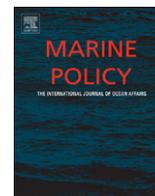




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## Structuring decision-making for ecosystem-based management

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## ABSTRACT

Ecosystem-based management (EBM) has been widely accepted as the new paradigm to manage marine ecosystems. Although various efforts have been made to define key components, guidelines, and principles, in support of its implementation, there is still a gap between theory and practice. To implement EBM, managers require a decision-making framework in which the values of constituents, objectives and performance measures are consistent and used to evaluate and choose between alternatives. Structured decision-making (SDM) is a systematic approach that can contribute to develop this framework for EBM. SDM was used for the on-going EBM process on the west coast of Vancouver Island, British Columbia, Canada. This case study provides insights into how SDM can be implemented for EBM, as well as some challenges and opportunities encountered during the process.

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## 1. Introduction

Ecosystem-based management (EBM) has been called, by national and international institutions, the new approach to managing the human activities that affect marine ecosystems [1]. This approach goes beyond traditional management based on single species and single sectors [2] and recognizes deep connectivity amongst all elements of the ecosystem—including humans [3]—and the underlying processes of producing the services people need and want [4,5]. It is place-based and requires a coordinated effort to sustainably manage the human activities that impact ecosystems [2,5,6].

Although there have been various efforts to define the key aspects, principles and guidelines [2,3,7] of what EBM is and requires, there is still a gap between theory and practice [4,7,8]. Managers face political, legal, social and scientific difficulties in implementing the complex concepts of EBM, which has come to be seen as daunting and expensive [4,7,9].

More science will not necessarily lead to the implementation of EBM [7]. This is reflected in research studies, which argue that the main challenges for the implementation of EBM include building a collective vision and objectives for EBM, designing metrics to evaluate the accomplishment of the objectives and creating ocean governance frameworks [2], as well as bridging the gap between scientific concepts and operational goals [4]. Successful initiatives aimed at implementing EBM (e.g., Great Barrier

Reef in Australia, Puget Sound in United States, and Raja Ampat in Indonesia) show that meaningful involvement of stakeholders in the definition of objectives and in monitoring processes have been key elements for success [4,9]. Put differently, environmental management is never an exclusively science-based undertaking. Human values, articulated and pursued within appropriate governance processes, are at the heart of why EBM is important and they define what EBM should achieve [10].

Because management is the process of making decisions [11], the implementation of EBM requires a participatory and systematic framework to identify the values of the constituents with respect to EBM and to make decisions that best satisfy those values. This framework would help managers anticipate and address the concerns of stakeholders and make more informed decisions about the use of natural resources [12]. In addition, if stakeholders see their values reflected they are more likely to trust the process and/or support its implementation [12].

## 1.1. The need to improve decision-making processes

EBM proponents have suggested the Integrated Ecosystem Assessments (IEAs) developed by the US National Oceanic and Atmospheric Administration (NOAA) as the most useful decision-making framework for marine management that integrates science to assist decision makers [13]. This framework, increasingly seen as central to EBM, is rooted in the decision analysis field [9,13], and it implicitly recognizes the importance of systematic decision-making.

The six steps of IEA include the following: (1) definition of objectives, threats to ecosystems and ecosystem management

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drivers; (2) development of indicators for ecosystem state; (3) establishment of thresholds for each indicator; (4) risk analyses to evaluate how indicators respond to human and environmental disturbances and the probability that indicators will reach an undesirable state; (5) evaluation of management strategies to predict the effects on the indicators; and (6) monitoring management strategy outcomes [9,13].

Although IEA suggests stakeholder involvement [9,13], it does not require it; and although it suggests a systematic decision-making process, it does not pay detailed attention to the definition of objectives and of indicators specifically related to stakeholder values or objectives. Lack of attention to these aspects may contribute to the observed inconsistency between values, objectives, indicators and management decisions. For example, objectives may dismiss important values, scientists may suggest lists of indicators for EBM that may not be useful for managers to make decisions, or may not even reflect management objectives and stakeholders values [10,14].

Structured decision-making (SDM) is a systematic process that can help stakeholders and managers construct the framework for EBM based on the values of the participants, which can be used to create, evaluate and select between alternatives [15]. Structured decision-making refers to applied decision analysis conducted with stakeholders and technical specialists to gain insight of and guide management decisions. Since it is a well-explored field for multiple stakeholder planning processes, it provides methodologies and approaches for each stage of the process. Additionally, it can help integrate science in a way that is useful for decision makers and meaningful for stakeholders.

The SDM process is summarized below. This process was applied to the EBM initiative on the west coast of Vancouver Island (WCVI), British Columbia, Canada, which has been led by West Coast Aquatic (WCA)—a multiple-stakeholder regional management board. Specifically, this work gives insights on how to define operational objectives that reflect the values of the constituents and how to derive indicators based on those objectives so as to facilitate the process of decision-making within an EBM context.

### 1.2. The SDM process

As a first step, the decision to be made must be defined [15]. For this context, the decision represents the design of a decision-making framework for EBM. The second step is to identify what matters to stakeholders in the EBM context, as well as the objectives that need to be achieved (see [15,16]). Generally, a list of wants, desires, and concerns that reflect stakeholder values and their collective vision on a particular issue is derived at this stage. This list needs to be categorized to identify the collective objectives [15].

Subsequently, objectives are separated into fundamental and means objectives. Fundamental or end objectives are those that are important because they directly reflect the values of the participants, while means objectives are those that are important because they contribute to the achievement of fundamental objectives [17]. For example, for a company, working fewer hours may be seen as an objective, but its importance relies on allowing employees to spend more time with their families, to relax or do hobbies. Therefore, minimizing work hours is a means objective for maximizing employee's spare time [17]. Fundamental objectives should be identified and used to guide decision-making [18]. When means objectives are mistaken for end objectives, the risks are that management may achieve means objectives in a manner that fails to achieve the end objectives.

Fundamental objectives should be non-redundant to be clear and concrete; measurable to facilitate the evaluation of

alternatives and the achievement of objectives; and meaningful to those who are going to use them to ensure their applicability for decision-making and the engagement of stakeholders [15].

The next step is to define the attributes for each fundamental objective. The attributes represent the meanings or the context in which the fundamental objectives are perceived [14]. For example, if the objective is to maximize economic benefits, the attributes can be the net profits or the local retention of benefits. The clear articulation of attributes is essential to define appropriate indicators for the fundamental objectives [14].

Subsequently, performance measures or indicators are defined. The importance of measuring the achievement of EBM objectives through the use of indicators has been widely recognized [5,9] and great efforts have been made to define multiple indicators for ecosystem conservation, not all of which are useful for decision makers, and which collectively may not reflect stakeholder values and objectives [14]. In an SDM approach, the only indicators that are selected are those based on the attributes of fundamental objectives. In SDM, the definition of indicators is usually a technical process, involving subsequent consultation with stakeholders to ensure that expert-chosen indicators reflect the objectives and are meaningful to them. In the case of EBM, communication between stakeholders and scientists is essential to identify indicators that reflect what matters and also how the ecosystems work.

Once indicators are defined, the following step is to create alternatives based on fundamental objectives and then evaluate the performance of alternatives based on the selected indicators. The identification of fundamental objectives and attributes often spurs participants to create more innovative alternatives that better satisfy the full range of objectives [12].

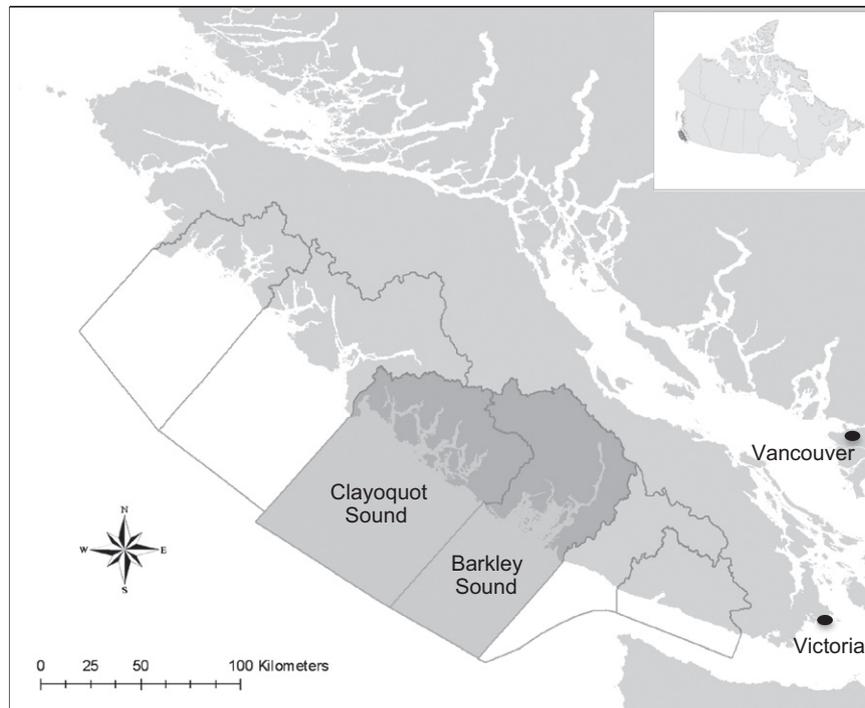
Choosing between alternatives involves tradeoffs. A key strength of SDM is that such tradeoffs are made explicit and stakeholders are able to understand what tradeoffs each alternative entails. Stakeholders often end up choosing amongst only a small set of alternatives, as those that poorly satisfy the objectives are quickly eliminated. When there is disagreement on a group's preferred alternative, stakeholders could be asked to choose their preferred alternative, and then present the reasons for choosing it, as well as the expected winners, losers, pros and cons [12]. After this, stakeholders will likely be more amenable to agree on a preferred alternative. If they do not, the whole SDM process can nonetheless provide managers with good insights about the advantages and disadvantages of each alternative [12].

### 1.3. Considerations for the implementation of SDM for EBM

When organizations or multiple stakeholder groups have already defined their initial set of objectives to achieve EBM, these objectives should be revised to ensure that they reflect the values of the participants and that they are clearly articulated to guide decision-making. It will also be essential to verify with stakeholders the attributes of each fundamental objective to define appropriate indicators for the objectives. If objectives are not appropriate, well-defined and well thought out, decisions may not satisfy the fundamental objectives regardless of the rest of the process [19].

### 1.4. Case study: EBM initiative on the WCVI

The WCVI is a large and diverse area that supports multiple human activities such as commercial, recreational and subsistence fisheries, aquaculture, tourism and transportation [20]. Therefore, diverse and conflicting objectives characterize the use of the natural resources in the area.



**Fig. 1.** West coast of Vancouver Island study area. Under a regional ecosystem-based management (EBM) initiative, West Coast Aquatic is developing three management plans: one for its entire jurisdictional area (outlined), and one for each of two subareas, Clayoquot and Barkley Sounds.

WCA is a forum for coastal communities and those affected by marine management decisions to participate in the decision-making process for managing the area [21]. Members of the WCA include Federal, Provincial, Local and First Nations governments; representatives of commercial and recreational fisheries; the aquaculture and tourism industries; and conservation organizations, among others [22]. The ethical principles under which WCA operates include an ecosystem-based approach to management, conservation, precaution, adaptivity, sustainability, shared responsibility, inclusivity, benefits and flexibility [23].

WCA has initiated a planning process for an overarching marine plan and two spatial regional plans with an EBM approach (Fig. 1). WCA has already defined eight objectives that reflect both “what matters” and “what EBM entails” to the stakeholders as well as the goals and sub-goals required to achieve the eight main objectives.

The eight objectives are as follows: (1) integration and collaboration; (2) sustainable economic benefits; (3) healthy ecosystems; (4) healthy, prosperous and safe communities and waterways; (5) First Nations, reconciliation and relationships-strengthening; (6) collection of knowledge, information and technology; (7) capacity building; and (8) good governance [23].

## 2. Methods

SDM was applied to WCA marine planning process to help them design a decision-making framework for EBM. The original set of objectives defined by WCA (Table 1) involved important aspects for EBM; however, they were stated in a complex way, making their use for decision-making very difficult. Therefore, these objectives were reviewed and re-structured in an operational way without losing or distorting their intended meanings.

Fundamental objectives were separated from means objectives using the “why each objective is important” test defined by Clemen and Reily [17]. When an objective was important because it contributed to the achievement of another objective, it was

defined as a means objective. When an objective was important because it represented WCA values, it was defined as a fundamental objective.

The goals and sub-goals documents (see [23]) were reviewed to understand the attributes of each of the eight objectives. Attributes usually appeared in more than one objective or were stated as fundamental objectives, this often occurs because stakeholders strive to elevate particular interests as much as possible in the objectives. The result is that operationalizing the objectives is very difficult.

Any attributes with the same meaning were combined and any attributes that better fit with other fundamental objectives were moved to those respective objectives. For objectives that were broadly described, attributes were suggested based on a review of existing literature and other case studies that expressed similar objectives.

Indicators were suggested for the attributes of fundamental objectives. For attributes that were not informative for measures, such as ‘vibrancy’ of communities, indicators were selected based on a review of other case studies that measure those attributes.

One of the co-authors (DMD) is the Executive Director of WCA and was involved in the process of defining the initial set of objectives. This helped to ensure that the new structure reflected WCA original values, and that indicators were appropriate and meaningful to them.

## 3. Results

From the list of eight main objectives defined by WCA for their marine planning process, four were considered fundamental objectives: (1) foster economic benefits; (2) foster healthy ecosystems; (3) foster healthy communities; and (4) foster good governance.

Adaptive management (AM) was included as a fifth fundamental objective. It was part of one fundamental objective (“healthy ecosystems”), but from conversations with WCA it

**Table 1**  
Original set of objectives and attributes of West Coast Aquatic (WCA) based on the draft goals for aquatic management on the West Coast of Vancouver Island (WCVI) . FN means First Nations.

| Objectives   | Attributes   |   |   |
|--|--|---|---|
| Integration and collaboration                          | <ul style="list-style-type: none"> <li>● Collaboration with other states and global links;</li> <li>● Shared responsibilities;</li> </ul>  | <ul style="list-style-type: none"> <li>● Integrated and participatory management;</li> <li>● Efficient communication;</li> </ul>  | <ul style="list-style-type: none"> <li>● Responsible and participatory decisions;</li> <li>● Sustainable and holistic management consistent with traditional values.</li> </ul>   |
| Sustainable economic benefits                          | <ul style="list-style-type: none"> <li>● Opportunities for locals;</li> <li>● Sustainable social, cultural and economic benefits;</li> <li>● Balance ecological, social and economic aspects;</li> </ul>                     | <ul style="list-style-type: none"> <li>● Future generations;</li> <li>● Conservation first in fisheries management;</li> <li>● Sustainable fisheries and aquaculture;</li> </ul>  | <ul style="list-style-type: none"> <li>● Sustainable management;</li> <li>● FN access to natural resources;</li> <li>● Monitoring, enforcement and regulations.</li> </ul>  |
| Healthy ecosystems                                     | <ul style="list-style-type: none"> <li>● Ecosystem productivity;</li> <li>● Healthy, diverse and resilient ecosystems;</li> <li>● EBM and values in planning and decision-making;</li> <li>● Adaptive management;</li> </ul> | <ul style="list-style-type: none"> <li>● Integrity of fish and habitat;</li> <li>● Genetic diversity (salmon and other species);</li> <li>● Conservation as a first priority;</li> <li>● Precautionary approach;</li> </ul> | <ul style="list-style-type: none"> <li>● Plans for natural disasters;</li> <li>● Adaptation to climate change;</li> <li>● Network of marine protected areas;</li> <li>● Species at risk protection;</li> <li>● Waste water management (water pollution and disposal management).</li> </ul> |
| Healthy, prosperous and safe communities and waterways | <ul style="list-style-type: none"> <li>● Safety (infrastructure, modernized transportation, and response services);</li> <li>● Health (ecosystem health and community health);</li> </ul>                                    | <ul style="list-style-type: none"> <li>● Vibrancy (diversified economies, cultural practices);</li> <li>● Partnerships;</li> </ul>  | <ul style="list-style-type: none"> <li>● Traditional knowledge into decision-making.</li> </ul>   |
| FN reconciliation and relationships strengthening      | <ul style="list-style-type: none"> <li>● Respecting aboriginal rights and title;</li> <li>● Clear understanding of the needs of FN;</li> <li>● Ensuring benefits for FN;</li> </ul>  | <ul style="list-style-type: none"> <li>● Participation of FN in decision-making;</li> <li>● FN as the second priority after conservation;</li> <li>● Ensuring FN access to natural resources;</li> </ul>                    | <ul style="list-style-type: none"> <li>● FN sharing the wealth of marine resources;</li> <li>● Resolutions between FN and other governments.</li> </ul>   |
| Knowledge information and technology                   | <ul style="list-style-type: none"> <li>● Stewardship efforts;</li> <li>● Expertise and knowledge from diverse sources;</li> <li>● Integration of information and knowledge on ecosystem health;</li> </ul>                   | <ul style="list-style-type: none"> <li>● Education;</li> <li>● Passing on traditional knowledge;</li> <li>● Training for users, managers, stewards, community capacity;</li> </ul>  | <ul style="list-style-type: none"> <li>● Equipment and technology;</li> <li>● Information gathering.</li> </ul>   |
| Capacity building                                      | <ul style="list-style-type: none"> <li>● Safety and efficiency of marine transportation and shipping;</li> <li>● Resource use and management;</li> </ul>   | <ul style="list-style-type: none"> <li>● Improve FN economic self sufficiency and community stability;</li> <li>● Stakeholders participation in aquatic conservation;</li> </ul>  | <ul style="list-style-type: none"> <li>● Modernization of the Canadian Coast Guard fleet;</li> <li>● New industries;</li> <li>● Strong FN cultures.</li> </ul>  |
| Good governance  | <ul style="list-style-type: none"> <li>● Establishment of priorities;</li> </ul>   | <ul style="list-style-type: none"> <li>● Public reporting;</li> </ul>   | <ul style="list-style-type: none"> <li>● Responsibility and accountability.</li> </ul>  |

was agreed to include it as a separate objective due to its importance for the whole process rather than only for that particular fundamental objective, and because it represents an ethical principle for WCA. This has also been recommended in other multiple stakeholder processes where SDM has been applied [24].

Three of the eight original objectives—'integration and collaboration', 'knowledge, information and technology', and 'capacity building, engagement and communications'—were identified as *means* objectives, as their importance relies on their contribution to the fundamental objectives. Three attributes of the 'integration and collaboration' objective (i.e. shared responsibilities, collaboration with other plans, and participatory management) were re-identified as falling under the fundamental objective of 'good governance'.

All attributes of the last objective 'First Nations reconciliation and relationships strengthening' proved to fit within other fundamental objectives. These attributes were thus made explicit within the other fundamental objectives. For example, 'respect aboriginal and treaty rights' was re-grouped within 'healthy communities'; and 'participation in decision-making' was

grouped under 'participatory management' as part of the 'good governance' objective.

The new structure (Table 2) of fundamental objectives, attributes and suggested indicators are presented below.

### 3.1. Framework for EBM: fundamental objectives, attributes and indicators

#### 3.1.1. Foster economic benefits

This objective includes generating benefits derived from the ecosystem and their fair distribution across present and future generations. Benefits can include profits and employment, but also the goods or services themselves, because trading is a traditional practice in the region. The retention of benefits by local communities, specifically First Nations, was stated twice in the original document of objectives, goals and sub-goals, and also emphasized in WCA planning process.

WCA included as part of this objective the balance of ecological, social and economic components as well as sustainable management; one would think that both are related and

**Table 2**

New structure of fundamental objectives, attributes and indicators for a decision-making framework for EBM. FN means First Nations. CS means constructed scales.

| Fundamental objectives                  | Attributes  | Attributes components  | Indicators  |
|---|---|--|---|
| Foster economic benefits                | Distribute benefits and costs across stakeholders and over time | Net benefits   | Net present value   |
| Foster healthy ecosystems               | Minimize adverse effects on ecosystem integrity                 | Income   | Net income per year   |
|   |   | Employment   | Number of skilled, unskilled, temporal and permanent jobs   |
| Foster healthy communities              | Avoid adverse effects on health and safety                      | Goods  | Weight  |
|   |   | Diversity  | Species richness and evenness within defined boundaries   |
|   | Avoid adverse effects on vibrancy                               | Productivity   | Community composition: species richness and abundance of selected groups                                    |
|   |   |  | Community composition: mean trophic level   |
|   |   | Marine environmental quality   | Community/habitat diversity   |
|   |   |  | Biomass per trophic level   |
|   | Foster good governance  | Foster participatory management  | Target species catch and biomass  |
|   |   |  | Concentrations of toxics in sediments, water and biota  |
|   |   |  | Habitat quality (area impacted or magnitude of the activity that impact the habitat)                        |
|   |   |  | Noise   |
| Foster shared responsibilities          |   | People   | Atmospheric pollution   |
|   |   | Private and public property  | Number of people exposed, magnitude and probability of the risk   |
| Foster alignment with other plans       |   | Access to natural resources  | Illness and death associated to marine resources or the alternative   |
|   |   |  | Number of private or public property exposed, magnitude and probability of the risk                         |
| Foster social agreements                | FN rights and title   | CS: Are the conditions of access fair?   |   |
|   |   | CS: Are the conditions of access impacted?   |   |
| Foster a precautionary approach         | Cultural practices  | CS: Is the compensation fair?  |   |
|   |   | CS: Are FN rights, treaties and title respected?   |   |
| Foster adaptive management              | Foster learning from other participants                         | Aesthetics   | CS: To what level of satisfaction?  |
|   |   | Representativeness   | CS: Impacts on identified cultural practices  |
|   | Foster learning from the process                                | Fairness   | CS: Is the compensation fair?   |
|   |   |  | CS: Perceived magnitude of the visual, odor and water quality impacts                                       |
|   | Foster treating policies as experiments                         | Competence   | CS: Were all stakeholders represented in the process?   |
|   |   |  | CS: Were there opportunities for the public and stakeholders to participate in the decision-making process? |
|   | Foster a precautionary approach                                 | Resolutions between FN and other governments   | CS: Were there a capacity building program and training opportunities for locals?                           |
|   |   |  | CS: Was there a capacity building program and training opportunities for locals?                            |
|   | Foster learning from the process                                | Resolutions between FN and other governments   | CS: Do all members agree with the distribution of tasks?  |
|   |   |  | CS: Do the members have the capacity to do the work they were tasked with?                                  |
| Foster treating policies as experiments | Resolutions between FN and other governments                    | CS: Were synergies and partnerships made during the process?   |   |
|   |   | CS: To what extent there is respectful relationship between FN and other governments?                      |   |
| Foster learning from the process        | Resolutions between FN and other governments                    | CS: Was there a comprehensive consideration of possible negative effects of human activities?              |   |
|   |   | CS: Was a monitoring plan adopted to evaluate the harm on ecosystem and human health?                      |   |
| Foster treating policies as experiments | Resolutions between FN and other governments                    | CS: Do proponents of actions/activities have responsibility to demonstrate small likelihood of major harm? |   |
|   |   | CS: Were alternatives adopted to reduce harm?  |   |
| Foster learning from the process        | Resolutions between FN and other governments                    | CS: If uncertainty was the reason for inaction, was there a concrete plan adopted to reduce uncertainties? |   |
|   |   | CS: How did the board solve the conflicts?   |   |
| Foster learning from the process        | Resolutions between FN and other governments                    | CS: How did the board learn from conflict resolution?  |   |
|   |   | CS: Did stakeholders learn during the process?   |   |
| Foster learning from the process        | Resolutions between FN and other governments                    | CS: Are the members satisfied with the process experience?   |   |
|   |   | CS: Was new information identified and integrated to the process?  |   |
| Foster learning from the process        | Resolutions between FN and other governments                    | CS: Were there opportunities to review and adjust agreements and policies?                                 |   |
|   |   | CS: Were there learning opportunities over time?   |   |
| Foster learning from the process        | Resolutions between FN and other governments                    | CS: Were key sources of uncertainty identified?  |   |
|   |   | CS: Were opportunities to reduce uncertainty identified?   |   |
| Foster learning from the process        | Resolutions between FN and other governments                    | CS: Did members define means of applying policies to realize such opportunities?                           |   |
|   |   | CS: Did members define means of applying policies to realize such opportunities?                           |   |
| Foster learning from the process        | Resolutions between FN and other governments                    | CS: Were those policies implemented?   |   |
|   |   | CS: Were those policies implemented?   |   |

represent what the decision-making process should entail rather than attributes of this particular objective. WCA also mentioned sustainable fisheries and aquaculture, monitoring, enforcement and regulations, which represent means objectives and may contribute not only to this objective. Conservation as the main priority for fisheries management was also included here; however, this represents a value or preference towards certain

alternatives. First Nations access to natural resources was moved to the 'foster healthy communities' objective.

*3.1.1.1. Suggested indicators.* A commonly used indicator for profits is the net present value—aggregated benefits minus aggregated costs, discounted over time. Discount rates are applied

to estimate the present value of future revenues or costs; and these rates can vary among individuals or social levels [25]. Net present value is a well-known indicator but insufficient alone, because it does not capture the distribution of benefits and costs among stakeholders [26].

Income per capita has been also used to represent benefits [27,28]. For the case of employment, WCA could account for the number of skilled, unskilled, temporary and permanent jobs derived from each alternative [26,29]. For the case of the goods, WCA can consider the weight in pounds or kilograms.

The proportion of these benefits and losses (in terms of net revenues, income per capita, employment and the goods themselves) retained by each stakeholder group (adapted from Philcox 2007) over time [26,29] can help measure the distribution of benefits and losses. WCA could also measure the proportion of benefits and loss retained among local communities or First Nations to evaluate if the most vulnerable groups are retaining benefits (e.g., [27]).

### 3.1.2. Foster healthy ecosystems

For this objective, WCA will focus on minimizing the adverse effects of human activities on the integrity of ecosystems. Based on the approach used by the Department of Fisheries and Oceans Canada (DFO) in the Eastern Scotian Shelf [30], WCA has defined three main aspects of integrity: diversity, productivity and environmental quality. Diversity includes species, populations and communities; productivity refers to primary and secondary productivity, as well as trophic and population productivity; and marine environmental quality involves physical, chemical and habitat quality [30,31].

Resilience was mentioned as part of this objective. Ecological resilience is generally understood as the system's ability to absorb shocks or disturbances while maintaining its function, structure, identity and feedbacks [32]. Resilience is often assumed to be good, as people often assume one desirable state and the ability of the system to maintain or go back to this state after disturbances. However, it has been demonstrated that many systems, including marine ecosystems, have multiple states or attractors (e.g. from kelp-dominated ecosystems to 'urchin barrens'). Some states may be undesirable for societies; maintaining the resilience of these states may therefore not be desired. In addition, the resilience of an ecosystem is influenced by the feedbacks between social and ecological systems [1], a fact that applies not only to this objective but also to others such as 'economic benefits' and 'healthy communities'. It is thus appropriate to consider resilience as a means objective for the fundamental objectives. It will be important for societies or groups to identify the desirable states for which resilience is sought.

This objective included other means objectives such as the protection of species at risk, the establishment of marine protected areas, development of plans to respond to natural disturbances, and adaptation to climate change. Other considerations within this objective were conservation as a first priority, which represent implicit preferences towards objectives and alternatives. EBM and the integration of values in the planning and decision-making processes were included, which represent the overall objective. Adaptive management (AM) was included as a separate fundamental objective and the precautionary principle was moved to the 'good governance' objective.

#### 3.1.2.1. Suggested indicators

- a. Diversity: species, populations and communities  
Species richness—number of species—within defined boundaries such as communities or habitats [33] and evenness—distribution of species biomass—have been suggested to measure diversity.

However, the composition of biological communities is also important: while species richness may show a high number of species in the region, this number may also include introduced species, which are not members of the native community and can cause negative impacts to native species and ecosystems. Because it is very difficult to focus on all species in the community or habitat, it is necessary to select species or groups whose characteristics represent attributes of other species, the ecosystem and environmental conditions [34]; or groups that play an important role ecologically or culturally such as endemic species, species at risk, etc.

Endemic species for example are important because they only occur in specific places, regions, ecosystems or communities [35]; and their populations are usually small and vulnerable to extinction [36]. Some studies demonstrate that the conservation of sites with high levels of endemism can capture large proportions of all identified species of a region [36]. Species at risk, can also be useful in the sense that it highlights biodiversity components that might be lost, but this measure can also be limited because of the political process of listing, and because simple species counts are far removed from ecological integrity. It is advisable to look at species richness and abundance across the selected groups, as well as the historical trends to evaluate if their populations are increasing, stable or declining [9].

The mean trophic level (TL) [37,38] is a well-known indicator that can be used as a proxy for the community composition. It is calculated by assigning species to trophic levels and using information on species' catch and diet composition. The TL has been often used to indicate the impacts of fisheries [37,38]; however, it can be also used to analyze the trophic structure of an ecosystem by including non-target species' abundance and diet composition.

In terms of diversity, it has also been suggested to pay attention to community and habitat diversity [30] because their conservation can ensure the conservation of species [33].

- b. Productivity: primary, secondary, trophic level and population productivity.

Abundance per trophic level can be used as an indicator of the productivity at trophic level [39,40] as well as for primary and secondary production. Historical catch and biomass of target species can also be used to measure productivity of species and populations [30] and provide insights on the status (increasing, stable, declining) of those species.

- c. Marine environmental quality: physical, chemical and habitat quality

This can be accounted by evaluating the concentration of toxics in the water, sediments [30,40] and species (e.g., Harbor seals, pelagic and benthic fish, clams, mussels and juvenile salmon) [41] as well as the generation of noise and atmospheric pollution [30] derived from each of the alternatives.

For habitat quality, WCA could select those habitats or communities that are important to conserve, and evaluate the potential impacts of alternatives on those habitats. This can be done by assessing the total area of 'selected' habitat impacted (e.g., [12]) or by identifying the main threats for those habitats (e.g. trawlers) and the magnitude of the particular threat (e.g., number of trawlers).

### 3.1.3. Foster healthy communities

This objective refers to avoiding adverse effects on the health, safety and vibrancy of local communities. Attributes for minimizing the adverse effects on health and safety can be related to people, private and public property [42].

Vibrancy is understood as those things that make locals stay in their communities as well as the survival of groups and traditions

over time. After restructuring the original attributes, vibrancy include the 'respect of First Nations rights and title', which was part of the objective 'First Nations reconciliation and relationships strengthening', and 'First Nations access to natural resources', which was an attribute of the 'economic benefits'. Other attributes included in this objective are cultural practices [26,29] and esthetics (adapted from [27]).

**3.1.3.1. Suggested indicators.** Effects on human health and safety, specifically on people, private and public property can be measured by identifying risks, their magnitudes and probabilities, who (or what, in the case of private and public property) is exposed, and to what extent. This can be based on science and stakeholders' perceptions [28]. Illness and deaths that could be associated with marine resources—in this case those associated to the management alternatives—have been suggested as a health indicator [41].

Attributes of vibrancy can be measured qualitatively using constructed scaled (e.g., 1–5; low, medium, high) indicators to answer questions determined by WCA. Some suggestions for scoring each attribute previously mentioned are presented below.

For the impacts on access to natural resources including land: Are the conditions of access perceived locally to be fair? If the conditions of access to locals are negatively impacted, is the compensation fair? (adapted from [29]).

For the impacts on First Nations rights and title: Are the First Nations' rights, treaties and title respected? To what level of satisfaction according to local perception? (adapted from [29]).

For the impacts on the cultural practices identified as important for locals (e.g., potlatch, festivities, transmission of traditional knowledge, language): What are the impacts of different alternatives on these practices (adapted from [27,41,43])? If a cultural form is lost or negatively impacted, for those who are affected, is the compensation fair [29]?

For impacts on esthetics: What is the perceived magnitude of the visual, odor and water quality impacts in the region (Satterfield, pers. comm.)?

#### 3.1.4. Foster good governance

Good governance has been identified as a key element and a challenge for the implementation of EBM [2,3]. For WCA this objective includes participatory management, shared responsibilities (originally in the 'integration and collaboration' objective), compatibility with other plans and social agreements (originally in the 'First Nations reconciliation and relationship' objective), implementation of the precautionary principle (originally in the 'healthy ecosystems' objective) and public accountability.

Attributes of participatory management include the following: representativeness, fairness and competence [44]. Representativeness means that all stakeholders are represented when making decisions. Fairness refers to the equitable access to participatory processes, equal opportunities to make and reject claims during deliberation, and the consideration of different sources of information. Competence means that all participants have a sufficient level of understanding of the consequences of each alternative, including knowledge, uncertainties and ambiguities [44].

Other aspects originally included in this objective were the identification of priorities, the responsible use of financial resources, and the evaluation of WCA performance on a regular basis, each of which represent means objectives.

**3.1.4.1. Suggested indicators.** The attributes of this objective can be measured qualitatively using constructed scales as suggested for the 'vibrancy' attributes.

For the participatory management: Were all stakeholders represented in the process? Were there opportunities (e.g., forums, meetings) for the public and stakeholders to participate in the process?

Was there a capacity building program and training opportunities for locals and other stakeholders to improve their competence [26,29]?

For the responsibilities distribution: Do all the members agree with the distribution of tasks? Do the members have the capacity to do the work they were tasked with?

For alignment with other plans: Were synergies and new partnerships with other organizations made during the process?

For resolutions between First Nations and other governments: To what extent is there a respectful relationship and agreement between First Nations and other governments [26,29]?

For the precautionary approach: Was there a comprehensive consideration of possible negative effects of human activities, including those with considerable uncertainty? Was a monitoring plan adopted to evaluate the harm on ecosystems and human health? Do proponents of potentially actions/activities have responsibility to demonstrate small likelihood of major negative effects? Were alternatives considered and adopted to reduce harm on ecosystems and human health? If uncertainty was a reason for inaction, was a concrete plan adopted to reduce uncertainties?

For public accountability: Was information on financial resources available for all members of the board? Was information—on the impacts of management alternatives in relation to the objectives—available for all members? Are there sufficient measures in place to ensure transparency?

#### 3.1.5. Foster learning through adaptive management

Adaptive management represents the ability to learn from other participants, from the process as new information arrives [24,42] and treating policies as experiments to explore possible outcomes [45].

**3.1.5.1. Suggested indicators.** Most attributes of these objectives can be also qualitatively measured with constructed scales to answer questions defined by WCA. Some examples are presented below.

For learning from other participants: Did the board learn from conflict resolution (adapted from [29])? Did stakeholders learn from each other during the process?

For learning from the process: Are members satisfied with the process? Was new information identified and integrated to the process? Were there opportunities to review and adjust agreements and policies [26,29]? Were there learning opportunities over time [12]?

For learning through treating policies as experiments: Were key sources of uncertainty identified? Were opportunities to reduce uncertainties identified? Did members consider means for applying such opportunities in policy/management alternatives? Were those means implemented?

## 4. Discussion

The implementation of EBM is of interest of scientists, managers and stakeholders; therefore, a collective vision of what is wanted from EBM to achieve is very important. Understanding and articulating values in a proper way can help direct decisions to achieve what is desired/wanted. This work intended to help WCA identify their most fundamental objectives and articulate them in an operational way to guide decision-making processes.

The process of restructuring objectives requires the involvement of stakeholders for two main reasons. First, to ensure that stakeholder values are well understood and reflected in the new structure. And second, for stakeholder to understand the process and realize that their objectives and attributes were not changed, left out or ignored, but only re-structured to make them operational in order to guide the decision-making. If stakeholders are not involved, they may resist the changes included in the new

structure. For this particular case, one of the co-authors (DMD), as representative of WCA, confirmed that WCA values were reflected in the new structure of objectives and attributes. However, for the implementation, the results will have to be consulted with all WCA members.

Little attention has been paid to the definition of indicators for EBM that reflect stakeholder values and guide decision-making. This work emphasizes the importance of linking indicators to fundamental objectives as well as involving stakeholders and scientists in the definition of indicators to integrate value judgments and technical information. The proposed set of indicators (quantitative and qualitative) may seem extensive; however, it reflects WCA fundamental objectives. It is essential that WCA explore them using particular decisions to select the most useful ones according to their goals, priorities and constraints.

As EBM involves complex decisions, conflicting objectives and massive uncertainties, a systematic framework to make decisions has significant potential as it can be repeatedly used for any decision even in the most complex situations [18].

The new structure of objectives, attributes and indicators presented here can be considered as a first step in building the framework for implementing EBM on the WCVI. Once it is reviewed and confirmed by all members, WCA could use it for any complex issue of concern—from the marine zoning initiative, to the unregulated float homes in Barkley Sound, to the water pollution—in which multiple objectives, emotions and history are involved. The framework can help work (in a systematic way) through these issues with stakeholders, create better alternatives, evaluate alternatives, identify information needs and opportunities to reduce uncertainties [46].

Because the framework is built for multiple decisions, it needs to be flexible as particular decisions might be different from each other, and the weighting of objectives might require re-negotiations for each decision, in part because the people strongly affected by particular decisions will differ.

SDM gives the opportunity to bring together stakeholders, scientists and managers for the implementation of EBM. Stakeholders need to be able to explicitly state what matters to them in detail and their values must be incorporated in the decision-making process; decision-makers need to be able to express their constraints on management/monitoring; and scientists need to be able to express the differences between metrics and suggest adequate indicators to measure the objectives given the values and management constraints. This can be best done through a communication involving representatives of the three groups.

SDM can make management more consistent as all the decisions are meant to achieve the same fundamental objectives; it can make the decision-making process more transparent as tradeoffs are made explicit; and it can build trust in the process as stakeholders and their values are involved since the beginning. Stakeholders might support decisions that they would not have supported otherwise, by understanding the tradeoffs and the benefits of each alternative in terms of the fundamental objectives.

## 5. Conclusions

This work provides an example of how to apply SDM for the implementation of EBM. Specifically, it shows how to restructure objectives to make them operational and how to integrate values, objectives and indicators in a consistent framework. Managers can use these frameworks to create and evaluate alternatives, to make more informed decisions based on stakeholder values, as well as to identify data gaps and opportunities to reduce uncertainties. By no means do this work intend to provide the EBM

framework to be applied for the WCVI, but rather insights and a first step towards building it.

This work demonstrates that stakeholders-derived objectives and values can help shape a collective vision and objectives for EBM; however, a systematic process and the communication between stakeholders, managers and scientists will be required to identify fundamental objectives and indicators that are consistent with stakeholder values. Without a systematic approach, objectives will be often stated in a redundant and complex way making their operationalization very difficult, and indicators may also be defined independently of stakeholder objectives and the decision-making process.

SDM should result in decision-making processes for EBM that are more consistent and transparent. SDM will help build trust in the process. Stakeholders are likely to feel more engaged with the planning and implementation of EBM if they are involved and see their values reflected since the beginning of the process.

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