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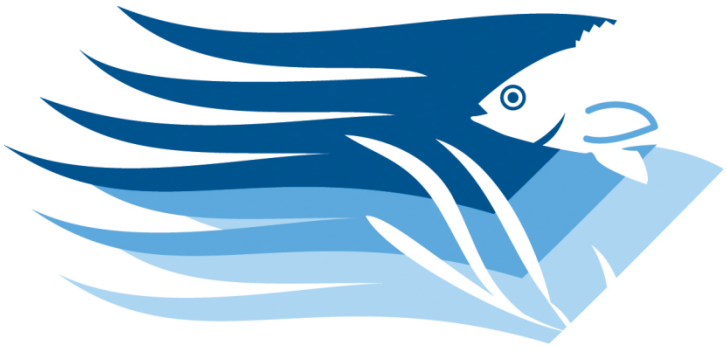

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Marine Ecosystem Based Management Knowledge Gaps Study

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Pacific Marine and Analysis Research Association

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Executive Summary

Ecosystem-Based Management (EBM) represents an integrated approach to environmental decision-making. Enabled in Canada under the Ocean's Act, marine EBM reflects the realization that single-objective management decisions can lead to unintended and often detrimental consequences for other marine ecosystem components.

EBM requires a broad understanding of all of the components and functions of the ecosystem. While we cannot understand everything about the ecosystem, we can prioritize our monitoring, analysis and research so that in the short term we focus on activities that will inform our understanding of the most critical and influential components and functions of the ecosystem and help us to understand how these are affected by human actions.

The objective of this project is to help inform the EBM community of practice about information and data gaps existing in the EBM framework in BC marine waters and plan to fill the gaps. Section 4 of this report, documents the state of marine EBM readiness. Some components of information that would support EBM in BC marine waters are incomplete or missing. Research indicates that gaps exist in the policy framework, management instruments, decision tools and methods and there is no formal performance evaluation framework.

This document provides background material for input to the PacMARA Marine EBM Gaps Workshops. During the workshops members of the marine EBM community of practice will work together to prioritize the gaps and issues that must be resolved to help move EBM forward in the BC marine environment. This document supports that objective employing a four step approach:

1. Identify knowledge gaps that need to be addressed to proceed with EBM in BC marine waters.
2. Catalogue what data / information are currently available to fill these needs for BC marine waters.
3. Determine what data / information gaps exist for implementation of EBM.
4. Research possible methods for addressing the knowledge gaps by prioritizing the filling of needed data / information.

Secondary issues for this project include examining ways to:

1. Make the knowledge and related data/information that does exist more usable for scientists, managers and policy developers working on EBM in BC marine waters.
2. Improve access to the existing knowledge and related data/information that is needed for EBM in BC marine waters.

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1 Introduction

The Oceans Act, Canada's Ocean Strategy and the Oceans Action Plan together commit the federal government to undertaking integrated oceans management in each of five Large Ocean Management Areas (LOMAs) across Canada. Such plans are to incorporate ecosystem, socio-economic, cultural and institutional management objectives and indicators into an Ecosystem-Based Management (EBM) approach[1].

1.1 The PacMARA EBM Gaps Program

The PacMARA Marine EBM Gaps Program is a series of activities supported and facilitated by PacMARA to improve marine EBM definition and practice in support of its implementation on Canada's west coast and to improve capacity to undertake marine EBM on the Pacific Coast of Canada. The activities, of which this project, the Marine Ecosystem Based Management Knowledge Gaps Study is a part, include:

- Framing the marine EBM environment.
- Facilitating the application of EBM in marine planning and decision-making.
- Leveraging EBM investments to date, including existing tools, skills and knowledge.
- Linking EBM science with marine policy development.
- Developing and delivering a strategy for an outreach and training program.

Ecosystem-based management requires a broad understanding of all of the components and functions of the ecosystem. While we cannot understand everything about the ecosystem, we can prioritize our monitoring, analysis and research so that in the short term we focus on activities that will inform our understanding of the most critical and influential components and functions of the ecosystem and help us to understand how these are affected by human actions.

That prioritization can only be done if we understand the Marine EBM Value Chain[2] and how it relates to the marine EBM Framework[3] including policy, regulation and enforcement. With that understanding we can fill knowledge gaps effectively in the short term while defining research programs which will help refine our management practices as they mature.

What is needed now is:

- A complete view of the Marine EBM Value Chain
- A completed Marine EBM Framework and roadmap, and
- A method to prioritize those activities that will allow us to implement EBM as effectively and rapidly as possible.

[1] Ecosystem-Based Management EBM is an integrated approach to management that considers the entire ecosystem, including humans. The goal of EBM is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need.
[2] The Marine EBM Value Chain provides a holistic view of the entire marine EBM process identifying all of the components that make up EBM as links in a chain, each of which needs to be effectively functioning for EBM to work as a management process.
[3] The Marine EBM Framework is comprised of the supporting management system including legislation and policy and the implementation instruments supporting management, regulation and enforcement.

1.2 Project Goals

The goal of the PacMARA Marine EBM Knowledge Gaps Study was to provide background material for workshops PacMARA is hosting to prioritize the gaps and issues that need to be resolved to help move ecosystem-based management (EBM) forward in BC marine waters. This goal was approached in four steps;

1. Identify the knowledge gaps that need to be addressed to better enable EBM in BC marine waters.
2. Catalogue what data / information are currently available to fill those knowledge gaps for BC marine waters.
3. Determine the data / information gaps that still exist for implementation of EBM.
4. Research possible methods for:
   - Validating the identified knowledge gaps.
   - Prioritizing the data/information needs.
   - Choosing the means to address the data/information gaps, and
   - Implementing programs to address the gaps.

2 Information for Successful EBM in BC Marine Waters

Under the Oceans Act, the federal government is mandated to consider the impacts of all human activities on Canada's marine ecosystems in all management decisions. Ecosystem-Based Management (EBM) requires that we attempt to include the ecosystem as a whole in all management decisions. This means that all activities in the region must consider the impacts they might have on the ecosystem components including habitats, functions and structural roles (Figure 1) as well as, what services the ecosystem provides to its members (including humans).

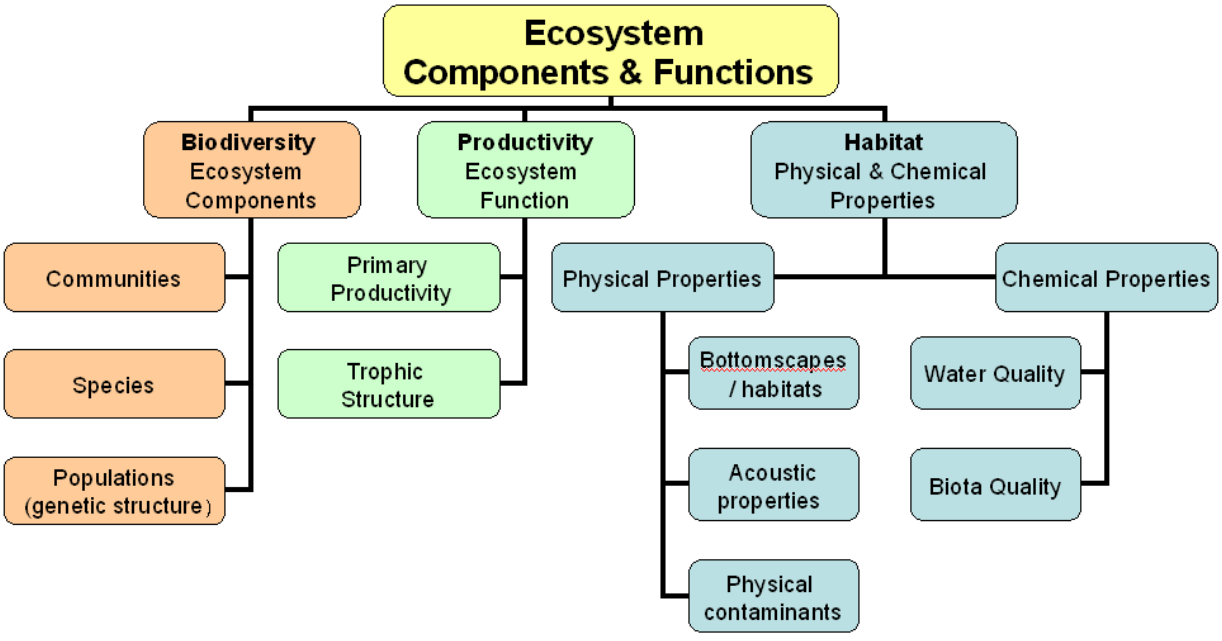


Figure 1: A simple tree diagram of the ecosystem components (adapted from Jamieson et al. 2001)

From an overall EBM Knowledge point of view, underlying data/information needs can be broken down into two sets of generalized categories. The first set is based on the ecosystem component shown in Figure 1:

- Information on the biodiversity of the management area: what species, communities and populations are present in what abundance and in what regions of the management area?
- Information on the ecosystem functions of the management area: What, how large and where are the energy inputs into the ecosystem; how does that energy move through the system (trophic structure) and how is it recycled or exported from the ecosystem. How do the species within the ecosystem interact (e.g., competition, predation, mutualism)?
- Information on the habitats of the management area: What are they, where are they, how extensive are they and what is their current state?

The second set is based on the need to understand the interaction of humans with the ecosystem within a socio-ecological systems view (Walker & Salt, 2006). This systematic view seeks to incorporate the interactions and relationships at multiple scales and levels that are inherently dynamic and complex (non-linear, unpredictable etc) and often not fully understood. These interactions exist across ecosystem components (e.g. within and between species, habitats and the abiotic environment); within and between human society components, and between ecosystems and human systems.

This interrelatedness conveys connectedness among various parts of a complex system. Incorporating this into marine EBM requires that there is an appreciation of the connectedness, complexity and uncertainty. To establish that appreciation requires information as follows:

- Information on the human activities of the management area: What human activities occur in the management area and what is their nature and trends. Are there human activities outside the management area that impact the ecosystem components and functions within it?
- Information on the anthropogenic stressors of the management area: What are the stressors generated from human activities; where do they occur, what ecosystem components and functions do they impact and how intense are those impacts?

This information must be fully integrated into decision making and management practices so that they adequately consider the implications of any actions over the appropriate scope and scales within the socio-ecological system.

The following subsections describe the information components and what they contribute to our overall knowledge and understanding.

2.1 Information on the biodiversity of the region

Information on the biodiversity – the species, populations, and communities present in a region, allows us to monitor how they are affected by anthropogenic stressors, including climate change and harvesting. It also aids us in creating realistic models of the ecosystems and their functional processes (e.g. trophic connections) and thus the response of these processes to stressors.

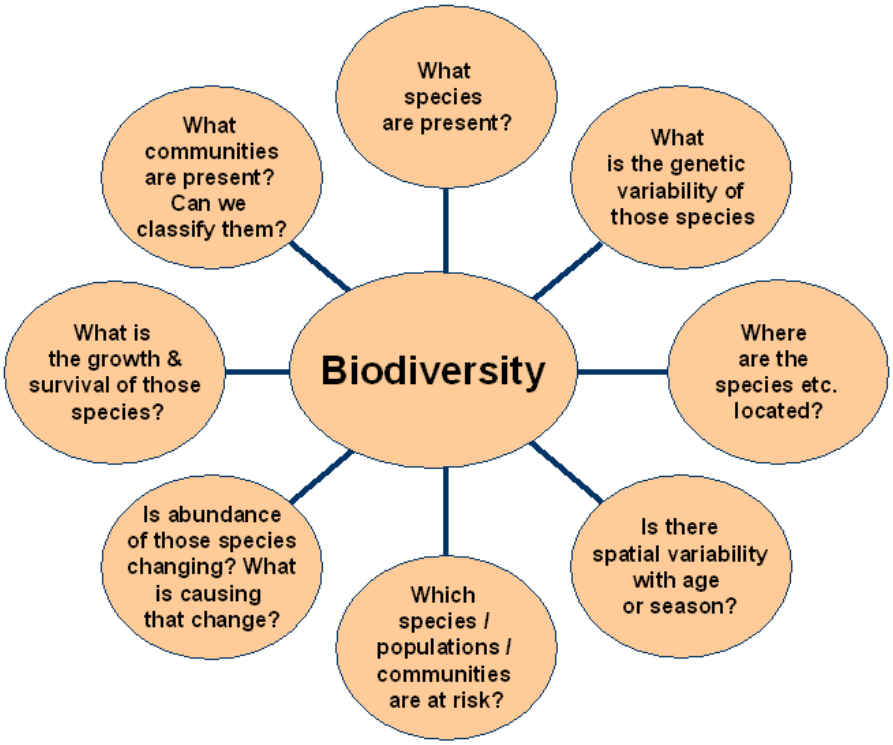


Figure 2: Data and information about the biodiversity of the region needed for EBM.

2.2 Information on the habitats of the region

Habitats include both those in the benthic environment (in, on and just above the bottom) and those in the water column. The atmosphere above the region provides habitat for birds as well as a conduit for airborne pollutants.

Information on the habitats of the region allows us to identify critical areas, monitor for degradation, and protect and enhance habitats where appropriate. Baseline information on levels of chemical pollutants, marine debris and marine noise are all needed before we can accurately monitor change in those parameters. Baseline measurements of ocean circulation and water chemistry are needed to understand processes affecting primary production as well as to monitor or predict changes in those parameters attributable to climate change.

Tools are needed to help us identify, describe and map habitats. Benthic habitats, for example are composed of substance (sediment, biogenic, substrate), structure (complexity, texture), energy (waves, currents) light, depth, and temperature to name a few of the more obvious characteristics. Before we can map where habitats occur or measure how intact or healthy they are, we need to be able to describe and identify them.

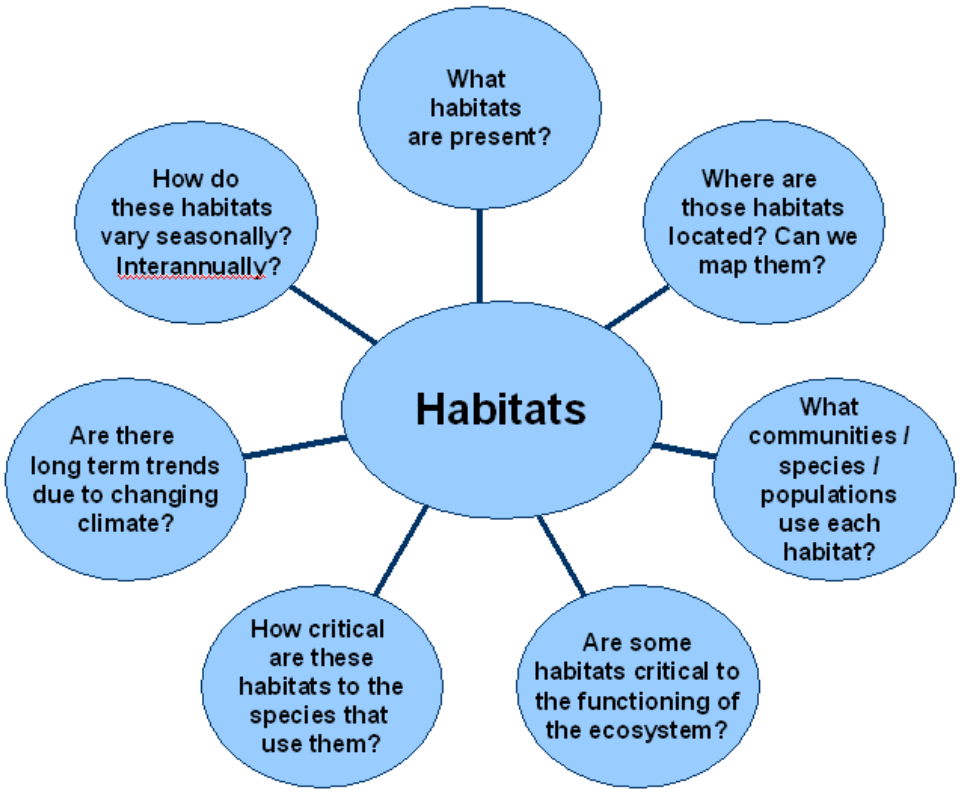


Figure 3: Data and information about the habitats of the region needed for EBM.

2.3 Information on the ecosystem functions in the region.

By understanding the ecological functions of the region we can start to predict how these processes are affected by stressors placed on the system, including those by human activity in the past, present and possibly future. The ecosystem functions include the energy imports into the system (primary production), transfer of that energy between trophic levels, recycling of nutrients by decomposers and interactions between species and communities. The structure and hence stability of the trophic dynamics of the ecosystem can have a large impact on the biodiversity; conversely certain key species (e.g. keystone, highly interactive, structural species) can play an important role in stabilizing the trophic structure.

To completely understand how the ecosystem functions is a daunting task; however there has been a considerable amount of research into identifying the key pieces of information that are needed to help us:

1. Predict how stressors (e.g. biomass removal from fishing) might impact the ecosystem;
2. Monitor the ecosystem to let us know how it is responding to stressors.

Figure 4: Data and information about the ecosystem functions of the region needed for EBM.

2.4 Information on the human activities in the marine ecosystem

For the most part we have reasonable information on the spatial distribution and intensity of human activities that are currently or have recently occurred in BC waters. The ongoing BC Marine Conservation Analysis Project (BCMCA) is updating the coverage and quality of this information and the outputs will be ready for publication in late spring 2010.

There is less knowledge and greater uncertainty of future activities and we are only beginning to gather information on historic activities through TEK and ecosystem modeling. The recent Marine Use Analysis for the Pacific North Coast Integrated Management Area, while specific to the PNCIMA, indicates the main sources of information for human activities in BC marine waters (MacConnachie et al. 2007). The human activities that are known to occur in or adjacent to BC marine waters are listed in Table 1 below.

Table 1: Human activities known to occur in or adjacent to BC marine waters.

Land based activities		
Agriculture	Industry	Water Diversions/impoundments

Onshore mining	Human settlements	Forestry
Harvesting		
Clam fishery	Salmon seine fishery	Tuna fishery
Prawn trap fishery	Salmon troll fishery	Groundfish trawl fishery
Crab trap fishery	Salmon gillnet fishery	Groundfish longline fishery
Urchin Dive Fishery	Salmon First Nations Fishery	Groundfish trap fishery
Geoduck/Horse clam diver fishery	Salmon sport fishery	Seal cull and harvest
Seacucumber diver fishery	Herring roe-on-kelp fishery	Sea otter hunt
Opal squid net fishery	Herring roe fishery	Waterfowl hunting
Abalone dive fishery	Herring food and bait fishery	Sea lion cull and harvest
Shrimp trawl fishery	Sardine/anchovy/eulachon/ smelt fisheries	Whale hunting
Extraction of Non-renewable Resources		
Offshore oil and gas decommissioning	Offshore oil and gas development	Marine Mining
Offshore oil and gas exploration	Offshore oil and gas production	
Extraction of Renewable Energy		
Wave energy	Wind energy	
Tidal energy	Geothermal energy	
Marine Transport*		
Small vessels (<350-ton deadweight)	Larger vessels	Navigation aids
* The category of marine transport includes all vessel activity: fishing, recreation, transport of people and materials, research, fisheries patrol, search and rescue, and military operations		
Marine Tourism		
Sea kayaking	Cruising: large ships	Whale watching and nature viewing
Private boating (powered and sail)	Cruising: small (pocket) cruisers	Scuba diving
Wilderness and coastal lodges		
Military Operations		
Torpedo testing	Submarine detection	Munitions dumping and loss
Coastal Marine Based Industry		
Float homes and float camps	Shellfish Aquaculture	Log dumping, handling and storage
Private docks, ramps and	Marine Plant Aquaculture	Regulated At-Sea-

wharves		Disposal
Marinas and Ports	Finfish Aquaculture	Undersea cables and pipelines
Marine Research		
Wildlife sampling/tagging (marine mammals & birds)	Oceanographic sampling & measurements	Earth Sciences (seismic, sediment cores, Venus project)
Fisheries surveys	Benthic sampling	
Global Stressors		
Climate change	Ozone depletion	Long range transport of contaminants
Invasive species		

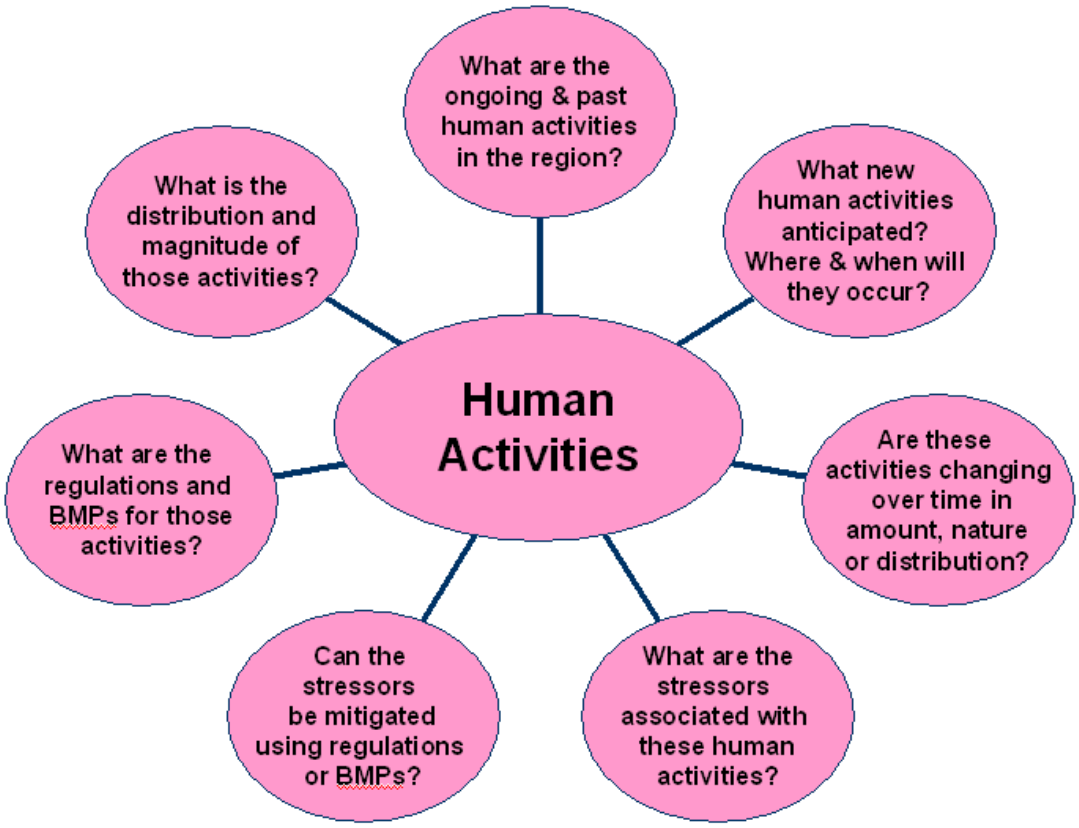


Figure 5: Data and information about the human activities in the region needed for EBM

2.5 Information on the anthropogenic stressors on the ecosystem

Practitioners applying EBM have to make decisions on how to manage anthropogenic stressors on the ecosystem. Human activities (such as marine transport), may result in the foundering of a large vessel (a possible component of that activity) that can lead to the spillage of oil into the marine environment which is a stressor on that environment. The

stressor (which in this example is spilled oil) may impact a number of receptors such as larval fish or marine mammals.

The anthropogenically generated stressors on the BC marine environment can range from selective biomass removal from the ecosystem by marine harvesters to habitat modification by industrial activity or certain fishing practices to indirect impacts on the ocean climate brought on by human activities that contribute to global climate change[4]. The information needed to manage those stressors can be divided into five categories:

1. What we know about what human activities are occurring in the region and where they are occurring. This includes information on what activities occurred where in the past and what future activities may happen in BC marine waters.
2. Information on the nature of each human activity and on how that activity has or will change over time. This includes such parameters as how much of each species is harvested using what methods, the size of aquaculture operations and culture methods employed, the amount and nature of shipping etc.
3. The information on the possible components of the anthropogenic activities affecting the BC marine ecosystem and the stressors associated with them. We also need to know how those stressors will impact the ecosystem.
4. Information on the current background level of stressors in the ecosystem (noise, contaminants, biomass removals, invasive species, etc.) in order to document change due to stressors from human activities in the region or external to the region (i.e. climate change, long range transport of pollutants or invasive species).
5. Knowledge of how cumulative effects from multiple stressors impact the BC marine ecosystem (or component thereof), over space and time. Cumulative effects may occur when similar stressors from different activities act upon the same receptors (e.g., water quality), or when different types of stressors interact. However, cumulative effects can also occur as a density effect of a stressor arising from one type of activity. Stressors generated by both present and past can incrementally add up and interact additively, synergistically or antagonistically depending on the nature of the stressor. There are very few studies of the interactions of multiple stressors in the marine environment. Studies are needed to first identify what stressors may be cumulative; for example marine mammals stressed due to a high body load of POPs may be more susceptible to stress from a decline in available prey. The next step is field and/or laboratory studies to examine how those stressors interact.

By understanding how these stressors are produced and the impacts they have on ecosystem components we can create appropriate Best Management Practices (BMPs) and regulations for industry including the exclusion of harmful activities from MPAs and other sensitive areas.

[4] While external stressors such as those introduced by climate change may be largely outside of the control of EBM in BC marine waters, they need to be understood and taken into consideration as they may interact with locally produced stressors in an additive, synergistic or antagonistic manner (see point 5 of this section – cumulative effects)

Figure 6: Information on the stressors acting on the biodiversity and ecosystem function.

3 Data Quality and Metadata

Data gaps can exist if the information is present but at too small a spatial scale or with an accuracy that does not provide enough information to meet our needs. Conversely collection of information with a higher resolution than is needed may preclude the scope of coverage that is needed.

For each of the categories we can have data or information that informs us with a certain accuracy and precision. It is important to have the right variables measured with appropriate precision at correct scale and sufficient spatial and temporal coverage. The factors that affect this include the:

1. Spatial coverage (areas and depths covered).
2. Temporal coverage (days, seasons, years).
3. Attributes measured (including what variables are reported on).
4. Precision of sampling (how precisely the variable value or spatial position is reported/measured)
5. Accuracy of measurement (sample size, collection/measurement method, expertise of person collecting data, calibration etc.).

In addition it is critical that all data sets have associated metadata that describes all of these data attributes in an easily readable format. DFO and the province have both moved towards a metadata standard (FGDC metadata standard) that is a requirement for all data collected by and for them in BC. This metadata should help to ensure that data is not 'misused' (e.g. at inappropriate scales or does not assume spatial detail and coverage where it does not exist).

More details of the importance of each of these factors as to how they affect EBM related data and information are listed below.

3.1 Spatial scale and coverage

Ocean planning currently is implemented in BC at two spatial planning levels: 'large ocean management areas' (LOMAs) where the primary thrust is to identify ecosystem-based management objectives, and smaller 'coastal management areas' (CMAs) where it is intended that LOMA-level guidance will be reflected and interpreted into more localized management direction. There are a number of data sets that capture information coastwide at a generalized 'LOMA' level while others have more spatial detail but only for certain areas of the coast. For example the Provincial ShoreZone mapping indicates the presence of kelp beds in physical shorezone units along the entire BC coast. This mapping does not include information on the biomass or relative species compositions of the beds and only indicates the presence (continuous or patchy) of kelp within a physical ShoreZone unit. On the other hand when the province did detailed mapping of the larger kelp beds on the north and central coasts between 1974 and 1993 they measured relative species composition and biomass for the beds and mapped the exact boundaries of each bed. There is additional data on the location of kelp beds collected from LEK that is more comprehensive in some areas than others and for which the precision can vary greatly. Combining these data for a single purpose can pose challenges if one wants to avoid misrepresenting what we know.

Spatial scale can also be important in the vertical dimension. Although satellite images give a measure of sea surface chlorophyll for large areas of the ocean simultaneously, this sampling gives no information on the vertical distribution of chlorophyll. In late summer and in areas with high levels of water column stratification, this can miss much of the phytoplankton biomass, which tends to be below the surface in depths where nutrients are more plentiful.

Density of sampling can be critical especially for planktonic species where sampling can also miss a significant portion of the animals in an area if patch size and vertical migrations are not taken into consideration. Use of acoustic sampling can help with this problem but incurs a concurrent loss of information on species and development stages.

3.2 Temporal Coverage

Because of the difficulties associated with sampling during the winter months, much of our oceanographic data has been collected during the summer months. Satellite imagery is also hampered during the winter months by cloud cover. Intertidal surveys are also hampered by the lack of daytime low tides during the winter. As a result our knowledge of species distributions and oceanographic parameters are lacking in seasonal information. Datasets that include measurements of species and oceanographic parameters with a seasonal component (e.g. plant biomass, migratory species, physical parameters) all require metadata that explains the limitation of the seasonal coverage.

Long term trends are a very useful tool in defining ecosystem parameters. For many reasons, including the on-going costs of measurement, there is a lack of long term datasets for BC marine waters. Ocean Station Papa (the only ocean climate station in the global network of OceanSITES time series reference sites which is in the NE Pacific) monitors ocean-atmosphere interactions, carbon uptake, and ocean acidification. Measurements at this site have been continuous since 1949; at the current time NOAA funding for continuation of the station is pending. Fisheries databases that have a long term temporal coverage include the spatial distribution and magnitude of herring spawn, annual numbers

of salmon returning to natal streams (escapement) and fisheries catch data. The methods for collecting and compiling these data have changed over the years and so temporal artifacts may be present. For example, herring spawn surveys are more limited now in spatial extent although the few areas that are well surveyed are accessed by scuba divers and as a result the accuracy and precision of the spawn at those locations is much improved. There is a need for metadata that indicates how the accuracy and precision of datasets has varied over time along with methods for analyzing these data.

3.3 Attributes Measured

The most common attributes for biological features are biomass numbers, species (or life stage), and spatial distribution. Additional features may include productivity, level of contamination and so forth. Depending on the question posed more or fewer details are needed. If we are trying to access productivity of herring stocks then it is important to know the amount of spawn in a location; if we are looking at identifying sensitive shorelines and herring spawn is a factor in our sensitivity rating then perhaps all we need is the presence or absence of spawn in the last 10 years. We are often using data sets for purposes that they were not originally intended. The recent push to identify MPAs is using spatial data originally collected for a multitude of other purposes such as stock assessment, bycatch sampling or oil spill response.

3.4 Precision and Accuracy of Sampling

Data sets such as the Marine Ecounits are only useful at the LOMA scale for planning as they have been generalized to a scale of about 1:250,000. These data sets can have misleading accuracy if they are used at larger (more detailed) scales. For example high current areas such as Active Pass are not identified as such in the Marine Ecounit mapping as they are too small a feature to appear at the scale of mapping.

On the other hand site surveys, such as mapping of an individual eelgrass bed or an intertidal transect, have little geographic extent but may be both very precise and accurate. LEK and TEK are generally of low precision as they are done from memory rather than field work, but can be very accurate as they involve personal observation.

4 Data/Information Gaps Affecting EBM in BC Marine Waters

The list of the main data/information gaps that currently limit our ability to implement EBM in BC marine waters was compiled from the documents produced from the recent ecosystem assessment completed for the PNCIMA[5] (Booth et al. 2007, Johannessen et al. 2007a, Johannessen et al. 2007b, Lucas et al. 2007, MacConnachie et al. 2007). This assessment and overview included the current knowledge of the federal government experts for each aspect of the BC marine environment. It was supplemented by an extensive literature research and reviewed by subject experts and stakeholders during a 3 day workshop. While the ecosystem assessment was focused on the PNCIMA, most of the issues for that area are relevant to all of BC's marine waters. A total of 68 specific information/data gaps were identified. These gaps were then classified into five topic areas based on the classification used in Chapter 2 above:

[5] The Pacific North Coast Integrated Management Area or PNCIMA is a federally designated large ocean management area extending from the Canada-Alaska border in the north to Brooks Peninsula on NW Vancouver Island and Quadra Island and Bute Inlet in the south; from the outer limit of the continental slope in the west to the coastal watersheds in the east.

Table 2: Topic areas for information/data gaps identified for BC marine waters.

Topic	Description
Biodiversity	Uncertainties about the Ecological Components (biodiversity)
Habitat	Uncertainties about the Habitat
Functions	Uncertainties about the Ecological Functions
Activities	Uncertainties about the Extent of Human Activities
Stressors	Uncertainties about environmental stressors created by human activities

The data gaps were further categorized into 14 data categories. The table below shows the number of gaps identified for each category by topic area. While there may be other research questions that need to be added, it is anticipated that the major questions have been identified.

Table 3: Number of information gaps by category for BC marine waters.

Category↓ Topic→	Biodiversity	Habitat	Ecosystem Functions	Human Activities	Stressors	Total
Pollutants, marine debris		10			1	**11**
Invasive species			1		2	**3**
Noise, sonar, electromagnetic fields		1			3	**4**
Cumulative effects					1	**1**
Offshore oil & gas development				1	2	**3**
Benthic habitat impacts					4	**4**
Biomass removal				2	4	**6**
Physiological stressors					1	**1**
Offshore benthic habitat and communities	2	2	2			**6**
Trophic structure, species interactions	2		2		1	**5**
Population parameters, stock status, genetics	6		3			**9**
Primary productivity, oceanographic processes	1	1	4			**6**
Industry developments				5		**5**
Climate change			2	1	1	**4**
Total	**11**	**14**	**14**	**9**	**20**	**68**

While the greatest number of unknowns/uncertainties lies within the topic of understanding the impacts of anthropogenically generated stressors on the marine environment, the magnitude of the individual data gaps listed under Ecosystem Functions is perhaps the most daunting. The single largest category of gaps falls into those associated with the sources and fates of contaminants followed by gaps in our understanding of primary productivity and oceanographic processes. The numbers are somewhat biased by our current knowledge and therefore the specificity and magnitude of the data/information gaps. For example the questions related to climate change are very broad as the level of uncertainty is high; on the other hand there have been several recent reports on the status of our knowledge of

contaminants in BC marine waters and as a result the data/information gaps have been clearly and specifically identified. A complete list of all of the identified data gaps from the PNCIMA is listed in Appendix A of this report.

5 DFO Current Research Directions and Priorities

5.1 National Research Priorities

As the lead agency in Canada for managing fisheries and oceans, DFO leads the way in marine research related to EBM. DFO has identified eight priority areas for which it will provide support for under its Ecosystem Science Framework (DFO 2007). These include:

1. Setting clear ecosystem objectives for monitoring and protection
2. Developing ecosystem indicators and reporting systems
3. Developing risk-based frameworks
4. Generating integrated information for fisheries management
5. Identifying habitats of special importance and sensitivity
6. Considering impacts on aquatic biodiversity (Species at Risk Act and invasive species)
7. Understanding pathways of effects driving changes
8. Understanding climate variability and impacts on resources

Within this Ecosystem Science Framework DFO has further identified nine components that they feel "reflect the highest priority management and policy challenges of both the department and the Government of Canada, as well as the multi-functional nature of an ecosystem science approach" (ibid.). These components can be defined as a series of tools (e.g. models or analysis methods), knowledge (e.g. model parameters, ecological connections) or understanding (e.g. ecosystem structure and function) and include:

Table 4: DFO Ecosystem Science Framework highest priority components

Component	Description
Risk assessment tools	Tools to help assess the risks associated with human activities which can then be considered in management and policy decisions.
Performance evaluation tools	Tools for evaluating the performance of ecosystem indicators or suites of indicators. These are needed for scientific evaluation of management decisions in a manner that can be reliably applied in operational situations.
Rule-based management tools	Methods for evaluating rule-based management decisions. Long term research on what are effective management rules in variable environments.[6]
Regime shifts tools	Tools that explore the management implications of climate variability and ecosystem shifts caused by over-fishing.
Productivity changes knowledge and tools	Consolidate existing knowledge of changes in stock and ecosystem productivity, and develop approaches to ensure that knowledge is reflected in science advice.
Depleted species understanding and	Identify factors affecting recovery of depleted populations to support long-term and short-term stock-rebuilding efforts.

[6] In 'rule based' systems management follows a set of rules with no pre-defined vision of the final state of the ecosystem, stock, etc. Rules are established to try and meet objectives, but their effect over a long term planning horizon often cannot be properly visualized. In the alternative 'target based management systems the state of the ecosystem at the end of the planning horizon is determined and the model works to create this effect in the shortest amount of time. (For example management to achieve specific stock sizes.)

knowledge	
Ecosystem structure understanding and knowledge	Identify the measurable properties that matter most to ecosystem structure and function. These might include components such as predators or prey, habitat features, and even integrative functional properties reflecting community resilience and energy transfers.
Knowledge access tools	Tap into existing information on aquatic habitats and use spatial information in science advice to take full advantage of databases and to focus on localized issues. Issues include data organization, format (esp. spatial data), easy access to international data and data not yet in easily accessible formats.
Ecosystem assessments tools	Enhancement of the current EAOR approach for LOMAs. Goal is a "best practices" method for ecosystem assessment under EBM.

5.2 Pacific Regional Research Priorities

In the Pacific Region funding for the LOMA approach for EBM in the PNCIMA ended in 2007 and was not renewed by the Treasury Board. The intent had been to take the bio-physical analysis and integrate it with socio-economic aspects of the ecosystem. Incremental funds will be needed before this work proceeds. Because of the large number of data gaps there was not a lot of internal support for the PNCIMA LOMA.

The new focus of DFO in the Pacific region "The Strait of Georgia Ecosystem Research Initiative (ERI)" was announced in April 2008 (DFO 2008)[7]. This initiative includes smaller pilot projects to develop tools/methods, models, and policy scenarios for applying these models and tools to EBM. A limited amount of field work will be funded to support modelling effort. New funding announced by DFO in April 2008 for scientific research projects across Canada totals $2.3 million annually for a five-year period; the amount allocated to the Pacific region is only $400,000 over the five year project (Ian Perry, pers. comm. 2008).

In order to work within this budget requires that most of the research is based on existing data. Because the Strait of Georgia is the most data-rich region in BC marine waters, it has been selected as the region of study for the Pacific region. The focus of studies is to determine what has driven past changes in the Strait, what is causing present changes, and what will the Strait be like in the future? The research plan circulated in February 2008 describes the plan as follows.

Priority areas for research in the Pacific Region include:

- Habitat and Population Linkages.
- Ecosystem Assessment and Management.
- Fish population and community productivity.
- Climate Change/Variability.

At this time DFO has identified two research questions to move forward on. These investigate the productivity, timing and ecosystem resilience of the system:

[7] The Central Theme of this Ecosystem Research Initiative is "The Strait of Georgia in 2030", i.e. what might the Strait of Georgia be like in 2030. Responding to this challenge of imagining the future, or constructing scenarios, involves: 1) understanding how this ecosystem works, 2) identifying the various drivers of change most likely to determine future conditions, and finally 3) analyzing the future responses of the system under the influences of these drivers of change. The research conducted within this Initiative is designed to align with the Departmental goals of ensuring a healthy and productive aquatic ecosystem in the Strait of Georgia, and to support sustainable fisheries and aquaculture in the Strait.

1. What controls the productivity of the Strait of Georgia? (including timing mismatches)
2. What properties/characteristics of the Strait of Georgia ecosystem provide or erode its resilience against major stresses and disruptions of the system?

Expected outcomes include a detailed description of the Strait of Georgia ecosystem with models that illustrate the ecosystem structure and function (e.g., circulation models, trophic models); identification of ecosystem indicators for rapid assessment of ecosystem state; identification of ecologically and biologically significant areas (EBSAs); and finally, a set of decision support tools that provide a scientific basis for evaluating the potential outcomes of management decisions and plausible scenarios for the future of the Strait of Georgia.

About 50 scientists are involved in the Strait of Georgia ERI, and there are 28 currently funded projects in three research areas including:

1. Development of tools for ecosystem-based marine management including:
   - Models: a physical circulation model, a lower trophic level model, an upper trophic level model, and a whole-ecosystem model which uses a different modeling framework from the previous three models.
   - Indicators and historical information to assess the current status of the Strait and to reveal linkages for use in the computer models.
   - A small number of field projects to support the above including classification of bottom types and near shore habitats throughout the Strait, high-frequency observations of winds and resulting plankton blooms, satellite observations, and exchanges of nutrients and contaminants between the bottom and the water column.

2. Research into problems with salmon populations, in particular coho and Chinook including studies on:
   - The quality of prey for salmon.
   - How coho, Chinook and sockeye use the Strait of Georgia (migration patterns, key growing areas, when they leave the Strait).
   - The impact of large numbers of pink salmon on the feeding environment for coho and Chinook salmon.

3. Research into the structure of food webs and the role of Harbour seals in the Strait of Georgia. Projects include:
   - Studies of seal-hake-herring interactions.
   - Abundances of and key locations for forage fishes.
   - Predators of forage fish in addition to seals (e.g., cetaceans, dogfish).
   - The physiological health of the seals as an indicator of contaminant stresses.

In addition work is underway to compile a bibliography of literature relevant to the Strait of Georgia and to collect and organize relevant data for the Strait of Georgia marine ecosystem. A list of all of the specific DFO projects that have been funded as part of the Strait of Georgia ERI and their principal investigators can be found on the DFO web site at: http://www-sci.pac.dfo-mpo.gc.ca/sogeri/researchprojects_e.htm.

DFO expects the Strait of Georgia Ecosystem Research Initiative to generate considerable interest from groups and agencies external to DFO that have expertise in the Strait of Georgia. They see external groups as helping to expand the DFO initiative into locations and issues which DFO is unable to address, using the DFO activities as an integrating framework. They specifically identified the analyses of historic changes and future projects of the socio-economic characteristics of the Georgia Basin system as a project for outside agencies. Additionally, DFO has instructed its internal researchers to collaborate (as appropriate) with non-DFO partners so as to combine funding and expertise regarding the Strait of Georgia ecosystem.

5.3 Other DFO Current Research Initiatives

DFO has three areas of programs under the Ocean's Act; Integrated Management, Marine Environmental Quality and Marine Protected Areas. As stated above, in the Pacific region the Strait of Georgia ERI is dominating research in the first two areas, Integrated Management and Marine Environmental Quality. There is also research planned to push forward research and management on the two existing MPAs, Endeavour Hydrothermal Vents and Bowie Seamount, and to move forward on the designation of Race Rocks as the third MPA in the region.

5.4 Impact of DFO Priorities on EBM in BC Marine waters

Current DFO research priorities involve research using mostly existing data in the Strait of Georgia and the two existing and one proposed MPA. All of the MPAs are primarily focused on benthic habitats and the Strait of Georgia ecosystem studies are dominated by pelagic species and stressors caused by human activities such as pollutants, disturbance and invasive species. As a result of this focus there is now a marked lack of research into ecosystems that include groundfish and offshore benthic habitats such as sponge reefs. Regions of the BC marine waters where there are significant impacts of offshore trawling including habitat damage, bycatch and overfishing of groundfish stocks are all outside of the current research focus. EBM issues around finfish aquaculture and the impacts of offshore oil and gas development, which are virtually absent from the Strait of Georgia, will also be outside of the scope of the Strait of Georgia ERI.

On the other hand, aspects of EBM that will come into focus include the issues surrounding invasive species, contaminants and disturbance. The two central questions being posed by the Strait of Georgia ERI - What is controlling productivity and what properties of the ecosystem provide resilience? - should produce tools, indicators and approaches supporting EBM in other regions.

6 Considerations in Prioritization

A primary objective of this project is to help inform the EBM community of practice about information and data gaps existing in the EBM framework in BC marine waters. As indicated in Section 4 of this report, some components of information that would support EBM in BC marine waters are incomplete or missing. Research by other groups[8] indicates that gaps exist in the policy framework, management instruments, decision tools and methods and there is no formal performance evaluation framework. A conceptual framework for how these components fit together is shown in Figure 7. PacMARA is leading this EBM gaps initiative to aid all stakeholders in selecting priorities and deciding how to proceed in filling those gaps given limited resources.

[8]Taylor, Peter H. and V. DeLauer. 2009. "EBM Roadmap." COMPASS and EBM Tools Network. *Aug. 10, 2009* <www.ebmtools.org/about_ebm/roadmap.html>. Federal and Provincial Ocean Information in BC", Assessment of Current Barriers to Inter-Agency Data Integration, Synetric Consulting Group, 2007; Assessment of Current Information to Support the Oceans Strategy, LGL Limited and Archipelago Marine Research Ltd., 2007; Integrated Ocean Information Management System, Agency Information Systems – Recommendations and Final Report, Sierra Systems, 2008.

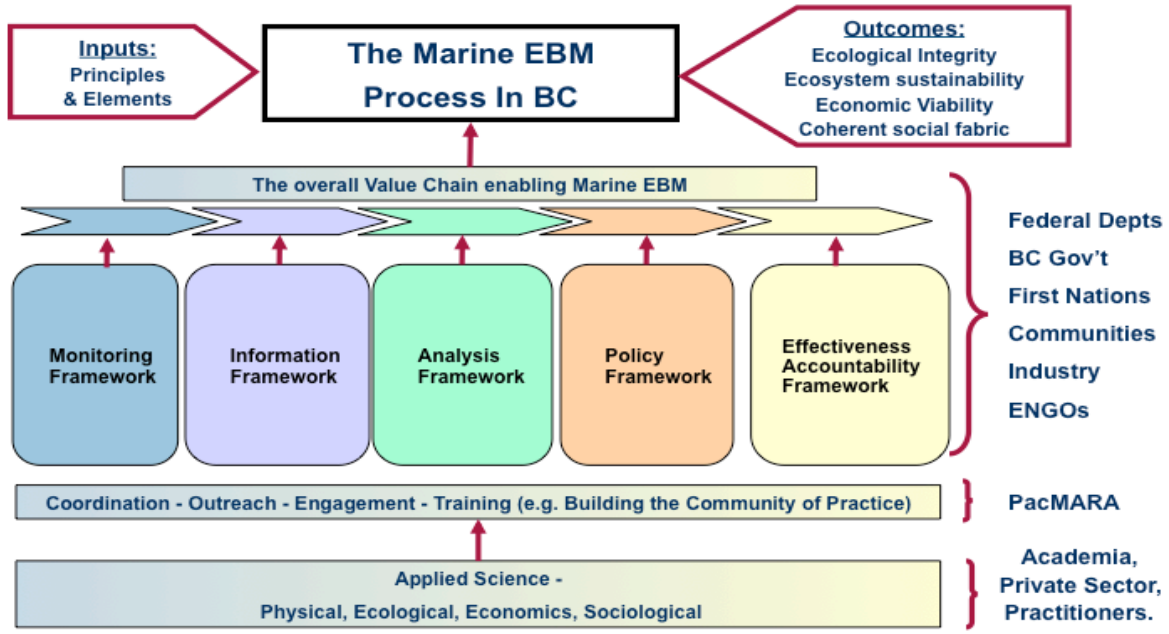


Figure 7: A conceptual view of the marine EBM framework for BC

When prioritizing projects for funding it is important to consider a number of distinct factors including:

1. Feasibility: Is the project feasible? Can the project be completed in a timely manner (i.e., are personnel and infrastructure available) with the available funds?
2. Integration: Does the work compliment, supplement or support research funded by other agencies in support of EBM in BC? Does the work compliment, supplement or support other research currently being undertaken in support of EBM in BC?
3. Priority: Are the data/information gaps that are addressed by the projects those that are the most critical to fill from the point of view of proceeding with EBM in BC marine waters? Does the project contribute more to supporting EBM in BC marine waters than other proposed projects?

The following section reviews the factors that should be considered in prioritizing research opportunities.

6.1 Feasibilty

While there are a multitude of projects that could be selected to support EBM in BC marine waters, some of these projects may not be possible given resources available (people, funding, time, tools). One way for funding organizations to help address this problem is to announce specific area(s) targeted for funding and then to ask for proposals focused on those areas. This approach puts the onus on the applicants to formulate feasible projects that fall into the specified area(s) of funding. This approach commonly involves two rounds of prioritization, an initial round to determine the priority areas for funding and a second round to select the specific projects from the proposals submitted.

6.2 Integration

For PacMARA a primary consideration in becoming involved in the support of EBM in BC marine waters is whether PacMARA wishes to act as a facilitator, supporter, leader or

advocate. As the government body responsible for the Ocean's Act, DFO has taken on the lead role of implementing marine EBM in Canada. As such it is important to understand how a group like PacMARA could augment the activities of DFO, BC ILMB, or any other specifically mandated government agency. PacMARA could facilitate the process of establishing a sustainable marine EBM community of practice by undertaking projects that increase the overall understanding of EBM and the methods and tools used to implement EBM. It could also build positive relationships between the various government agencies and the ENGOs involved in EBM in BC marine waters. As such the approach taken should consider other ongoing initiatives in BC. Three possible ways that PacMARA can approach this are to;

1. Augment DFO's current EBM programs by funding projects complementary to the Strait of Georgia ERI. These could include projects that DFO has identified but is unable to fund, projects that are outside of DFO's expertise (e.g. socio-economic aspects of the project), or projects where DFO has an internal conflict (e.g. aquaculture, fisheries impacts). The advantage of this approach is that DFO has stated their desire to work with other groups on the Strait of Georgia ERI and funding on their projects is in place for the next five years. This could be an opportunity for PacMARA to develop a good working relationship with DFO. The disadvantage of this approach is that a large area of BC marine waters and their associated issues will be left out of current EBM initiatives.
2. Concentrate funding in regions where DFO has science gaps, such as the PNCIMA or west coast of Vancouver Island where issues such as trawling, finfish aquaculture and offshore oil and gas development are important. PacMARA could take the lead in research areas where there is internal conflict within DFO (groundfish trawl fishery and salmon farming) or the province (offshore oil and gas) and provide a less biased approach to help resolve issues around these activities which are central to EBM in northern BC. The approach could keep some focus on the PNCIMA LOMA and go forward from the foundation built up by the PNCIMA EAOR that was started.
3. Facilitate discussion between DFO and other data collection agencies to develop models to improve access to marine data in support of EBM in BC. DFO and the province of BC drafted a MOU to develop an integrated oceans management system and initiated work to develop a 5-year plan to implement it. Talks with individuals in both the federal and provincial governments indicate that work on this project came to a standstill at the end of the last fiscal year, partially as a result of the retirement of its main champion in the Provincial government. PacMARA could champion this project and help it move forward. An advantage of PacMARA filling this role would be to ensure that the project addresses the needs of the whole EBM community of practice as a whole. A government-dominated process might not achieve this balance. PacMARA also has the advantage of taking an independent look at data structures while both levels of government are dealing with legacy systems. A description of the 5-year plan and a summary of work done to date are included in Appendix B of this report.

The decision on which direction to take has significant implications for PacMARA, as such it should be decided on by the PacMARA board. The decision taken will influence the suite of data/information gaps that will be assembled to meet marine EBM community needs in BC.

7 Method of Clarification and Prioritization

The EBM Gaps Challenge Dialogue Project being sponsored by PacMARA is being undertaken to work with the marine EBM community of practice to collaboratively prioritize the list of possible projects by:

- Vetting previous work[9] identifying such gaps.
- Leveraging the knowledge and experience of marine EBM practitioners, including resource users, decision makers and subject matter experts to prioritize the gaps.
- Identifying actions to address the gaps.

The approach being proposed to address the knowledge and process gaps in Marine Ecosystem Based Management on Canada's Pacific Coast will leverage innovative analysis tools - the EBM Value Chain, the Challenge Dialogue System and strategic Outcome Mapping.

By leveraging the EBM Value Chain the intent of the dialogue is to identify the key knowledge gaps limiting the effective application of marine EBM and developing a strategy and action plan to address those knowledge gaps. Addressing key gaps in knowledge should improve political acceptance of EBM and application to policy.

The EBM Value Chain provides a holistic view of the entire EBM process identifying all of the components that make up EBM as links in chain, each of which needs to effectively function for EBM to work as a management process in support of both broader policy development and in-situ decision making.

The EBM Value Chain is characterized by steps, or links in a chain, with each link receiving inputs from the previous link, and providing outputs to the next link. Once the value chain is populated to capture the current status of each link in the EBM chain it provides the necessary information to undertake an EBM Knowledge Gap Analysis. It will allow us to identify what gaps exist in things like policy; process; management systems; people, skills and training; analysis and information products; access infrastructure; and data. Because of the nature of the value chain and its links it also provides us with an effective tool to determine what organizations, or groups, and what people should be working or talking with each other to identify and address the gaps in the chain.

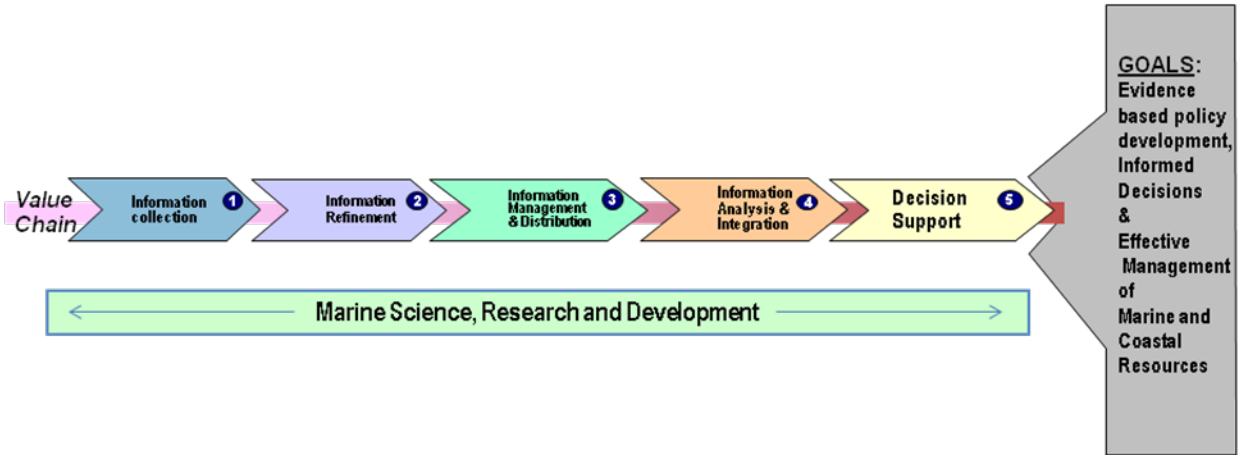


Figure 8: Value Chain Model:

[9] Previous work includes: EBM Data Gaps, Jacqueline Booth & Assoc., 2008 (Draft); "Federal and Provincial Ocean Information in BC", Assessment of Current Barriers to Inter-Agency Data Integration, Synetric Consulting Group, 2007; Assessment of Current Information to Support the Oceans Strategy, LGL Limited and Archipelago Marine Research Ltd., 2007; Integrated Ocean Information Management System, Agency Information Systems – Recommendations and Final Report, Sierra Systems, 2008.

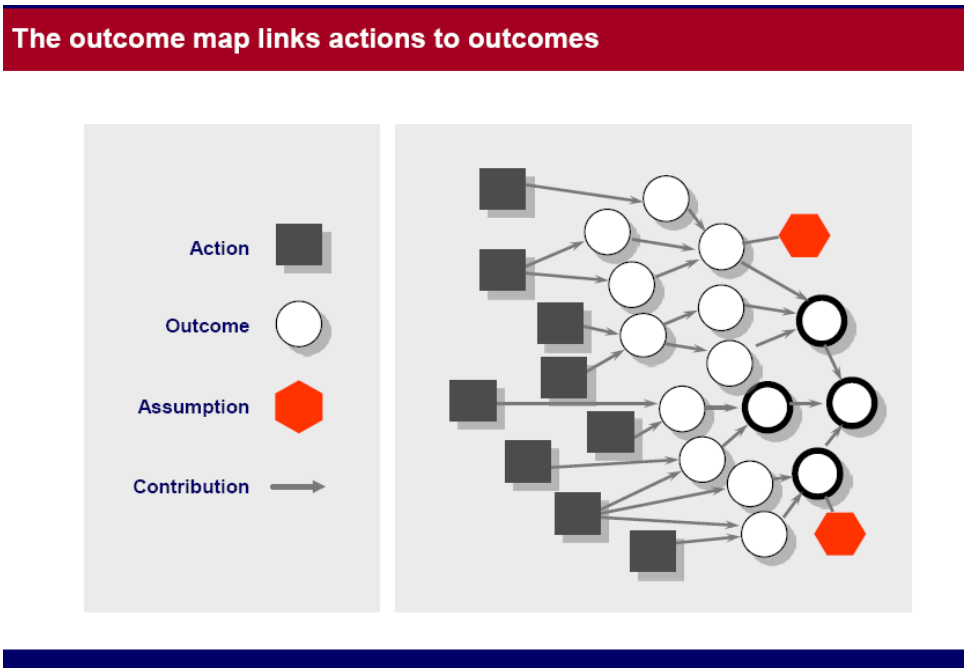
In addition, the approach will involve adapting the Challenge Dialogue System™ (CDS) to the unique needs in this dialogue. CDS transforms diverse individuals into high-performing teams, expert in co-creating solutions that deliver results. The approach will involve:

- The development of a *Challenge Paper* including Key Challenge, Background Statements, Assumptions, Expected Outcomes, Questions-Issues-Opportunities-Ideas with Action Options and Next Steps.
- Leveraging the internet, The *Challenge Paper* will be distributed to Dialogue participants inviting their feedback electronically.
- The feedback will be used to design and plan for a series of face-to-face workshops which is focused on acknowledging areas where there is alignment already, areas of confusion that need further clarification and areas of miss-alignment that need further dialogue.
- Outcome from the face-to-face workshops will result in a set of *key learnings* and *moving forward action plan* which will be used to build an EBM Gaps Strategy and Action Plan.

The EBM Gaps Strategy and Action Plan will be developed using the Strategic Outcome Mapping Process[10]. The outcome mapping process:

- Ensures that programs produce outcomes that are aligned with strategic objectives
- Explicitly links actions to outcomes
- Clarifies expected program outcomes
- Identifies specific outcome streams
- Establishes metrics to measure the achievement of results
- Results in an action plan that has a much higher likelihood of delivering the anticipated results

[10] The Outcome Mapping Process was formalized by Global Vision Consulting and Innovation Expedition Inc. It has been applied successfully to develop several National and international strategic and operational action plans for undertakings that involve complex issues and multiple stakeholders.



In summary, the *PacMARA Marine EBM Gaps Program* is a series of activities supported and facilitated by PacMARA to improve marine EBM definition and practice in support of its implementation on Canada's west coast and to improve capacity to undertake marine EBM on the Pacific Coast of Canada. The activities, of which this project, the Marine Ecosystem Based Management Knowledge Gaps Study is a part, include:

- Framing the marine EBM environment.
- Facilitating the application of EBM in marine planning and decision-making.
- Leveraging EBM investments to date, including existing tools, skills and knowledge.
- Linking EBM science with marine policy development.
- Developing and delivering a strategy for an outreach and training program.

8 Acronyms

BMP	Best Management Practice
CDS	Challenge Dialogue System
CMA	Coastal Management Area
DFO	Department of Fisheries and Oceans
DSS	Decision Support Services
EAOR	Ecosystem Assessment Overview Report
EBM	Ecosystem Based Management
EBSA	Ecologically and Biologically Significant Area
EMF	Electromagnetic Frequency
ERI	Ecosystem Research Initiative

FGDC	U.S. Federal Geographic Data Committee
IOS	Institute of Ocean Sciences
LEK	Local Ecological Knowledge
LOMA	Large Ocean Management Area
MPA	Marine Protected Area
NOAA	National Oceanic and Atmospheric Administration
PacMARA	Pacific Marine Analysis and Research Association
PAH	Polycyclic Aromatic Hydrocarbon
PBDE	Polybrominated Diphenyl Ethers
PBS	Pacific Biological Station
PNCIMA	Pacific North Coast Management Area
POP	Persistent Organic Pollutant
RFP	Request for Proposal
TEK	Traditional Ecological Knowledge
UBC	University of British Columbia

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