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Biophysical Research Requirements for Beaufort Sea Hydrocarbon Development

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Executive Summary

KAVIK-AXYS was contracted by the Environmental Studies Research Fund (ESRF) to undertake a review to identify Biophysical Research Requirements (data gaps) for Beaufort Sea Hydrocarbon Development. The objective of the study is to identify and prioritize environmental data gaps relevant to the regulatory review, assessment and management of effects associated with offshore oil and gas exploration and development in the Canadian Beaufort Sea. The geographic scope of the study is illustrated in Figure 2-1.

To provide consistency and guidance to the team specialists, KAVIK-AXYS developed and utilized a structured framework for this study:

- Identification of important biophysical components of the Beaufort Sea marine environment that could potentially be affected by offshore oil and gas development.
- For each of the most important biophysical components, the potential major effects of critical activities or groups of activities during each phase of the offshore oil and gas development cycle on the component are identified (i.e., an interaction matrix). This includes the risk of affecting the long-term sustainability of the biophysical component in the region and/or the risk of affecting communities and traditional harvesting. The latter takes into account the susceptibility of the biophysical resource and community use to other influences such as environmental effects.
- Identification of the key types of information, for each interaction for each component, required to:
- adequately characterize current baseline conditions prior to the development or the start of a phase
- assess and quantify potential project-specific and cumulative effects on the component
- develop appropriate mitigation or environmental management plans for these effects
- compare existing information and information from ongoing research to these three major needs (baseline, effects and mitigation) for information
- identify the major gaps between what is known and what is required
- identify key research, data collection and/or data analyses required to address major data gaps. Potential synergies for developing an integrated research program are discussed. The timeframe required to complete this work is noted.
- Ranking of information needs, based on the following three criteria:
- our current understanding of the biophysical component in terms of present status and long-term sustainability
- the potential for oil and gas development to affect the current state and long-term sustainability of the biophysical component in question
- the timeline for completion of the research relative to the expected development cycle for the Beaufort Sea (i.e., the duration of the required research relative to the duration of elements of the development cycle for which such information is required)

As a component of the gap analysis, previous gap analyses reports for the Beaufort Sea and other assorted technical reports were reviewed. It is important to note that a comprehensive literature review was not within the scope of this study; therefore, it was assumed that previous gap analyses were accurate. Recent scientific reports and environmental assessments were also reviewed.

To efficiently facilitate stakeholder input to the final identification of the key overall research priorities, a series of web-based workshops were held in May 2008. Representatives of industry, government, regulatory and scientific bodies across Canada were invited to attend.

Table E-1 lists the final research priorities and gaps that were determined during the web-based workshops. The studies were selected from the draft lists presented, with adjustments as necessary, based on feedback from stakeholders during the sessions. The studies are represented in the order in which the VECs appear throughout the main document, and not in order of comparative importance. Each of the research gaps are considered to be a high priority.

Table E-1 High Research Priorities as Agreed at WebEx Workshops

VEC	Research Priority
Physical Oceanography	Assessment of effects of climate change and industrial activities on ice stability in landfast ice zone and deepwater offshore (i.e., in vicinity of 2008 and 2009 offshore leases)
Plankton/Benthos/Macrophytes/Marine and Anadromous Fish	Baseline surveys of deepwater plankton, benthos and fish (species composition, abundance, seasonal distributions and habitat use)
	Identification of key areas for macroalgae (e.g., kelp) and macro-invertebrates (e.g., crabs, squid); stratify by area's most at risk due to potential industrial development
	Determination of fish habitat use (overwintering, spawning, migration); stratify by five major habitat types (brackish/Mackenzie plume, inshore pelagic, inshore benthic, offshore pelagic, offshore benthic)
Marine Mammals	Prediction of bowhead whale feeding concentration areas (how do oceanographic conditions result in copepod blooms that result in concentrations of feeding bowhead whales)
	How to detect bowhead whales and beluga whales during low visibility conditions (i.e., night, fog, high seas) in conjunction with marine mammal observations during offshore seismic surveys
	How to predict effects of multiple offshore seismic programs on marine mammals and fish
	Philopatry of ringed seals (i.e., annual re-use of the same area by the same seals each year)
	Vibroseis effects on polar bear denning (response of denning bars to equipment and human disturbances); includes determination of underwater/under ice sound propagation of vibroseis
	Effects of climate change on polar bear distributions and potential for increased bear-human conflicts
Marine and Nearshore Avifauna	Update on offshore bird distributions (focus on specific groups such as eiders, loons, etc., and specific geographic areas most at risk (e.g., offshore lease areas)
Archaeology and Palaeontology	Assessment of archaeological and palaeontological resources in coastal areas; stratify assessments by areas of high risk due to natural processes (slumping and erosion) and potential industrial activities. This will form basis for later development of broader archaeological atlas (i.e., assessment of sites, value and interpretive potential)
	Identification of ship wreck sites. Use of historical literature on sinking's of vessels to identify potential sites. Note need for guidelines on identification of shipwreck artefacts during site-specific surveys for individual projects
Traditional Land Use	Identification of important coastal camp sites and harvesting sites, with emphasis on remote locations (i.e., gaps in current inventory)
	Update of harvest studies and development of means to make data available in some form to industry

VEC	Research Priority
Accidents and Malfunctions	Dispersion modelling: need to verify current oil spill models for conditions in Beaufort Sea (models have advanced substantially in last decade); includes updating of oceanographic data to satisfy updated modelling requirements
	Update on methods to contain and collect spilled hydrocarbons in arctic conditions
	Oil Spill Sensitivity Atlas: need to update Beaufort Sea Atlas to reflect current biophysical and cultural conditions, as well as infrastructure and response measures
	Fate and effect of released hydrocarbons with an emphasis on the dynamics of contaminant cycling; need to consider under ice and open water situations, as well as behaviour of oil under ice

Résumé

Le Fonds pour l'étude de l'environnement (FEE) a retenu les services de KAVIK-AXYS afin d'entreprendre un examen visant à déterminer les exigences en matière de recherche biophysique (données manquantes) pour la mise en valeur des hydrocarbures dans la mer de Beaufort. L'étude vise à cerner et à prioriser les données environnementales manquantes pertinentes pour l'examen réglementaire, l'évaluation et la gestion des effets reliés à la prospection et à la mise en valeur de pétrole et de gaz dans la partie canadienne de la mer de Beaufort. L'étendue géographique de l'étude est illustrée à la figure 2-1.

À des fins d'uniformisation et afin d'orienter les spécialistes de l'équipe, KAVIK-AXYS a élaboré et utilisé un cadre structuré pour les besoins de cette étude :

- Détermination des composantes biophysiques importantes du milieu marin de la mer de Beaufort qui pourraient être touchées par une mise en valeur du gaz et du pétrole extracôtiers.
- Pour chacune des plus importantes composantes biophysiques, sont définis les principaux effets éventuels des activités vitales ou groupes d'activités à chaque phase du cycle de mise en valeur du pétrole et du gaz extracôtiers (tableau synoptique d'interactions). Cela comprend le risque de modifier la durabilité à long terme de la composante biophysique dans la région, ou encore les collectivités et les récoltes traditionnelles. Ce dernier point tient compte de la vulnérabilité de la ressource biophysique et de l'utilisation communautaire face à d'autres influences, telles que les effets environnementaux.
- Détermination des principaux types de renseignements, pour chaque interaction et composante, répondant aux critères suivants :
- caractériser adéquatement les conditions de base actuelles avant la mise en valeur ou le début d'une phase;
- évaluer et quantifier les effets potentiels propres au projet et cumulatifs sur la composante;
- élaborer les plans d'atténuation ou de gestion environnementale pour ces effets;
- comparer les renseignements existants et ceux qui proviennent de la recherche continue aux trois principaux besoins d'information (conditions de base, effets et atténuation);
- cerner les principales lacunes entre ce qui est connu et ce qui est nécessaire;
- déterminer les principales recherches et collectes ou analyses de données requises pour obtenir les données manquantes importantes (discussion sur les synergies potentielles pour élaborer un programme de recherche intégré – le délai d'exécution pour exécuter ce travail est noté).
- Classement des besoins d'information en fonction des trois critères suivants :
- notre connaissance de la composante biophysique en ce qui a trait au stade actuel et à la durabilité à long terme;
- la possibilité que la mise en valeur de pétrole et de gaz modifie l'état actuel et la durabilité à long terme de la composante biophysique en question;
- le délai d'exécution de la recherche relative au cycle prévu de mise en valeur pour la mer de Beaufort (durée de la recherche requise par rapport à la durée des aspects du cycle de mise en valeur pour lequel l'information est requise).

Les rapports précédents d'analyse des lacunes pour la mer de Beaufort et divers autres rapports techniques ont été passés en revue. Il importe de noter que cette étude ne comportait pas d'analyse documentaire complète; on a donc présumé que les analyses précédentes des lacunes étaient exactes. Des rapports scientifiques et des évaluations environnementales ont également été passés en revue.

Afin de faciliter la participation des parties prenantes à la détermination finale des priorités clés globales de recherche, une série d'ateliers sur le Web ont eu lieu en mai 2008. Des représentants du secteur, des gouvernements et des organismes de réglementation et scientifiques de partout au Canada ont été invités à y assister.

Le tableau E-1 montre les priorités de recherche finales et les lacunes qui sont ressorties des ateliers sur le Web. Les études ont été sélectionnées à partir des listes présentées, avec les modifications nécessaires, d'après la rétroaction des parties prenantes pendant les séances. Les études sont représentées dans le même ordre que les composantes de valeur égale dans tout le document principal, et non pas en ordre d'importance comparative. Chacune des lacunes de recherche est considéré comme hautement prioritaire.

Tableau E-1 Priorités de recherche élevées d'après les ateliers Web

Composante de valeur égale	Priorité de recherche
Océanographie physique	Évaluation des effets du changement climatique et des activités industrielles sur la stabilité de la glace de rive et en eau profonde (à proximité des concessions en mer de 2008 et 2009).
Plancton, benthos, macrophytes, poissons marins et anadromes	Enquêtes de base sur le plancton, le benthos et les poissons de profondeur (composition taxinomique, abondance des espèces, répartitions saisonnières et utilisation de l'habitat).
	Identification des principaux secteurs de macro-algues (p. ex. : varech) et de macro-invertébrés (p. ex. : crabe, calmar); classer par secteurs les plus à risque en raison du développement industriel potentiel.
	Détermination de l'utilisation de l'habitat (hivernage, frai, migration); classer selon les cinq principaux types d'habitat (saumâtre, panache du Mackenzie, pélagique côtier, benthique côtier, pélagique extracôtier, benthique extracôtier).
Mammifères marins	Prédiction des zones de concentration où s'alimentent les baleines boréales (comment les conditions océanographiques favorisent la prolifération de copépodes, entraînant des concentrations de baleines boréales).
	Comment repérer les baleines boréales et les bélugas dans les conditions de faible visibilité (noirceur, brouillard, haute mer) lors d'observations des mammifères marins durant les études sismiques en mer.
	Comment prédire les effets de travaux sismiques multiples en mer sur les mammifères marins et les poissons.
	Philopatrie des phoques annelés (réutilisation de la même zone par les mêmes phoques année après année).
	Effets vibrosismiques sur la mise bas des ourses polaires (réaction des aires de mise bas à l'équipement et aux perturbations humaines), y compris la détermination de la propagation du son vibrosismique sous l'eau ou la glace.
	Effets du changement climatique sur la distribution des ours polaires et risque d'augmenter les conflits entre ours et humains.
Faune aviaire marine et sublittorale	Compte rendu sur la distribution des oiseaux du large (groupes spécifiques comme eiders, huards, etc.) et zones géographiques précises les plus à risque (p. ex. : zones de concession extracôtières).

Composante de valeur égale	Priorité de recherche
Archéologie et paléontologie	Évaluation des ressources archéologiques et paléontologiques dans les zones côtières; classer les évaluations par zones à risque élevé en raison de processus naturels (effondrement et érosion) et d'activités industrielles potentielles. Cela constituera la base d'un futur atlas archéologique plus vaste (évaluation de sites, valeur et potentiel d'interprétation).
	Repérage de sites d'épave. Utilisation de documentation historique sur les naufrages pour repérer des sites potentiels. Noter le besoin de directives sur l'identification d'objets d'épave lors d'études propres à un site pour des projets particuliers.
Utilisation des terres à des fins traditionnelles	Repérage d'importants sites côtiers de campement et de secteurs coquilliers, surtout dans les endroits éloignés (p. ex. : lacunes dans l'inventaire actuel).
	Mise à jour des études sur les récoltes et mise au point de moyens pour rendre les données accessibles au secteur.
Accidents et défaillances	Modélisation de la dispersion : besoin de vérifier les modèles actuels de déversement de pétrole pour déterminer les conditions dans la mer de Beaufort (les modèles ont évolué considérablement au cours de la dernière décennie); cela inclut la mise à jour des données océanographiques pour répondre aux exigences de modélisation à jour.
	Compte rendu sur les méthodes utilisées pour contenir et nettoyer les déversements d'hydrocarbures dans les conditions arctiques.
	Atlas des zones sensibles aux déversements : mise à jour nécessaire de l'atlas de la mer de Beaufort pour tenir compte des conditions biophysiques et culturelles actuelles, ainsi que de l'infrastructure et des moyens d'intervention.
	Sort et effet des hydrocarbures libérés, en particulier dynamique du cycle des contaminants; nécessité de considérer les situations sous la glace et en eau libre, de même que le comportement du pétrole sous la glace.

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Abbreviations

ArcticNet NCE .... ArcticNet Network of Centres of Excellence
BREAM .... Beaufort Region Environmental Assessment and Monitoring Program
BSStRPA ....Beaufort Sea Strategic Regional Plan of Action
BWASP ....Bowhead Whale Aerial Survey Program
CCGS Nahidik .... Canadian Coast Guard Service Nahidik
CCP ....Community Conservation Plan
Cd ....Cadmium
COPE..Committee for Aboriginal Peoples Entitlement
COSEWIC................................Committee on the Status of Endangered Wildlife in Canada
CWS .... Canadian Wildlife Service
DFO ....Fisheries and Oceans Canada
DFO-NRCan..............................Fisheries and Oceans Canada-Natural Resources Canada
DP... development plan
E&P...Exploration & Production
EARP .... Environmental Assessment and Review Process
EIRB ....Environmental Impact Review Board
EISC ....Environmental Impact Screening Committee
ESL .... Environmental Sciences Limited
ESRF .... Environmental Studies Research Fund
FJMC .... Fisheries Joint Management Committee
Hg .... mercury
Hz .... Hertz
ISR...Inuvialuit Settlement Region
JIP.. Joint Industry Project
kHz... kiloHertz
MGP.. Mackenzie Gas Project
MORICE..Mechanical Oil Recovery in Ice Infested Waters
NEB ....National Energy Board
NOAA... National Oceanic and Atmospheric Administration
NOGAP ....Northern Oil and Gas Action Program
NWT...Northwest Territories
OGP... International Association of Oil and Gas Producers
Pb .... lead
PD..Project Description
PERD...Program of Energy Research and Development
SARA ....Species at Risk Act
TAG .... Technical Advisory Group
TD ....total depth
3D .... three dimensional
2D ....two dimensional
USGS...United States Geological Survey
VEC ....Valued Environmental Component

Glossary

Anadromous	Species (fish) which utilise both salt and freshwaters during their lifecycle.
Benthos	Benthos is the species which live in or on the seabed. In the context of this report benthos includes large invertebrates such as crabs.
Biodiversity	The variation of life forms within a given ecosystem, biome or for the entire earth.
Biomass	The total number of living organisms in a given area, expressed in terms of living or dry weight per unit area.
Fauna	A term used to describe all the animal life of a given place or time.
Flora	A term used to describe all the plant life of a given place or time.
Macrophytes	Aquatic plants
Pelagic	Occurring in the upper waters of the open sea.
Plankton	Organisms inhabiting the pelagic component of the sea. In the context of this report plankton also refers to zooplankton and larger pelagic invertebrates such as squid.
Sustainability	Characteristic of a process or states that can be maintained at a certain level indefinitely.
Transition Zone	The area of ocean situated between the marine and estuarine zones.
Zooplankton	The animal constitute of plankton, which consists mainly of small crustaceans and fish larvae.

1 Introduction

KAVIK-AXYS was contracted (ESRF-07-088) by the Environmental Studies Research Fund (ESRF) to undertake a review to identify Biophysical Research Requirements (data gaps) for Beaufort Sea Hydrocarbon Development.

Data relating to both biophysical and human components of the Beaufort Sea and adjacent coastal areas are required to guide and support strategic development and management of offshore hydrocarbon resources. Numerous studies have been completed to date; however, there is a recognition that data gaps remain which may result in potential delays and restrictions to offshore development.

ESRF, under its mandate *"to finance environmental and social studies pertaining to the manner in which, and the terms and conditions under which, exploration, development and production activities on frontier lands under the Canadian Petroleum Resources Act, or any other Act of Parliament, should be conducted"*, wishes to consolidate a list of outstanding data gaps and prioritize research requirements to assist in establishing a program to address current information deficiencies, which is provided by this report.

2 Program Objectives

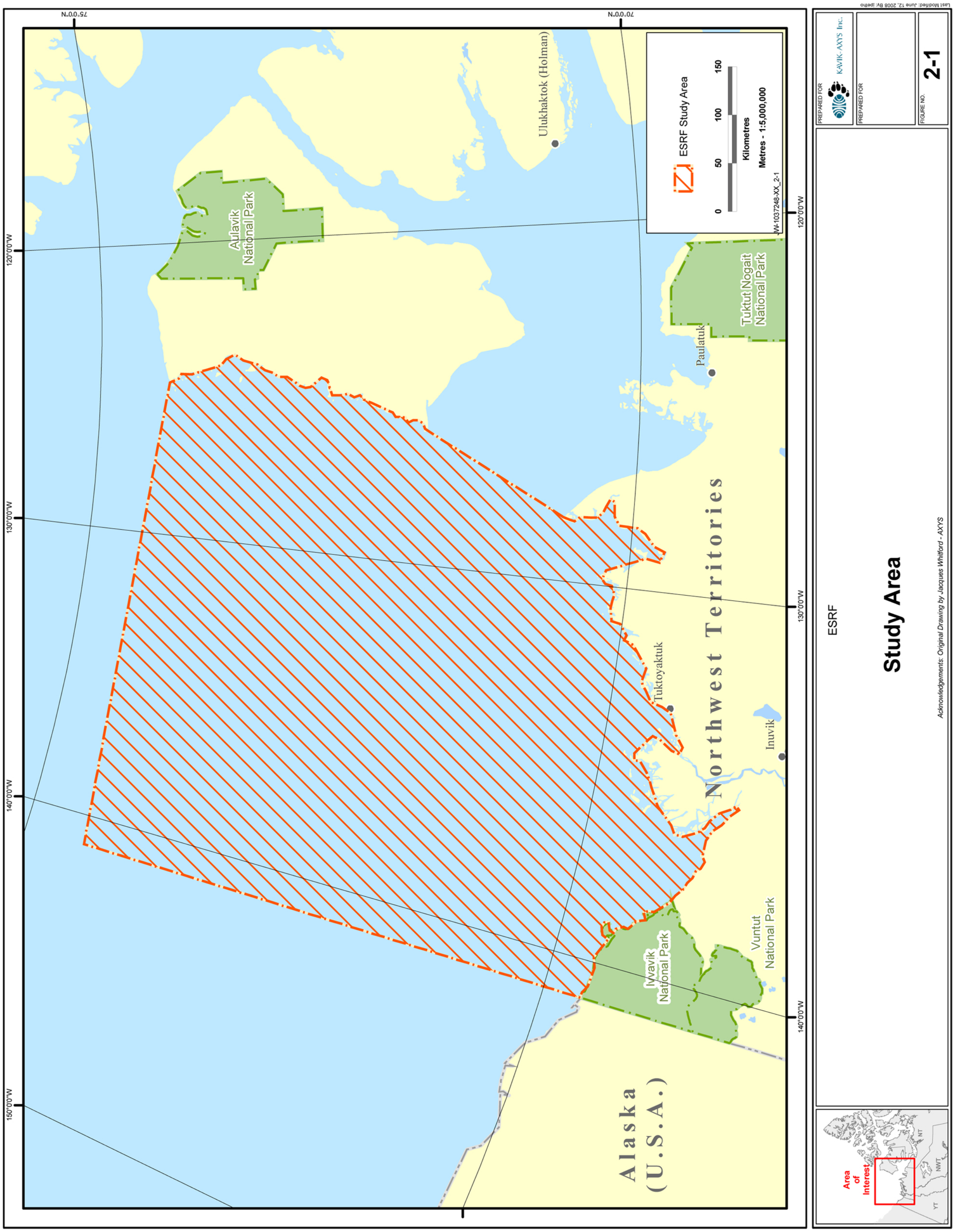
The objective of the study is to identify and prioritize environmental data gaps relevant to environmental assessment and management of effects associated with offshore oil and gas exploration and development in the Canadian Beaufort Sea. The environmental assessments may contribute to the regulatory process. The geographic scope of the study is illustrated in Figure 2-1. The study area along the coastal sections extends to the high water mark, including potential landfall sites for infrastructure i.e., pipelines and coastal communities that may be affected by exploration and development activities.

To identify and, in particular, prioritize data gaps, it is important to recognize the common 'issues' associated with such an undertaking. These issues include:

- a tendency by specialists to want to favour research in their area of practice
- a poor understanding by some stakeholders and researchers about the need for different types of information important to understanding the development cycle for the offshore oil and gas industry; particularly in an emerging development area such as the Canadian Beaufort Sea.
- a reluctance to accept information and experience from other geographic areas or earlier research, as valid to the specific area of interest and the current time

To provide consistency and guidance to the team specialists, KAVIK-AXYS developed and utilized a structured framework for this study which is described in detail in Section 3.

Figure 2-1 Study Area



3 Approach and Methodology

3.1 Introduction

The determination of data gaps for offshore hydrocarbon exploration and development in the Canadian Beaufort Sea focused on the information needs for assessing and managing environmental effects, including cumulative effects, associated with seismic exploration, exploration and delineation drilling, field development and decommissioning. The potential effects of offshore transportation in support of these activities were also addressed. Data gaps are identified for key aspects of the biophysical and human environment (referred to as Valued Environmental Components [VEC]).

Prioritization of identified data gaps ensures that future research is focused on providing the information required to complete credible environmental assessments, support regulatory review processes and develop effective management plans. The prioritization process also takes into account the length of time required to obtain data (i.e., survey and analysis duration given the specific challenges of working in an arctic environment) and when that data will be required in the planning and permitting process. As an example, data specific for a seismic environmental assessment will be required prior to data specific for a development assessment; however, data for the development may take longer to acquire and, therefore, the work may need to commence at the same time as or before any seismic-related research.

3.2 Overview of Previous Gap Analyses

To avoid repetition of work already undertaken, the project team have reviewed the following studies, which identified data gaps for oil and gas development in the Beaufort region.

- Executive Summary for Knowledge Gaps Associated with Exploration and Development of Natural Gas in the Mackenzie Delta Region (KAVIK-AXYS 2002).
- Report on the Federal Science Experts Meeting on Northern Oil and Gas Development. Calgary 2001. (Appendix 1 – Summary Table and Analysis of Information and Science Gaps).
- Beaufort Sea and Mackenzie Delta Future Directions – Inuvik Workshop – November 2005.
- Devon Comprehensive Study (Devon Canada 2004) and associated technical assessment and baseline reports (KAVIK-AXYS 2004a; 2004b).
- Draft Final Report for the 1993/1994 BREAM Program (AXYS 1994).
- Beaufort Region Environmental Assessment and Monitoring Program (BREAM) – Final report for 1991/1992 (AXYS et al. 1992).
- BREAM report 1990/1991 (ESL 1991).
- Beaufort Environmental Monitoring Project 1983/1984. (LGL Ltd., ESL Ltd., and ESSA Ltd. for DIAND 1984).
- Beaufort Sea Environmental Assessment and Review Process (EARP) Panel Report: 1982-1985.
- Beaufort Sea Strategic Regional Plan of Action (BSSTRPA), 2007 (Draft Report). Draft Research Framework for the Beaufort Sea, (KAVIK-AXYS 2007).

These studies were considered the starting point for this project. The status of the data gaps identified by each of the studies was reviewed to establish whether the gaps still exist. It is important to note that a comprehensive literature review was not within the scope of this study; therefore, it was assumed that previous gap analyses were accurate. Recent scientific reports and environmental assessments were also reviewed.

The study did not identify physical issues in relation to engineering design (i.e., seabed stability, ice dynamics). The scope of the study was to address biophysical data gaps from the perspective of environmental assessment and regulatory review only.

3.3 Identification and Prioritization of Research Requirements for each VEC

The approach to prioritizing individual relevant environmental data gaps consists of the following steps:

STEP 1 – Completion of an Interaction Matrix: The interaction matrix (Table 3-1) identifies potential interactions between specific activities (for each stage of hydrocarbon development) and the biophysical and human environment. An X on the table indicates were a potential interaction has been identified. The interaction matrix focuses the research requirements analysis on the most important environmental effects associated with hydrocarbon exploration, development and decommissioning.

STEP 2 – Identification and Ranking of Potential Effects on each VEC: The relative importance/overall ranking of *the potential effects on each VEC* is calculated by adding the numerical rankings for the three criteria listed below. The effects are then listed in order of their ranking to determine the priority in which knowledge/environmental data gaps should be addressed.

Risk to the Sustainability of the Resource. This takes an additional three aspects:

- potential for effect to result in a change that may affect the long-term viability or sustainability of the population, resource or human value
- the status of the species (i.e., a protected species or resource)
- the importance of the resource to traditional harvesting

The risk to sustainability ranking is based on a numerical scale of 1 to 3 (1 = low/no risk, 2 = moderate risk, 3 = high or unknown risk). If the risk is unknown then a conservative approach was applied and the highest risk ranking allocated i.e., 3. If the risk to the sustainability of the resource is ranked as a 1 (low or no risk), then the effect is not considered further in the identification of research requirements. The risk to sustainability is only relevant to the biological VECs and not to the physical VECs (i.e., physical and chemical oceanography).

Understanding of the Effect. The effects of offshore hydrocarbon development have been widely studied and the level of understanding of certain effects can be considered high. For instance, it is known that the discharge of top hole cuttings will smother benthos and lead to mortality; however, the effects of acoustic disturbance due to drilling activities is less well understood. This factor also takes into account the adequacy of baseline information to support assessment of environmental effects. The understanding of the effect is ranked on a numerical scale of 1 to 3 (1 = high level of understanding, 2 = moderate level of understanding, 3 = low level of understanding or no knowledge).

Ability to Mitigate with Proven Techniques. Standard industry mitigation techniques are frequently used. If a proven mitigation technique is available, then this would reduce the ranking of the effect. The availability of proven mitigation techniques is ranked on a numerical scale of 1 to 3 (1= proven and widely used mitigation available, 2 = unproven mitigation available, 3 = no known mitigation).

STEP 3 –- Identification of Information Needs: Once the effects are ranked in terms of priority, a list of the information required to credibly assess the potential effect is compiled.

Table 3-1 Interactions between Project Activities and Valued Environmental Components

	Physical Oceanography	Chemical Oceanography	Plankton	Benthos	Macrophytes	Marine and Anadromous Fish	Marine and Nearshore Avifauna	Whales	Seals	Polar Bear	Archaeology	Traditional Land Use
Seismic Survey												
Underwater Acoustic Disturbances (vessel and seismic)				X[1]		X	X	X	X			X
Discharge of Effluent(sewage, drainage)		X					X					
Physical Presence of Equipment (seismic vessel and equipment)							X	X	X	X		X
Aircraft Use and Support							X					X
Exploration Drilling (including delineation)												
Underwater Acoustic Disturbances (drilling rig, support vessels)						X	X	X	X			X
Discharge of Effluent(sewage, drainage, rig wash)		X		X	X		X					
Discharge of Drilling Wastes (muds, cuttings)		X		X	X		X					
Physical Disturbance of Seabed (physical footprint and sediment suspension)	X	X	X	X	X	X	X					
Light (presence and illumination)							X			X		X
Physical Presence of Equipment (drill platforms)				X		X	X	X	X	X		X
Aircraft Use and support							X					X
Ice Platforms and Roads	X								X	X		X

Table 3-1 Interactions between Project Activities and Valued Environmental Components (cont'd)

	Physical Oceanography	Chemical Oceanography	Plankton	Benthos	Macrophytes	Marine and Anadromous Fish	Marine and Nearshore Avifauna	Whales	Seals	Polar Bear	Archaeology	Traditional Land Use
Field Development												
Underwater Acoustic Disturbances (vessels and drill rigs)						X	X	X	X			
Discharge of Effluent(sewage and drainage)		X		X	X[2]		X					
Discharge of Drilling Wastes (muds, cuttings and water)		X		X	X		X					
Physical Disturbance of Seabed(platform and pipeline footprints and sediment suspension)	X		X	X	X	X	X				X	X
Coastal disturbance due to onshore support infrastructure (i.e., pipeline landfall)			X	X	X	X	X			X	X	X
Light (presence and illumination)							X			X		X
Physical Presence of Equipment (drill rigs, support vessels, other equipment)				X		X	X	X	X	X	X	X
Dredging	X	X	X	X	X		X				X	
Aircraft Use and Support							X					X
Ice Platforms and Roads	X								X	X		X

Table 3-1 Interactions between Project Activities and Valued Environmental Components (cont'd)

	Physical Oceanography	Chemical Oceanography	Plankton	Benthos	Macrophytes	Marine and Anadromous Fish	Marine and Nearshore Avifauna	Whales	Seals	Polar Bear	Archaeology	Traditional Land Use
Production												
Underwater Acoustic Disturbances (production platform/rig and support vessels)						X	X	X	X			
Discharge of Effluent(sewage, drainage)	X	X	X	X	X	X	X					X
Discharge of Produced Water	X	X	X	X	X	X						X
Aerial Emissions (support vessel and production platform/rig)												
Light (presence and illumination)							X					
Physical Presence of Equipment						X	X	X	X	X		X
Ice Platforms and Roads	X								X	X		X
Decommissioning												
Underwater Acoustic Disturbances (vessels and aircraft)						X	X	X	X			X
Discharge of Effluent(sewage and drainage)	X	X	X	X	X	X	X					X
Physical Disturbance of Seabed(sediment re-suspension and physical smothering of fauna)	X	X	X	X	X	X	X					X
Coastal disturbance due to removal of coastal support infrastructure (i.e., pipeline landfalls)	X	X	X	X	X	X	X					X
Light (presence and illumination)							X					

Table 3-1 Interactions between Project Activities and Valued Environmental Components (cont'd)

	Physical Oceanography	Chemical Oceanography	Plankton	Benthos	Macrophytes	Marine and Anadromous Fish	Marine and Nearshore Avifauna	Whales	Seals	Polar Bear	Archaeology	Traditional Land Use
Decommissioning (cont'd)												
Physical Presence of Equipment							X	X	X	X		
Ice Platforms and Roads	X									X		
Accidents and Malfunctions												
Hydrocarbon or chemical spill	X	X	X	X	X	X	X	X	X	X	X	X
Fire (fire fighting chemicals)	X	X	X	X	X	X					X	X

NOTE:
[1] Magnitude of risk depends on how localized the population range is (i.e., crabs)
[2] Effluents in general are known to have the potential to cause effects on macrophyte composition and abundance. The potential for effects in the Beaufort will depend on the location of facilities.
An "X" indicates that an interaction between the activity and the Valued Environmental Component may result in an important environmental effect, even with application of existing regulations. An "X" can represent a negative or positive effect.

STEP 4 – Existing Information and Identification of Data Gaps: Existing resource information relevant to each of the effects is discussed and focuses on the broad types of information available. This discussion is not intended to summarize or synthesize the available information. Once the extent of existing information is established, the existing information is compared with the information needs and data gaps identified in Step 3. In addition to existing information, recent and ongoing research was reviewed to assess whether ongoing programs were likely to address any of the identified data gaps. The quality of existing data is also assessed to determine whether additional research would be required. The final product of this step in the process is a list of essential research requirements to support the assessment of important environmental effects.

STEP 5 – Timelines: The research requirements are listed at this stage according to the ranked effects. Two further concepts are then addressed to produce a final ranking:

- time required to obtain the data
- timing within the development process in which the data is required

For instance, data that is required early in the exploration phase (e. g., for the assessment of seismic activities) may take precedence over data required for the assessment of exploration drilling or some component of field development. However, if the data for field development will take several years to obtain, then it may rank higher on the priority list.

STEP 6 – Stakeholder Input: The final step in the process was the integration of stakeholder feeder. This was achieved by conducting a series of web-based workshops in May 2008. Representatives of industry, government, regulatory and scientific bodies across Canada were invited to attend. The list of invitees was compiled with input from KAVIK-AXYS discipline specialists and the TAG, and approved by the TAG.

Three web-based/ "WebEx" workshops covered the following topics: biological VECs, physical/archaeological and traditional use VECs, and accidents and malfunctions, including oil spills. Prior to each workshop, the attendees were provided with the draft gap analysis tables and listings of research priorities in preparation for providing feedback during the conference. Each workshop commenced with an overview of the scope and objectives of the study. For each VEC, the KAVIK-AXYS author provided an overview of the results and an explanation of the rationale for the selection of the research gaps. The discussion was then opened to the attendees to ask any questions and provide feedback. Thus, each workshop culminated in a discussion and agreement by attendees on the final research priorities.

3.3.1 Methodology by Worked Example

To illustrate how the above 6 stage process works an example has been provided in this section. Benthos was the VEC selected for illustration, specifically the effects of physical disturbance of the seabed on benthos.

STEP 1 – Completion of the Interaction Matrix

As illustrated in Table 3-1 wherever physical disturbance of the seabed is listed under a project activity it has been marked with an X, indicating a potential interaction with benthos.

STEP 2 – Identification and Ranking of Potential Effects

Step 2 establishes the relative importance of the potential effect by adding the numerical rankings for the three criteria. The risk to the sustainability of benthos from seabed disturbance is considered to be a 2 i.e., moderate risk. As noted in the table below the effects may be localized or broader in scope. Although a localised effect could be considered to represent a low risk in some instances, given the lack of information on benthic species and habitat in the Beaufort, it may be that critical habitat could be affected and as such a rating of 2 is selected.

The understanding of the effect is rated as a 1 i.e., there is a high level of understanding of the effects of seabed disturbance on benthos. The ability to mitigate with proved techniques is given a rating of 3 as there are no proven mitigation methods. Based on the ratings allocated the effect of seabed disturbance on benthos is given an overall ranking of 6.

Potential Effect	Risk to Sustainability of Benthos	Understanding of the Effect	Ability to Mitigate with Proven Techniques	Ranking of Potential Effects
Seabed Disturbance (physical footprint, sediment re-suspension and physical smothering of fauna)	2[1]	1	3	6
NOTES: [1] Effect may be localized or broader in scope. Some localized areas may be critical habitat for some benthic species.				

STEP 3 – Identification of Information Needs

Once the effect has been ranked a list of information required to enable assessment of that effect is compiled, as illustrated below. The information requirements are based on professional opinion and experience of environmental assessment.

Ranking	Effect	Information Required to Enable Assessment of Effect
6	Seabed disturbance (Exploration, Field Development and Decommissioning)	• Baseline data on species presence, distribution and abundance of benthos and macro-invertebrates • Data on critical habitat areas and timing for macro-invertebrates (e.g., crab spawning areas) • Data on effects of increased sedimentation on benthic distribution and abundance • Data on the uptake and effects of contaminants related to sediment re-suspension on benthos

STEP 4 – Existing Information and Identification of Data Gaps

Once the information requirements for the potential effect are established each Discipline Lead reviews, at a high level, the extent of existing information and also recent and ongoing research. The quality of the existing data is also assessed to determine whether additional research may be required. The data required is then compared with the data available to establish data gaps, see below.

Ranked Effect	Information Required to Enable Assessment of Effect	Existing Information and Recent/Ongoing Research	Quality of Existing Data	Data Gap
Seabed disturbance	Baseline data on species presence, distribution and abundance of benthos and macro-invertebrates (all depth ranges)	Data widely geographically collected – limited data on macro-invertebrates. Data is better for depths less than 100m.	Low	Baseline data on species presence, distribution and abundance of benthos and macro-invertebrates with focus on water depths >100m
	Data on critical habitat areas and timing for macro-invertebrates (e.g., crab spawning	No data	-	Data on critical habitat areas and timing for macro-invertebrates (e.g., crab spawning

	areas)			areas)
	Data on effects of increased sedimentation on benthic distribution and abundance	Limited data	Low	Data on effects of increased sedimentation on benthic distribution and abundance
	Data on the uptake and effects of contaminants related to sediment re-suspension on benthos	Industry and government data but most old	Medium	Data on the uptake and effects of contaminants related to sediment re-suspension on benthos

STEP 5 – Timelines

Step 5 in the process introduces the concept of timing into the ranking process. For instance, as illustrated in the table below, data on critical habitat areas and data on species presence and abundance will both be required from the exploration stage through to decommissioning. However, data on critical habitat will take longer to obtain (3-5 yrs) compared with data on species presence (2-3 yrs). Therefore, data on critical habitat is given a higher rating that species presence and abundance, because research on this topic will need to commence before work on species presence and abundance to provide adequate data for assessment.

Ranked Effect	Data Gap	Time to Obtain Data	When in the Development Process is the Data Required	Relative Overall Ranking
Seabed disturbance	Baseline data on species presence, distribution and abundance of benthos and macro-invertebrates with focus on water depths >100m	2–3 years	Exploration drilling through to decommissioning	Moderate
	Data on critical habitat areas and timing for macro-invertebrates (e.g., crab spawning areas)	3–5 years	Exploration drilling through to decommissioning	High
	Data on effects of increased sedimentation on benthic distribution and abundance	3–5 years	Exploration drilling through to decommissioning	Moderate

STEP 6 - Stakeholder Input

Upon completion of the initial list of research priorities a series of web-based workshops were held in May 2008 to elicit stakeholder feedback into the process. Representatives of industry, government, regulatory and scientific bodies across Canada were invited to attend.

Prior to each workshop, the attendees were provided with the draft gap analysis tables and listings of research priorities in preparation for providing feedback during the conference. Each workshop commenced with an overview of the scope and objectives of the study. For each VEC, the KAVIK-AXYS author provided an overview of the results and an explanation of the rationale for the selection of the research gaps. The discussion was then opened to the attendees to ask any questions and provide feedback. Thus, each workshop culminated in a discussion and agreement by attendees on the final research priorities. The workshop enabled the data gaps, were appropriate, to be integrated into common themes. For example, as illustrated below, the final research priorities for benthos were integrated, in some cases, with plankton, macrophytes and marine and anadromous fish, because the research priorities had a common theme i.e., better baseline information.

VEC	Research Priority
Plankton/Benthos/Macrophytes/Marine and Anadromous Fish	Baseline surveys of deepwater plankton, benthos and fish (species composition, abundance, seasonal distributions and habitat use)
	Identification of key areas for macroalgae (e.g., kelp) and macro-invertebrates (e.g., crabs, squid); stratify by area's most at risk due to potential industrial development
	Determination of fish habitat use (overwintering, spawning, migration); stratify by five major habitat types (brackish/Mackenzie plume, inshore pelagic, inshore benthic, offshore pelagic, offshore benthic)

3.3.2 Hypothetical Development Timeline

Figure 3-1 illustrates the hypothetical shortest duration of each stage of offshore development from initial exploration licensing to final production in the Beaufort Sea. The timeline has been derived from review of regulatory approval processes, hypothetical development scenarios and input from industry experts; it also takes into account the planning and implementation timeline for each stage of hydrocarbon development, as well as reasonable regulatory timelines. This hypothetical timeline provides context in relation to the ranking of research priorities and is used by the report authors; it is not intended to provide specific information for industry.

Figure 3-2 illustrates the regulatory approvals required at each stage of the exploration and development and implicitly incorporates the timeline shown in Figure 3-1.

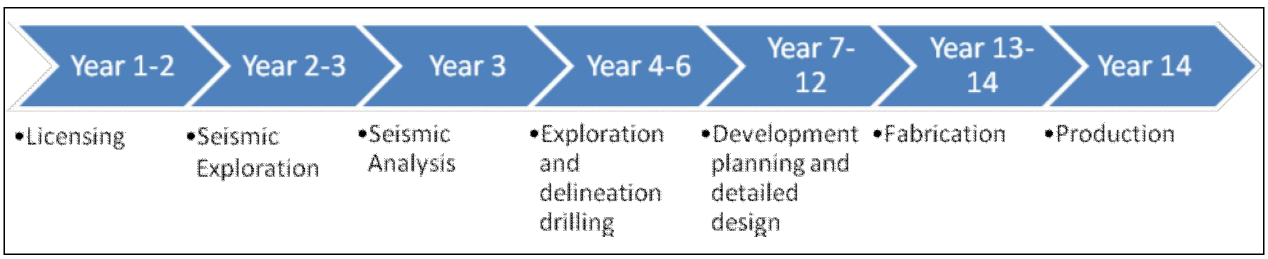
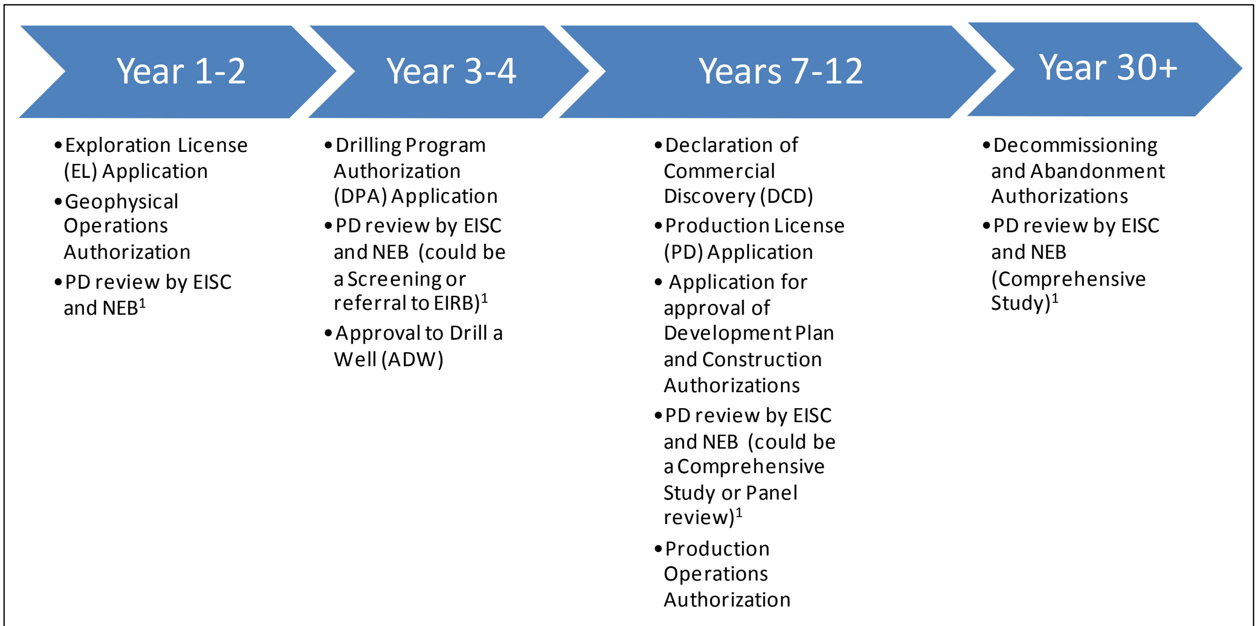


Figure 3-1 Hypothetical Offshore Hydrocarbon Development Timeline

KAVIK-AXYS Inc.



NOTE:[1] The EISC and NEB requirements for review are generally harmonized and one document is produced, the Project Description, which satisfies each requirement. It is assumed a screening is required and not referral to the EIRB.

Figure 3-2 Hypothetical Regulatory Requirements Timeline

3.4 Overall Research Priorities

3.4.1 Final Prioritization

Three processes were used to assist in the development of a final prioritized list of research requirements for all aspects of the biophysical and human environment:

- Research gaps were discussed with a range of government, industry, and aboriginal and consulting specialists in northern offshore oil and gas (these discussions included one-on-one interviews and small group meetings).
- A facilitated meeting was held involving members of the ESRF Technical Advisory Group and senior members of the Project Team. During the meeting, the suite of research priorities identified for each VEC and stakeholder feedback was reviewed. Subsequently, the committee completed a draft final prioritized list of research requirements.
- Three web-based workshops (focusing on the physical environment and socio-cultural components, biological components, and accidents and malfunctions) were held to review the draft final prioritized list of research requirements with a wide range of government, Inuvialuit, university, industry and consultant representatives. At the end of each workshop, a facilitator reviewed the most important research gaps that had been identified during the session and asked participants if they agreed on the research priorities that had been identified. Additional details on the workshops are provided in Section 6.

3.4.2 Presentation of Prioritized Data Gaps

The last step in the data gap process involved the review of the outcome of each of the three workshops by the Discipline Leads. As discussed in Section 6, the Discipline Leads reviewed the research priorities and, where necessary, provided additional explanation on the information need and the necessary research. The data gaps are listed in the same order as the presentation of disciplines in the main report. This list represents the key research priorities to support environmental assessments for oil and gas exploration and development in the Canadian Beaufort Sea.

The Discipline Leads also identified some additional high research priorities that were (1) not generally agreed to during the web-based workshops or (2) were not discussed during these workshops. These additional research priorities have been noted in Table 6-2 for reference as, although they were not included in the main list, they were considered to be important by the Discipline Leads.

Several issues were identified that required further review and discussion, but are outside the scope of the present data gaps study. These issues are summarized in Section 7.

4 Overview of Typical Offshore Hydrocarbon Development Cycle

4.1 Introduction

The development of an offshore hydrocarbon resource from identification to final production consists of a number of standard stages, with typical activities (see Figure 4-1).

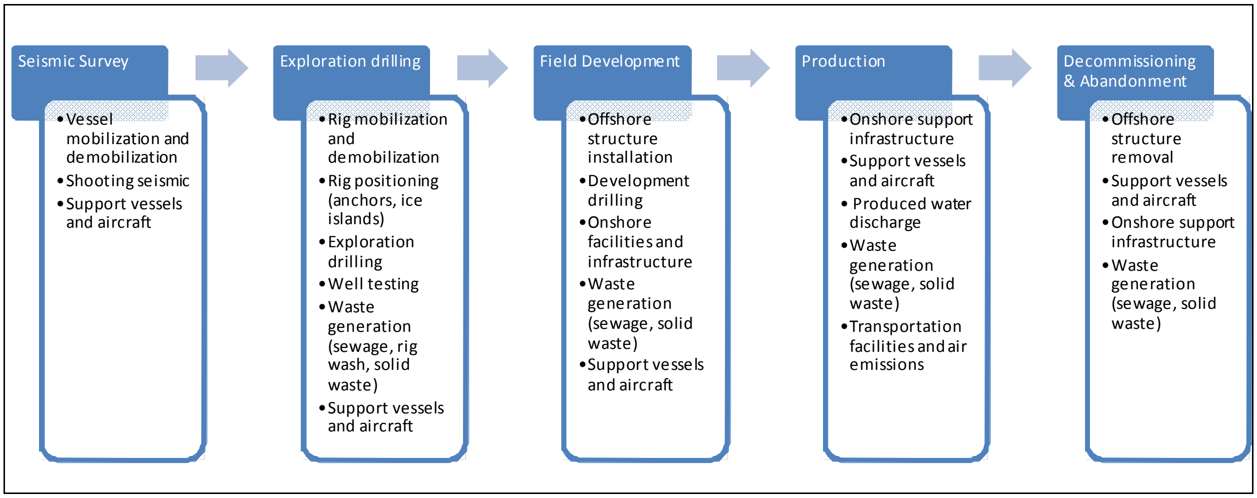


Figure 4-1 Typical Offshore Hydrocarbon Development Cycle

4.1.1 Seismic Survey

The first stage of exploratory activity is generally a seismic survey to provide information about the geology under the ocean floor. Seismic surveys involve the generation of seismic energy waves, which propagate through the ‘overburden” rock to the reservoir targets and beyond, being reflected back to receivers where they register as a pressure pulse. The reflections are interpreted to provide an acoustic image of the subsurface. Offshore seismic surveys are conducted using a marine seismic vessel towing a submerged acoustic energy source array (or airgun array). The seismic vessel will traverse along predetermined lines in the area to be surveyed with the airgun arrays discharging at regular intervals dependent upon the survey requirements.

Seismic surveys can either be two dimensional (2D) or three dimensional (3D). 3D surveys are considerably more expensive than 2D surveys, but do produce more extensive data.

Dependent upon the duration of the particular survey, the seismic vessel may be supported by other vessels or aircraft for the provision of supplies and crew changes.

Waste generation from seismic survey are generally limited to standard ship wastes such as sewage, drainage and atmospheric emissions.

4.1.2 Exploration Drilling

While seismic surveys can identify targets of interest, drilling is required to confirm the presence or absence of hydrocarbons. Exploration drilling involves the mobilization of the drilling rig to the site, positioning on site, drilling of the well(s), well completion and testing, well abandonment and demobilisation of the drilling rig.

There are a number of different types of drilling rigs available (i.e., barges, jack-ups, semi-submersibles and drill ships). The choice of rig depends on a variety of factors, including location, water depth, season of operation, ice conditions, flexibility and cost. Some rigs (i.e., drill ships) are self-propelled while others (i.e., jack ups) are required to be towed into position. In early Beaufort operations, drilling was undertaken from artificial islands constructed from bottom sediments, ice islands, temporarily anchored drilling rigs or drill ships in deeper water.

Offshore exploratory wells are drilled in a number of sections of decreasing diameter, much like a telescope in design. To provide structural strength to the well and to isolate unstable formations and formation fluids, steel casing is run down the well and cemented in place. Drill cuttings and drill fluids are returned to the surface in the space between the drill string and the steel casing. A marine riser (pipe) is used to link the well head with the drill rig, enabling cuttings and fluids to be returned to the rig for cleaning prior to disposal. Drilling fluid is often recycled and used more than once prior to disposal.

Dependent upon the geology of the upper sediments, the top section may be drilled without a conductor casing, thus resulting in drill cuttings and fluids being discharged directly to the surrounding seabed.

Upon completion of the well, if hydrocarbons are encountered, it is standard industry practice to test the potential production of the well. A well test involves allowing hydrocarbons to flow up the well bore to the rig under controlled conditions. In this way, hydrocarbon samples can be taken for analyses and the capability of the reservoir to deliver oil and/or gas can be established. Well testing generally also includes flaring (i.e., burning of the reservoir oil and/or gas).

Once well testing is complete, exploration wells are usually plugged and abandoned. Mechanical packers and cement plugs are used to seal the well and the casing is cut below the seabed and removed.

Dependent upon the specifics of the drill program, a number of support vessels will be required (i.e., supply vessels) to transport equipment and supplies to the rig. A standby vessel is usually present to provide emergency evacuation support and helicopter support is often provided to transport crew.

In addition to offshore facilities, operations may require a base or support facilities onshore for storage and transhipment of supplies.

Waste generation from an exploratory drilling program includes drill cuttings, drilling fluids and chemicals, cement, sewage, drainage, rig wash, assorted solid wastes and atmospheric emissions.

4.1.3 Field Development

Field development is initiated with the completion of a field development plan (DP). The plan provides details as to the type of production platform and other installations, well configurations and support facilities. Once the DP is complete and approved, the following activities prior to first production are required:

- detailed design of facilities
- procurement of materials
- fabrication of facilities
- installation of facilities
- commissioning of all plant and equipment

Field development can use fixed production platforms or floating production facilities. Offshore fields are developed using numerous directed wells radiating from a single production facility to drain a large area reservoir. Sub-sea infrastructure, such as tie-backs and pipelines, can be used to connect wells back to the production facility.

Production facilities are fabricated onshore and then installed offshore using construction vessels. Numerous support vessels and aircraft are required during construction, often supported from base facilities onshore. Construction of near shore production sites may also be required, dependent upon the development.

Waste generation from field development includes sewage, drainage, drill cuttings, drilling fluids, cement, assorted solid wastes and atmospheric emissions.

4.1.4 Production

Once installed, commissioned and certified, a facility is ready to move into production. Hydrocarbons produced offshore are transported onshore either by pipeline or tanker. Dependent on the development and the chemical composition of the hydrocarbons, some processing may occur on the production facility. For instance, natural gas may require processing to meet intake standards of transport pipelines.

During production, additional wells may be drilled in the field and tied into the production facility. To achieve as high a recovery factor as possible, reservoir pressures must be maintained. Operators may seek to enhance recovery using such techniques as water or gas injection, gas lift, acidizing[1] or fracturing[2].

Support from supply vessels, helicopters and onshore infrastructure will be required throughout the production cycle.

Wastes generated from production facilities include produced water, production chemicals, sewage, drainage, assorted solid wastes and atmospheric emissions.

4.1.4.1 Decommissioning and Abandonment

Eventually fields come to the end of their economic lives. This life span may differ from the original projection, depending on the success of further exploration, the market value of the product and quality of the reservoir. Decisions on the most appropriate means of decommissioning and abandonment are made on a balance of safety, environmental and economic matters. In general, while operators are expected to remove structures in their entirety, the decision needs to be based, among other factors, on an understanding of the incremental effects of removal.

[1] A method used to increase production in a well that is producing from a carbonate formation by using acid to dissolve the reservoir rock.

[2] Fluids pumped into the well to artificially fracture a reservoir rock to increase permeability and production.

5 Data Needs and Priorities

5.1 Physical Oceanography

5.1.1 Summary of Data Needs and Existing Data

5.1.1.1 Potential Effects

Table 5-1 lists the potential effects of hydrocarbon exploration and development on physical oceanography. Each effect is ranked based on the three criteria: (1) risk to resource; (2) level of understanding of the effect; and (3) ability to mitigate with proven techniques.

Table 5-1 Potential Effects of Hydrocarbon Exploration and Development on Physical Oceanography

Potential Effect (Activity stage)	Risk to Physical Oceanography	Understanding of the Effect	Ability to Mitigate with Proven Techniques	Ranking of Potential Effects
Seabed Disturbance-sediment re-suspension (Exploration Drilling, Field Development, Decommissioning)	1	1	1	3
Coastal Disturbance due to onshore support infrastructure (Field Development)	1	2	2	5
Stabilization or destabilization of Ice Cover (Exploration)	2	2	2	6
Stabilization or destabilization of Ice Cover (Production)	2	3	3	8
Hydrocarbon or chemical spill (Accidents and Malfunctions)	1	2	2	5

Stabilization or Destabilization of Ice Cover

Exploration Drilling

Risk: Short term (during the exploration program and in the immediately following period) effects could occur that might affect local fast ice stabilization and clearance rates and dates. Their likelihood and magnitude would be dependent upon the size, composition and timing of the exploration program. Effects are most probable from fall and spring drilling and support activities. Fall programs are most likely to result in effects through associated marine traffic, which could produce additional local ridging in relatively level, inner portions of landfast ice zone, possibly interfering with on-ice traditional use traffic. Less likely spring activities in the landfast ice zone could interact with natural crushing and seaward ice movement events to destabilize outer portions of the landfast ice used for traditional harvesting activities. In the region, natural destabilizations are most likely to occur in Mackenzie Bay and north of Cape Bathurst adjacent to Amundsen Gulf.

Understanding the Effect: In addition to a long record of coarse-scale satellite observations, a very limited amount of data exists on smaller scale movements that are characteristic of the landfast ice cover (Marko and Wright 2005). These movements seem to be consistent with forcing by strong regional wind events, which alternately move ice toward the coastline compressing and deforming thinner portions of the landfast ice zone and, then in reversals, remove the more mobile portions of the outer sectors of this zone (Melling 2005). The significance of these processes for Inupiat hunters off Arctic Alaska has been discussed by George et al. (2004). To date, we know of no data relevant to quantitatively assessing the effects of off shore structures or vessel activity on destabilization probabilities.

Ability to Mitigate with Proven Techniques: Mitigation would involve minimizing external disruption of existing or forming stable ice fields by avoiding movements of drilling and support vessels during the spring and fall. Such restrictions would appear to be feasible in some, but not all, development scenarios.

Production

Risk: Production-related risks can extend through and beyond the lifetime of the production field. As in the case of the exploration drilling phase, the risks include ice destabilization which, again, is dependent upon the timing and extent of ice-transiting vessel traffic. Production also holds potential for increasing ice cover stability, at least locally. This additional effect can have longer term significance, which goes beyond direct interference with hunting and other on-ice activities. Specifically, any additional tendency toward extended accumulations of ice in the spring and summer could affect underlying water properties that are important to biota of the region and could affect seasonal marine mammal distribution in the region. Spring and summer ice conditions are naturally highly variable, but concerns are warranted regarding possibilities for a shift in the duration of the ice season that may last for decades. The effects of such a shift are particularly difficult to anticipate in the light of present uncertainties about the rate of climate change in adjacent Arctic Basin and Archipelago areas. Such a shift would affect production activities.

Understanding the Effect: Assessing that existing knowledge is weak is justified by a combination of 1) evidence for imminent climate change in the study area and 2) lack of data on the effects of intensive offshore development in areas with similarly extensive zones of landfast and mobile ice exposed to variable and potentially drastically changing influences from a) the rest of the Arctic Ocean, b) its overlying atmosphere, and c) large scale, climate-sensitive, terrestrial freshwater inputs. Results from a limited number of local and Canadian Beaufort Sea studies (Marko and Wright 2005; Melling 2005; Melling et al. 2005, 2006) are available to provide an initial basis for understanding possible effects. Parallel development of relevant knowledge on the processes underlying changes in Chukchi Sea landfast ice zones has also been underway for several years (Mahoney et al. 2004, 2007a, b). As in the Canadian studies, complex linkages with the offshore pack ice and rising air temperatures have been found. However, they have yet to be fully integrated into a quantitative picture or model that could support meaningful forecasting or development of mitigation strategies/tactics.

Ability to Mitigate with Proven Techniques: Mitigation must involve designing a development plan that minimizes development effects on the natural stability of the ice cover. In principle, this task should be feasible. Unfortunately, as the rating of the present state of understanding suggests, we presently lack knowledge sufficient to assure that any production program (that is economic in size and scope) will not introduce local or larger scale changes in the environment that could measurably affect the ice resource. The possibility that natural conditions may be changing under global influences, which are beyond the scope of proposed developments, only complicates the developing effective mitigation and emphasizes the need for a substantial upgrading of existing knowledge.

5.1.1.2 Information Requirements

Information needs are identified for each ranked effect based on the premise of what information is required to undertake a credible environmental assessment. Table 5-2 lists the information requirements.

Table 5-2 Information Requirements for Physical Oceanography

Ranking	Effect	Information Required to Enable Assessment of Effect
8	Stabilization or destabilization of Ice cover (Production)	• Quantitative knowledge of regional landfast ice [1]
6	Stabilization or destabilization of Ice cover (Exploration)	• As above

NOTE:
[1] quantitative data would preferably be in the form of a verifiable numerical model, sufficient to guide the production portion of the proposed development. Inevitably, effective use of this knowledge will require accompanying knowledge of other environmental components such as the regional atmosphere, ocean and the behaviour of the ice pack, which exists seaward of the landfast ice zone. Major changes in these components may occur over the lifetime of the development and should be capable of being represented in the model.

5.1.1.3 Existing Information

Overview of Existing Data

For the stabilization and destabilization of landfast ice, a whole body of work carried out in the Beaufort Sea by Melling, Blasco, Eicken and other researchers provide a considerable information base relevant to the properties of the regional ice cover and the extensive zone of landfast ice, which could be affected by an offshore hydrocarbon production program. However, only a relatively small proportion of the data collected has been obtained by direct measurements on landfast ice; most of the data has been collected in adjacent fields of mobile ice that move over deployed bottom-moored monitoring instrumentation or measurements made on sea floor scours produced by mobile ice keels. Details of processes in the landfast ice itself have been deduced from satellite imagery or marine radar data used in conjunction with on-ice measurements and by inference from profile data acquired in adjacent mobile ice regions. Information on important interactions between the landfast ice and the sea floor is contained in the large and growing body of ice scour data; however, that data is characterized by uncertainties as to the ages (and, hence, contemporary sea levels) associated with individual scours and in the degree of mobility associated with past scour-generating keels.

The scour database (Blasco, Bennett and Solomon, 2007) is an important element in understanding landfast ice stability and provides at least empirical guidance as to its sensitivity to environmental conditions and changes in different portions of the proposed production regions. A one-dimensional model of seasonal fast ice advance, which has been developed by Melling, is now being used as a basis for extending similar capabilities to two dimensions. Dependences of the local and regional stability of landfast ice features have been postulated to be associated with:

- underlying ice thicknesses and topography
- water properties (oceanographic and river)
- sea floor characteristics
- degrees of ice consolidation and strength
- magnitudes, directions and timings of coastal and offshore winds

Overview of Data from Previous Gap Analyses

Previous gap analyses have identified four main categories of data gaps. Filling these gaps will improve the quality of effects assessments and will provide the basis for effective monitoring and mitigation programs.

- Mackenzie River-Delta-Shelf process knowledge linked to sources/inputs, pathways and fate of contaminants, as well as their role in biophysical processes related to plankton, fish and marine mammal utilization of this large area (e.g., food availability distributions as determined by biophysical processes)
- regional process knowledge of physical oceanography and sea ice dynamics to improve inputs to contaminants fate/transport and to biological and food chain dynamics
- effect that global climate change may have on oceanographic (currents, waves, water properties) and sea-ice processes (pack ice and landfast ice) and the resulting changes on assessments of transport of contaminants, oceanographic processes in determining ocean productivity and changes on the ice-based habitat of key VECs
- effects of the physical and geophysical environment on offshore oil and gas activities for which knowledge is required for design of platforms and operations to reduce risks of accidents which could affect the environment. Major topics identified include ocean currents and waves, sea-ice thickness and movement, effect of ice on structural stability, availability of borrow materials, ice scouring of the seabed, sediment distributions and dynamics, seabed deformation and displacement and permafrost conditions

Comparison of Existing Data with Previous Data Gap Analyses

Existing data have advanced the knowledge of the physical, ice and geophysical dynamics in the study area, but the understanding is still incomplete; none of the above data gaps have been adequately addressed. The requirement for ongoing field measurements in support of process studies is also related to the possibility that the physical climate is changing as part of global climate.

Recent and Ongoing Research

Information required for modeling of the turbulent mixing is readily available for open water conditions, but is limited for estimating dilution effects under stationary (landfast) ice. Recent investigations by T. Weingartner and colleagues (e.g., Wang et.al. 2003) on the Alaskan Beaufort Sea shelf are relevant to these issues. However, the presence of the Mackenzie River plume waters under the inner and middle portions of the Mackenzie Shelf may introduce additional uncertainties in estimating dilution parameters.

Sea ice and oceanographic research studies on the continental shelf are ongoing through the work of DFO scientists, including Dr H. Melling (sea-ice processes on the shelf) and Drs. E. Carmack and R. Macdonald on oceanographic processes. DFO is involved in oceanographic data collection through the DFO-NRCan CCGS Nahidik program, funded by the Northern Oil and Gas Science Research Initiatives Program and the Program on Energy Research and Development.

Research is being conducted through the ArcticNet NCE, which focuses on climate change and process-oriented issues, related to large-scale interactions between physical processes, shelf dynamics and contaminant cycling and fate. Research being conducted during the International Polar Year (2007/2008) will also provide data relevant to the data gaps.

5.1.1.4 Identification of Data Gaps

Based on the ranked effects and the information required to assess the effects, existing relevant information is identified in Table 5-3. Comparison of required and existing data will enable identification of data gaps.

Table 5-3 Existing Information and Identified Data Gaps for Physical Oceanography

Ranked Effect	Information Required to Enable Assessment of Effect	Existing Information and Recent/Ongoing Research	Quality of Existing Data	Data Gap
Stabilization or destabilization of ice cover	• Quantitative knowledge of regional landfast ice • Dynamical effects of mobile pack ice, currents, Mackenzie River discharges and seafloor interactions on landfast ice	• Sequences of satellite imagery and ice charts to monitor changes in landfast ice • Landfast ice movements • Ocean currents • Seafloor interactions • River discharges	• Good, but very limited direct measurements of landfast ice properties	• Require near-simultaneous collection of all types of data during major local and regional stabilization and destabilization events to support development of a model for landfast ice response to ice pack, ocean current, sea-floor and river forcing that can be used to assess effects of oil and gas development activities relative to natural processes

5.1.2 Final Prioritization of Research Requirements

Table 5-4 introduces timing to the ranked effects and data gaps to provide a final prioritization. The aim of this step is to provide an objective and useful list and avoid a conclusion where all research requirements are considered to be high priority.

Table 5-4 Research Requirement Prioritization for Physical Oceanography

Ranked Effect	Data Gap	Time to Obtain Data	When in the Development Process is the Data Required	Relative Overall Ranking
Stabilization or destabilization of ice cover	• Quantitative knowledge of regional landfast ice	• 7 years	• Exploration and Production	• High

•

5.2 Chemical Oceanography

5.2.1 Summary of Data Needs and Existing Data

5.2.1.1 Potential Effects

Table 5-5 lists the potential effects of hydrocarbon exploration and development on chemical oceanography. Each effect is ranked based on the three criteria: (1) risk to resource, (2) level of understanding of the effect and (3) ability to mitigate with proven techniques.

Table 5-5 Potential Effects of Exploration and Hydrocarbon Development on Chemical Oceanography

Potential Effect	Risk to Chemical Oceanography	Understanding of the Effect [2]	Ability to Mitigate with Proven Techniques	Ranking of Potential Effects
Change in water quality (Seismic, Exploratory drilling, Field development, Production, Decommissioning, Fire fighting chemicals, Hydrocarbon/chemical spill)	1	1	1	3
Change in sediment Quality (Seismic, Exploratory drilling, Field development, Production, Decommissioning, Fire fighting chemicals, Hydrocarbon/chemical spill)	1	1	1	3

5.2.1.2 Information Requirements

In Table 5-6, baseline data includes quantification of temporal and spatial variability at the drill site.

Table 5-6 Information Requirements for Chemical Oceanography

Ranking	Effect	Information Required to Enable Assessment of Effect
3	Change in water quality	• Baseline data for drill site • Dynamics of contaminant cycling
3	Change in sediment quality	• Baseline data for drill site • Dynamics of contaminant cycling

5.2.1.3 Existing Information

Overview of Existing Data

There exists an adequate understanding of the types, chemical composition and volumes of wastes associated with typical offshore seismic exploration, development and production activities (NAS 1983; Thomas et al. 1983; Neff 1981; GESAMP 1993). There are also data showing that technological advances are occurring regularly, which improve waste treatment, thereby, reducing the volumes of waste produced and the concentrations of contaminants in the wastes. Some of these advances have been used in the offshore oil and gas industry in the Barents and Norwegian seas and support an ultimate goal of 'zero waste discharge of harmful substances'.

In addition, there is a large database that describes environmental concentrations, and spatial and temporal trends in contaminants of concern (e.g., Hg, Pb, Cd and hydrocarbons [particularly polycyclic aromatic hydrocarbons]) in the biotic and abiotic compartments of the Beaufort Sea study area (CACAR 1997; CACAR II 2003; AMAP 1998; Yunker and Macdonald 1995; Thomas et al. 1990; Braune et al. 1999, INAC 2005). Generally, the geographical density of existing data is greatest for nearshore (less than 10 m water depth) areas and becomes less dense with increasing distance from shore, to the 200 m isobath and beyond.

Overview of Data from Previous Gap Analyses

Previous gap analyses have identified three main data gaps. Filling these gaps will improve the quality of effects assessments and will provide the basis for effective monitoring and mitigation programs.

- Mackenzie River-Delta-Shelf process knowledge linked to sources/inputs, pathways and fate of contaminants
- the effect that global climate change could have on coastal processes and the input, cycling and fate of contaminants
- site-specific data for environmental concentrations of contaminants at locations where offshore oil and gas activities might occur

Comparison of Existing Data with Previous Data Gap Analyses

Existing data have advanced the knowledge of contaminant dynamics in the study area, but the understanding is still incomplete. None of the above data gaps have been addressed.

Recent and Ongoing Research

There has been significant on-going research that addresses the above-noted data gaps. Research conducted through the ArcticNet NCE focuses on climate change and process-oriented issues. For example, several studies are examining mercury (Hg) sources and partitioning into the various environmental compartments of the study region. Other studies deal with large-scale interactions between physical processes, shelf dynamics and contaminant cycling and fate. Research being conducted during the International Polar Year (2007/2008) will also provide much relevant data. The Northern Contaminants Program of Indian and Northern Affairs Canada, in conjunction with various government departments such as Fisheries and Oceans Canada (DFO), Environment Canada and Natural Resources Canada, continue to add new, relevant information as well.

It is likely that the information resulting from the above research activities will address most of the data gaps on process knowledge and the potential effects of climate change within a timeframe appropriate for hydrocarbon development in the Beaufort Sea.

However, it is unlikely that much progress will be made on increasing the database of environmental concentrations of the contaminants of concern for the deeper shelf area.

5.2.1.4 Identification of Data Gaps

Completing a credible environmental assessment will depend on the exact location of the activity and the anticipated volumes, treatment and management of the wastes discharged. Within the study area, some locations have sufficient existing baseline data and there is an adequate understanding of inputs, pathways and fate of the contaminants of concern to support a credible assessment. For other areas, this is not the case. The entries in Table 5-7 apply to those areas where baseline data is limited or non-existent. The status of the data gap would therefore be resolved once specific development sites are identified.

Table 5-7 Existing Information and Identified Data Gaps for Chemical Oceanography

Ranked Effect	Information Required to Enable Assessment of Effect	Existing Information and Recent/Ongoing Research	Quality of Existing Data	Data Gap
Changes in water quality	Baseline data for drill site	None	N/A	Baseline data for drill site
	Dynamics of contaminant cycling	Incomplete on a regional basis	High for some locations	Dynamics of contaminant cycling
Changes in sediment quality	Baseline data for drill site	None	N/A	Baseline date for drill site
	Dynamics of contaminant cycling	Incomplete on a regional basis	High for some locations	Dynamics of contaminant cycling

5.2.2 Final Prioritization of Research Requirements

Table 5-8 introduces timing to the ranked effects and data gaps to provide a final prioritization. The aim of this step is to provide an objective and useful list and avoid a conclusion where all research requirements are considered to be high priority.

Table 5-8 Research Requirement Prioritization

Ranked Effect	Data Gap	Time to Obtain Data	When in the Development Process is the Data Required	Relative Overall Ranking
Change in water quality	Baseline data for drill site	1 year	Exploration Drilling	Moderate
	Dynamics of contaminant cycling	ca. 2- 10+ years depending on location	Exploratory Drilling	High
Change in sediment Quality	Baseline data for drill site	1 year	Exploration Drilling	Moderate
	Dynamics of contaminant cycling	ca. 2-5 years	Exploration Drilling	High

5.3 Plankton

For the purpose of this report, plankton also refers to zooplankton and larger pelagic invertebrates such as squid.

5.3.1 Summary of Data Needs and Existing Data

5.3.1.1 Potential Effects

Table 5-9 lists the potential effects of hydrocarbon exploration and development on plankton. Each effect is ranked based on the three criteria: (1) risk to sustainability, (2) level of understanding of the effect and (3) ability to mitigate with proven techniques.

Table 5-9 Potential Effects of Hydrocarbon Exploration and Development on Plankton

Potential Effect	Risk to Sustainability of Zooplankton	Understanding of the Effect	Ability to Mitigate with proven techniques	Ranking of potential effects
Change in water quality (sewage and drainage, rig wash)	1	2	1	4
Change in water quality (discharge of produced water)	1[1]	1	1	3
Physical Disturbance of Seabed (physical footprint, sediment re-suspension and physical smothering of fauna)	1[1]	1	2	4
Change in ice structure and stability (ice breaking, rubble formation)	1	1	3	5
Exposure of marine flora and fauna to drill chemicals	1	1	1	3
Coastal disturbance due to onshore support infrastructure, i.e., pipeline landfall	1	2	2	5
Hydrocarbon or chemical spill	2[1]	2	2	6
Fire (fire fighting chemicals)	1	2	3	6

NOTE:
[1] Effect may be localized or broader in scope.

5.3.1.2 Information Requirements

Table 5-10 details the information requirements to assess each of the effects identified in Table 5-9.

Table 5-10 Information Requirements for Plankton

Ranking	Effect	Information Required to Enable Assessment of Effect
6	Accidents and malfunctions: hydrocarbon or chemical spill	• Baseline data on species presence, distribution and abundance especially in offshore waters • Baseline data on water quality and contaminants including petroleum hydrocarbons • Data on contaminant pathways • Data on embryonic and physiological effects of contaminants on plankton • Data on behavioural responses (e.g., avoidance) of

		plankton due to changes in water quality

5.3.1.3 Existing Information

Overview of Existing Data

Wide ranging zooplankton geographic surveys were conducted in the Beaufort Sea during the Beaufort Sea Project in the 1970s (Grainger 1975) and through the Northern Oil and Gas Action Program (NOGAP) in the 1980s (Hopky et al. 1994a, b, c). The most common and diverse groups of zooplankton are copepods, hydrozoans and amphipods (Percy et al. 1985; Hopky et al. 1994a, b, c). Zooplankton in the Beaufort Sea can be of freshwater, estuarine or marine in origin.

Species composition and distribution of zooplankton is strongly affected by the characteristics of water masses, including temperature and salinity. Zooplankton biomass is found to be highest in water unaffected by the Mackenzie River plume, while concentrations of zooplankton can be found in areas of wind induced upwelling (Bradstreet et al. 1987).

Near the mouth of the Mackenzie River, freshwater species of zooplankton such as the copepods *Diaptomus* and *Cyclops* and cladocerans such as *Daphnia* and *Bosmina* occur (DFO 2007). In nearshore areas, where low salinity and fluctuating temperatures dominate, zooplankton species are often copepods such as *Acarti clausi*, *Haliitholus cirratus*, *Limnoclanus macrurus* and *Derjuginia tolli* (Percy et al. 1985).

The upper 250 m of the Beaufort Sea (Arctic Surface Layer) is characterized by the copepods *Aglantha digitale* and *Calanus glacialis*. Within the Arctic Surface Layer, there is a small band of water at about 25 m depth that originates from the Pacific Ocean and includes copepod species such as *Calanus cristatus*, *Eucalanus bungii* and *Metridia pacifica* (Percy et al. 1985).

Water originating from the Atlantic Ocean can be found approximately between 250 and 1000 m. Within this Atlantic layer, common copepod species are *Chiridius obtusifrons, Gaidus tenuispinus* and *Heterorhabdus norvegicus* (Percy et al. 1985).

Gelatinous zooplankton such as cnidarians, ctenophores, chaetognaths and pelagic tunicates also show trends related to the physical properties of water and geographic location. In the Canada Basin, the ctenophores *Mertensia ovum* and *Bolinopsis infundibulum* are common in the near surface of the Arctic Mixed Layer. Below the Pacific layer, the most common species is the cnidarian, *Sminthea arctica* (Raskoff et al. 2005).

Overview of Data from Previous Gap Analyses

Previous gap analyses have mainly focused on plankton as a prey source for bowhead whales. A more recent gap analyses prepared for the Beaufort Sea Strategic Regional Plan of Action recommends the mapping of zooplankton abundance and biomass.

Comparison of Existing Data with Previous Data Gap Analyses

Some studies (e.g., LGL 1988) have been conducted with respect to bowhead feeding and zooplankton but more research is required to understand the mechanisms which lead to large aggregations of zooplankton being formed. Understanding these mechanisms will help better predict whale feeding areas and timing. An extensive four-year NOGAP zooplankton data set was compiled in the late 1980s. This data set is currently being analyzed and integrated into the Mackenzie Gas Project (MGP) funded CCGS Nahidik program. This integrated data set would contribute to our understanding of the distribution and abundance of zooplankton along the Beaufort shelf.

Recent and Ongoing Research

Plankton surveys are being conducted as part of the DFO and Natural Resources Canada Seabed and Habitat Mapping Program from the CCGS Nahidik. Plankton research from the CCGS Nahidik may be able to be used for validating older plankton shelf data collected in the 1970s and 1980s. However, it will not address gaps related to the lack of knowledge for the outer shelf and slope. A plankton survey was conducted for Devon Canada Corporation's exploratory drilling program in 2002. Plankton surveys were conducted through Arctic Net in 2007–2008 near the Bathurst polyna.

5.3.1.4 Identification of Data Gaps

Table 5-11 lists the identified data gaps for plankton.

Table 5-11 Existing Information and Identified Data Gaps for Plankton

Ranked Effect	Information Required to Enable Assessment of Effect	Existing Information and Recent/Ongoing Research	Quality of Existing Data	Data Gap
Hydrocarbon or chemical spill*	• Baseline data on species presence, distribution and abundance especially in offshore waters	• Data from Beaufort Sea Project & NOGAP but mainly for inner shelf	• High (depths >200 m) • Low (depths <200 m)	• Lack of information for plankton in waters deeper than 200 m .Baseline data on species presence, distribution and abundance for outer shelf and slope required. Stratification of zooplankton and its ecological importance (e.g. prey availability for marine mammals) is poorly understood
	• Data on contaminant pathways	• Arctic Monitoring and Assessment Program (AMAP)	• High	• No significant gaps
	• Data on embryonic and physiological effects of contaminants on zooplankton	• Limited international data	• Low	• Data on embryonic and physiological effects of contaminants on plankton
	• Data on behavioural responses (e.g., avoidance) of zooplankton due to changes in water quality	• Government and industry data	• Low	• Data on behavioural responses (e.g., avoidance) of plankton due to changes in water quality

NOTE:
* The two effects ranked 1st have been merged because the information requirements are the same.

5.3.2 Final Prioritization of Research Requirements

Table 5-12 introduces timing to the ranked effects and data gaps to provide a final prioritization. The aim of this step is to provide an objective and useful list and avoid a conclusion where all research requirements are considered to be high priority.

Table 5-12 Research Requirement Prioritization for Plankton

Ranked Effect	Data Gap	Time to Obtain Data	When in the Development Process is the Data Required	Relative Overall Ranking
Hydrocarbon or chemical spill	• Require baseline data on species presence, distribution and abundance for outer shelf and slope	• 3–5 years	• All phases	• High
	• Data on embryonic and physiological effects of contaminants on zooplankton	• 5–10 years	• All phases	• Low
	• Data on behavioural responses (e.g., avoidance) of zooplankton due to changes in water quality	• 5–10 years	• All Phases	• Low

5.4 Benthos

For the purpose of this report benthos, also refers to large invertebrates such as crabs.

5.4.1 Summary of Data Needs and Existing Data

5.4.1.1 Potential Effects

Table 5-13 lists the potential effects of hydrocarbon exploration and development on benthos. Each effect is ranked based on the three criteria: (1) risk to sustainability, (2) level of understanding of the effect and (3) ability to mitigate with proven techniques.

Table 5-13 Potential Effects of Hydrocarbon Exploration and Development on Benthos

Potential Effect	Risk to Sustainability of Benthos	Understanding of the Effect	Ability to Mitigate with Proven Techniques	Ranking of Potential Effects
Change in water quality (sewage and drainage)	1	2	1	4
Underwater acoustic disturbance on macro-invertebrates (e.g., crab) (vessel and seismic)	1[1]	3	2	6
Seabed Disturbance (physical footprint, sediment re-suspension and physical smothering of fauna)	2[2]	1	3	6
Exposure of marine flora and fauna to drill chemicals	1	1	1	3

Coastal disturbance due to onshore support infrastructure (i.e., pipeline landfall)	1	1	2	4
Change in water quality (discharge of produced water, sewage and drainage)	2[2]	2	1	5
Hydrocarbon or chemical spill	2[2]	2	2	6
Fire (fire fighting chemicals)	1	2	3	6

NOTES:
[1] Magnitude of risk depends on the population range (e.g., crab).
[2] Effect may be localized or broader in scope. Some localized areas may be critical habitat for some benthic species.

5.4.1.2 Information Requirements

Table 5-14 lists the ranked information requirements for benthos.

Table 5-14 Information Requirements for Benthos

Ranking	Effect	Information Required to Enable Assessment of Effect
6	Seabed disturbance (Exploration, Field Development and Decommissioning)	• Baseline data on species presence, distribution and abundance of benthos and macro-invertebrates • Data on critical habitat areas and timing for macro-invertebrates (e.g., crab spawning areas) • Data on effects of increased sedimentation on benthic distribution and abundance • Data on the uptake and effects of contaminants related to sediment re-suspension on benthos
6	Hydrocarbon or chemical spill (Accidents and Malfunctions)	• Baseline data on species presence, distribution and abundance of benthos and macro-invertebrates • Baseline data on water quality and contaminants including petroleum hydrocarbons • Data on contaminant pathways • Data on critical habitat areas and timing for macro-invertebrates (e.g., crab spawning areas) • Data on effects of contaminants on the health of benthos and macro-invertebrates
5	Change in water quality (Production)	• Baseline data on species presence, distribution and abundance of benthos and macro-invertebrates • Data on critical habitat areas and timing for benthos and macro-invertebrates (e.g., crab spawning areas) • Data on effects of contaminants on the health of benthos and macro-invertebrates

5.4.1.3 Existing Information

Overview of Existing Data

Benthic studies in the Beaufort Sea have either been conducted over wide geographic distances (Wacasey 1975) or have been very localized and related to specific industrial activities (Heath et al. 1982; North/South Consultants and KAVIK-AXYS 2004; Thomas and Heath 1982). Extensive surveys have been conducted in embayments such as Tuktoyaktuk Harbour (Hopky et al. 1994; Thomas et al. 1981) and Mason Bay (Hopky et al. 1994). A summary and synthesis of benthic literature on the southeastern Beaufort Sea was conducted by Wong (2000).

The outflow of the Mackenzie River, ice scouring, salinity, temperature and depth play important roles in the diversity and abundance of benthic fauna presence (Wong 2000). Wacasey (1975) divided the Beaufort Sea into four biogeographic benthic zones based on water depth, salinity and temperature: the estuarine zone, transition zone, marine zone and continental slope. There is also a west–east gradient that is driven largely by productivity and substrate (DFO 2007).

The estuarine zone is heavily influenced by the freshwater outflow and suspended sediment from the Mackenzie River. This zone is also subject to frequent ice scouring, variable temperatures and variable salinity. Due to the harsh conditions for most benthic species, biodiversity in this zone is very low. Common organisms found here include the polychaete *Ampharete vega*, amphipods *Onisimus glacialis* and *Boeckosimus affinis*, clams *Yoldiella intermedia* (DFO 2007; Percy et al. 1985) and the isopod *Mesidotea entomon* (Percy 1983). Starfish are absent from this zone. The exception to low biodiversity and abundance in the estuarine zone are the various protected bays such as Mason Bay and Tuktoyaktuk Harbour where there is much higher diversity and abundance (Hopky et al. 1994; Wacasey 1975).

The transition zone, which is situated between the marine zone and the estuarine zone, is also affected by the discharge of the Mackenzie River but not to the same degree as the estuarine zone. Ice scouring also occurs in this zone. In the transition zone, biodiversity increases with the presence of both marine and estuarine zoobenthos tolerant of a wide range of salinity. Common organisms include the polychaete worms *Artacama proboscidea* and *Trochocaeta carica*, the clam *Portlandia arctica* (Percy et al. 1985) and the isopod *M sibirica* (Percy 1983).

The marine zone provides a more stable environment for benthic organisms where salinity is fairly stable at about 30 parts per thousand and temperatures are -0.1° to 1.58°C. This zone, on average, has the highest diversity and biomass of all four zones. Representative species include polychaete worms *Maldane sarsi*, *Aricidea suecica*, *Paraonis gracilis* and *Pectinaria hyperborean*, the amphipod *Haploops laevis*, bivalves *Astarte borealis* and *A. montagui* (DFO 2007) and the isopod M. sabini (Percy 1983). Starfish, octopi, whelks and other macro invertebrates are also found in this zone.

The continental slope zone also provides a stable environment for benthic organisms; however, biodiversity and biomass are less than in the marine zone. The reduction in zoobenthos diversity and biomass may be related more to food availability than to physical conditions (Percy et al. 1985). Representative groups of organisms include polychaetes *Onuphis quadricuspis* and *Laonice cirrata*, amphipods *Haploops tubicola* and *Hippomedon abyssi* and the isopod *Gnathia stygia* (DFO 2007).

Little information exists on the macro-invertebrates that inhabit the Beaufort Sea floor. In a benthic survey of the Sachs Harbour area, low numbers of cockles, whelks, Greenland scallop, brittle and sea stars, sea urchins and toad crabs were captured (Siferd 2001).

There have been some studies that examined the responses of amphipods (*B. affinis* and *G. oceanicus*) and the isopod *M. entomon* to various types of crude oils (Percy 1976) and oil contaminated sediments (Percy 1977). Both amphipod species avoided the crude oil and oil contaminated sediment, while the isopod showed no avoidance response to either (Percy 1976 and 1977). The amphipods showed variable avoidance responses to different varieties of weathered oil (Percy 1976).

Overview of Data from Previous Gap Analyses

In the 1970s and 1980s, benthic research activities were largely related to the understanding of benthic productivity and the uptake of contaminants and its eventual pathway to harvested animals. No research gaps were identified nor research conducted related to macro-invertebrates such as crabs.

Comparison of Existing Data with Previous Data Gap Analyses

Due to the research conducted in the 1970s and 1980s, there is an improved understanding of the uptake of contaminants, including hydrocarbons, by benthic invertebrates. There is also a general knowledge regarding benthic productivity throughout the Beaufort Sea. Current research being conducted may contribute to this existing knowledge and provide some validation to older data. There are still large data gaps regarding macro-invertebrates in the Beaufort Sea.

Recent and Ongoing Research

Benthic sampling is occurring as part of the DFO and Natural Resources Canada Seabed and Habitat Mapping Program, which is being conducted from CCGS Nahidik. There has also been some very limited benthic sampling in the mouth of the Mackenzie River (in support of the Mackenzie Gas Project).

5.4.1.4 Identification of Data Gaps

Table 5-15 lists the identified data gaps for benthos.

Table 5-15 Existing Information and Identified Data Gaps for Benthos

Ranked Effect	Information Required to Enable Assessment of Effect	Existing Information and Recent/Ongoing Research	Quality of Existing Data	Data Gap
Seabed disturbance	Baseline data on species presence, distribution and abundance of benthos and macro-invertebrates (all depth ranges)	Data widely geographically collected – limited data on macro-invertebrates. Data is better for depths less than 100m.	Low	Baseline data on species presence, distribution and abundance of benthos and macro-invertebrates with focus on water depths >100m
	Data on critical habitat areas and timing for macro-invertebrates (e.g., crab spawning areas)	No data	-	Data on critical habitat areas and timing for macro-invertebrates (e.g., crab spawning areas)
	Data on effects of increased sedimentation on benthic distribution and abundance	Limited data	Low	Data on effects of increased sedimentation on benthic distribution and abundance
	Data on the uptake and effects of contaminants related to sediment re-suspension on benthos	Industry and government data but most old	Medium	Data on the uptake and effects of contaminants related to sediment re-suspension on benthos
Hydrocarbon or chemical spill* Change in water Quality (produced water)*	Baseline data on species presence, distribution and abundance of benthos and macro-invertebrates (all depths)	Data widely geographically collected – limited data on macro-invertebrates. Data is better for depths less than 100m	Low	Baseline data on species presence, distribution and abundance of benthos and macro-invertebrates with focus on water depths >100m
	Data on critical habitat areas and timing for macro-invertebrates (e.g., crab spawning areas)	No data	N/A	Data on critical habitat areas and timing for macro-invertebrates (e.g., crab spawning areas)
	Data on effects of contaminants on the health of benthos and	Industry and government data (mainly old)	Medium	Data on effects of contaminants on the health of benthos and

	macro-invertebrates			macro-invertebrates
	Data on contaminant pathways	AMAP	Medium	Data on the uptake and transfer of contaminants in deep water benthos
NOTE: * Hydrocarbon or chemical spills and change in water quality have been merged in this table because the information requirements are the same.				

5.4.2 Final Prioritization of Research Requirements

Table 5-16 introduces timing to the ranked effects and data gaps to provide a final prioritization. The aim of this step is to provide an objective and useful list and avoid a conclusion where all research requirements are considered to be high priority.

Table 5-16 Research Requirement Prioritization for Benthos

Ranked Effect	Data Gap	Time to Obtain Data	When in the Development Process is the Data Required	Relative Overall Ranking
Seabed disturbance	Baseline data on species presence, distribution and abundance of benthos and macro-invertebrates with focus on water depths >100m	2–3 years	Exploration drilling through to decommissioning	Moderate
	Data on critical habitat areas and timing for macro-invertebrates (e.g., crab spawning areas)	3–5 years	Exploration drilling through to decommissioning	High
	Data on effects of increased sedimentation on benthic distribution and abundance	3–5 years	Exploration drilling through to decommissioning	Moderate
	Data on the uptake and effects of contaminants related to sediment re-suspension on benthos	5–10 years	Exploration drilling through to decommissioning	Low
Hydrocarbon or chemical spill Change in water quality (produced water)	Baseline data on species presence, distribution and abundance of benthos and macro-invertebrates with focus on water depths >100m	1–3 years	All phases	Moderate
	Data on critical habitat areas and timing for macro-invertebrates (e.g., crab spawning areas)	3–5 years	All phases	High
	Data on effects of contaminants on the health of benthos and macro-invertebrates	3–5 years	All phases	Moderate

	Data on the uptake and transfer of contaminants in deep water benthos	3–5 years	All phases	Moderate

5.5 Macrophytes

5.5.1 Summary of Data Needs and Existing Data

5.5.1.1 Potential Effects

Table 5-17 lists the potential effects of hydrocarbon exploration and development on macrophytes.

Table 5-17 Potential Effects of Hydrocarbon Exploration and Development on Macrophytes

Potential Effect	Risk to Sustainability of VEC [1]	Understanding of the Effect	Ability to Mitigate with Proven Techniques	Ranking of Potential Effects
Change in water quality (sewage, drainage, rig wash, produced water)	2[1]	3	1	6
Seabed Disturbance (physical footprint, sediment re-suspension and physical smothering of fauna)	2[1,2] (Unknown)	2	3	7
Exposure of marine flora and fauna to drill chemicals	2[1]	3	1	6
Coastal disturbance due to onshore support infrastructure, i.e., pipeline landfall	2[1,2] (Unknown)	2	3	7
Hydrocarbon or chemical spill	3[1,2]	2	2	7
Fire (fire fighting chemicals)	2[1,2]	2	3	7

NOTES:
[1] Some localized areas may be critical habitat and consequently disturbance could be of greater consequence to sustainability of population.
[2] The distribution and abundance of macrophytes is largely unknown. Kelp and eelgrass beds provide important habitat for a variety of aquatic organisms. It is unknown whether these macrophyte beds are limited in number and size.

5.5.1.2 Information Requirements

Table 5-18 lists the ranked information requirements for macrophytes.

Table 5-18 Information Requirements for Macrophytes

Ranking	Effect	Information Required to Enable Assessment of Effect
7	Hydrocarbon or chemical spill, fire fighting chemicals (Accidents and malfunctions)	• Baseline data on species presence, distribution and abundance of macrophytes • Data on the effects of contaminants on plant growth and health
7	Seabed disturbance (Exploration, Field Development, Decommissioning)	• Local baseline data on species presence, distribution and abundance of macrophytes • Data on the effects of increased sedimentation on plant growth and health
7	Coastal disturbance (Field development, Decommissioning)	• Local baseline data on species presence, distribution and abundance of macrophytes • Data on the effects of increased sedimentation on plant growth and health
6	Change in water quality (all phases)	• Local baseline data on species presence, distribution and abundance of macrophytes • Data on the effects of contaminants on plant growth and health
6	Exposure to drill chemicals (Exploration)	• Local baseline data on species presence, distribution and abundance of macrophytes • Data on the effects of contaminants on plant growth and health

5.5.1.3 Existing Information

Overview of Existing Data

There is a paucity of information on the presence, distribution, and abundance of macrophytes in the Canadian Beaufort Sea. The Beaufort shelf is mostly underlain by mud and subjected to ice scouring, and the inner shelf is subjected to heavy sediment loading from the Mackenzie River. Because macrophytes are most likely to be located in areas sheltered from excessive sediment transport and ice scouring, these conditions suggest macrophytes beds in the Canadian Beaufort Sea are likely limited

A summary of macrophyte presence and growth in the Beaufort Sea is presented in Percy et al. 1985. In other studies (Hsiao 1976), kelp (*Laminaria* sp.) and *Phyllophora* sp. were collected in Liverpool Bay and Husky Lakes. Large beds of kelp can be found in Balena Bay, Cape Parry (Percy et al. 1985). Siferd (2001) found occasional patches of kelp (*Laminaria solidungula*) and the seaweed *Fucus* sp. in Sachs Harbour. Spawning Pacific herring (*Clupea harengus pallasi*) have been reported by Gillman and Kritofferson (1984) in Tuktoyaktuk Harbour indicating the presence of macrophyte beds. Other macrophyte beds likely exist in the Canadian Beaufort Sea, but have not yet been identified.

Macrophytes do not appear to play an important role in the ecosystem of the Beaufort Sea (DFO 2007). Locally, however, macrophytes beds can be important. Macrophytes such as kelp and seaweed can increase fauna diversity and biomass at local levels (Dunton et al. 1982, Bushdosh et al. 1985) and provide important habitat for fish species (DFO 2007) such as Pacific herring and some Liparids.

Overview of Data from Previous Gap Analyses

Past gap analyses have not dealt specifically with macrophytes.

Comparison of Existing Data with Previous Data Gap Analyses

Macrophyte data gaps and research requirements provided in this report have not been dealt with in previous gap analyses.

Recent and Ongoing Research

No research is currently ongoing.

5.5.1.4 Identification of Data Gaps

Table 5-19 lists the identified data gaps for macrophytes.

Table 5-19 Existing Information and Identified Data Gaps for Macrophytes

Ranked Effect	Information Required to Enable Assessment of Effect	Existing Information and Recent/Ongoing Research	Quality of Existing Data	Data Gap
Hydrocarbon or chemical spill, fire fighting chemicals	Data on species presence, distribution and abundance of macrophytes	Limited	Good	Data on species presence, distribution and abundance of macrophytes
	Data on the effects of contaminants on plant growth and health	Limited	Poor	Data on the effects of contaminants on plant growth and health
Seabed* disturbance Coastal* disturbance	Local data on species presence, distribution and abundance of macrophytes	Limited	Good	Local data on species presence, distribution and abundance of macrophytes
	Data on the effects of increased sedimentation on plant growth and health	Limited	Medium	Data on the effects of increased sedimentation on plant growth and health
Change in water quality** Exposure to drill chemicals**	Local data on species presence, distribution and abundance of macrophytes	Limited	Good	Local data on species presence, distribution and abundance of macrophytes
	Data on the effects of contaminants on plant growth and health	Limited	Poor	Data on the effects of contaminants on plant growth and health

NOTES:
* Seabed and coastal disturbance have been merged in this table as the information requirements are the same.
** Change in water quality and exposure to drill chemicals have been merged in this table as the information requirements are the same.

5.5.2 Final Prioritization of Research Requirements

Table 5-20 introduces timing to the ranked effects and data gaps to provide a final prioritization. The aim of this step is to provide an objective and useful list and avoid a conclusion where all research requirements are considered to be high priority.

Table 5-20 Research Requirement Prioritization for Macrophytes

Ranked Effect	Data Gap	Time to Obtain Data	When in the Development Process is the Data Required	Relative Overall Ranking
Hydrocarbon or chemical spill, fire fighting chemicals	Data on species presence, distribution and abundance of macrophytes	1–3 years	Seismic through to Decommissioning	High
	Data on the effects of contaminants on plant growth and health	2–5 years	Seismic through to Decommissioning	Moderate
Seabed disturbance Coastal disturbance	Data on species presence, distribution and abundance of macrophytes	1–3 years	Exploration through to decommissioning	High
	Data on the effects of increased sedimentation on plant growth and health	2–5 years	Exploration through to decommissioning	Moderate
Change in water quality Exposure to drill chemicals	Data on species presence, distribution and abundance of macrophytes	1–3 years	Exploration through to production	Moderate
	Data on the effects of contaminants on plant growth and health	2–5 years	Exploration through to production	Low

5.6 Marine and Anadromous Fish

5.6.1 Summary of Data Needs and Existing Data

5.6.1.1 Potential Effects

Table 5-21 lists the potential effects of hydrocarbon exploration and development on marine and anadromous fish.

Table 5-21 Potential Effects of Hydrocarbon Exploration and Development on Marine and Anadromous Fish

Potential Effect	Risk to Sustainability of Marine and Anadromous Fish [1]	Understanding of the Effect [2]	Ability to Mitigate with proven techniques	Ranking of potential effects
Underwater acoustic disturbance (vessel and seismic) (nearshore only)	1[1]	2	2	5
Underwater acoustic disturbance (vessel and seismic) (shelf and slope)	1[1]	2	2	5
Change in water quality	1	2	1	4

(sewage and drainage)				
Interference with traditional land and resource use	1[2] (No risk)	1	1 (None required)	3
Underwater acoustic disturbance (drilling rig, support vessels and aircraft) (nearshore only during periods of fish migration)	2	3	2	7
Underwater acoustic disturbance (drilling rig, support vessels and aircraft) (shelf and slope)	1	3	2	6
Seabed Disturbance (physical footprint, sediment re-suspension and physical smothering of fauna)	2[4]	3	3	8
Exposure of marine flora and fauna to drill chemicals (inner shelf)	1	2	1	4
Exposure of marine flora and fauna to drill chemicals (outer shelf and slope)	1	2	1	4
Coastal disturbance due to onshore support infrastructure, i.e., pipeline landfall	2[5]	2	2	6
Change in water quality (discharge of produced water , sewage and drainage)	1	2	1	4
Hydrocarbon or chemical spill	2[6]	2	2	6
Fire (fire fighting chemicals)	1	2	3	6

NOTES:
[1] Multiple seismic programs have potential to increase the physiological and behavioural effects on fish.
[2] As effect is expected to be positive with no risk to sustainability, interference with traditional land and resource use will not be continued through the remaining gap process.
[3] Nearshore areas only.
[4] Mainly related to spawning or over wintering areas.
[5] Potential to impact migrating fish, or over wintering, or spawning areas.
[6] Rating could be a three if spill occurs in spawning location at spawning time for some species.
Knowledge of fish fauna in deeper waters >100 m is poor and could affect ratings upwards.

5.6.1.2 Information Requirements

Table 5-22 lists the ranked information requirements for marine and anadromous fish.

Table 5-22 Information Requirements for Marine and Anadromous Fish

Ranking	Effect	Information Required to Enable Assessment of Effect
8	Seabed disturbance and sediment re-suspension (Exploration, Field Development and Decommissioning)	• Baseline data on fish over wintering areas • Baseline data on fish spawning areas and timing • Baseline data on fish species presence, distribution and abundance on the shelf • Baseline data on fish species presence, distribution and abundance on the slope • Data on effects of increased sedimentation on fish distribution and abundance • Data on the uptake and effects of contaminants related to sediment re-suspension on fish • Monitoring data for subsistence fisheries
7	Acoustic disturbance (shipping - nearshore only)	• Data on effects of acoustic noise on nearshore migrating fish (e.g., coregonids, Dolly Varden charr) • Baseline data on species presence, distribution and abundance in the nearshore • Baseline data on nearshore migrations of fish
6	Coastal disturbance (Field development and decommissioning)	• Baseline data on coastal fish over wintering areas • Baseline data on coastal fish spawning areas and timing • Baseline data on species presence, distribution and abundance in the nearshore • Data on nearshore migrations of fish • Monitoring data for subsistence fisheries
6	Hydrocarbon or chemical spill (Accidents and malfunctions)	• Baseline data on fish over wintering areas • Baseline data on fish spawning areas and timing • Baseline data on fish species presence, distribution and abundance on the shelf • Baseline data on fish species presence, distribution and abundance on the slope • Data on nearshore migrations of fish • Monitoring data for subsistence fisheries • Data on fish tainting and quality • Data on effects of contaminants on fish health
5	Acoustic disturbance (seismic)	• Baseline data on fish spawning areas and timing • Baseline data on species presence, distribution and abundance in the nearshore • Data on effects of seismic on nearshore migrating fish (e.g., coregonids, Dolly Varden charr) • Data on physiological effects of seismic on fish • Monitoring data for subsistence fisheries

5.6.1.3 Existing Information

Overview of Existing Data

Much of the fisheries-related research conducted in the Canadian Beaufort Sea has focused on nearshore or coastal areas (Bond 1982; Bond and Erickson 1989; Chang-Kue and Jessop 1992; Lawrence et al. 1984; Kendal et al. 1975; Percy 1975). With the exception of larval fish surveys, there has only been limited sampling along the shelf between 10 to 100m (Ratynski et al. 1988) and only a few occurrences of sampling at depth greater than 100m. Coad and Reist (2004) have compiled the occurrences of marine and anadromous fish in Canadian Arctic marine waters.

The outflow of the Mackenzie River allows for a narrow corridor of freshwater to form along the coast. This corridor is critical to migrating and feeding coregonids such as Arctic cisco (*Coregonus autumnalis*), least cisco (*C. sardinella*), broad whitefish (*C. nasus*), lake whitefish (*C. clupeaformis*) and inconnu (*Stenodus leucichthys*). Dolly Varden char (*Salvelinus malma*), which spawn in mountain rivers west of the Mackenzie River, also use this corridor for feeding. Other species utilizing nearshore areas include the fourhorn sculpin (*Myoxocephalus quadricornis*), arctic (*Liopsetta glacialis*) and starry (*Platichthys stellatas*) flounder, and saffron cod (*Eleginus gracilis*).

During winter, freshwater trapped in Mackenzie and Kugmallit bays and around the barrier Islands of the Mackenzie outer delta makes for a virtual freshwater lake and provides overwintering habitat for some coregonids and freshwater species. There has been a limited number of overwintering fish studies along the coast and embayments of the Beaufort Sea (Bond 1982; Chiperzak et al. 1991; Kendel et al. 1975; Lawrence et al. 1984; Percy 1975), with a low number of sampling sites provides a summary of overwintering studies in the delta and Beaufort Sea coast.

Chum salmon (*Oncorhynchus keta*) is the most common Pacific salmon found in the western Arctic and has spawning populations in the Mackenzie River drainage (Stephenson 2006). Four other species of Pacific salmon are captured periodically in communities bordering the Beaufort Sea and in the Mackenzie River and its tributaries. Although their frequency appears to be increasing, it is unclear whether this is a result of increased interest and effort in recording their appearance or a trend related to climate change (Stephenson 2006).

Along the shelf between 10 to 100 m depth, the two most common fish species captured include Arctic cod (*Boregogadus saida*) and Pacific herring (*Clupea harengus pallasi*) (Majewski et al 2006; North/South Consultants and KAVIK-AXYS Ltd. 2004). Other common groups of fish include sculpins and snailfish. Between the depths of 150 m and 240 m along the Beaufort shelf, Arctic Laboratories Ltd (1987) captured 13 species in six families using otter trawls. Arctic cod was the most common and abundant species captured. Arctic cod is considered a critical link in the Arctic marine food chain (Bradstreet et al. 1986).

Little is known about the fish fauna in the Atlantic water layer which occurs at depths of around 250 m to 1000 m. Only three species of fish have been captured to date in this layer: Greenland halibut (*Reinhardtius hippoglossoides*) (Chiperzak et al. 1995), thorny skate (*Raja radiata*) and three spot eelpout (*Lycodes rossi*) (Chiperzak unpublished data). The lack of knowledge of fish fauna at these depths is directly related to the limited sampling effort in this water layer.

A number of larval fish surveys have been conducted along the Beaufort Sea shelf and Tuktoyaktuk Harbour (Bradstreet et al. 1986; Chiperzak et al. 1990; Chiperzak et al. 2003a, b, c; Majewski et al. 2006, and Ratynski 1983). The three most commonly captured families of fish are the sculpins (Cottidae), cods (Gadidae) and snailfish (Liparidae) (DFO 2007).

There is limited information on spawning areas for marine fish. Pacific herring are known to spawn in Liverpool Bay and Tuktoyaktuk Harbour (Gillman and Kristofferson 1984), but they are also thought to spawn in other embayments along the Beaufort Sea coast. Capelins are known to spawn in Sachs Harbour on Banks Island (Usher 1965). Ripe Greenland cod have also been captured at the mouth of the Sachs River in Sachs Harbour (Chiperzak unpublished data).

Overview of Data from Previous Gap Analyses

The gap analysis related to development and transportation of oil and gas from the western Canadian Arctic and Alaska only referred to one fisheries research gap. This gap was the use of fish in nearshore areas during the ice-on period. Gaps identified through BREAM included fish tainting from hydrocarbons and heavy metals, as well as the effect on the harvest of broad whitefish and Arctic cisco due to development of nearshore production facilities. Gaps or research requirements identified through

BSStRPA included the identification of fish spawning and overwintering areas, species presence, distribution and abundance for offshore areas and the validation of old nearshore data.

Comparison of Existing Data with Previous Data Gap Analyses

Data gaps on fish usage during the ice-on period and of spawning areas still exist, as do gaps on fish information for offshore areas. Some validation of data has occurred and more validation is being conducted.

Recent and Ongoing Research

Fish surveys are currently being conducted (Majewski et al. 2006) as part of the DFO and Natural Resources Canada seabed and habitat mapping program being conducted from the research vessel the Nahidik. DFO is also replicating a study along the Yukon coast originally done by Bond and Erickson (1989). This new study will help validate past coastal fish presence and movements.

5.6.1.4 Identification of Data Gaps

Table 5-23 lists the identified data gaps for marine and anadromous fish.

Table 5-23 Existing Information and Identified Data Gaps for Marine and Anadromous Fish

Ranked Effect	Information Required to Enable Assessment of Effect	Existing Information and Recent/Ongoing Research	Quality of Existing Data	Data Gap
Seabed disturbance and sediment re-suspension	Baseline data on fish overwintering areas	Limited data for some coastal areas	Low	Baseline data on fish overwintering areas
	Baseline data on fish spawning areas and timing	No data	N/A	Baseline data on fish spawning areas and timing
	Baseline data on fish migrations	Data for coregonids and Dolly Varden char but limited to no data for marine species	High for coregonid species and Dolly Varden. Low for marine species	Baseline data on marine fish migrations
	Baseline data on fish species presence, distribution and abundance on the shelf (brackish/Mackenzie plume, benthic and pelagic)	Extensive coastal data but limited for remainder of shelf	High for coast and low for shelf	Baseline data on fish species presence, distribution and abundance on the shelf (benthic and pelagic)
	Baseline data on fish species presence, distribution and abundance on the slope (benthic and pelagic)	Limited data	Low	Baseline data on fish species presence, distribution and abundance on the slope
	Data on effects of increased sedimentation on fish distribution and abundance	Limited data	Low	Data on effects of increased sedimentation on fish distribution and

				abundance
	Data on the uptake and effects of contaminants related to sediment re-suspension on fish	Industry and government data available	Medium	Data on the uptake and effects of contaminants related to sediment re-suspension on fish
	Monitoring data for subsistence fisheries	Historic data	Medium	Re-start monitoring of subsistence fisheries
Underwater acoustic disturbance (drilling rig, support vessels and aircraft) (nearshore only during periods of fish migration)	Data on the effects of underwater acoustic disturbance on coregonid and Dolly Varden coastal migrations	Limited data, some data from Mackenzie River	Low	Data on the effects of underwater acoustic disturbance on coregonid and Dolly Varden coastal migrations
Underwater acoustic disturbance (drilling rig, support vessels and aircraft) (shelf and slope)	Data on the effects of underwater acoustic disturbance on marine fish (pelagic and benthic)	Data mainly from non-Arctic areas and mostly does not simulate normal operating conditions	Low	Data on the effects of underwater acoustic disturbance on marine fish (pelagic and benthic)
	Baseline data on fish spawning areas and timing	No data	N/A	Baseline data on fish spawning areas and timing
Coastal disturbance	Baseline data on coastal fish overwintering areas	Limited data for some coastal areas	Low	Baseline data on coastal fish overwintering areas
	Baseline data on coastal fish spawning areas and timing	No data (except pacific herring)	N/A	Baseline data on coastal fish spawning areas and timing
	Baseline data on species presence, distribution and abundance in the nearshore (brackish/Mackenzie plume, benthic and pelagic)	Recent nearshore data except NW Tuk Peninsula and validation study underway)	High	Validate data on species presence, distribution and abundance in the nearshore and fill gap for northern nearshore areas of Tuk Peninsula
	Data on nearshore migrations of fish	Nearshore data but 20 + years old and one validation study underway	Medium	Validate data on nearshore migrations of fish
	Monitoring data for subsistence fisheries	Historic data	Medium	Re-start monitoring of subsistence fisheries
Hydrocarbon or chemical spill	Baseline data on fish overwintering areas	Limited data	Low	Baseline data on fish overwintering areas
	Baseline data on fish spawning areas and timing	No data (except pacific herring)	N/A	Baseline data on fish spawning areas and timing
	Baseline data on species presence, distribution and abundance	Extensive coastal data but limited for remainder of shelf and slope	Low	Validate nearshore data and collect baseline data on species presence, distribution and abundance for outer shelf and slope

	Data on nearshore migrations of fish	Data but 20 years old but little on northern portion of Tuk Peninsula	Medium	Validate data on nearshore migrations of fish and collect data on northern portion of Tuk Peninsula coastline
	Data on migrations of marine fish nearshore and offshore	No data, except limited data for Pacific herring	Low	Data on marine fish migration for nearshore and offshore areas
	Monitoring data for subsistence fisheries	Data from harvest study but study is discontinued	Medium	Re-start monitoring of subsistence fisheries
	Data on fish tainting and quality	Older data exists	Low	Tainting data only required after spill Fish quality baseline data is lacking
	Data on effects of contaminants on fish health	Data on subsistent harvested species but little on marine species	Low	Data on effects of contaminants on fish health
	Data on uptake and transfer of contaminants in fish	Data on relatively few species	Low	Data on uptake and transfer of contaminants in fish

5.6.2 Final Prioritization of Research Requirements

Table 5-24 Research Requirement Prioritization for Marine and Anadromous Fish

Ranked Effect	Data Gap	Time to Obtain Data	When in the Development Process is the Data Required	Relative Overall Ranking
Seabed disturbance and sediment re-suspension	Baseline data on fish overwintering areas (nearshore areas and bays only)	3–5 years	Exploration Drilling, Field Development & decommissioning	High
	Baseline data on fish spawning areas and timing	3–5 years	Exploration Drilling, Field Development & decommissioning	High
	Baseline data on fish species presence, distribution and abundance on the deepwater shelf and slope	3–5 years	Exploration Drilling, Field Development & decommissioning	High
	Data on effects of increased sedimentation on fish distribution and abundance	3–5 years	Exploration Drilling, Field Development & decommissioning	Moderate
	Data on the uptake and effects of contaminants related to sediment re-suspension on fish	2–3 years	Exploration Drilling, Field Development & decommissioning	Moderate
	Restart monitoring data	Immediate	Exploration Drilling,	High

	of subsistent fisheries		Field Development & decommissioning	
Underwater acoustic disturbance (drilling rig, support vessels and aircraft) (nearshore only during periods of fish migration)	Data on the effects of underwater acoustic disturbance on coregonid and Dolly Varden coastal migrations	2–3 years	All phases	Moderate
Underwater acoustic disturbance (drilling rig, support vessels and aircraft) (shelf and slope)	Data on the effects of underwater acoustic disturbance on marine fish (pelagic and benthic)	3–5 years	Seismic	Moderate
Coastal disturbance	Baseline data on sensitive coastal fish habitat (i.e., overwintering areas, spawning areas and timing)	3–5 years	Field development and decommissioning	High
	Validate data on coastal species presence, distribution and abundance and collect data for northern Tuk Peninsula	2–3 years	Field development and decommissioning	Moderate
	Validate data on nearshore migrations of fish	2–3 years	Field development and decommissioning	Moderate
	Monitoring data for subsistent fisheries	Immediate	Field development and decommissioning	High
Hydrocarbon or chemical spill	Baseline data on fish overwintering areas	3–5 years	Exploration and Production	Moderate
	Baseline data on fish spawning areas and timing	3–5 years	Exploration and Production	High
	Validate nearshore data and collect baseline data on species presence, distribution and abundance for outer shelf and slope	2–5 years	Exploration and Production	Moderate
	Validate data on nearshore migrations of fish and collect data on northern portion of Tuk Peninsula coastline	1–3 years	Exploration and Production	Moderate
	Data on marine fish migration for nearshore and offshore areas	3–5 years	Exploration and Production	Low
	Re-start monitoring of subsistent fisheries	Immediate	Exploration and Production	High
	Data on fish tainting and quality	1–3 years	Exploration and Production	Moderate
	Data on effects of	1–2 years	Exploration and	Moderate

	contaminants on fish health		Production	
	Data on uptake and transfer of contaminants in fish	3–5 years	Exploration and Production	Moderate

5.7 Marine Mammals

Common marine mammals found in the Beaufort Sea span four taxonomic sub-orders: toothed whales, baleen whales, seals and polar bears, all of which possess notable life history differences. For this reason, the following analysis focused on three categories: i) toothed and baleen whales (whales); ii) seals; and iii) polar bears.

5.7.1 Summary of Data Needs and Existing Data

5.7.1.1 Potential Effects

Tables 5-25 to 5-27 list the potential effects of hydrocarbon exploration and development on marine mammals. Each effect is ranked based on the three criteria: (1) risk to sustainability; (2) level of understanding of the effect; and (3) ability to mitigate with proven techniques.

Table 5-25 Potential Effects of Hydrocarbon Exploration and Development on Whales

Potential Effect	Risk to Sustainability of Whales	Understanding of the Effect	Ability to Mitigate with proven techniques	Ranking of potential effects
Seismic Survey				
Underwater acoustic disturbance (vessel and seismic)	2	1 [1]	1	4
Discharge of Effluent(sewage, drainage)	1	1	1	3
Physical Presence of Equipment (seismic vessel and equipment)	1	1	1	3
Aircraft Use and Support	1	1 [2]	1	3
Exploration Drilling (including delineation)				
Underwater Acoustic Disturbances (drilling rig, support vessels)	1 [ŧ]	1 [3]	2	4
Discharge of Effluent(sewage, drainage, rig wash)	1	1	1	3
Discharge of Drilling Wastes (muds, cuttings)	1	1	1	3
Light (presence and illumination)	1	1	1	3
Physical Presence of Equipment (drill platforms)	2	1	3	6
Aircraft Use and support	1	1	1	3

Field Development				
Underwater Acoustic Disturbances (vessels and drill rigs)	1[ŧ]	1	2	4
Discharge of Effluent(sewage and drainage)	1	1	1	3
Discharge of Drilling Wastes (muds, cuttings and water)	1	1	1	3
Light (presence and illumination)	1	1	1	3
Physical Presence of Equipment (drill rigs, support vessels, other equipment)	1[ŧ]	1	3	5
Dredging	1	1	1	3
Aircraft Use and Support	1	1	1	3
Production				
Underwater Acoustic Disturbances (production platform/rig and support vessels)	1[ŧ]	1	2	4
Discharge of Effluent(sewage, drainage)	1	1	1	3
Light (presence and illumination)	1	1	1	3
Physical Presence of Equipment	1[ŧ]	1	2	4
Decommissioning				
Underwater Acoustic Disturbances (vessels and aircraft)	1[ŧ]	1	1	3
Discharge of Effluent(sewage and drainage)	1	1	1	3
Light (presence and illumination)	1	1	1	3
Physical Presence of Equipment	1[ŧ]	1	1	3
Accidents and Malfunctions				
Hydrocarbon or chemical spill	1	1[4]	1	3

NOTE:
[ŧ] Specific location and habitat value dependant

SOURCES:
[1] Clark and Johnson 1984; Richardson and Fraker 1985; Richardson et al. 1986; Cummings and Holliday 1987; Greene 1988; Ljungblad et al. 1988; Richardson et al. 1999; Southall 2008.
[2] Patenaude et al. 2002; Efroymson 2000.

[3] Davis et al. 1987; Richardson et al. 1990a; Richardson et al. 1990b.
[4] St. Aubin et al. 1984; Birtwell and McAllister 2002.

Table 5-26 Potential Effects of Hydrocarbon Exploration and Development on Seals

Potential Effect	Risk to Sustainability of Seals	Understanding of the Effect	Ability to Mitigate with proven techniques	Ranking of potential effects
Seismic Survey				
Underwater acoustic disturbance (vessel and seismic)	1	1 [1]	1	3
Discharge of Effluent(sewage, drainage)	1	1	1	3
Physical Presence of Equipment (seismic vessel and equipment)	1	1	1	3
Aircraft Use and Support	1	1 [2]	1	3
Exploration Drilling (including delineation)				
Underwater Acoustic Disturbances (drilling rig, support vessels)	2*	1	2	5
Discharge of Effluent(sewage, drainage, rig wash)	1	1	1	3
Discharge of Drilling Wastes (muds, cuttings)	1	1	1	3
Light (presence and illumination)	1	1	1	3
Physical Presence of Equipment (drill platforms)	1	1	3	5
Aircraft Use and support	1	1	1	3
Ice Platforms and Roads	2	1	1	4
Field Development				
Underwater Acoustic Disturbances (vessels and drill rigs)	1	1	1	3
Discharge of Effluent(sewage and drainage)	1	1	1	3
Discharge of Drilling Wastes (muds, cuttings and water)	1	1	1	3
Coastal disturbance due to onshore support infrastructure (i.e., pipeline landfall)	1	1	1	3
Light (presence and illumination)	1	1	1	3

Field Development				
Physical Presence of Equipment (drill rigs, support vessels, other equipment)	2	1	3	6
Dredging	1	1	1	3
Aircraft Use and Support	1	1	1	3
Ice Platforms and Roads	2	1	1	4
Production				
Underwater Acoustic Disturbances (production platform/rig and support vessels)	1	1	1	3
Discharge of Effluent(sewage, drainage)	1	1	1	3
Aerial Emissions (support vessel and production platform/rig)	1	1	1	3
Light (presence and illumination)	1	1	1	3
Physical Presence of Equipment	1	1	3	5
Ice Platforms and Roads	2	1	1	4
Decommissioning				
Underwater Acoustic Disturbances (vessels and aircraft)	1	1	1	3
Discharge of Effluent(sewage and drainage)	1	1	1	3
Coastal disturbance due to removal of coastal support infrastructure i.e., pipeline landfalls	1	1	1	3
Light (presence and illumination)	1	1	1	3
Physical Presence of Equipment	1	1	3	5
Ice Platforms and Roads	1	1	2	4
Accidents and Malfunctions				
Hydrocarbon or chemical spill	2	1[3]	3[ŧ]	6

NOTES:
*Location dependant.
[ŧ] Ice dependant.

SOURCES:
[1] Terhune and Ronald 1975; Kastak and Schusterman 1998; Kastak et al. 2005; Southall 2008.
[2] Efroymson 2000.
[3] Becker 2000; Peterson 2001; Barron et al. 2003.

Table 5-27 Potential Effects of Hydrocarbon Exploration and Development on Polar Bears

Potential Effect	Risk to Sustainability of Marine Mammals	Understanding of the Effect	Ability to Mitigate with proven techniques	Ranking of potential effects
Seismic Survey				
Underwater acoustic disturbance (vessel and seismic)	1	2 [1]	1	4
Discharge of Effluent(sewage, drainage)	1	1	1	3
Physical Presence of Equipment (seismic vessel and equipment)	1	1	1	3
Aircraft Use and Support	1	1	1	3
Exploration Drilling (including delineation)				
Underwater Acoustic Disturbances (drilling rig, support vessels)	1	2	1	4
Discharge of Effluent(sewage, drainage, rig wash)	1	1	1	3
Discharge of Drilling Wastes (muds, cuttings)	1	1	1	3
Light (presence and illumination)	1	1	1	3
Physical Presence of Equipment (drill platforms)	2	1	2	5
Aircraft Use and support	1	1	1	3
Ice Platforms and Roads	1	1	3	5
Field Development				
Underwater Acoustic Disturbances (vessels and drill rigs)	1	2	1	4
Discharge of Effluent(sewage and drainage)	1	1	1	3
Discharge of Drilling Wastes (muds, cuttings and water)	1	1	1	3
Coastal disturbance due to onshore support infrastructure (i.e., pipeline landfall)	2	1	2	5
Light (presence and illumination)	1	1	1	3
Physical Presence of Equipment (drill rigs, support vessels, other equipment)	2	1	3	6

Dredging	1	1	1	3
Aircraft Use and Support	1	1	1	3
Ice Platforms and Roads	2	1	3	6
Production				
Underwater Acoustic Disturbances (production platform/rig and support vessels)	1	2	1	4
Discharge of Effluent(sewage, drainage)	1	1	1	3
Aerial Emissions (support vessel and production platform/rig)	1	1	1	3
Light (presence and illumination)	1	1	1	3
Physical Presence of Equipment	2	1	3	6
Ice Platforms and Roads	2	1	3	6
Decommissioning				
Underwater Acoustic Disturbances (vessels and aircraft)	1	2	1	4
Discharge of Effluent(sewage and drainage)	1	1	1	3
Coastal disturbance due to removal of coastal support infrastructure i.e., pipeline landfalls	2	1	2	5
Light (presence and illumination)	1	1	1	3
Physical Presence of Equipment	1	1	3	5
Ice Platforms and Roads	1	1	3	5
Accidents and Malfunctions				
Hydrocarbon or chemical spill	2	2 [2]	3	7

SOURCES:
[1] Blix and Lentfer 1992; Nachtigall et al 2007.
[2] Stirling 1990; St. Aubin 1990; Øritsland et al. 1981.

5.7.1.2 Information Requirements

Table 5-28 lists the ranked information requirements for whales. Tables 5-28 to 5-30 provide a framework for listing information needs.

Table 5-28 Information Requirements for Whales

Ranking	Effect	Information Required to Enable Assessment of Effect
6	Physical Presence of Equipment (drill platforms, drill rigs, support vessels, other equipment)	• Timing of use of habitat • Spatial use of habitat • Magnitude and location of development • Behavioural effects (short and long-term) • Knowledge of/effectiveness of mitigation • Physical processes affecting ecology
4	Underwater acoustic disturbance (vessel & seismic, drilling rig, support vessels, production platform/rig)	• Physiological effects (short and long-term) • Behavioural (short and long-term) effects • Ecological effects (i.e., prey) • Timing of use of habitat • Spatial use of habitat • Physical properties of environment • Knowledge of/effectiveness of mitigation

Table 5-29 Information Requirements for Seals

Ranking	Effect	Information Required to Enable Assessment of Effect
6	Hydrocarbon or chemical spill	• Timing of use of habitat • Spatial use of habitat • Physiological effects (short and long-term) • Ecological effects (i.e., prey) • Knowledge of/effectiveness of mitigation
5	Underwater Acoustic Disturbances (seismic, drilling rig, support vessels)	• Timing of use of habitat • Spatial use of habitat • Magnitude and location of development • Behavioural effects (short and long-term) • Ecological effects (i.e., prey) • Knowledge of/effectiveness of mitigation
5	Ice platforms and Roads	• Timing of use of habitat • Spatial use of habitat • Magnitude and location of development • Behavioural effects (short and long-term) • Knowledge of/effectiveness of mitigation

Table 5-30 Information Requirements for Polar Bears

Ranked Effect	Effect	Information Required to Enable Assessment of Effect
7	Hydrocarbon or chemical spill	• Timing of use of habitat • Spatial use of habitat • Physiological effects (short and long-term) • Behavioural effects (short-term) • Ecological effects (i.e., prey) • Knowledge of/effectivness of mitigation
6	Physical Presence of Equipment (drill platforms, drill rigs)	• Timing of use of habitat • Spatial use of habitat • Magnitude and location of development • Behavioural effects (short and long-term) • Knowledge of/effectivness of mitigation

		• Physical processes affecting ecology
6	Ice Platforms and Roads	• Timing of use of habitat • Spatial use of habitat • Magnitude and location of development • Behavioural effects (short and long-term) • Knowledge of/effectivness of mitigation
5	Coastal Disturbance (on shore support)	• Timing of use of habitat • Spatial use of habitat • Magnitude and location of development • Behavioural effects (short and long-term) • Knowledge of/effectivness of mitigation
5	Underwater Acoustic Disturbance (seismic, drilling, production)	• Timing of use of habitat • Spatial use of habitat • Magnitude and location of development • Behavioural effects (short and long-term) • Ecological effects (i.e., prey) • Knowledge of/effectivness of mitigation (drilling/production)

5.7.1.3 Existing Information

Overview of Existing Data

Beluga Whale – Eastern Beaufort Sea Population

Belugas have a northern circumpolar distribution that ranges south into the subarctic (COSEWIC 2004).The Eastern Beaufort Sea stock is one of five stocks that makeup the Bering-Chukchi-Beaufort Sea population. This population represents one of the largest of seven populations in Canada (Fisheries Joint Management Committee 2001), with conservative population estimates of 39,258 individuals (Angliss and Lodge 2004).

The Beaufort Sea beluga whale (*Delphinapterus leucas*) has been designated as 'Not at Risk' nationally (COSEWIC 2004) and 'Secure' in the NWT (Government of the Northwest Territories 2000 Internet site);it is not presently listed under *SARA*.. Guidelines for managing belugas in the Canadian Western Arctic have been developed under the Beaufort Sea Beluga Management Plan (Fisheries Joint Management Committee 2001) and the Inuvialuit Inupiat Beluga Whale Agreement (2000). The population appears to be stable or increasing based on the continued presence of large and old individuals and the lack of change in the age and size structure of the harvest in recent years (Angliss et al. 2001; Harwood et al. 2002).

Potential development around the MacKenzie Delta and increasing interest in offshore oil and gas development in the Beaufort sea have provided a catalyst for research into beluga movement patterns (Harwood and Ford 1983; Richard et al. 2001; LGL Limited and Canning & Pitt Associates Inc. 2007) and seasonal concentrations (Harwood et al. 1996; DFO 2000a); however, critical habitat has not yet been defined for this population (COSEWIC 2004). Information on seasonal distribution and habitat use in coastal regions of the Beaufort Sea has been fairly well documented over the past two decades through satellite tagging programs, aerial or ship-based surveys, monitoring programs, and analysis of subsistence harvesting records Island (Fraker and F.F.S.C. Limited 1978; Fraker et al. 1979; Harwood and Smith 2002). Beluga use of the deepwater off-shore Beaufort Sea is less understood and constitutes a notable data gap.

Life history patterns of beluga whales are also well documented. Stomach analysis has provided information on typical prey items (Fraker and F.F.S.C. Limited 1978; DFO 2000a; Percy 1975; Lawrence et al. 1984; Orr and Harwood 1998), and surveys have identified preferred foraging habitat (Fraker and F.F.S.C. Limited 1978; Fraker et al. 1979; Richard et al. 2001) and calving locations (Norton and Harwood 1986; Harwood and Smith 2002). Life history data on this beluga whale population suggests that its age–size characteristics have not changed since 1980 (Harwood et al. 2002). This is further supported by the fact that whales harvested through subsistence hunting are typically older individuals, a trend that is characteristic of a lightly harvested and healthy population that is being minimally affected by current harvesting levels (DFO 2000a).

With respect to seismic exploration, studies conducted by LGL Limited for Anderson Exploration (now Devon Canada) indicated that beluga whales avoided an active seismic vessel at distances of up to 20 km (Miller and Davis 2002).

Behavioural audiograms indicate that beluga hearing extends from about 80 to 150 kHz to at least as low as 40 to 75 Hz. The majority of construction noise is below 1 kHz (Richardson and Malme 1995) and, therefore, may not preclude prey detection and communication. However, in past studies, belugas have been known to perceive composite underwater industrial sounds such as dredging, tug and crew vessel support at 2.9 km, occasional transient noises, pipe couplings at 4.0 km (Ford 1977), and tug-barge tow noise at a range of 3.3 km (Fraker et al. 1978). Most of these noises overlap with beluga communication sounds, which range up to about 2000 Hz (400 Hz to 12 kHz for social signals; 100 Hz to 75 kHz for orientation), but not with beluga echolocation, which is primarily above 5000 Hz (from 2000 to 75000 Hz).

Currently, there is no evidence to suggest that vessel activity and human-induced underwater noise, such as that emitted by vessels and dredging activity, is affecting trends in beluga populations in the Beaufort Sea. However, there is potential that these activities could have an effect on their behaviour in the future.

Bowhead Whale – Bering-Chukchi-Beaufort Population

The global bowhead population is divided into five stocks, the largest of which is the western Arctic population, comprising about 90% of the world's bowheads (Joint Secretariat 2000). This population is considered 'Endangered' by the *U.S. Endangered Species Act* (United States Fish and Wildlife Service 2007, Internet site), and classified as a strategic stock by the U.S. National Marine Fisheries Service (Angliss et al. 2001). The Bering-Chukchi-Beaufort population of Bowhead whales in Canadian waters is currently designated as a species of Special Concern by COSEWIC (2005) and listed as endangered on Schedule 2 of *SARA (*and currently pending public consultation for addition to Schedule 1) (Environment Canada 2006 Internet site). Owing to its endangered status sand economic and cultural value to northern communities, this bowhead whale population has been the focus of numerous research programs to identify habitat use, life history characteristics, and population dynamics.

The Bering-Chukchi-Beaufort population is most recently estimated to range between 8,100 to 13,500 individuals and is increasing at a rate of about 3.4% per year (George et al. 2004). Historical whaling records, traditional local knowledge and annual subsistence harvest records provide additional information for estimates of abundance and population trends over the past century (Marquette and Bockstoce 1980; Raddi and Weeks 1985; Reeves and Mitchell 1985; Zellen 1992; Stoker and Krupnik 1993; Woodby and Bodkin 1993; Shelden and Rugh 1995; Smith 1996; Raftery and Zeh 1998; NWMB 2000; Tassugat 2001).

The seasonal range of the western Arctic population extends from its wintering area in the Bering Sea to its summering area in the Amundsen Gulf and Beaufort Sea. Migration routes and seasonal concentration areas have been well documented through satellite tagging programs, aerial surveys, and ship-based monitoring (Marquette et al. 1982; Ljungblad et al. 1986; Richardson et al. 1987; Rugh 1990; Moore and Reeves 1993; Mate and Krutzikowsky 1995; Mate et al. 2000; Moore et al. 2000; Schick and Urban 2000). Mark recapture studies using photo identification have provided data on habitat use, migration patterns and population structure (Davis et al. 1986; Rugh 1990; Rugh et al. 1992a; Rugh et al. 1992b).

During their summering period, the population's distribution is thought to be correlated with zooplankton concentrations, as bowheads filter copepods and other small crustaceans from the water, (Ford et al. 1987, BEMP 1987-1988) and much of their food intake for the entire year is thought to occur during this time (Beaufort Environmental Management Program 1987).

At present, offshore industrial activities east of Nuiqust and Cross Island must cease when the bowhead hunt begins in early September (KAVIK-AXYS and LGL 2001). There is concern that industrial activity or presence may disturb the migrating whales causing them to travel further offshore where they would be inaccessible to subsistence hunters. Most available information on effects of oil and gas activities on bowheads has centred on acoustic disturbance from seismic activities (Richardson et al. 1986; Wartzok et al. 1989; Richardson et al. 1990a; Richardson et al. 1990b; Richardson et al. 1999) and their effect on habitat usage (Richardson et al. 1987; Schick and Urban 2000).

Sightings of Grey Whales (*Eschrichtius robustus*) have been recorded within the Canadian Beaufort Sea. However, they are not considered a regular visitor and are therefore not considered further within this report.

Ringed Seal

The ringed seal is the most widespread and abundant (marine mammal in the circumpolar Arctic (Stirling and Oritsland 1995), and serves as an important element in the marine ecosystem. It constitutes the major prey species for the polar bear, is a major consumer of marine fish and invertebrates, and is an important food source in the local subsistence economies (Smith 1987).

Although there is some information available on seasonal habitat use by ringed seals in the Beaufort Sea, movement patterns during the open water season are poorly understood. During summer, ringed seals are dispersed throughout open water, although in some regions they move into coastal areas. In the eastern Beaufort Sea and Amundsen Gulf, ringed seals concentrate in similar offshore areas from one year to the next, often in large groups (Harwood and Stirling 1992).

Winter habitat is better understood as ringed seals occupy landfast ice and offshore pack ice (Smith 1975; Smith and Hammill 1981; Harwood and Stirling 1992). Because of the relatively small amount of landfast ice in the southeastern Beaufort Sea compared to the large amounts of offshore pack ice, the numbers of ringed seals on the offshore pack ice may exceed the numbers on the fast ice. Concentrations on moulting habitat appear to be found in areas of greater food abundance and may be related to oceanographic features. Similar summer concentrations have not been reported in nearshore waters of the central and western Beaufort Sea.

Seals inhabiting the landfast ice of western Alaska migrate through the Bering Strait as they follow the receding pack ice northward in spring, then move ahead of the advancing ice in autumn (Reeves 1998). Some ringed seals from the eastern Beaufort Sea move westward to the Chukotka Peninsula (Smith 1987). Smith and Stirling (1978) suggested that there is a westward movement of seals out of Amundsen Gulf in late summer when many young-of-the-year move west past Cape Bathurst and Herschel Island. Recent information gathered from satellite tags deployed on four sub-adult ringed seals in Amundsen Gulf supports this suggestion (Harwood, pers. comm, 2008).

Ringed seals give birth in subnivean lairs, in both inshore and offshore areas, to a single pup between March and early April (Smith 1975; Kingsley 1990). Mating occurs in late April and May toward the end of the lactation period (Smith 1975, 1987).

Ringed seals are most vulnerable to human influences when they are restricted to ice and land as pups. During this time, they are susceptible to oil spills, hunting, and disturbance such as ice breakers. Ringed seals hauled-out on pack ice have been observed reacting to icebreaker activity by diving into the water when ships are within 0.93 km. They appeared to be less sensitive when ships are underway in open water (Brueggeman et al. 1992).

There is evidence to suggest that on-ice seismic exploration using Vibroseis has some localized effects on ringed seal distribution. Specifically, seal holes less than 150 m from seismic lines were more likely to be abandoned than holes farther away. However, effects on distribution and numbers appear to be minimal (Richardson and Malme 1995). Little detailed data on the reactions of seals to noise from seismic exploration in open water is available (Richardson and Malme 1995).

Bearded Seal

Little information is available on the Bearded seal in the Beaufort Sea region. They are large and solitary and found at low densities throughout their range in the Canadian Beaufort Sea. Seasonal movements of bearded seals are directly related to the advance and retreat of sea ice and water depth. Due to their limited capability to maintain breathing holes in fast ice, they prefer areas of shifting ice and shallow water. Their numbers in the Beaufort Sea are reduced in winter as they migrate to the Bering Sea. From mid-April to June as the sea ice recedes, some of the bearded seals that overwinter in the Bering Sea migrate northward through the Bering Strait and into the Beaufort Sea. Nonetheless, a population of unknown size overwinters in the moving pack ice of the Beaufort Sea (Stirling et al. 1975).

Pupping occurs in late April and early May. Pups are born on the ice and are capable of entering the water shortly after birth. The bearded seal is primarily a bottom feeder and is most abundant where it can feed in water depths of less than 200 m. Its diet comprises a wide variety of benthic invertebrates and demersal fish (Burns 1967; Burns and Frost 1979; Lowry et al. 1980; Finley and Evans 1983).

Polar Bear

The polar bear is listed as a species of ‘Special Concern’ by COSEWIC (2008) and is not scheduled under *SARA*. In Canada, 13 polar bear populations are recognized: two are increasing in number, five are stable, five are decreasing and one has insufficient data to determine a status (PBSG 2006). In the Beaufort Sea, two populations of polar bears are recognized: southern and northern Beaufort Sea. Recent evidence (Regher et al. 2006) suggests recruitment and body size of southern Beaufort polar bears is declining (present population estimate of 1526). Northern Beaufort Sea polar bears appear to be stable in number (present population estimate of 980; Stirling et al. 2007).

The life cycle of the polar bear revolves around the sea ice that is home to their dietary mainstay, the ringed seal and, to a lesser extent, the bearded seal. Consequently, polar bear distribution roughly mirrors that of ringed and bearded seal distribution (e.g., leads, polynyas). Their preferred habitat is the annual ice over the relatively shallow waters of the continental shelf and inter-island archipelago channels; which tend to be more productive than deeper water areas (Fischbach et al. 2007). With regards to the southern Beaufort population, it appears that a shift of pack ice over much of the Beaufort Sea, a longer open-water season and sea ice being farther offshore are correlated with the decline in recruitment alluded to earlier (Stirling et al. 2007). With regards to northern Beaufort polar bears, at least some sea ice remains over continental waters (west coast of Banks Island, McClure Strait); thus bears still have access to ice (Stirling et al. 2007).

Pregnant polar bears establish maternal snow dens in autumn or early winter, give birth in mid-winter, and nurture their young until they are able to leave the security of the den. Throughout most of their range, polar bears den mainly on land (as cited in Fischbach et al. 2007). In the northern Beaufort, this trend is supported by evidence of dens on the west coast of Banks Island; however, in the southern Beaufort (and particularly along the Canadian mainland and nearby islands), this trend is less clear; as satellite telemetry and Inuvialuit knowledge indicate denning in off-shore ice (Stirling and Andriashek 1992; Stirling 2002). Authors of these findings (Stirling and Andriashek 1992; Stirling 2002) suggest two hypotheses associated with the lack of land-based dens on the Canadian mainland: i) the connection, or lack thereof, of ice between off-shore pack ice and land as a controlling factor; and, ii) over harvesting of pregnant females in this region (Stirling 2002). Recently, Fischbach et al. (2007) have concluded that in Alaska, landward shift of polar bear denning is consistent with recent losses of stable sea ice and delays in autumn freeze-up. Implications of such changes include a potential increase in terrestrial denning and the possible prevention of pregnant bears foraging offshore from reaching the coast in advance of autumn den entry (Fischbach et al 2007; Amstrup et al. 2007). A further theory regarding land denning by southern Beaufort polar bears comes from Durner et al. (2006) who postulate that availability of denning habitat is greater in Alaska than in Canada.

Climate warming is predicted to become a major environmental factor in polar bear distribution, due to increases in the amount of open water and earlier ice breakup (Stirling 2002). Polar bears are entirely dependent on sea ice as a platform to travel and hunt such that changes to its distribution, characteristics and timing have the potential to have profound effects on the survival and reproductive success of polar bears (Amstrup 2003; Stirling et al. 2007). There is a highly significant relationship between break-up of the sea ice and the condition of bears when they come ashore; earlier sea ice break-up causes bears to be in poorer condition by shortening their critical feeding period, thus reducing the amount of fat they are able store and fast upon during the four month open water period (Stirling et al. 2007). This deterioration of physical condition may trigger a cascade of impacts such as lowered reproductive and survival rates, and a decline in total population size (Regehr et al. 2007). Observations of drowned, emaciated and cannibalized polar bears have already been reported in the Southern Beaufort Sea region (Regehr et al. 2007). Furthermore, changes in sea ice will likely alter seal distributions which will, in turn, result in changes in the distribution of polar bears. Derocher et al. (2004) predict these changes in sea ice will act to reduce the abundance and availability of seals, the bears' main prey, further exacerbating nutritional stress.

Additionally, as sea ice thins, it is likely to move more quickly in response to winds and currents so that polar bears will need to walk or swim more (and thus use greater amounts of energy) to maintain contact with their preferred habitats (Derocher et al. 2004). Depletion of energy stores has implications for polar bear demographics as it may result in the production of fewer cubs (more single litters) and smaller cubs with lower survival rates, as well as in the reduction of the proportion of pregnant females that are able to initiate denning (Derocher et al. 2004). Because of the suite of potential adverse effects on polar bears and their habitat, climate change should be taken into account when determining the stability of these populations in the future; however, it is worth noting that the effects of climate change are likely to show large geographic, temporal and even individual differences and be highly variable, making it difficult to develop adequate monitoring and research programs (Derocher et al. 2004)

Increased polar bear–human interactions were predicted as a result of climate warming (Stirling and Derocher 1993). A study by Amstrup (1993) on the north-eastern Alaskan coast demonstrated that bears have substantial tolerance for human activities such as capture and handling and aircraft overflights. However, denning polar bears are sensitive to disturbance and may abandon their dens if the annoyance is prolonged (Blix and Lentfer 1992). Petroleum exploration and development are occurring in various locations in the Arctic, where there are important denning sites for polar bears, and these activities usually involve winter operations, which coincide with the period when bears use dens (Blix and Lentfer 1992). Although dry and wind-beaten Arctic snow muffles both sound and vibrations extremely well (Blix and Lentfer 1992), polar bears were found to show sensitive hearing over a wide frequency range, which prompts the need to operate with caution (Nachtigall et al. 2007). The loss of a single den site following human disturbance will not always lead to deleterious effects, particularly if alternative denning areas are available within the home range; however, disturbance during the winter could cause pregnant females or females with young to abandon their dens resulting in death (Linnell et al. 2000).

Overview of Data from Previous Gap Analyses

Previous gap analyses prepared for the Beaufort Sea Region have identified gaps in the knowledge base that typically focus on behavioural effects of underwater noise and ecological parameters such as distribution, movement patterns, and identification of critical habitat. A review of gap analyses, proponent and government reports has highlighted the following gaps in the current knowledge of marine mammal species and their ecology as they relate to offshore oil and gas exploration activities.

- thresholds for tolerance of acoustic activity associated with seismic exploration - Beluga (KAVIK-AXYS 2002)
- physiological effects of seismic activity (research on captive animals) - Beluga (KAVIK-AXYS 2002)
- improve understanding of movements, distribution, and population numbers (satellite tagging programs)
- improve understanding of sound transmission and attenuation at various depths and in various waters to estimate the zone of influence
- develop a better understanding of the effect of vessel traffic on whale movement - Beluga (KAVIK-AXYS 2002)
- identify highly suitable (critical) habitat
- identify sensitive and highly productive habitat (Beaufort Sea Strategic Regional Plan of Action Steering Committee 2007)
- develop a better understanding of the effect of climate change on sea ice and its subsequent effects on populations - Ringed seal (KAVIK-AXYS 2002)
- better understand the role of climate change and effects on distribution patterns, prey availability, predator population change (KAVIK-AXYS 2002)
- separate and identify the effects of climate change from those of development (through long-term monitoring) - Polar bear (KAVIK-AXYS 2002)
- lack of long-term research into the basic physical and biological processes of the northern environment (Beaufort Sea Hydrocarbon Production and transportation 1984)
- lack of baseline data upon which effective monitoring and mitigation programs can be developed (Beaufort Sea Hydrocarbon Production and transportation 1984)

Comparison of Existing Data with Previous Data Gap Analyses

Progress in nearly all the previously identified research gaps has been made, though in some cases our understanding is far from complete. Little information exists on the effects of climate change on marine mammal distribution and ecology. Effects of acoustic energy on marine mammals is a widespread topic and, consequently, receives much attention in the scientific literature; hence indirect (but relevant) knowledge from similar species groups can be brought to bear on Beaufort species. Advances on the understanding of captive beluga hearing/vocalizations and acoustic monitoring in Alaska on migrating bowheads, has also partially addressed knowledge gaps specific to potential affects to hearing (injury and behavioural avoidance). Recent instrumentation of marine mammals with satellite tags has done much to fill knowledge gaps pertaining to species ranges and habitat use.

Recent and Ongoing Research

A notable amount of recent and current research is helping to close the data gaps relating to effects of development on marine mammals in the Canadian and Western Beaufort; specific recent and ongoing research efforts include:

Bowhead Whale

Department of Fisheries and Oceans

- aerial surveys of Canadian Beaufort 2007 to 2009
- to update data collected in early 1980s on bowhead habitat use, feeding areas, migration routes (L. Harwood)
- satellite tagging of bowheads 2007 to 2009
- identify patterns, variability in timing and locations of bowhead feeding in the Canadian Beaufort (L. Harwood)

Alaska Department of Fish and Game

- satellite tracking of Western Arctic Bowhead 2006 to 2007
- evaluate long-term cumulative effects of oil and gas exploration activities on the bowhead migration corridor

NOAA – National Marine Mammal Laboratory – Cetacean Assessment & Ecology Program

- Bowhead Whale Aerial Survey Program (BWASP)
- evaluate long-term cumulative effects of oil and gas exploration activities on the bowhead migration corridor
- ensure that subsistence needs are met, exploration activities do not cause whales to abandon or avoid hunting areas
- Bowhead Foraging Ecology
- identify patterns, variability in timing and locations of bowhead feeding in the Western Beaufort
- estimate temporal and spatial patterns of habitat use
- document prey distribution
- fine scale oceanographic and environmental conditions
- bowhead abundance, trends, and life history
- genetic analysis, photo identification, satellite tagging to refine knowledge of stock structure
- acoustic monitoring of year-round presence–absence

Beluga Whale

Department of Fisheries and Oceans

- aerial surveys of Canadian Beaufort, 2007 to 2009
- satellite tagging of belugas, 2004 to 2005 (Prichard)

- identify patterns, variability in timing and locations of belugas in the Canadian Beaufort

NOAA - National Marine Fisheries Service

- Satellite Tracking Point Lay (Western Beaufort) Beluga Whales 1998 to 2007

Ringed Seal

Department of Fisheries and Oceans

- satellite tagging (open water period)
- identify patterns, variability in timing and locations in Canadian Beaufort (L. Harwood)

Environmental Studies Research Fund

- *Assessing the Potential Effects of Near Shore Hydrocarbon Exploration on Ringed Seals in the Beaufort Sea Region 2003-2006* (Harwood, Smith and Melling, 2007)

Polar Bear

Canadian Wildlife Service

- movements and population dynamics of polar bears in the Beaufort Sea (map)
- assessment of possible impacts on polar bears of oil and gas activities in the outer Mackenzie Delta and the nearshore Southern Beaufort Sea.(Polar Continental Shelf Project)

USGS – Ongoing research of abundance, distribution, ecology

- status reports for Southern and Northern Beaufort Sea, 2007 and 2006
- a Joint Industry Project (JIP) was initiated in early 2005. In the summer of 2006, this program moved to fruition, launched as the E & P Sound and Marine Life Programme, and funded with donations from a consortium of oil and gas companies, all part of the OGP. The primary focus of the work will be on marine mammals, with some emphasis also on fish, invertebrates, and other prey species.

The results of studies funded through the JIP are intended to provide information that will:

- afford a more comprehensive understanding of the potential environmental risks from oil and gas operations
- inform and update policy decision makers, and regulatory development processes that affect our operations globally
- determine the basis for mitigation measures that are protective of marine life, cost effective, and credible with outside stakeholders
- feed into planning for efficient E & P project development that is environmentally protective
- JIP research priorities include: sound source characterization and propagation, physiological effects, behavioural reactions and biologically significant effects, mitigation and monitoring and research tools

5.7.1.4 Identification of Data Gaps

Based on the ranked effects and the information required to assess the effects, existing relevant information is identified in Tables 5-31 to 5-33. Comparison of required and existing data was used to identify data gaps.

Table 5-31 Existing Information and Identified Data Gaps for Whales

Ranked Effect	Information Required to Enable Assessment of Effect	Existing Information and Recent/Ongoing Research	Quality of Existing Data	Data Gap
Physical Presence of Equipment (drill platforms, drill rigs, support vessels, other equipment)	• Timing of use of habitat • Spatial use of habitat • Magnitude and location of development • Behavioural effects (short and long-term) • Knowledge of/effectivness of mitigation • Physical processes affecting ecology	• Timing of use of habitat • Spatial use of habitat • Physical processes affecting ecology • Behavioural responses	• Low to moderate for timing and spatial information • Low for behavioural effects	• Physical processes affecting ecology • Behavioural (short and long-term) effects • Timing and use of habitat • Spatial use of habitat
Underwater acoustic disturbance (vessel & seismic, drilling rig, support vessels, production platform/rig)	• Physiological effects (short and long-term) • Behavioural (short and long-term) effects • Ecological effects (i.e., prey) • Timing of use of habitat • Spatial use of habitat • Physical properties of environment • Knowledge of/effectivness of mitigation	• Physiological effects (short and long-term) • Behavioural (short and long-term) effects • Ecological effects (i.e., prey) • Timing of use of habitat • Spatial use of habitat • Physical properties of environment	• Moderate to high for physiological • Moderate for behavioural • Moderate to high for ecological effects • Low to moderate for timing and spatial use • Low to moderate for physical properties	• Knowledge of/effectivness of mitigation • Timing of use of habitat • Spatial use of habitat • Physical properties of environment • Behavioural (short and long-term) effects

Table 5-32 Existing Information and Identified Data Gaps for Seals

Ranked Effect	Information Required to Enable Assessment of Effect	Existing Information and Recent/Ongoing Research	Quality of Existing Data	Data Gap
Hydrocarbon or chemical spill	• Timing of use of habitat • Spatial use of habitat • Physiological effects (short and long-term) • Ecological effects (i.e., prey) • Knowledge	• Physiological effects • Physical properties of environment • Spatial use of habitat • Timing of seal use	• Low to moderate for timing and spatial information • Moderate for physiological effects • Low for	• Physiological effects (long term) • Ecological effects (i.e., prey) • Timing and use of habitat • Spatial use of habitat

	of/effectivness of mitigation	of habitat	ecological effects	• Mitigation and effectiveness in ice conditions
Underwater Acoustic Disturbances (seismic, drilling rig, support vessels)	• Timing of use of habitat • Spatial use of habitat • Magnitude and location of development • Behavioural effects (short and long-term) • Ecological effects (i.e., prey) • Knowledge of/effectivness of mitigation	• Spatial use of habitat • Timing of seal use of habitat • Behavioural effects (short and long-term) • Ecological effects (i.e., prey)	• Low to moderate for timing and spatial information • Moderate to high behavioural effects • Low to moderate for ecological effects (i.e., prey)	• Knowledge of/effectivness of mitigation • Timing and use of habitat • Spatial use of habitat • Behavioural effects (short and long-term)
Ice platforms and Roads	• Timing of use of habitat • Spatial use of habitat • Magnitude and location of development • Behavioural effects (short and long-term) • Knowledge of/effectivness of mitigation	• Spatial use of habitat • Timing of seal use of habitat	• Low to moderate for timing and spatial information	• Behavioural effects (short and long-term) • Knowledge of/effectivness of mitigation • Timing and use of habitat • Spatial use of habitat

Table 5-33 Existing Information and Identified Data Gaps for Polar Bears

Ranked Effect	Information Required to Enable Assessment of Effect	Existing Information and Recent/Ongoing Research	Quality of Existing Data	Data Gap
Hydrocarbon or chemical spill	• Timing of use of habitat • Spatial use of habitat • Physiological effects (short and long-term) • Behavioural effects (short-term) • Ecological effects (i.e., prey) • Knowledge of/effectivness of mitigation	• Timing of use of habitat • Spatial use of habitat	• Moderate to high for timing and spatial habitat • Moderate for ecological effects	• Physiological effects (short and long-term) • Knowledge of/effectivness of mitigation • Timing and use of habitat • Spatial use of habitat • Ecological effects (i.e., prey) • Behavioural effects (short-term)
Physical Presence of Equipment (drill platforms, drill rigs)	• Timing of use of habitat • Spatial use of habitat • Magnitude and location of development • Behavioural effects (short and long-term) • Knowledge	• Timing of use of habitat • Spatial use of habitat	• Moderate to high for timing and spatial habitat	• Behavioural effects (short and long-term) • Knowledge of/effectivness of mitigation • Physical processes affecting ecology • Timing and use of

	of/effectivness of mitigation • Physical processes affecting ecology			habitat • Spatial use of habitat
Ice Platforms and Roads	• Timing of use of habitat • Spatial use of habitat • Magnitude and location of development • Behavioural effects (short and long-term) • Knowledge of/effectivness of mitigation	• Timing of use of habitat • Spatial use of habitat	• Moderate to high for timing and spatial habitat	• Behavioural effects (short and long-term) • Knowledge of/effectivness of mitigation • Timing and use of habitat • Spatial use of habitat
Coastal Disturbance (on shore support)	• Timing of use of habitat • Spatial use of habitat • Magnitude and location of development • Behavioural effects (short and long-term) • Knowledge of/effectivness of mitigation	• Timing of use of habitat • Spatial use of habitat	• Moderate to high for timing and spatial habitat	• Behavioural effects (short and long-term) • Knowledge of/effectivness of mitigation
Underwater Acoustic Disturbance (seismic, drilling, production)	• Timing of use of habitat • Spatial use of habitat • Magnitude and location of development • Behavioural effects (short and long-term) • Ecological effects (i.e., prey) • Knowledge of/effectivness of mitigation (drilling/production)	• Timing of use of habitat • Spatial use of habitat	• Moderate to high for timing and spatial habitat	• Behavioural effects (short and long-term) • Ecological effects (i.e., prey) • Knowledge of/effectivness of mitigation (drilling/production)

5.7.2 Final Prioritization of Research Requirements

Tables 5-34 to 5-36 introduce timing to the ranked effects and data gaps to provide a final prioritization. The aim of this step is to provide an objective and useful list and avoid a conclusion where all research requirements are considered to be high priority.

Table 5-34 Research Requirement Prioritization for Whales

Ranked Effect	Data Gap	Time to Obtain Data	When in the Development Process is the Data Required	Relative Overall Ranking
Physical Presence of Equipment (drill platforms, drill rigs,	Physical processes affecting ecology	2–5 years	Drilling, fabrication, production	Low

support vessels, other equipment)				
	Behavioural (short and long-term) effects	2–5 years	Exploration drilling, fabrication, production	Low
	Timing of use of habitat	2–5 years	Seismic, exploration drilling, fabrication, production	High
	Spatial use of habitat	2–5 years	Seismic, exploration drilling, fabrication, production	High
Underwater acoustic disturbance (vessel & seismic, drilling rig, support vessels, production platform/rig)	Knowledge of/effectiveness of mitigation	2–5 years	Seismic, exploration drilling, production	Moderate
	Timing of use of habitat	2–5 years	Seismic, exploration drilling, fabrication, production	High
	Spatial use of habitat	2–5 years	Seismic, exploration drilling, fabrication, production	High
	Behavioural effects (short and long-term)	10 years	Seismic, exploration drilling, fabrication, production	High
	Physical properties of environment	2–5 years	Seismic, exploration drilling, fabrication, production	Low

NOTES:
1. Data gaps associated with where and when whales use the Canadian Beaufort was consistently prioritized as high for all Ranked Effects. To address these data gaps over the next decade, research will be required to understand the effect of climate change on the ecology of marine mammal species and the potential for change in species ranges (i.e., expansion of range for killer whales, fin whales, gray whales).
2. Though an interaction between marine mammals (whales, seals, polar bears) and industry is likely (in both open water and ice covered seasons) the majority of Ranked Effects are not likely to pose notable risks to sustainability.

Table 5-35 Research Requirement Prioritization for Seals

Ranked Effect	Data Gap	Time to Obtain Data	When in the Development Process is the Data Required	Relative Overall Ranking
Hydrocarbon or chemical spill	Physiological effects (long term)	2–5 years	Seismic, exploration drilling, fabrication, production	Moderate
	Ecological effects (i.e., prey)	10 years	Seismic, exploration drilling, fabrication, production	High
	Timing and use of habitat	2–5 years	Seismic, exploration drilling, fabrication, production	High
	Spatial use of habitat	2–5 years	Seismic, exploration drilling, fabrication,	High

			production	
	Mitigation and effectiveness in ice conditions	2–5 years	Seismic, exploration drilling, fabrication, production	High
Underwater Acoustic Disturbances (drilling rig/production)	Knowledge of effectiveness of mitigation	2–5 years	Exploration drilling, production	Moderate
	Behavioural effects (short and long-term)	10 years	Exploration drilling, production	Moderate
	Timing and use of habitat	2–5 years	Exploration drilling, production	High
	Spatial use of habitat	2–5 years	Exploration drilling, production	High
Ice platforms and Roads	Behavioural effects (short and long-term)	2–5 years	Production	Moderate
	Knowledge of/effectivness of mitigation	10 years	Production	Moderate
	Timing and use of habitat	2–5 years	Production	High
	Spatial use of habitat	2–5 years	Production	High

NOTE:
1. Data gaps associated with where and when seals use the Canadian Beaufort was consistently prioritized as high for all Ranked Effects. To address these data gaps over the next decade, research will be required to understand the effect of climate change on the ecology of marine mammal species and the potential for change in species ranges (i.e., expansion of range for killer whales, fin whales, gray whales).

Table 5-36 Research Requirement Prioritization for Polar Bears

Ranked Effect	Data Gap	Time to Obtain Data	When in the Development Process is the Data Required	Relative Overall Ranking
Hydrocarbon or chemical spill	Physiological effects (short and long-term)	10 years	Exploration drilling, production	Moderate
	Behavioural effects	2–5 years	Exploration drilling, production	Moderate
	Knowledge of/effectiveness of mititigation	10 years	Exploration drilling, production	High
	Timing and use of habitat	2–5 years	Exploration drilling, production	High
	Spatial use of habitat	2–5 years	Exploration drilling, production	High
Hydrocarbon or chemical spill (cont'd)	Ecological effects (i.e., prey)	10 years	Exploration drilling, production	Moderate
Physical Presence of Equipment (drill platforms, drill rigs)	Behavioural effects (short and long-term)	10 years	Exploration drilling, production	Low
	Knowledge of/effectiveness of	2–5 years	Exploration drilling, production	Low

	mitigation			
	Physical processes affecting ecology	2–5 years	Exploration drilling, production	Low
	Timing and use of habitat	2–5 years	Exploration drilling, production	High
	Spatial use of habitat	2–5 years	Exploration drilling, production	High
Ice Platforms and Roads	Behavioural effects (short and long-term)	10 years	Exploration drilling, production	Low
	Knowledge of/effectiveness of mitigation	2–5 years	Exploration drilling, production	Low
	Timing and use of habitat	2–5 years	Exploration drilling, production	High
	Spatial use of habitat	2–5 years	Exploration drilling, production	High
Coastal Disturbance (on shore support)	Behavioural effects (short and long-term)	10 years	Exploration drilling, production	High
	Knowledge of/effectivness of mitigation	2–5 years	Exploration drilling, production	Moderate
	Timing and use of habitat	2–5 years	Exploration drilling, production	High
	Spatial use of habitat	2–5 years	Exploration drilling, production	High
Underwater Acoustic Disturbance (seismic, drilling, production)	Behavioural effects (short and long-term)	10 years	Seismic, exploration drilling, production	Low
	Ecological effects (i.e., prey)	2–5 years	Seismic, exploration drilling, production	Low
	Knowledge of/effectivness of mitigation	2–5 years	Seismic, exploration drilling, production	Low
Underwater Acoustic Disturbance (seismic, drilling, production)	Timing and use of habitat	2–5 years	Seismic, exploration drilling, production	High
	Spatial use of habitat	2–5 years	Seismic, exploration drilling, production	High

NOTE:

1. Data gaps associated with where and when polar bears use the Canadian Beaufort was consistently prioritized as high for all Ranked Effects. To address these data gaps over the next decade, research will be required to understand the effect of climate change on the ecology of marine mammal species and the potential for change in species ranges (i.e., reduction/expansion of polar bear habitat, importance of remaining ice, importance of flow edges, etc.).

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5.8 Marine and Nearshore Avifauna

5.8.1 Summary of Data Needs and Existing Data

5.8.1.1 Potential Effects

Table 5-37 lists the potential effects of hydrocarbon exploration and development on marine and nearshore avifauna. Each effect is ranked based on the three criteria: (1) risk to sustainability; (2) level of understanding of the effect; and (3) ability to mitigate with proven techniques.

Table 5-37 Potential Effects of Hydrocarbon Exploration and Development on Marine and Nearshore Avifauna

Potential Effect	Risk to Sustainability of Marine and Nearshore Avifauna	Understanding of the Effect [2]	Ability to Mitigate	Ranking of Potential Effects
Hydrocarbon or chemical spill (resulting in bird mortality and/or changes in bird health, forage availability, and habitat availability)	3	1	2	6
Change in water quality from effluent and waste discharges (resulting in change in bird health and forage availability)	1	1	1	3
Light pollution on vessels and rigs (resulting in attraction to lights and flares and collisions with tall structures)	2	1	1	4
Coastal habitat degradation or loss from development of onshore support infrastructure (resulting in loss of nesting and foraging sites)	2	1	1	4
Seabed habitat degradation or loss from drilling, dredging and sediment re-suspension (resulting in loss of forage)	2	1	1	4
Noise from underwater seismic and drilling activity (resulting in sensory disturbance and habitat avoidance)	2	2	1	5
Noise and physical presence of surface vessels and aircraft (resulting in sensory and visual disturbance and habitat avoidance)	2	1	1	4

5.8.1.2 Information Requirements

Table 5-38 lists the ranked information requirements for marine and nearshore avifauna.

Table 5-38 Information Requirements for Marine and Nearshore Avifauna

Ranking	Effect	Information Required to Enable Assessment of Effect
6	Hydrocarbon or chemical spill (resulting in bird mortality and/or changes in bird health, forage availability, and habitat availability)	• Updated information on the seasonal distribution and abundance of avifauna in offshore and nearshore areas (timing of use, high use areas, numbers/types of birds present, and population trends) • Data on the dispersal pattern/trajectory and persistence of oil and chemical spills in winter and summer, particularly around polynyas, open leads and in nearshore areas • Information on the clean-up potential of oil and chemical spills in winter and summer, particularly around polynyas, open leads and in nearshore areas • Information on the effectiveness and feasibility of use of new bird dispersal/deterrent techniques in the Beaufort Sea during different seasons • Information on the potential for bioaccumulation of toxins in avifauna, particularly fish and benthos feeders, and effects on productivity or survival
5	Noise from underwater seismic and drilling activity (resulting in sensory disturbance and habitat avoidance)	• Updated information on the seasonal distribution and abundance of avifauna in offshore and nearshore areas (timing of use, high use areas, numbers/types of birds present, and population trends) • Data on the response of birds to seismic and drilling noise: Key questions include: (1) Will birds be displaced from key foraging, moulting or staging areas? (2) Will foraging behaviour and foraging efficiency be affected, resulting in changes in productivity or survival of birds?
4	Noise and physical presence of surface vessels and aircraft (resulting in sensory and visual disturbance and habitat avoidance)	• Updated information on the seasonal distribution and abundance of avifauna in offshore and nearshore areas (timing of use, high use areas, numbers/types of birds present, and population trends) • Updated data on the response of birds to disturbance from different sized aircraft and vessels at various frequencies of use. Key questions include: (1) Will birds be displaced from key foraging, moulting and staging areas? (2) Will foraging behaviour and foraging efficiency be affected, resulting in changes in productivity or survival of birds?
4	Seabed habitat degradation or loss from drilling, dredging and sediment re-suspension (resulting in loss of forage)	• Updated information on the seasonal distribution and abundance of avifauna in offshore and nearshore areas (timing of use, high use areas, numbers/types of birds present, and population trends) • Data on the area (ha) of seabed that could be impacted by disturbance activities (zone of influence) • Data on the distribution and abundance of benthic species that are consumed by birds prior to and following disturbance (e.g., using a before-after-control-impact, or BACI, study design) • Data on the abundance of benthic species available versus consumed by birds before and after development (BACI study design)
4	Coastal habitat degradation or loss from development of onshore support infrastructure (resulting in loss of nesting and foraging sites)	• Updated information on the seasonal distribution and abundance of avifauna in nearshore areas (timing of use, high use areas, numbers/types of birds present, and population trends) • Updated information on the response of birds to coastal disturbance. Key questions include: (1) Will birds be displaced from key foraging, staging and moulting sites

		because of disturbance? (2) What area (ha) will be affected by direct and indirect (sensory) disturbances?
4	Light pollution on vessels and rigs (resulting in attraction to lights and flares, and collisions with tall structures)	• Updated information on the seasonal distribution and abundance of avifauna in offshore and nearshore areas (timing of use, high use areas, numbers/types of birds present, and population trends) • How will different species of bird in the Beaufort Sea, particularly sensitive SARA listed gulls, react to vessel and platform lights (e.g., attraction to lights, collisions) • When are birds most vulnerable to effects of light pollution (migration, staging, moulting)?

5.8.1.3 Existing Information

Overview of Existing Data

The key potential effects of hydrocarbon developments on marine and nearshore avifauna are:

- hydrocarbon or chemical spills and change in water quality
- noise from underwater seismic and drilling activity
- noise and physical presence of surface vessels and aircraft
- degradation or loss of coastal and seabed habitat
- light pollution

Existing information on these effects is identified below. Fundamental to understanding these effects is knowledge on the seasonal distribution and abundance of birds in marine, nearshore and coastal environments and the location of key bird habitats or areas. Considerable information has been summarized on important bird areas in offshore and coastal areas (Salter and Davis 1974; Alexander et al. 1988; Cornish and Dickson 1994; Alexander et al. 1997; Dickson and Gilchrist 2002; Dickson et al. 2003; Mallory and Fontaine 2004; Dickson et al. 2005; Dickson et al. 2006; Latour et al. 2006) and this information base is considered good, although data in some areas is not current.

Hydrocarbon or chemical spills and change in water quality

Large- and small-scale chronic oil spills are considered the most important potential environmental effect of hydrocarbon developments on marine birds because of the potential to kill birds en masse and degrade large areas of coastline. Bird mortality can occur from direct contact with oil or consumption of contaminated fish or benthic fauna. Considerable work has been done on the rehabilitation of birds following oil spills, and recent attention has focused on displacement and deterrant methods to keep birds away from polluted areas (Environment Canada 2008, Internet site). Overall, the effects of hydrocarbon spills on bird physiology and survival are generally well understood (e.g., reviews by Levy 1983; Lawrence and Davies 1993; Leighton 1995) and the chronic, long-term impacts of nearshore spills on marine bird populations have become apparent (e.g., Peterson et al. 2003). Several studies have examined the effects of drilling wastes and chemicals on benthic fauna, as reviewed by Hurley and Ellis (2004).

Noise from underwater seismic and drilling activity

Very limited information is available on the effects of underwater noise on the behaviour and distribution of marine and nearshore birds. Only one comprehensive study is known to have been conducted, in Alaska, on the effects of underwater seismic noise on the distribution and abundance of moulting long-tailed ducks (Lacroix et al. 2003).

Noise and physical presence of surface vessels and aircraft

Much of the information on the effects noise from aircraft on birds is dated, although several recent studies have been completed. Little information is available from the Beaufort Sea or other areas on disturbance of birds by the presence of seismic vessels. Some marine birds are reported to be relatively tolerant of vessel traffic (MMS 2006).

Ward and Sharp (1974) examined the response of moulting sea ducks in the Beaufort Sea nearshore environment to aircraft disturbance, while Ward et al. (2000) examined aircraft disturbance on moulting brant and Canada geese at Izambek Lagoon, Alaska. Numerous other studies have assessed the effects of aircraft disturbance in onshore areas, primarily in Alaska and the Yukon Territory (LGL 1972; Renewable Resources 1972; Davis and Wisely 1974; Salter and Davis 1974; Barry and Spencer 1976; Johnson et al. 2003). The recent study at Alaska's Alpine oil field development (Johnson et al. 2003) provides a long-term and comprehensive assessment of aircraft noise on terrestrial breeding birds.

Seabed habitat degradation or loss

Disturbance of seabed habitat is important because it may affect the availability of benthic forage for diving birds. Several studies have examined the effects of drilling wastes and subsequent seabed disturbance on benthic fauna, as reviewed by Hurley and Ellis (2004), which may provide some information in changes in prey availability for diving ducks. Data from the Beaufort Sea is limited.

Coastal habitat degradation or loss

Loss or degradation of coastal habitats can affect availability of key nesting, foraging, molting and staging areas for birds. The effects of coastal developments on birds and bird habitat have been assessed in the Beaufort Sea as part of the Environmental Impact Statement for the Polar Gas Pipeline Project and the Mackenzie Gas Project (AMEC 2004; AMEC 2005).

Light pollution

Lighting on vessels, drilling rigs and production platforms can attract to marine birds and result in collisions with structures during night-time. Collisions of marine birds with vessels and structures have been well documented (e.g., Wiese et al. 2001; Corre et al. 2002). The general effects of light pollution on marine birds have been summarized by Hurley and Ellis (2004). No research has been conducted in the Beaufort Sea study area, although work has been conducted in Alaska (Day et al. 2005).

Overview of Data from Previous Gap Analyses

ESL (1991) and BSStRPA (2007) provide the most comprehensive summary of research needs for marine birds and wildlife. KAVIK-AXYS (2002) also summarize research needs for birds, with a focus on both onshore and nearshore areas of the Mackenzie Delta.

Information requirements identified in ESL (1991) for wildlife species are as follows:

- abundance
- distribution
- population dynamics
- critical habitats and life histories
- concentration areas, timing and movements
- vulnerability to oil exposure

- sensitivity to oil and counter measures
- recovery potential

Information requirements identified in BSStRPA (2007) for seabirds are as follows:

- 2D and 3D Seismic Exploration: physiological data on the effect of seismic sound on hearing of seabirds; data collection and analysis to identify best practices; identification and development of appropriate monitoring protocols
- Exploratory Drilling Nearshore Zone: update coastal seabird surveys; assess impact of noise on nesting, moulting, and staging seabirds and shorebirds; determine noise threshold levels; renew harvest studies; monitor garbage and refuse management systems
- Exploratory Drilling Offshore Zone: conduct offshore surveys for seabirds; identify important habitat criteria
- Nearshore and Offshore Support: review and update air flight guidelines; develop preferred shipping routes
- Dredging: develop Beaufort Sea–specific guidelines for dredging; monitor potential effects from dredging activities; identify key habitats where dredging should not occur
- Oil Spills: review and revise oil spill trajectories; update oil spill atlas; develop protection plans for key marine fauna; develop new technologies to recover oil in ice infested or covered waters
- Development Nearshore Zone: update coastal seabird surveys; assess effect of noise on nesting, moulting, and staging seabirds; determine noise threshold levels; renew harvest studies
- Development Deep Water Zone (>60 m): conduct offshore surveys for seabirds; identify important habitat criteria
- Traditional Knowledge: finalize manuals on Traditional Knowledge; conduct regional TK study
- Databases: make databases accessible to all researchers and communities; maintain and update databases; develop data collection and data format protocols

Information requirements identified by KAVIK-AXYS (2002) for birds in the nearshore environment (outer Mackenzie Delta) are as follows:

- Pollution and Contamination: monitor pollutants and contaminants in air, water, soil and birds in outer Mackenzie Delta
- Habitat Alteration: monitor bird populations and habitats and monitor subsistence harvest in the outer Mackenzie Delta
- Activity, Noise and Disturbance: establish aircraft, vessel and vehicle travel corridors away from bird concentration areas and traditional hunting areas. Monitor bird populations and the subsistence harvests near noisy industry activities
- Inadequate Baseline Information: conduct baseline studies of shorebirds in the outer Delta and near proposed development sites prior to major industrial activities. Monitor bird populations in the outer Mackenzie Delta during development
- Outdated Information: conduct focused studies on important bird species in the outer Delta and near proposed development sites prior to major industry activities. Monitor bird populations in the outer Mackenzie Delta during development
- Inadequate Information Management: establish information management systems and consult with other researchers in northern areas where petroleum developments have also occurred

Comparison of Existing Data with Previous Data Gap Analyses

The data gaps identified above can be summarized as follows:

- baseline data on the seasonal distribution, abundance and population trends of birds in marine and nearshore habitats during nesting, moulting, staging and migration and identification of important habitats/areas, including traditional use areas
- response of birds to disturbance (seismic noise, drilling noise, aircraft and vessel disturbance, dredging and other industrial activities) and identification of threshold noise level and aircraft and vessel guidelines
- effects of air and water pollution and contamination on birds; update of oil spill trajectories and oil spill atlas, and species protection plans

Considerable baseline data is available on the seasonal distribution and abundance of birds in nearshore areas (e.g., Alexander et al. 1988; Latour et al. 2006); however, much of this information is 20+ years old and requires updating (BSStRPA 2007). For example, the location of some high use areas may have changed over time with slowly changing climatic conditions. Similarly, baseline information is available on the use of offshore polynyas and open leads during spring migration (Alexander et al. 1997); however, this information is also old (Dickson, pers. comm.2008) and requires updating. Currently, limited data is available from satellite collared birds to update information on use of polynyas and open leads during spring migration, and also the pattern of offshore migration and location of key areas during the fall (Dickson et al. 2003, 2005, 2006).

The bulk of information on the response of bids to noise and other industry activities in the Beaufort Sea study area was collected during the 1970s and 1980s (e.g., LGL 1972; Renewable Resources 1972; Davis and Wisely 1974; Salter and Davis 1974; Ward and Sharp 1974; Barry and Spencer 1976) and in many cases was not scientifically rigorous, and may not be representative of current disturbances. More recently, considerable research has been conducted elsewhere in Alaska on the effects of noise and industrial disturbance on several bird species, including brant and long-tailed ducks (Ward et al. 2000, Lacroix et al. 2003); however, extrapolation of this information to the Canadian Beaufort region should be done cautiously because of differences in environmental conditions and disturbance types (Hines, pers. comm.).

The effects of oil spills on birds are well understood; however, information is outdated on oil spill trajectories in the Canadian Beaufort Sea and how oil spills can be contained and removed in ice laden water. In addition, effects of spills on benthic fauna and how this may affect bird foraging ability and bioaccumulation of toxins is not clearly understood. This has important implications for high use areas such as the offshore polynyas and open water leads that are used by hundreds of thousands of birds during spring migration, as well as important coastal habitats and traditional use areas. Oil and chemical spills in these regions can have a significant effect on local populations of birds.

Recent and Ongoing Research

The Canadian Wildlife Service (CWS) is responsible for managing migratory birds in Canada and is the primary organization conducting research on birds in the Beaufort Sea. The following research projects are underway by CWS in the Canadian Beaufort Sea study area:

- Identification of Beaufort Sea Migration Corridor for Sea Ducks (2006 to 2010; Lynne Dickson)
- This study will provide detailed information on location and timing of use of the Beaufort Sea migration corridor by sea ducks to better predict and mitigate any adverse effects of offshore oil and gas development. The study will also provide important new information on population definition/delineation by linking specific breeding areas in western Arctic Canada to moulting and wintering areas (Environment Canada, Internet site 2007).

- This study will also provide critical information on the migration corridor of sea ducks in offshore areas thus addressing an important data gap. The study will be completed within a timeframe appropriate for hydrocarbon development in the Beaufort Sea.
- *The Red-throated Loon as an Environmental Indicator* (1985 to undetermined end point; Lynne Dickson and Jessica Beaubier):
- This study evaluates the breeding population and productivity of an indicator species, the Red-throated Loon, before and after development. The first five years of the study were completed from 1985 to 1989. And additional two to three years of information on pre-development condition will be collected starting in 2007. Timing of the second phase of the project will depend on the timing of offshore oil and gas development (Environment Canada Internet site 2007).
- This study will provide important data on baseline conditions and the environmental effects oil and gas activity in the Beaufort Sea on the breeding population and productivity of red-throated loons, including information on bioaccumulation of toxins, thus filling an important data gap. Data will presumably be analyzed as it is collected and thus will be useful for hydrocarbon development in the Beaufort Sea.
- Distribution and Abundance of Waterfowls and Other Migratory Birds in the Mackenzie Delta Region (2002 to 2009: Jim Hines).
- This project is to document changes in numbers of waterfowl species in the Mackenzie Delta. Its purpose is to evaluate the effects of oil and gas development on migratory bird populations in the Inuvialuit Settlement Region and to guarantee that sustainable and high numbers of waterfowl are maintained in the Mackenzie Delta region for the use of Inuvialuit and other Canadians. The Mackenzie Delta, Tuktoyaktuk Peninsula, and neighbouring parts of the mainland Inuvialuit Settlement Region are among the most important breeding areas for waterfowl and other migratory birds in North America. Many species of waterfowl are harvested by local residents for subsistence use. For this reason, Inuvialuit want regional populations of these species to be carefully managed. As well, general concerns about the status of many species exist at national and continental levels, further emphasizing the need for careful management. (Environment Canada Internet site 2007).
- This study will provide useful information on the distribution, abundance and population trends of waterfowl in some coastal (and inland) areas and will partially fill an important data gap. Additional studies are required to update existing data on important coastal and nearshore areas for waterbirds. This study will be completed within a timeframe appropriate for hydrocarbon development in the Beaufort Sea.

- Survey of Pacific Common Eiders in the Bathurst Inlet area of Nunavut (2006-2009, then repeated periodically; Garnet Raven, Lynne Dickson).

  Aerial surveys as well as recent satellite telemetry data suggest the entire Canadian breeding population stops for several weeks in the early open water in the southeastern Beaufort Sea to rest and feed, making them vulnerable to offshore oil and gas development in the region. This project is intended to monitor changes in the size of the Canadian breeding population of number of Pacific Common Eiders. This is achieved by obtaining an annual estimate of the number of breeding pairs of eiders in a core part of their breeding range.

- Waterfowl Breeding Population Survey for Central and Western Arctic Canada (annually for 2006 onward; Lynne Dickson, Tim Moser, Russ Oates).
  - Aerial surveys as well as recent satellite telemetry data suggest the entire Canadian breeding population of king eiders stops for several weeks in the early open water in the southeastern Beaufort Sea to rest and feed. Long-tailed ducks also stage in large numbers in the Beaufort Sea during spring migration, as well as moult by the tens of thousands in coastal areas in midsummer. Thus both species are vulnerable to offshore oil and gas development. This annual survey is intended to monitor population trends of several waterfowl including the western arctic populations of king eiders and long-tailed ducks. The annual counts are estimated based on

observations taken on transect lines flown over a large portion of the breeding range during the nesting period.

5.8.1.4 Identification of Data Gaps

Based on the ranked effects and the information required to assess the effects, existing relevant information is identified in Table 5-39. Comparison of required and existing data will enable identification of data gaps.

Table 5-39 Existing Information and Identified Data Gaps for Marine and Nearshore Avifauna

Ranked Effect	Information Required to Enable Assessment of Effect	Existing Information and Recent/Ongoing Research	Quality of Existing Data	Data Gap
All	• Seasonal occurrence, distribution and abundance of avifauna in offshore and nearshore areas (timing of use, high use areas and numbers/ types of birds present)	• Historical information on key coastal habitat areas • Ongoing studies of offshore sea duck migration routes and onshore/ coastal studies of waterbirds	• High, but some is outdated	• Updated information on key coastal and offshore areas, species distributions and abundance and timing of movement
Hydrocarbon or chemical spills; change in water quality	• Dispersal pattern /trajectory and persistence of oil and chemical spills in winter and summer, particularly around polynyas, open leads and in nearshore areas	• Historical information on trajectories	• Outdated	• Updated information on oil spill trajectories and persistence of oil and chemical spills during winter and summer
	• Clean-up potential of oil and chemical spills in winter and summer, particularly around polynyas, open leads and in nearshore areas	• No recent information	• None	• Updated information on success of oil spill clean-up procedures during winter and summer
	• Effectiveness of bird deterrent/dispersal techniques in the Beaufort Sea during different seasons	• No recent information	• None	• Data on effectiveness deterrent/dispersal techniques the Beaufort Sea in different seasons
	• Potential for bioaccumulation of chemicals in avifauna, particularly fish and benthos feeders, and effects on productivity or survival	• Ongoing study on red-throated loons (fish consumer)	• High (fish consumer • Low (benthic feeder)	• Information on bioaccumulation of toxins in benthic feeders (e.g., scaup or scoter) • Baseline information on contaminant levels in benthic feeders and benthic

				organisms (e.g., bivalves)
Noise and physical presence of surface vessels and aircraft	• Response of aircraft and vessel noise (displacement from key foraging, moulting and staging areas; change in foraging behaviour and foraging efficiency)	• Historical information on response to aircraft noise in Beaufort Sea region • Recent studies elsewhere in Alaska on brant and Canada geese in coastal areas and inland at the Alpine oil field development	• Low (historical studies) • High (recent studies)	• Applicability of recent Alaska studies to Beaufort Sea unknown • Updated information on response of birds to aircraft and vessel noise and threshold values in the Beaufort Sea (studies on aircraft disturbance have been recommended as part of effects monitoring for the Mackenzie Gas Project)
Noise from underwater seismic and drilling activity	• Response of birds to seismic and drilling noise (effects on foraging behaviour and efficiency, and potential for displacement from key foraging, molting and staging areas)	• Recent studies of effects of seismic noise in Alaska on long-tailed ducks	• High	• Applicability to Canadian Beaufort Region unknown (although species are similar to Alaska study)
Seabed habitat degradation and loss	• Area (ha) that will be impacted by seabed disturbance (zone of influence)	• No known studies in Beaufort Sea	• None	• Data on spatial extent of seabed disturbance
	• Distribution and abundance of benthic species consumed by marine birds and potential changes caused by development	• No known studies in Beaufort Sea	• None	• BACI study assessing changes in benthic fauna availability prior to and following development
Coastal habitat degradation or loss	• Response of birds to coastal disturbance (displacement from key foraging, staging and moulting sites because of disturbance).	• Historical information on response to aircraft noise in Beaufort Sea region • Recent studies elsewhere in Alaska on brant and Canada geese in coastal areas and inland at the Alpine oil field development	• Low (historical studies) • High (recent studies)	• Applicability of recent Alaska studies to Beaufort Sea unknown. • Updated information on response of birds to aircraft and vessel noise and threshold values in the Beaufort Sea (studies on aircraft disturbance have been recommended as part of effects monitoring for the Mackenzie Gas Project)
Light pollution	• How will different species of birds in the Beaufort Sea,	• No known studies in Beaufort Sea	• None	• Monitoring data during production on the type of species

	particularly sensitive SARA listed gulls, react to vessel and platform lights (e.g., attraction to lights, collisions) • When are birds most vulnerable to effects of light pollution (migration, staging, moulting)?			that will be attracted to offshore and nearshore developments in the Beaufort Sea, the magnitude of attraction and timing of attraction.

5.8.2 Final Prioritization of Research Requirements

Information on oil spill trajectories, clean-up procedures, and deterrent methods are considered critical to allow for identification and mitigation of potential project effects. It is also critical to have a good understanding of important bird areas so that effects are adequately assessed and appropriate project-specific mitigation plans are identified and developed. Information on the effects of noise disturbance from seismic vessel and aircraft operations are also important but less critical because effects are more localized. Similarly, understanding effects on coastal habitat and seabed habitat degradation or loss are important but less critical than studies on oil spills, and some effects may be assessed during monitoring programs for the Mackenzie Gas Project, should it proceed. The effects of light pollution on birds may result in mortality of a small number of individuals only and thus this research is considered low priority.

Table 5-40 introduces timing to the ranked effects and data gaps to provide a final prioritization. The aim of this step is to provide an objective and useful list and avoid a conclusion where all research requirements are considered to be high priority.

Table 5-40 Research Requirement Prioritization for Marine and Nearshore Avifauna

Ranked Effect	Data Gap	Time to Obtain Data	When in the Development Process is the Data Required	Relative Overall Ranking
All	• Updated information on key coastal and offshore areas, species distributions and abundance and timing of movement	• 3 years	• Seismic through to operations	• High
Hydrocarbon or chemical spills; change in water quality	• Updated information on oil spill trajectories, persistence of oil and chemical spills during winter and summer, and effectiveness of bird deterrent/ dispersal techniques. • Also data on bioaccumulation of toxins in benthic feeding birds	• 3+ years	• Exploratory drilling	• High
Noise from underwater seismic and drilling activity	• Updated information on response of birds to seismic and drilling noise and threshold values (zones of	• 3+ years	• Seismic	• Moderate

	influence)			
Noise and physical presence of surface vessels and aircraft	• Updated information on response of birds to aircraft and seismic vessel noise and threshold values (zones of influence)	• 3+ years	• Seismic though to operations	• Moderate
Seabed habitat degradation or loss	• Data on spatial extent of seabed disturbance and changes in benthic fauna availability	• 3+ years	• Exploratory drilling	• Moderate
Coastal habitat degradation or loss	• Updated information on response of birds to aircraft and infrastructure, and threshold values (zones of influence)	• 3+ years	• Seismic through to operations	• Moderate
Light pollution	• Data on the type of species that will be attracted in the Beaufort Sea, magnitude of attraction and timing of attraction	• 3 + years	• Seismic through to operations	• Low

5.9 Archaeology and Palaeontology

5.9.1 Summary of Data Needs and Existing Data

5.9.1.1 Potential Effects

Table 5-41 lists the potential effects of hydrocarbon exploration and development on archaeological and palaeontological sites. Each effect is ranked based on the three criteria: (1) risk to sustainability; (2) level of understanding of the effect; and (3) ability to mitigate with proven techniques.

Disturbance to archaeological and palaeontological sites can occur during all phases of offshore hydrocarbon development. However, interaction between hydrocarbon development and archaeological/palaeontological materials is typically greatest at the field development stage. Procedures for managing regulated interactions are in place at this stage and mitigative options are available to ensure that adverse effects are minimized.

In determining effects on archaeological and palaeontological sites, it is assumed that seismic survey and exploration drilling require land-based support to expedite these activities. Potential unregulated interaction could occur during certain shallow water seismic activities should ship wrecks lie on the predetermined survey lines. Specific direct effects on submerged vessels are unknown; no data was found on appropriate disturbance mitigation.

Table 5-41 Potential Effects of Hydrocarbon Exploration and Development on Archaeological and Palaeontological Sites

Potential Effect	Risk to Sustainability of Archaeological and Palaeontologial Sites	Understanding of the Effect	Ability to Mitigate with Proven Techniques	Ranking of Potential Effects
Disturbance of shipwrecks	2	3	2	6
Disturbance of onshore remains by increased erosion and slumpage	2	2	1	5
Disturbance of coastal sites during cleanup activities associated with hydrocarbon spills	2	2	2	6
Compaction and disturbance by construction and use of ice pads and ice roads on archaeological materials	2	3	2	7
Disturbance of palaeontological sites by borrow extraction	2	3	1	6

Accidents and malfunctions, particularly hydrocarbon cleanup, could have the greatest effect on archaeological and palaeontological sites. It is anticipated that cleanup activities would be unregulated as the focus would be on immediate remediation. Use of booms, shoreline staging sites, vegetation stripping and containment areas, shoreline 'washing' and cleanup have the potential to adversely affect significant archaeological and palaeontological sites. Further, cleanup requires large crews which, when deployed in the spill area, could result in artifact collection and feature disturbance unrelated to direct cleanup activities. All of these activities could result in loss of artifacts and or fossils, disturbance of site features, loss of site content, and loss of potential for dating sites through contamination of organic materials with hydrocarbon rendering them inappropriate for radiometric dating. Although zones of known archaeological and palaeontological sensitivity could be mapped and flagged for consideration during clean up activities, procedures to monitor/audit and mitigate the effects of these activities on both known and currently unrecorded sites need to be developed in consultation with Prince of Wales Northern Heritage Centre. Mapping of archaeological and palaeontological site sensitivity must incorporate individual heritage site values for sites currently in the inventory, as well as consider the potential for as yet undiscovered sites.

There is a need for information on the potential contribution of winter exploration programs to slumping, particularly in association with lake/pond shores and the coast. These areas of high archaeological potential are generally investigated as part of the project assessment program because of the season in which activities are scheduled and the perception that there is no consequent interaction with archaeological materials.

Similarly, there is a lack of understanding regarding potential interaction and verification that construction of ice pads on archaeological sites are effective in mitigating impacts to site content and context. The same data gap is relevant to construction and use of winter roads and effects on archaeological materials underlying these facilities. The probability that winter roads conflict with archaeological sites is greater than ice pads for facility construction; ice road alignments are generally not included in the archeological field assessment programs.

Borrow extraction of gravel deposits disturbs areas of high potential to contain fossil vertebrates such as mammoths, bison, and other Quaternary mammals. These gravel deposits are the main source of Quaternary vertebrates, although these remains are volumetrically rare. Similarly, coring of coastal deposits has brought up both fossils and preserved plant remains. Reports on impact assessment, specific to palaeontological remains, were not identified; the interaction with these activities is poorly known to unknown.

5.9.1.2 Information Requirements

Information needs will be identified for each ranked effect based on the premise of what information is required to undertake a credible environmental assessment. Table 5-42 provides a framework for listing information needs.

Table 5-42 Information Requirements for Archaeology and Palaeontology

Ranking	Effect	Information Required to Enable Assessment of Effect
7	• Compaction and disturbance of sites during construction and use • Direct site specific effect	• Field audit of known areas of conflict • Potentially excavation to determine site specific effects
6	• Disturbance of coastal sites during cleanup activities associated with hydrocarbon spills • Geographically, largest direct potential effect	• Inventory of coastal sites in vicinity of development • Dispersion patterns • Likely types of activities • More detailed regional data regarding site types, distribution and interpretive potential
6	• Disturbance of ship wrecks • Direct site specific effect	• Documented inventory of ship wrecks • Historical associations • Content and interpretive potential
6	• Disturbance of palaeontological sites by borrow extraction	• Locations of potential borrow sources • Inventory and evaluation of known fossil sites associated with potential borrow sources
5	• Disturbance of onshore remains through erosion and slumpage • Secondary, site specific effect	• Site elevation and terrain associations • Information on relative terrain sensitivity to slumping • Locations of known slumping • Monitoring data at known slumpage to determine presence of archaeological materials and effects on these materials

5.9.1.3 Existing Information

Overview of Existing Data

Archaeological studies in the study area began in the mid-1900s. Research-oriented studies such as those associated with the Northern Oil and Gas Action Plan, Tuktut Nogait National Park, Ivvavik National Park and Aulavik National Park are responsible for recording most of the sites within the current inventory. A summary and evaluation of available information to 1999 is presented in *Inuvialuit Heritage Resources in the Mackenzie Delta Area of the Inuvialuit Settlement Region* (KAVIK-AXYS 2003).

In 2001, a survey of a number of small areas of the Mackenzie delta was completed at the request of a number of developers operating in the area (Hanna 2002). In summary, the *Inuvialuit Heritage Resources in the Mackenzie Delta Area of the Inuvialuit Settlement Region* report review indicates that early investigations were biased toward large village sites, inconsistently covered large land tracts, provided minimal detailed site information and lacked data on content and cultural affiliation. Because these studies relied on aerial reconnaissance, sites containing well defined stone features dominate the inventory. Excavation programs focused on multi-component Inuvialuit villages, with little investigation of smaller, more dispersed Inuvialuit sites.

The *Geological Atlas of the Beaufort-Mackenzie Area* (Dixon 1996) provides a detailed account of the geology of the area and a summary of palaeontological information. Many of the coastal palaeontological sites are late Tertiary to Quaternary (up to 20 million years old) and contain fossil plant and insect material useful for climate reconstruction. The fossil material is often exceptionally preserved in permafrost environments.

During the last ice age, much of the Yukon and Alaska were not glaciated and acted as refugia for a rich vertebrate fauna. Fossils of these Quaternary vertebrates are most comonly found in gravel deposits, and many have been recovered during placer gold mining operations (Harington 1978).

Overview of Data from Previous Gap Analyses

Archaeological and palaeontological sites were not addressed in any of the previous data gap analyses reviewed.

Comparison of Existing Data with Previous Data Gap Analyses

In the absence of data from previous gap analyses, the NOGAP studies and the Arctic archaeological sensitivity maps are discussed briefly to provide background information regarding data gaps relevant to effects on archaeological sites. The NOGAP archaeological projects were instituted in the 1980s to provide information to address needs relating to the “proper assessment of the potential impacts of proposed oil and gas developments in the Mackenzie Valley, Beaufort Sea and Northwest passage areas...” (Cinq-Mars and Pilon 1991). The information that resulted from these studies increased regional knowledge on site distributions throughout the Inuvialuit Settlement Region (ISR) but contributed relatively little to management processes associated with identifying site-specific effects or mitigating regional effects.

The Arctic Environmental Sensitivity Atlas (Environment Canada, 2000) provides information regarding archaeological site distribution based on a site inventory current to 1999. In this document, site sensitivity is based on site density rather than site type or heritage value of site contents. As a result, the site density information presented in these maps more accurately reflects geographic foci of past field reconnaissance, rather than actual site distribution or site value. As a consequence, this document should not be used for assessing effects relative to archaeological sensitivity of geographic locations.

The study area is well known for winter villages which form the basis for current cultural chronologies and descriptions. However, relative to the potential for offshore activities, there is still a lack of a comprehensive site inventory specific to the coast which can be used to base effects assessment and management process. As such, each development requires an archaeological impact assessment to identify sites and evaluate project effects without the benefit of adequate regional data for comparison.

Recent and Ongoing Research

There is currently no known research aimed at filling gaps in the regional inventory database applicable to effects assessment. Although archaeological and palaeontological research projects may be ongoing, they largely consist of academic or project-related studies concerned with regional chronologies and single site interpretation. There is no known research relative to effects of winter development activities on archaeological sites.

5.9.1.4 Identification of Data Gaps

Based on the ranked effects and the information required to assess the effects, existing relevant information is identified in Table 5-43. Comparison of required and existing data will enable identification of data gaps.

Table 5-43 Existing Information and Identified Data Gaps for Archaeology and Palaeontology

Ranked Effect	Information Required to Enable Assessment of Effect	Existing Information and Recent/Ongoing Research	Quality of Existing Data	Data Gap
Compaction and disturbance of sites during construction and use	• Field data from audits of ice pads/roads built on known archaeological/ palaeontological sites	• None known	• N/A	• Likelihood of effect • Nature of effects, if any
Disturbance from cleanup activities	• Inventory of coastal sites • Spill dispersion patterns • Likely types of activities • More detailed regional data regarding site types, distribution and interpretive potential	• Exxon Valdez spill • North Slope findings • Site Inventory data at PWNHC • Geological Atlas	• Reactive measures • Little effects data • Limited geographic inventories	• Likelihood of effect • Heritage values likely to be affected • Mitigation options
Disturbance of shipwrecks	• Documented inventory of ship wrecks • Historical associations • Content and interpretive potential	• Northern Shipwrecks Database	• Literary inventory only	• Likelihood of effect • Nature of effect • Heritage value of wreck • Mitigation options
Disturbance of palaeontological sites by borrow extraction	• Locations of potential borrow sites • Age of borrow site materials • Inventory of fossil sites associated with borrow sources	• None known	• N/A	• Lack of data - • Site presence • Potential age • Heritage value
Disturbance of onshore remains through erosion and slumpage	• Site elevation and terrain associations • Information on relative terrain sensitivity to slumping • Locations of known slumping • Monitoring data at known slumpage to determine presence of archaeological/ palaeontological materials and effects on these materials	• None known	• N/A	• Likelihood of effect • Nature of effect on site integrity • Mitigation optiions

5.9.2 Final Prioritization of Research Requirements

Table 5-44 introduces timing to the ranked effects and data gaps to provide a final prioritization. The aim of this step is to provide an objective and useful list and avoid a conclusion where all research requirements are considered to be high priority.

Table 5-44 Research Requirement Prioritization for Archaeology and Palaeontology

Ranked Effect	Data Gap	Time to Obtain Data	When in the Development Process is the Data Required	Relative Overall Ranking
Compaction and disturbance of sites during construction and use	• Field data from audits of known ice pads/roads built on archaeological/ palaeontological sites	2 years	Seismic, Exploration and Field Development	High
Disturbance from cleanup activities	• Inventory of coastal sites • More detailed regional mapped data regarding site types, distribution and heritage value • Effects of activities on archaeological and/or palaeontological sites	1 year	Exploration and Production	High
Disturbance of shipwrecks	• Information on potential for ship wrecks • Information on effects from activities	1 year	Seismic, Exploration and Field Development	Moderate
Disturbance of palaeontological sites by borrow extraction and coring activities	• Locations of borrow sites • Age of borrow site materials • Inventory of fossil sites associated with borrow sources	2 years	Seismic, Exploration and Field Development	High
Disturbance of onshore remains through erosion and slumpage	• Site elevation and terrain associations • Information on relative terrain sensitivity to slumping • Locations of known slumping • Monitoring data at	2 years	Seismic, Exploration and Field Development	High

	known slumpage to determine presence of archaeological materials and effects on these materials			

5.10 Traditional Land Use

5.10.1 Summary of Data Needs and Existing Data

5.10.1.1 Potential Effects

Table 5-45 lists the potential effects of hydrocarbon exploration and development on Traditional Land Use. Each effect is ranked based on the three criteria: (1) Risk to sustainability; (2) Level of understanding of the effect; and (3) Ability to mitigate with proven techniques.

Table 5-45 Potential Effects of Hydrocarbon Exploration and Development on Traditional Land Use

Potential Effect	Risk to Sustainability of VEC	Understanding of the Effect	Ability to Mitigate with proven techniques	Ranking of potential effects
Acoustic disturbance (all phases)	1	2	1	4
Change in water quality (all phases)	1	2	1	4
Interference with traditional land and resource use (all phases)	2	1	1	4
Seabed disturbance – sediment re-suspension (Exploration, Field development and Decommissioning)	1	1	2	4
Exposure of fauna to drill chemicals (Exploration)	1	1	1	3
Coastal disturbance (Field development, Production, Decommissioning)	2	2	2	6
Hydrocarbon or chemical spill	3	2	2	7
Fire (fire fighting chemicals)	1	2	2	5

5.10.1.2 Information Requirements for Traditional Land Use

In Table 5-46, baseline data includes harvest data monitoring.

Table 5-46 Information Requirements for Traditional Land Use

Ranking	Effect	Information Required to Enable Assessment of Effect
7	Hydrocarbon or chemical spill	• Baseline data on harvesting sites and camps • Baseline data on species and timing of harvests • Baseline data and monitoring on species harvested and quantity
6	Coastal disturbance	• Baseline data on harvesting sites and camps • Baseline data on species and timing of harvests • Baseline data and monitoring on species harvested and quantity
4	Interference with traditional land and resource use (all phases)	• Baseline data on harvesting sites and camps • Baseline data on species and timing of harvests • Baseline data and monitoring on species harvested and quantity

5.10.1.3 Existing Information

Overview of Existing Data

Traditional land use is supported by a strong base of knowledge.

All six Inuvialuit communities have their own community conservation plans (e.g., Tuktoyaktuk CCP 2000) that detail traditional land use areas and provide information on their overall importance to the community. The Inuvialuit Harvest Study, which ran from 1987 to 1992, provides information on harvest locations, timing of harvest and numbers by community.

The Fisheries Joint Management Committee's (FJMC) Beluga Monitoring Program keeps close track of the number of whales harvested each month, locations of harvest and statistical data on the whales.

Environmental assessments in the Inuvialuit Settlement Region must discuss traditional land use in their assessments. These assessments (e.g., Devon 2004) are building an additional base of knowledge on land use. Unfortunately this information is fragmented by project and at times difficult to access.

Overview of Data from Previous Gap Analyses

Previous gap analyses have focused on how animals will be affected by development and, in turn, how harvest success will be affected. Gaps focused on key harvest species such as anadromous fish, polar bears, seals, whales, and seabirds. General gaps included:

- effects of infrastructure on movements of animals and resulting changes to harvest levels
- infrastructure leading to higher mortality of animals (e.g., polar bear) and the resulting effects on harvest levels
- effects of contamination on the health and quality of animals (e.g., fish tainting) and the impact this may have on harvesting

Comparison of Existing Data with Previous Data Gap Analyses

Previous gap analyses have focused on the effects on animals that are harvested by Inuvialuit and how these effects may alter harvest success. These gaps, which are addressed further under different discipline headings in this report, have been partially but not completely filled and more research is required. . The accessibility of harvest grounds should also be considered when addressing data gaps.

Recent and Ongoing Research

Traditional land use was examined as part of Devon's Comprehensive Study for their offshore drilling program (Devon 2004). A study was conducted through the Inuvialuit Cultural Resource Centre to capture coastal- and marine-related traditional knowledge and use contained in transcripts from the COPE and Oblate tapes. The six community conservation plans are being considered for review. Whether this review will include a review of current land use practice is not known at this stage. The Beaufort Sea Partnership which is in the process of developing an integrated management plan for the Beaufort Sea has struck a traditional knowledge working group to advice on the collection and use of traditional knowledge in the integrated management process and plan. Traditional knowledge is interpreted to include traditional land use.

5.10.1.4 Identification of Data Gaps

The establishment of the Inuvialuit Settlement Region relied heavily on traditional land use. Over time land use patterns change based on where people live and on the changing migration routes of the animals they harvest. The information in Table 5-47 applies to those areas where baseline data is limited or requires updating or validating. A current understanding of past and current harvesting areas is required prior to exploration or development; therefore gaps should be filled prior to the sale of leases.

Table 5-47 Existing Information and Identified Data Gaps for Traditional Land Use

Ranked Effect	Information Required to Enable Assessment of Effect	Existing Information and Recent/Ongoing Research	Quality of Existing Data	Data Gap
Hydrocarbon or chemical spill	Baseline data on harvesting sites and camps	Existing data available for most areas, some validation may be required for remote areas.	High for most areas	Validate location of camps in remote coastal areas
	Baseline data on species and timing of harvests	Existing data	High	No gaps
	Baseline data and monitoring on species harvested and quantity	Harvest study but ended in 1992	Medium (data becoming outdated)	Update harvest data and analyse existing data
Coastal disturbance	Baseline data on harvesting sites and camps	Existing data available for most areas, some validation may be required for remote areas	High for most areas	Validate location of camps in remote coastal areas
	Baseline data on species and timing of harvests	Existing data	High	No gaps
	Baseline data and monitoring on species harvested and quantity	Harvest study but ended in 1992	Medium (data becoming outdated)	Update harvest data and analyse existing data
Interference with traditional land and resource use (all phases)	Baseline data on harvesting sites and camps	Existing data available for most areas, some validation may be required for remote areas.	High for most areas	Validate location of camps in remote coastal areas
	Baseline data on	Existing data	High	No gaps

	species and timing of harvests			
	Baseline data and monitoring on species harvested and quantity	Harvesting study but ended in 1992	Medium (data becoming outdated)	Update harvest data and analyse existing data

5.10.2 Final Prioritization of Research Requirements

Table 5-48 introduces timing to the ranked effects and data gaps to provide a final prioritization. The aim of this step is to provide an objective and useful list and avoid a conclusion where all research requirements are considered to be high priority.

The process could result in a research requirement that is considered a lower priority in ecological terms being moved up in the ranking; this is based on when the information will be required in the development process.

Table 5-48 Research Requirement Prioritization for Traditional Land Use

Ranked Effect	Data Gap	Time to Obtain Data	When in the Development Process is the Data Required	Relative Overall Ranking
Hydrocarbon or chemical spill	Validate location of camps in remote coastal areas	1–2 years	Exploration to decommissioning	High
	Update harvest data and analyse existing data	5 + years	Exploratory to decommissioning	High
Coastal disturbance	Validate location of camps in remote coastal areas	1–2 years	Exploration to decommissioning	High
	Update harvest data and analyse existing data	5 + years	Exploration to decommissioning	High
Interference with traditional land and resource use (all phases)	Validate location of camps in remote coastal areas	1–2 years	Exploration to decommissioning	High
	Update harvest data and analyse existing data	5 + years	Exploration to decommissioning	High

5.11 Accidents and Malfunctions

5.11.1 Introduction

Although consideration of accidents and malfunctions is inherent within each of the earlier VEC sections, given the high profile and importance of the subject, it is also addressed as a standalone section. The discussion focuses on the research and planning requirements in relation to an oil spill, given that this is the primary accidental event with the potential to result in significant effects on biophysical VECs.

5.11.2 Research Priorities

Considerable effort is underway internationally to improve understanding of how spilled oil behaves in Arctic and ice-infested waters. In addition, numerous response strategies are being tested in an attempt to determine the most appropriate spill response in a given situation. For instance, the Mechanical Oil Recovery in Ice Infested Waters (MORICE) Joint Industry Program was initiated in 1995, to develop technologies for more effective recovery of oil spills in ice-infested waters. This was a multinational effort involving Norwegian, Canadian, American and German researchers, with SINTEF Applied Chemistry coordinating the study. The study involved practical trials of ice processing testing during freeze-up at Prudhoe Bay in the Alaskan Beaufort Sea. The study was completed in 2003 and a series of technical reports and recommendations published. Another Joint Industry Program on Oil in Ice is currently in progress in conjunction with SINTEF.

Although considerable research is being undertaken, currently there is no capability in the Canadian Beaufort Sea to deal with a large oil spill, and detailed information relating to the fate and effects of oil in the Beaufort Sea is lacking.

Table 5-49 lists the research priorities relating to oil spills from each of the previous VEC sections. A general section is provided at the beginning of the table which encompasses issues common to all VECs.

Table 5-49 Research and Planning Priorities for Accidental Hydrocarbon Spills (with an emphasis on oil)

Ranked Effect	Data Gap	Time to Obtain Data	When in the Development Process is the Data Required	Relative Overall Ranking
General				
Hydrocarbon or Chemical Spill	Dispersion modelling: need to verify current oil spill models for conditions in Beaufort Sea (models have advanced substantially in last decade)	1–2 years	Exploration drilling	High
	Update on methods to contain and collect spilled hydrocarbons in arctic conditions	2–3 years	Exploration Drilling	High
	Oil Spill Sensitivity Atlas: need to update Beaufort Sea Atlas to reflect current biophysical and cultural conditions, as well as infrastructure and response measures	2 years	Exploration Drilling	High
	Fate and effect of released hydrocarbon with an emphasis on the dynamics of contaminant cycling	2–10 years	Exploration Drilling	High
	Behaviour of oil under ice	2–3 years	Exploration Drilling	Moderate
Physical Oceanography				
Hydrocarbon or Chemical Spill	Additional information on the fate and transport of oil beneath the ice cover in	2–3 years	Exploration and Production	Moderate

	Beaufort Sea			
Chemical Oceanography				
Change in water quality	Dynamics of contaminant cycling	ca. 2–10+ years depending on location	Exploratory Drilling	High
Change in sediment Quality	Dynamics of contaminant cycling	ca. 2–5 years	Exploration Drilling	High
Plankton				
Hydrocarbon or chemical spill	Data on embryonic and physiological effects of contaminants on plankton	5–10 years	All phases	Low
	Data on behavioural responses (e.g., avoidance) of plankton due to changes in water quality	5–10 years	All Phases	Low
Benthos and Macro-invertebrates				
Hydrocarbon or chemical spill	Data on effects of contaminants on the health of benthos and macro-invertebrates	3–5 years	All phases	Moderate
Macrophytes				
Hydrocarbon or chemical spill	Data on species presence, distribution and abundance of macrophytes	1–3 years	Seismic through to Decommissioning	High
	Data on the effects of contaminants on plant growth and health	2–5 years	Seismic through to Decommissioning	Moderate
Marine and Anadromous Fish				
Hydrocarbon or chemical spill	Data on fish tainting and quality	1–3 years	Exploration and Production	Moderate
	Data on effects of contaminants on fish health	1–2 years	Exploration and Production	Moderate
Seals				
Hydrocarbon or chemical spill	Physiological effects (long term)	2–5 years	Seismic, exploration drilling, fabrication, production	Moderate
	Ecological effects (i.e., prey)	10 years	Seismic, exploration drilling, fabrication, production	High
	Mitigation and effectiveness in ice conditions	2–5 years	Seismic, exploration drilling, fabrication, production	High
Polar Bear				
Hydrocarbon or chemical spill	Physiological effects (short and long-term)	10 years	Exploration drilling, production	Moderate
	Behavioural effects	2–5 years	Exploration drilling, production	Moderate
	Ecological effects (i.e.,	10 years	Exploration drilling,	Moderate

	prey)		production	
	Knowledge of/effectiveness of mitigation	10 years	Exploration drilling, production	High
Marine and Nearshore Avifauna				
Hydrocarbon or chemical spills	Effectiveness of bird deterrent/ dispersal techniques	3+ years	Exploratory drilling	High
	Data on bioaccumulation of toxins in benthic feeding birds	3+ years	Exploratory drilling	High
Archaeology				
Disturbance from cleanup activities associated with a hydrocarbon spill	• Inventory of coastal sites • More detailed regional data regarding site types, distribution and interpretive potential	2 years	Exploration and Production	High
Traditional Land Use				
Hydrocarbon or chemical spill	Validate location of camps in remote coastal areas in order to update oil spill sensitivity atlas and develop spill response plans	1–2 years	Exploration to decommissioning	High
	Update harvest data and analyse existing data in order to update oil spill sensitivity atlas and develop spill response plans	5 + years	Exploratory to decommissioning	High

6 Overall Research Priorities

6.1 Introduction

In discussion with the ESRF Technical Advisory Group (TAG) it was agreed that a multi-disciplinary workshop should be held to refine the list of discipline-specific data gaps for the Beaufort Sea, as well as prioritize these data gaps across all disciplines. The workshop involved a broad range of selected specialists from government, industry, aboriginal organizations and other organizations. The following sections describe the stakeholder input process, and the final prioritization of data gaps.

6.2 Stakeholder Input

To efficiently facilitate stakeholder input to the final identification of the key overall research priorities, a series of web-based workshops were held in May 2008. Representatives of industry, government, regulatory and scientific bodies across Canada were invited to attend. The list of invitees was compiled with input from KAVIK-AXYS discipline specialists and the TAG, and approved by the TAG.

Three web-based/ "WebEx" workshops covered the following topics: biological VECs, physical/archaeological and traditional use VECs, and accidents and malfunctions, including oil spills. Prior to each workshop, the attendees were provided with the draft gap analysis tables and listings of research priorities in preparation for providing feedback during the conference. Each workshop commenced with an overview of the scope and objectives of the study. For each VEC, the KAVIK-AXYS author provided an overview of the results and an explanation of the rationale for the selection of the research gaps. The discussion was then opened to the attendees to ask any questions and provide feedback. Thus, each workshop culminated in a discussion and agreement by attendees on the final research priorities.

6.3 Final Ranked Research Priorities

Table 6-1 lists the final research priorities and gaps that were determined during the WebEx workshops. The studies were selected from the draft lists presented, with adjustments as necessary, based on feedback from stakeholders during the sessions. The studies are represented in the order in which the VECs appear throughout the main document, and not in order of comparative importance. Each of the research gaps are considered to be a high priority.

Table 6-1 High Research Priorities as Agreed at WebEx Workshops

VEC	Research Priority
Physical Oceanography	Assessment of effects of climate change and industrial activities on ice stability in landfast ice zone and deepwater offshore (i.e., in vicinity of 2008 and 2009 offshore leases)
Plankton/Benthos/Macrophytes/Marine and Anadromous Fish	Baseline surveys of deepwater plankton, benthos and fish (species composition, abundance, seasonal distributions and habitat use)
	Identification of key areas for macroalgae (e.g., kelp) and macro-invertebrates (e.g., crabs, squid); stratify by area's most at risk due to potential industrial development
	Determination of fish habitat use (overwintering, spawning, migration); stratify by five major habitat types (brackish/Mackenzie plume, inshore pelagic, inshore benthic, offshore pelagic, offshore benthic)
Marine Mammals	Prediction of bowhead whale feeding concentration areas (how do oceanographic conditions result in copepod blooms that result in concentrations of feeding bowhead whales)
	How to detect bowhead whales and beluga whales during low visibility conditions (i.e., night, fog, high seas) in conjunction with marine mammal observations during offshore seismic surveys
	How to predict effects of multiple offshore seismic programs on marine mammals and fish
	Philopatry of ringed seals (i.e., annual re-use of the same area by the same seals each year)
	Vibroseis effects on polar bear denning (response of denning bars to equipment and human disturbances); includes determination of underwater/under ice sound propagation of vibroseis
	Effects of climate change on polar bear distributions and potential for increased bear-human conflicts[1]
Marine and Nearshore Avifauna	Update on offshore bird distributions (focus on specific groups such as eiders, loons, etc., and specific geographic areas most at risk (e.g., offshore lease areas)
Archaeology and Palaeontology	Assessment of archaeological and palaeontological resources in coastal areas; stratify assessments by areas of high risk due to natural processes (slumping and erosion) and potential industrial activities. This will form basis for later development of broader archaeological atlas (i.e., assessment of sites, value and interpretive potential)

	Identification of ship wreck sites. Use of historical literature on sinking's of vessels to identify potential sites. Note need for guidelines on identification of shipwreck artefacts during site-specific surveys for individual projects
Traditional Land Use	Identification of important coastal camp sites and harvesting sites, with emphasis on remote locations (i.e., gaps in current inventory)
	Update of harvest studies and development of means to make data available in some form to industry
Accidents and Malfunctions	Dispersion modelling: need to verify current oil spill models for conditions in Beaufort Sea (models have advanced substantially in last decade); includes updating of oceanographic data to satisfy updated modelling requirements
	Update on methods to contain and collect spilled hydrocarbons in arctic conditions
	Oil Spill Sensitivity Atlas: need to update Beaufort Sea Atlas to reflect current biophysical and cultural conditions, as well as infrastructure and response measures
	Fate and effect of released hydrocarbons with an emphasis on the dynamics of contaminant cycling; need to consider under ice and open water situations, as well as behaviour of oil under ice
[1] Although consideration of the effects of climate change were not included within the scope of this study, the issue was raised during the WebEx conferences in relation to polar bear, and it was agreed that in this instance it should be included as a research priority	

Table 6-2 lists the remaining research gaps, prioritized as high by the discipline leads, but not selected for inclusion within Table 6-1. The data gaps identified here are presented in the order in which the VECs appear throughout the main document, and not in order of comparative importance. Each of the research gaps is considered to be a high priority

Table 6-2 Additional High Research Priorities

VEC	Research Priority
Chemical Oceanography	Dynamics of contaminant cycling (this would be covered by the fate and effect of released hydrocarbons (see above)
Marine and Anadromous Fish	Monitoring data for subsistence fisheries
Marine Mammals	Timing and spatial use of habitat for Polar Bear
	Behavioural responses of Polar Bear to coastal infrastructure (short and long-term)
Marine and Near Shore Avifauna	Update information on the effectiveness of bird dispersal/deterrent techniques in the Beaufort Sea during winter and summer
	Baseline information on bioaccumulation of toxins in benthic feeding birds
Archaeology and Palaeontology	Monitoring data at known slumpage to determine presence of archaeological/palaeontological materials and effects on these materials (site specific)
	Palaeontological site inventory at existing borrow sites
	Monitoring data at known conflicts between ice pads/winter roads and sites

7 Additional Issues for Consideration

During the stakeholder consultation process a number of issues were raised which were not within the scope of the study. However, given the importance of some of the issues, it was considered prudent that they should be recorded. These included:

- *Engineering Design*. The study did not identify physical issues in relation to engineering design (i.e., seabed stability, ice dynamics). The scope of the study was to address biophysical data gaps from the perspective of environmental assessment and regulatory review only. The workshop participants acknowledged that this type of research is within the mandate of the Program and Energy Research and Development (PERD) rather than ESRF.
- *Climate Change*. The scope of the study did not include specific consideration of climate change and how it could affect the recommendations of the study. Therefore, all recommendations are based on current understanding of the VECs and do not include potential effects of climate change on the future sustainability of VECs.
- *Socio-economic effects and implications to community wellness and traditional culture* were not within the scope of work for this review. Based on the concerns raised during the Mackenzie Gas Hearing, there is increasing concern at the community and regional levels about the effects of oil and gas development on local and regional economies and culture.

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