) and is prevalent in current management planning (e.g., DFO 2016*a*). "Good governance structure", including growing interest in collaboration, shared stewardship, and participation in management, and "effective decision-making processes" reflect the need for democratic, participatory, transparent, openly communicated, integrated, and structured decision-making. These are prevalent aspirations in policy documents, including the Sustainable Fisheries Framework (DFO 2016*a*). For each candidate objective, we have identified a suite of candidate or potential indicators from the literature. A more detailed version of the table, with a complete set of candidate indicators, is presented in Supplementary Material #2[2]. Such a framework enables more structured and comprehensive inclusion of ecological,

social, economic, and institutional aspects of management in integrated decision-making (see also Stephenson et al. 2018).

Further evaluation and application of the framework in Canadian situations

This project investigated some elements and candidate objectives from policy in more detail in applied case studies. In this way, the project attempted to link aspirational and bottom-up considerations to objectives. Case studies (undertaken between 2011 and 2016) were not exhaustive but covered some areas identified by industry participants and other participants as important to the fisheries and relatively neglected in the applied literature relating to Canadian fisheries — especially in relation to distribution of benefits, well-being, institutional considerations, and practical framework implementation.

Case studies on distribution of benefits

D. Mombourquette and A. Charles (Saint Mary's University, Halifax, N.S., unpublished data) evaluated cumulative changes in distribution of fishing benefits from local fisheries in relation to the island community of Grand Manan, New Brunswick, resulting from changes within individual fisheries. The study found that groundfish and herring (*Clupea harengus*) licenses have been sold or transferred away from the island, with the result that the community has not only lost overall benefits from fishing but is now reliant almost completely on a single fishery (American lobster, *Homarus americanus*). This demonstrates an unintended, or at least untracked, negative consequence of economic redistribution resulting from (*i*) deliberate management actions such as the introduction of individual transferrable quotas (ITQs) within single fisheries and (*ii*) inadequate consideration of community-level objectives. Further, within the current lobster fishery, the next generation of fishers is facing increasing barriers to entry. Notably, higher ownership costs are reducing profit margins (compared with the past), which are forcing many to seek equity financing or enter controlling agreements with processors. These dynamics have weakened fleet independence and shifted power in the fishery. Conflicts continue between the interests of independent operators and vertically integrated firms in this part of the Bay of Fundy. This case study illustrates the consequences of individual decisions (in this case regarding sale of ITQs) on the overall distribution of benefits, with unintended negative consequences regarding overall community well-being, when these objectives are not specified and not monitored.

Squires (2016) studied, through extensive interviews with fishery participants (2014–2015), how benefits from the Eastern Nova Scotia snow crab (*Chionoecetes opilio*) fishery quotas, which were distributed to fish harvesters in 2005, have affected the recipients and what has happened to those allocations in the intervening years. The study documents the great value that has been derived from this expanded fishery and, most importantly, recent trends that seem destined to incrementally narrow and reduce the community base of those benefits. The study documents conflict between established and aspiring fishery rights holders as well as trade-offs between narrow and wider community fishery benefits. Should current trends continue, community benefits will fade as individual harvesters transfer their rights to a diminishing number of resource owners. Some concentration of benefits over time had been anticipated by fishermen, but this case study demonstrates the extent to which policy choices around managing the distribution of benefits have had an influence on fish harvesters' operational and investment behaviors. This finding, along with the documentation of diminishing community benefits, reinforces the need for fishery policy development to take a broader view of sustainability over time so that it addresses community sustainability. As indicated by the Grand Manan case study, explicit attention to the distribution of benefits and contributions to community well-being, as proposed in the CFRN framework, would allow explicit management of these aspects.

Barnett (2017) surveyed lobster fishermen in Port La Tour, Cape Sable Island, and Woods Harbour, Nova Scotia, to examine the factors that contribute to livelihood vulnerability. The results indicated that dependency on lobster has increased substantially, along with inequality and a decrease in quota ownership in other fisheries. Captains and crews who were more dependent on lobster had lower incomes and were less able to maintain their income during the downturn in lobster prices. Further, evidence from this study indicates that the licensing system, which has increased entry costs and contains loopholes that allow controlling agreements by companies, may threaten incomes. Fishermen in the area did not see a future for themselves and their children in the fishery at the time of this study. This was true both for those who had quota in other fisheries and for those who did not. While it was hypothesized that quota ownership would have a major impact on a captain's ability to maintain his or her income during economic downturns, it was surprising to find those who still had quota were equally uncertain about their future in the fishery. This study raises questions of how long-term economic viability and sustainability of fishing livelihoods are being tracked in this fishery, which is currently integral to Maritime coastal communities.

Haas et al. (2016) studied the change in distribution of economic benefits associated with license concentration in Pacific salmon and herring (*Clupea pallasii*) fisheries in British Columbia. This case study revealed that (*i*) the profile of fisheries license ownership has shifted over the past 20 years, from larger percentages of licenses held by "owner–operators" at the beginning of the time series to greater percentages of licenses held by "fish processors" at the end of the time series and (*ii*) the distribution of fisheries licenses has become more inequitable over the time period under examination (i.e., there was a greater concentration of licenses held by fewer and fewer entities — namely fish processors, including one in particular). This case study also identified that evaluations of equitable distribution of fisheries access is an element not present in current fisheries assessments. It was hypothesized that the degree of concentration of fisheries licenses would have risen over the time period under examination; however, markedly fewer entities than anticipated were responsible for that concentration.

Foley et al. (Foley et al. 2013, 2015; Foley and Mather 2016) used key informant interviews in their comparative study of the impact of fisheries allocation policy on regional development in the northern shrimp (*Pandalus borealis*) fishery in three regions of Newfoundland and Labrador from the late 1970s to 2012. Key aspects of the study included attention to economic elements of policy impact (sustainable livelihoods, distribution of access and benefits, and regional economic benefits to community) and social elements (sustainable communities and ethical fisheries). The study determined that federal allocation policies guided by ethically informed principles of adjacency, community, and regional economic development goals since the 1970s resulted in the creation of innovative community-based organizations in southeast Labrador (Labrador Fisherman's Union Shrimp Company Ltd.) and in Newfoundland's Northern Peninsula (St. Anthony Basin Resources Inc.) and strengthened a third organization on Fogo Island (the Fogo Island Co-operative Society Ltd.). These organizations used wealth derived from relatively small allocations of shrimp to help sustain local inshore and nearshore owner–operator fisheries, as well as creating or sustaining employment for processing workers during a period of dramatic social–ecological restructuring triggered by the collapse of regional groundfish stocks in the early 1990s. Investment of royalty revenues in this way helped sustain the tax base for regional communities and, to varying degrees, contributed to broader regional economic diversification and development outcomes. Outcomes of allocation policies in these

cases measure well against the objectives of social sustainability contained in the CFRN framework and increasingly articulated as aspirations by fisheries management agencies around the world. As expected, allocations to inshore harvesters since the late 1990s have been a crucial factor advancing regional economic development for each organization specifically and in each region more generally. The results of this study suggest that allocation policies in offshore fisheries can be designed to benefit inshore owner–operators, shore-based processing plants, and communities through allocations to organizations with a mandate to benefit inshore fisheries and communities. In the cases examined, the community-based organizations generated royalties that help support inshore fisheries and community development. Separate allocations to inshore owner–operator harvesters since the late 1990s have also been a crucial factor advancing regional economic development for each organization specifically and in each region more generally.

Case studies on well-being

Angel (2017) studied integrated assessment of sustainability for the Skeena River salmon fishery with an emphasis on the well-being of dependent communities. From the findings of this study, it was apparent that the existing fisheries management system is compelled to restrict severely the type and quantity of value extracted from the fishery resource to maintain a limited degree of control over human impacts on the natural system. It is hypothesized that this is the case because of two exogenous factors: (*i*) attenuation of value chains under globalized trade systems and increasing environmental uncertainty and (*ii*) internal limitations, principally a structural inability to experiment productively with power-sharing arrangements. As hypothesized, this case study documented a high degree of conflict among participants in the fishery. Likewise, there was a broadly similar perception across stakeholder groups of the management system as ineffective and lacking in legitimacy. Indicators of the well-being of commercial fishermen and fishing communities showed this had declined substantially in the previous 20 years, which is in keeping with broader trends in salmon fisheries in British Columbia. Unexpectedly, the study found that salmon populations are healthier than the public perception of crisis in salmon fisheries would suggest. While chum salmon (*Oncorhynchus keta*) populations were a concern in some areas, coho (*Oncorhynchus kisutch*) stocks appeared to have recovered from the low abundances seen in the 1990s, and the status of the majority of sockeye (*Oncorhynchus nerka*) conservation units was acceptable. Furthermore, commercial fishing has declined to such a degree that there would not seem to be any demonstrable impact on the status of sockeye populations from harvesting.

The findings led the author to suggest moving from management, which is a technocratic system of control focused on producing results, to governance, conceived as a way of making choices about enhancing human well-being that are more broadly legitimate. Second, it was argued that governance regimes should be built around natural systems and their dynamics, in this case watersheds and ocean basins, rather than unnatural boundaries that are administratively convenient. Finally, findings from this study were used to argue that given the complexity of social–ecological interactions in the contemporary world, the only long-term solution that is sufficiently robust is one that involves shared decision-making with all stakeholders across the entire suite of fisheries management functions. Additional studies of the importance of coastal community well-being in the evaluation of fisheries policies (Pinkerton 2009, 2013, 2015; Pinkerton and John 2008; Pinkerton et al. 2014) have examined new knowledge and analysis of moral economy, strategies for rebuilding fisheries management institutions, and policy control, as well as involving people in the management of natural resources. These studies demonstrate the importance and scope of the relatively understudied elements of well-being and of governance in the CFRN framework.

Case studies on institutional considerations

Parlee (2016) and Parlee and Wiber (2014) studied institutional elements of management including co-operation, institutional resourcing, transparency, accountability, and inclusiveness of the Southwest New Brunswick Bay of Fundy Marine Advisory Committee (MAC). Comparing and contrasting the MAC's Community Values Criteria (CVC) and the CFRN fisheries evaluation framework exposed interesting similarities and differences. Noticeably absent from the CVC are institutional values. These were intentionally left out to "avoid the biases of politics". However, the researchers found that it was obvious that without explicit institutional values, trade-offs were made in favor of short-term efficiency and economics rather than addressing institutional requirements essential for longer-term effectiveness such as conflict resolution, transparency, and accountability.

A case study of decision-making processes related to a change in start time in a lobster fishery (Barnett et al. 2016) in southwest Nova Scotia Lobster Fishing Area 34 documented problems around decision-making in response to market or ecosystem change. This research documented problems with the operation of species management boards, lack of transparency in decision-making, and related issues around participatory governance.

Fraser et al. (S. Fraser, E. Angel, and M. Saunders, unpublished data) examined DFO's experience with five participatory resource management processes. DFO is moving towards more broad-based collaborative processes for its decision-making on policy and program development. The general intent is to give stakeholders and others with an interest in fisheries and oceans resources a more direct say in decisions that affect them and to provide for broader consideration of social and economic factors in decision-making. The overall objective is to improve decision-making by making it more relevant to the affected interests, more easily understood, and better accepted. The way in which more collaborative management is being pursued within DFO varies a lot in terms of geographic scale, overall mandates for the processes, the extent of participation, and the procedures being used to facilitate dialogue and ultimate decision-making. Findings from this case study indicate that fully collaborative or empowering processes are inevitably time-consuming and resource-intensive.

These case studies provide support for the inclusion in the CFRN framework of specific attention to "good governance structure" (including collaboration, shared stewardship, participation, roles and responsibilities of participants, policies, agreements) and "effective decision-making process" (democratic, participatory, transparent, openly communicated, integrated, structured decision-making, collaborative, cooperative, responsible and effective management, compliance, accountability, adaptive management). We suggest there has been insufficient attention to the institutional or governance aspects of fisheries management. Use of the CFRN framework provides an opportunity for explicit attention to aspects that will enable improved attention to other objectives.

Framework implementation

The project also considered aspects of framework implementation. An analysis of IFMPs (S.D. Paul and R.L. Stephenson, DFO, unpublished data) included a gap analysis of the objectives and information in current Canadian IFMPs in relation to the CFRN framework for comprehensive evaluation of fisheries. That study documented the great imbalance that currently exists in both objectives and information from ecological aspects (well considered) to social, economic, and institutional considerations (poorly considered). It demonstrated the need for increased attention to social and economic objectives, information, and analysis in fisheries management planning. The framework of objectives pro-

vided in this paper, linked to policy statements and candidate performance indicators, should be useful in fleshing out how IFMPs could include the four pillars of sustainability anticipated in the IFMP planning document (DFO 2010).

Long et al. (2015, 2017) undertook a synthesis of key principles of ecosystem-based management from the literature and identified differences between fishing industry priorities (from interviews with fish harvesters) and literature priorities, which was used to inform the scope of the framework. That study produced a refined definition of ecosystem-based management and emphasized the need to resolve apparent differences in industry versus literature priorities for effective implementation of ecosystem-based management. The scope of the framework presented in this paper is similar to the spectrum of elements of ecosystem-based management identified by Long et al. (2015) and indicates that this framework may be used to move towards ecosystem-based management in fisheries management planning.

C. Mussells (unpublished CFRN Working paper) compared the elements of the CFRN framework with those of Marine, Aquaculture and Forest Stewardship Council certification schemes. The Marine Stewardship Council does not have specific criteria for social and economic aspects of fisheries, and the scope of the CFRN framework is much more closely aligned with that of the Forest Stewardship Council.

Benson and Stephenson (2018) compared analytical options for integrating ecological, social, and economic aspects in evaluation and management of fisheries. That synthesis addressed the need to identify practical tools and methodologies that can facilitate implementation of the CFRN framework in fisheries management. The initial goal was to develop an inventory of methods that have been proposed to be able to incorporate ecological, social, and economic aspects and to provide a more comprehensive evaluation of fisheries and of management. However, over the course of the research, analysis was broadened to develop a structure for understanding the nature of the trade-offs inherent in holistic management and showed that the information required differs in scale (fishery, ecosystem, society), timeline, use (tactical, strategic, research), and the nature of advice (prescriptive, descriptive, insight) potentially provided to decision makers. This study additionally developed a set of criteria for evaluating methods in terms of the relevance and influence of advice in the policy area. Evaluation provides insight into why some apparently practical approaches (e.g., ecosystem models) are not used in fishery decision-making in many situations. The synthesis showed that the diversity of information required cannot be provided by any single method or approach and that it is important to select methods according to their intended use.

Discussion

Defining and implementing a comprehensive suite of sustainability objectives

Ecosystem-based and integrated management, which have been identified as key for sustainably managing fisheries and other marine activities (Charles 2014; Charles et al. 2014), require a broader set of objectives than have been explicit in management to date. They require consideration of the four (ecological, social (including cultural), economic, and institutional) pillars of sustainability. We have identified the spectrum of considerations needed for a comprehensive approach to integrated fisheries management representing all four pillars of sustainability in a Canadian context. We recognize that the pillars are not entirely discreet, but have produced a logical and useful list that covers the spectrum of objectives with potential performance indicators required of an ecosystem-based approach (see for example Long et al. 2015; Stephenson et al. 2017).

Our summary of Canadian fisheries policy (Table 2) demonstrates that there is an adequate policy basis for all four pillars of sustainability in evaluations and management. However, our study also shows that current assessments and management focus on only a subset (of primarily biological aspects) of policy. There are several factors contributing to the lack of integration of the four pillars in Canada. There is a definite bias towards ecological considerations in the structure and function of DFO. The structure of DFO separates science from economic–policy and fisheries management aspects and is an impediment to integration (Lane and Stephenson 1998). The Canadian Science Advisory Secretariat (DFO 2017), which has a respected process of peer review, considers and provides advice only on ecological aspects. DFO science is staffed almost completely by those with biological backgrounds, and there is a dearth of in-house capacity for social and economic aspects. Previous attempts to bring social science capacity together to be useful to DFO, notably in the Oceans Management Research Network, have had limited success (OMRN Network Secretariat 2009). This narrow focus has been criticized by the Commissioner for Sustainable Development (OAG 2011), and the lack of specific attention to social and economic aspects has been at the root of recent legal challenges related to access and distribution of benefits (for example Elson vs Canada (Attorney General) 2017 FC 459–2017–05–05). The lack of integration is also the case in other countries, including USA (see for example Sharp and Lach 2003; Abbot-Jamieson and Clay 2010), Australia and Europe (Begg et al 2015).

This work was designed to be used to help guide incremental improvement of existing integrated fisheries management plans and processes. We approached this by asking how little we need to change existing management planning to make improvements. The result is a framework that may be used as a basis for the development of more comprehensive management plan objectives, as a basis for comparison of management scenarios, and as a comprehensive "report card" for fisheries management (these aspects are elaborated in Stephenson et al. 2018). These should help overcome the current inconsistent treatment of objectives (emphasis on biological productivity, absence of evaluation of distribution of benefits, etc.) and should fulfill the aspirations of IFMP planning (DFO 2010). The framework presented here with policy links and performance indicators (Table 2) should assist in fulfilling the aspirations of IFMPs and the recommendations of the 2011 Report of the Commissioner of the Environment and Sustainable Development (Office of the Auditor General 2011) to include ecological, social, and economic aspects in fisheries evaluation and management.

Requirements for new information and modified processes

The framework presented in this paper will allow comprehensive evaluation and can form the basis for a more comprehensive approach to include the four pillars of sustainability required of a social–ecological systems approach, but it will require new and different information, as well as some modification to processes for analysis, review, and use of that information within fisheries evaluation and management. There will be an ongoing need for attention to data availability, institutional structure, and methodological requirements in support of the following steps in fisheries' plans:

1. articulation of specific objectives of relevance to the management plan
2. agreement–choice of specific performance indicators
3. identification of best sources of information relevant to the achievement of each objective
4. choice–development of appropriate methods to acquire information
5. choice–development of appropriate method(s) for evaluating information
6. modified institutional processes to enable discussion of the diverse aspects and use of the information in decision-making

The case studies completed as part of this project demonstrated lack of attention to the full suite of relevant objectives, including the distribution of access to fisheries benefits within and between groups and communities and its impacts on well-being. In the absence of specific objectives, such social and economic aspects of management are not being tracked and are therefore not informing fisheries management initiatives. There is a need for modification to governance processes to enable articulation of the relevant suite of objectives in management plans. There will be difference of opinion about the priority of objectives. We have presented our framework as "candidate" objectives, recognizing the need for governance processes in which objectives may be debated and specified for a particular situation. All of the candidate objectives are tractable. In a companion paper, we have articulated the need for scenario comparisons that will demonstrate trade-offs among objectives (Stephenson et al. 2018).

At present, only some of the information related to the social (including cultural), economic, and institutional aspects of sustainability is available for management. There is a requirement for further development of the data streams that will support evaluation of diverse objectives and for integration of the resulting data into fishery evaluation and management planning processes. We contend that development of a process in which objectives may be better defined, and the addition of specific objectives into management plans, will result in rapid development of relevant data streams. Much of this information will come from research carried out with the commercial fishery participants (e.g., Chouinard et al 2015; Stephenson et al 2016), but there will be additional information required from First Nations participants, environmental nongovernmental organizations (ENGOs), provincial government representatives, and others.

Analysis of the diverse information represented by the four pillars of sustainability poses an additional challenge. At present Canada (like many other nations) has a well-established process for acquisition, evaluation, peer review, and advice that is restricted to ecological aspects and no analogous process for economic, social, or institutional aspects. Furthermore, and of particular concern in Canada, is the lack of social science capacity in advisory or management processes. While Canada has a long history of academic social science research related to fisheries, that expertise remains divorced from management. There is a need to either expand the scope of consideration of the Canadian Science Advisory Secretariat (which coordinates the peer review of information for assessment and management; DFO 2017) or develop another process for analysis, evaluation, and review of social, economic, and institutional considerations. One key to effective integration is the recognition of both a routine (perhaps annual) operational cycle of evaluation that may deal with some aspects (such as stock productivity) and a less frequent strategic cycle that would consider major changes in strategic direction with respect to other (perhaps social, cultural, and economic) aspects (as discussed by Benson and Stephenson 2018; Stephenson et al. 2017).

There is currently a capacity shortfall with respect to information acquisition, analysis, and use for most fisheries. This will be an ongoing challenge. It will require strategic consideration of information need (e.g., what information would be of most use in relation to objectives) and ongoing collaboration (industry, government, and others) in gathering and analyzing relevant information. For example, Stephenson et al. (2016) synthesized international experience in integrating fishers' knowledge in science and management. Fishery participants are able to provide unique knowledge, which should form an essential part of "best available information" for fisheries science and management. Fishers' knowledge includes, but is much greater than, basic biological fishery information. It includes ecological, social, economic, and institutional knowledge, as well as experience and critical analysis of experiential knowledge, which is part of the new and different information required in evolving "ecosystem-based" and "integrated" management approaches. While fishers' knowledge may be added to traditional assessment with appropriate analysis and explicit recognition of the intended use of the information, it is best implemented in a participatory process designed to receive and use it (see also Curtis Maillet et al. 2017). Co-generation of knowledge in appropriately designed processes facilitates development and use of fishers' knowledge and facilitates the participation of fishers in assessment and management and is suggested as best practice in improved fisheries governance.

Process of interdisciplinary–transdisciplinary collaboration

This project had several novel aspects. (*i*) It was novel in scope. There has been no research program in Canada (and few if any in the world) attempting to define practical requirements of conservation as well as social, economic, and institutional aspects of fisheries. This paper demonstrates that it is possible to identify specific objectives for each of the four pillars of sustainability and put forward a framework that could be used in developing an improved governance process. (*ii*) It was practical. Much of the research, especially on social science aspects of fisheries, has been descriptive, analytical, and theoretical, but not linked directly to efforts to improve current decision-making. This project put an interdisciplinary team together with industry and government (researchers and managers) in a way that would result in recommendations that would be of use in management. Such practical research on the more extensive suite of aspects is necessary to inform a broader view of sustainability as required, for example, in gaining social acceptance and sustainability certifications–verifications that are critical for market access. (*iii*) The combination of framework development and case studies (top-down + bottom-up or pincer approach) is unique in that it allows conceptual development and practical testing.

This project required collaboration on knowledge requirements for ecosystem-based management. In addition to linking to industry, academics, and government (as in all projects of the Network), this project linked researchers from diverse fields with different literatures, research traditions, and approaches. We recognized that the Project and Network would be stronger if we put effort into understanding these differences so that we could collaborate more effectively. As anticipated in literature (e.g., by Star 2010 in relation to "boundary objects"), it took considerable effort (and time) to ensure our own commonality, flexibility, and shared structure in this work. This slowed initial project start-up — but once underway, the collaboration was productive. The project enhanced collaboration among industry, academics, and government in development of understanding and appreciation of the complexity of interdisciplinary research and of needs of management. We were able to generate knowledge of the scope of ecological, social, economic, and institutional requirements for emerging ecosystem-based and integrated management approaches. As our collaboration involved co-construction of the research and co-production of knowledge (e.g., Jasanoff 2004) across actors and disciplines, it was, in fact, transdisciplinary (e.g., Paterson et al. 2010). This is a feature of "postnormal science" and of the move from interdisciplinary to transdisciplinary collaboration (e.g., Funtowicz and Ravetz 1993). We recognize the importance of this approach as the basis for future participatory management (Novy et al 2013). While the project formally concluded in 2016, new interactions and collaborative research projects among various participants have been developed, and we expect the CFRN Project 1.1 initiative to have long-term impact and legacy. This research marks a substantial step in ongoing attempts to integrate social science in fisheries in Canada (building on projects such as Coasts under Stress (Ommer 2007), the Coastal Community – University Research Alliance (Coastal CURA; e.g., Wiber et al 2008), and the Community–University Research for Recovery Alli-

ance (CURRA; Neis et al. 2014). It is our hope that the research presented here is useful in meeting Canada's ambition (stated in the Oceans Act, IFMP guidance documents, and elsewhere) for full spectrum sustainability.

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Appendix A

Appendix Table A1 appears on the following page.

Table A1. Participants in Canadian Fisheries Research Network (CFRN) Project 1.1 framework development.

First name	Surname	Position	Affiliation
Marc	Allain	Facilitator	CFRN
Sharmane	Allen	Policy analyst, Ph.D. student	Fisheries and Oceans Canada, Memorial University of Newfoundland
Eric	Angel	Ph.D. student	Simon Fraser University
Allain	Barnett	Postdoctoral student	University of New Brunswick
Ashleen	Benson	Research associate	University of New Brunswick–Simon Fraser University
Barb	Best	Manager	Fisheries and Oceans Canada
Christian	Brun	Industry representative	Maritime Fishermen's Union
Erin	Carruthers	Industry representative	Fish, Food and Allied Workers Union
Anthony	Charles	Professor	Saint Mary's University
Omer	Chouinard	Professor	Université de Moncton
Ratana	Chuenpagdee	Professor	Memorial University of Newfoundland
Marc	Clemens	Manager	Fisheries and Oceans Canada
Allan	Debertin	Ph.D. student	Guelph University
David	Decker	Industry representative	Fish, Food, and Allied Workers Union
Dan	Edwards	Industry representative	United Fisheries and Allied Workers Union–UNIFOR
Danielle	Edwards	Ph.D. student	The University of British Columbia
Paul	Foley	Postdoctoral student, assistant professor	Memorial University of Newfoundland
Aaron	Greenberg	Ph.D. student	The University of British Columbia
Andrea	Haas	Masters student	The University of British Columbia
Mike	Hawkshaw	Ph.D. student	The University of British Columbia
Sarah	Hawkshaw	Ph.D. student	The University of British Columbia
Jennifer	Herne	Network office	CFRN
Lindsay	Jennings	Postdoctoral associate	University of New Brunswick
Owen	Jones	Research assistant	University of New Brunswick
Dan	Lane	Professor	University of Ottawa
Rachel	Long	Masters student	Saint Mary's University
Murdoch	McAllister	Professor	The University of British Columbia
Jim	McIsaac	Industry representative	T. Buck Suzuki Foundation
Robin	Messenger	Masters student	University of New Brunswick
Dan	Mombourquette	Masters student	Saint Mary's University
Claire	Mussells	Research assistant	University of New Brunswick
Barb	Neis	Professor	Memorial University of Newfoundland
Bethany	Nordstrom	Research assistant	University of New Brunswick
Tom	Nudds	Professor	Guelph University
Rosemary	Ommer	Professor	University of Victoria, Scientific Committee, CFRN
Courtenay	Parlee	Ph.D. student	University of New Brunswick
Barbara	Paterson	Postdoctoral student	University of New Brunswick
Stacey	Paul	Biologist	CFRN, Fisheries and Oceans Canada
Evelyn	Pinkerton	Professor	Simon Fraser University
Maria	Recchia	Industry representative	Fundy North Fishermen's Association
Kevin	Reid	Ph.D. student	Guelph University
Mark	Saunders	Manager	Fisheries and Oceans Canada
Anna	Schuhbauer	Ph.D. student	The University of British Columbia
Kevin	Squires	Industry representative	Maritime Fishermen's Union
Robert	Stephenson	Principal investigator, research scientist, professor	CFRN, Fisheries and Oceans Canada, University of New Brunswick
U. Rashid	Sumaila	Professor	The University of British Columbia
John	Sutcliffe	Industry representative	Canadian Council of Professional Fish Harvesters
Susan	Thompson	Manager	CFRN
Melanie	Wiber	Professor	University of New Brunswick
Catarina	Wor	Ph.D. student	The University of British Columbia