

Appendix A

Identified data/Information Gaps and Uncertainties

Topic **Uncertainties about the Ecological Components (biodiversity)**

Subtopic **Offshore benthic habitat and communities**

Information on the biodiversity and distribution of offshore macrobenthos There have been very few studies of macrobenthos in BC marine waters, especially offshore. Monitoring of changes in community structure and species distribution in response to stressors and management actions is difficult without a good baseline.

Locations and species compositions of deep-sea coral gardens Not only is there poor inventory data for these deep-sea species but the number of species depending on or associated with these reefs and their full ecological importance is still unknown. There are currently no trawl closures for corals in BC as there are on the east coast or as is afforded the sponge reefs. Areas of known high incidence of coral bycatch (from commercial and research trawling) could be a starting point for more systematic mapping and community studies of corals.

Subtopic **Population parameters, stock status, genetics**

Clarification of the current size and trends of herring stocks Herring are thought to be a key species in the BC marine ecosystem however there is a discrepancy between First Nations LEK and DFO's stock assessment for the central coast stock. Further studies are needed to resolve this.

Information on the biodiversity of phytoplankton communities Productivity and availability of that productivity to herbivores is affected by the species composition of the phytoplankton community. It will be very difficult to identify and assess the impact of invasive species or climate change if our knowledge of the existing communities is limited.

Information on the biodiversity, numbers and population parameters of deepwater fishes information to establish sustainable catch rates for those fish stocks (including deep-water fish species) which are being exploited commercially despite insufficient data and knowledge to assess their status reliably.

Information on the distribution, biomass and trends of populations of non-commercial forage fish Forage fish are important in the diet of piscivorous fish and marine birds and mammals yet except for herring, we know little of their distribution, biomass and population trends in BC marine waters. Our lack of knowledge of Sandlance populations has been identified as a key data gaps for some

Information on the genetic biodiversity of most commercially exploited species With the except of some salmon stocks, very little is known about the genetic biodiversity of commercially exploited species in BC marine waters.

Information on the population parameters of exploited species Most ecosystem models of responses to stressors such as harvesting require information on size structure, size and maturity at age, mean and maximum length of all impacted species. These are lacking for many species in BC.

Topic **Uncertainties about the Ecological Components (biodiversity) continued**

Subtopic **Primary productivity, oceanographic processes**

Clarification of the status of northern kelp beds LEK has suggested that there has been a decrease in the extent of the large northern kelp beds. This needs to be confirmed and if measurable the causes need to be understood.

Subtopic **Trophic Structure, Species Interactions**

Information on past states of the marine ecosystem structure and function Recently, it has been realized that the reconstruction of past human activity and its ecological consequences are vital to understanding the current state of large marine ecosystems (back to the future modeling). Research into the historical levels of harvest by First Nations of marine fish and shellfish could input into these studies.

Information on the population growth of sea otters and their impact on the recovery of abalone in BC The recovery of Northern abalone to its former abundance may also be threatened by predation by sea otter which are currently expanding their range. As sea otters also predate on urchins, thus enhancing the abundance of kelp forests that support abalone, the relationship between sea otters and abalone is still unclear and needs further study. Rates of sea otter population growth have declined since the early 1990s and sources of mortality are not fully assessed. The uncertainty about how large the sea otter population will be and its ultimate distribution when it stabilizes is linked to the study of its influence on abalone recovery.

Topic **Uncertainties about the Habitat**

Subtopic **Noise, sonar, electromagnetic fields**

Current background level of underwater noise in BC marine waters.

There are no comprehensive studies of the level or source of background underwater noise in BC. Most observers appear to concur that, at this time, shipping and marine transportation traffic is the primary anthropogenic source of sounds in the area (e.g. LGL Limited and JASCO Research Ltd. 2006, p.101). Our current estimates of underwater noise are all based on extrapolation from measurements elsewhere.

Subtopic **Offshore benthic habitat and communities**

Large scale (detailed) mapping of sensitive habitats

The shorezone mapping is thought to miss some of the sensitive habitats such as ribbon or deeper eelgrass beds, northern clam bed, nearshore spawning areas and other features that could be picked up by LEK

Mapping of offshore benthic habitats

The geographic extent of the many different sorts of subtidal benthic habitat, remains largely uncharted. There is a need to extend our mapping of seabed substrate, sediments, biogenic structures and detailed bathymetry. Current knowledge of seafloor sediments and substrate material is patchy and limited by the need to extrapolate between widely spaced sampling points. The advent of multibeam sonar technology is providing extremely accurate information but will take many years to complete a shelf-wide map. The variability in the transport, deposition and erosion of submarine sediments is also poorly constrained but likely to improve with technological advances.

Subtopic **Pollutants, marine debris**

Amount of (and source of) debris in pelagic and benthic habitats

Surveys in other areas have shown high concentrations of debris both in the habitats and entangled or ingested by marine organisms. There are no estimates in BC waters. Ingestion and entanglement can be a significant source of mortality for seabirds, sea turtles and marine mammals.

Current background level of chronic hydrocarbon contamination

Prior to any offshore oil and/or gas development it would be useful to have a measure of the current background level of chronic contamination from oily waste and an assessment of its sources.

Current background level of POP

Our current knowledge of the distribution of POPs is limited to certain specific areas and they have been measured in a limited number of species.

Current levels of contaminants from the use of fire retardants and their pathways through the ecosystem.

Contaminants arising from global use of fire retardants using polybrominated diphenyl ethers (PBDEs) have been widespread in forestry and other sectors. These have become a source of increasing alarm for local species such as the Orcas and grizzly bears. There is information lacking on their pathways through the ecosystem.

Current levels, sources and discharge rates of pharmaceuticals and their impacts on marine organisms

Pharmaceuticals are currently discharged in the sewage of cruise ships and coastal municipalities. The levels of these contaminants and their ecological impacts are not well known.

Topic **Uncertainties about the Habitat continued**

Subtopic **Pollutants, marine debris**

Fate of heavy metals from coastal mining operations

The extent to which some heavy metals are transferred into the marine food chain through solution or food chain pathways needs further study.

Level of contaminants entering the marine waters from outside the system

Land based sources of contaminants and the global transport of marine contaminants are currently not well monitored.

Source of increased cadmium levels in BC marine waters

Although it is suspected that increased cadmium levels in the North Pacific food chain were related to subsea volcanic activity, industrial sources have not been ruled out and need to be investigated.

Sources of, and impacts caused by, endocrine disruptors

Endocrine disrupting chemicals are known to occur in pulp mill effluent and are suspected in other effluents. Currently these chemicals are not well studied as to their levels, sources or effects.

The forms and pathways that PAHs follow in marine environments.

Little is known about the degradation products of PAHs in the sea, such as their sulphone, hydroxy and nitro analogues, which are often appreciably more toxic than their parent compounds. Some of these can be expected to have a greater persistence than their precursors.

Subtopic **Primary productivity, oceanographic processes**

Understanding of water column chemical and physical properties and factors controlling them

Most oceanographic research is based on limited data points extrapolated to cover vast areas. Very few long-term time series programs exist. Harsh winter conditions mean that much of our knowledge comes from summer data. Technology such as satellite images are improving some areas of knowledge, but often require ground-truthing and can not 'see' far below the surface of the ocean. Models also allow us to develop an understanding of conditions over a large area, but again, ground-truthing is critical to the verification of their results. The variability of oceanographic conditions is generally not predictable with the exception of El Niño conditions which may be predicted three to six months ahead. Modelling of climate and coupled climate-ocean conditions is limited both by computing capacity (most of these efforts require supercomputers), and by a lack of monitoring data, especially over and within the Pacific Ocean. BC is severely lacking in climate and stream gauging, sediment discharge stations, and climate station density and is somewhat lacking in monitoring of evaporation, hydrometric networks and snow course density monitoring.

Topic **Uncertainties about the Ecological Functions**

Subtopic **Climate Change**

How primary production will respond to climate change

There is a lack of knowledge concerning the relationship between climate variability and changes in physical conditions and how this might influence patterns of water circulation and biological production.

How the marine ecosystem structure will respond to climate change stressors (temperature, pH, circulation and coastal upwelling, nutrients, freshwater inputs, storm frequency, sea level rise, UV-B radiation).

The ramifications for populations, communities and whole marine ecosystems remain fundamentally a matter of speculation and growing concern for this region. Uncertainties surround species survival, species distribution, reproductive timing, growth and predation rates and the cumulative effects and impacts on communities and ecosystem structure.

Subtopic **Invasive species**

Ecological consequences of invasive species and factors leading to increased invasiveness of non-native species

With changes due to climate change and other stressors which de-stabilize the community structures there could be a greater potential for range extension of southern species or establishment of non-native species. There have been few in-situ studies to observe what makes a community more vulnerable to invasion. Experimental studies are needed to assess the ecological consequences of invasion.

Subtopic **Offshore benthic habitat and communities**

Identification of the species and communities associated with offshore benthic habitats

There is a lack of information on the communities associated with subtidal benthic habitats. Information is needed on both the infauna and epifauna and demersal species associated with offshore benthic habitats.

Information on benthic habitat functions

The ecological role of key physical and biogenic habitats in supporting species and communities is poorly documented or understood e.g. role of sponge reefs, sea mounts, rock reefs, deep sea corals.

Subtopic **Population parameters, stock status, genetics**

Identification of Ecosystem Indicators to assess and monitor ecological change and ecosystem function

Identification and testing of indices such as biomass ratios, size-based indicators, trophodynamic indicators and population-based indicators to monitor changes in the ecosystem structure

Information on the vulnerability of early life history stages of commercially important species

This requires two set of knowledge: 1) the distribution of these life history stages: knowledge of the precise spawning times and areas for all commercial species, the seasonal and vertical distribution of eggs and larvae, and juvenile nursery grounds and depth distributions. And 2) The sensitivity of these life history stages to stressors generated by human activities and climate change.

The reasons for the dramatic coastwide decline of eulachon

Populations have declined throughout their range in the last 20 years with intermittent but unsustainable signs of rebounding. Despite some greater recent research and monitoring attention, determining the relative importance of several possible causes remains largely speculative.

Topic **Uncertainties about the Ecological Functions continued**

Subtopic **Primary productivity, oceanographic processes**

Composition and role of detritivores in recycling of nutrients, carbon and contaminants

There is increasing evidence that a considerable amount of Carbon is recycled within both the planktonic and benthic communities by detritivores and bacteria. Our knowledge is lacking on the biodiversity, biomass and functioning of this.

Distribution and rate of primary productivity

Currently almost all of our information on the distribution of primary production in BC marine waters comes from estimates of surface chlorophyll derived from satellite imagery. This does not measure rates of primary production or take into account sub-surface production and its seasonal and interannual cycles.

Factors controlling primary productivity

If the patterns of primary production change then the consequence can be a lower rate of transfer of energy from the primary producing phytoplankton to the next stage in the trophic structure which ultimately leads to less food available for commercial fish stocks. Our understanding of how human generated stressors, especially those associated with climate change, will affect phytoplankton productivity is very poor.

Information on the relationship between environmental conditions and at sea survival of many species (e.g. herring, salmon)

In order to better predict year class strength of commercial species more research is needed on rates and causes of mortality of early life history stages of species such as herring, salmon, and rockfish.

Subtopic **Trophic Structure, Species Interactions**

Identification of strongly interactive species in the ecosystem

Fishing and overfishing can also have indirect effects in food webs due to competition and predation. These effects can cascade through food webs especially when strongly interactive species are involved through competition, mutualism, predation, and/or habitat enrichment.

Information on the resilience of the trophic structure of BC marine ecosystem to stressors

Research on how various stressors affect the trophic structure of BC marine ecosystems is of critical importance for the implementation of EBM. Stressors resulting from top down influences (e.g. selective biomass removal), and bottom up influences (e.g. those causing changes in primary productivity and associated zooplankton and forage fish). Research is expected to include modelling and adaptive management. Note that field research and data mining to determine model inputs is also required.

Topic **Uncertainties about the Extent of Human Activities**

Subtopic **Biomass removal**

The current amount and location of poaching of marine fish and shellfish

In the case of abalone this could be significant. Also may be occurring with crabs, clams, halibut and salmon.

The current size and location of the sport and FN harvest of marine fish and shellfish

There is less monitoring and reporting and fewer regulations for these fisheries than there is for commercial fisheries. In some areas the catch may be higher than that of the commercial.

Subtopic **Climate Change**

How the rate of release of greenhouse gasses will continue in the future

Depending on many socio-economic, political and possibly abiotic (e.g. volcanic activity) factors.

Subtopic **Industry developments**

Current and future use of “new generation” of submarine detection systems by the military

These have been linked to stranding and mortality of marine mammals. Information on where these arrays will be tested and deployed is currently classified.

Future development of offshore mining

While at this time there are no development plans for offshore mining in the marine waters off British Columbia, even for the longer term, there is a potential for mining of aggregates, manganese nodules, polymetallic sulphides and gas hydrates.

Future developments of renewable ocean energy: wind, wave, tidal and geothermal

The locations, size and nature of future projects to harness renewable energy from the ocean is still unknown. The Naikun wind development project in Hecate Strait is currently (June 2008) in the pre-application phase of an EIA review and there is a single small tidal power project run by Pearson College at Race Rocks.

Future extent of finfish aquaculture

There is uncertainty in the future regulations surrounding fish farms: the regional distribution, siting criteria and operating regulations are under pressure to change both from those who want more restrictions and those that want to expand.

Future large scale marine transport projects

There has been recent interest in establishing new terminals associated with LNG and oil/gas pipelines; These and other yet to be proposed projects are based primarily on political decisions and economic opportunities but would have significant implications for EBM.

Subtopic **Offshore Oil and Gas development**

Future extent of offshore oil and gas

While this could have significant implications for EBM it is subject to political decisions and the economic pressures of the price and availability of other oil sources. The possibility of development would be better known if the size and nature of reserves were known but studies to determine this have their own ecological consequences.

Topic **Uncertainties about environmental stressors created by human activities**

Subtopic **Benthic habitat impacts**

Impacts of the bottom trawl fishery on the benthic habitats and species of BC

There is a recognised need to measure the impact of bottom trawling on BC's benthic habitats and their associated species. Studies have been done on the BC sponge reefs and in other parts of the world, but are lacking for most BC habitats. It has been observed that no single activity has the potential to create as large an impact on the benthic habitat of the continental shelf as bottom trawling has. Impacts on organisms appear to be habitat specific.

Impacts of the trap and longline fishery on the benthic habitats and species

Longlines and traps may be damaging benthic habitat structure however there has been far less research on this topic area than there has been on the impacts of trawling. There has been some work in Alaska that indicates that longlines are more damaging than traps

Impacts of the use of predator nets over intertidal clam leases.

Diving ducks (esp. Harlequin) and juvenile salmon feed on benthos in the tidal ranges and it has been speculated that the extensive use of predator nets in key staging areas could be impacting certain species. This is especially significant in Baynes Sound where the industry is expected to grow and a significant portion of the worlds population of harlequin ducks spends a portion of the year.

Long-term impacts of geoduck harvesting on benthic communities

There is little information on the long term impacts on the benthic environment resulting from the use of "stingers" in commercial geoduck clam harvesting.

Subtopic **Biomass removal**

Composition and quantity of trawl fishery bycatch

While bycatch data is recorded it is not always released and when it is the taxonomic resolution is often not sufficient to access the impact and soft bodied species are not retained. Also species encountered but not caught by the trawl or caught and releases.

Impact on the genetic structure of populations arising from commercial harvesting - removal of selected individuals or sub-populations of a species

Management practices often result in selective fishing (e.g. halibut - faster maturing individuals that mature before they enter the fishery, salmon - by the timing of their return, herring – by their spawn location). In halibut this has been observed to result in smaller fish; impacts on other stocks and resulting amount of decrease in genetic diversity are not well known but could have significant impacts on a species ability to respond to stressors associated with climate change.

Impacts on the community structure arising from commercial harvesting

Changes in community structure arising from removal of large numbers of a key member of that community (e.g. forage fish or top predators) by fisheries.

Information on the impact of discarded bycatch on the food web

It is speculated that large numbers of discards may possibly increase the scavenger populations resulting in impacts on the trophic structure.

Topic **Uncertainties about environmental stressors created by human activities continued**

Subtopic **Climate Change**

Indirect stressors resulting from climate change How will climate change impacts in coastal terrestrial ecosystem impact the marine ecosystems. For example an increased frequency of fires in coastal forests could lead to increased nutrients and sediments entering coastal waters.

Subtopic **Cumulative effects**

Cumulative effects - mapping of overlapping stressors Cumulative effects resulting from interactions between stressors esp. between stressors from local activities (e.g. marine harvesting) and climate change. Including additive/incremental, synergistic and antagonistic effects. Requires mapping and modelling of overlapping stressors and experimental study and observation of the interactions.

Subtopic **Invasive species**

Community changes caused by the introduction of non-native species for aquaculture. Current protocols for introduction have eliminated the threat of co-introduction of diseases or parasites, however the manila clam and Japanese oyster introduced over 50 and 100 years ago respectively have significantly changed intertidal communities in southern BC marine waters. The recently introduced (last 10 years) non-native mussels and scallops have not yet spread to the same extent but the impacts, especially of the rapidly colonizing non-native mussels could be significant. The ability of escaped farmed salmon to establish viable populations and the ability of those salmon to out compete wild stocks is still debated.

Introduction of non-native species by shipping There is little monitoring of the numbers and species that are introduced via ballast water or fouling.

Subtopic **Noise, sonar, electromagnetic fields**

Impacts of multi-beam sonar on marine organisms Recently, several geophysical scientists elsewhere have recognized the need to at least consider the possible impacts of multi-beam sonar impacts on marine mammals and if needed develop ways to mitigate those impacts.

Impacts of ocean noise on marine organisms Most research has been on marine mammals. Increasing awareness on other organisms but less study. Absent any clear data at this time, shipping and maritime transportation (ferries, cruise ships) are generally presumed to be the major source of any acoustic stress at this time in BC marine waters. But knowledge is nonexistent of how and to what extent, if any, these or other transitory noises are impacting most of the biota.

Impacts of subsea electrical transmission on marine organisms Some species (notably sharks) are highly sensitive to EMFs and migration routes could be impacted. While well maintained cables generally do not create problematic EMF but that magnetic fields of local consequence do arise

Topic **Uncertainties about environmental stressors created by human activities continued**

Subtopic **Offshore Oil and Gas development**

Contamination risks associated with oil and gas development

There is still uncertainty in the possible level of contamination well as the fate and effects of contaminants in drilling muds and production water. There is growing concern that very fine particles suspended during drilling and from its wastes may have effects, especially on filter-feeders much further from the actual well site than previously imagined

Impact of seismic testing on a wide variety of marine organisms

Disagreement still abounds among offshore development advocates and opponents as to whether permanent harm could befall organisms that are close to seismic transects. More recently, concerns have also been raised about the largely unstudied impacts of this high intensity survey noise on invertebrates.

Subtopic **Physiological stressors**

Impact of coastal forestry on stream and nearshore habitat

The impacts of forest management activities on stream ecosystems are complex and vary in timing and duration, depending on watershed characteristics, forestry activity, and fish species and stage present. It has been found that forestry activities may combine with conditions in the marine environment to limit fish population numbers.

Resolution of the role of fish farms in the concentration of sea lice in coastal waters

Despite considerable debate this issue is still unresolved. The possible link to the collapse of pink salmon stocks in the Broughton area and the desire of the industry to expand into other areas of the coast are further reason to resolve this

Subtopic **Pollutants, marine debris**

Effects of relatively new and/or recently identified chemicals in the marine environment.

A number of newly discovered chemicals in BC's marine environment including pesticides used in salmon farming, new POPs, and degradation products of contaminants are poorly studied as to their impacts on marine organisms, levels of contamination and pathways in the ecosystem.