Strategic Vision for Transport Canada's Cumulative Effects of Marine Shipping Program

South Coast of British Columbia Regional Pilot

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Strategic Vision for Transport Canada's Cumulative Effects of Marine Shipping Program

South Coast of British Columbia Regional Pilot

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1 Introduction

What is the CEMS Program?

Commenced in 2017, Transport Canada's Cumulative Effects of Marine Shipping (CEMS) initiative aims to better understand coastal ecosystems and the potential effects of vessel activities on the environment and the people surrounding it. The initiative is being developed collaboratively; Transport Canada is working with Indigenous governments, coastal communities, marine stakeholders and other interested parties. The CEMS initiative is an important component of Transport Canada's Oceans Protection Plan (OPP), which sets out to develop a marine safety system to keep Canadian waters and coasts safe and clean, in partnership with Indigenous and coastal communities.

The South Coast of BC is one of six areas in Canada where the CEMS initiative is being piloted. The geographic scope for the South Coast region spans approximately from Smith's Inlet south to the marine border with the United States, on both sides of Vancouver Island, and includes coastal regions of the lower mainland (Figure 1-1).

Figure 1-1. Regional and sub-regional scope of the CEMS multi-layered assessment approach in South Coast BC. Image courtesy of TC CEMS program

For the South Coast region, a multi-layered assessment approach is being adopted. Given the large scope of the region, a number of First Nations communities expressed interest in engaging bilaterally or collaboratively to address local concerns that may not have been reflected in a region-wide approach. Therefore, the assessment will be conducted **regionally** (at the scale of the South Coast region), and **sub-regionally**. The sub-regional scale consists of self-identified First Nations that are participating individually, or in groups. The regional and sub-regional assessments will mutually inform each other, and the regional assessment itself will be implemented through the Ship Movement and Vessel Management Coordinating Committee (VMCC) (Figure 1-2).

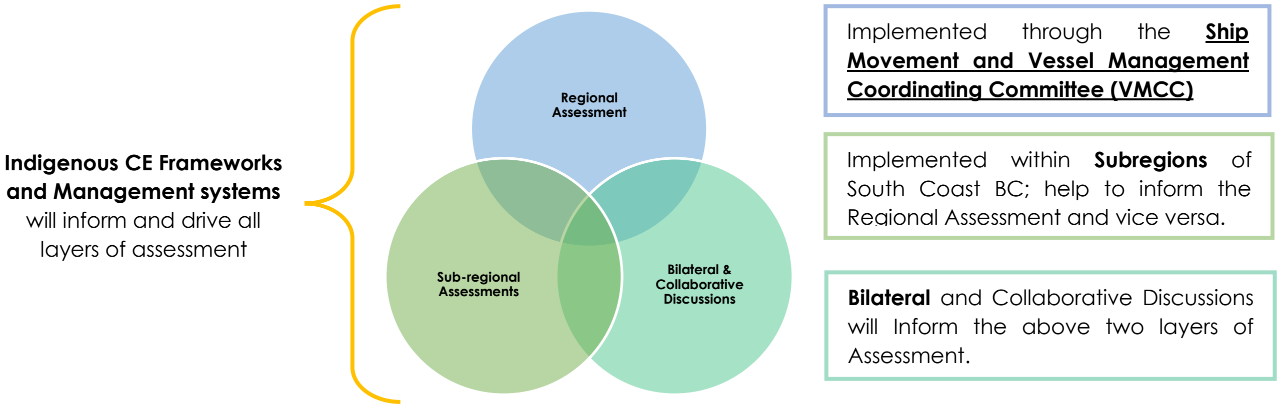


Figure 1-2. Conceptual diagram illustrating the multi-layered assessment approach for the CEMS multi-layered assessment approach in South Coast BC. Image courtesy of TC CEMS program.

What is ESSA doing?

Transport Canada retained ESSA in January 2022 to assist in developing the multi-layered assessment approach for the CEMS South Coast regional pilot. ESSA's work consists of three key phases:

- Conducting outreach to First Nations participants in the South Coast regional pilot to understand the importance of, and outcomes of a successful multi-layered assessment approach.
- Conducting a literature review to identify key considerations and best practices for multi-layered cumulative effects assessment approaches.
- Synthesizing findings from the literature review and outreach to develop a strategic vision for the multi-layered assessment. The strategic vision consists of a roadmap, which describes the key milestones that will be reached in the assessment process, as well as a menu of options that will assist in implementing the assessment.

This report captures the results of this work and is structured into sections:

- **Section 2** describes the methods for the literature review, and presents the key findings, including challenges and best practices for multi-layered marine cumulative effects assessment. This section is accompanied by an annotated bibliography (Appendix A).
- **Section 3** summarizes guidance heard from delegates of First Nations partners during two feedback sessions held in March 2022. The guidance is supporting the objective of co-developing the strategic vision.
- **Section 4** describes the current context in the CEMS South Coast BC regional pilot, summarizing the work that has been done so far, who is participating, and the goals of the assessment.
- **Section 5** presents the strategic vision, which consists of a roadmap, which outlines the key milestones that will be reached in the assessment process, and a menu of options that will assist in accomplishing each of the milestones.

Box 1. Key Definitions and Acronyms

Marine shipping: within the context of the CEMS program, marine shipping includes commercial vessels, ferries, cruise, fishing and recreational vessels operating in waters within Canadian jurisdiction, if the data is available and accessible to support their inclusion in the assessment (VMCC 2020)

South Coast region: the scope of the South Coast region includes BC First Nations' territories from Smith's Inlet south to the USA border. It includes both the east and west coast of Vancouver Island, as well as the coastal regions of the lower mainland, where marine shipping is occurring, within Canadian jurisdiction (VMCC 2020).

VMCC: the Ship Movement and Vessel Management Coordinating Committee (VMCC) collaborates with the CEMS program to advance the work being done in the South Coast region. The VMCC provides guidance, direction, and recommendations to CEMS, and works to enhance the role of First Nations in the program.

2 Characteristics of Multi-Layered Cumulative Effects Assessments

ESSA conducted a high-level literature review to identify challenges of, and best practices / enabling factors for multi-layered cumulative effects assessments, focusing on those conducted in the marine environment. The contents of the literature review were informed by (1) conducting keyword searches for relevant terms in Google Scholar, and (2) by identifying relevant past projects completed by ESSA staff relating to effects framework development, or multi-layered integration of monitoring programs. The initial set of documents was pared down based on an initial read of the abstract, conclusions, and / or executive summary. A total of 16 documents were reviewed in detail (additional documents were reviewed and are cited in-text). The final selection of documents for the annotated bibliography included peer-reviewed articles, project reports, a conference presentation, and a website.

2.1 Findings

The annotated bibliography is presented in Appendix A. The annotated bibliography includes the citation for each document, a summary of its contents, and highlights key considerations relevant to the development of the strategic vision. In the sub-sections below, we summarize key challenges and best practices relevant to multi-layered cumulative effects assessments that emerged from the review.

There was an extensive body of literature for the three topics the literature review focused on (cumulative effects assessments; multi-scale monitoring and assessment; and marine cumulative effects). The literature we found focused on one or two of the three topics, with the bulk of the findings focused on cumulative effects assessment (comparatively few papers touched on multi-layered assessments). There were no examples that addressed all three topics in one place (i.e., a multi-scale, marine focused cumulative effects assessment). The findings below draw on concepts from all topics, focusing on relevance to the CEMS multi-layered assessment approach in South Coast BC regional pilot.

2.1.1 Challenges

Common challenges in developing multi-layered or cumulative effects assessment programs are described below. The challenges below (as well as the best practices discussed in the subsequent section) apply to all phases - development, implementation, and decision making within - a cumulative effects program. Challenges can be grouped under three headings: **governance**, and **technical**, and **cross-cutting** (both governance and technical) (Jones et al 2010; Ball et al 2013; Judd et al 2015; Pickard et al 2018a; Hollarsmith et al 2021).

Governance

- Insufficient **political will** and or **political tools** (i.e., legislation and policy) to implement and enforce cumulative effects monitoring, assessment, and management.
- Lack of **trust** between government, industry, and affected communities. Specifically, when processes are not transparent, it is difficult for affected communities to develop trust.
- Lack of **coordination** between, and / or **unclear responsibilities** among responsible agencies, which can result in logistical challenges (e.g., gaps in assessment or duplicated effort).
- **Developing consensus about the objectives and priorities** is critical, but can be difficult to achieve in a participatory process due to the varying concerns among participants and across the region.
- Limited **capacity** and **funding** to implement long-term cumulative effects monitoring.

Technical

- Lack of clarity around **monitoring terminology** can cause confusion among participants and lead to conflict about how cumulative effects are assessed and managed.
- Limited **data/knowledge availability** can result in a difficulty in specifying the reference condition at an appropriate scale and resolution. When data/knowledge is compiled from multiple sources, differences in site selection methodologies, sampling methods, and indicators used may make it difficult to compare data. Likewise, there might be too few samples to robustly estimate site-specific conditions, or insufficient historical data/knowledge to quantify pre-impact conditions.
- **Scaling up, or scaling down information about ecological processes** is limited by the availability of scaling functions. For many ecological systems, such scaling functions have not been quantified.

- Insufficient consideration in **scoping the spatio-temporal scale and boundaries** of the assessment. Utilizing political boundaries can lead to inappropriately characterizing risks. For example, migratory species may be exposed to a variety of stressors across their range, and it is important that an assessment can properly account for those stressors, and identify appropriate management actions.
- Characterizing **cause-effect relationships** is a complex but important exercise to get right. This can be particularly difficult when data/knowledge about valued components or stressors are limited. Assumptions about the nature of stressors, and / or the vulnerability of valued components can lead to management actions that are not effective.
- In many multi-layered monitoring programs, **data collection focuses only on ecological condition**, to the exclusion of monitoring stressors. This can make it difficult to precisely understand the causes of changes in ecological indicators.

Cross-cutting

- Defining the correct **threshold** to trigger certain management actions can be a challenging exercise. Research to make a quantitatively informed recommendation may be limited, and it can be difficult to define thresholds based on values.
- **Aligning Indigenous Knowledge and Western Science** is difficult, however there is an emerging body of academic work on this topic (Smith 2010; Kimmerer 2013; Two Worlds Consulting 2019).

2.1.2 Best Practices

A number of strategies to address the aforementioned challenges emerged in the literature review. Like the challenges, they can be grouped as **governance**, **technical**, or **cross-cutting** (Kurtz et al 2001; Jones et al 2010; Dube et al 2013; Scholes et al 2013; Judd et al 2015; Pickard et al 2018a; Pickard et al 2019; Pickard et al 2021; Hollarsmith et al 2021):

Governance

- **Rights holders and stakeholders should be meaningfully involved** at each phase of the process. Ensuring fulsome participation of Indigenous communities means a commitment to enabling meaningful engagement/consultation at all phases of an assessment (a recent trend has been to involve Indigenous communities in the risk assessment phase, but fulsome engagement in the planning and scoping phase has been comparably infrequent). After all, who gets to contribute to planning and decision-making will have a substantial influence on the process and its outcomes.
- Developing and **following a clear cumulative effects assessment framework** is critical for successful implementation. At their most basic, cumulative effects assessments include three key steps:
  - **Scoping**, which includes defining the purpose and objectives of the study; identifying the spatio-temporal boundaries and assessment scale; identifying the valued components and stressors to focus on; and understanding cause-effect relationships.

- **Assessment**, which includes determining the reference or baseline condition; assessing the magnitude, significance, and associated uncertainty for each pathway of effect; and assessing alternative scenarios.
- **Management**, which includes implementing management alternatives and mitigation strategies; and implementing a monitoring and evaluation plan.

Each of the three steps may be subdivided into two or more intermediate steps to provide additional clarity into specific objectives or approaches, and responsibilities of various parties involved (e.g., defining explicit linkages to planning frameworks, establishing a data/knowledge collection phase, providing explicitly guidance around pre-planning and early engagement). The framework should clarify how the assessment will link to other governance processes, including informing local or regional (marine) planning frameworks, setting limits on development activities, informing project-based impact assessments, and informing marine science.

Table 1

Some of the techniques that can be used to address scale issues in social–ecological assessments. Some of the techniques are expanded on in the text

Techniques	Steps in the assessment process (not necessarily sequential)				
	Scoping, planning, establishing	Assess current state	Develop and explore scenarios	Identify and analyse response options	Communicate to stakeholders
Scenario analyses [23,24]	Identification of key drivers and uncertainties that may shape the future can help identify the relevant scales for assessment	Places current state in the context of past trends and potential future trajectories	Explores the consequences of potential alternative future trajectories of the system, depending on how key uncertainties unfold	Can help highlight key actions needed to avoid undesirable future trajectories of development, or actions that would be robust in the face of a range of very different futures	Qualitative storylines (potentially supported by quantitative analyses) can be a very powerful way of engaging stakeholders in a discussion of the future, and consideration of key system uncertainties
Space–time domain plotting (e.g. [31])	GIS overlays for spatial footprint. Log–log space–time plots for key interactions	'Characteristic scale' can be formally determined from Fourier analysis or semivariograms	Concept of 'fast variables', 'slow variables' and 'very slow variables'	Timelags for implementation Biophysical and social–cultural area of suitability	Time and space frames of: politics, business, major infrastructure planning, social–cultural change
Institution/actor power, reach and jurisdiction mapping (e.g. [30,32])	Legal responsibilities, market arrangements (e.g. economic blocs, trade, social–cultural links)	Resource tenure: protected, private, communal	Exploring how decisions at one institutional level may impact on/ interact with decisions taken at another level	Jurisdictional scope	To whom you must communicate? Consider the time and space frames of politics, business, civil society and social–cultural change. Reflexive governance [32]
Network/connectivity analysis (e.g. [30])	Decide if this is a scale-specific, multi-scale or cross-scale problem with each issue	Use to identify semi-discrete SESs — strong interactions within, weak between ecological components and/ or social actors	What key interactions need to be represented in the models? What can be treated as boundary conditions? Which social connections might shift in future?	Use to identify key actors for leveraging system change, as well as vulnerable areas, unintended ecological consequences and secondary effects	Can help to highlight key actors so that they can be engaged to help bring about system change
Nested/downscaled modelling [25]		Good way of doing complex, non-linear downscaling	Nested scenario modelling		
Disaggregation [12•]		Disaggregation of data is always a one-to-many problem, therefore can only be probabilistic	High-resolution modelling, driven by high-res covariates	How do actors and incentives change as scale changes?	Fine resolution mapping is often more satisfying to users, but should be done with caution if based on coarser scale analyses
Aggregation [12•]		Issues of sample bias and loss of information as you upscale	Feed local outcomes upwards to higher scale scenarios as integrity test	Can responses be scaled up or down or are they scale-specific? Should they be rolled out or replicated?	Necessary to simplify messaging, but needs to be transparent and accompanied by distributional and error. Be aware of morphing of variables and drivers information

Figure 2-1. Scale-aware methods for multi-layered cumulative effects assessments. Excerpted from Scholes et al (2018).

- Traditional project-based impact assessments focus on project-specific activities and stressors and evaluate the anticipated impacts to valued components. These assessments are inherently limited in scope, as they may neglect to assess impacts to valued components in context of other non-project-based stressors (e.g., climate change, other developments). A strength of cumulative effects assessment is the ability to **focus on valued components**, and assess the effects of all stressors, regardless of source. The current BC and Federal legislation require project-specific assessments to consider cumulative effects and regional cumulative effects assessments are one tool within the current Impact Assessment Act (2019).

Technical

- **Establishing standardized terminology** for commonly used concepts can help to get participants and practitioners align their understanding of the process and its objectives. For the CEMS program, we found that multiple terms were used to describe what many impact assessment practitioners refer to as valued components - for example, receptors, assessment priorities, and connections.
- Cumulative effects assessments should use **ecologically relevant boundaries**, rather than political boundaries. Valued components don't often conform to political boundaries, and using appropriate boundaries ensures a more complete understanding of stressor-valued component relationships.
- **Centre the assessment on valued components**. Focusing on stressors rather than valued components narrows the assessment to a subset of the stressors that affect valued components. A more holistic approach starts with valued components, and understanding the full range of stressors that affect them (after all, valued components are what people are about).
- **Using "scale-aware" methods** can help in addressing some of the complexities inherent to multi-layered cumulative effects assessments. These methods explicitly force practitioners to confront scale issues (e.g., assessing the scale at which valued components are best assessed, identifying linkages between processes at different scales, or exploring how decisions made at one scale will affect other scales). Scholes et al (2018) compile a set of methods applicable to one or more phases of multi-layered cumulative effects assessments, reproduced in Figure 2-1.
- Since it is not possible to "measure everything," **indicators for each valued component should be carefully selected**. Indicators should satisfy multiple criteria:
    - They should be relevant to the assessment question being asked and accurately characterize the social, cultural, economic, or ecological process.
    - They should be feasible to implement, given technological, financial, logistical, and other constraints.
    - They should accurately characterize conditions for relevant spatio-temporal scales and minimize bias.
    - They should provide information that is directly relevant to decision-making processes (e.g., the selection of management alternatives).
- **Data/knowledge should be collected for both valued components (status, trend) and stressors,** to better link changes in stressors to the condition of valued components.
- Novel **qualitative methods** can help overcome data/knowledge gaps, which are common in cumulative effects assessments by incorporating a variety of data/knowledge sources and enabling collaboration between experts with different knowledge sets.

Cross-cutting

- **Choose an appropriate scale for the assessment. Right scaling** refers to "adjusting the scale of a study to be close to the desired scale required by key stakeholders and the resolution to be small enough to adequately represent the within-system heterogeneity and processes insofar as they materially affect the decisions that may be based on the study" (Scholes et al 2013, p.18). Right-scaling should also consider: the scale of the stressors, and their impacts to individuals and populations; the scale of relevant ecosystem services; the necessary resolution of data/knowledge to inform management decisions; recovery time and recovery potential; the interests of participants; and information availability.
- For cumulative effects assessments that include data/knowledge collection, establishing a system to **coordinate and standardize data/knowledge collection among participating agencies** can help to eliminate duplication and reduce data/knowledge gaps. A commonly used method to coordinate between agencies is the master sample, which consists of a single set of sampling points, shared among agencies (Larsen et al 2008; van Dam-Bates 2018; Eyzaguirre et al 2019). Although this method requires additional effort up front, it can lead to strengthened collaboration among agencies, and reduces the effort required to integrate data/knowledge from multiple agencies. Likewise, successful implementation of multi-layered data/knowledge collection requires the use of comparable measurements for indicators within each scale, and the ability to link indicators across scales.
- Indicator **conditions should be explicitly linked to management changes** or escalations (including intensifying data/knowledge collection or monitoring) based on evidence-based thresholds.
- In cumulative effects assessment, it is important to **correctly establish the reference condition**. Deciding how to define the reference condition can be controversial and can be a road-block to getting started. Depending on the objectives of the assessment, the reference condition may be characterized as the present conditions, or historical baseline. Quantitative historical data may not be available, especially if the aim is to establish a pre-impact baseline. Indigenous Knowledge and / or expert elicitation may be used to support the development of a reference condition.
- It is important to consider the Indigenous perspective at all stages of a cumulative effects initiative. Indigenous Knowledge should not be pigeonholed as a data-source, but conceptualized as a functional way of thinking about the how to address the problem. Indigenous and Western world views may be woven together to create a more informed and holistic understanding of the ecosystem.

3 Community Guidance

Co-development is a foundational aspect of Transport Canada's CEMS initiative and as such, community participation is a critical component to all aspects of the CEMS. While this report was

drafted in a relatively short time-frame (less than three months), it was guided by input from participating Nations during two virtual meetings held on March 16th and 17th, 2022.
The objectives of the virtual meetings were to:

- Introduce the ESSA project team and explain our role in supporting the CEMS initiative.
- Listen to First Nation delegates and have them provide direction with regards to (a) what they would like a multi-layered assessment to accomplish (i.e., what does success look like?) and (b) provide guidance on the proposed content of the report.

3.1 What Does Success Look Like?

Previous engagement sessions between Transport Canada and some of the participating Nations included soliciting feedback (through Mentimeter) where participants felt the biggest opportunity / value of the CEMS work (Figure 3-1).

Figure 3-1. Feedback from First Nations participants during a pre-assessment workshop (17 January 2022) to the question "What do you see as the biggest opportunity/value of the CEMS work?"

These comments can loosely be organized into the following themes:

1. Collaboration between Nations, across the region
2. Baseline data collection & data integration
3. Conservation benefits & habitats
4. Stewardship (including capacity building and Guardian programs)
5. Government to Government relationship

During the virtual meetings, participants were asked to reflect on the first 4 of these themes and share insights or guidance for each theme including: special considerations, challenges, or opportunities related to a multi-layer initiative like the CEMS. Insights were shared using mentimeter.com, a virtual engagement tool (Figure 3-2 through Figure 3-5) as well as through dialogue. The following sections summarize the contents of the discussion.

3.1.1 Collaboration

Figure 3-2. Mentimeter feedback for the discussion focusing on how collaboration would be addressed in the CEMS multi-layered assessment approach in South Coast BC.

The Mentimeter feedback on collaboration (Figure 3-2) and subsequent discussion suggested three key themes: the need for transparency throughout all aspects of the process, the need to ensure participation is possible and fair, and the need to be flexible to the needs and challenges of different Nations. In addition, a number of specific collaboration opportunities were identified.

Transparency

- Transparent decision making, setting goals and objectives
- Clear communication
- Communication of analyses

Participation

- Patience to ensure participation is possible for everyone
- Equal opportunity for input
- Recognizing differing capacity of different Nations
- Different levels of leadership (community members, technical representatives, Nations, organizations such as Ka:'yu:'k't'h'/Che:k:tles7et'h' First Nations or Maa-nulth Treaty Society, across international borders)

Flexibility

- Different ways of communicating
- Different abilities to participate
- Differing capacity

Opportunities

- The Indigenous Technical Advisory Network (ITAN) could be expanded to support collaboration

- Connection with other Nations, longer term partnerships
- Collaborate to solve common problems
- Could share methods, data, training

3.1.2 Baseline Data and Data Integration

Figure 3-3. Mentimeter feedback for the discussion focusing on how data integration and baseline data collection would be addressed in the CEMS multi-layered assessment approach in South Coast BC.

The Mentimeter feedback on baseline data and data integration (Figure 3-3) and subsequent discussion raised a number of issues or considerations including:

Understanding Current and Baseline Conditions

- The current condition of the environment should not be considered the pre-impact “baseline.” It is important to include Indigenous communities in defining an appropriate baseline (i.e., point of comparison) for the current context.

Indigenous Knowledge and Western Science

- Respect of Indigenous knowledge.
- Build on Indigenous knowledge w systematic surveys.
- Integrating or braiding world views. This conversation has started but only at a relatively high level, thinking about community driven values and recognizing that there is a spectrum of Indigenous Knowledge integration.

Data Governance

- Respect for confidential information.
- Data sharing agreements.

Participation and Access

- First Nations should be involved in collection of data and documenting knowledge (if applicable to CEMS).
- Data should be accessible, it can be hard to access within some projects currently.
- Don't know where the information is going, generally speaking.
- Access to data and management tools.
- Analyses should be accessible to everyone and understood by everyone (refer to transparency theme from above).

Relevance - Decisions

- What resolution is needed to answer the questions or inform decisions of interest?
- Informed decision making.
- Understanding the link to the management levers, finding the point where data/knowledge is useful to inform management at both sub-regional and regional scale.

3.1.3 Conservation Benefits and Priorities

Figure 3-4. Mentimeter feedback for the discussion focusing on conservation benefits and priorities for the CEMS multi-layered assessment approach in South Coast BC.

The insights shared and discussion on **conservation benefits** centered around the question of *how the regional initiative can support the sub-regional interests,* and to a lesser extent how the sub-regional initiative can support regional interests.

Power in Collaboration

- More informed decision making.
- Evidence to support protection of Valued Components.
- More voices to influence policy and legislation.
- Understanding of broader conservation priorities, including identifying areas of concern to each Nation.
- Better understanding of the whole picture.
- Power in common priorities.

Efficiencies

- Comparison to different approaches.
- Less duplication of efforts.
- Learning from other processes (from other sub-regions / Nations), what worked or didn't work.

The concept of **prioritization** was also discussed at length and the point was raised that in general Indigenous communities have a hard time with prioritization because the very nature of their world view recognizes the holistic nature of the ecosystem and the inherent importance of all components as part of the whole. Some interesting opportunities and thoughts emerged from the discussion.

- Finding similarities in priorities among Nations for more wide spread conservation projects and co-management opportunities.
- Can learn from other processes (sub-regions) what worked or didn't work, these lessons may be useful from the regional to sub-regional scale, across sub-regions, or from the sub-regional to regional scale.
- The project team suggested that it might be helpful to reframe as 'providing focus' rather than 'prioritizing values'. This idea may allow for better use of resources to address key uncertainties or mitigate / manage the most severe or impacts, while still recognizing the value of all components.
- Another opportunity that emerged was to recognize that there is **also value in the differences** among sub-regions. Consider a scenario where each sub-region investigates different valued components which might be of particular concern locally. Each sub-region can take the lead on figuring out how to monitor and interpret the information, they may develop protocols, analysis tools, identify thresholds or generate other insights that could all be leveraged by other sub-regions over time. In addition, with this scenario, Transport Canada would at least have some information about a large number of valued components within the region, even if at a reduced spatial scale.

3.1.4 Stewardship and capacity

Figure 3-5. Mentimeter feedback for the discussion focusing on opportunities to advance stewardship objectives and build capacity for participating First Nations.

There was substantial overlap in this conversation with themes from earlier discussions, in particular with respect to **capacity and the limitations of some First Nations to participate**. There were however a few new points that were shared:

Developing long-term capacity

- This initiative is just a starting point.
- Recognize the importance of building capacity and processes (e.g., methods, monitoring and data collection /knowledge documentation) that can endure for the long-term (i.e., beyond the funding cycle of the current CEMS initiative).
- Informing the "care for the shorelines and ocean affected by future changes in marine shipping".
- More human resources are required.

Decision making and bi-lateral conversations

- As noted above, there are concerns around how decisions are made given the different levels of capacity for different Nations.
- There are multiple decision making fora that First Nations may participate in in the South Coast region. Decisions made at any one forum may affect a First Nation, but fulsome participation in each is limited by available capacity.
- Bi-lateral conversations are very important. First Nations would like to ensure that they are provided with the opportunities to meaningfully contribute to the CEMS process, and that they have the necessary time to consider their input at each engagement phase.
- As the CEMS process proceeds, transparency (in how data/knowledge is used, how decisions are made, etc.) is key to the relationship between First Nations and the government.
- Co-development of stewardship programs and involvement of First Nations in those programs.

3.2 Round Table Discussions

The mini-workshops wrapped up with a brief round table to allow participants the opportunity to provide feedback and / or guidance to the project team. Insights from First Nation delegates who participated are briefly summarized here:

- As we move into the 'assessment' phase (data and analysis) trust is a huge issue. It is important to make sure First Nation communities are at the table, to have early discussions, while recognizing the capacity limitations.
- Would echo the comments about trust. Time and political will (is there the political will to take the time that this process needs?). We are meeting with so many people, we are excited but overwhelmed. There is limited data/knowledge and CEMS doesn't have funds to support new environmental data collection. I want to ensure we can trust the process. I worry about decision making based on limited data that isn't representative of the whole coast. It is important to be clear about gaps in data/knowledge. The small-scale is important… but *also* - how do you connect everything with the big picture too. It is challenging to identify priorities. I like the idea of using natural boundaries not political boundaries.
- Trust and capacity are extremely important. In addition, making sure the assessment approach is long-term. There is a lot of work going into it and it is important to make sure it is relevant in an ongoing way. Trying to address the challenges, making sure all the valued components are included, and limiting gaps across the region.
- The FNFC is developing a CE assessment framework that may be complementary to this work.

Insights from the Transport Canada and project team are briefly summarized here:

- We are hearing the message about differences in capacity and diversity of priorities. Sub-regions operate differently based on local priorities and the CEMS needs to reflect that back, reducing redundancies while allowing for flexibility.

- The purpose of this vision is to eliminate redundancies to make the best use of people's time. To think about how to scale up and scale down based on interest.
- One way for a community to ensure longevity is to take the lead on their own vision for how cumulative effects should be addressed in their Territory (i.e., develop their own Cumulative Effects Management Strategy). This puts the community in the 'driver's seat' and helps position them to take advantage of opportunities like Transport Canada's CEMS, where the community can obtain support from Transport Canada where there are overlapping interests. This is becoming more common and there are examples of this described below in the Strategic Vision.

4 Context in South Coast

The CEMS multi-layered assessment approach in South Coast BC is following the national CEMS cumulative effects assessment framework, which defines six phases: Early Engagement and Planning; Scoping; Assessment; Decision Making; Action; and Evaluation and Reaction (all phases are linked through an adaptive management approach) (Figure 1-2).

The South Coast regional assessment approach has progressed through the Early Engagement and Planning, and the Scoping phase is almost complete. The Early Engagement and Planning phase consisted of engaging First Nations to discuss how collaborative planning should take place, resulting in coming to a common understanding about the goals for the initiative, and the guiding principles that should inform the process. Engagement with the First Nations Fisheries Council (FNFC) and the VMCC in the Early Engagement and Planning phase resulted in the drafting of a living workplan, which outlines five project goals, quoted below:

- *“Co-develop a suite of mitigation and management measures which will be jointly (FNFC/TC) recommended to address adverse regional cumulative effects of marine shipping, and used to influence decision-making processes that may affect the manner in which First Nation’s territories are managed. The recipient of these recommendations will depend on relevant authority and the nature of the recommendation, e.g. Departmental technical working groups; TC’s Regulatory process; other relevant authority within TC, CCG, DFO, etc).*
- *“Create working relationships and seek opportunities for collaboration with relevant federal government departments, First Nations, provincial governments, the shipping industry, coastal communities, non-governmental organisations and other marine stakeholders, as needed and appropriate.*
- *“Identify shared priority marine shipping issues and assessment priorities that are founded on the Indigenous values identified by the VMCC, specific to the area of South Coast BC and complete an RCEA for these issues and assessment priorities.*
- *“Develop a knowledge library / database of existing information that can be used to inform and undertake the CEMS RCEA*

- *"Provide input into the development of a national CEMS framework, a guidance document that will help inform the conduct of regional cumulative effects assessments across the country."*

One major and recurring concern heard though early engagement with the VMCC was the need to also engage First Nations in South Coast BC at a bilateral or collaborative level around localized marine shipping issues. Since the geographic scope of the South Coast BC regional pilot is large, some First Nations were concerned about their interests being lost at the VMCC table. To address this, TC began meeting with interested First Nations in South Coast BC on a bi-lateral and/or collaborative basis, forming sub-regions, as depicted by the green dots in Figure 1-1 (see also multi-layered assessment approach depicted in Figure 1-2).

The Scoping phase is either underway or complete at the regional table and the majority of the sub-regional tables. This phase included defining the regional and sub-regional scales; determining assessment priorities (valued components, stressors, and pathways of effect) at each scale; and defining a strategic vision for the multi-layered assessment approach.

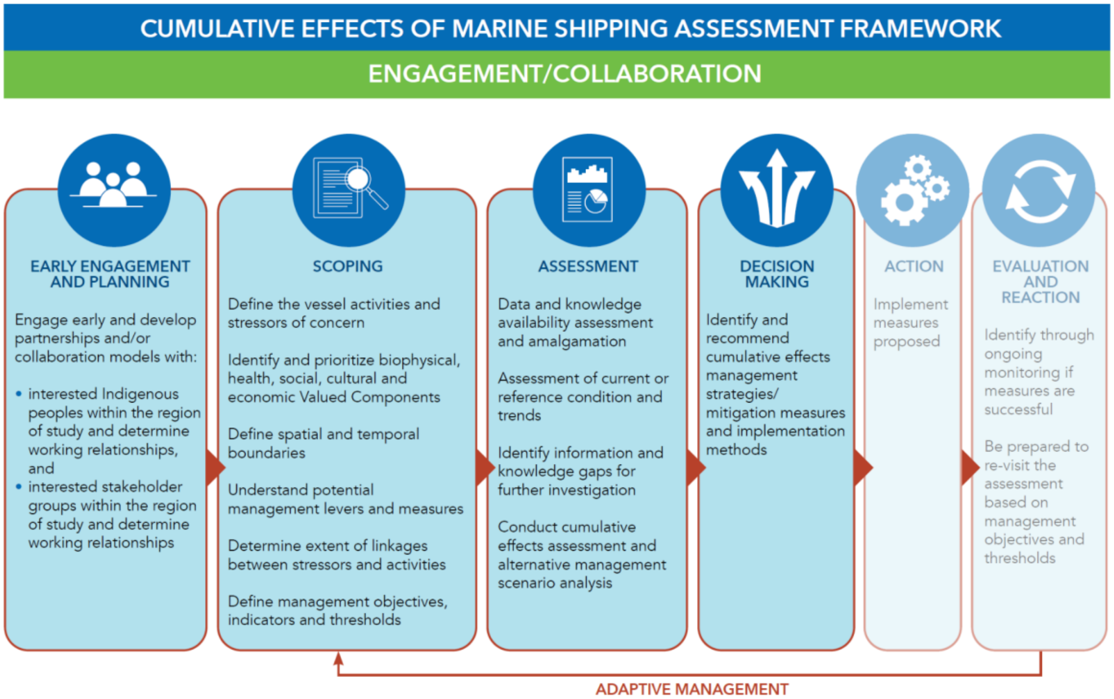
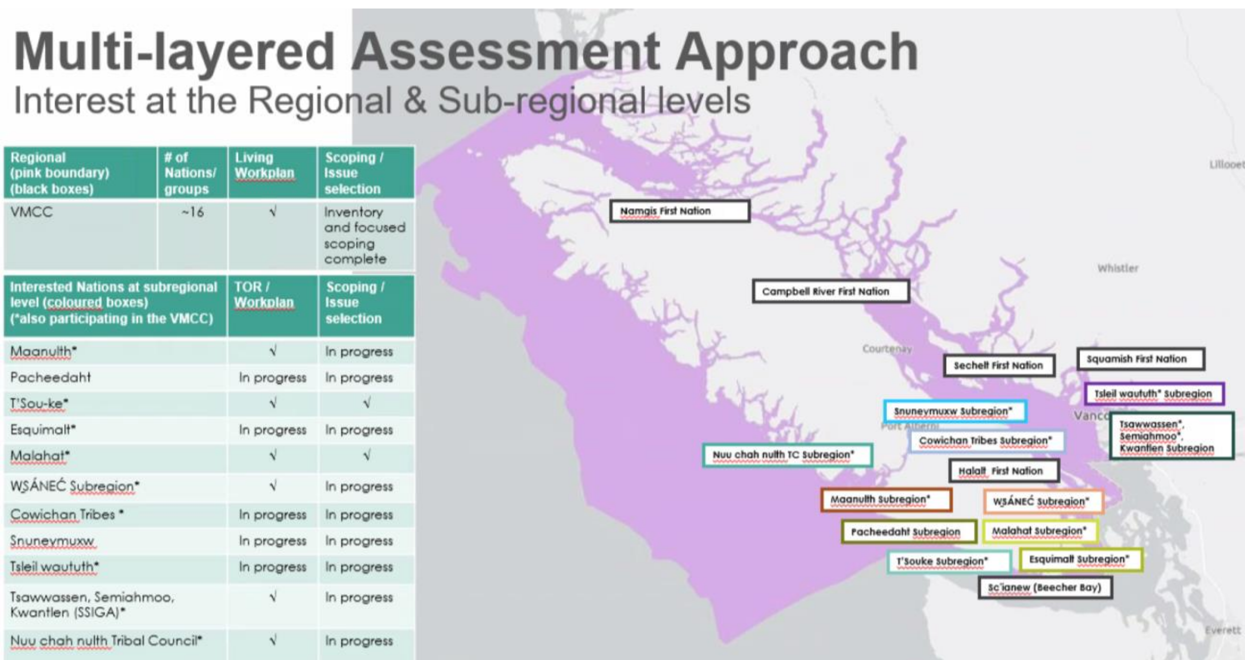


Figure 4-1. Transport Canada's CEMS national assessment framework.



Regional (pink boundary) (black boxes)	# of Nations/ groups	Living Workplan	Scoping / Issue selection
VMCC	~16	√	Inventory and focused scoping complete
Interested Nations at subregional level (coloured boxes) (*also participating in the VMCC)		**TOR / Workplan**	**Scoping / Issue selection**
Maanulth*		√	In progress
Pacheedaht		In progress	In progress
T'Sou-ke*		√	√
Esquimalt*		In progress	In progress
Malahat*		√	√
WSÁNEĆ Subregion*		√	In progress
Cowichan Tribes *		In progress	In progress
Snuneymuxw		In progress	In progress
Tsleil waututh*		In progress	In progress
Tsawwassen, Semiahmoo, Kwantlen (SSIGA)*		√	In progress
Nuu chah nulth Tribal Council*		√	In progress

Figure 4-2. Status of regional and sub-regional scoping for the South Coast BC Regional Pilot.

4.1 Indigenous Knowledge

Indigenous peoples are the sole owners of their knowledge and therefore the only ones who can define it. Indigenous knowledge (IK) is gathered over generations of experience and interactions within an environment and are inseparable from regionally specific Indigenous values and culture. IK and science represent different ways of understanding the environment and our place within it. All should be understood as complementary worldviews that, when appropriately weaved together, create a more informed and holistic understanding of an ecosystem.

There are no universally accepted definitions of IK. These terms are used to communicate a body of knowledge borne out of Indigenous ways of life and informed by Indigenous peoples' intimate relationship with their natural world. Among available definitions of IK, certain common traits exist. For example, IK is:

- Rooted in Indigenous traditions, languages, cultures, and history;
- Holistic in nature and closely linked to the environment;
- Cumulative and dynamic, growing and expanding with the experiences of individuals and communities; and
- Integral to and inseparable from the livelihoods of Indigenous peoples

4.1.1 Working with Indigenous Knowledge

The United Nations Declaration on the Rights of Indigenous Peoples states that "Indigenous peoples have the right to maintain, control, protect and develop their cultural heritage, traditional knowledge and traditional cultural expressions, as well as the manifestations of their sciences, technologies and cultures, including human and genetic resources, seeds, medicines, knowledge of the properties of fauna and flora, oral traditions, literatures, designs, sports and traditional games and visual and performing arts. They also have the right to maintain, control, protect and develop their intellectual property over such cultural heritage, traditional knowledge, and traditional cultural expressions."

On June 21, 2021, the United Nations Declaration on the Rights of Indigenous Peoples Act received Royal Assent and immediately came into force. This legislation advances the implementation of the Declaration as a key step in renewing the Government of Canada's relationship with Indigenous peoples.

While the weaving of IK is a foundational piece to the CEMS initiative[1], this knowledge can be culturally sensitive and include information the community may want to protect from public disclosure. Knowledge holders and / or their communities have control over their knowledge and may have requirements or conditions for working with it. It is important to TC to remain adaptable and respectful when approaching sensitive Indigenous knowledge, as well as to abide by the OCAP® (ownership, control, access and possession) principles outlined by the First Nations

[1] At the national scale, the CEMS initiative will also work alongside Inuit communities; the same principles will therefore apply to Inuit Qaujimajatuqangit.

Indigenous Governance Centre. TC employees working with IK must respect community protocols, including any protocols concerning the handling, storage, access or integration of knowledge. One way TC is demonstrating this respect is by helping establish data sharing agreements between third-party contractors and Indigenous peoples. Through this process, a third-party contractor may work directly with Indigenous peoples to access and incorporate IK and IQ in their work, while only providing TC with a high-level summary of that information to bypass the need for TC to access the specific sensitive data/knowledge itself. It is important to note that this is just one approach to incorporating IK within a CEA, and that each approach should be regionally specific and directly informed by Indigenous partners.

5 Strategic Vision for the South Coast

The proposed Strategic Vision is not prescriptive, recognizing that different sub-regions will have different needs. It is framed as a 'road map,' with pit-stops along the way. Each pit-stop is associated with a 'menu' of options for how to proceed, allowing for maximum flexibility, and leveraging insights from the literature review.

The road map provides a list of considerations as the CEMS process in South Coast BC moves from the **scoping** phase into the **assessment phase** and eventually on to **decision making** and subsequent phases and achieving success as defined by participants.

As for any vision, it is important to have clear goals which are understood by all partners. The goals of this strategic vision for a multi-layered assessment, from Transport Canada's perspective is to:

- Enable concurrent assessments, at the regional, and sub-regional scale, that are mutually supportive.
- Enable collaboration with partners, including (existing or future) Indigenous-led cumulative effects frameworks, other government departments, academia, ENGO’s, and / or the marine shipping industry.
- Efficiently utilize resources, and reduce duplication.
- Enable braiding and aligning of Indigenous knowledge and western science in the approach.
- Develop an understanding of how the assessment layers relate to each other (e.g., with regards to baselines, current conditions, valued components/indicators, conceptual models, data/knowledge amalgamation, metrics used for assessment, management objectives, thresholds/benchmarks and mitigation/management actions).

First Nations participants identified a combination of process and outcome goals including: improved collaboration across the region; data/knowledge integration; improved stewardship and capacity, and ultimately achievement of conservation benefits (Figure 3-1). More detailed insights are provided in Section 3.

Understanding how both Transport Canada and First Nation participants view success sets the target or destination for the road map.

5.1 Road map

The road map is intended to be a simple and flexible framework that can be employed to support the CEMS multi-layered assessment approach in South Coast BC (Figure 5-1). The pit stops or considerations along the way were identified through a combination of ESSA's collective experience and challenges and best practices from the literature review (Section 2).

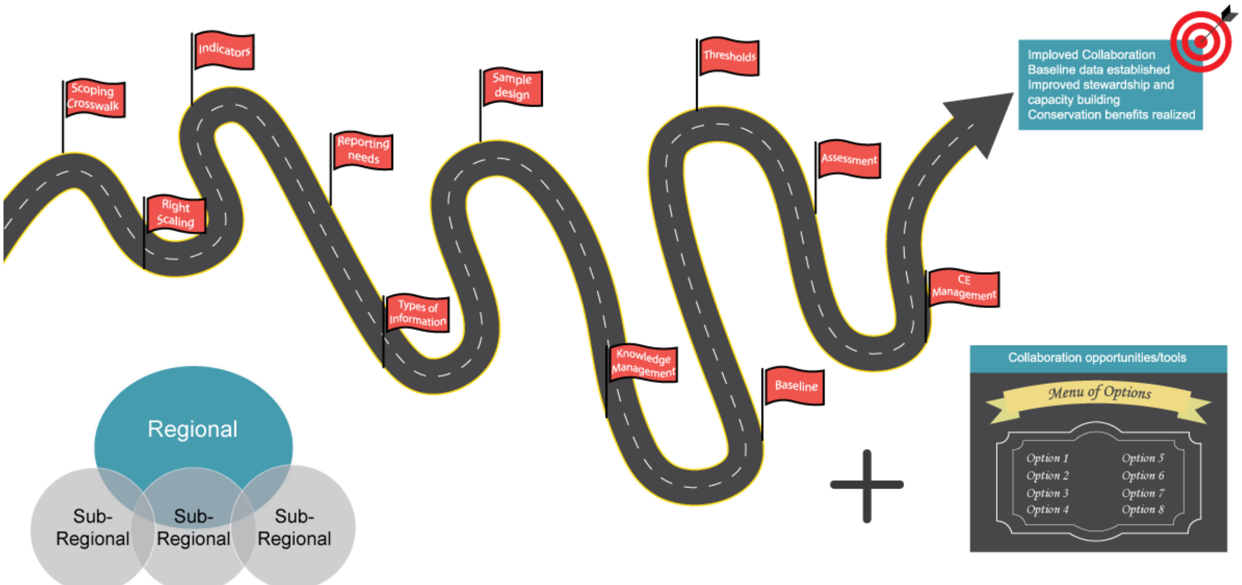


Figure 5-1. This figure illustrates the possible pit stops or considerations that may be important as the initiative moves from scoping into the assessment phase, and ultimately towards CE management and success as defined by participants. For each consideration, a menu of options is provided.

5.2 Opportunities for Collaboration

Within each menu item, there may be opportunities for participating First Nations to collaborate and share knowledge with each other that could be leveraged to provide direction for the CEMS multi-layered assessment approach in South Coast BC (see Table 5-1). Collaboration opportunities exist at both the regional and sub-regional scale, and effort should be allocated to ensuring that lessons learned at one scale can inform processes at the other scale.

As the CEMS multi-layered assessment approach in South Coast BC will rely on existing environmental data/knowledge for the assessment, the opportunities for collaboration primarily lie in workshops where the various components of the assessment can be discussed. If data/knowledge collection is enabled either through CEMS or through identifying linkages to other projects, different opportunities for collaboration may be unlocked, including: developing sampling plans, sharing personnel, equipment, or data, skill sharing exchanges, and applying for funding together.

Table 5-1. Opportunities for collaboration within each Pit Stop and Menu Item.

Pit Stop	Menu Item	Collaboration Opportunities
Scoping	**Identify valued components, stressors, activities, and pathways of effect**	Sharing knowledge about valued components, stressors, activities, and pathways of effect. Provide spaces for community members to share knowledge and build common understanding.
	Develop Indigenous-led cumulative effects framework.	First Nations seeking to develop their own cumulative effects frameworks may reach out to, and learn from other Indigenous Nations (e.g., Metlakatla, Gitxaała, Tsleil-Waututh, co-management boards established through northern land claims) who have developed their own frameworks and will be able to share lessons learned. First Nations may opt to develop their own framework, or partner with other Nations to develop a regional approach to cumulative effects management.
	Decisions / Management Options (relevant to TC)	Sharing knowledge to identify and scope management alternatives. Preferred management alternatives may differ by sub-region, depending on each First Nations' concerns, interests, and values and those available to TC.
Scoping Crosswalk	**Identify common ground**	Identifying indicators for which First Nations see value in amalgamating data/knowledge, conducting a regional assessment, or reporting regionally.
Right scaling	**Identify natural boundaries**	Bring First Nations assessment participants together to collaboratively identify natural boundaries, and discuss the optimal spatial and temporal scale of assessment for each valued component. This step may involve one or more "right-scaling" workshops that could make use of scale-aware methodologies (Figure 2-1) to facilitate discussion around boundaries and scale.
Indicators	**Indicators**	For the regional and sub-regional assessments, First Nations should be involved in collaborative discussions to develop indicators. In the Indicators section below, we provide a list of discussion questions and propose a tiering strategy that could be used to facilitate discussions around indicator selection.
Reporting Needs	**Reporting Needs**	There may be opportunities for First Nations to collaborate in a workshop to discuss: ● The appropriate scale for reporting (reporting need not be at the same scale as data/knowledge analysis). ● Data privacy concerns and how to address them in reporting. Optimal reporting modalities to communicate information in a culturally sensitive way (i.e., finding the "story" in the data).
Types of Data or Information	**Data Type** **Uncertainties** **Gaps**	There may be opportunities for First Nations to be partners in developing and implementing data/knowledge collection and analysis approaches.
	Redundancies	First Nations may be able to participate together in training opportunities to build local capacity (e.g., participatory mapping, Indigenous knowledge documentation, GIS data management and analysis, facilitation).
Data and Knowledge Management	**Data and Knowledge Management**	There may be opportunities to share raw data/knowledge and / or results between First Nations, or contribute to a regional data/knowledge collection initiative. It may be possible to establish a single data management system (e.g., a relational database) for a group of First Nations to support shared interests in data/knowledge collection and reporting.

Pit Stop	Menu Item	Collaboration Opportunities
Integrated Sample Design	Sampling Design	If data/knowledge collection is initiated, sub-regions could establish standardized collection methods, and utilize a regional master sampling frame to maximize interoperability and find efficiencies in sampling effort. First Nations could also collaborate to develop a CE oriented monitoring program (e.g., the Coastal First Nations' Regional Monitoring System).
Thresholds	Thresholds	There may be knowledge sharing opportunities to identify thresholds. There may not be regional agreement about thresholds however, as thresholds will reflect how each community values a particular feature.
Baseline	Historical or Current Condition	Sharing knowledge to understand the historical and / or current condition of each valued component. Given limited information availability, an approach that brings together members of multiple First Nations may help to address gaps, and provide valuable opportunities to share knowledge.
Assessment Methods	Assessment Methods	Collaboration to develop scenarios, identifying analysis methods, data/knowledge interpretation.

5.3 Menu

For each pit stop or consideration identified in the road map, a corresponding menu of options, considerations, and in some cases, tools are provided. This report does not provide an exhaustive selection of options, instead, we provide a useful starting place and could be updated over time with new tools or lessons learned. The focus of the content in this section is on ***resolving common challenges associated with multi-layered initiatives*** as identified in Section 2. An earlier Transport Canada report (Pickard et al 2019) provides a detailed summary of cumulative effects assessment methodologies that might be applied to marine shipping issues.

5.3.1 Scoping

For the purpose of this strategic vision, it is assumed that scoping is complete (or at least the preliminary round) before working through the next steps/considerations described in this section.

As illustrated in Figure 1-2, Transport Canada's CEMS multi-layered assessment approach in South Coast BC requires scoping at multiple scales. Transport Canada's CEMS initiative uses a stressor or activity based cumulative effects approach (Murray et al 2020); therefore, scoping is focused on impacts of marine shipping. This approach makes sense given that Transport Canada's authority is limited to marine shipping activities. However, this activity centric approach may not fully address the concerns of participating Nations given that marine shipping is only one among many impacts affecting valued components. This is a fundamental challenge of the Transport Canada CEMS initiative and a common challenge in cumulative effects assessment and management (Pickard et al 2018a). However, this filter does not need to limit Indigenous led CE frameworks. Rather **Indigenous communities are encouraged to develop their own cumulative effects management strategy/framework**, scoped to address all of the community's concerns in a way that reflect their unique knowledge, governance, and relationships (Zeeg et al 2019; Taft and Herbert 2022; Pickard et al 2022). The community can then work with Transport Canada to identify common interests (valued components) and concerns (stressors) and can leverage the funding from Transport Canada to compile information and assess those pathways of effect. Other funding sources can be pursued to support concerns that are not relevant to Transport Canada.

Taking ownership over the cumulative effects management strategy and employing multiple funding sources is one way to **ensure longevity** of the initiative. This was a concern raised by community delegates (see Section 3).

5.3.2 Scoping crosswalk

The intent of this pit stop is to lay the groundwork for potential cross-scale collaborations. It is assumed that at least a preliminary scoping has been completed for each of the sub-regions as well as at the regional scale. An excel spreadsheet can be used to compare elements across scales to identify common elements as well as those elements which are unique to a particular sub-region (see Table 5-2).

- Complete a crosswalk of **valued components** identified for each sub-region and at the regional scale. It may also be helpful at this stage to identify common categories of valued components (e.g., environmental, species, habitat, cultural, economic etc.).
- Complete a crosswalk of **stressors** identified for each sub-region and at the regional scale.
- Complete a crosswalk of **terminology** and if possible, standardize the terminology used (or at least document how different terms are used so that it is possible to translate among scales).
- Complete a crosswalk of **decisions** of interest to each sub-region as well as at the regional scale.

Table 5-2. A simple illustration of how an excel spreadsheet could be used to visually identify overlapping valued components, stressors, terminology, and decisions.

Valued Component	Assessment Layer					Opportunities
	Regional	Sub-region A	Sub-region A	...	Sub-region *N*	
Crab Habitat	X	X	X		X	
Glass Sponge Reef			X			
Knowledge Transfer					X	
...			X			
Valued Component *N*	X	X				

Another alternative tool or approach for identifying linkages among scales is to use some variation of a network analysis (Figure 5-2 and Figure 5-3) which illustrates the connections between elements.

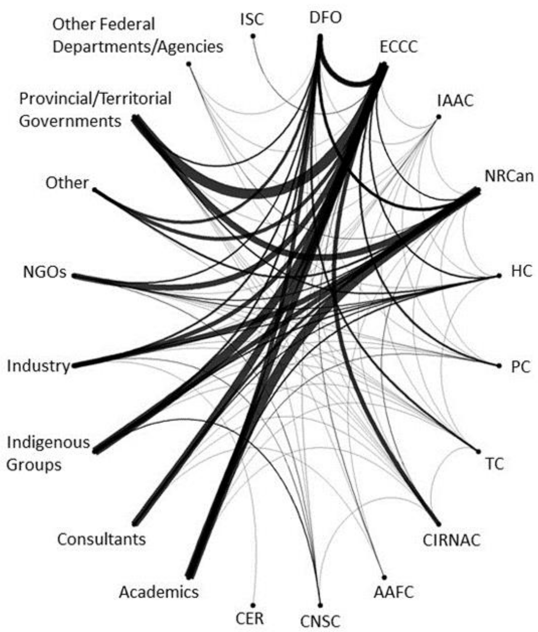


Figure 5-2. Network figure (developed in R) indicating the number of connections among Federal cumulative effects initiatives (Pickard and Litt 2020).

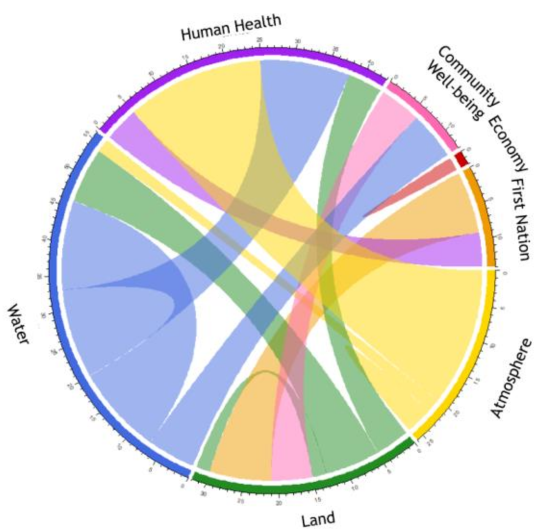


Figure 5-3. A chord diagram showing connections among indicators commonly used in Environmental Assessment (Ouellet Dallaire et al., in prep).

Once the crosswalk and / or network analysis is complete, it is possible to have a conversation about where it does or does not make sense to collaborate and how sub-regional assessments can support each other and / or the regional assessment as well as how the regional assessment can support the sub-regional efforts.

5.3.3 Right scaling

As noted in Section 2, scale must be considered at all stages of a cumulative effects assessment. Scale affects the data/knowledge collection, interpretation, reporting and management decisions. Failure to consider scale can limit the effectiveness of the assessment and in the case of multi-scale initiatives like this one, may lead to redundancies, information that can't be used to its potential, or gaps. This pit stop involves (a) describing natural boundaries (e.g., ecologically or culturally relevant boundaries rather than political boundaries) and (b) understanding the spatial and temporal context of key elements of the assessment. With this information in hand, it will be possible to determine the most appropriate multi-layer methods (e.g., scaling up or down) at each of the later pit stops (e.g., data/knowledge collection or reporting).

Identify natural boundaries

For each valued component and stressor, describe the natural boundaries relevant to each element (e.g., anchoring impacts are not a concern beyond a depth threshold depth; the range of glass sponge reefs is limited in spatial extent; the spatial extent of cultural use among Indigenous community members). The same exercise can be completed for temporal boundaries (e.g., at what point in a species life history are they vulnerable to shipping activities, and when do those shipping activities occur?). Where there are uncertainties, document this as well.

Understand the spatial and temporal context

The CEMS multi-layered assessment approach in South Coast BC includes sub-regional and regional scales as illustrated in Figure 1-2. The sub-regional scale ranges from individual Nations to groups of Nations that have chosen to align themselves. It is important to note that some sub-regional groups also participate in the regional scale initiative while others have chosen not to. The South Coast BC regional pilot can also be thought of as nested within the National CEMS initiative. This is consistent with the literature review which found that most multi-scale assessments tend to have three levels and while they are defined differently in each case they typically range from 'local', 'regional', and 'national'.

For each valued component and stressor, it is helpful to think about the spatial and temporal scales of: the life history[2], impacts, and potential recovery. One tool that may be useful is a Stommel diagram (Figure 5-4) which could be used to facilitate conversations about scale and in some cases identify interactions among elements.

It is also helpful to identify linkages between processes at different scales and explore how decisions made at one scale will affect other scales.

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[2] For non-biophysical VCs, e.g., knowledge transmission, or cultural / burial sites, life-history many not be applicable. For these VCs, it is still important to consider all aspects of scale. For example, for burial sites, one may ask whether they may be more vulnerable at certain times of the year, or at what scale it may make most sense to conduct data collection, or to assess the condition of the VC.

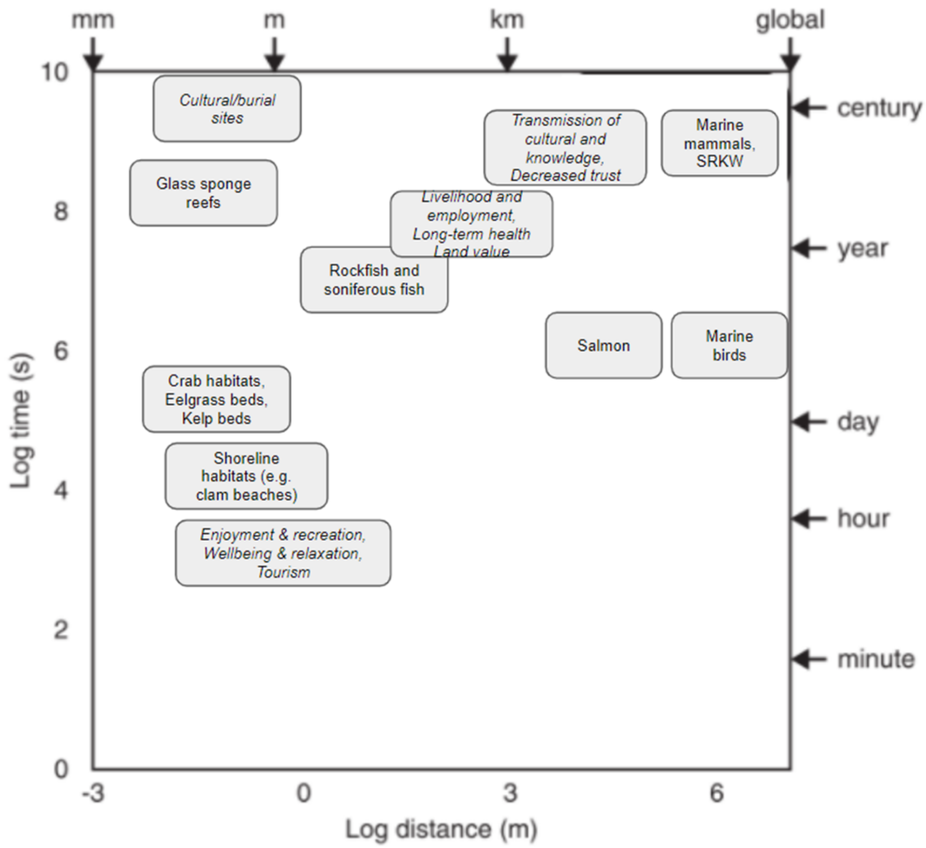

Figure 5-4. A Stommel figure to illustrate the spatial and temporal scales of each of the valued components identified in the regional assessment.

Scale is important for assessment of all valued components and stressors, however for the purpose of this report it is especially important to think about how information flows between scales. How can one scale inform the other and vice versa. With an understanding of where there are common elements (scoping crosswalk) and an understanding of the relevant scales (right scaling) it is possible to begin to identify collaboration opportunities as the assessment step progresses.

5.3.4 Indicators

As Transport Canada moves forward from the **Scoping** to the **Assessment** phase of the CEMS multi-layered assessment approach in South Coast BC (Figure 4-1), it will be necessary to determine an appropriate set of indicators for the assessment. We have developed a preliminary list of questions that can help guide discussions around which indicators to use for each valued component, and explicitly consider issues of scale (i.e., for indicator selection, reporting and analysis) (Kurtz et al 2001; Olson et al 2018). In addition, we describe a Tiered Approach to indicator selection which has been used in other multi-layered initiatives and may be suitable for the South Coast regional pilot.

Discussion Questions:

- **Value of information.** Does data/knowledge about this indicator provide useful information to help guide management decisions? (i.e., is this "nice to know," or "need to know" information?). Is this indicator closely tied to the condition of the valued component? How responsive is this indicator to changes in stressor conditions?
- **Data availability.** Is there data/knowledge available to assess the condition of this indicator? Is this indicator amenable to being assessed with both western scientific and Indigenous knowledge? Limited data/knowledge should not result in a pathway of effect being ignored; rather, the uncertainty should be identified and alternative assessment methods (e.g., expert elicitation) should be identified.
- **Temporal scale and resolution.** Is this an indicator for which a snapshot in time is sufficient to capture the current conditions? Alternatively, is a longer time-series necessary to understand its state and trends? If so, what is the necessary temporal resolution of data/knowledge (i.e., hourly, daily, monthly, annual), and is that data/knowledge available?
- **Spatial scale and resolution.** Is data/knowledge for this indicator more valuable if collected across the entire region (rather than in a subset of sub-regions)? What is the ideal spatial resolution of data/knowledge to inform this indicator?
- **Collaboration, partnerships, and capacity.** If data/knowledge availability is limited, is it possible to partner with Indigenous communities or other organizations to support data/knowledge collection? Do First Nations currently have the capacity to collect data/knowledge for this indicator given current capacity (if not, how may they be supported to develop that capacity)?
- **Standardization.** Is this an indicator for which value would be gained through standardized datasets (i.e., to enable apples-to-apples comparisons across the region)? Alternatively, is this an indicator where the metrics are likely to differ among sub-regions (e.g., sub-regions may want to adopt different approaches to measure impacts to "Transmission of culture & knowledge" differently)? Indicators meeting the former criteria are better assessed at a regional scale, while those that meet the latter are likely to be suitable for a sub-regional assessment.
- **Privacy.** Can raw data for this indicator be shared between sub-regions, or with the government? If raw data cannot be shared, can sub-regional results be combined to assess this indicator at a regional scale? (e.g., for cultural/burial sites, First Nations may not want to share the location of specific sites, but it may be feasible to share data about the number or proportion of vulnerable or degraded sites).
- **Thresholds.** Can different thresholds be developed for this indicator (i.e., depending on community-specific valuation and risk-assessment)? Is it possible to develop sub-regional management actions that could be informed by sub-regional thresholds?
- **Assessment and Reporting**. For each indicator, what is the appropriate scale for assessment and reporting? If the local condition of an indicator is highly variable across the region, or highly dependent on local conditions, it may be best to assess and report at the sub-regional scale.

Tiered Approach to Assessment:

Agreeing to **common indicators is a simple strategy to improve efficiency and rigour of a multi-layered assessment**. With common indicators, it is easier to share data, share methods, scale information up and down, improve power to evaluate functional relationships, and to better understand the variability of metrics over space and time. However, there is tension between efficiency and sub-region specific interests, concerns, and capacity. Capacity limitations and variability in capacity among sub-regions was raised repeatedly by community delegates (Section 3). **A tiered approach to data/knowledge collection and assessment is one approach to balancing efficiency with local needs and capacity** (Olson et al 2018; Eyzaguirre et al 2019). This advice is specific to cases where there are overlapping valued components and an interest in collaboration among scales.

Tiering indicators involves identifying a range of indicators for a given valued component that differ in terms of the information they provide but also in terms of the complexity and effort involved.

- Assessment **Tier A**[3] - For a given valued component, identify the lowest common denominator. In other words, what is the most basic and important piece of information that all sub-regions (interested in that valued component) can agree to collect & analyze. This should be an indicator that can be collected by all interested parties, in other words the level of effort should be defined by the sub-region with the most limited capacity. For environmental components this is usually extent or distribution.
- Assessment **Tier B** - The second tier would represent the next most desired piece of information, recognizing that not all sub-regions will have the capacity to evaluate this tier in each year. However, by agreeing on the indicator and associated methods, these data/knowledge can still be combined over time and space even with some gaps. Examples of common **Tier B** indicators are abundance or density.
- Assessment **Tier C** and beyond - The next tier provides those sub-regions with a particular interest in the valued component to dig deeper. A typical example would be to look at indicators of health. As more tiers are added the capacity needs increase, but as with **Tier B**, the power in this approach is the way in which information and inferences (e.g., functional relationships) can be shared among sub-regions.

From the regional perspective, the **Tier A** indicator ensures broad spatial coverage for at least the most critical piece of information. The **Tier B** and **C** indicators can also be aggregated to look at additional impacts over time even if on a smaller spatial scale.

[3] The "tiered" approach referenced here is different from the Tier 1 and Tier 2 language used to describe the meeting structure used by the VMCC to support Tier 1 (First Nation to First Nation) and Tier 2 (First Nation to Transport Canada) discussions.

5.3.5 Reporting Needs

It is helpful to consider reporting needs well in advance of the reporting phase. Understanding how data should be reported to provide evidence for decision making will help in determining appropriate indicators, assessment methods, as well as collaboration opportunities. Reporting needs should be driven by both regional and sub-regional decision-making processes. As noted by First Nations delegates (Section 3) there are many potential benefits to sharing information. There are a few challenges to consider, as well as a number of strategies to facilitate reporting for multi-layered initiatives.

Reporting on sensitive information

While this is an important concern, it can be readily managed by ensuring that publicly available reports share summary statistics (e.g., the number or proportion of cultural sites that have been damaged), rather than sharing raw data, such as the location of one or more cultural sites.

Ensuring accessibility of information to First Nations community members

Emerging and readily accessible technology (e.g., smartphone apps) provide potential avenues for improved reporting accessibility (this challenge is also discussed in the Data and Knowledge Management Section). An example of this is the Kotawân Portal[4] which provides access to wildlife and environmental data collected through an Indigenous led monitoring program to assess impacts of environmental contaminants resulting from oilsands development in the Athabasca region of Alberta.

Transparency of analysis and reporting

Community delegates noted the importance of transparency in how information is analyzed and used. This is an important consideration in all reports for two reasons: first, to ensure that the affected people understand and therefore can trust the information; and two to ensure that any weaknesses in the information (e.g., gaps, uncertainties, and assumptions) are explicitly noted so that the information may be interpreted with appropriate caveats. At a minimum, reports should include plain language summaries alongside graphical or map based interpretations.

Combining information that has been collected using multiple methods, or at multiple spatial scales

It is easiest to combine information collected using the same methods (i.e., using consistent field protocols within a consistent or integrated survey design). However, it is possible to combine information across scales as well as using different methodologies, although less efficient.

[4] Kotawan is a Cree word for campfire and this portal refers to the stories told around the fire. See kotawanportal.ca

In order to scale information up, it is important to watch for pseudo-replication (Hurlbert 1984), in which unequal sampling effort across space or time leads to results being skewed (e.g., if we had 100 observations in one sub-region and 20 across the remaining sub-regions but treated all 120 observations equally, thus skewing the regional estimate to the one sub-region). Instead of simply averaging all raw data, raw data should be aggregated to the lowest common scale (e.g., a sub-region), then, estimates from sub-regions can be combined to get a region wide estimate[5].

Scaling down must be done with caution and may not always be appropriate. There are situations where it may be possible to interpolate among values (e.g., interpolating sea surface temperature from a grid of gages), but doing this requires assumptions about the functional relationship between the observed data points. Pseudo-replication is also a concern for scaling down (e.g., assume a grid of 100 points representing sea surface temperature (a 10x10 grid, with 100m between each point). If these points are downscaled to a 10m resolution (now a 100x100 grid with 10,000 points), it might be tempting to treat the data as though there were 10,000 independent data points when in fact there are only 100 observations. In the context of the CEMS, it may be appropriate (with appropriate caveats) to use a regional average as a surrogate for sub-regions with no information. As noted elsewhere, it may be helpful to consult a statistician about the appropriate use / analysis of the data.

When different data collection methods are used there are a few approaches that can be used to combine data. In some cases, it may be possible to use multiple methods to estimate the same indicator. While this is not ideal (it adds additional noise to the estimate), the indicators can still be combined, although effort should be taken to estimate and incorporate the measurement error of the different methods (Hankin et al 2019). Another approach involves establishing a crosswalk between methods. This is commonly known as ratio or regression estimation and essentially involves determining the quantitative relationship between the two methods (this requires that some sampling sites use the same methods) and then using this relationship to predict one variable from the other. This approach is often employed when there is a relatively inexpensive approach (or surrogate) which can be used in most places in favour of the more expensive but more precise approach.

5.3.6 Types of Data / Knowledge / Information

There are many kinds of information, but in general the word information implies an interpretation of data, which can then inform decision making processes. The assessment of cumulative effects requires data/knowledge connecting the activities and stressors to the valued components. A wide range of types of data/knowledge can be used in cumulative effects assessments, including quantitative or qualitative information, georeferenced data, Indigenous

[5] More nuance may be found in the statistical literature (i.e., an undergraduate level statistics textbook). Some sub-regions may have better (i.e., more precise estimates) than others and this will influence the overall precision of the region wide estimate. If a sub-region is missing entirely, this should be noted and depending on whether it is missing at random or not, it may not be possible to make inference to the missing sub-region.

knowledge, etc. These various types of data or knowledge aries from a variety of sources, including studies and reports, workshops, monitoring programs, field studies, outputs of modeling exercises, etc. These can be grouped into those which are based on empirical data, originating in or based on observation or experience, and those based on inference (Pickard et al 2019). The Transport Canada initiative is scoped to use the best available data/knowledge and not to collect new environmental data, this may limit the ability to complete the assessment step (evaluate current condition, evaluate pathways of effect, and evaluate alternative scenarios). However, it is possible that additional information collection will be possible at some point in the future either through the government of Canada or through various Indigenous led initiatives. The type of data/knowledge available for different valued components or stressors at different scales affects the assessment method (Section 4) and will influence the ways in which information can be shared across scales.

For the purpose of the South Coast BC multi-layered pilot, which is based on the best available data, it will be helpful to: **identify the nature of the available data/knowledge, articulate any underlying assumptions or uncertainties, identify any knowledge gaps, and identify any redundancies**. Given the breadth of the South Coast BC regional pilot, it is inevitable that the best available data/knowledge will include a combination of many different kinds of information collected at different spatial and temporal scales. How this information is combined to inform both sub-regional and regional scale objectives is a complex challenge. In particular, it is important to consider how to align Indigenous knowledge with western science.

Types of data/knowledge/information

Landscape level data

This refers to information that is generated from remote-sensed technology such as satellite imagery to produce complete coverage of a particular variable in space. These methods typically involve complex processing of raw imagery to produce the relevant maps. There are many relevant landscape level datasets for the South Coast pilot including: bathymetric digital elevation model, modeled wave and wind energy, substrate etc. which may serve as useful inputs to a variety of different assessment methods (refer to below), e.g., habitat suitability models etc.

Field data

This refers to information collected 'on the ground' and could involve a variety of field methods including but not limited to visual observation (e.g., whale counts), measurements (e.g., water quality or eelgrass extent), or tracking devices (for species or boats). Of particular relevance to Transport Canada is vessel traffic data provided by the automatic identification system (AIS).

Spatial data

Spatial data in the form of georeferenced information (i.e., points, lines and polygons) on the location and intensity of pressures (e.g., density of vessel traffic) and on the occurrence of ecosystem components (e.g., polygons representing the habitat distribution of a given species) are routinely used in spatial cumulative effects assessments (Korpinen and Andersen 2016). Even if the assessment is not spatially-explicit, some form of spatial data is usually included in most assessment methods. Landscape level data are always spatially explicit. Field data can be spatial but are not necessarily.

Survey data

This refers to data/knowledge collected from people through some form of questionnaire (e.g., interviews, online survey etc.). In the context of the South Coast pilot this may be relevant to informing some of the social or cultural indicators (e.g., wellbeing and relaxation).

Indigenous Knowledge

Indigenous knowledge refers to the knowledge held by Indigenous groups who have a long relationship with the territories where they live, and the resources found in these areas. This type of knowledge is invaluable, especially for providing a historic perspective in the absence of long-term scientific data. Specifically, one of the shortcomings of the ecological baselines in cumulative assessments is that the available data are usually recent and reflect the environment in a degraded condition as affected by historical impacts (Clarke Murray et al 2015, Korpinen and Andersen 2016). In this context, traditional and local ecological knowledge can contribute to understanding ecological trends or define the reference or pre-development conditions of the valued components (Clarke Murray et al 2015).

Expert Elicitation

Lack of empirical information on stressors-receptors interactions is a common problem in cumulative effects assessments. One way to overcome a lack of empirical information is by eliciting expert knowledge on certain aspects of the assessment; such as determining the vulnerability of marine ecosystems to multiple anthropogenic stressors (Teck et al 2010) or analyzing the pathways of effects and assigning impact scores (Singh et al 2017). Expert knowledge is usually collected through surveys and/or technical workshops; usually in an iterative manner.

5.3.7 Data and Knowledge Management

Planning for data and knowledge management should occur early to ensure that, in the planning process. Data collection and assessment initiatives involving First Nations should consider the OCAP principles: ownership, control, access, and possession. The OCAP principles assert that First Nations should control "data collection processes in their communities, and that they own and control how this information can be stored, interpreted, used, or shared" (FNIGC 2022).

Knowledge holders and communities need to retain control over the appropriate use of their knowledge. Open data principles and data-sharing platforms may be at odds with the handling of Indigenous knowledge and other culturally sensitive data. Therefore, agreeing on protocols for data/knowledge sharing at the outset is critical to ensuring that OCAP principles are respected, and that community-specific desires can be accommodated (CIER 2018).

Where data/knowledge collection is involved, monitoring initiatives can generate large datasets (including sensitive data) and require consideration of technical issues such as restricted user access controls, data encryption, back-ups, and data interoperability (Olson et al 2018).

Addressing these issues requires advanced planning and the technical capacity to implement and maintain.

5.3.8 Integrated Sample Design

While the current initiative uses the best available data, it may be helpful in the future to think about how to collect data/knowledge in a way that facilitates integration across scales and across components. The way in which the data/knowledge are collected affects the assessment approach (e.g., how the information is aggregated).

It is necessary to first describe the basic elements of a sample design. The sampling design describes where and when measurements are to be made, and the process by which those locations and times are selected (Stevens and Urquhart 2000). There are a few key concepts to understand which are common to any text on sampling design (e.g., Hankin et al 2019):

Target population is the population about which you wish to make inference (e.g., all glass sponge reefs in the South Coast region). The **sample unit** is the unit which is measured (e.g., individual beds). In some cases, we use a multi-stage design or sub-sampling approach (e.g., quadrats within beds). The **sample frame** is the list of all sample units, ideally it is the same as the target population but often there are discrepancies. For example, we may not have a complete list of all glass sponge reefs in the region. In many cases **stratification** can improve the efficiency of the sample design. Stratification is most valuable when there is a known factor which correlates with the indicator of interest. For example, if we had a habitat suitability model for glass sponge reef, this could be used to stratify the design and target more effort in high suitability habitat. Finally, a **probabilistic selection approach** is used to select sample units from the sample frame with a known probability. The probabilistic design is what enables inference to sites that have not been observed. In a simple random sample all sample units have an equal probability of selection.

Integrating across scales

Aggregation from sub-region to region.

It may be desirable to have different sampling intensities in different sub-regions to allow for local priorities but still be able to aggregate to a broader region as illustrated in Figure 1-2. below. Rolling up from a sub-region to a larger region can be done but care needs to be taken to weight the individual data points correctly. If all data points were averaged you would find that some sub-regions would have an undue influence on the regional estimate, simply because more samples were taken. A probabilistic design addresses this by weighting points based on their inclusion probability. In simple terms you can imagine taking an average of each sub-region first and then averaging across sub-regions. There are some nuances to this but a statistician can easily be consulted to confirm the appropriate aggregation approach.

Master Sample

The concept of a master sample was developed by Larsen et al (2008) to address the situation where multiple organizations were collecting similar water quality data at a variety of scales through uncoordinated efforts and could not easily be combined. The master sample provides a master list of possible sample points, which can then be sorted based on the sub-region of interest. Within each sub-region there is an ordered list. If sub-region 1 would like to sample 10 points, they take the first 10 sites from their list. If sub-region 2 would like to sample 50 points, they take the first 50 sites from their list. In each case, the list maintains a probabilistic design but the density of points will be different. There are different types of probabilistic designs (e.g., simple random sample, stratified random sample, generalized random tessellation, balanced acceptance sampling) but the master sample concept remains the same. When well established, master samples can enhance collaboration and reduce duplication of effort; however, effort is required to establish the master sample, and ensure cooperation among agencies.

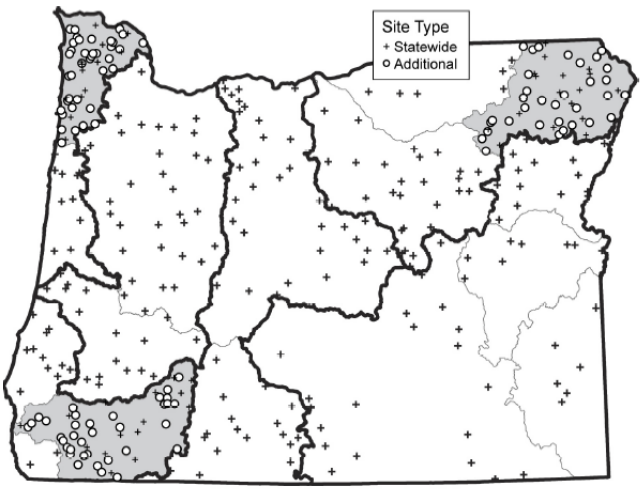

Figure 5-5. Example of the Oregon Master sample showing how additional sites could be added to sub-regions to address local concerns within a regional scale coordinated and statistically robust design.

Integrating across Valued Components

Data collection efficiency can also be improved by integrating the sample design across valued components and indicators. The cost of traveling to a site is often one of the limiting factors and so where it makes sense (i.e., where sample frames intersect) sampling can often be designed in such a way to allow multiple valued components and/or indicators to be assessed simultaneously. There are other benefits to co-located sites in that analytical assessments of correlation among elements can also be considered, instead of siloed assessments of one indicator at a time. A regional Climate-Smart Fisheries Monitoring framework was developed for the Caribbean using this approach (Eyzaguirre et al 2019). As is often the case with different Indigenous Nations, different countries within the Caribbean differ in their capacity and a master sample approach combined with tiered indicators was used to provide a regional monitoring framework that was flexible enough to accommodate the varied capacity. In this example, nine big questions (similar to valued components) were identified and for each question, a tiered list of about 30 indicators was selected, including both environmental and social / economic indicators. However, these indicators could all be collected from a consistent master sample frame with only 4 different site types (e.g., landing sites, reef surveys, pelagic surveys, and infrastructure) (Figure 5-6).

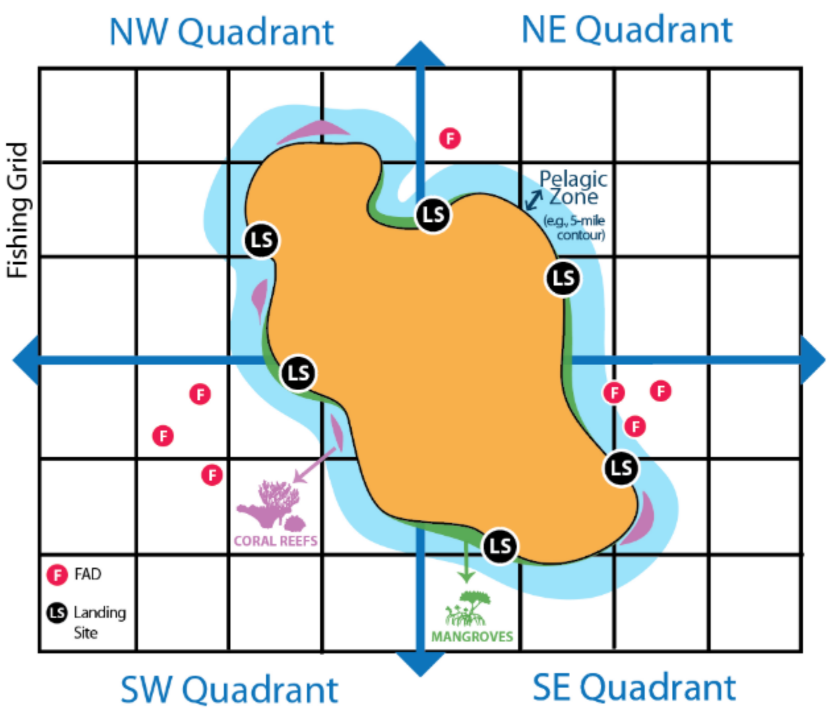

Figure 5-6. Use of a common master sample frame within which all sampling efforts can be nested enables data aggregation and reporting efforts within countries and across the region.

Another example of co-located and nested sites within a master sample frame is shown in the Trinity River Integrated Assessment Plan (Figure 5-7; TRRP and ESSA 2009). The selection of sites uses a common master sample frame, but the intensity of monitoring varies between protocols. Co-located sites which result from using a nested design facilitate additional, more comprehensive (i.e., multi-indicator) analyses.

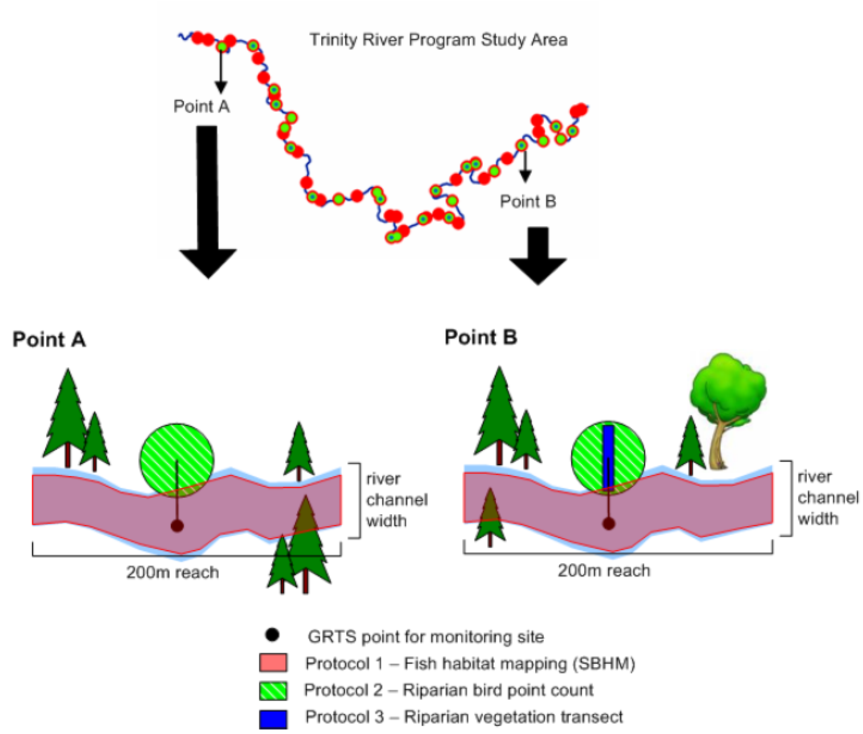

Figure 5-7. A hypothetical example of multiple assessments undertaken at integrated monitoring sites selected from a master sample.

5.3.9 Thresholds

Without defensible thresholds for valued components, it is not possible to evaluate cumulative effects (Duinker et al 2013). Defining thresholds or triggers (i.e., exceedance of a value that would lead to a change in management or monitoring) was identified as a key challenge by participants from a multi-jurisdictional workshop on cumulative effects monitoring organized by CCME (Pickard et al 2018a). Thresholds should be "technically defensible, politically acceptable, and administratively efficient" (Salmo Consulting Inc. 2006). Thresholds are informed by scientific information but are fundamentally decision making tools and must also recognize social values (Pickard et al 2018a). Metlakatla use a management trigger framework to show how the condition of valued components translates into management actions (Figure 5-8).

Figure 5-8. Management trigger framework, from the Metlakatla Cumulative Effects Management Program (see http://metlakatlacem.ca/phase-3-setting-management-triggers-actions/)

In the context of the CEMS multi-layered assessment approach in South Coast BC, all of the challenges identified above still hold. However, there are some potential opportunities to leverage the information across scales to more efficiently develop meaningful thresholds.

Acceptable levels and management triggers may differ by sub-region based on local concerns. However, there is potential to share knowledge about the condition of valued components, the spatial and temporal variability, and the relationship between stressors and valued components. This knowledge is critical to development of defensible thresholds.

There are two basic approaches to defining thresholds (from the knowledge point of view, as noted above the social filter will be sub-region dependent).

Mechanistic understanding of the functional response and associated tipping points

Where possible, it is always helpful to understand the mechanistic response between a stressor and a valued component (i.e., the cause-effect mechanism) as opposed to simply recognizing that there is a correlative relationship. Ecosystems may occasionally undergo rapid shifts from one stable state to another when a 'tipping point' is exceeded. A common example of this is lake eutrophication (Scheffer et al 2001). Where mechanistic relationships are understood and tipping points are known, thresholds or management triggers should be set well short of the critical point (Grieg and Pickard 2014).

The more data, the better when it comes to understanding the functional relationships among stressor-valued component connections and predicting tipping points. All sub-regions will benefit from sharing data/knowledge about the connections, even if they choose to use different thresholds.

Comparison to a reference condition, whether that is a comparison over time or space

In absence of good information about the functional relationships, it is common to compare data/knowledge across time and space. The basic premise is to try to understand what 'normal' looks like (e.g., condition and spatial and temporal variability) and then to make statements about the difference from normal. It is strictly a 'relative' assessment, so if the point of comparison is already impacted, then it may not be a suitable choice. This section discusses commonly used approaches for comparing across space. Temporal comparisons are discussed in more detail in the baseline section below.

- Regardless of the method employed, the South Coast multi-layered assessment could benefit from sharing data/knowledge on common valued components to provide additional context for comparisons.
- Sub-regions could be grouped into those with high or low levels of stressors and compared to demonstrate impacts to specific sub-regions but also to better understand the potential impacts at the regional scale.
- Regional scale data/knowledge will provide a better understanding of the spatial variability which is key to interpreting differences from 'normal'.

Bowman and Somers (2005) provide a useful decision tree to inform the type of study which might be most relevant depending on the specific context (Figure 5-9). They also provide helpful guidance in terms of how to select reference sites (Figure 5-10).

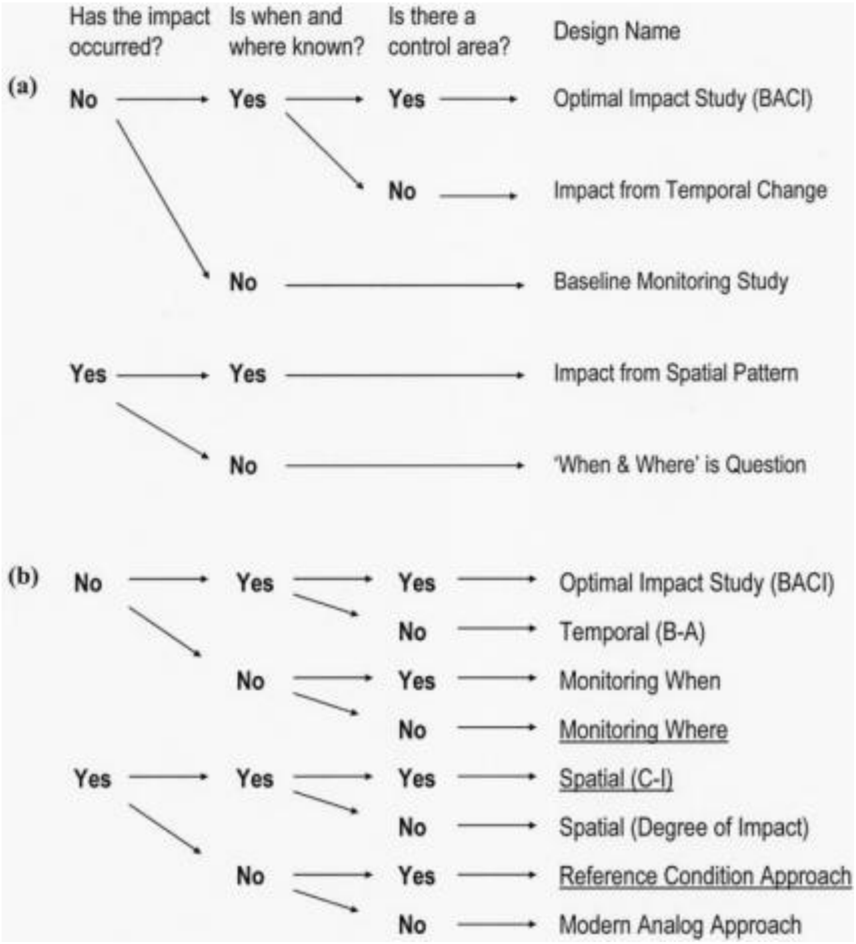

Figure 5-9. A decision key to help in selecting the environmental study design from Bowman and Somers (2005).

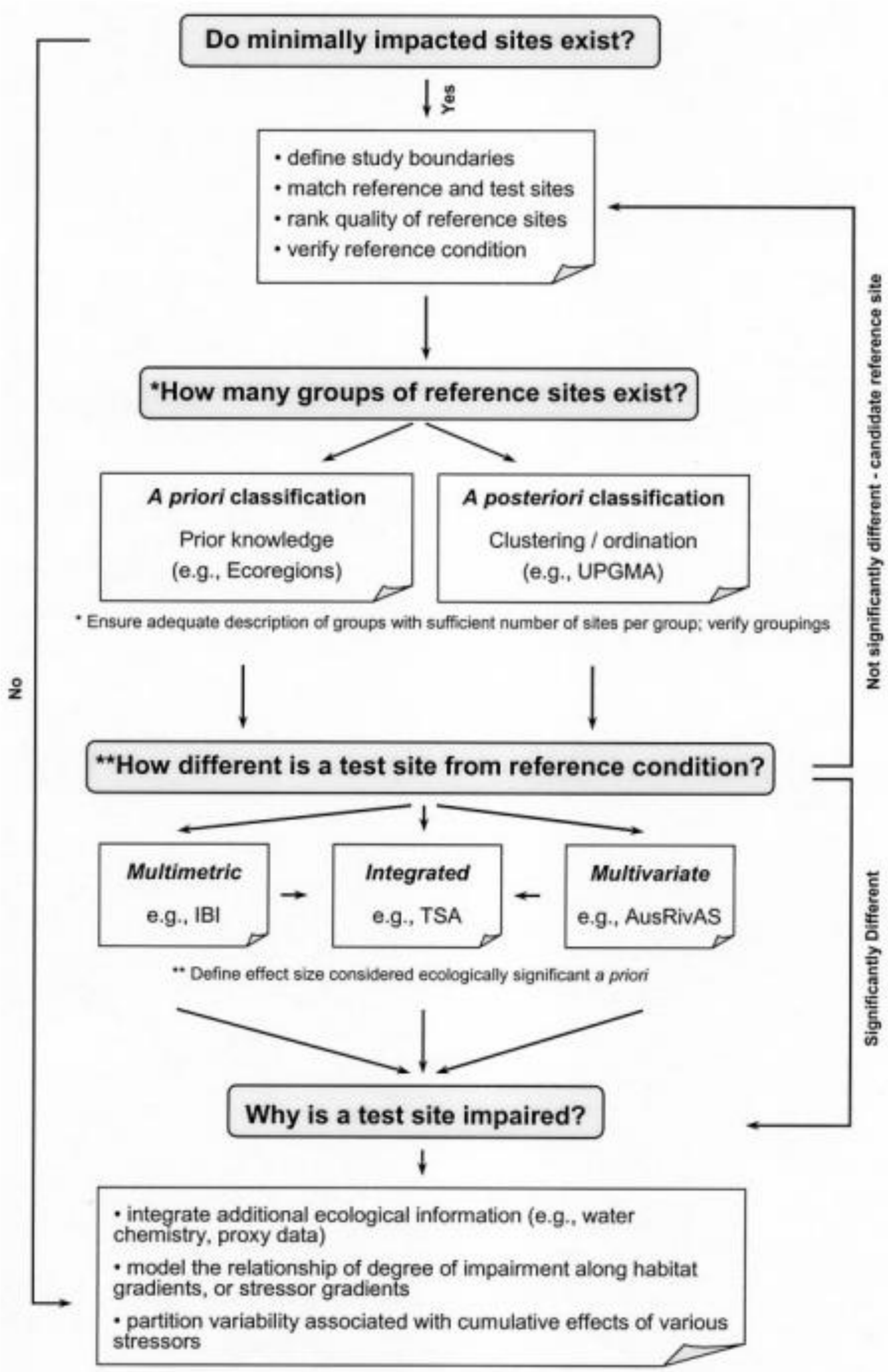

Figure 5-10. Common steps used in assessment of potentially impacted sites using the reference condition approach, from Boman and Somers (2005).

5.3.10 Baseline

Guidance from community delegates on developing baselines (Section 3) noted that the **current condition of valued components (environmental and social) are already impacted and that it is important to include Indigenous communities in defining an appropriate baseline** (i.e., point of comparison) for the current context. Guidance on how to address the concept of 'baseline' is provided here based on content from the literature review as well as the author's experience.

Establishing a pre-impact baseline can be challenging but at a minimum, the earliest data/knowledge on valued components should be compiled, a timeline of known impacts (e.g., port expansion) and Indigenous communities should be consulted to describe their understanding of impacts to date. There is no arbitrary guidance on how far back to go, this decision will be context specific but should be informed by the participating Nations[6].

Spatial contrasts may also be helpful, and in this way a sub-region with low levels of marine shipping might be able to act as a comparison for sub-regions with higher levels of marine shipping.

Given the challenges in agreeing to a baseline, a useful starting point is to assess the current condition and then determine whether the condition is increasing, decreasing or stable. Simultaneously Nations can be consulted to determine if the current condition is acceptable or unacceptable and ideally to identify the levels of acceptable change. This can help to move the conversation forward even if a baseline has not yet been agreed to (Pickard et al 2018a).

Levels of acceptable change may differ by sub-region, and this will influence the regional interpretation. At the regional scale the information could be summarized as the number of sub-regions that are in 'acceptable/unacceptable' condition or another approach could be to use the most conservative definition.

5.3.11 Assessment methods

Pickard et al 2019 provide a comprehensive evaluation of cumulative effects methods for marine shipping. The report makes the point that there is not a one-size fits all cumulative effects assessment method and that the CEMS initiative will require a combination of methods. The choice of method will depend on the availability of data/knowledge, spatial and temporal scale, and the nature of the valued component and activities/stressors within each region. Assessment methods were categorized as: **spatial** (e.g., map based), **analytical** (i.e., informed by empirical or observed information), or **modeling** (e.g., abstraction of the system which allows for scenario analysis) (Figure A-2). Methods were then compared based on their relevance, rigour, and feasibility (see Table 5.2 in Pickard et al 2019). Section 8.2 of the methods report provides guiding questions to help determine what assessment approach is most appropriate for a given context. As noted in the data types discussion above, it is likely that the CEMS multi-layered assessment approach in South Coast BC will have a variety of data/knowledge sources to

[6]This section is partially informed by guidance prepared by the Impact Assessment Agency of Canada's Technical Advisory Committee on Science and Knowledge.

contend with and is by definition multi-scale. With that in mind a few specific examples are highlighted from the methodology report for consideration in the South Coast regional pilot.

Spatial methods

Spatial methods are expected to be broadly relevant to the South Coast regional pilot. These methods are relatively simple, easy to interpret, and flexible. They can be employed with a variety of data types including landscape level, field data, Indigenous knowledge, and expert elicitation, the only requirement is that the data are spatially explicit. It is possible to combine data/knowledge from different scales and to use different data/knowledge sources in different sub-regions. Methods for aggregating from smaller scale to larger scale are relatively simple. Care must be taken if trying to use information at a finer scale than the resolution of the raw data. Generally speaking, spatial methods can't be used to quantify condition of valued components (on their own) or to estimate the cause-effect relationships between stressors and valued components (on their own).

- Map the distribution or occurrences of valued components by sub-region.
- Map distribution of activities (mapping stressors, generally requires additional modeling effort - see section below on modeling).

Analytical methods

Analytical methods are expected to be more limited in their application to the CEMS multi-layered assessment approach in South Coast BC, at least in early iterations, except in cases where there are pre-existing studies which can be leveraged. A few methods stand out as particularly relevant to the South Coast regional pilot, where data types are expected to vary across scales:

- **Habitat suitability models** are used to predict the quality or suitability of habitat for a given species based on known affinities with habitat attributes such as habitat structure, habitat type and spatial arrangements between habitat features (e.g., depth, substrate, cover type, etc.). This method is valuable as it can predict distributions without direct observations once the relationship has been established. This information can then be used to inform future management scenarios. However, this approach is likely not possible without focused data/knowledge collection and a rigorous study design. Existing models should be leveraged and future data/knowledge collection may consider developing habitat suitability models for important species (e.g., eelgrass distribution could be predicted from (Morton et al 2021).
    - A focused study in one sub-region could then be employed by other sub-regions as well as at the regional scale, albeit with some validation.
- **Risk assessment** is considered a high priority for the South Coast regional pilot. Risk assessment approaches range in complexity but in general involve evaluating the likelihood (or exposure) and consequence (or magnitude) of an event (e.g., stressor - valued component). In this context, a risk assessment could identify high priority areas or pathways of effect (stressor - valued component) where the exposure and consequence are high.
    - These methods can integrate a variety of data/knowledge types, including Indigenous knowledge and are well suited to a broad spatial scale application.

    - This approach would be helpful for narrowing focus (in terms of which sub-regions and which pathways of effect) should be targeted for future more quantitative and complex assessment methods. The idea of providing focus on pathways of effect with greatest risk rather than prioritizing valued components was an idea that also emerged from the community guidance (Section 3).
- **Weight of evidence** approaches can be used to systematically evaluate the relative importance of different pathways.
    - The approach uses a combination of quantitative and qualitative information including Indigenous knowledge and like risk assessment can be used to focus future assessment methods.

Modeling

Models can be defined as tools for the abstraction and simplification of natural systems which allow for the analysis of the system and making predictions about its behaviour. In the context of cumulative effects assessment, models are necessary to evaluate alternative management scenarios. Models range from very simple (conceptual pathways of effect) to very complex (spatially explicit simulation models). Consistent with the methodology report, the following categories of models are thought to be particularly useful for the South Coast BC regional pilot and are presented in the order in which they should be employed.

- Simple **conceptual models** describing connections between stressors and valued components (i.e., pathways of effect or connection wheels) are an important outcome of the scoping step and help to lay the foundation for the assessment step.
    - These models are a simple way to ensure a common understanding of the system and should be developed with the participating Nations to ensure their concerns are reflected.
    - Models for different Sub-regions may look different. Commonalities and differences will be identified in the 'scoping crosswalk'.
    - Simple conceptual models should be developed for all valued components, for each sub-region and the region at large.
- **Stressor models** use information about the activity (e.g., vessel movement) and translate it into spatially explicit information (e.g., maps) about the stressor (e.g., noise) based on our understanding of the system. These tend to be complex models and likely beyond the scope of the South Coast BC regional pilot, however, many of these models have already been developed and can simply be leveraged.
    - Identify and leverage existing stressor models to develop stressor maps (as described in the earlier section).
    - Identify knowledge gaps and determine a path forward to quantify / map the stressors.
    - In the context of marine shipping in the South Coast, there is good information for most activities (where and when activities occur). Ideally this information can be translated into spatially explicit stressor maps for the region. In this way, sub-regions inform the regional assessment and vice versa.

- **Bayesian Belief Networks** (BBNs) are probabilistic models that can incorporate a variety of data/knowledge inputs. They are not mechanistic models. They explicitly address uncertainty and can be improved over time with new information.
    - BBNs are flexible in terms of the type of input types and can perform calculations based on expert opinion if empirical data are not available, thus addressing a common challenge of cumulative effects assessment.
    - BBNs can aggregate information from the sub-regional scale to the regional scale even if the nature of the data/knowledge or the impacts in each region vary. Information from other sub-regions or the region at large about how stressors affect valued components could be used as surrogate values to make predictions within sub-regions that are lacking data.
    - A hierarchical BBN could be considered however, it is important to recognize the limitations. The more model components that are included and the less empirical data the greater the uncertainty will be and the less valuable the predictions.
    - This approach is intuitive in its set up as it mirrors the conceptual model but it can be challenging to communicate results and interpret the uncertainty.
- **Spatially explicit simulation model**. This method was identified as the gold standard for assessing cumulative effects and evaluating future management scenarios.
    - These methods are complex, require extensive empirical data, and given limited capacity should be saved for priority pathways of effect (i.e., high risk) where potential benefits are high (i.e., there is a management lever).
    - These methods may require additional data/knowledge collection to address critical data/knowledge gaps. In particular, they require information about the functional relationship between the stressor and the valued component. They can employ expert opinion and Indigenous knowledge but these exercises still take effort.
    - While complex to implement, the outputs are generally spatial (e.g., maps) and therefore intuitive to interpret.
    - As with the BBN models, information about functional relationships can be shared across sub-regions, with some assumptions. However, given that these methods are spatially explicit the modeling effort increases with scale. It may not make sense to apply these at the regional scale but rather in sub-regions or areas of particular concern.

5.4 Specific opportunities for South Coast BC Regional Pilot

This section provides high level recommendations from the authors based on the literature review, our limited interaction with the participating First Nations, and our own experience, for consideration by the VMCC. They are not intended to be an exhaustive or prescriptive list. In addition, Table 5-3 provides an illustration of how the road map / menu options could be applied to two example valued components.

5.4.1 High Level Recommendations for Consideration

- If possible, standardize terminology or at least provide a crosswalk among sub-regions.

- Develop community-led holistic (i.e., not limited to marine shipping) cumulative effects management strategies/frameworks so that they can intersect with various projects/initiatives including CEMS.
- To the extent possible, develop a common approach to data collection (including equipment) and reporting improve efficiency and power of resulting information.
- Leverage the Indigenous Technical Advisory Network (ITAN)[7] or other networking tools.
- Start with a collaborative assessment of baseline and current condition. Follow this with an exercise to determine levels of acceptable change according to participating First Nations at the regional and sub-regional scale.
- Complete preliminary risk assessment based on a simple spatial overlay of stressors and valued components to identify priority threats at both the sub-regional and regional scale. Focus subsequent monitoring and research efforts on identifying the most effective management actions to achieve goals (i.e., protect or enhance valued components).
- Use a tiered approach to indicator selection and integrated sample design concepts for future data collection to facilitate collaboration while recognizing differences in capacity.
- All types of information will have uncertainty associated with them and it is critical that those **uncertainties and any data gaps or assumptions are explicitly identified** in the assessment.
- Leverage existing work (e.g., data collection, models, assessments).

5.4.2 Examples

The exercise of developing a multi-layered vision is an iterative process. In drafting the vision, we found it necessary to jump back and forth between considering the pit-stops and menu items and thinking about how they would apply to different valued components. In this section, we take two example valued components (which represent a range of considerations) and describe the considerations involved in each of the pit-stops (Table 5-3).

[7] https://www.fnfisheriescouncil.ca/program/indigenous-technical-advisory-network/

Table 5-3. Considerations for each Pit Stop are described for two valued components: Glass Sponge Reefs, and Cultural or Burial Sites.

Pit Stop	Menu Item	Glass Sponge Reef	Cultural or Burial Sites
Scoping	Stressor	• Anchoring • Substrate Disturbance	• Wake • Visual disturbance • Noise / Light disturbance • Obstruction • Vessel discharges
	Pathway of Effect	Glass Sponge Reefs are vulnerable to damage from anchor strikes (vessel at rest), as well as smothering due to substrate resuspension (movement underway).	Vessel wake may physically damage burial or other cultural sites that are in proximity to the coastline. Various marine shipping activities may also restrict access to cultural sites (e.g., through obstruction), or enjoyment of cultural sites (e.g., due to vessel discharges, visual or other disturbances, or an unacceptable level of marine traffic).
	Terminology	Standardizing terminology used in the assessment for valued components will help to develop common understanding about the issue and how it may be addressed.	Standardizing terminology used in the assessment for valued components will help to develop common understanding about the issue and how it may be addressed.
	Decisions / Management Options (relevant to TC)	• Area closures • Anchoring • Shipping routes • Velocity	• Shipping routes • Velocity • Total traffic
Crosswalk	Identify common ground	Important questions to ask, to develop an understanding of common ground are: • Is interest in Glass Sponge Reefs high among all sub-regions? • Is the nature of each Nation's concern the same, or do concerns about stressors differ among the region? • Do First Nations agree on the management levers that would be used to mitigate stressors to Glass Sponge Reefs?	Important questions to ask, to develop an understanding of common ground are: • What are the common interests and concerns with regards to cultural sites among sub-regions? Are the concerns the same, or different? • If the concerns are different, it may be necessary to utilize different indicators or assessment methods among the sub-regions.
Right scaling	Spatial context	Though glass sponge reefs range throughout the South Coast BC Pilot Area, their distribution is patchy. Impacts (sediment resuspension, bottom contact) are therefore likely to be highly localized. The condition of one glass sponge reef is likely to be indicative of local conditions only.	Impacts to cultural and / or burial sites from wave action are likely to be similar in nature across the region, but impacts to access and enjoyment of cultural sites may differ depending on the spatial pattern of marine traffic.

Pit Stop	Menu Item	Glass Sponge Reef	Cultural or Burial Sites
	Temporal context	Damage to Glass Sponge Reefs is likely to operate on short time spans (i.e., one anchoring event may cause substantial impact). Due to their slow growth rates, Glass Sponge Reefs will be slow to recover from damages due to marine shipping activities.	Damage to cultural sites from wave action operates on a lengthy time scale. Recovery from wave action damage may not be possible, depending on the nature of the site. Graves may be re-located, but that may not be the same as recovery. Impacted access and enjoyment of cultural sites operates is (nearly) instantaneous, as is recovery (if a site is obstructed due to traffic one day, the removal of traffic may resolve the problem).
Indicators	**Indicators**	• Extent (area of seafloor) • Growth rates • Biomass • Species diversity	• Site condition (good, fair, poor) • Threats (site specific)
Reporting Needs	**Reporting Needs**	Given the patchy distribution of Glass Sponge Reefs and localized nature of impacts, it may make sense to report at the sub-regional scale.	Reporting must consider concerns around data privacy and ownership. Communities may want to keep information about cultural and / or burial sites private, and may want to share only results in aggregate, such as the number or proportion of sites in a given condition (e.g., good, fair, poor).
Types of Data or Information	**Data type**	Data has not yet been assembled for the assessment. Data types are likely to include field data and spatial data, and may also include Indigenous Knowledge (to inform location, assessment methods, etc.) and expert elicitation (which may be used to estimate vital rates or other key parameters).	Likely data types will include Indigenous Knowledge, field data, and spatial data. Quantitative (archaeological) methods may lack the nuance needed to characterize the importance of cultural or burial sites. Qualitative methods may be used in data collection (e.g., participatory mapping, semi-structured interviews) and in assessing the importance or vulnerability of each site.
	Uncertainties	The distribution of Glass Sponge Reefs may be a key uncertainty. We may be confident in the condition of known Glass Sponge Reefs, but we may not be confident that all Glass Sponge Reefs in the South Coast region have been mapped? Other uncertainties may arise as data is assembled.	There is uncertainty with regards to the nature and magnitude of the impacts at each site, which will be highly dependent on site conditions.
	Gaps	As Transport Canada collects data and commences the assessment, gaps will be reveled.	Privacy concerns around the location of burial and other cultural sites may be a barrier to data sharing. As Transport Canada collects data and commences the assessment, other gaps will be reveled.
	Redundancies	As Transport Canada collects data and commences the assessment, redundancies will become evident.	As Transport Canada collects data and commences the assessment, redundancies will become evident.

Pit Stop	Menu Item	Glass Sponge Reef	Cultural or Burial Sites
Data or Knowledge Management	**Data management**	We are not aware of any sensitivity concerns about Glass Sponge Reef data.	First Nations should be given the opportunity to define how data is used, stored, and shared for this indicator. Data sharing agreements should be negotiated with participating First Nations.
Integrated Sample Design	**Sample design**	If data collection for Glass Sponge Reefs is initiated, sample design should follow the considerations laid out in the Sample Design section of the report.	If data collection for cultural and / or burial sites is initiated, sample design should follow the considerations laid out in the Sample Design section of the report.
Thresholds	**Thresholds**	Thresholds should apply at the scale of each reef, but be consistent across the region.	Thresholds should reflect sub-regional concerns.
Baseline	**Historical baseline** **Current condition**	Knowledge about Glass Sponge Reefs is limited, as their discovery in the South Coast of BC dates only to 2001. A historical baseline that captures pre-impact conditions may not be available. Pre-impact conditions may be estimated using expert elicitation or through predictive habitat mapping methods. The current condition of Glass Sponge Reefs may need to be used as a substitute for historical conditions.	A historical baseline may be informed by Indigenous knowledge, supplemented by archaeological and ethnographic research. Given the myriad impacts to cultural and / or burial sites, a pre-impact baseline will be exceedingly difficult to establish.
Assessment	**Spatial Methods**	Map anchoring sites against the distribution and condition of known Glass Sponge Reefs.	Participatory mapping may be used to document site locations as well as threats.
	Analytical Methods	Risk Assessment: a simple overlay of anchoring sites, and the distribution of Glass Sponge Reefs can inform a risk assessment and indicate whether more detailed study is required.	Cultural and / or burial can be overlaid against marine traffic density to inform a risk assessment. This overlay can be used to identify vulnerable sites and / or identify whether a more detailed assessment method is needed to better characterize risk.
	Modelling	If risks to Glass Sponge Reefs are high, consider for scenario evaluation - may require more data collection to inform	If risks to cultural and / or burial sites are high, consider for scenario evaluation - may require more data collection to inform

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Appendix A – Annotated Bibliography

This annotated bibliography presents a list of references that were reviewed as we prepared the strategic vision. For each citation, we briefly summarize its contents, and extract key themes or conclusions that are relevant to the development of the strategic vision. The annotated bibliography is presented in alphabetical order.

Dube et al 2013

Dubé, M. G., P. Duinker, L. Greig, M. Carver, M. Servos, M. McMaster, B. Noble, H. Schreier, L. Jackson, and K. R. Munkittrick. 2013. A framework for assessing cumulative effects in watersheds: an introduction to Canadian case studies. Integrated Environmental Assessment and Management, 9(3), 363–369. https://doi.org/10.1002/ieam.1418

This study describes a framework to assess cumulative effects in watersheds. The framework includes a regional water monitoring program with three outputs: an accumulated state assessment, stressor-response relationships, and the development of predictive cumulative effects scenario models. The framework considers core values, indicators, thresholds, and use of consistent terminology. It emphasizes that cumulative effects assessment requires 2 components, accumulated state quantification and predictive scenario forecasting. It recognizes both of these components must be supported by a regional, multiscale monitoring program.

The framework consists of four key components: harmonized local and regional-scale monitoring; watershed planning, assessing the accumulated watershed state; and using scenario planning to predict the future state of the system given various development trajectories. This framework is shown in the image below.

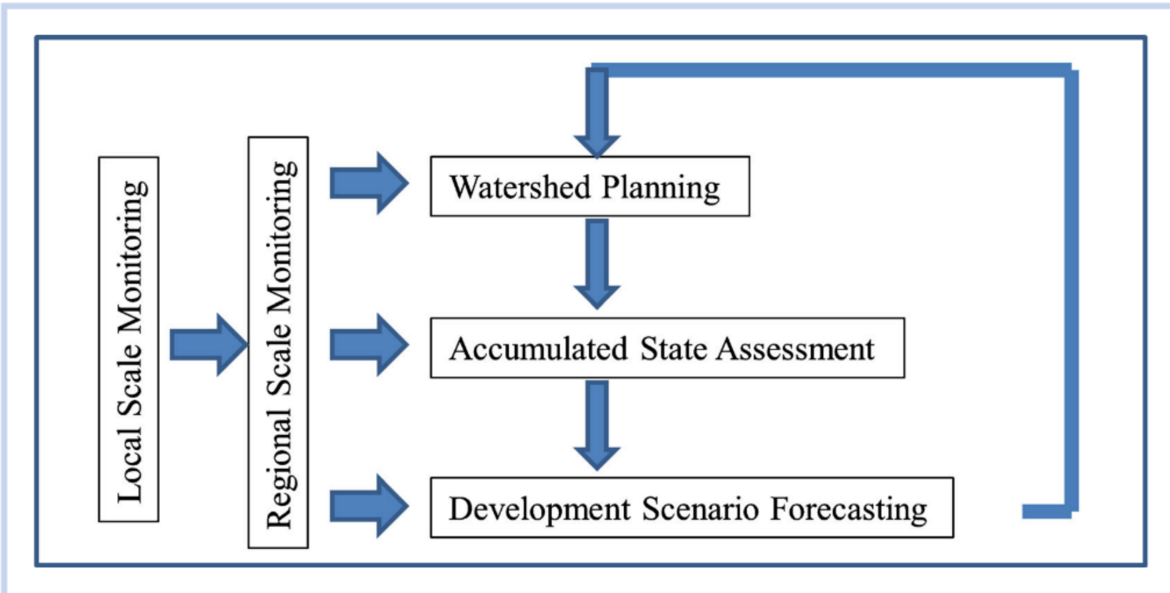


Figure 1. Key components of a framework for watershed cumulative effects assessment.

- **Local and regional-scale monitoring** is essential to develop a baseline understanding of the current state within an environmental system, and for the ongoing assessment of impacts. As development occurs, predictions can be evaluated against monitoring data.
- **Watershed planning** is a key component of cumulative effects assessment in that it reflects the desires of people, industries, and agencies with regards to how much, and what type of impact permissible in a given area.
- **Accumulated state assessment** establishes the current watershed status or condition relative to the limits established through a planning process.
- **Scenario models** are used to predict alternative future conditions, using indicators as proxies for various states of development.

To assess the impact of development, the authors draw on their experience to recommend the use of **effects-based** rather than **stressor-based** methods. Effects based methods assess changes in the state of an indicator (e.g., water quality), whereas stressor-based methods assess changes in development itself, often through indicators (e.g., the number of stream crossings). The authors argue that effects-based methods more specifically draw attention to changes that matter to people (whether or not they were caused by development).

The authors conclude by noting that the success of watershed cumulative effects assessment is dependent on all components being implemented (i.e., success is not guaranteed if one element is missing). Watershed cumulative effects assessment "required more than assessing accumulated state (effects- based approach). It also required more than stressor-based and risk-based approaches. Assessment of accumulated state and prediction of alternate development trajectories supported by regional monitoring and directed by a watershed plan were essential components to complete watershed CEA." (p. 368).

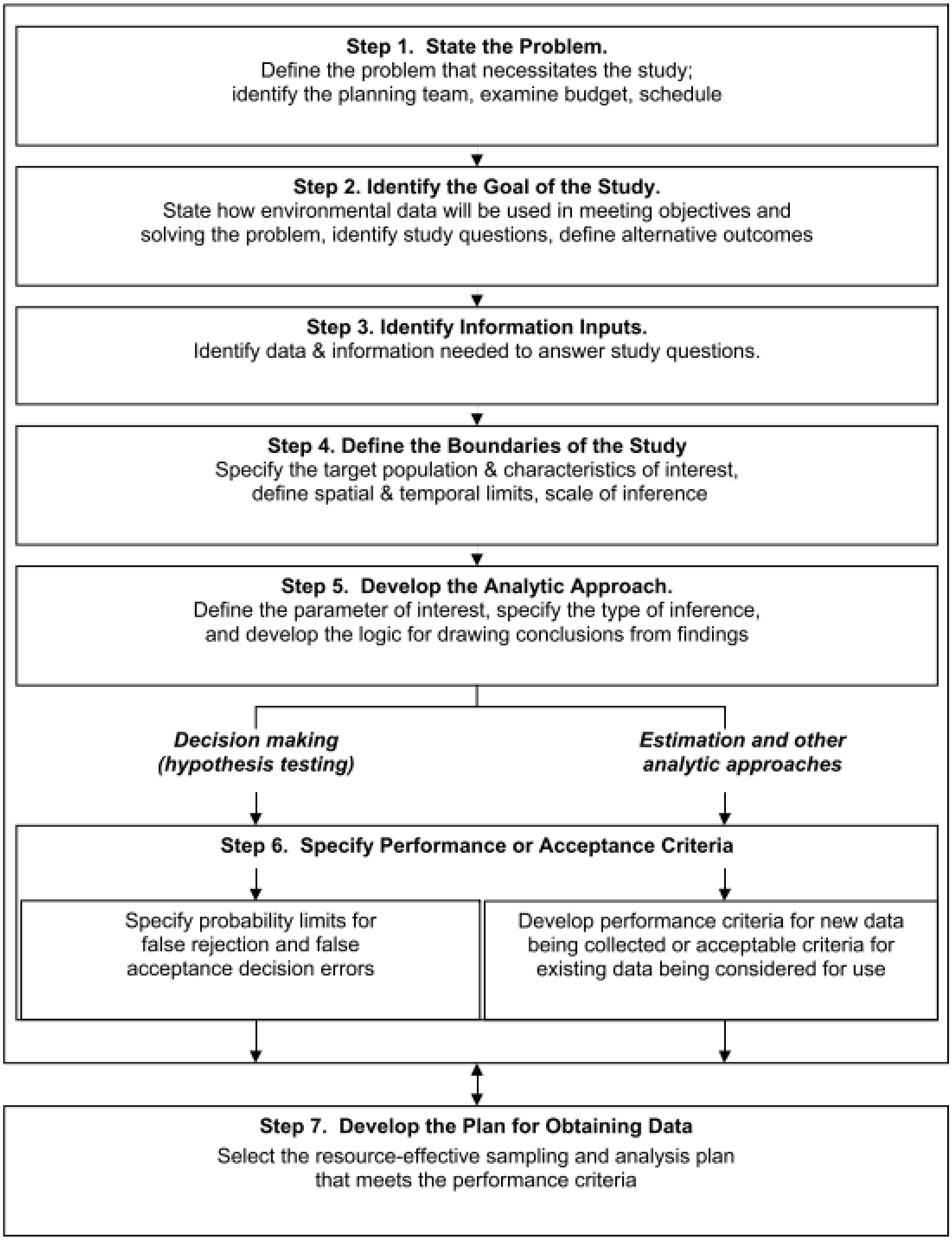
EPA 2006

EPA. 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process. EPA QA/G-4. 111p. https://www.epa.gov/quality/guidance-systematic-planning-using-data-quality-objectives-process-epa-qag-4

The EPA's Data Quality Objectives (DQO) process provides a set of logical decision processes to guide the development and evaluation of alternative management options. The DQO process is iterative and flexible, and can be applied to both big picture decision making processes, as well as technical quantitative parameter estimation projects.

The DQO process consists of a set of steps that help to clarify program objectives, define the appropriate types of data to collect/analyze and specify tolerable limits on potential decision errors.

The DQO process consists of seven steps, documented in the image below. These steps are meant to follow one another, but successful implementation of the DQO process may require iterating over the process as new information becomes available.



The DQO process, when followed, offers numerous benefits:

- The process is participatory, and focused, through each step, on determining how inputs will support decision making.
- In focusing on decision making, the process is an effective planning tool that helps cut down on data collection for the sake of data collection, increasing efficiency.
- The process offers a consistent way to document activities and decisions
- The process provides a method to define performance requirements that are relevant to the decision being made

European Parliament 2008

European Parliament. 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Official Journal of the European Union. L 164/19.

The Marine Strategy Directive outlines a framework, called the Marine Strategy Framework (MSF), which seeks to protect, preserve, and restore marine environments under the jurisdiction of the European Union (EU). The Directive defines the objectives and approaches for the MSF, including consultation, monitoring, program of measures, and reporting. The Directive outlines descriptions of “good environmental status” for marine ecosystems, using widely accessible indicators like species distribution and abundance.

The environmental conditions identified in the initial assessments identified the need for measures that members could employ to rehabilitate their marine ecosystems to achieve good environmental conditions. Ongoing monitoring programs are required to help maintain good marine environmental conditions and collaboration with adjacent members of the EU is also required.

Annexes to the Marine Strategy Directive outline 11 standard qualitative descriptors to evaluate “good environmental status”, excerpt below:

1. Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic, and climatic conditions.
2. Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.
3. Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.
4. All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity
5. Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters.
6. Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.
7. Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.
8. Concentrations of contaminants are at levels not giving rise to pollution effects.
9. Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.

10. Properties and quantities of marine litter do not cause harm to the coastal and marine environment.
11. Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

The MSF directive achieves multiple objectives:

- It acknowledges the importance of assessing cumulative effects, requiring that marine ecosystem assessments integrate cumulative effects;
- It requires identification and implementation of the measures that would be needed to restore environmental components to "good environmental condition;" and

It requires ongoing follow-up and management to maintain the established good environmental condition.

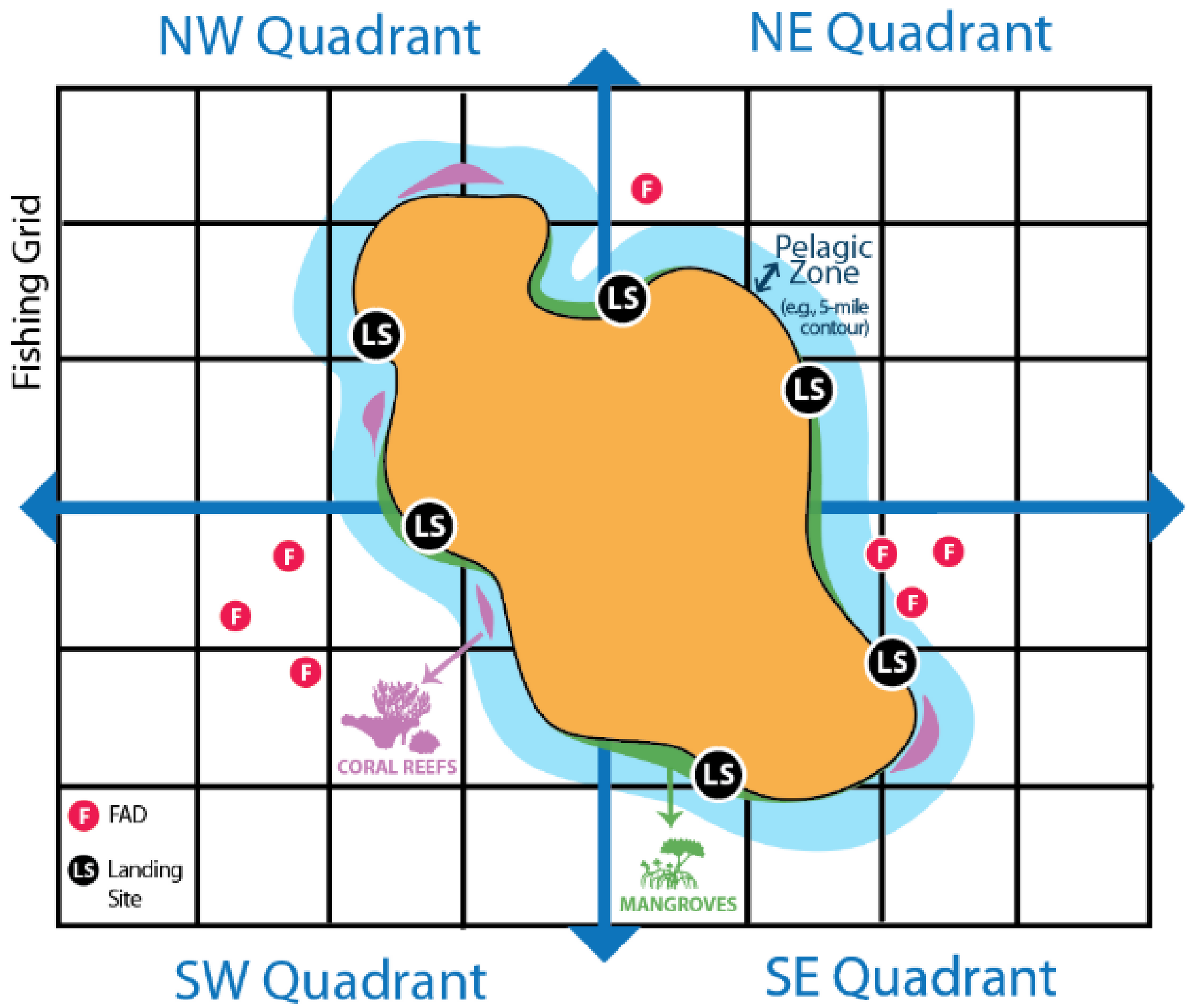
Eyzaguirre et al 2019

Eyzaguirre, J., N. Tamburello, D. Pickard, H. Stimson, R. Boyd, M. Jones, and G. Reygondeau. 2019. Analytical Tools and Monitoring Guidance for Monitoring Climate Change Impacts. CRFM Technical & Advisory Document, No. 2019 / 19. 138pp

This report is focused on providing guidance to improve the accessibility and useability of information for "climate-smart" planning in the fisheries and aquaculture sectors in the Caribbean, taking into account climate concerns. They define a framework for climate change adaptation planning, one, one element of which is a Climate-Smart Fisheries Monitoring framework, that includes guidance on indicators, sampling and data-collection methods. The fisheries monitoring framework was built to integrate data for fisheries across multiple species, at multiple scales (national and sub-national) within the Caribbean.

The framework was scoped though a situational review that profiled fisheries monitoring and management context and objectives among participant nations. Nations then defined key monitoring questions that would inform the monitoring activities within the framework. The framework itself consists of a set of monitoring cards that describe specific monitoring activities to address each question. Key features of the monitoring cards include:

- Monitoring is embedded within an adaptive management learning loop
- Protocols are standardized at the regional scale, with a small but consistent set of key indicators
- Monitoring cards account for local context, with recommendations for different activities depending on local capacity and priorities. For all participants, baseline monitoring to achieve objectives is recommended, with additional, optional monitoring activities (and levels of effort) that could be undertaken to provide additional context and data.
- Monitoring cards use a master sampling frame (see image below), which provides regional consistency, improves data collection efficiency, and facilitates local and regional level analyses.
- Monitoring cards recommend using historical data for monitoring site selection in order to maximize the ability to utilize historical data for long-term analyses.



Example master sample frame. Nesting within the sample frame enables data aggregation and reporting efforts within countries and across the region.

Hollarsmith et al 2021

Hollarsmith, J. A., T. W. Therriault, and I. M. Côté. 2021. Practical implementation of cumulative-effects management of marine ecosystems in western North America. Conservation Biology, (May 2020), 1–12. https://doi.org/10.1111/cobi.13841

The authors of this paper review marine cumulative effects (CE) management frameworks, focusing western North America, and highlighting commonalities, including enabling factors and challenges. Their review reveals that many CE management frameworks consist of three phases:

- **Scoping and structuring the system**: defining key questions, goals of the analysis, and identifying the spatial and temporal scale;
- **Characterizing relationships**: understanding the relationships between system components through a risk assessment, in order to assess the probability and magnitude of undesirable events; and

- **Evaluating management options**: at this stage, data from the assessment is used to make decisions regarding how to mitigate or eliminate risks.

Common challenges in CE frameworks, and proposed solutions included:

- **Scale and scope:** data collection and analysis was bounded by political, rather than ecological jurisdictions, resulting in improper risk analysis. Likewise, many are too temporally limited, and fail to include a historic baseline. Cross-boundary and cross-agency coordination can help amend the issues by enabling CE management on ecological scales.
- **Participation:** many CE projects fail to include diverse sources of knowledge, in both scoping, and data collection, and therefore only meet the needs of those included in the process. Empowering Indigenous communities will help ensure they are represented in CE processes (for example, through resource co-management).

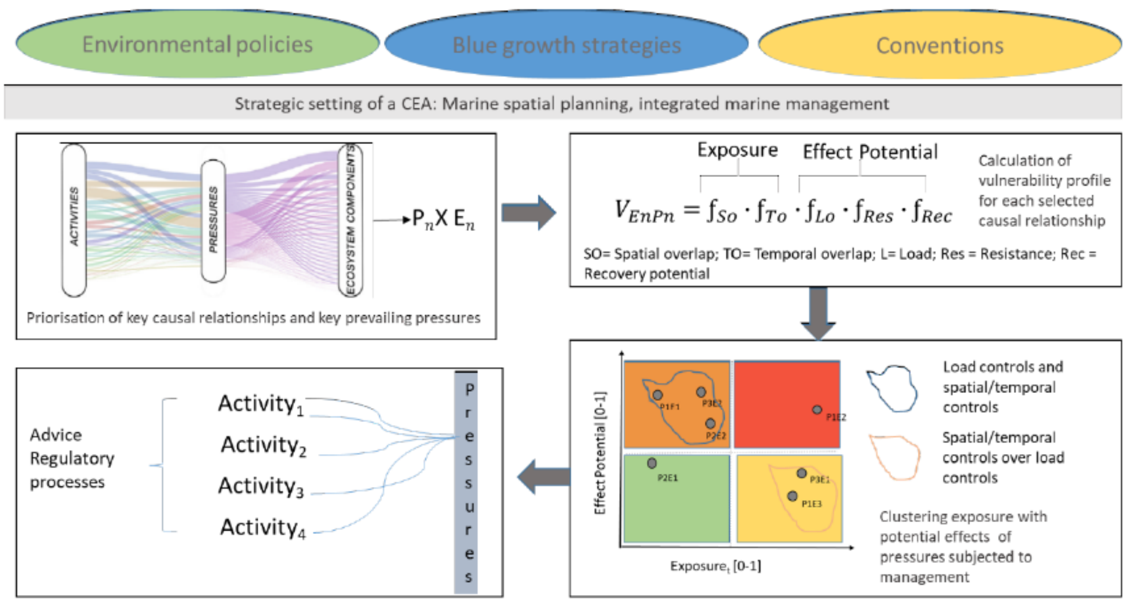
CE projects attempt to model complex ecosystems, and therefore require extensive data as well as information about how components interact. In practice, many CEs make simplifying assumptions that may not hold in reality. Limited data, and high uncertainty can result in underestimation of risks. Diverse and novel data sources and analytical methods are increasingly being used to meaningfully incorporate qualitative data that can help reduce uncertainties in CE projects.

ICES 2019

ICES. 2019. Working Group on Cumulative Effects Assessment Approaches in Management (WGCEAM). ICES Scientific Reports. 1:92. 23 pp. http://doi.org/10.17895/ices.pub.5759

The conceptual model for cumulative effects management framework produced by ICES focuses on the assessment of VEC vulnerabilities. In the top-left corner, key cause-effect relationships are prioritized based on the potential for impact to VECs; in the top-right corner, vulnerability to pressures is then evaluated through both exposure (through space and time) and the effect potential (magnitude, resistance, and recovery potential); subsequently this information is integrated into a vulnerability profile to evaluate and prioritize the vulnerability of all pressure-VEC combinations within the system.

Conceptual CEA framework for management (ICES 2019)



Jones et al 2010

Jones, K. B., H. Bogena, H. Vereecken, and J. F. Weltzin. 2010. Design and Importance of Multi-tiered Ecological Monitoring Networks. In F. Müller, C. Baessler, H. Schubert, & S. Klotz (Eds.), Long-Term Ecological Research (pp. 355–374). Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-90-481-8782-9_25

This paper describes the importance of incorporating multiple scales in environmental monitoring networks, the associated challenges, and discusses relevant case studies that showcase multi-scaled environmental monitoring networks.

Environmental monitoring and research often occurs at a single scale; however, many important environmental phenomena require understanding processes and relationships across spatial and temporal scales. In developing stronger understanding of environmental phenomena, multi-tiered ecological monitoring offers numerous benefits:

- "An understanding of important synchronies among ecological characteristics and processes across space and time, and analysis of changes in the timing and synchrony of important biological, eco- logical, and hydrologic relationships;
- Cross-scale analysis of ecologically important attributes and processes and their relationships;
- Evaluation of cascading effects of natural and anthropogenic drivers and stressors across scales, as well as the magnitude of ecological change and lag times;
- Detection and evaluation of ecological thresholds and tipping points (for forecasting);
- Detection of surprises in ecological processes and how they cascade across spatial and temporal scales;

- Early warning of ecological process changes that affect important ecological services;
- How scaling functions and importance of variables in predicting ecological conditions and responses vary within and among biophysical settings." (p. 357)

Multi-tiered monitoring networks target a variety of tiers, including intensive research sites, to in-situ and spatially intensive monitoring, to large-scale monitoring which often leverages remote sensing to capture "wall to wall" data (see image below). As the spatial extent increases, the spatial representativeness of data increases, but the ability to characterize site-specific variance is diminished. Successful implementation of multi-tiered monitoring requires both the "implementation of a core set of similar or comparable measurements within each tier" as well as the ability to link measurements "quantitatively across tiers" (p. 357).

The paper describes the challenges of linking measurements across scales. The authors note that it is feasible to link measurements using statistically derived relationships, however, they note that linking functions more often than not do not exist for key ecological processes.

Kurtz et al 2001

Kurtz, J. C., L. E. Jackson, and W. S. Fisher. 2001. Strategies for evaluating indicators based on guidelines from the Environmental Protection Agency's Office of Research and Development. Ecological Indicators, 1(1), 49–60. https://doi.org/10.1016/S1470-160X(01)00004-8

This paper describes guidelines for the selection and evaluation of indicators in ecological studies. The guidelines are aggregated into four "phases" that each focus on a fundamental question:

- Phase 1 assesses the conceptual relevance of the indicator, and asks whether (and the extent to which) the selected indicator directly captures the state of the ecological resource and relevant stressors.
- Phase 2 assesses the feasibility of implementing monitoring for a given indicator, asking whether there is sufficient capacity to accomplish monitoring given the desired field methods and sampling design.
- Phase 3 assesses whether measurement errors are sufficiently understood, and whether natural variability in space and time is captured?
- Phase 4 assesses the utility of the indicator in informing possible management alternatives.

In selecting indicators, it is valuable to evaluate each indicator against the set of guidelines within each phase. The guidelines identified in this paper provide a consistent and thorough set of criteria to identify the strengths and weaknesses of different indicators against the context of a specific program's objectives. The complete set of guidelines is excerpted in the image below.

Table 1
Overview of the evaluation guidelines for ecological indicators

Phase 1: Conceptual relevance	
	Guideline 1: Relevance to the assessment
	Guideline 2: Relevance to ecological function
Phase 2: Feasibility of implementation	
	Guideline 3: Data collection methods
	Guideline 4: Logistics
	Guideline 5: Information management
	Guideline 6: Quality assurance
	Guideline 7: Monetary costs
Phase 3: Response variability	
	Guideline 8: Estimation of measurement error
	Guideline 9: Temporal variability (within-season)
	Guideline 10: Temporal variability (across-year)
	Guideline 11: Spatial variability
	Guideline 12: Discriminatory ability
Phase 4: Interpretation and utility	
	Guideline 13: Data quality objectives
	Guideline 14: Assessment thresholds
	Guideline 15: Linkage to management action

Larsen et al 2008

Larsen, D. P., A. R. Olsen, and D. L. Stevens. 2008. Using a Master Sample to Integrate Stream Monitoring Programs. Journal of Agricultural, Biological, and Environmental Statistics, 13(3), 243–254. https://doi.org/10.1198/108571108X336593

This paper describes the use of a **master sample** (using spatially balanced sampling; SBS) to enhance collaboration among various agencies, and “[facilitate] integrated monitoring and data sharing” (p. 243).

In the Pacific Northwest, state agencies had each developed their own sampling programs, with each applying their own sampling methods. Agency-level improvements in sampling design (i.e., each agency applying SBS) has increased monitoring efficiency for each agency, but inter-agency collaboration was hindered due to the lack of a common sampling framework. In such a system, aggregating data, and making inferences across agencies is possible, but is inefficient and requires rejecting certain non-compatible data.

A master sample consists of a set of sampling locations from which a random, spatially balanced "sample of a specified size, *n*, can be obtained by selecting the first *n* sites in sequence from the ordered list (or from any start point on the list) for any grouping of the sites" (p. 246). A master sample can be further subdivided by other environmental variables (e.g., habitat type, stream order, elevation) to enable statistically robust samples given a set of sampling needs.

With a master sample in place, agencies can sub-sample points according to their focal area and study needs, while still meeting "the important design criterion of spatial balance, as well as randomization" (p. 245). The master sample thus offers multiple benefits for cross-agency collaboration:

- Facilitating data sharing among agencies. In sharing data, agencies can more efficiently allocate effort to achieve a given sample outcome.
- Reduce monitoring redundancies that occur when multiple agencies conduct overlapping monitoring independently using different sampling frames. Combining data that has been sub-sampled from the master sample is much simpler than combining data that was drawn from different, unconnected, random samples.
- Increased total sample size when aggregating monitoring data across multiple agencies or initiatives. With increased data, there will be increased power to detect trends, and better temporal and spatial coverage.

The figure below shows four examples of sample points selected from the Oregon master sample: "Examples of the spatial distribution of sample points selected from the Oregon master sample. **Figure 1(a)** illustrates a statewide sample with an equal number of sites in each of Oregon Department of Environmental Quality's five reporting regions (reporting regions are outlined by heavier lines); sites are coded by "agency ownership." **Figure 1(b)** illustrates additional sites (open circles) allocated to each of three subbasins (shaded) within three of five reporting regions. **Figure 1(c)** illustrates additional sites (open circles) allocated to a national forest (shaded) and to a Bureau of Land Management district (shaded). **Figure 1(d)** illustrates additional sites (open circles) allocated to small watersheds (shaded)."

MaPP 2022

MaPP. 2022. The Marine Plan Partnership. [Website]. Accessed March 01 2022. http://mappocean.org/

The Marine Plan Partnership (MaPP) is a partnership between 17 First Nations situated on the North Pacific Coast, and the Government of British Columbia. The organization develops and implements marine use plans using the best available Indigenous knowledge and science. MaPP's marine use plans apply to four sub-regions: Haida Gwaii, North Coast, Central Coast, and North Vancouver Island. MaPP, in addition to developing plans at the sub-regional scale, also has developed a regional action framework (RAF) that considers issues and priorities that are common across all four sub-regions (e.g., climate change, cumulative effects, governance, etc.)

At the regional and sub-regional scale, MaPP's processes are grounded in the principles of ecosystem-based management (EBM) that focuses on ecological integrity, human well-being and governance. In applying the EBM approach, MaPP will follow an adaptive management process, meaning that information and lessons learned from environmental monitoring will be utilized to adjust plans and management directions.

The sub-regional marine plans and background documents consistently highlight the benefit of linkages with planning processes and programs involving the federal government, such as the PNCIMA initiative. In addition, the sub-regional marine plans make recommendations for improvements to federal-provincial-First Nations environmental assessments for proposed major projects, including opportunities for better collaboration. Marine economic development is a shared priority of the MaPP partners in the MaPP region; an improved working relationship with proponents and industry can enable sustainable development opportunities.

2.2 Regional Actions on Governance

The recommended regional actions on governance focus on collaborative management across the MaPP region, and are consistent with sub-regional marine plan objectives and strategies. The order of listing does not imply or reflect a priority:

» **Action 2.2a –** Advance collaborative governance arrangements for marine management, including efficient and effective arrangements for implementing MaPP and other related recommendations and priorities (e.g., PNCIMA).

» **Action 2.2b –** Continue to identify and advance opportunities for more effective and collaborative First Nations-provincial environmental assessment processes.

» **Action 2.2c –** Review existing provincial government agency processes for encouraging proponents' effective engagement with First Nations, including relevant agreements, to improve working relationships.

Olson et al 2018

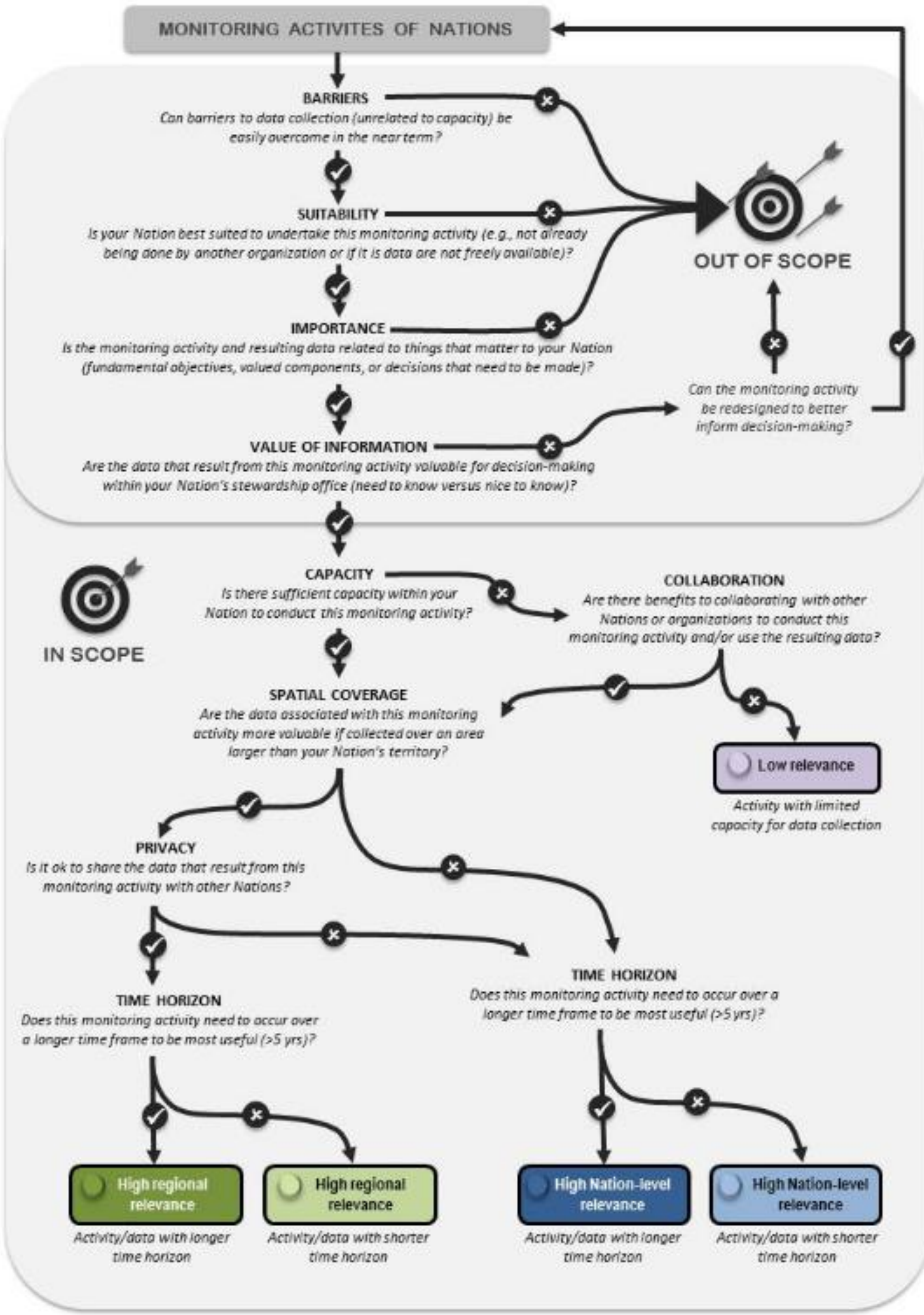
Olson, E., B. Connors, L. Hoshizaki, J. Kotaska, D. Pickard, M. Nelitz, A. Groesbeck, J. Benner, K. Kellock, A. Pitts. 2018. Designing data collection for decision-making: shaping the coastal First Nations regional monitoring system to meet the needs of the Nations. Salish Sea Ecosystem Conference, 532. https://cedar.wwu.edu/ssec/2018ssec/allsessions/532

The Coastal First Nations' (CFN) Regional Monitoring System (RMS) was developed in 2009. The purpose of the RMS was to align monitoring among all nine CFN members by defining a core set of monitoring activities, and collecting data in a standardized format. Thus, data from all Nations can be leveraged into statistically valid baselines for decision-making processes (e.g., planning and management).

The RMS was driven by the capacity, needs, and concerns of each member Nation. The program has adopted an adaptive management approach, undergoing a formal evaluation in 2013, and has recently revised which monitoring activities they are undertaking, as well as their data collection, analysis, reporting, and storage protocols.

A key challenge that the RMS tackled was determining how Nations would collaborate within the RMS, and balancing the concerns of each Nation with those that are broadly applicable to the entire region. The RMS used a scoping framework (see image below) to categorize activities into high regional and Nation-level relevance to acknowledge the multiple ways in which the importance of monitoring activities are determined. In developing each monitoring activity, the RMS adopted a tiered approach: each monitoring activity consisted of a base tier that all participating Nations would commit to undertaking. The base tier would be an accessible and affordable monitoring activity. Additional tiers would consist of increasingly rigorous and targeted monitoring efforts (therefore requiring additional capacity), which would enable more nuanced analyses.

While widely supported among each Nation, the RMS demonstrates the challenges inherent to developing a regionally focused stewardship program. Key challenges that the RMS encountered included: (1) finding balance between what is desired, and what there is capacity to do, (2) finding balance between Nation-level, and regional-scale priorities remains, and (3) continuing to provide relevant information, given continually evolving circumstances that the Nations are encountering.


MONITORING ACTIVITES OF NATIONS
BARRIERS
Can barriers to data collection (unrelated to capacity) be easily overcome in the near term?
SUITABILITY
Is your Nation best suited to undertake this monitoring activity (e.g., not already being done by another organization or if it is data are not freely available)?
IMPORTANCE
Is the monitoring activity and resulting data related to things that matter to your Nation (fundamental objectives, valued components, or decisions that need to be made)?
VALUE OF INFORMATION
Are the data that result from this monitoring activity valuable for decision-making within your Nation's stewardship office (need to know versus nice to know)?
OUT OF SCOPE
Can the monitoring activity be redesigned to better inform decision-making?
IN SCOPE
CAPACITY
Is there sufficient capacity within your Nation to conduct this monitoring activity?
COLLABORATION
Are there benefits to collaborating with other Nations or organizations to conduct this monitoring activity and/or use the resulting data?
Low relevance
Activity with limited capacity for data collection
SPATIAL COVERAGE
Are the data associated with this monitoring activity more valuable if collected over an area larger than your Nation's territory?
PRIVACY
Is it ok to share the data that result from this monitoring activity with other Nations?
TIME HORIZON
Does this monitoring activity need to occur over a longer time frame to be most useful (>5 yrs)?
TIME HORIZON
Does this monitoring activity need to occur over a longer time frame to be most useful (>5 yrs)?
High regional relevance
Activity/data with longer time horizon
High regional relevance
Activity/data with shorter time horizon
High Nation-level relevance
Activity/data with longer time horizon
High Nation-level relevance
Activity/data with shorter time horizon

Pickard et al 2018a

Pickard, D., L. Beckwith, L. Greig, and K. Munkittrick. 2018. Cumulative Effects Monitoring: Key Elements. Report prepared by ESSA Technologies Ltd. for the Canadian Council of Ministers of the Environment 101pp.

This report evaluates a large number of case studies to identify the key elements of a cumulative effects monitoring system.

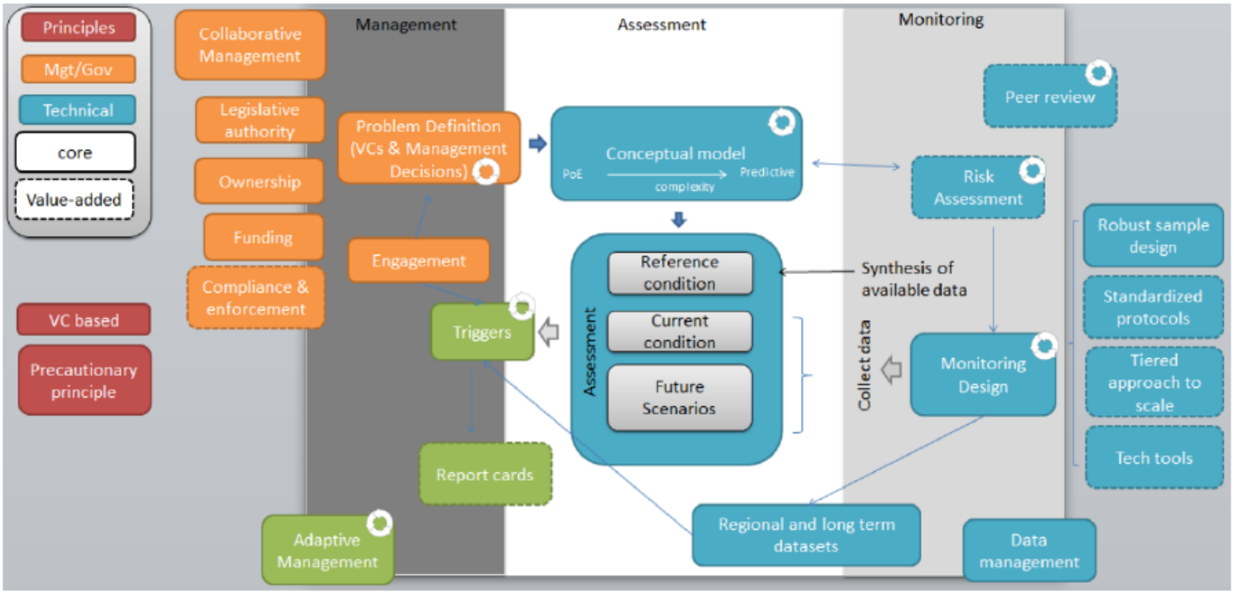
The authors first identify a set of challenges inherent to cumulative effects monitoring, grouped as follows:

- **Governance / Management**, including (lack of) political will to implement a cumulative effects framework; lack of trust between government, industry, and the public; a lack of legislative and policy tools; unclear responsibilities which can lead to gaps in monitoring; limited capacity or funding to monitor all priority indicators; data ownership and data dissemination (keeping data and results private erodes trust between parties); lack of coordination between agencies results in duplication and inefficiencies; and competing objectives (which may result in de-prioritizing cumulative effects monitoring).
- **Technical**, including insufficient clarity around monitoring terminology (terminology often differs among agencies); limited data availability; the difficulty of developing a suitable data management system; correctly scoping the spatio-temporal scale of monitoring; and correctly defining cause-effect relationships (including climate change) and evaluating the magnitude of stressor impacts.
- Both **Governance / Management and Technical**, including defining triggers to move between tiers of management actions; and understanding how best to align western science and Indigenous Knowledge.

The authors also identify the key enabling elements of a cumulative effects monitoring system, many of which directly address the challenges listed above:

- **Governance / Management** factors include defining clear objectives, having the proper legislative tools, ensuring long-term funding, establishing responsibilities and accountability among all parties, strong relationships founded on trust (emphasizing early engagement and collaborative management), utilizing compliance and enforcement, and focusing on VECs rather than stressors.
- **Technical** factors include regional monitoring (necessary to evaluate the spatial extent of effects); standardized protocols (which ensure consistency across programs); robust sampling design; long-term datasets; conceptual models (which help to clarify cause-effect relationships); scenario modelling; risk assessment (to prioritize monitoring); developing monitoring tiers (to enable flexibility); leveraging novel technologies for monitoring; and external review of monitoring design.
- Factors that touch on both **Governance / Management and Technical** elements include the importance of **reporting back to the public**, the usefulness of monitoring within an **adaptive management** framework, and linking monitoring outcomes to management action through evidence-based **triggers**.

Cumulative effects monitoring should be scoped such that it informs cumulative effects assessment, which should in turn be designed with cumulative effects management in mind. The image below maps out the ways in which cumulative effects monitoring, assessment, and management should be linked.



Pickard et al 2018b

Pickard, D., M. Porter, E. Olson, B. Faggetter, J. Hawryshyn, and D. Robinson. 2018. ESI North Coast Cumulative Effects Project (Estuary): Part 1 Developing the foundation. Report prepared by ESSA Technologies Ltd. for the Tsimshian Environmental Stewardship Authority. 106 p.

The British Columbia Environmental Stewardship Initiative set forth a program to develop a cumulative effects (CE) framework for the North Coast of BC. As a part of that project, the Tsimshian Environmental Stewardship Authority (TESA) set out to develop a set of indicators of estuary value and a protocol for assessing estuary value. The project was driven by **Tsimshian values**, which are reflected in the selection of indicators as well as the methods by which value is assessed.

A multi-step process was used to develop the indicators and protocols:

- Existing literature and data were reviewed to determine a preliminary understanding of the science.
- A user needs assessment was undertaken to understand data needs.
- Four conceptual models (for abiotic water conditions; eelgrass; marine invertebrates; and fish) were developed iteratively, with feedback from a Tsimshian working group. The conceptual model was used to identify key activities, stressors, and ecosystem components.
- ESSA and the Tsimshian working group collaborated to develop and implement a methodology to identify indicators for each element using a consistent set of criteria. This information was used to select a set of indicators that could be used to monitor

across estuary components. The resulting indicators consisted of a combination of pressure, state, and vulnerability indicators.

Pickard et al 2019

Pickard, D., P. de la Cueva Bueno, E. Olson, and C. Semmens. 2019. Evaluation of Cumulative Effects Assessment Methodologies for Marine Shipping. Report prepared by ESSA Technologies Ltd. for Transport Canada. 118pp + appendices.

This report provides a comprehensive overview of cumulative effects assessment and associated methodologies relevant to Transport Canada's Cumulative Effects of Marine Shipping Initiative (CEMS). There are three main components to the report. First, it proposes a framework (Figure A-1) which shows how the assessment step (e.g., Phase 3 of Transport Canada's CEMS) fits within a broader cumulative effects initiative. Second, involves a detailed evaluation of alternative assessment methodologies. Third, it provides guidance specific to implementation of Transport Canada's CEMS initiative.

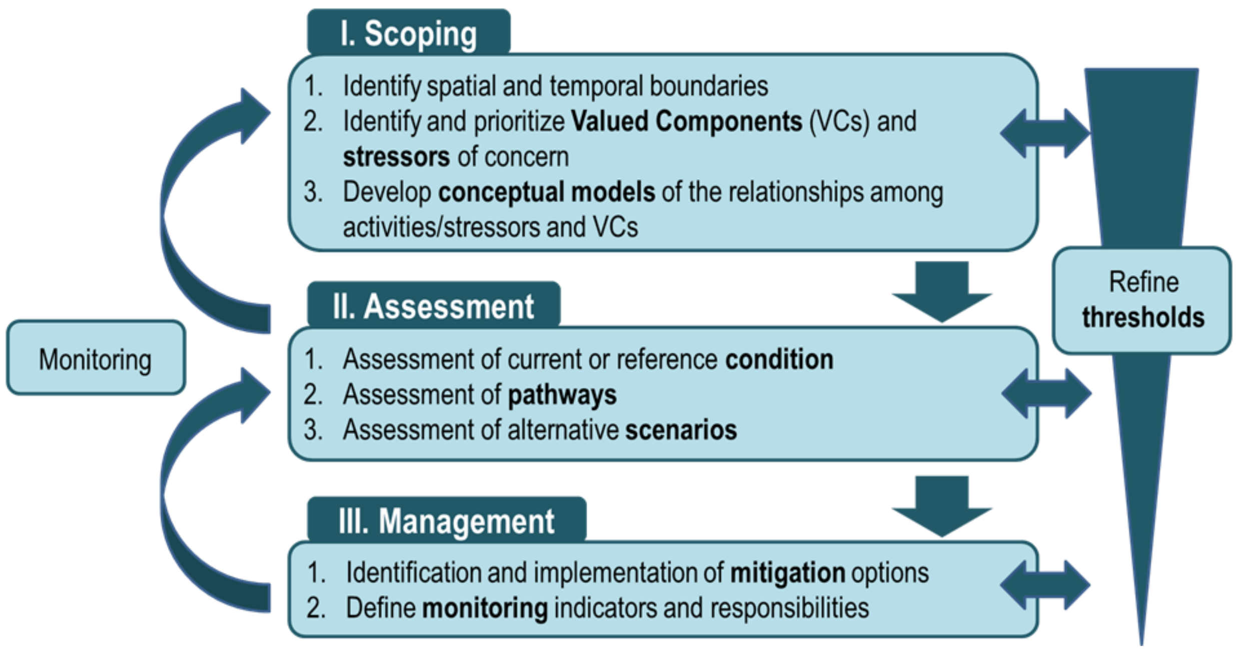


Figure A-1. This figure shows how the assessment step fits within a broader cumulative effects assessment framework.

The report makes the point that there is not a one-size fits all cumulative effects assessment method. Rather, there are many different methods which may be applied alone or in combination depending on the specific context. For example, the choice of method will depend on the data availability, spatial and temporal scale, and the nature of the valued component and activities/stressors. The report uses a simple pathways of effect conceptual model which includes '**stressors**' which apply pressure to '**valued components**' through '**pathways**'. The pathway is the functional relationship which describes how the stressor affects the valued component. As shown in Figure A-1, it is important to understand both the current condition of the stressors and valued components as well as the functional relationship (pathways) between them. With the goal being to identify the most important pathways, i.e., the drivers of the system, so that alternative management scenarios may be evaluated. Different methods may be employed at each step. Methods were further organized as: **spatial** (e.g. map based), **analytical** (i.e., informed by empirical or observed information), or **modeling** (e.g., abstraction of the system which allows for scenario analysis) (Figure A-2). Methods were then compared in terms of their relevance, rigour, and feasibility. Specific opportunities were provided to show how the CEMS initiative could use methods in each category. In addition the report provides guidance on cross-cutting subjects including: Indigenous Knowledge, Expert Elicitation, and Decision Support Tools.

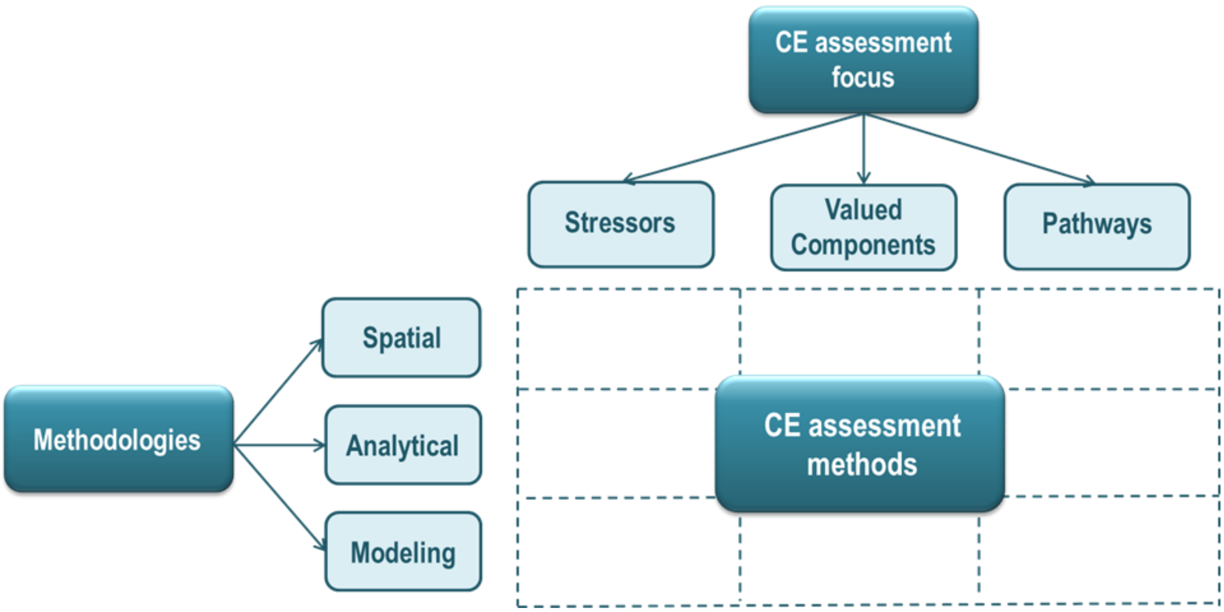


Figure A-2. This figure shows the structure used by the report to organize cumulative effects assessment methods.

Scholes et al 2018

Scholes, R., B. Reyers, R. Biggs, M. Spierenburg, and A. Duriappah. 2013. Multi-scale and cross-scale assessments of social–ecological systems and their ecosystem services. Current Opinion in Environmental Sustainability, 5(1), 16–25. https://doi.org/10.1016/j.cosust.2013.01.004

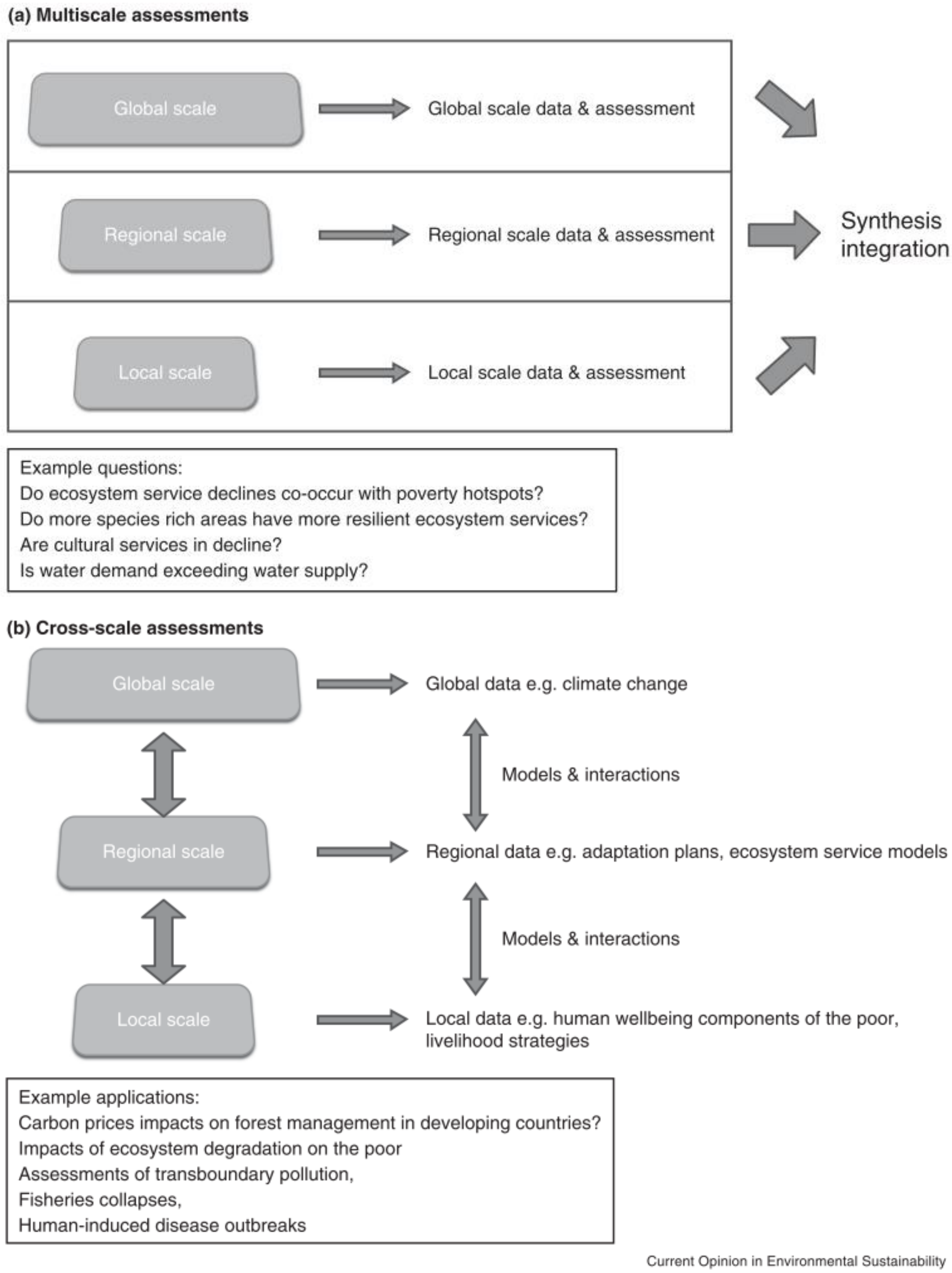
This paper outlines alternatives to single-scale social-ecological assessments, namely, multi-scale and cross-scale assessments, and describes relevant considerations and methods for each.

In deciding the scale and resolution for a social-ecological assessment, several considerations must be balanced: the scale at which management actions can be applied; the needs of the user; the scale of environmental phenomena; the scale of the stressors; and available data.

The authors term this process "**right scaling,**" which they define as "adjusting the scale of a study to be close to the desired scale required by key stakeholders and the resolution to be small enough to adequately represent the within-system heterogeneity and processes insofar as they materially affect the decisions that may be based on the study" (p. 18).

The authors then go on to define and differentiate multi-scale from cross-scale studies (summarized in the image below):

- **Multi-scale** studies consist of multiple studies at different scales, done simultaneously, but independently (where each of the scales have been selected through a right scaling exercise). At different scales, indicators and sampling protocols are harmonized to the extent possible to enable aggregation, which is done after studies have been completed.
- **Cross-scale** studies are a subset of multi-scale studies which explicitly pay attention to the linkages and interrelationships between scales. Cross-scale studies are required when "understanding of the processes at a particular scale is insufficient because processes at larger [or smaller] scales interact with it in ways which lead to outcomes which would not have been predictable from information at the chosen scale alone" (p. 19). Cross-scale studies therefore focus on drivers of change and their impacts across scales.



The authors describe several “scale aware” techniques which are useful at the different stages in a multi- or cross-scale assessment. These are summarized in the table below.

Table 1

Some of the techniques that can be used to address scale issues in social–ecological assessments. Some of the techniques are expanded on in the text

Techniques	Steps in the assessment process (not necessarily sequential)				
	Scoping, planning, establishing	Assess current state	Develop and explore scenarios	Identify and analyse response options	Communicate to stakeholders
Scenario analyses [23,24]	Identification of key drivers and uncertainties that may shape the future can help identify the relevant scales for assessment	Places current state in the context of past trends and potential future trajectories	Explores the consequences of potential alternative future trajectories of the system, depending on how key uncertainties unfold	Can help highlight key actions needed to avoid undesirable future trajectories of development, or actions that would be robust in the face of a range of very different futures	Qualitative storylines (potentially supported by quantitative analyses) can be a very powerful way of engaging stakeholders in a discussion of the future, and consideration of key system uncertainties
Space–time domain plotting (e.g. [31])	GIS overlays for spatial footprint. Log–log space–time plots for key interactions	'Characteristic scale' can be formally determined from Fourier analysis or semivariograms	Concept of 'fast variables', 'slow variables' and 'very slow variables'	Timelags for implementation Biophysical and social–cultural area of suitability	Time and space frames of: politics, business, major infrastructure planning, social–cultural change
Institution/actor power, reach and jurisdiction mapping (e.g. [30,32])	Legal responsibilities, market arrangements (e.g. economic blocs, trade, social–cultural links)	Resource tenure: protected, private, communal	Exploring how decisions at one institutional level may impact on/interact with decisions taken at another level	Jurisdictional scope	To whom you must communicate? Consider the time and space frames of politics, business, civil society and social–cultural change. Reflexive governance [32]
Network/connectivity analysis (e.g. [30])	Decide if this is a scale-specific, multi-scale or cross-scale problem with each issue	Use to identify semi-discrete SESs — strong interactions within, weak between ecological components and/or social actors	What key interactions need to be represented in the models? What can be treated as boundary conditions? Which social connections might shift in future?	Use to identify key actors for leveraging system change, as well as vulnerable areas, unintended ecological consequences and secondary effects	Can help to highlight key actors so that they can be engaged to help bring about system change
Nested/downscaled modelling [25]		Good way of doing complex, non-linear downscaling	Nested scenario modelling		
Disaggregation [12•]		Disaggregation of data is always a one-to-many problem, therefore can only be probabilistic	High-resolution modelling, driven by high-res covariates	How do actors and incentives change as scale changes?	Fine resolution mapping is often more satisfying to users, but should be done with caution if based on coarser scale analyses
Aggregation [12•]		Issues of sample bias and loss of information as you upscale	Feed local outcomes upwards to higher scale scenarios as integrity test	Can responses be scaled up or down or are they scale-specific? Should they be rolled out or replicated?	Necessary to simplify messaging, but needs to be transparent and accompanied by distributional and error. Be aware of morphing of variables and drivers information

van Dam-Bates et al 2018

van Dam-Bates, P., O. Gansell, and B. Robertson. 2018. Using balanced acceptance sampling as a master sample for environmental surveys. Methods in Ecology and Evolution, 9(7), 1718–1726. https://doi.org/10.1111/2041-210X.13003

This article describes a statistical sampling method (termed Balanced Acceptance Sampling; BAS) that enables efficient sampling within the framework of a master sample. The BAS method that is proposed provides better spatial balance than prior methods to establish Master Samples. The BAS is also more robust than prior Master Sample methods when sampling is conducted at different scales.

For the purposes of this review, the technical details about the BAS, and instead, attention is paid to Master Sample concept.

A master sample consists of a core "a set of [sampling locations] that can be subsampled for different monitoring activities" (p. 1719). Master samples can be used to ensure consistency in the information that is gathered (even when data is collected at different scales), and increase the robustness of estimates.

Master samples are useful to use when multiple agencies or organizations would benefit from coordination. Master Samples can also accommodate pre-existing studies, so long as no known biases are included in their design. With a Master Sample, data from multiple studies can then be combined, even if those studies have different sampling intensities, or use different scales.

When well established, master samples can enhance collaboration and reduce duplication of effort; however, effort is required to establish the master sample, and ensure cooperation among agencies.

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