The Yukon North Slope Pilot Project: An Environmental Risk Characterization Using a Pathways of Effects Model

S.A. Stephenson and L. Hartwig

Oceans Programs Division
Central and Arctic Region
Fisheries and Oceans Canada
501 University Cres.
Winnipeg, Manitoba
R3T 2N6

2009

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2896

Fisheries and Oceans Canada Pêches et Océans Canada

Canada

Canadian Manuscript Report of
Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 901-1425 were issued as Manuscript Reports of the Fisheries Research Board of Canada. Numbers 1426-1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des
sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministére des Pêches et des Océans, e'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complèrwa. Le titre exact paraît au-dessus du résumés de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques,*et ils sont classés dans l'index annuel des publications scientifiques et techniques du Ministére.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et aprés le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur don't le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2896

2009

The Yukon North Slope Pilot Project:
An Environmental Risk Characterization
Using a Pathways of Effects Model

by

S.A. Stephenson and L. Hartwig

Oceans Programs Division
Central & Arctic Region
Fisheries and Oceans Canada
501 University Crescent
Winnipeg, Manitoba
R3T 2N6

Cat. No. Fs Fs 97-4/2896E ISSN 0706-6473

Correct citation for this publication:

Stephenson, S.A., and L. Hartwig. 2009. The Yukon North Slope Pilot Project: An Environmental Risk Characterization using a Pathways of Effects Model. Can. Manuscr. Rep. Fish. Aquat. Sci. 2896: vi+57p.

TABLE OF CONTENTS

ABSTRACT

Stephenson, S.A., and L. Hartwig. 2009. The Yukon North Slope Pilot Project: An Environmental Risk Characterization using a Pathways of Effects Model. Can. Manuscr. Rep. Fish. Aquat. Sci. 2896: vi+57p.

Pathways of Effects (PoE) are a graphic representation of the predicted relationships between human activities and the impacts they can produce within ecosystems. Understanding these relationships helps to identify how to mitigate the effects. Moreover, understanding where cumulative effects are likely to occur helps in characterizing the environmental and planning assessment to help managers decide how best to regulate certain activities.

We developed a series of PoE models as part of a pilot project for the Yukon North Slope in the Beaufort Sea to determine what activities might have a potentially negative effect on valued or vulnerable components of the ecosystem. Part of the purpose of this pilot was to see how these models worked in "real life" and to determine if PoE might be a useful tool which could be used to help manage some activities in the Beaufort Sea.

Assessment of the models we created suggests that the largest potential threats to the Yukon North Slope may come from oil and gas development (both exploration and exploitation). Transportation, especially if it does increase due to more use of the Northwest Passage or increased tourism, brings with it other possible risks. Additional activities we examined were found to have far fewer risks associated with them. Ultimately, however, even high risk activities can be permitted if enough care is taken in their planning and execution.

This pilot study showed the usefulness of the Pathways of Effects method to display the potential threats from proposed activities and therefore could be used as a valuable tool to assist marine planning by industry, stakeholders, managers and co-managers. It also shows how Pathways of Effects can be the basis of an essential analysis role as a precursor for risk assessment. Pathways of Effects is therefore a central tool in risk management and can be used to inform the decision making process in environmental assessments and marine management.

Key Words: Pathways of Effects, Beaufort Sea, Yukon North Slope, Ecologically and Biologically Significant Areas, Marine Protected Area, Integrated Ocean Management, Ecosystem-Based Management, Risk Assessment.

RESUME

Stephenson, S.A., et L. Hartwig. 2009. The Yukon North Slope Pilot Project: An Environmental Risk Characterization using a Pathways of Effects Model. Rapp. man. can. sci. halieut. aquat. 2896: vi+57p.

Les diagrammes de séquences des effets (SdE) sont utilisés pour décrire les relations prévues entre les activités humaines et les effets qu'elles peuvent avoir sur les écosystèmes. La compréhension de ces relations aide à trouver comment en atténuer les effets. En outre, le fait de savoir où des effets cumulatifs sont susceptibles de se produire favorise l'évaluation environnementale et la planification, ce qui permet d'aider les gestionnaires à décider de la meilleure façon de régir certaines activités.

Nous avons développé une série de modèles de SdE dans le cadre d'un projet pilote pour le Versant nord du Yukon, dans la mer de Beaufort, afin de déterminer quelles activités pourraient avoir des incidences négatives sur des éléments précieux ou vulnérables de l'écosystème. Une partie de l'objectif de ce projet pilote était de voir comment ces modèles fonctionnaient dans la « vraie vie » et de déterminer si les SdE pourraient constituer un outil utile pour aider à gérer certaines activités, dans la mer de Beaufort.

L'évaluation des modèles que nous avons créés suggère que les plus importantes menaces pour le Versant nord du Yukon pourraient venir du développement du pétrole et du gaz (tant de l'exploration que de l'exploitation). Le transport, surtout s'il s'accentue en raison d'une utilisation accrue du passage du Nord-Ouest ou d'une augmentation du tourisme, suscite d'autres risques potentiels. En examinant des activités supplémentaires, nous avons découvert que beaucoup moins de risques leur étaient associés. En fin de compte, toutefois, même des activités présentant des risques élevés peuvent être autorisées, si l'on accorde suffisamment de soin à leur planification et à leur exécution.

Ce projet pilote a démontré l'utilité de la méthode de séquences des effets pour montrer les incidences possibles des activités proposées et, de ce fait, elle constitue un outil très utile pouvant être utilisé pour aider l'industrie, les intervenants, les gestionnaires et les cogestionnaires à faire une bonne planification maritime. Le projet a également démontré en quoi les séquences des effets peuvent constituer la base d'une fonction analytique essentielle, en tant que précurseure de l'évaluation du risque. Les séquences des effets sont de ce fait un outil central de la gestion du risque, et peuvent contribuer au processus décisionnel lié aux évaluations environnementales et à la gestion maritime.

Mots réservés: Séquences des effets, mer de Beaufort, Versant nord du Yukon, régions importantes du point de vue de l'écologie et de la biologie, aire marine protégée, gestion intégrée des océans, gestion axée sur l'écosystème, évaluation du risque.

INTRODUCTION

Pathways of Effects (PoE) models were first developed to meet Fisheries and Oceans (DFO) Habitat Management requirements. These early models dealt with single activities that affected habitats and species for which DFO had a legislated mandate to manage or protect. As the Habitat models were project-based, they demonstrated only the relationship between a single activity, the pressures created by the activity, and the final, potential negative effects on fish and fish habitat. While the Habitat models worked well for highlighting which activities were causing effects of concern, they had limited application where multiple activities were occurring or where, as an example, an activity could potentially affect fish or marine mammals through multiple pressures. The Aquaculture Management Directorate of DFO has also developed their own PoE models to show the potential impact of aquaculture practices on natural ecosystems. Other DFO sectors have expressed varying degrees of interest in applying PoE models to achieve their own mandates.

As DFO moves away from single species management to Integrated Management (IM) and includes Ecosystem-Based Management (EBM) considerations, it is becoming clear that management decisions will be increasingly risk-based. This means identifying which parts of the ecosystem are most likely to be negatively affected by activities and which activities are likely to have the greatest effects on these ecosystem components. PoE models can be a central tool in risk analysis and provide the science-based foundation for the environmental assessment process. PoE models help managers to prioritize and focus limited resources on identifying, managing and regulating those activities that have the greatest potential to produce negative effects on the most important resources. By visually establishing the linkages between activities and threats to the ecosystem, PoE models fit within the Risk Assessment framework which can help DFO meet its responsibilities under the Treasury Board Risk Management guidance (Treasury Board of Canada Secretariat, 2001). PoE models can also help identify which regulators should be involved in the planning and management process in order to minimize or avoid negative effects to the ecosystem.

Pathways of Effects are essentially a conceptual desk-top tool in that it is a model and there is no guarantee that the relationships illustrated by the PoE model diagrams will occur. PoE models are created for specific geographic areas which may be either small or large. PoE models use the best available information about the potential effects of an activity, often using information about how the activity has influenced the environment under similar circumstances in different geographical locations. Creating PoE models does rely on the knowledge, and to some extent, the judgement of the people creating them and as such, the creation of PoE models is to a large extent a qualitative process. PoE models allow for a greater understanding and visual illustration of the complexity present within ecosystems.

Because PoE models are graphic, they are an excellent communication tool by which the cause-effect relationship of planned activities can be presented to stakeholders or managers. In addition, because multiple activities are displayed at once, it is possible to view where potential cumulative effects may arise due to multiple activities. PoE models may therefore be an important part of the decision making process when deciding whether or not certain activities should be permitted to proceed.

An Oceans-Habitat National Working Group led by the Oceans sector and including NHQ representatives from all DFO sectors was formed in mid 2008 to look at PoE as the way forward for managing human activities and informing risk analysis within the department. One goal of the Working Group is to eventually develop a library of PoE models with all known activities and pressures operating in the marine environment validated by Science that can be used nationally. Because PoE can be applied to more than just DFO mandated activities, there is an expectation and hope that once work has been competed on the models they will be used by other departments, agencies or Environmental Non-Government Organizations (ENGOs) in their own decision making processes.

With the recent completion of an Integrated Ocean Management Plan for the Beaufort Sea Large Ocean Management Area (LOMA) (Beaufort Sea Partnership, 2009) there was interest in determining the value of developing PoE models to help support decisions in regards to key issues or areas of commercial or conservation interest. The intent was to avoid attempting to manage all activities throughout the Beaufort Sea at once, perhaps using a variety of tools and methods each suited for specific circumstances. Additionally, efforts by DFO and Indian and Northern Affairs Canada (INAC) to arrive at a tool which could be used to support decisions regarding commercial use of specific areas suggested that PoE models could provide assistance. PoE was therefore not only a tool that could be used to look at the potential upsurge in commercial activities, but also a means to support management decisions in areas like the Ecologically and Biologically Significant Areas (EBSA) of DFO (DFO, 2004). Because many of the activities projected to take place in the Beaufort will be similar from area to area, PoE models were thought to be well suited as a management tool. Once an understanding of an activity and its pressures were well known, the model could perhaps be applied to other areas where that same activity might occur and where the species or aspects of the ecosystem were similar. It was with these thoughts in mind that we began exploring PoE in a pilot study as a possible tool to support management decisions in the Beaufort Sea.

The Central and Arctic Region of DFO differs from other DFO regions in that the majority of the management area includes large portions covered by comprehensive land claims. The majority of people within the coastal region of the western Arctic are Inuvialuit and many still maintain a traditional subsistence culture. While this itself cannot be built into PoE models, subsistence fishing, marine mammal harvest and other traditional uses were considered as we produced the models. The fact that the Arctic marine environment is ice covered for over 50% of the year limits the window of commercial activity to only a few months and could result in potential conflicts between groups wanting to use the same areas for different commercial purposes possibly interfering with subsistence activities. While this aspect cannot be built into the PoE models, it is discussed when appropriate.

METHODS

Perhaps the most widely used PoE model is called a holistic model. It displays all activities and pressures at once (Fig. 1). The benefit of this model is illustrating where multiple pressures from several activities may have a cumulative effect on ecosystem components. Holistic models show the socio-economic dependencies at the top of the diagram illustrating how these dependencies rely on Valued Ecosystem Components (VECs) (see below). The creation of a holistic model showing all activities on the Yukon North Slope was one of the goals of this study. However, because these models begin by looking at a single activity and follow their effect on the VECs, we present our results below as a series of individual activity models before showing a final holistic model. PoE models for this manuscript were created using Microsoft Visio and methods determined by the Oceans-Habitat National Working Group.

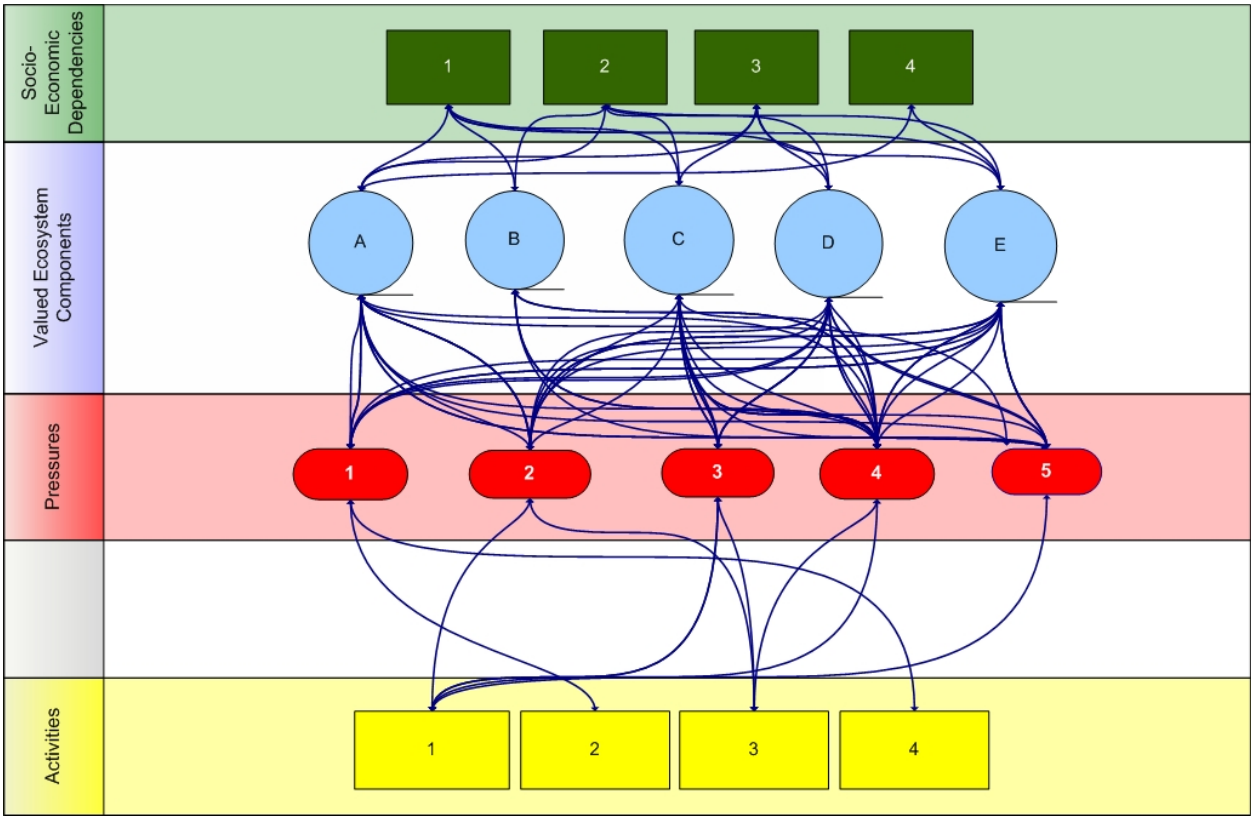

Figure 1: A fictitious example of a simple Pathways of Effects holistic model.

Terminology

Pathways of Effects uses a terminology derived largely from DPSIR (Drivers, Pressure, State, Impact, Response) framework (Smeets and Weterings, 1999) (Fig. 2). However, the PoE terminology is different enough from that of DPSIR that some explanation of terms is required. Many of the terms we used have equivalencies so the reader is advised that not all PoE documents may use the same terms. The terms used in this manuscript are defined below.

Activities – These are also sometimes referred to as drivers, social-economic activities or anthropogenic activities. Regardless of name, they all have an affect on the ecosystem or some component of the ecosystem. Activities are typically shown at the bottom of PoE diagrams. By nature, activities in the marine environment are usually commercial/industrial activities such as fishing, marine transportation or oil and gas related activities. For this pilot study we were largely concerned with commercial activities which showed simple and fairly direct linkages to ecosystem components and could be directly managed so that the process of using PoEs could be illustrated in a straightforward manner. We included subsistence fishing/hunting as an activity primarily due to its' great importance to people in the area.

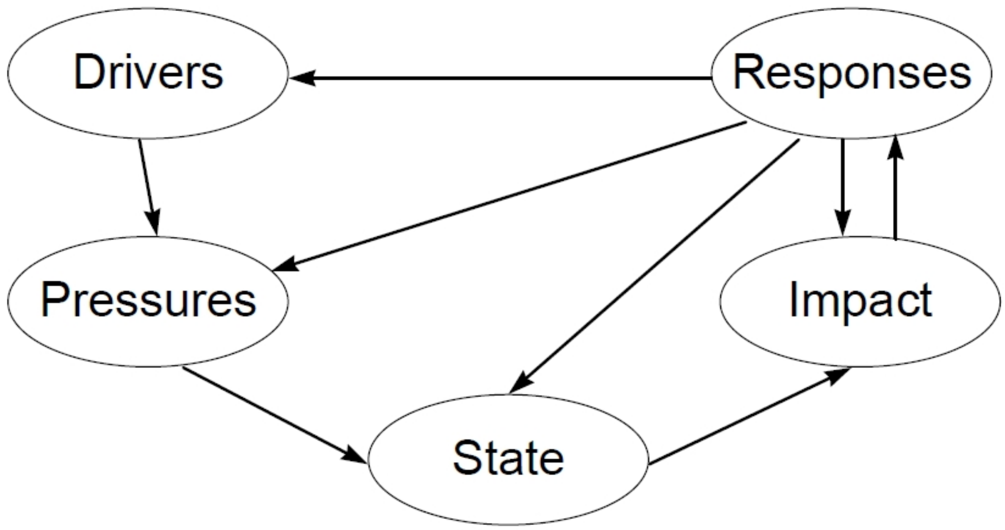

Figure 2: The DPSIR (Driver, Pressure, State, Impact, Response) model (from Smeets and Weterings, 1999) from which Pathways of Effects terminology is largely derived.

Stressors – Activities create stress on the VECs (Smeets and Weterings, 1999) and are represented by the lines in the PoE diagram that extend from the activities to the pressures. Stressors represent the area where planning may make it possible to use mitigation to lessen or eliminate the effect of the activity on the ecosystem components. Stressors are always denoted with lines of the same thickness and colour. To use colours, such as the "stoplight" green-amber-red or to use lines of different thicknesses or types of lines (*e.g.*, dashed) would infer predetermination of severity or likelihood of harm that is not part of the PoE process.

Pressures – Pressures are the direct result of human activities which have an effect on all or portions of the ecosystem. Pressures are the things we are interested in ameliorating if we are to protect the ecosystem and its components. Pressures are typically described as changes to or additions of things to the ecosystem (*e.g.*, destruction of habitat, introduction of pollutants, noise from industrial activities, introduction of non-indigenous species). It should be noted that because the terms pressure and stressor are often interchangeable, so to prevent confusion we have not labelled stressors in our diagrams and instead refer only to pressures.

Valued Ecosystem Components (VECs) – Whether they are called Vulnerable Ecosystem Components or Aquatic Ecosystem Goods and Services, these are specific portions of the ecosystem that people are most interested in protecting due to some value, cultural, social, aesthetic, economic or scientific, over other such components (*e.g.*, Canadian Environmental Assessment Agency, 2006). The selection of VECs does not mean that other components of the ecosystem are less valuable, only that there is a focus on these components as they are considered important for some reason (see DFO, 2006). In some models, VECs will form the endpoint of the diagram and be at the top of the diagram.

Lines are drawn from the pressures to the VECs to indicate that the pressure has some kind of potential link to the VEC. Similar to stressors, lines connected from pressures to VECs are of the same weight. The reason for this is because the functional effects of different stressors can't be directly compared and doing so would infer some level of risk assessment. Noise may, as an example, affect a given VEC far more than an oil spill under some circumstances and noise does not affect all VECs in a similar manner.

Socio-Economic Dependencies (SED) – The Socio-Economic Dependencies or values mirror the activities at the bottom of the PoE diagram. While not all human activities actually depend on the VECs remaining in good condition for the activities to occur (*e.g.*, marine transportation does not require clean water or the presence of marine mammals to take place), many of them do and thus lines are placed from the VECs to the SEDs to show the reliance of the SEDs on the VECs remaining healthy and (partially or completely) unaffected by the activities.

The Study Area

The Yukon North Slope lies in the extreme northwest corner of Canada sharing a border with Alaska on the west and the Northwest Territories to the east. There are no communities and no permanent inhabitants of the many traditional Inuvialuit camps in the area. There are no roads and no forestry, agriculture, non-renewable resource extraction activities or port and docking facilities within the area. Herschel Island Territorial Park, situated approximately 5 km off the mainland, is staffed only during the summer months and is accessible by boat or plane. Ivvavik National Park lies on the mainland opposite of Herschel Island and itself extends from an eastern border marked by the Babbage River to the Alaskan border in the west. Most tourist facilities in Ivvavik are far inland and therefore have little influence on the marine environment.

The Yukon North Slope was chosen for this pilot project for several reasons. The Yukon North Slope is an area that has a long history of human use and has been the location of many research studies and surveys of fish, marine mammals, birds and other wildlife (*e.g.*, Cobb *et al.*, 2008). The Aklavik Inuvialuit Community Conservation Plan (CCP) (2000) designates an area defined as "a 16 km (10 mile) area of coastal waters from the Yukon/Alaska border to the eastern boundary of Escape Reef in Mackenzie Bay" as the Yukon North Slope Coastal Zone. The area is classed in the CCP as category "D" which designates "Lands and waters where cultural or renewable resources are of particular significance and sensitivity throughout the year. As with Category C, these areas shall be managed so as to eliminate, to the greatest extent possible, potential damage and disruption" (Aklavik Inuvialuit Community Conservation Plan, 2000). Thus the area has previously been identified by the Inuvialuit as an important and sensitive area worthy of protection.

The creation of Ivvavik National Park in 1984 and Herschel Island Territorial Park in 1987 led to numerous monitoring programs which added to the information available for the North Slope. In addition, work by government agencies and departments besides DFO and by the oil and gas industry led to a good body of knowledge of biological and physical processes occurring within the area. As a result, there was a large amount of data that could be used to help model the effects of potential commercial activities. Creating PoE models in a relatively data rich environment was thought to be preferable rather than attempting to do so in an area in which little was known about the ecosystem. The Yukon North Slope is also the location of a DFO EBSA (DFO, 2004) referred to as the Herschel Island/Yukon North Slope EBSA (Cobb *et al.*, 2008). This EBSA was identified using science and Traditional Knowledge as an important area for a number of species including polar bears, bowhead and beluga whales, numerous species of anadromous fish and aquatic birds. A final advantage of using the North Slope as a pilot over other areas was that it currently has very few current anthropogenic activities working on it.

Geographic Limits of the Study Area

One of the challenges associated with this pilot study was defining the borders. The western boundary was dictated by the Alaskan border while the coast demarcated the southern boundary. We did not want to use latitude to denote the northern boundary believing that this would not properly encompass biological processes. While the area had to include the Herschel Island/Yukon North Slope EBSA, the actual offshore boundaries of the EBSA are rather poorly defined (*e.g.*, Cobb *et al.,* 2008). We decided to follow the 50 m depth contour from the Alaskan border to the area at 137°30'W believing that whatever biological activities were occurring in less than 50 m of water to the east of Herschel Island (*e.g.*, feeding by seals) were also occurring in waters of similar depth to the west, regardless of distance from shore. Thus the North Slope study area was considered all water less than 50 m deep from the Alaskan border to just west of Shingle Point, Yukon (Fig. 3). This created an area which is much further from shore in the west than the east and exceeds the area of what is generally recognized as the Herschel Island/Yukon North Slope EBSA.

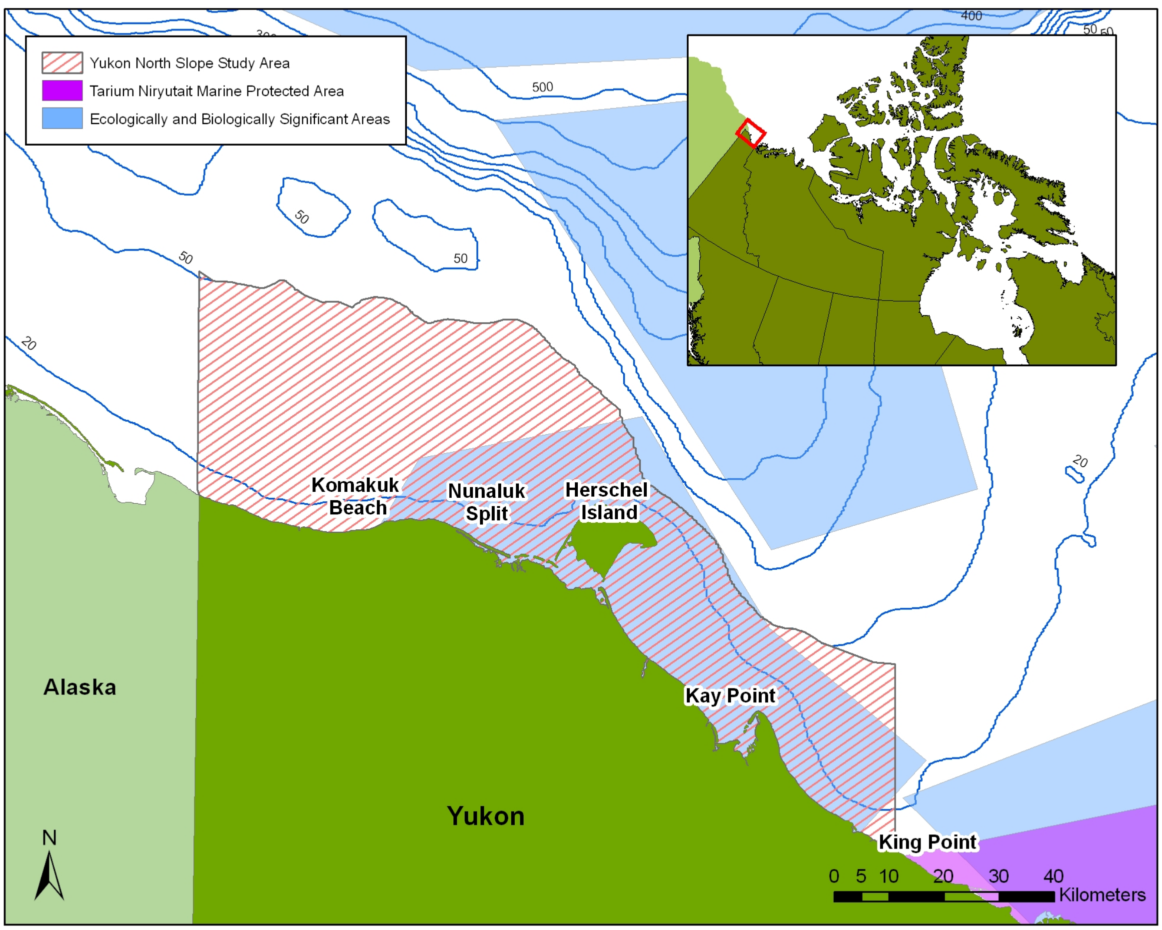

Figure 3: The Yukon North Slope study area.

Activity Scope

This pilot study looked at commercial and subsistence activities, but only those in the marine environment. We therefore rarely discuss the implications of marine activities on any aspect of the freshwater or terrestrial environment. As an example, migratory seabirds are occasionally mentioned in relation to their use of the marine environment for staging or feeding although we do not discuss how activities in the marine environment (*e.g.*, pollution, transportation) might affect nesting areas or breeding success, even though on and offshore activities are linked. We elected to focus on the DFO mandate, including organisms covered by the federal *Fisheries Act*.

Collection of Biological Data

The Ecosystem Overview and Assessment Report (Cobb *et al.*, 2008) prepared for the Beaufort Sea LOMA contained a great deal of information on former studies and the outlook for potential activities on the North Slope. In addition, a report (North/South Consultants, 2009) was contracted to provide the basic background basis for the PoE models and to collect any more recent information not in Cobb *et al.* (2008).

Identification of VECs

The available DFO reports, primary literature manuscripts as well as our own knowledge of the area allowed us to make an informed decision as to what might be the most important components along the North Slope in terms of VECs and ecosystem goods and services. For the purpose of this pilot study we chose the VECs ourselves believing that based on our knowledge of the area, it was possible to pick the same species that local stakeholders would. As a result, the primary species selected were Dolly Varden (*Salvelinus malma*), beluga whale (*Delphinapterus leucas*) and bowhead whale (*Balaena mysticetus*).

The northern form of Dolly Varden, a close relative to Arctic char (*Salvelinus alpinus*), are in the early process of being considered for possible listing under the Canadian Species at Risk Act (SARA) and most of the known stocks of the northern form of this species are found in rivers which drain along the Yukon North Slope (DFO, 2002 a,b,c). The Bering-Chukchi-Beaufort population of bowhead whales are currently listed under the SARA as a species of Special Concern. Beluga whales are an important species to the Inuvialuit and the Tarium Niryutait Marine Protected Area (MPA) is being established in the nearby Mackenzie Delta to protect important beluga whale habitat. Both bowhead and beluga whales were identified as ecologically significant species due to their being “influential predators/nutrient importing and exporting species” as defined in DFO (2006) by Cobb *et al.* (2008). Dolly Varden was identified as a “sensitive” species at the same time (Cobb *et al.*, 2008). We did not make a category specific to SARA species as most were already included as individual VECs and distribution of others on the North Slope was unknown.

For other important ecosystem goods and services, we judged water quality as being the single most important element. Other ecosystem goods and services that we considered included other fish species, especially Arctic cisco (*Coregonus autumnalis*) and shell fish, seals (ringed and bearded) and ice. The Arctic is probably one of the few areas in the country in which ice may be considered a VEC due to its’ importance as a temporary platform for many activities and forms of life, both above and below its’ surface as well as being an important medium for transportation. More detailed information on all VECs considered for this study is presented in Appendix 1.

Because of the quantity of information available to us on bowhead whales and because the Bering-Chukchi-Beaufort population of bowhead whales has been identified as a species of Special Concern under the SARA, we produced a species specific PoE diagram illustrating the potential pressures from all activities on bowhead whales. While the purpose of this PoE model was primarily to show the potential of PoE, it also helped to clearly illustrate the concept of cumulative effects by showing that multiple activities were having a compounding effect on bowhead whales.

Identification of Potential Anthropogenic Activities

At present there are few anthropogenic activities along the Yukon North Slope and, due primarily to the harsh conditions and climate, none that operate on a continual basis. A complete list of activities and greater details on all of them are presented in Appendix 2. What follows below is a brief summary of the activities considered. While many of the potential scenarios using these activities are several years off, we typically took a decadal view in our models so that activities that are possible or even tentatively planned could be incorporated into our models. Activities were identified by our knowledge of the area and reports of current activities (*e.g.*, North/South Consultants, 2009).

Commercial fisheries are non-existent in the area although small commercial fisheries have existed along the North Slope in the past (Kendel *et al.*, 1975). There have also been several attempts over the past decade to explore the area, especially the area immediately east of Herschel Island, to determine if there are specific areas or species that might provide for a small, high market value, fishery. To date, attempts have been unsuccessful. Concerns remain among area residents that a large commercial fishery could one day develop and they have voiced apprehension that commercial fisheries could compete for food with beluga whale and other wildlife species. Some gear types could introduce the potential for entanglements, especially with whales. We did not give commercial fisheries a high probability of occurring in the near future due to the aforementioned factors. A ban on Arctic fishing in the American Beaufort Sea by the U.S. North Pacific Fishery Management Council, with pressure being put on Canada to create its own ban, further suggests that commercial fisheries may never develop in the Canadian Beaufort.

Subsistence fishing has a long history along the Yukon North Slope. Harvests were higher historically before people began adjusting to a wage based economy and settled in communities like Aklavik (Kendel *et al.*, 1975). Harvesting today centres on the use of fish, primarily Dolly Varden (Stephenson, 2004). Fishing still takes place at Herschel Island, Shingle Point and other traditional camping areas typically during the months of July and August. The harvest of beluga whales is very low and bowhead whale hunting has not taken place in the area since 1996 when a single whale was harvested. In consideration of the above, subsistence harvesting was not considered to be a major activity.

The call area for interest by the oil and gas industry along the Yukon North Slope does not include the area within 10 km from shore (T. Duncan, Indian and Northern Affairs Canada, pers. comm.). Therefore, immediate threats from exploration work in this area can be considered almost non existent. Past work in the area resulted in the drilling of two dry wells to the west of Herschel Island (Osadetz *et al.*, 2005). The oil and gas industry is currently concentrating its efforts in the areas offshore the Mackenzie Delta and the Tuktoyaktuk Peninsula. However, threats brought on by movement to or activity within other areas may have some effect on the North Slope area, perhaps, as an example, if oil is piped from offshore through the area.

Marine transportation in the North Slope offshore area is currently limited to those ships bringing supplies into communities (including the possible increased barging of a greater amount of supplies to northern communities from British Columbia rather than from Hay River), ships supporting scientific research or the few industries in the area, a few tourist ships and the few, typically smaller, vessels that attempt to transit the Northwest Passage every year. Ship traffic can be expected to increase should the Northwest Passage become a viable transportation route or if large projects anticipated to take place throughout the region do come to fruition. A port in Bathurst Inlet serving diamond mines in the area, potential mines south of Coronation Gulf, a potential mine near Paulatuk or full production of oil and gas in the Mackenzie Delta leading to the Mackenzie Valley pipeline, could result in greatly increased traffic.

Tourism at both the large and small scale is presently limited along the North Slope. The only known destination for large tourist ships along the Yukon North Slope is at Herschel Island Territorial Park where, infrequently, between 60 and 120 tourists may disembark from a ship within a short period of time (Yukon Environment, 2006). Therefore, large scale tourism is currently limited to the passage of a few large ships per year, generally offshore from the North Slope, but probably not as far offshore as cargo ships. Due to distances involved from any community and the vagaries of weather in the area, there is very limited small boat tourism and that is primarily undertaken by recreational fishers and campers.

Identification of Potential Pressures

The potential pressures brought on by activities such as shipping or oil exploration activities that could operate in the area are described in greater detail in Appendix 3. What follows is a brief overview of those pressures and why they were considered or else considered and then largely discarded.

Noise in the marine environment is increased by almost any anthropogenic activity in the water, including boat/ship traffic, airgun seismic programs, oceanographic surveys, ice breaking and noise generated by oil and gas drilling and production platforms (Richardson *et al.*, 1995; Harvey and Eguchi, 1997). Noise generated during any of these activities may reduce the ability of some marine mammals to communicate or navigate and may cause fish and marine mammals to avoid some preferred feeding, migration or socializing areas. Noise associated with anthropogenic activity, except for that associated with oil and gas extraction, is most often transitory and of short duration although the volumes associated with shipping are almost always the loudest (Richardson *et al.*, 1995). Noise in the marine environment may be masked by other natural noises in the environment such as wind, waves and rain and therefore the distance that anthropogenic noise may travel is often dependant on conditions in the ocean at the time of the activity (Richardson *et al.*, 1995; Sikumiut Environmental Management Ltd., 2008). We did not use any specific frequencies or volumes when attempting to determine the effect of noise on marine life as this would properly be part of a Science review and circumstance specific.

Habitat alteration or degradation of the seabed could be brought on by trawling during commercial fishing activities or by the oil and gas industry creating artificial islands for drilling or while carrying out temporary drilling programs. Trawling could in some cases scour the bottom less than natural processes and the benthic organisms along the Yukon North Slope have evolved to adapt to annual scouring (Carmack and MacDonald, 2002). However, trawl scouring below the limit of natural ice scouring (approximately 50 m) (Lewis and Blasco, 1990) could be cause for concern as it could threaten benthic marine communities that have not adapted to regular disturbances. Depending on the location, negative changes to local organisms could occur due to the creation of artificial islands or borrow pits although it is also possible that artificial structures could create habitat for some species. It is unknown what possible effect an artificial island or a series of islands might have on marine mammals if it were built, as an example, in the middle of a migration route or important feeding area.

Contaminants included, although they were categorized further when considered, hydrocarbon and non-hydrocarbon (including persistent pollutants) based compounds. These could be introduced through oil and gas exploration and exploitation activities (*e.g.*, contaminants from ships, drilling fluids and wastes), any activity that included the use of a ship (*e.g.*, bilge water release, accidental discharge or accident itself) and through long and short-range transport. Many of the most persistent organochlorines are found at high levels in the Arctic (Bidleman *et al.*, 1989) and made their way into wildlife seemingly through long-range transport. Marine mammals, generally being at the top food chain, might potentially be affected by accumulating a successive number of small contaminant releases. We did not include long-range transport in our considerations, but instead discuss only local sources.

Invasive species (also called non-indigenous species) were considered to have the potential for introduction from every ship, barge or other floating structure that entered the waters of the Yukon North Slope. While the greatest potential for introductions might come from near shore ballast water exchange, new species could also arrive attached to the hull of ships or other objects, such as caissons (the basis for some artificial islands used as drilling platforms) towed into the area. Non-indigenous species could also be attached to incompletely dried gear such as trawls, gill nets, cables used for towing seismic arrays, anchor ropes/chains and mooring lines.

There are two main mechanisms (other than catastrophic accident) of biota removal that could occur along the Yukon North Slope; commercial fishing and subsistence activities. Commercial activities, depending on the gear type, could produce a large amount of by-catch and could threaten feeding by some other species through disruption of food chains. Subsistence fisheries operate at a very small scale compared to commercial fisheries and are very directed in their target species. We determined that a limited amount of biota removal may occur during tourism activities, but primarily only those associated with small-scale tourism. Ultimately, we viewed the removal of a few fish during small-scale tourism as not being a significant pressure. Until or unless commercial fishing begins in the area, we considered biota removal as only a minor concern with localised, ephemeral effects.

Gear loss resulting from commercial or subsistence fishing was considered possible, but only gill nets and the lines from other stationary gears would pose a risk to marine life. Other gear types (crab pots and trawls) would collapse upon loss or rot quickly therefore no longer posing harm to marine life. Scientific research was thought to probably not have gill net loss due to the tendency to remain close to the gear or have only brief soak times, thereby reducing the potential for loss. The use of both crab pots and trawls along the Yukon North Slope is currently restricted to research use.

Marine transportation (shipping) considered the physical movement of all types of ships and concerned the possibility of ship strikes to large whales as well as changes to ice conditions. Oil/fuel spills and noise are discussed separately and were considered unique pressures and are also possible. As a result of the possible pressures considered, our concerns here were mostly from large tankers, container ships or research vessels of great weights as smaller vessels do not have ice breaking capability or carry large amounts of fuel.

Several other pressures were considered but not included in our models. These pressures included sedimentation and the introduction of pathogens and nutrients. While these could all be important for some PoE models and under some circumstances, we viewed these as having only a minimal effect on the VECs or not likely to occur. As an example, the large sediments load brought in by the Mackenzie River seemed likely to dwarf any possible anthropogenic input. Excluded pressures are discussed below.

Environmental Risk Characterization and Assessment

Environmental risk characterization and assessment as they relate to ecological assessment are sometimes called hazard characterization and assessment, environmental characterization or ecological risk assessment (EPA, 1992). This is far beyond PoE, but something we felt was necessary to illustrate how PoE can feed into this process and how an analysis of risk can make the results obtained from PoE more useful. Risk characterization, in this context, is one step in a decision making process that can assist in making management decisions by helping to determine the overall effect of various anthropogenic activities on ecological endpoints (*i.e.*, VECs). The objective of risk characterization is to identify and assess the combined effects of both the probable effect and risk of the pressure occurring. This provides a comparable set of values which can then be ranked in terms of likely magnitude and impact. Creating the PoE models provide the information required so that the risk can be assessed as the probable result of spatial overlap and the severity and likelihood of the identified pressures.

As outlined in Allen *et al.* (2006), the first step in the analysis of risk is problem formulation and model selection. In this case, we used PoE models as a visual tool to illustrate the relationship between pressures and the VECs. While the PoE models show that there is some kind of potential relationship between the pressures and the VECs, the PoE models themselves do not speak as to how severe the negative effect of the pressure may be on these VECs. Information from the impact tables is used to create the risk profile. We had populated the PoE models with the information required to assess the risk as the probable result of spatial overlap (*e.g.*, a ship strike on a whale) and the severity and likelihood of the event occurring.

In the impact tables the likelihood and severity provides a set of values which are ranked in terms of likely magnitude and impact (EPA, 1998). When quantitative data is available for the pressures, such as contaminant concentrations in PPM or decibels of noise produced from shipping, the data can be used in the risk assessment. This type of data can come from field observations, models, or estimates. Unfortunately, the lack of similar data for the Yukon North Slope left only categorical (qualitative) ranking of pressures as the appropriate risk characterization method for the pilot project.

Activity and Pressure Impact Tables

The first step in this risk characterization process is to rank the activities and pressures based on their potential impact. The activities are ranked (high, medium or low) to determine their potential impact on the VECs. This impact level is evaluated by five standard parameters which include intensity, duration, geographic extent and trend (tendency) of the activity. An additional parameter, regulatory response, refers to how much the activity is currently regulated by government with the assumption that an unregulated activity may have a greater hazard level than an activity which is highly regulated. The definitions of these parameters are described in Appendix 4. A high rank is meant to be an order of magnitude greater than a medium rank such that the differences between high, medium and low represent clear and observable differences that can be easily seen and interpreted even by non-experts.

The observed and expected severity of the effect of the pressures is characterized based on the magnitude, ecosystem sensitivity and reversibility of the pressure. Pressures are further characterized based on observed and expected outcomes based on a five point scale of the pressure being certain, likely, moderate, unlikely or rare in occurrence (Appendix 5). The process of ranking was completed using information in various reports (*e.g.*, Cobb *et al.*, 2008; North/South Consultants, 2009) and our own knowledge. Ideally this step would be completed in a formal process with the assistance of Science. While we did not have Science validation for our models we believed that using the available published literature was a sufficient surrogate to not having a full review to quantify the identified pressures. The likelihood of an event occurring (*e.g.*, the introduction of invasive species) and severity/impact of the expected and observed impact were ranked using a five point score further illustrated in Appendix 6.

While considering exactly how to determine the effects of pressures and activities, we wondered if we were too conservative in our estimates as to what would happen in the near future. Based on rapidly changing commodity prices or the changing value of the Canadian dollar compared to other currencies over the past few years, we felt that even our best predictions for the future could be widely off the mark. To remedy this we produced two sets of activity and pressure matrices; one of what we thought was most likely to happen within the next ten years as well as one illustrating what could potentially happen if activity proceeded at a pace far quicker than what we envisioned. This had the benefit of allowing for comparisons under various conditions and perhaps provides an illustration of “middle ground”; the pace at which activity might actually occur (Fig. 4). The concept of an “expected” and “worst case” scenario can be seen in Elmetri and Felsing (2007).

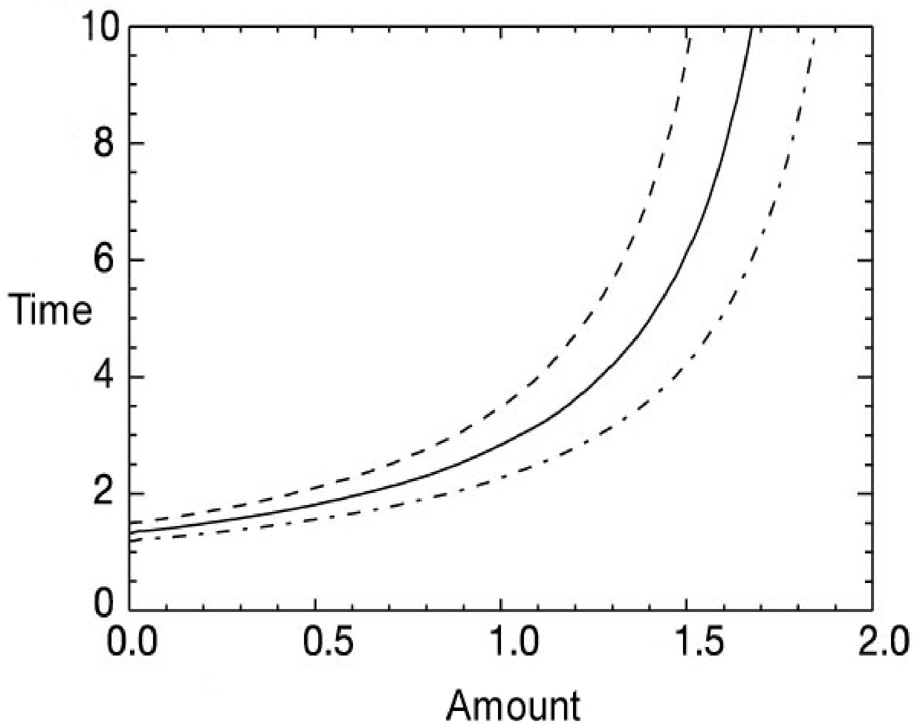

Figure 4: When plotting the expected and the worst case scenario (both represented by dashed lines), the true result is often lying somewhere in between (solid line).

Risk Matrix and Risk Profiles

The impact tables allowed us to assess the pressures and activities against each. The relative risk model developed by Landis and Wiegers (1997) was adapted for our purposes and used to create the risk profiles. This technique has been used in risk assessment world wide. This approach to risk assessment is unique because it accounts for multiple pressures, multiple VECs and accounts for the cumulative impacts of multiple activities.

The purpose of the risk profile is to visually display the risk of the pressures relative to one another. The risk profiles are developed by combining the impacts of both the activities and the pressures. The risk of the pressure is shown as the likelihood of the risk and the severity of the risk. The severity of the risk is the product of the severity of the pressure and the sum of the severities of the activity which cause the pressure. The same calculation is used for the likelihood.

This method of calculating risk requires only one value rank for the severity, and one value rank for likelihood, therefore if there are numerous criteria for which the severity and likelihood are determined they must be averaged. For example, if the severity of a hypothetical activity is determined by the ”scope” and the “magnitude” which are ranked on a three point scale at ‘3’ and ‘1’ respectively, then the severity for this activity would be ‘2’.

The risks from the pressures are then plotted in terms of likelihood and severity on an x/y axis using the “stoplight” green-amber-red colours. The resulting profile is a qualitative assessment which does not allow for comparison between different pressures, but does show which are most likely to occur and which will be most severe.

Pressures cannot be directly compared to each other because their functional effects are completely different (*e.g.*, the effect of noise on a species is different than that brought on by invasive species). The risk profile is therefore a way of displaying the relative risk of each pressure. When used in conjunction with the “stoplight” colour gradient representing low to high risk it places the pressures in general risk categories. The hypothetical risk profile (Fig. 6) clearly shows that the greatest risk is posed by “Pressure 1” as it is located in the red zone indicating both high severity and likelihood of occurrence. This is followed by “Pressure 2” at medium risk and “Pressure 3” which causes very little risk. The risk profile puts the pressure risks into relative perspective for the decision maker. While this method provides information on the sources of risk, it does not explicitly identify what VEC or VECs the pressures may effect.

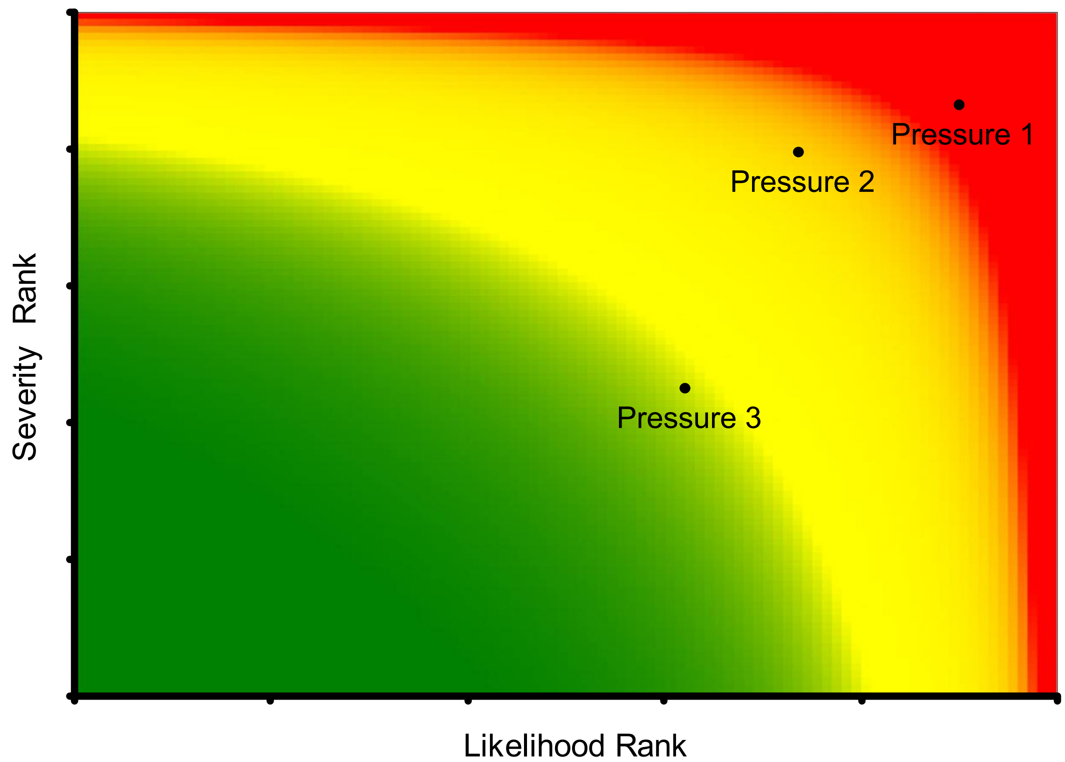

Figure 6: An example of a risk profile.

Geographic Mapping of the Risks

Following completion of the risk profile, the pressures or activities can be taken one step further by displaying them geographically. This portion of the study focuses on mapping the risks associated with various activities as they pertain to a single VEC. This was completed mainly to produce a map which might "speak" better to some stakeholders or managers than a risk profile and also to show how VECs and activities could come into contact and conflict. Geographic Information Systems (GIS) is a tool often used for spatial risk analysis. GIS can be used to display risk in a number of ways ranging from simple "layer overlays" to complex spatial analysis systems. Currently, GIS is being used for risk analysis pertaining to: air, water and soil pollution, ecological imbalance and natural disasters (Raheja, 2003).

The available information determines how the risk is displayed and the type of analyses that are possible. The information for the activities in this study consists of three components:

1.) Linkages to pressures and VECs (derived from the PoE model),
2.) A risk rank (from the environmental risk characterization), and
3.) A spatial reference (a known geographic area where the risk is likely to occur).

The spatial risk analysis used for this study is a multi-step process which involves mapping both the VEC and activities.

1/ Mapping the VEC

In the first step, the chosen VEC was mapped according to aspects of density, abundance and habitat. Bowhead whales were chosen because extensive sighting data was available for the study area. Bowhead whale aerial sightings were collected along transects flown throughout the Yukon North Slope in 1983, 1984, 1985, 1986, 2007 and 2008 (Harwood *et al.*, 2009). Due to the limited data that was available for any individual year, all years were included in this analysis. This raw point data (Fig. 7) was then interpolated to a raster image (Fig. 8). A raster in a geospatial context is a grid of x and y coordinates on a display space consisting of a pixel filled area, like a picture in which every point in that picture has a value.

In ArcGIS there are tools which can create rasters from points. This is most commonly done using the Inverse Distance Weighted (IDW) spline or natural neighbour techniques (Andrews, 2003) (Fig. 8). All techniques use the distance and value of nearby points to estimate the raster. In this case, IDW was used because it works well with small data sets. For the purposes of this study which was to illustrate a technique only, the raster estimation was done without input from DFO Science personnel. Collaboration with Science personnel on acceptable use of the data would be a needed aspect in a real exercise prior to decision making.

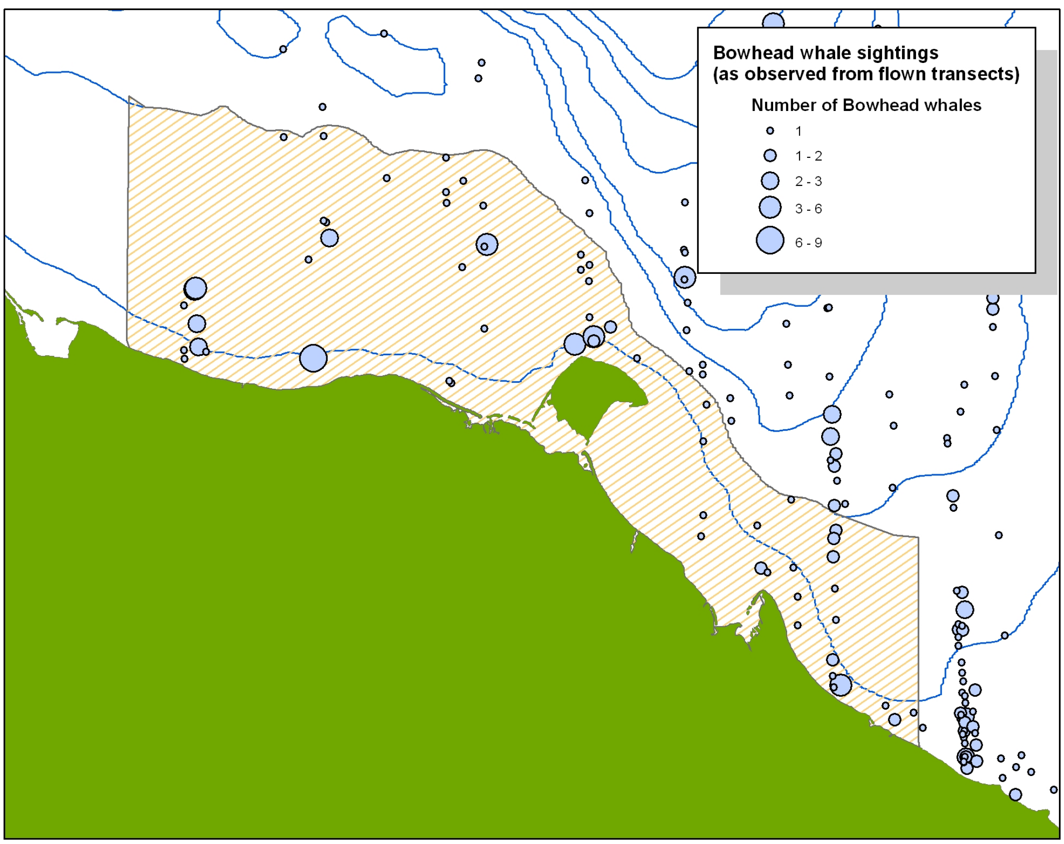

Figure 7: Composite of bowhead whale sightings along the Yukon North Slope - 1983, 1984, 1985, 1986, 2007 and 2008 (from Harwood *et al.*, 2009).

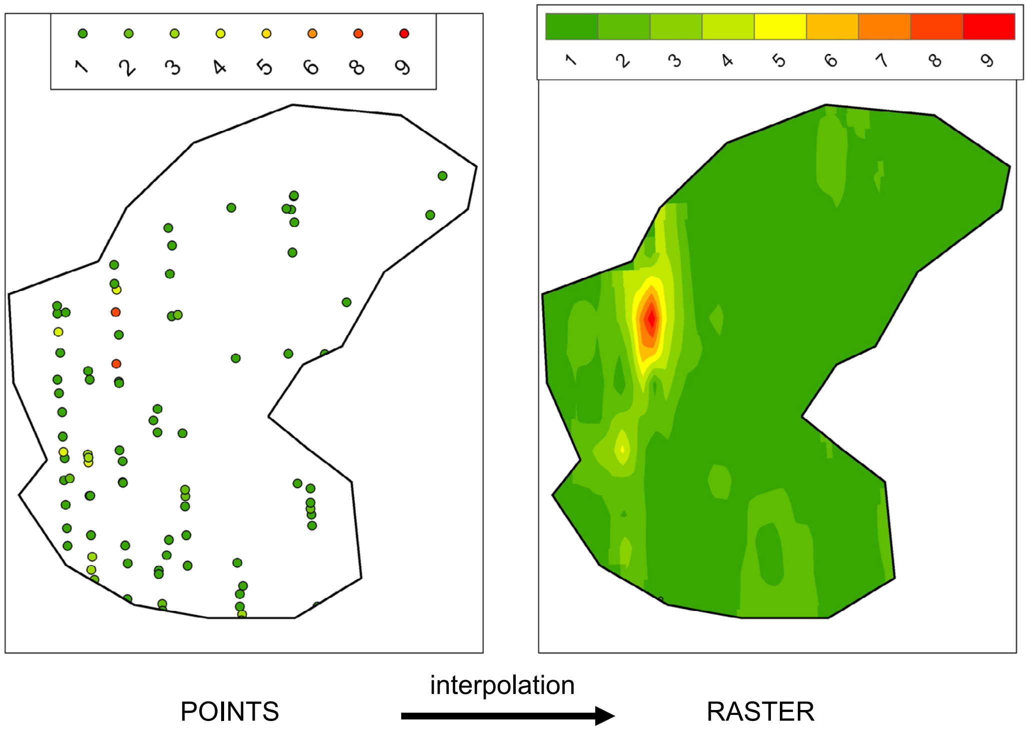

Figure 8: An example of point to raster conversion using the Inverse Distance Weighted interpolation technique (Andrews, 2003).

2/ Mapping the Activities

Once the VEC had been mapped, the activity or activities which posed the greatest potential threat to that VEC as identified by the risk characterization were also mapped. Mapping the activities most likely to negatively effect a VEC was simply another means of conveying information to an audience that might respond better to a visual display of data. The areas in which activities have occurred in the past (*e.g.*, areas with current oil and gas leases) and are likely to occur in the future (*e.g.*, marine shipping routes, commercial fishing areas, oil production facilities) were identified and mapped. The areas where activities occurred were given a value according to the risk of that activity. Where activities overlapped the sum of all risk values was calculated. For example, if an area was identified as likely to become part of a shipping route as well as a location for oil and gas exploration in the next 10 years, the value of the area would be the risk from shipping plus the risk from oil and gas. This step is critical as it accounts for the cumulative impact from multiple pressures. The map produced for the Yukon North Slope focuses on activities and contains values from zero, where none of the activities were present, to 16, where two of the activities overlapped. In this case, we used the three activities of greatest risk as identified in the risk characterization exercise for the "worst case" scenario.

Buffers (*e.g.*, expanding the possible area of influence around an activity) were plotted to show that although an activity may be localized, the pressures generated by the activity have potential impacts that range over a wider geographic area (*e.g.*, a transiting vessel producing noise or a vessel running through a shipping lane that may be several kilometres wide).

3/ Combining the VEC and Activities

After the activities were mapped they were added to the bowhead whale distribution map. This resulted in an overall hotspot map with values ranging from “0”, a location with no activities and not indicated as a major part of the bowhead whale range, to “56” where there was a high likelihood of bowhead whale occurrence overlapping with two of the three activities. This creates a diagram which provides a visual representation of the cumulative risk from the activities to the chosen VEC. Figure 9 illustrates the concept of geographic overlap which can also be interpreted as an area of cumulative impact (assuming the activities and VEC occur at the same time). Note that a map created by this process, like the PoE models themselves, is only another tool and does not guarantee that there will be any effect on the VEC. The map only illustrates where potential conflicts may occur. The benefit of mapping the activities and VECs is that some managers or stakeholders may respond better to a map rather than a PoE diagram and this may help them understand the potential need for or the result of a management decision.

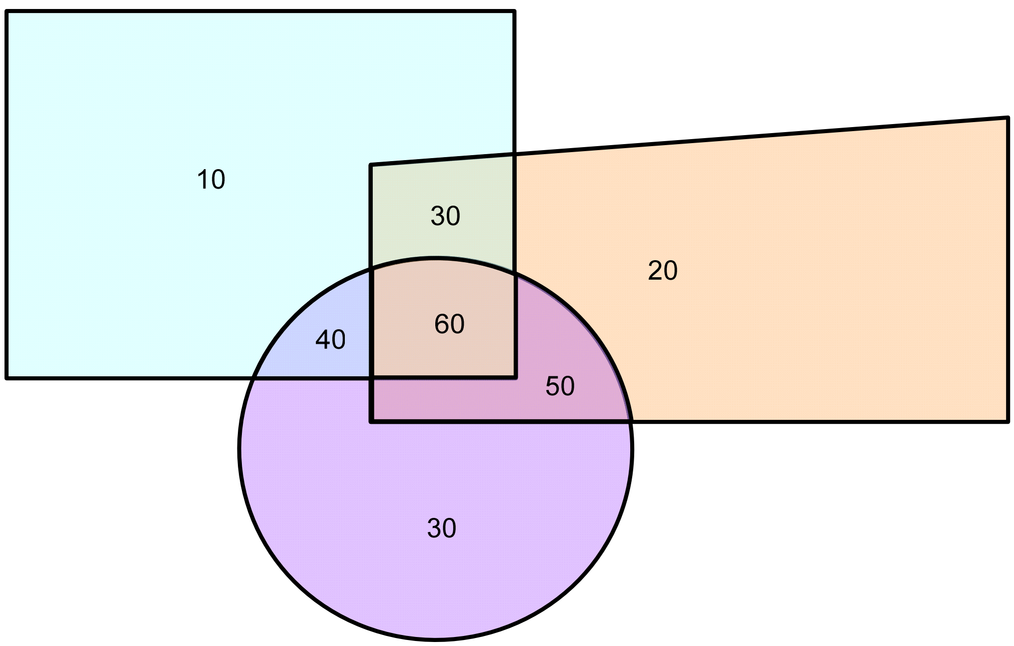

Figure 9: The concept of a geographical overlay.

The resulting map shows decision makers the areas that are at greatest risk of activity interaction and possibly negative impacts on VECs. However, the nature of such information is not as simple as the map depicts and, therefore, a nearest neighbour re-sampling technique (Chou, 1997) was used to regenerate the map. This map algebra operates by regenerating the value at each point based on the mean of the surrounding points. The result is a visually smoother data set which is more representative of the nature of potential risk.

RESULTS and DISCUSSION

This pilot project study resulted in the creation of PoE models for all identified activities and their associated pressures. The intent was to arrive at a holistic model which could be used to show stakeholders where cumulative negative impacts could potentially arise from multiple activities within the area. However, because all of our models began as single activity models, they are initially presented in that format. A final holistic model is presented as a summary following discussion and display of the individual activity models.

Marine Transportation

The PoE model developed for marine shipping is shown in Figure 10. As with any activity involving shipping of any kind, there is a potential for non-indigenous species introduction either through ballast water release, release from hull attachment or possible attachment to other associated ropes, chains or gear. Regardless of the method of transport, we rated the introduction of invasive species as potentially threatening almost all VECs although ultimately it would depend on the species introduced. Marine transportation, especially ballast water transport, has been the source of the majority of introductions in places like the Great Lakes (Mills *et al.*, 1993) therefore it seemed reasonable to believe that some introductions might occur on the Yukon North Slope with increasing ship traffic in the area. Additionally, the identification of a tentative alternate ballast water exchange zone just outside the western and northern boundary of the study area in approximately 75 m of water suggested that it might be possible for some species to be deposited in the area. Depending on what was introduced, we envisioned either direct competition with species or on the food of fish, shellfish, whales and seals. Introductions also included species that may parasitize other species and therefore reduce their fitness. That any introductions might also have an effect on water quality was not considered to be out of the question, but deemed to be unlikely. Effects of introductions could range from negligible to directly competing with certain species and possibly being a cause of death, either directly or indirectly, to some species. While the potential for introduction was large, we believed that the likelihood of a non-indigenous species establishing itself in the area was relatively low. Additionally, we considered that the vessels most likely to be used to export oil or liquefied natural gas from the Beaufort or ships that might ply the Northwest Passage had yet to be built and so they might be covered by the International Maritime Organization Ballast Water Convention (IMO, 2004) assuming it is ratified before the construction of these ships begin.

Ship strikes, however unlikely they may be, were considered to be a possibility that could affect bowhead whales or other large whale species like grey whales that occasionally appear in the Beaufort (COSEWIC, 2004). Although there is evidence of strikes on bowhead whales (George *et al.*, 1994) there are no records of fatal bowhead-ship collisions anywhere at this time (Jensen and Silber, 2004). However, ship strikes might occur or, if unreported, the incidence increase as Arctic waters become more travelled. Strikes were thought possible when ships were travelling at or near full speed through areas being used for bowhead feeding. This is, however, a seasonal issue that might occur in well known, localised areas (*e.g.*, known feeding grounds or migration routes determined from aerial surveys) and therefore could perhaps be avoided with regulations.

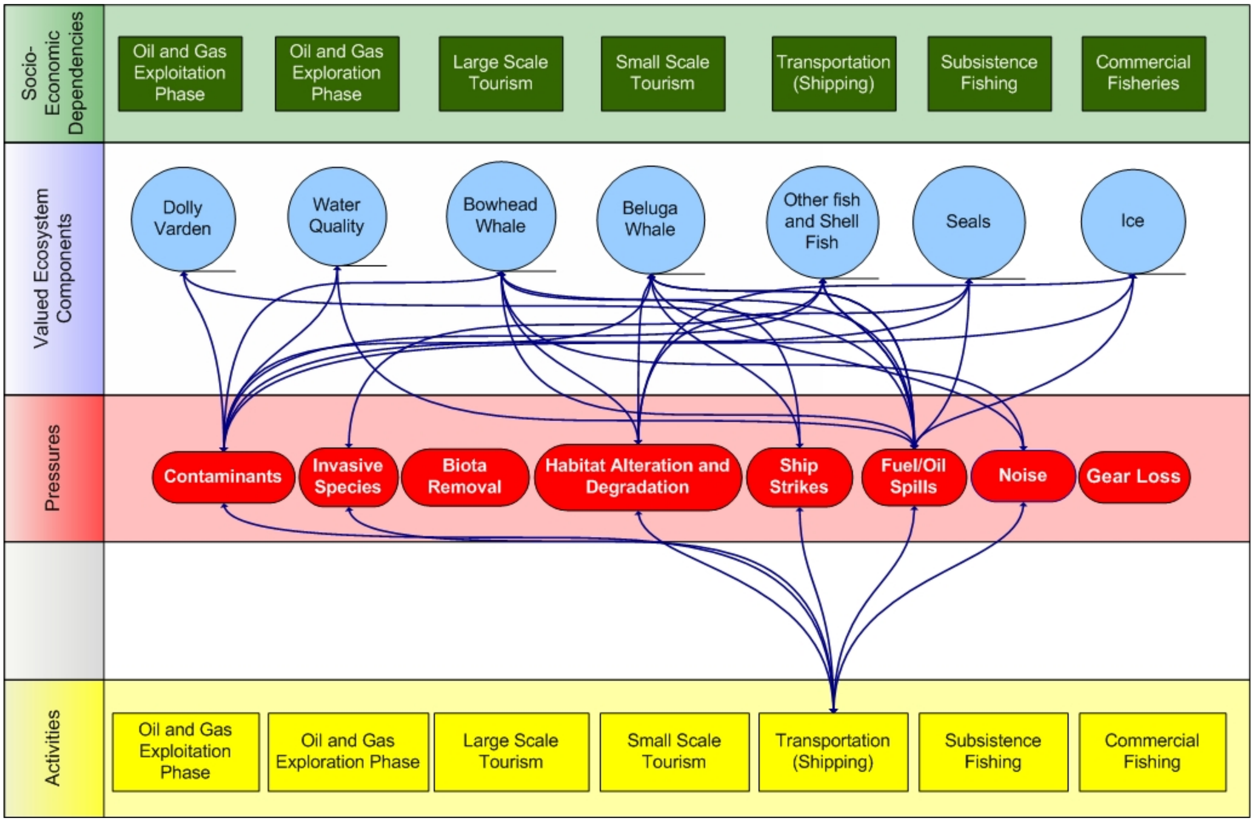

Figure 10: Single activity Pathways of Effects diagram for marine transportation.

Disruption of ice was thought possible by vessels with ice breaking capability and was believed to potentially pose its greatest risk to wildlife when this took place in the early spring period. Ice breaking was considered to potentially contribute to disrupting or destroying birth or haul out lairs created by ringed seals. Based on their known biology, other seal species were thought to be less affected than ringed seals. Only minor, temporary changes to ice algae and organisms feeding on it were thought to occur. Whales could follow the “artificial leads” created by ship traffic and travel into areas where the ice could close up behind them, possibly leading to entrapment and death. Some changes might be forced upon other forms of wildlife such as polar bears that den in offshore areas or arctic foxes that scavenge on the ice and might be kept from some areas due to broken ice.

All shipping activity generates noise and the effect of increased noise depends on the sensitivity of species within the area, the level of noise generated and the duration of it. Marine transportation was considered to be one of the most consistent producers of noise. Noise produced by shipping was thought to be at a fairly constant level that would vary in intensity depending on ship type. A moving ship would, generally, quickly pass through an area, allowing those species most sensitive to noise a reasonable warning and amount of time to move away. The possibility that organisms might become acclimatized to noise from ships was considered and could be possible if there were enough shipping traffic, probably with the same ship or type of ship, through an area on a regular basis (*i.e.*, Watkins, 1986) although we did not believe that acclimation would occur due to variation in frequency produced due to individual characteristics of each ship. Ice breaking would result in noise of different and louder frequencies and of a longer duration in an area than a ship moving in open water (Richardson *et al.*, 1995). Noise produced by ice breaking is also known to radiate more than that produced during a straight transit (Richardson *et al.*, 1995). Commercial fishing using trawls could increase the amount and duration of ship noise within a small area and could alternatively lead to acclimatization or cause organisms to avoid the area for an extended period of time. The literature is mixed as to whether noise from ships disrupts fish stocks or not (*e.g.*, Fernandes *et al.*, 2000; Røstad, 2006). We felt that noise produced by subsistence fishers and hunters was of a nature that was short lived, near shore and not persistent enough to greatly disrupt most fish or marine mammals.

Although amounts may be small from individual ships, greywater, blackwater and small amounts of various contaminants (mainly hydrocarbon based) will be released from most ships on an almost daily basis wherever they travel in the Beaufort. Currently, these were generally seen as minor issues with very localised, ephemeral impacts and *The Arctic Waters Pollution Prevention Act* (1985) or *The Regulations for the Prevention of Pollution from Ships and for Dangerous Chemicals* (2007) should effectively mange their occurrence. Large vessels (> 400 tons – *e.g.*, a "patrol boat" sized vessel of approximately 200 feet long) must retain all greywater which effectively limits much of the problem. Along the Yukon North Slope, these were not seen as issues of great or immediate concern.

Any ship brings with it the possibility of accidents ranging from small accidents with valves and hoses being opened or failing to a complete sinking with the subsequent release of all fuel, oil and any fuel related cargo. Ships operating in conditions where ice could contribute to vessel damage operate in a riskier environment than those not having to deal with ice. Currently, all vessels in the Arctic are class 3 type vessels and should be able to withstand most encounters with young ice. We considered the possibility of an accident as moderate considering that there were 28 vessels lost in Canadian waters in 2007 as well as a number of strikes on other vessels and capsizings (Transportation Safety Board of Canada, 2008). While many of these accidents occur in high traffic areas or during severe storms, we felt that travel in ice conditions made up for the lack of other traffic and that storms were not uncommon in the Beaufort. Wright (2001) stated that the Arctic was "at least as safe for shipping as the Gulf of St. Lawrence" during the winter when analysed relative to number of transits and per "000 km". Most incidents in the Arctic are ice related (Wright, 2001).

The trend for marine transportation was generally believed to be on the rise in the vicinity of the North Slope, if not immediately within the study area, certainly just outside of it, especially when considering large scale tourism as being one source of transportation. Potential developments in several areas of the central Arctic (*e.g.*, Paulatuk, Bathurst Inlet, Coronation Gulf) along with a possible increase in the use of the Northwest Passage by international traffic suggested there will be a significant increase in traffic, probably within the next ten years. Transportation related to oil and gas exploration activities near the Beaufort Shelf Break by itself will greatly increase the number of ships in the vicinity of the North Slope. Marine transportation, compared to other activities, was judged to have a moderate likelihood of creating serious damage.

Fishing

1/ Subsistence Fishing

Subsistence fishing and marine mammal harvesting was believed to produce few pressures (Fig. 11). While the intensive removal of biota from a single area is known to potentially affect single stocks, as subsistence harvesting has generally decreased over the past 20 or so years, especially along some areas of the North Slope (Stephenson, 2004), it seemed unlikely that subsistence harvesting would suddenly have a negative affect on any one stock. As the subsistence activities are targeted to specific species and carried out by only a few individuals within a given area, negative affects were thought to be limited. Along the North Slope, subsistence activities were deemed limited to fishing for Dolly Varden as well as possible opportunistic (or unintended) harvesting of other fish species. Seals and beluga whales were believed harvested only in low numbers and opportunistically with no concentrated hunting effort. All subsistence harvesting activities are known to be carried out very close to shore so any threat to offshore resources is non-existent. Most boats used for subsistence harvesting are small (< 9 m) and carry only limited fuel therefore making the possibility of a spill with long-lasting effects to the environment in the case of an accident highly unlikely. The general use of gill nets of only short lengths (< 50 m) suggests that loss of gear would produce only a minimal threat before becoming entangled with itself and no longer capable of fishing. The noise produced by small outboard motors was thought to be louder and of higher frequencies than those produced by ships, but unlikely to interfere with low frequency whale calls (*i.e.*, Richardson *et al.*, 1995).

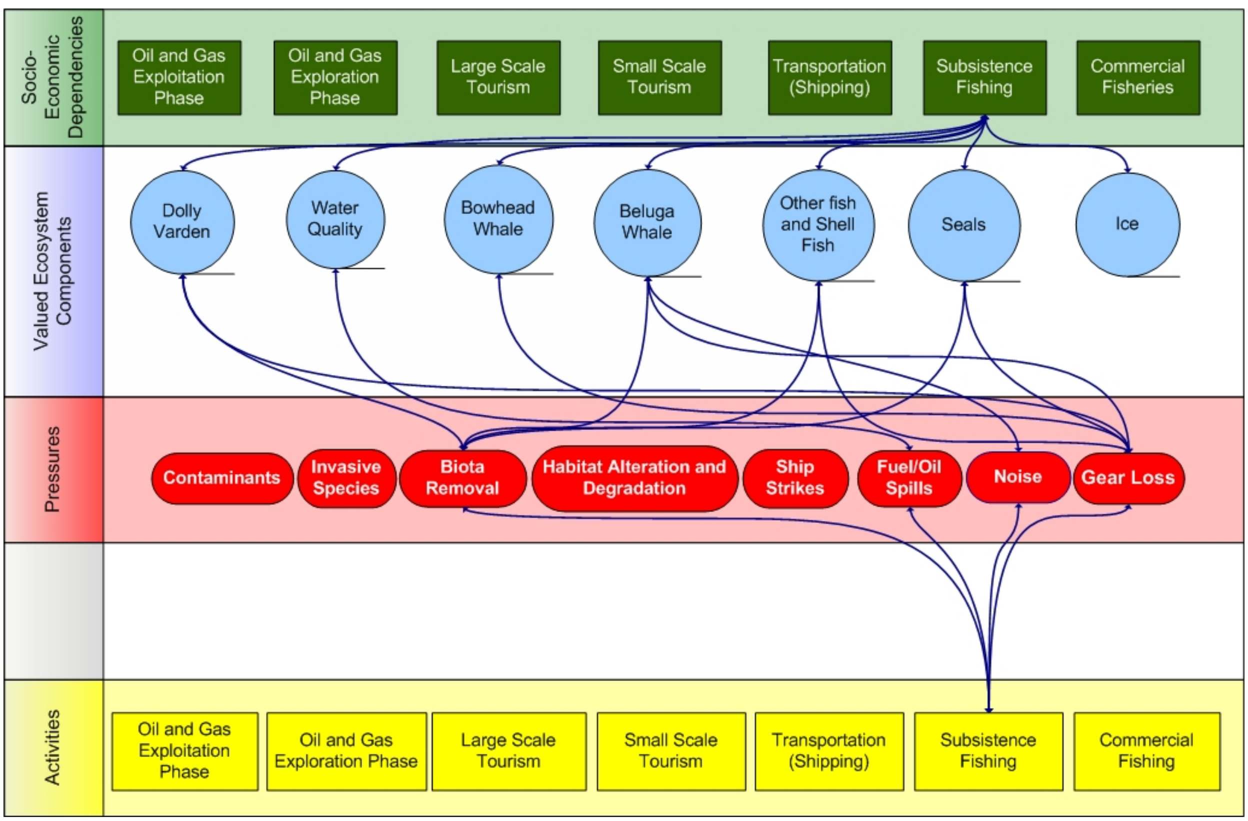

Figure 11: Single activity Pathways of Effects diagram for subsistence fishing.

2/ Commercial Fishing

Commercial fishing was thought unlikely to increase in the pilot area or anywhere in the Canadian Beaufort over the next decade for a number of reasons. Firstly, Inuvialuit spokesmen have stated that they do not want to see commercial fishing in the Canadian Beaufort (B. Spek, DFO, pers. comm.) and as there is a co-management agreement between Canada and the Inuvialuit, it is doubtful that commercial fishing would be permitted if the Inuvialuit were not in complete favour. Additionally, the US North Pacific Fishery Management Council voted in February 2009 to ban all commercial fishing in US waters north of the Bering Strait (see http://greennewstoday.org/?tag=beaufort-sea). The Council, part of the US National Oceanic and Atmospheric Administration, has sent its recommendation for a moratorium to the federal Commerce Department and the ban could become effective by the summer of 2009. Although there is a belief among some that some Pacific based commercial fisheries may move north in pursuit of stocks that could move due to climate change, as of yet there is no evidence that this will take place. The limited amount of interest in commercial fishing in the Canadian Beaufort Sea, in part due to a lack of evidence of any economically viable fish stocks that can be sustainably harvested, suggests that even though commercial fishing could bring a number of potential threats with it, it seemed unlikely that any of them will occur in the near future.

Should interest in commercial fishing in waters of the Canadian Beaufort Sea increase, there would be numerous potential pressures that should be considered prior to allowing the activity to occur. Similar to any activity involving ships, a certain amount of noise would be produced. Depending on the type of fishing and the ship chosen, it might produce less noise than a passing container ship, but the trade-off is that it would presumably remain in an area for an extended period of time. The noise might then interfere with the normal activities of whales or seals within the area and keep them out of that area. If trawling were used as the method of fishing, it might result only in limited habitat degradation (knowing that many areas in the Beaufort Sea are repeatedly scoured by ice every year) (Carmack and MacDonald, 2002). The fishing boat itself or its gear could be a vector for invasive species. The removal of fish could provide direct competition for resources with other fish species and marine mammals in the area as the fishing might be taking place in areas that exhibit high productivity (Fig. 12).

Fishing vessels could increase the risk of introduction of various types of pollutants into the environment through the introduction of oil and other fluids in bilge water. As fishing vessels seem to often be involved in the majority of major accidents (Transportation Safety Board of Canada, 2008), it seems reasonable to assume that increased fishing activity in the Beaufort Sea might increase the introduction of at least small amounts of fuel or oils to the area through these accidents and the sinking of a fishing vessel could release large amounts of fuel into the Beaufort Sea. Some level of waste disposal increasing available nutrients might occur if fish were cleaned on the ship and offal returned to the water. Greywater introduction from fishing vessels, due to a limited number that would be thought to potentially work the area, would have only a very small effect on the environment.

With the information currently available, it seems highly improbable that commercial fishing will develop in the Beaufort Sea and there is simply not enough data to suggest that such fishing would be concentrated within the study area of the Yukon North Slope. Because there is such sparse information on species presence or species distribution within the study area, it is difficult to imagine what any fishery might target.

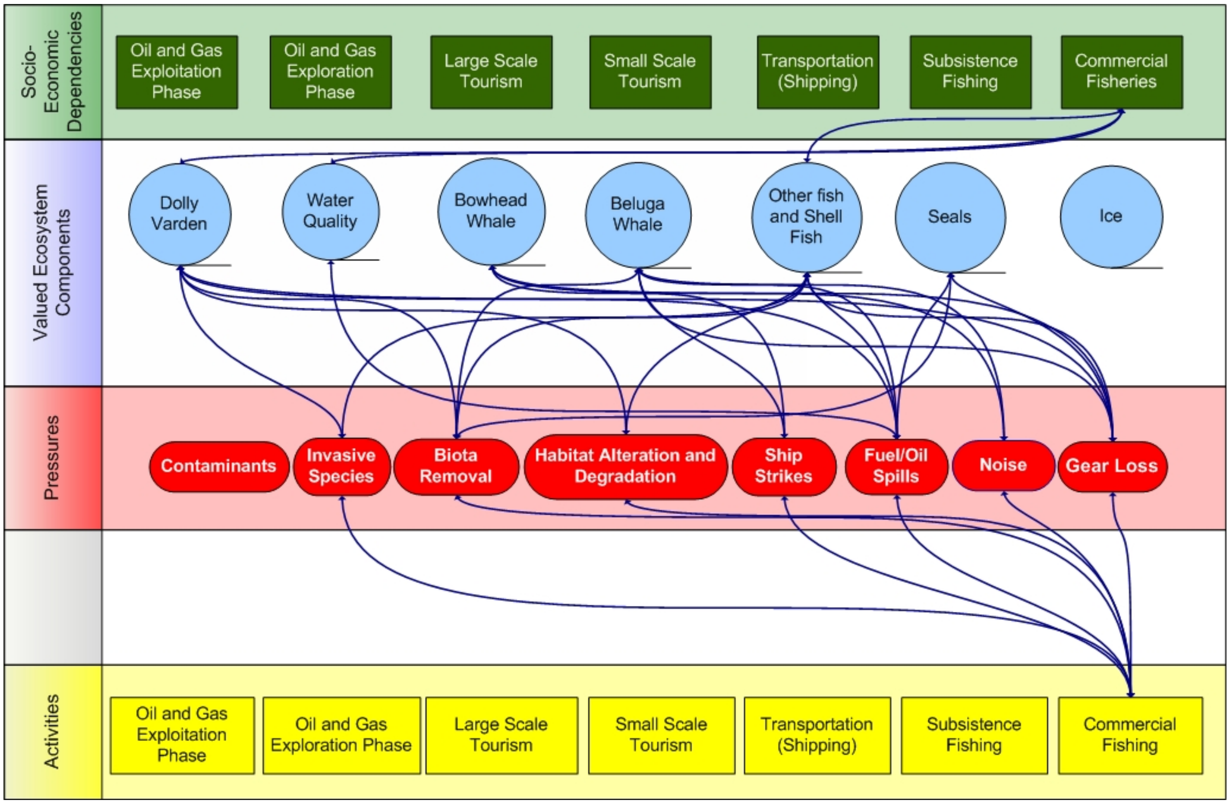

Figure 12: Single activity Pathways of Effects diagram for commercial fishing.

Oil and Gas

1/ Exploration

Oil and gas exploration brings with it numerous related activities, many of which are expected to create some pressures on the environment. As shipping and ships are involved, we do not repeat all of the concerns presented above for marine transportation. Figure 13 shows the PoE diagram illustrating the potential effects of oil and gas exploration on the Yukon North Slope.

Ships arriving to carry out seismic surveys or bringing in supplies might be bringing invasive species into the area although these would likely not be released via ballast water release. Species brought into the area would most likely be attached to the hulls of ships, barges or structures, but may be attached to anchor or mooring lines. As some vessels are specially outfitted to carry out seismic work, ships may travel long distances increasing the potential for bringing in organisms from distant sources. However, whether or not any ship arriving to the Arctic in support of oil and gas activities comes to a port (the only available “port” at the moment is Tuktoyaktuk Harbour) may make a difference as to whether or not an introduction is successful. A ship that carries coastal organisms on its’ hull, but carries out its work in deep water and never ventures close to shore poses a lower risk of introducing those species. While we did not anticipate that many of these ships would enter the waters of the Yukon North Slope, some mobile drilling platforms have been brought north and over wintered in the vicinity of Herschel Island (Yukon Environment, 2006). These drill platforms could prove to be vectors for invasive species.

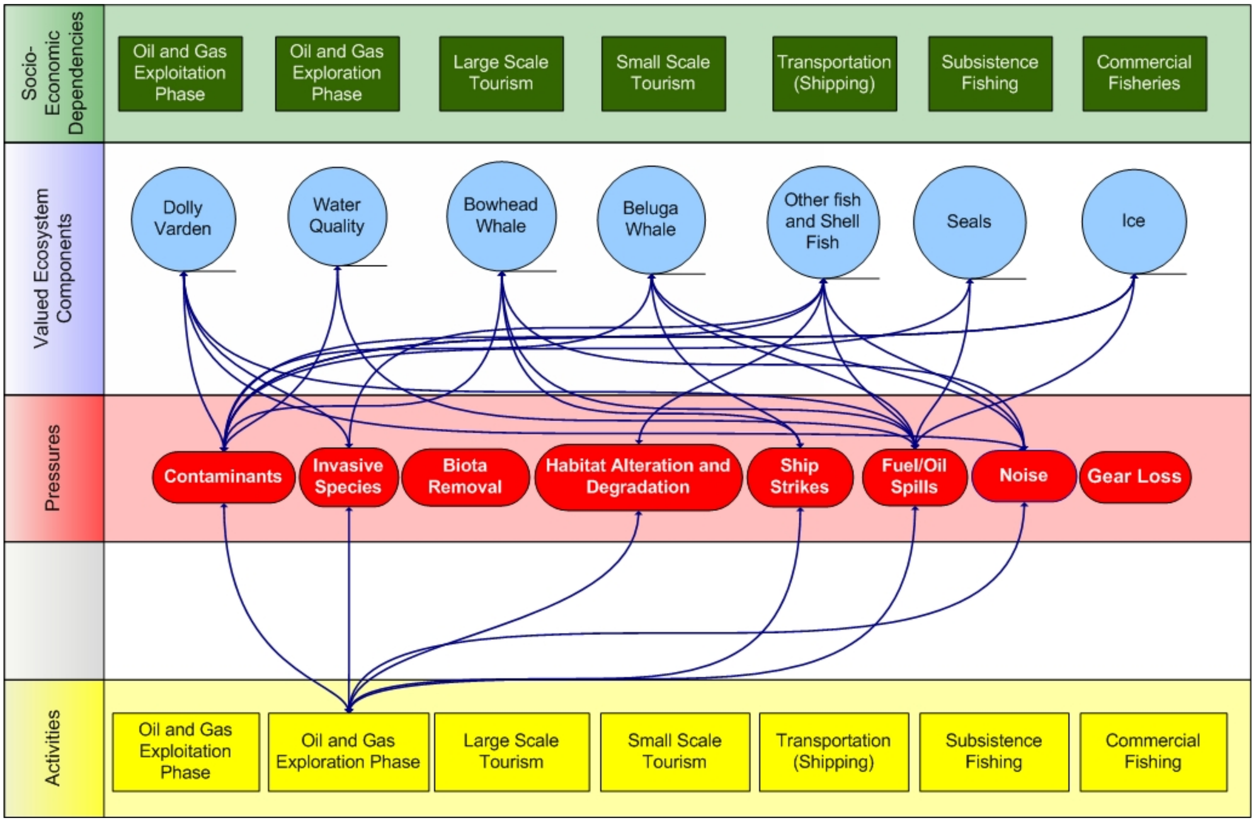

Figure 13: Single activity Pathways of Effects diagram for oil and gas exploration.

Apart from the noise generated by the seismic survey vessel as it repeatedly moves through an area in a grid pattern towing the airgun array, a large amount of noise would be created by the operation of the airguns themselves. While it seems unlikely that any organisms, except perhaps some zooplankton (including fish eggs) within a few metres of the gun, would be killed by airgun operation (LGL Ltd, 2001), the noise created by them is such that it may interfere with whale communication and may disrupt the normal migration or feeding patterns of both whales and fish (Richardson *et al.*, 1995). Because the airgun work can only be carried out when sea state is below a certain threshold, there may be breaks in the activity due to weather that marine mammals could take advantage of to access preferred areas. Normal procedures such as ramping up are thought to give enough “warning” to large, mobile organisms so that they can leave the areas before the airguns begin operating at full power (Caldwell, 2004). Ultimately, however, we did not envision it likely that any seismic activities would occur within the Yukon North Slope even under a worse case scenario.

The drilling of test or production wells increases the possibility of catastrophic release of hydrocarbons during all stages of this activity. The occurrence of oil spills is a matter of probability and there is no certainty regarding the amount of oil that would be released. Gulf Canada (1982) presented a review of offshore accidents and reported that throughout the Gulf of Mexico between 1955 and 1980 there were 4,794 wells drilled resulting in 30 blowouts and 68 accidents suggesting a blowout rate of 1 or 2 for every 100 wells drilled. The consequence of these exploration accidents resulted in the release of oil in 37% of these accidents (Gulf Canada, 1982). A review of spills from platforms during the period 1985 to 1999 throughout the

Gulf of Mexico showed that the size and number of spills had decreased by approximately 50% even though the number of platforms had risen (MMS, 2002a). This suggests better management and safety on platforms. MMS (2002b) reported that the probability of one or more spills greater than 1000 barrels in the American portion of the Beaufort Sea over the life of various projects was 6%. Overall then, it appears that the possibility of an accident may be low and the possibility of this occurring within the North Slope pilot area seems extremely low due to a current lack of interest in the geology of the area.

The drilling of a test well often necessitates the construction of an artificial platform which may temporarily increase local sedimentation and may destroy some nearby habitat. However, the habitat created by an artificial island may be of a kind that is limited in the area and therefore actually benefits some organisms. Test drilling involves the use of some chemicals and synthetic oils in drill "mud" and some of these could be released into the environment. As above, however, we thought it highly unlikely that any exploration will occur anywhere except perhaps on the margins of the Yukon North Slope pilot study area in the near future. Large scale accidents in adjacent areas could, however, damage the North Slope environment due to drift of released materials.

2/ Exploitation

The exploitation phase of oil and gas work is similar to the exploration phase, minus the airgun work and the need to drill new wells (assuming that test wells are put into production). However, the production phase does have other pressures (Fig. 14). As stated above, because we do not see exploration as occurring along the Yukon North Slope, we did not view exploitation as being a factor within these waters. However, exploitation in waters adjacent to the North Slope could have effects on VECs within the North Slope.

While noise from airguns is eliminated once production begins, noise emanating from the platform itself is now introduced into the environment. Although the noise from operating platforms is at significantly lower levels that that from airguns, the noise is persistent. While studies on the noise generated by oil or gas platforms have alternately found both minimal and great reactions from beluga whales, generally the whales can seem to choose to ignore the noise produced by platforms (Awbrey and Stewart, 1983). Researchers in other areas have found that whales exhibit an extreme flight reaction to ship noise suggesting that perhaps an animal's past experience to noise may determine how it reacts. If that is the case, then marine mammals in the Beaufort Sea might be expected to acclimatize to noise. Noise from producing platforms may have a limited effect on VECs along the North Slope as noise from artificial islands is not thought to carry more than a couple of kilometres and then only a very low frequencies (Richardson *et al.*, 1995).

The amount of ship traffic could increase in or just outside the area of the North Slope, depending on how any product might be moved from the platform. Thus shipping could increase in the north part of the area with a subsequent increase in shipping noise and other things associated with marine traffic (*e.g.*, potential whale strikes). Depending on the location of the platform and distance from shore, crew changes could be made by boat although they become impossible in the winter. Crew changes made using helicopters could increase surface noise which has been proven to disturb seals (Richardson *et al.*, 1995; Born *et al.*, 1999). Currently, all planned production facilities are far outside the area of this study.

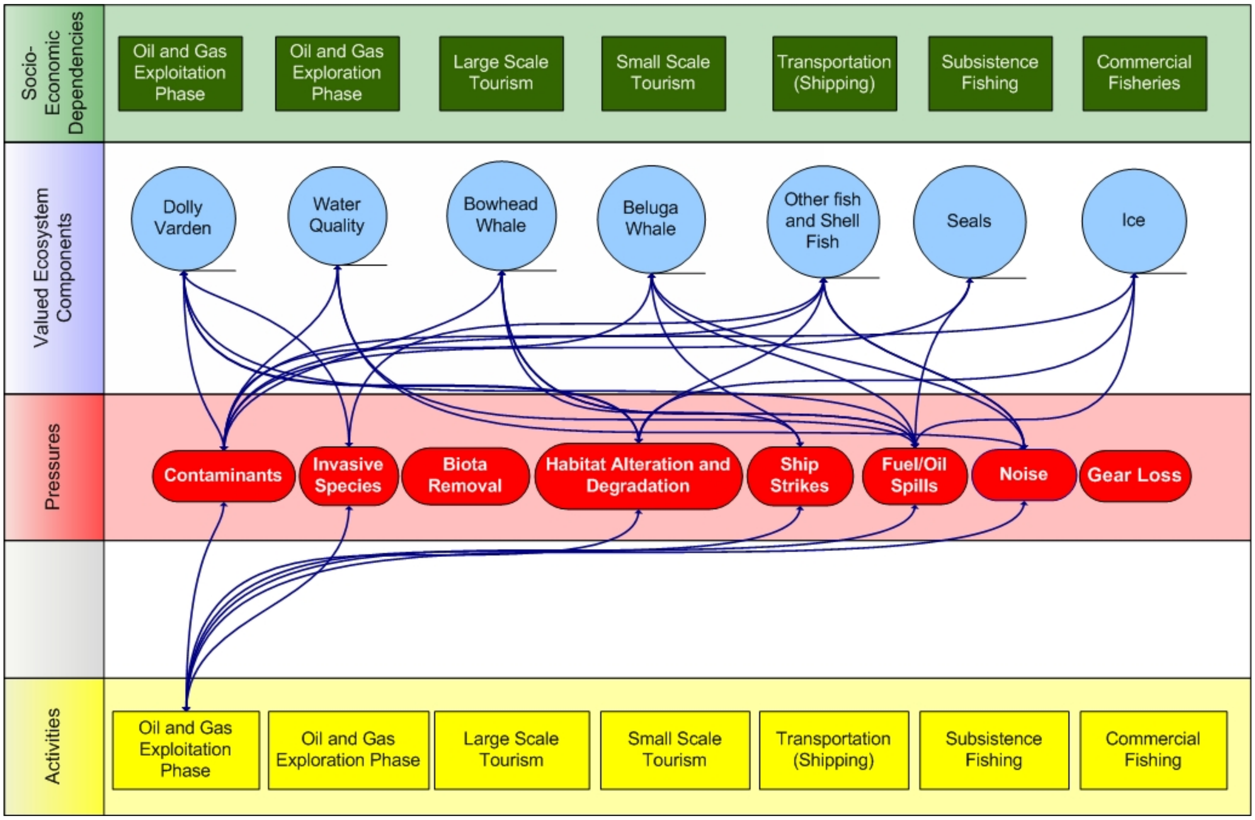

Figure 14: Single activity Pathways of Effects diagram for oil and gas exploitation.

Ultimately, the two greatest threats from production lie in those associated with transportation off the North Slope as well as the potential for some contamination from either small scale pollution or drift associated with a large accident further to the northeast of the study area. Whether product from the offshore area is moved by boat or pipeline, any large scale accident (including those associated with some large failure on the production platform itself) would greatly affect the North Slope and all VECs.

Tourism

1/ Large-scale Tourism

Most potential pressures from large-scale tourism have already been covered under the marine transportation section. Large-scale tourism involves the use of large ships, so anything that applies to marine shipping (*e.g.*, creation of noise, ship strikes, invasive species introduction) also applies here. However, there are a number of additional concerns brought on by large tourism. Perhaps one of the largest concerns is that unlike most marine transportation which generally is destinational in nature (*i.e.*, concerned with getting from point “A” to point “B” as efficiently as possible), large tourist ships may come much closer to shore and take a more meandering route to allow for better views of the area and wildlife. Tourist ships may also allow the launching of small boats taking people to or near shore. This may put the ship itself at greater risk of accident as it moves into areas possibly poorly charted. Additionally, because the ship is in an area considered most desirable for tourists (*i.e.*, most scenic, greatest concentration of marine mammals), a large scale accident within these areas would be particularly catastrophic to the area (Fig. 15). Small boats launched from a larger ship might interfere with the normal activities or otherwise harass marine mammals either due to physical interference or the high pitched noise produced from small boats like Zodiacs (Richardson *et al.*, 1995). Because the ship itself acts like a small floating community, it is able to put small boats close to areas not readily accessible to small-scale tourist ventures operating out of a community therefore greatly increasing the number of locales and the number of individual organisms (*e.g.*, seals or small whales) that might be disrupted by small boat traffic.

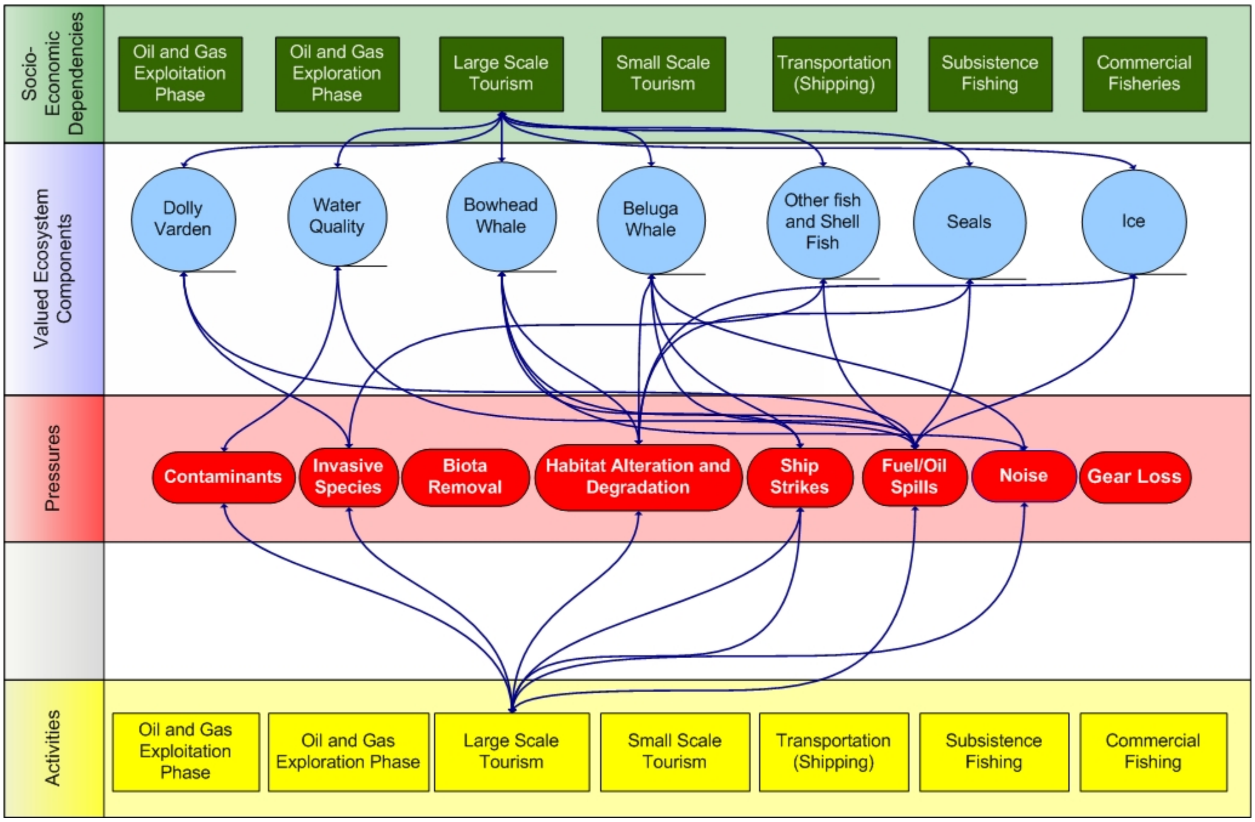

Figure 15: Single activity Pathways of Effects diagram for large scale tourism.

Because the number of tourist ships entering the western Arctic on an annual basis is largely unknown and their routing within the area is similarly unknown (although reporting requirements will become mandatory in 2010), the information available from which conclusions can be made regarding potential threats from tourist ships is limited. We know that some ships entering the western Arctic often travel along the North Slope due both to the landscape and the number of bowhead whales that can be seen in the area. The presence of the ship and the noise it creates may interfere with some bowhead whale activities. We also know that some tourist ships will stop at or near Herschel Island and allow passengers to disembark. The small boats associated with bringing passengers to the island may temporarily disrupt marine mammal activities.

While people on Arctic tourism cruises should be expected to be very environmentally friendly, the number of people on each cruise ship may increase the opportunities for at least small amounts of additional refuse or contaminants making it into the Arctic environment. Due to the popularity of the area and proximity to Alaska, we envisioned the Yukon North Slope as likely to experience an increase in the number of tourist ships over the next ten years.

2/ Small-scale Tourism

Small scale tourism was determined as having relatively few effects on the VECs in the area. We believed that small scale tourism would be run almost exclusively by people that resided near the area and would want the opportunity to exist indefinitely. The destination of many of these tourism trips was thought to be important harvesting (*e.g.*, locations of aggregations of marine mammals) or cultural sites that they would want protected. Because the same people running small scale tourism were also likely to do some harvesting, there would be a real knowledge of the dangers with interfering with marine life and concern about scaring it off so that it would be unavailable for harvesting at a later date. Noise generated by these activities is expected to be very short-term and small compared to noise generated by large vessels. Environmental threats as a result of accidents would be limited due to the size of boats involved and the amount and types of fuel used.

Small scale tourism is currently very limited along the North Slope and, probably primarily due to distance from any community, will remain that way. Noise produced by small boats is infrequent, transient and, while louder, of a higher frequency than that produced by ships and not believed to disturb marine life for long periods of time (Richardson *et al.*, 1995). Besides transient noise, the removal of a small number of fish was the only other real pressure we could envision (Fig. 16).

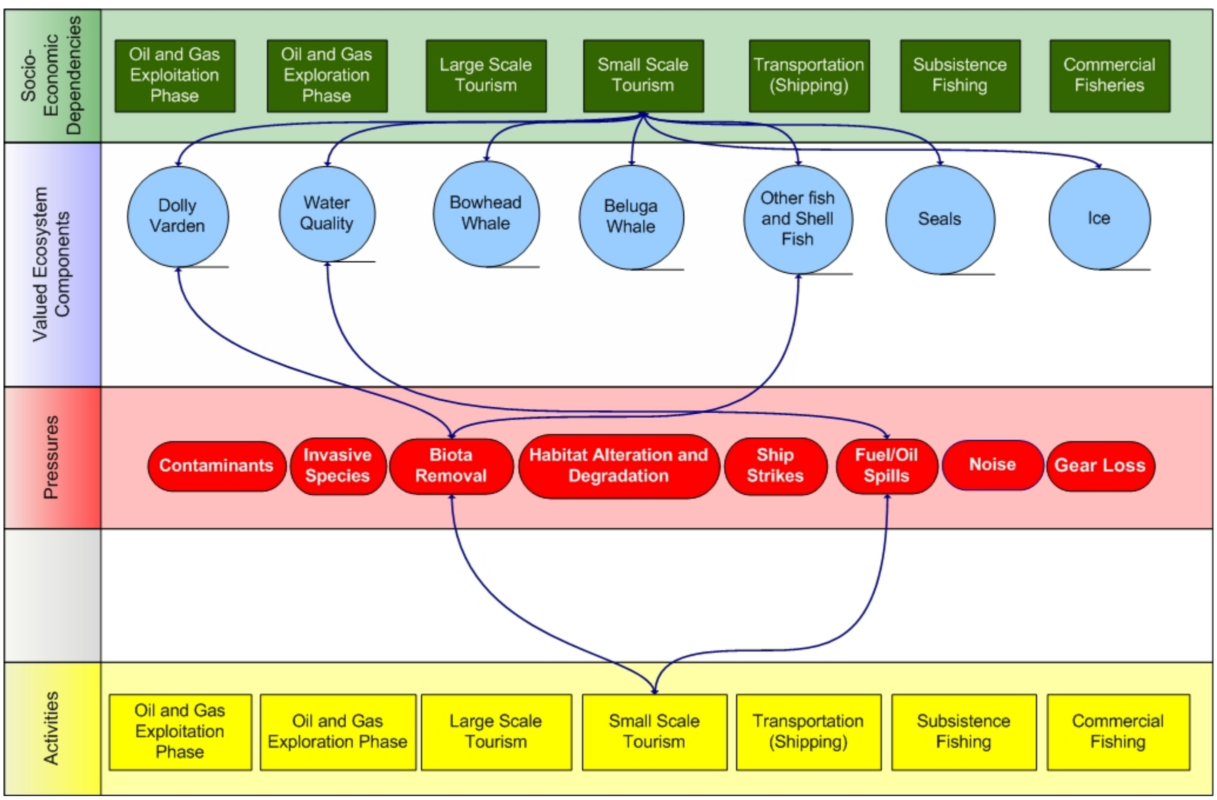

Figure 16: Single activity Pathways of Effects diagram for small scale tourism.

Holistic Pathways of Effects Model

A holistic diagram (Fig. 17) illustrating all the activities, pressures and VECs was created to show where potential cumulative impacts from all activities could occur. This model is the one which would typically be shown to stakeholders to help them understand the potential effects of a proposed activity or to help make decisions on other management activities. Although sometimes easier to see the effects of a proposed activity with the single activity models, some people will always want to see this model as it does show the location (*i.e.*, the VEC being affected) of potential cumulative impacts and illustrates the overall picture of all activities. Note that this diagram does not speak to how effects will be cumulative or how severe they may be, it simply shows that multiple activities may bring multiple pressures to bear on the same VEC.

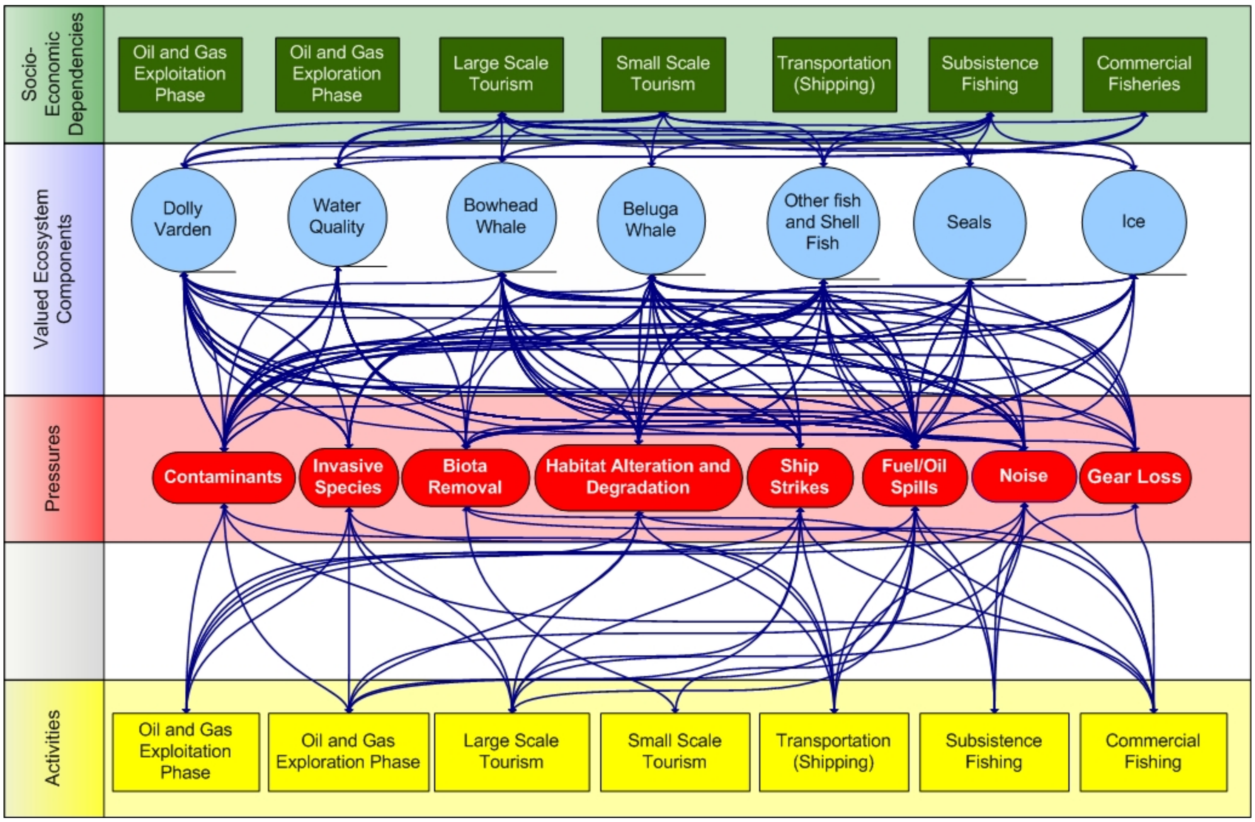

Figure 17: Holistic model diagram showing all relationships for activities, pressures and VECs in the Yukon North Slope study area.

A single PoE diagram produced to look at the source of pressures from all human activities on a single North Slope VEC was developed for bowhead whales (Fig. 18) and could be used to show stakeholders which activities were most likely to produce pressures that could have a negative impact on bowhead whales. As an example, as noise is produced by a number of activities and the amount of noise could have a cumulative effect on normal migration, feeding or communication, a manager or responsible agency might want to concentrate on ways to eliminate a percentage of the noise (where possible) emanating from each activity rather than mitigating the possibility of ship strikes or threats from other activities. This diagram therefore highlights another way that PoE diagrams can be used to understand and address the main concerns derived from anthropogenic activities.

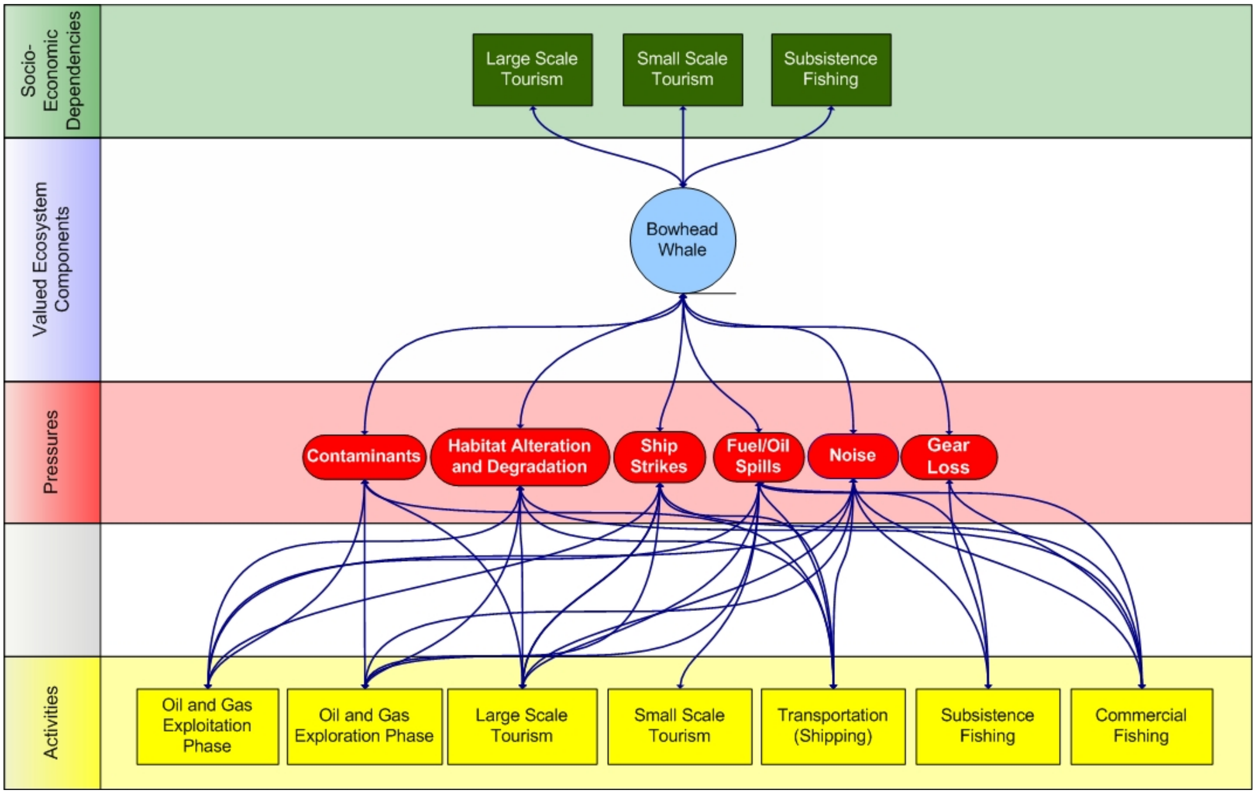

Figure 18: Species specific Pathways of Effects model for bowhead whale in the Yukon North Slope area illustrating the potential pressures derived from multiple activities.

Environmental Risk Characterization and Assessment

Risk Matrix

The purpose of producing the risk matrix tables was to identify activities and pressures which posed the greatest potential threat to the VECs. We ran two fictional exercises resulting in two distinct sets of matrices. The first activity matrix was an expected scenario (Fig. 19) where the intensity, duration, geographic extent and trend of all activities was categorized as low based of the lack of activity currently in the area and knowledge that little activity was likely to occur in the area over the next 10 years. However, even without any real increase in activity amongst most activities, large and small scale tourism and subsistence fishing are regulated to a lesser degree than other activities like oil and gas exploration and, therefore, increased the possibility of some risk to the VECs (*i.e.*, hence the medium risk relative to other activities).

In our fictional worst case activity scenario (Fig. 20) based on the thought that in volatile financial markets due to changes in the dollar, demands from various sectors and numerous other unforeseen circumstances, almost anything can quickly happen that was otherwise not planned or predicted, oil and gas exploration, marine transportation (especially that associated with potential transits of the Northwest Passage) and large scale tourism were thought to likely increase and be more severe than other activities and posed a possible high risk to the VECs due to the pressures they generate. Small scale tourism, simply because it is not well regulated in the Arctic, posed a possible threat although the actual effects were thought to be limited.

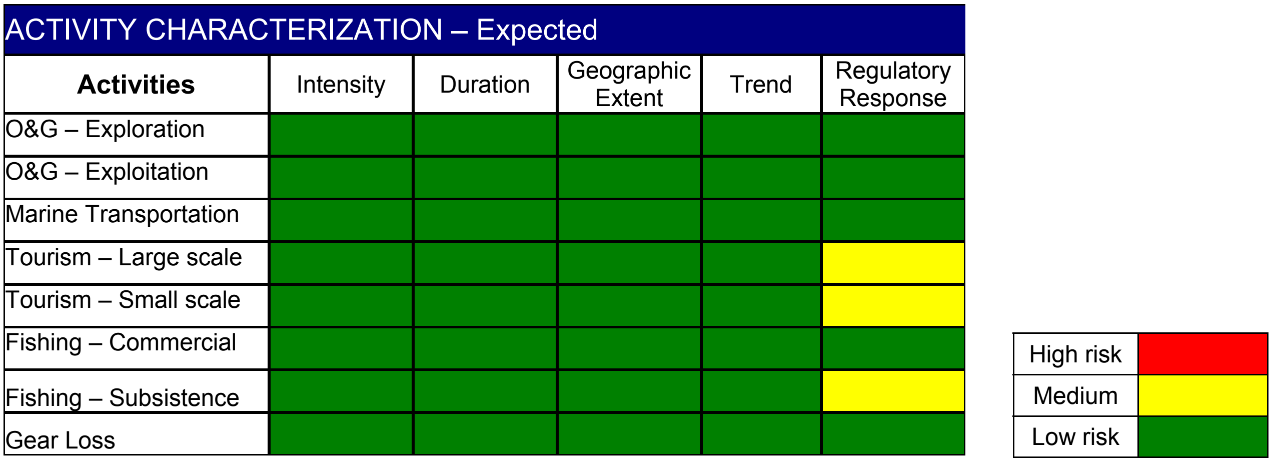

Figure 19: Ranking of potential impact of anthropogenic activities using an expected scenario on the Yukon North Slope.

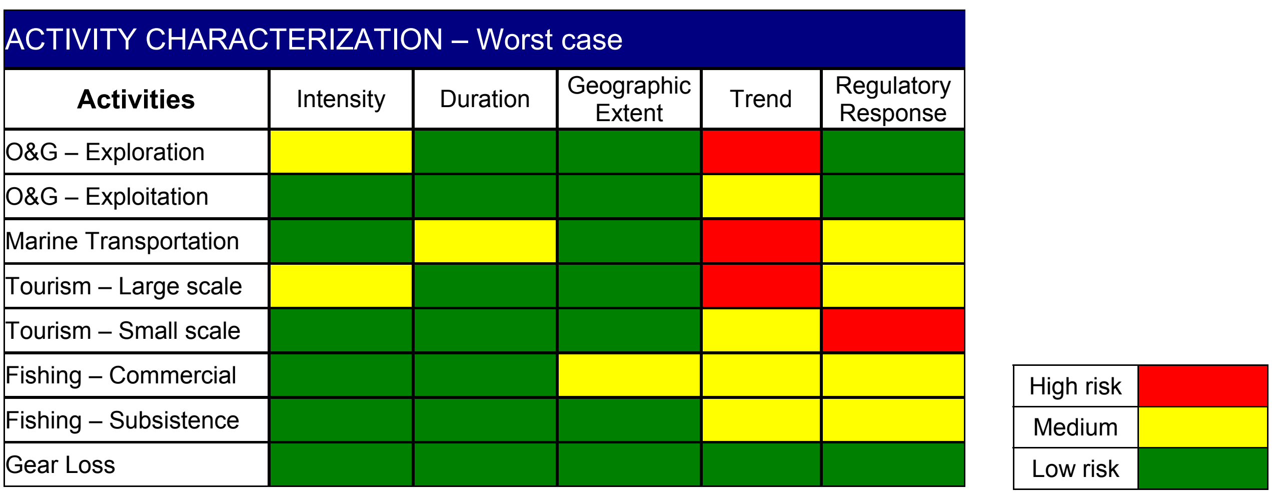

Figure 20: Ranking of potential impact of anthropogenic activities using a worst case scenario on the Yukon North Slope.

When characterizing pressures, oil or fuel spills were identified as having the most severe (greatest magnitude and low reversibility) potential threat in the risk matrix in an expected scenario (Fig. 21). This was followed by invasive species (low reversibility) and organic and inorganic contaminants respectively. The likelihood of occurrence was estimated to be greatest for noise because noise is produced by most marine activities and it is almost certain to be present and increase in the future. While not always conclusive, stress or changes in behaviour or activity of marine mammals due to noise seems to have been well documented. The second highest likelihood was found in habitat alteration and degradation followed by biota removal, organic and inorganic contaminants and oil or fuel spills. Invasive species and ship strikes seem unlikely to occur. Remaining pressures had a low severity ranking.

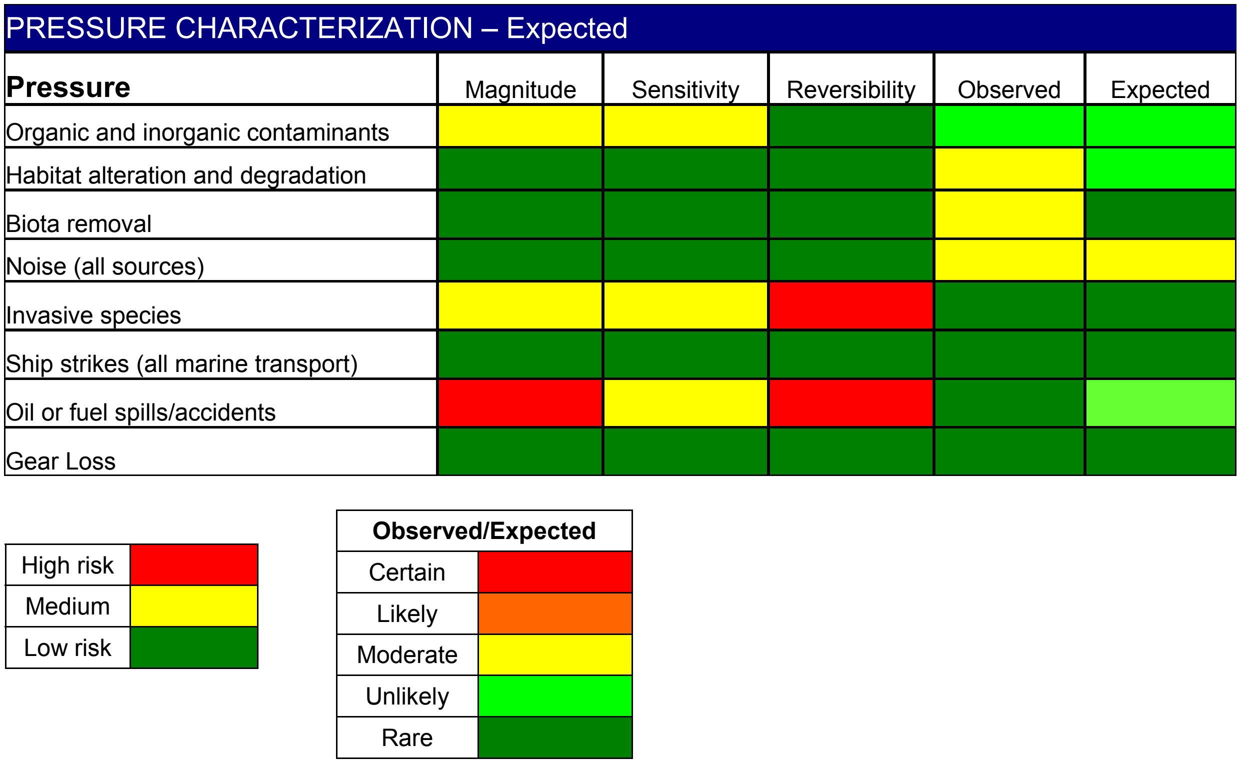

Figure 21: Ranking of risk from potential pressures in an expected scenario on the Yukon North Slope.

The severity from the pressures in the worst case scenario (Fig. 22) was greatest overall for invasive species because the magnitude of stress brought on by an introduction could be large and the sensitivity of the area is high. Based on experience in other parts of the world, the possibility of reversing an introduction, once established was considered to be near zero. This pressure was followed by oil and fuel spills and organic contaminants. However, the table also shows that the introduction of new species was thought to be low and that with the activities thought to be the ones most likely to take place along the Yukon North Slope, they had not been responsible for introductions in other areas of the world.

Oil and fuel spills could have a devastating effect on the North Slope, but potentially the majority of it could be cleaned up depending on the type of spill and the time of year in which it occurred. Biota removal and habitat alteration and degradation were all considered slightly more likely to occur than the low impacting habitat alteration and ship strikes. Note that the likelihood of the worst case scenario is the same as the expected. While the magnitude of some pressures may be high, the likelihood of them occurring is relatively small due to some combination of good regulations, use of best practices and lessons learned in other areas.

Some habitat alteration, biota removal and increases in noise are likely to occur within the area under a worst case scenario. Both noise and biota removal pose a moderate risk because of marine mammals sensitive to noise within the area and because removal of biota could have a negative effect on these same mammals. The waters of the North Slope were judged to be extremely sensitive to contamination and any large scale contamination (either chemical or oil based) could have a great effect on traditional subsistence harvesting practices.

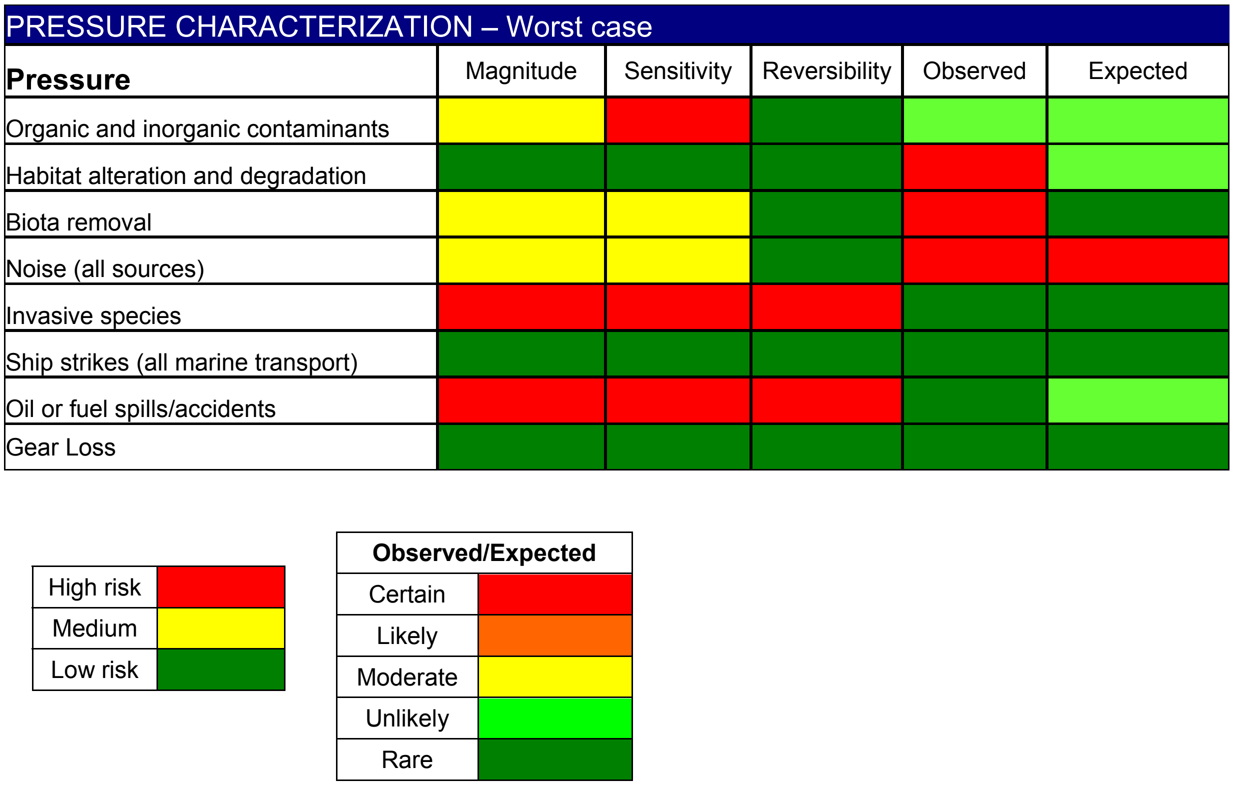

Figure 22: Ranking of risk from potential pressures in a worst case scenario on the Yukon North Slope.

Risk Profile

The identification of the potential pressures that could pose the greatest risk to the VECs is a key outcome of the risk matrix exercise. Understanding what is judged to pose the greatest risks to the VECs and the activities most likely to cause them provides managers with a basis for developing management plans, planning mitigative actions in advance of these activities or deciding if the possible risk associated with allowing these activities is even worth taking.

Two risk profiles using the results from the expected and worst case scenario tables were prepared. The pressure risk profile produced using the expected scenario information showed that fuel and oil spills (regardless of source) posed the greatest risk to the VECs along the Yukon North Slope (Fig. 23). There is only a moderate likelihood of this occurring, but the problem could be extremely severe if it did occur. Non-indigenous species also rank fairly high in terms of risk although both the probability of them actually being introduced and the problems caused by their establishment are considered considerably lower. Overall, there are many pressures that seem likely to occur (*e.g.*, production of noise, some habitat alteration or degradation), but their effects are not considered to be severe. Having this knowledge in advance, these pressures could perhaps be lessened through some form of mitigation. Gear loss, due to a low frequency of occurrence, rated very low so far as likelihood and severity was concerned.

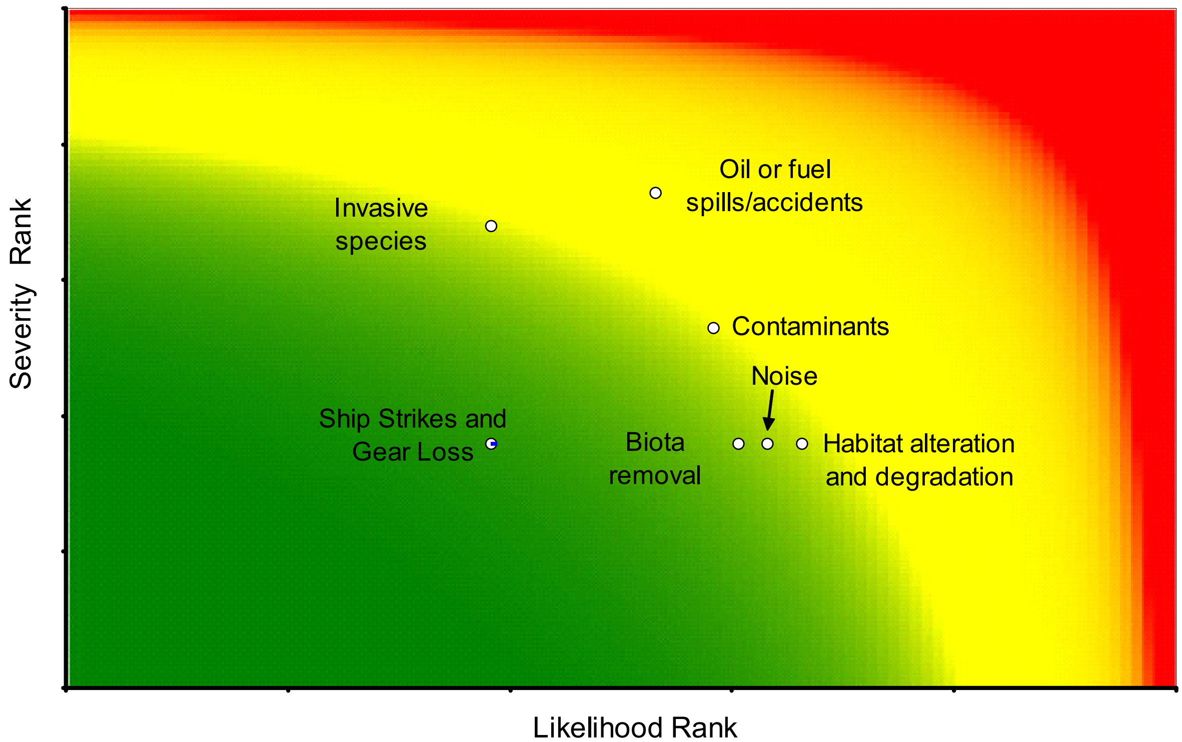

Figure 23: Risk profile diagram for potential pressures associated with the Yukon North Slope using the expected scenario.

The risk profile produced using the worst case scenario suggests much more certainty in pressures occurring such as noise and a greater likelihood that oil or fuel spills and accidents may occur (Fig. 24). Similarly, in a worst case scenario the likelihood and severity of invasive species being introduced is greatly increased although the likelihood of such an event is still low relative to other pressures and equivalent to the likelihood of ship strikes. Both events ultimately are dependant on the amount of ship traffic within the area with increasing ship traffic increasing the risk of either event occurring. Ship strikes and loss of fishing gear both have a similar, low likelihood and fairly low severity rank.

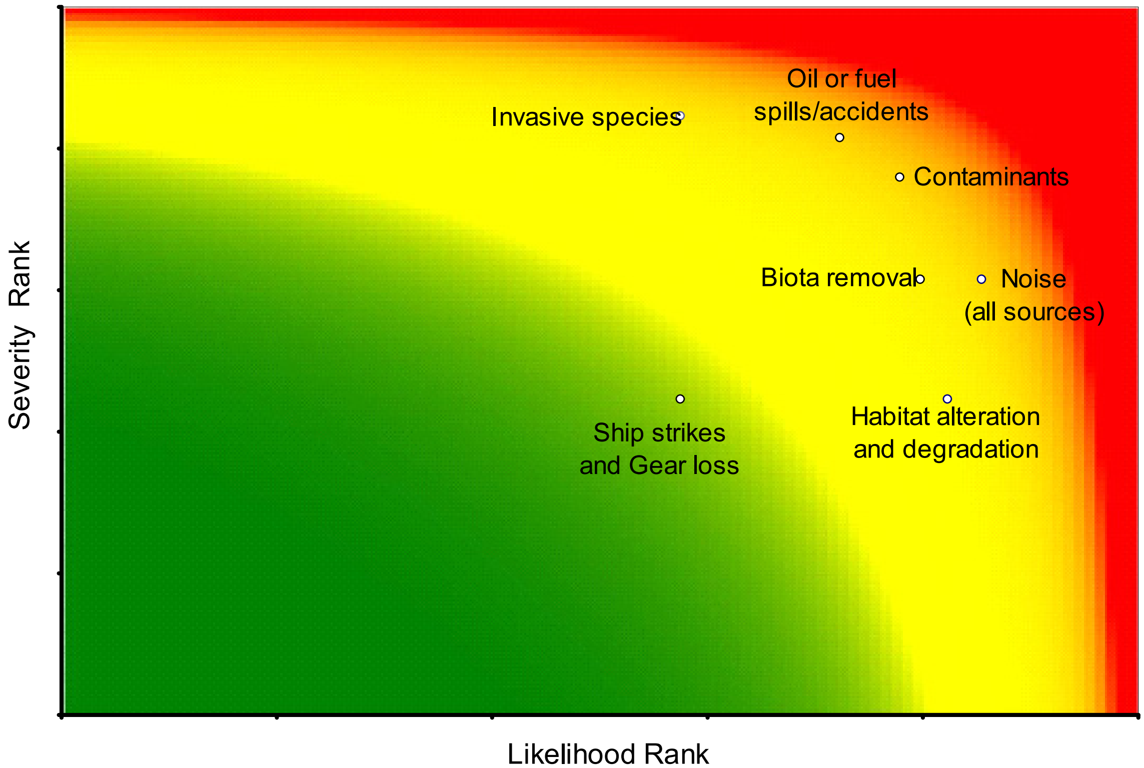

Figure 24: Risk profile diagram for potential pressures associated with the Yukon North Slope using the worst case scenario.

Mapping Activities and VECs

While the risk profile diagram is a suitable endpoint for many studies after using PoE as a basis, it is also possible to go a step further and take the information from the PoE model and environmental risk characterization and incorporate it into GIS to visually display the possible risks in time and space. Creating these "risk maps" puts the risk assessment information at a scale of common interest for decision makers and makes the interpretation of data easier. Landis and Wiegers (1997) emphasize the need for such a product in their assessment of ecological risk assessments. While the decision of which spatial analysis techniques to use is not discussed here, suffice it to say that there are many considerations to make before producing maps and we do not endorse any particular method. As a result, the maps produced for this example have been produced using different methods.

For illustrative purposes the risk maps were created only for bowhead whales (due to the quantity and quality of information available). The activities of transportation, large scale tourism and oil and gas exploration were chosen as they correspond to the top three activities as ranked during the risk characterization exercise for the "worst case" scenario. Transportation and large scale tourism routes were obtained from Transport Canada and both had a 2 km buffer zone applied. The oil and gas lease information was obtained from INAC (2009).

The interpolated data mapped to show where concentrations of bowhead whales are most likely to occur within the study area (Fig. 25) identified the area near Komakuk Beach as having the largest concentrations of bowhead whales. While bowhead whale distribution is variable on an annual basis, consistent concentrations have been found along the coast of Ivvavik National Park, especially during early September. Other important areas for bowhead whales identified via this method include the waters northwest of Herschel Island, near shore waters of Ptarmigan Bay and areas of the coastline between Kay and Shingle points. What this map does illustrate without the addition of any other data is the immediate knowledge that any commercial activities near areas where concentrations of bowhead whales have been consistently found could potentially cause some conflicts and result in the whales moving away from or otherwise avoiding what may be preferred areas. While some conflicts could be eliminated by having activities (*e.g.*, seismic programs) take place before or after the whales use the area, some activities may simply be deemed unacceptable under any circumstances.

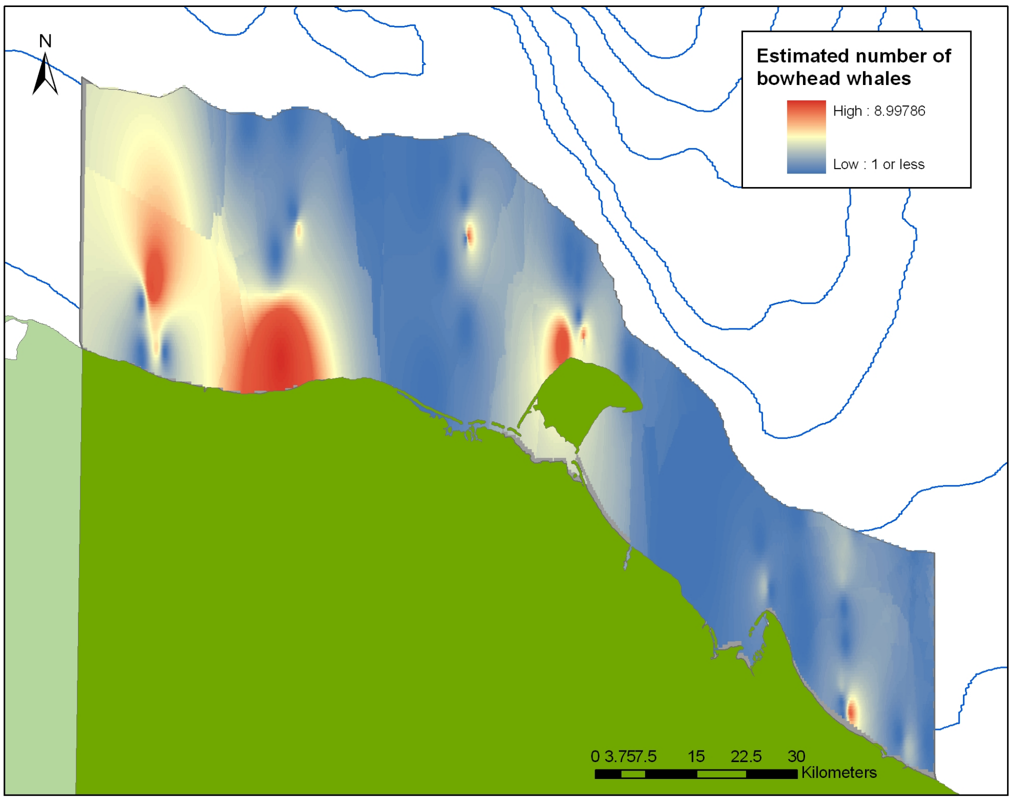

Figure 25: The likelihood of distribution of bowhead whales along the Yukon North Slope based multi-year bowhead sighting data from Harwood *et al.* (2009).

Mapping the current exploration licences for oil and gas along and off the Yukon North Slope (Fig. 26) shows that the licences and leases are primarily located in the northwest segment of the study area. Many of the largest licences and leases in the Beaufort Sea are just outside the study area itself. These licences represent current exploration or interest, but if significant discoveries were to be found, significant discovery licences and production licences could then be obtained leading to full production. The exploratory licences are valid for nine years and have a drilling requirement for the first part of the term (INAC, 2008).

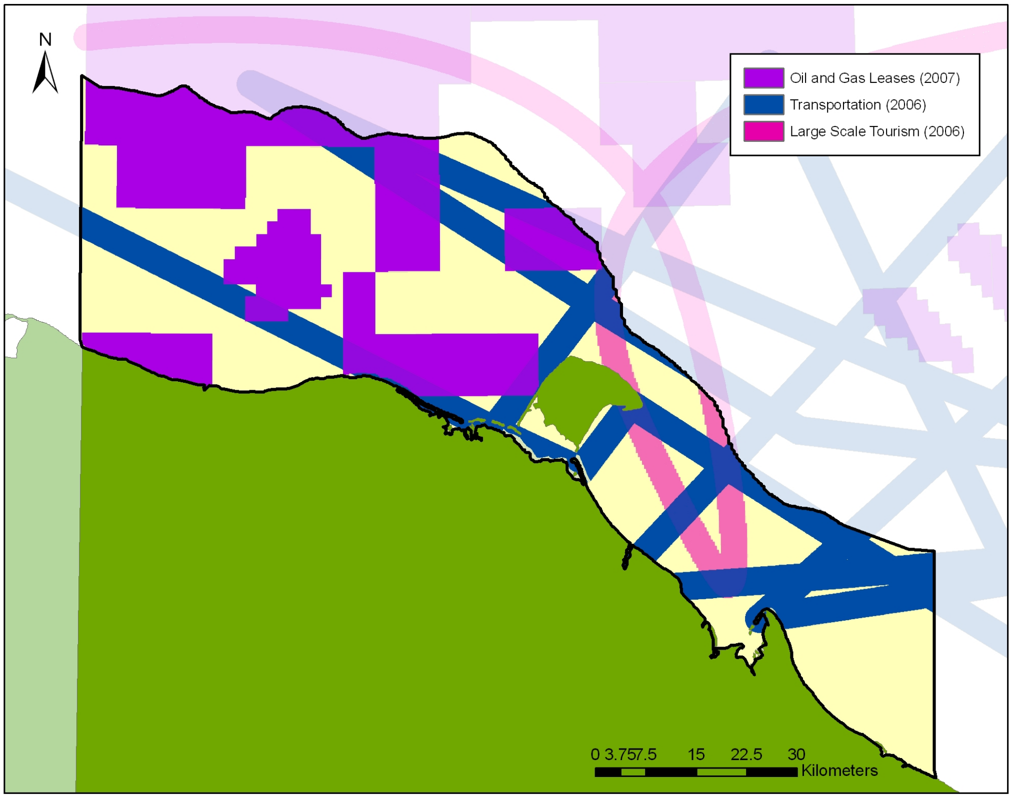

Figure 26: Map showing the study area and major activities along the Yukon North Slope. Ship tracks have been plotted with an approximately 2 km buffer.

The addition of major transportation routes and tracks taken by large tourist vessels within the area adds another layer of information and shows where multiple activities overlap (Fig. 26). Areas where activities overlap may be particularly stressful for bowhead whales if bowhead whale presence overlaps in time with anthropogenic activity within those areas.

The final map in this series combines the major activities, in this case oil and gas exploration, transportation and large-scale tourism, with the likelihood distribution of bowhead whales to arrive at a final “hot spot” map (Fig. 27). This map illustrates where potential overlap between activities and bowhead use is highest and therefore points to particular areas that need to be considered for complete, partial or seasonal avoidance when making management decisions regarding specific activities. Because the map illustrates the location where what are essentially potential cumulative impacts may occur (*e.g.*, noise, ship strikes), managers and decision makers may decide how to manage the risks. Note that these maps do not speak to pressures (*e.g.*, the amount of noise, the number of ship strikes, etc), only to human activities and the use of the area by bowhead whales by showing where the two overlap.

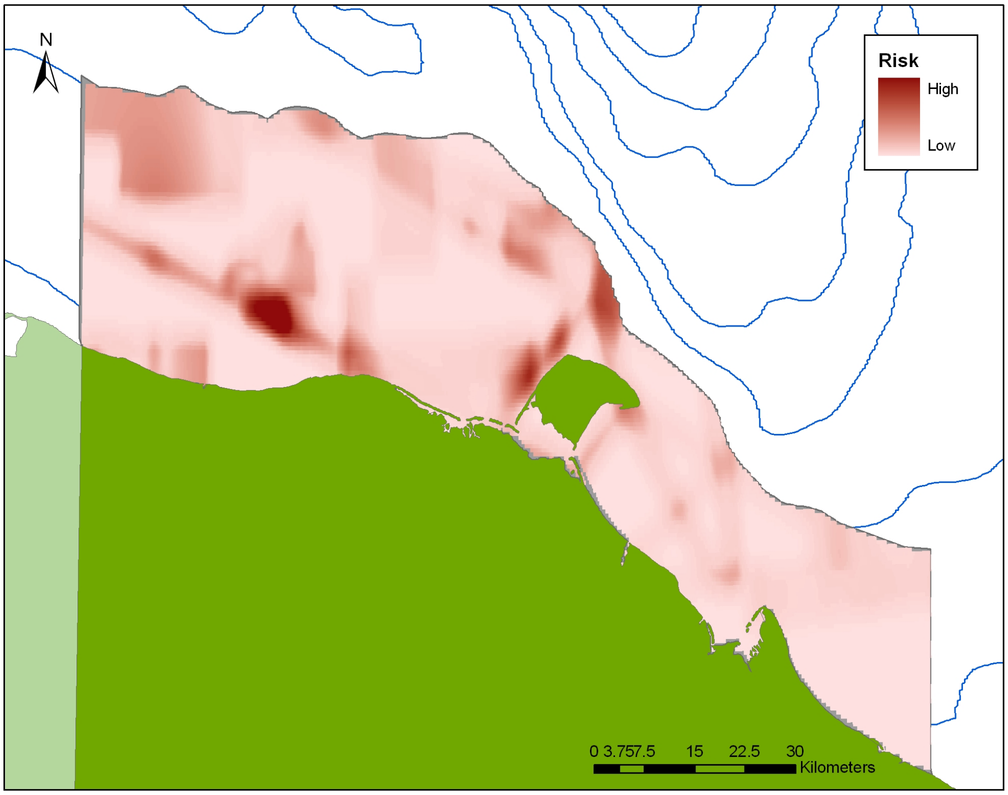

Figure 27: Composite "hot-spot" map of potential risks associated to bowhead whales from anthropogenic activities (oil and gas exploration, transportation and large scale tourism) within the Yukon North Slope study area.

CONCLUSIONS

Our initial question going into this pilot study was could PoE models assist in helping to discover the potential effects of proposed commercial activities and therefore, would their use aid in planning mitigation or supporting a decision as to whether an activity should proceed or not? The answer to this seems to be yes, although in the end PoE models are only one tool that can help support a management decision. PoE models do not speak to the possible threats to the VECs that might come as a result of an activity. PoE models only show that a potential interaction between the VECs and the activities is possible.

While the models that are created by PoE may be invaluable to some people in understanding the interrelationship of several anthropogenic activities, the models themselves do not say how harmful an activity is relative to another: to find that requires additional work. PoE models do not "decide" what activities may be suitable for any particular area, rather they provide guidance for making such a decision or they may support a decision which is already generally agreed to by managers and stakeholders. Because an ecosystem approach requires consideration and recognition of community or regional economic aspirations prior to making any decision on proposed activities within an area, PoE models are an excellent tool in demonstrating which socio-economic dependencies may be negatively affected by proposed activities due to their potential impact on VECs.

PoE models require fairly extensive knowledge of what is present and valued within an area and therefore what might be negatively affected by the proposed activities. In the Arctic, not just western science but also information based on Traditional Knowledge and subsistence use of the area would prove invaluable in protecting the most important components of the ecosystem and also identifying important areas. Although for this pilot we selected the VECs based on what we thought was important, meeting with all affected stakeholders and demonstrating that all types of knowledge will be included would be the best way of ensuring the results were accepted by the widest audience.

PoE models also help illustrate areas where mitigation might be required early on in the planning process as well as providing guidance as to which regulators should be involved. As an example, if marine transportation is shown by the PoE model to have a potential interaction with whales, those that govern shipping lanes could be brought into the process early to help develop shipping lanes that could potentially minimize the interaction between the two. Using PoE models as a precursor to risk characterization provides a firm foundation and a defendable position for any decision regarding proposed activities or new regulations.

One of the things we considered early in the PoE pilot process was where to place the cut off for pressures. When was a pressure so small in our analysis that it was not worth considering for the clutter it would add to the PoE diagrams? Every pressure tended to clutter the PoE diagrams and took attention away from what turned out to be the important pressures. In the end our decision to include/exclude pressures centred largely on a Delphic decision as to whether or not the risks associated with that pressure were large or small and whether or not, if a certain event did happen, would the effects be easily measurable? There was no doubt that nutrients could be added to the Beaufort Sea from the introduction of greywater, but could you measure it anywhere but directly at its' point of introduction? The answer, in this example, seemed to be probably not. We therefore considered pressures which would not produce a wide-scale, measurable effect as not worthy of detailed consideration and therefore excluded them from our PoE models. Others may find that including all pressures, no matter how small is desirable. In the case where known pressures have been excluded, we believe it would be beneficial to name what these pressures were so that people can see that they were considered at some stage.

The risk tables prepared to characterize the activities and pressures based on the PoE diagrams suggested that at present there may be few threats to the Yukon North Slope. Activities outside the area may pose some risk, but generally only in the worst case scenario. The general absence of most activities within the area suggests little impact to VECs unless there is some rather large accident. The utility of this portion of the pilot project was that it provides some repeatable means to assess risk associated with activities based on things like the trend, duration and geographic extent in the activity. This allows for an assessment of all activities and, coupled with an assessment of the pressures they produce, the basis for severity and likelihood which we then used in our mapping exercise of VECs and activities.

The PoE models are seen as an excellent way to scope out the effects of proposed activities and the models provide a relatively easy way to provide this information to decision makers. As DFO continues to move forward with EBM and IM with co-management partners and other stakeholders in a risk adverse environment, greater effort needs to be made to advance and use tools such as PoE. Taking the model to the next steps and producing risk profiles or maps that show the extent of geographic overlap between activities and VECs adds to the information available for decision makers.

The mapping of activities and VECs seems to be a very logical step of using the information garnered from the risk profiles to create another tool that can be used by decision makers. For some people, being able to see some or all VECs plotted in space against those activities thought most likely to pose some kind of threat to them could be very effective in clarifying what a decision could mean to those VECs.

ACKNOWLEDGMENTS

This manuscript would not have been considered without the assistance and encouragement of a large number of people with whom we have had numerous discussions and shared a number of ideas. While we undoubtedly have forgotten a few, discussions on Pathways of Effects and Characterization and Assessment with Roland Cormier, Matthew Hardy, Ernest Ferguson, John Legault, Martine Giangioppi, Edward Black and Adrienne Paylor led to a better defining of some of the basic concepts and ideas presented above. We both benefitted from the experience and presentations given at the September 2008 Geospatial Workshop in Winnipeg (DFO, 2009) which planted many of the seeds we have tried to present above. Major results from this study presented in an abbreviated form at a workshop in June 2009 also helped solidify some concepts discussed here. We especially thank Matthew Hardy for a valuable review of this manuscript, but ultimately accept full responsibility for the content.

LITERATURE CITED

Aklavik Inuvialuit Community Conservation Plan. 2000. Prepared by the Community of Aklavik, the Wildlife Management Advisory Council (NWT) and the Joint Secretariat. 155p.

Allen, C. R., Johnson, A.R., and L. Parris. 2006. A framework for spatial risk assessments: potential impacts of nonindigenous invasive species on native species. *Ecology and Society* 11(1): 39. [online]: http://www.ecologyandsociety.org/vol11/iss1/art39/

Andrews, B. 2003. Techniques for spatial analysis and visualization of benthic mapping data, final report. Prepared for NOAA Coastal Services Center. Newport, RI. SAIC Report No. 623. Available online: http://www.csc.noaa.gov/benthic/mapping/pdf/spatial.pdf

Awbrey, F.T., and B.S. Stewart. 1983. Behavioral responses of wild beluga (*Delphinapterus leucas*) to noise from oil drilling. J. Acoust. Soc. Am. 74, Suppl. 1: 54.

Beaufort Sea Partnership. 2009. Integrated Ocean Management Plan (IOMP) for the Beaufort Sea: 2009 and Beyond. Beaufort Sea Planning Office, Box 1871, Inuvik, NT X0E 0T0. x + 57p.

Bidleman, T.F., Patton, G.W., Walla, M.D., Hargrave, B.T., Vass, W.P., Erickson, P., Fowler, B., Scott, V. and D.J. Gregor. 1989. Toxaphene and other organochlorines in Arctic Ocean fauna: evidence for atmospheric delivery. Arctic 42(4):307-313. Available online: http://pubs.aina.ucalgary.ca/arctic/Arctic42-4-307.pdf

Born, E.W., Riget, F.F, Dietz, R., and D. Andriashek. 1999. Escape responses of hauled out ringed seals (*Phoca hispida*) to aircraft disturbance. Polar Biology, 21(3): 171–178.

Caldwell, J. 2004. Are seismic air-gun sources harmful to marine mammals? *Polarforschung* 72:103-107. Available online: http://epic.awi.de/Publications/Polarforsch2002_2-3_11.pdf

Canadian Environmental Assessment Agency. 2006. Glossary: Terms commonly used in federal environmental assessments. Canadian Environmental Assessment Agency, Ottawa. 30 p. Available online: http://www.ceaa.gc.ca/Content/D/A/C/DACB19EE-468E-422F-8EF6-29A6D84695FC/Glossary_e.pdf

Carmack, E.C., and R.W. MacDonald. 2002. Oceanography of the Canadian shelf of the Beaufort Sea: a setting for marine life. Arctic 55(Supp. 1):29-45.

Chou, Yue-Hong. 1997. Exploring spatial analysis in geographic information systems. Onword Press, Santa Fe. 500p.

Cobb, D., Fast, H., Papst, M.H., Rosenberg, D., Rutherford, R., and J.E. Sareault. 2008. Beaufort Sea large ocean management area: ecosystem overview and assessment report. Can. Tech. Rep. Fish. Aquat. Sci. 2780: ix + 188p.

COSEWIC. 2004. COSEWIC assessment and update status report on the grey whale (Eastern North Pacific population) *Eschrichtius robustus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 31 pp.

COSEWIC. 2005. COSEWIC assessment and update status report on the bowhead whale *Balaena mysticetus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. viii + 51p.

DFO. 2000. Eastern Beaufort Sea beluga. DFO Science Stock Status Report. E5-38 (2000). 14p.

DFO. 2001 Rat River Dolly Varden. DFO Science Stock Status Report. D5-61 (2001) 15p.

DFO. 2002a. Firth River Dolly Varden. DFO Science Stock Status Report. D5-63 (2001) 12p.

DFO. 2002b. Babbage River Dolly Varden. DFO Science Stock Status Report. D5-62 (2001) 12p.

DFO. 2002c. Big Fish River Dolly Varden. DFO Science Stock Status Report. D5-60 (2002) 15p.

DFO. 2004. Identification of ecologically and biologically significant areas. DFO Can. Sci. Advis. Sec. Ecosystem Status Rep. 2004/006. Available online: http://www.dfo-mpo.gc.ca/csas/Csas/status/2004/ESR2004_006_e.pdf

DFO. 2006. Identification of ecologically significant species and community properties. DFO Can. Sci. Advis. Sec. Ecosystem Status Rep. 2006/041. Available online: http://www.dfo-mpo.gc.ca/csas/Csas/status/2006/SAR-AS2006_041_E.pdf

DFO. 2009. Proceedings of the geospatial risk characterization workshop. Can. Manuscr. Rep. Fish. Aquat. Sci. 2866: v+54p.

Elmetri, I., and M. Felsing. 2007. Application of the Relative Risk Model (RRM) to Investigate Multiple Risks to the Miranda Ramsar Site. Environment Waikato Technical Report 2007/22. Available online: http://www.ew.govt.nz/PageFiles/5845/tr07-22.pdf

Fechhelm, R.G., and W.B. Griffiths. 1990. Effect of wind on the recruitment of Canadian arctic cisco (*Coregonus autumnalis*) into the Central Alaskan Beaufort Sea. Can. J. Fish. Aquat. Sci. 47:2164-2171.

Fernandes, P.G., Brierley, A.S., Simmonds, E.J., Millard, N.W., McPhail, S.D., Armstrong, F., Stevenson, P. and M. Squires. 2000. Fish do not avoid survey vessels. Nature, 404:35-36.

Fraker, M.A. 1979. Spring migration of bowhead (*Balaena mysticus*) and white whales (*Delphinapterus leucas*) in the Beaufort Sea. Fish. Mar. Serv. Tech. Rep. No. 59.

George,J.C., Philo, L.M., Hazard, K., Withrow, D., Carroll, G.M., and R. Suydam. 1994. Frequency of killer whale (*Orcinus orca*) attacks and ship collisions based on scarring on bowhead whales (*Balaena mysticetus*) of the Bering-Chukchi-Beaufort Seas stock. Arctic 47(3):247–255.

Gulf Canada. 1982. Analysis of accidents in offshore operations where hydrocarbons were lost. Calgary, AB. 250p.

Harvey, J.T., and T. Eguchi. 1997. Effects of ATOC sound on the harbor seal, *Phoca vitulina richardsi*, in Monterey Harbor. Moss Landing Marine Laboratories Technical Publication No. 97-1. Moss Landing, CA. 59p.

Harwood, L.A., and T.G. Smith. 2002. Whales of the Inuvialuit Settlement Region in Canada's Western Arctic: An overview and outlook. Arctic 55(Supp. 1):77-93.

Harwood, L. A., Joynt, A., Kennedy, D., Pitt, R., and S. Moore. 2009. Spatial restrictions and temporal planning as measures to mitigate for the effects of seismic noise on cetaceans: a working example from the Canadian Beaufort Sea, 2007-2008. Working Paper, Examination of the effectiveness of measures used to mitigate potential impacts of seismic sound on marine mammals, May 12-13, 2009, Ottawa, ON.

Hurley, G., and J. Ellis. 2004. Environmental effects of exploratory drilling offshore Canada: Environmental effects monitoring data and literature review – final report. Prepared for: The Canadian Environmental Assessment Agency, Regulatory Advisory Committee (RAC). 114p.

IMO (International Maritime Organization). 2004. International convention for the control and management of ships' ballast water and sediments, 2004. International conference on ballast water management for ships, Agenda item 8. 38p. Available online: http://www.bsh.de/de/Meeresdaten/Umweltschutz/Ballastwasser/Konvention_en.pdf

INAC (Indian and Northern Affairs Canada). 2008. Oil and gas in Canada's North - Active exploration and new nevelopment. Available online: http://www.ainc-inac.gc.ca/nth/og/pubs/nor/nor-eng.asp

INAC (Indian and Northern Affairs Canada). 2009. Oil and gas rights digital files. Available online: http://www.ainc-inac.gc.ca/nth/og/le/df-eng.asp

Jensen, A.S., and G.K. Silber. 2004. Large whale ship strike database. NOAA Technical Memorandum NMFS-OPR-25. 37p. Available online: http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/lwssdata.pdf

Joint Secretariat. 2003. Inuvialuit harvest study, data and methods report 1988-1997. The Joint Secretariat, Inuvik, NT. X0E 0T0 202p.

Kendel, R.E., Johnston, R.A. C., Lobsiger, U., and M.D. Kozak. 1975. Fishes of the Yukon Coast. Beaufort Sea Technical Report #6. Beaufort Sea Project, Victoria, BC. 114p.

Laist, D.W., Knowlton, A.R., Mead, J.G., Collet, A.S., and M. Podesta. 2001. Collisions between ships and whales. Marine Mammal Science 17(1):35-75.

Landis, W.G., and J.A. Wiegers. 1997. Design considerations and a suggested approach for regional and comparative ecological risk assessment. Human and Ecological Risk Assessment. 3:287-297.

Large, P.A., Graham, N.G., Hareide, N.R., Misund, R., Rihan, D.J., Mulligan, M.C., Randall, P.J., Peach, D.J., McMullen, P.H., and X. Harlay. 2009. Lost and abandoned nets in deep-water gillnet fisheries in the Northeast Atlantic: retrieval exercises and outcomes. ICES J. Mar. Sci. 66:323-333.

Lewis, C.F.M., and S.M. Blasco. 1990. Character and distribution of sea-ice and iceberg scours. *In*: J.I. Clark, *ed*. Workshop on ice scouring and design of offshore pipelines, 18–19 April 1990, Calgary, Alberta. Ottawa: Energy Mines and Resources Canada and Indian and Northern Affairs Canada.

LGL Ltd. 2001. Review of the potential effects of seismic exploration on marine animals in the Beaufort Sea. LGL Project TA 2582-281p.

McLaren, P.L., and R.A. Davis. 1985. The distribution of bowhead whales in the southeast Beaufort Sea, August – September 1983. Environmental Studies Revolving Funds Report, No. 001. Ottawa, 62p. Available online: http://www.esrfunds.org/documents/ESRF_001.pdf

Mills, E.L., Leach, J.H., Carlton, J.T., and C.L. Secor. 1993. Exotic Species in the Great Lakes: A history of biotic crises and anthropogenic introductions. J. Great Lakes Res. 19(1):1-54.

MMS (Mineral Management Services). 2002a. Final report, Volume II: Alternative oil spill occurrence estimators for the Beaufort and Chukchi Seas – fault tree method. OCS Study MMS 2002-047.

MMS (Mineral Management Services). 2002b. Oil-Spill Risk Analysis: Beaufort Sea Planning Area, Sales 186, 195, and 202. OCS Report MMS 2002-058. 128p.

NOAA (National Oceanic and Atmospheric Administration). 2006. Small diesel spills (500-5000 gallons). 2p. Available online: http://response.restoration.noaa.gov/book_shelf/974_diesel.pdf

North/South Consultants. 2009. Yukon North Slope – Coastal marine ecosystem overview. North/South Consultants, Winnipeg, MB. 64p.

NRC (National Research Council (US)). 2002. Oil in the Sea III: Inputs, Fates and Effects. National Academies Press, Washington, DC. 280p.

Osadetz, K. G., Dixon, J., Dietrich, J. R., Snowdon, L. R., Dallimore, S. R., and J.A. Majorowicz. 2005. A review of Mackenzie Delta-Beaufort Sea Petroleum Province conventional and non-conventional (gas hydrate) petroleum reserves and undiscovered resources: a contribution to the resource assessment of the proposed Mackenzie Delta-Beaufort Sea Marine Protected Areas. Geological Survey of Canada, Calgary Open File 4828, 1 CD-ROM

Raheja, N. 2003. GIS-based Software Applications for Environmental Risk Management. Map India Conference 2003. Available online: http://www.gisdevelopment.net/application/natural_hazards/overview/pdf/80.pdf

Richardson, J.W., Greene, Jr., C.R., Malme, C.I., and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego. 576p.

Røstad, A., Kaartvedt, S., Klevjer, T.A., and W. Melle. 2006. Fish are attracted to vessels. ICES Journal of Marine Science, 63:1431–1437.

Sikumiut Environmental Management Ltd. 2008. Final Report: Strategic Environmental Assessment Labrador Shelf Offshore Area. Prepared for Canada-Newfoundland and Labrador Offshore Petroleum Board. Project No. P 064.

Smeets, E., and R., Weterings. 1999. Environmental indicators: Typology and overview. EEA Technical report No 25. European Environmental Agency, Copenhagen. 19 p.

Smith, T.G. 1987. The ringed seal, *Phoca hispida*, of the Canadian western Arctic. Can. Bull. Fish. Aqaut. Sci. No. 21

Stirling, I., Kingsley, M.C.S., and W. Calvert. 1982. The distribution of ringed and bearded seals in the eastern Beaufort Sea 1974-1979. Can. Wildl. Serv. Occas. Pap. No. 47. 23 p.

Stephenson, S.A. 2003. Local and scientific observations of Dolly Varden (*Salvelinus malma*) (W.) in the Big Fish River, Northwest Territories, Canada: 1995-2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2644: v + 20 p. Available online: http://www.dfo-mpo.gc.ca/Library/273160.pdf

Stephenson, S.A. 2004. Harvest studies in the Inuvialuit Settlement Region, Northwest Territories, Canada: 1999 and 2001-2003. Can. Manuscr. Rep. Fish. Aquat. Sci. 2700: vi + 34p. Available online: http://www.dfo-mpo.gc.ca/Library/284031.pdf

Stephenson, S.A. 2006. A review of the occurrence of Pacific salmon (*Oncorhynchus* spp.) in the Canadian Western Arctic. Arctic. 59(1):37-46. Available online: http://pubs.aina.ucalgary.ca/arctic/Arctic59-1-37.pdf

Stevens, B.C., Vining, I., Byersdorfer, S., and W. Donaldson. 2000. Ghost fishing by Tanner crab (*Chionoecetes bairdi*) pots off Kodiak Alaska: pot density and catch per trap as determined from sidescan sonar and pot recovery data. Fish. Bull. 98:389-399.

Transportation Safety Board of Canada. 2008. Annual report to Parliament 2007-2008. 44p. Available online: http://tsb.gc.ca/eng/publications/ann/2008/2007-2008.asp

Treasury Board of Canada Secretariat, 2001. *Integrated Risk Management Framework.* Government of Canada. Available online: http://www.tbs-sct.gc.ca/pol/doc-eng.aspx?id=12254&section=text

Watkins, W.A. 1986. Whale reactions to human activities in Cape Cod waters. Mar. Mamm. Sci. 2:251-262.

Weilgart, L.S. 2007. A brief review of known effects of noise on marine mammals. Int. J. Comp. Psychology. 20:157-168.

Wright, C. 2001. Arctic navigation – the Canadian experience. Presented at Port and Ocean Engineering under Arctic Conditions, Ottawa, ON. Available online: http://www.mariport.com/pdf/Arctic%20Navigation%20-%20the%20Canadian%20Experience.pdf

Yukon Environment. 2006. Herschel Island - *Qikiqtaruk* - Territorial Park Management Plan. Yukon Dept. Environment. 54p. Available online: http://www.environmentyukon.gov.yk.ca/pdf/Final_version.pdf

APPENDICES

APPENDIX 1: List of Yukon North Slope Valued Ecosystem Components considered during the pilot project.

Bowhead Whale

Although not hunted by the Inuvialuit since 1996 (Harwood and Smith, 2002), the Beaufort-Chukchi-Bering stock of bowhead whale was assessed as a Special Concern stock by COSEWIC in 2005 (COSEWIC, 2005) and legally listed under the federal Species at Risk Act in 2007 (Canada Gazette, SOR/2007-284, 13/12/07). Bowhead whale numbers have perhaps doubled in the past 25-30 years bringing their numbers close to the pre-whaling estimates of the 1700s. That they are at least temporarily abundant in the study area can be illustrated by results of a 1983 survey that in a single day spotted 87 whales during two 35 km transects carried out within 5 km of shore between Shingle and Kay points (McLaren and Davis, 1983). Harwood and Smith (2002) present maps showing areas of bowhead whale concentration east of Herschel Island. Bowhead whales are very sensitive to noise and use vocalization to communicate over great distances (Richardson *et al.*, 1995). Sound pollution from shipping activity, airguns or other seismic devices and industrial noise from oil or gas platforms may disrupt communication and move whales to less favourable locations (COSEWIC, 2005). Some primary feeding areas for bowhead whales on the Yukon North Slope appear to be off Komakuk Beach and east or north of Herschel Island. Some studies have suggested that while feeding, bowhead may not leave an area even if noise levels approach those that may cause temporary or permanent damage. A study of scarring on harvested bowhead whale in Alaska (George *et al.*, 1994) showed that about 1.0% had scars attributed to ship strikes although it was impossible to determine where the strikes had occurred.

Beluga Whale

Of extreme interest to all Inuvialuit coastal residents who hunt beluga on an annual basis, largely near the Mackenzie estuary, but also, at least in some years, close to all Inuvialuit marine coastal communities (Harwood and Smith, 2002). Beluga whales migrate along the Yukon North Slope in the spring and may pause in leads as they wait for ice to leave the area of the Mackenzie Delta (Fraker, 1979). They may even enter areas far to the north near Banks Island prior to again moving south toward the Mackenzie estuary (DFO, 2000). An annual aggregation of beluga whales occurs in the waters of the Mackenzie estuary during late June through late July after which time they disperse towards Amundsen Gulf and Viscount-Melville Sound (DFO, 2000). While the exact reason for the Mackenzie aggregation remains unknown, theories hold that whales come to this area due to the warmer waters which may provide some thermal advantage, or feeding, moulting or socializing activities (DFO, 2000). There are an average (1990-1999) of 111 whales harvested annually, mainly by residents of the four Inuvialuit communities of Aklavik, Inuvik, Tuktoyaktuk and Paulatuk (DFO, 2000; Joint Secretariat, 2003). The beluga whale is a highly vocal species, with a well developed capability for echolocation (Harwood and Smith, 2002). Many of the sound frequencies produced by beluga whales overlap with those made by anthropogenic noise (Richardson *et al.*, 1995).

Dolly Varden

Of special interest on the North Slope due to their importance to residents of Aklavik and Fort McPherson as well as other parties that summer along the Yukon North Slope. Dolly Varden are known to over winter and spawn in a number of North Slope Rivers including the Firth (DFO, 2002a), Babbage (DFO, 2002b), Big Fish (DFO, 2002c), Rat and Vittrekwa (DFO, 2001). Other small populations may exist. The contribution of each stock to coastal fisheries is dependant on the location of the fishery and of course, the proportion of each stock within that area. The Vittrekwa River stock, as an example, appears to be limited in size. The Big Fish River stock has been depressed for years and likely contributes little to the Shingle Point fishery (DFO, 2002c). Fishing near Herschel Island results in the capture of fish predominantly from the Firth and Babbage stocks. There is the possibility of the capture of some fish from American rivers as well as fish from the Big Fish and Rat rivers. Dolly Varden are believed to move downstream from over wintering locations while ice still covers the rivers. Timing for this would be sometime in May. By late June or early July Dolly Varden have entered the marine environment and remain there feeding until sometime in late August or early September at which point they begin their migrations back to over wintering locations. Fisheries for the species take place at Shingle Point from late July until the last week of August; after that time most of the Dolly Varden have reached their over wintering rivers or are well into the Mackenzie River (Stephenson, 2003).

Seals (Ringed and Bearded)
The ringed seal is the most abundant of the seal species in the Arctic. The population estimates for the species have varied widely and been attributed to changes in ice conditions, with heavy ice years suggested as being responsible for a decline in numbers (Smith, 1987). Some of the largest concentrations of ringed seals are known from the Komakuk Beach – Hershel Island areas. Ringed seals prefer water over 50 m deep, feed primarily on fish, are a prime prey for polar bears and construct both birthing and haul out lairs. Rapid changes to ice conditions, such as those caused by ice breaking activities, may result in seal pups being introduced to the water prematurely before they are able to look after themselves.

Bearded seals make up less that 10% of the seal population in the Beaufort Sea. Bearded seals are solitary animals found in shallower water than ringed seals and feed primarily on benthic organisms. Like ringed seals, bearded seal populations have exhibited considerable variation, probably due to ice conditions (Stirling *et al.*, 1982). Bearded seals associate almost exclusively with disturbed ice areas which may include drifting ice associated with leads. Bearded seals do not create birth lairs, so ice disturbance may have a lesser affect on them than on ringed seals.

Other fish/shellfish species
Other species are important to the Inuvialuit at least on a seasonal basis. Capelin and Pacific herring are harvested in a number of locations as they appear during certain times of the year (*e.g.*, Stephenson, 2004). These and other species are preyed upon by larger species including fish, birds and mammals. Arctic cisco larvae drift from natal streams within the Mackenzie River westward along the Yukon North Slope to the Colville River in Alaska every year (Fechhelm and Griffiths, 1990). Here, the young remain for several years until they are able to return to the Mackenzie River area where they eventually contribute to the next generation. Repeated disruption of this drift over the course of several years could effectively eliminate all Arctic cisco from the North Slope although there is some evidence that when the western drift is interrupted, Arctic cisco that find themselves being pushed along the Tuktoyaktuk Peninsula by eastern currents use rivers in that area as nursery habitat, although the success is generally seen as much more limited.

Primarily freshwater species like ninespine stickleback, Arctic grayling, inconnu and other whitefish species may occur along the North Slope, but these fish are often dependant on fresh water flow originating from the Mackenzie River.

Marine species such as Arctic cod are found in marine waters. All five species of Pacific salmon may occasionally be present in near or offshore waters (Stephenson, 2006). Rainbow smelt, capelin and various species of sculpins can be found near shore.

With little rock or boulder substrate along the North Slope, as well as annual ice scouring, there is a limited benthic community near shore which tends to be most developed at depths of 10-15m (Cobb *et al.*, 2008). Amphipods, oligochaetes, toad crabs, starfish and sea urchins occur at greater depths and appear to be most common in areas where less ice scouring occurs. Scouring tends to favour those species that can re-colonize areas quickly.

Water Quality
The relatively pristine waters of the Beaufort Sea have remained so due to limited marine traffic, no large scale industrial activities and a small population in relatively widespread communities, none of them on the Yukon North Slope pilot area. All contribute to a very small “footprint” on coastal and offshore waters. Although probable changes to water quality in the Mackenzie watershed will eventually make its’ presence known through measurable changes in the near shore Beaufort Sea, at present, water quality conditions are generally good.

Water quality in the Beaufort might also be affected by gross changes in the Pacific Ocean. Water quality may occasionally be affected near sewage outfalls and might affect any shellfish within the vicinity although there are no such structures along the Yukon North Slope.

Ice
Although this VEC seems a bit out of place, Inuvialuit in some areas depend on ice for travel. Disturbance and breaking of ice by ice breakers can mean the difference between safe and unsafe travel and perhaps in some cases, between any travel at all.

Ice also provides a platform for ice algae, especially in the spring, which is important for feeding a number of invertebrate species which are in turn preyed upon by fish and marine mammals. A loss of ice would thus disrupt this food chain, the results of which are unknown. The ice community is a very important contributor to the Arctic food web when primary production has been limited due to ice cover.

The loss of ice during the late spring by ice breaking vessels could result in seal pups being introduced to the water prior to their being able to survive with limited blubber for insulation. Separation from the mothers prior to weaning by ship traffic could reduce survival. It is assumed that if ice is broken into smaller pieces in the spring that it results in quicker overall melting.

The effect of the loss of ice through climate change is not completely understood although it would certainly affect animals that have evolved to use ice as a feeding, birthing or nursery platform, such as the seals and polar bears and a platform for the production of ice algae.

APPENDIX 2: Description of activities used in the Yukon North Slope pilot project.

Oil and Gas (exploration and exploitation phases)

Although the oil and gas industry has a good record in the Arctic, activities related to the industry are probably ”the” greatest perceived and actual overall threat to the North Slope and surrounding Beaufort Sea due to the number of activities and related risks associated with it. Sikumiut Environmental Management Ltd. (2008) reports that during the entire history of operations on the US outer continental shelf and North Sea there have never been any large (> 1000 barrels) spills. Oil and gas development includes both the exploration and exploitation phases, with the exploitation phase perhaps posing the greatest level of risk.

Exploration is defined here as typically short term in that it does not occur all year, but generally, during the open water season when air gun arrays are towed within specific areas. While the operation of airguns has strict start up (“ramping” up) and shut down protocols (usually including the use of marine mammal observers on board), the effects of using airguns even with protocols in place is essentially unknown. While it is believed that fish are not harmed except perhaps for those within 3.0 m of an operating airgun, it is unknown if, at certain times of the year or in specific locations, the use of air guns might cause fish to avoid certain areas that might have otherwise spent time in. Similarly, while it is thought that harm to the hearing of whales does not occur, it is not known exactly what the effect of air guns might be on normal behaviour and movement. Communication by vocal species such as bowhead whales may be particularly disrupted during seismic surveys (Richardson *et al.*, 1995). Vessel traffic, either from the ship towing the air gun array or other vessels bringing needed supplies to the area or the seismic ship itself may cause additional stress or injury to marine mammals through collision or noise generation.

Exploitation brings a number of risks including;

- Noise generation by the drilling/production platform itself, ship traffic bringing supplies and crew changes to and from the platform and noise produced from shipping the product out of the area.
- Spills, including permissible “grey water” discharges from platforms, drill cuttings, leaks from vessels all the way up to large spills caused by well blow outs, faulty valves, shipping accidents or perhaps from pipeline damage if oil is pumped from offshore areas to loading facilities or locations on shore. However, the US National Research Council has estimated that there is more natural seepage of oil into Alaskan waters than is released annually by all North American platforms (NRC, 2002).
- Invasive species brought into the area via the movement of oil platforms and transport vessels. These species could exist on hulls or be transported in ballast water.
- Habitat destruction, generally limited to a small area of the ocean due to placement of a producing platform.
- Introduction of various emissions from burning of well fluids during production tests and well clean-up, particulate matter and unburned hydrocarbons introduced from engines, generators, heating exhausts, cranes, helicopters and support vessels. Many of these potentially contribute to degradation of air quality, particulate matter, climate change and possible ocean acidification.

Of most significance to this pilot study, oil and gas potential within the Yukon North Slope study area is expected to be minimal. Due to geology, near shore areas do not appear to possess the same potential for oil and gas as areas closer to the Tuktoyaktuk Peninsula.

Marine Transportation
Transportation in this category refers to all that needed for oil and gas development (exploration and exploitation), tourism, fishing, barging or otherwise moving needed supplies to communities, coast guard and scientific research vessels. Shipping may directly be responsible for strikes of marine mammals (George *et al.*, 1994; Laist *et al.*, 2001), the introduction of aquatic invasive species (either attached to hulls and anchors or in ballast water) and pathogens, air pollution (possibly contributing to climate change), changes to ice conditions, increasing noise levels and the introduction of pollutants through accidental spills and discharges as well as permitted discharges. Solid wastes may also be introduced incidentally from ships.

Tourism
This includes both large scale and small scale tourism so it runs the range from large ships to small boats; the larger ships to some extent being covered (above) by marine transportation. Tourism includes consumptive and non-consumptive uses and also includes simple transportation to areas which may be strictly cultural in nature. Transportation may be by boat, aircraft or snowmobile/ATV in the winter months. All generate noise, may cause various degrees of pollution (both air and aquatic) and can influence the behaviour or activities of organisms. The larger the mode of transportation, the greater the threat to marine aquatic resources from a greater number and greater size of potential events. Therefore, the threat from tourism is largely from the mode of transportation. The viewing of marine mammals as people try to get closer to them may result in additional stress to these animals as well as putting the ship itself in greater harms way.

Fishing (Commercial and subsistence fishing/marine mammal harvesting)
Although commercial fishing is currently not an activity within the Canadian Beaufort, it is one that has been considered numerous times and several attempts have been made to determine what species are present and may be profitable, usually as a specialized item, within the area. While subsistence fishing occurs in a number of locations on a regular basis, some recreational fishing, albeit limited, also takes place in a few areas. Almost all subsistence or recreational fishing takes very close to shore, typically associated with a river or some distinctive geographic feature (*e.g.*, Shingle Point, Kay Point, Herschel Island, Ptarmigan Bay). Fishing in marine waters takes place almost exclusively for anadromous Dolly Varden. Most of the marine fishing takes place in known feeding areas or along coastal migration routes as these fish make their way back to natal rivers for overwintering and spawning. While fishing does have the potential of fishing stocks down, it is not believed that fishing in the marine environment has contributed to the decline of any species. Dolly Varden stocks that are showing decline are thought so due to a combination of habitat changes in the over wintering areas and traditional fishing practices in these same over wintering grounds (DFO, 2002c; Stephenson, 2003).

Harvesting of marine mammals for subsistence purposes is included within this definition of fishing. Harvesting of marine mammals, primarily beluga, occurs in only a few areas, mainly near the Mackenzie Delta in areas whales enter in early July. Whales harvested in most other areas are taken opportunistically as there are few areas of aggregations other than the one in the Delta.

The possible threat to the environment from any lost fishing gear has not been quantified in the Beaufort and while it is believed that the amount of lost gear is probably minimal (short nets are typically used (*e.g.*, 30 metres), few people actually fish and almost all fishing in the Beaufort takes place very close to shore), the loss of gill nets could result in the capture of hundreds of fish before the net either rolled up or was carried to shore to waves or ice.

APPENDIX 3: Description of pressures used in the Yukon North Slope pilot project.

Noise (shipping, seismic, industrial development)

Any noise artificially generated in the marine environment may have a number of effects on marine life including hearing loss, discomfort and injury, social disruption, interference of communication or prey detection through masking, displacement from preferred habitats and variation in responsiveness (Richardson *et al.*, 1995).

Generally limited to relatively short durations (a relative term), noise can be generated by passing ships, fishing or tourist boats, oil and gas exploration using air guns or more long-term such as in the case of an established oil or gas platform (Richardson *et al.*, 1995). Some noise capable of disturbing marine mammals may also be generated by helicopter or fixed wing aircraft traffic (Hurley and Ellis, 2004). More noise is generated by helicopters than fixed wing aircraft and helicopter noise appears to bother seals more than whales (Richardson *et al.*, 1995). However, beluga whales tend to react to any aircraft flying at attitudes of less than 305 m when in shallow water (Richardson *et al.*, 1995).

Noise is produced during seismic surveys (both by the ship and air guns), construction and operation of offshore facilities and associated infrastructure (docks) and during their subsequent decommissioning. In marine mammals, noise could cause hearing loss, stress or discomfort, could mask communication form other whales or predators and may disrupt feeding or migration (Richardson *et al.*, 1995). Seals appear to not be affected by seismic surveys using air guns (Richardson *et al.*, 1995). Shock waves from seismic programs may kill fish or invertebrates, but only those very near the source (LGL Ltd, 2001). Fish generally move away from the area during seismic programs and they may, or may not, quickly return and resume the pre seismic activities (LGL Ltd, 2001).

Noise generated by air gun arrays and industry in general is that thought to be near the same frequencies at which bowhead whales use for communication. As such, seismic activities and shipping may have the largest negative effect on bowhead whales and they generally tend to avoid these areas (Richardson *et al.*, 1995). Air guns may also physically harm or kill organisms close to the source when the air gun is fired. Generally, this type of harm was thought to be of minimal concern in the Beaufort.

Noise is generated by ice breaking activities although depending on location and time of year, this may have only a minimal effect on marine mammals. The noise generated by breaking ice is a different frequency than that produced by ships engines and may travel further. Noise generated by ships during ice breaking may be greater and different than that produced during normal operation especially as engines are revved up to get a run to ram thick ice (Richardson *et al.*, 1995). Beluga appear to actively avoid areas of active ice breaking for 1-2 days (Weilgart, 2007).

Habitat Alteration and Degradation

These changes are almost all concerned with highly localised changes brought on by the establishment of an oil or gas platform. In some cases, these artificial structures might produce benefits to some species that will use the new environment as habitat. In some cases, however, the habitat destroyed could be very local or unique in nature and may result in significant loss of biota. Some habitat changes can also be brought on by trawling if benthic communities, especially coral or sponge based, are disturbed.

Contaminants (all sources including fuel spills)
Contaminants, as considered here, include not only small discharges of hydrocarbons or hazardous materials from vessels of all sizes and associated infrastructure as well as contamination from nearby terrestrial sites, but also large scale pollution resulting from major oil spills or shipping accidents. We did not include long-range transport in our discussions.

Hydrocarbons
Introduction of hydrocarbons into the environment most often comes about due to spills due to accidents while transiting, during refuelling of vessels or infrastructure or due to accidental discharge (*e.g.*, equipment failure or negligence). These types of discharge are more likely to occur than those involving more persistent contaminants such as PCBs or mercury. Hydrocarbon discharge may also occur during a blow out while drilling. Accidents involving hydrocarbons, especially when large scale, are likely to have a much greater and longer negative effect on the environment. As an example, it is currently unknown how successful a cleanup of a large release of oil under the ice could be if it were to happen as a result of a catastrophic well blow out. As such, contamination by hydrocarbons is the greatest threat to the Arctic environment. However, subsistence fishers typically use boats that use gasoline which, in the event of an accident, evaporates or disperses more quickly than marine quality diesel fuel used by large ships (NOAA, 2006).

Persistent Pollutants
The majority of these pollutants come to the area by one of five means; long range transport by air, long range transport in ocean currents, down the Mackenzie River from sources within the watershed, from contaminated sites on shore (as an example from former DEW Line locations) or from release in hydrocarbon based oil products. Most of these pollutants, while possibly having a very localised introduction site or small in quantity, will remain in the environment for years. In many cases if brought into the food chain they are capable of bio-magnification and thus affect top predators, typically marine mammals. Contaminants from drilling muds could negatively affect benthic species near the drilling site.

Invasive Species
Although invasive or non-indigenous aquatic species are typically thought of as fish, experience in the Great Lakes and other areas has now shown that many can be plant or invertebrate in nature. Vectors for these introductions could include ballast water from any large vessel, bait (in the case of commercial fisheries) or possibly attached to improperly cleaned fishing gear, cables, anchors chain and ropes or the hull of a boat. In any case, ballast water or hull attachment introductions seem to be the most likely although ballast water introductions only seem possible if a ship is coming to pick up some sort of product in the area. There is no aquaculture within the area and no reason to suspect that anyone would transfer fish or other organisms from one area to another. Invasive species could include species that act as parasites, compete directly for resources or interfere with the activities of indigenous species. We specifically were very unclear as to what an invasive species might interact with and we thought that “other fish or shell fish” were more likely to be negatively affected than would marine mammals. There is limited data as to how an Arctic ecosystem may respond to an invasive species and because surveys have not been completed in many areas of the Arctic, it may, in the future, be difficult to determine if something was always present or has only recently arrived.

Biota Removal
Biota removal refers to any activity that removes organisms (*i.e.*, fish, marine mammals, shellfish) from the environment. While commercial fishing and subsistence hunting/fishing are

the main mechanisms of removal, some limited removals of fish may occur during tourism activities (recreational fishing by individuals). We viewed the removal of a few fish during small-scale tourism as an insignificant pressure. Commercial activities are of the greatest concern as directed harvest or by-catch may result in shortages of some species preferred as forage items by predacious species. Commercial fisheries thus hold the potential to disrupt food chains. Subsistence fisheries, typically targeted to specific species, on a small scale and a short duration do not generally have the same potential to threaten VECs through their activities. The only way we saw subsistence fishing as having a significant potential impact was if fishing occurred in a concentrated manner in an area where a significant portion of the stock is aggregated, such as Dolly Varden near the mouth of a river as the fish are preparing for their annual migration. As this type of fishing is unknown, we maintain that subsistence harvesting has a minor effect on marine biota. Until or unless commercial fishing begins in earnest in the area, it was thought that biota removal was generally only of minor concern within the Yukon North Slope study area.

Gear Loss (Fishing)
A concern predominantly for the commercial fishing industry and perhaps the odd subsistence net left in too long. Gear loss is mainly concerned with large numbers of commercial fishing nets that could be lost due to rapid ice movement or encroachment. Loss of fishing nets and other gear types has been a problem in many areas, often when weather or ice has made their retrieval impossible (*e.g.*, Stevens *et al.*, 2000). While there is much debate about how long a net might fish after being lost, there is no doubt that the gear continues to fish for some period of time (Large *et al.*, 2009). Stevens *et al.* (2000) suggested that some crab pots might fish for four years or more and showed that they captured more than just crabs, but also captured benthic organisms and several fish species. That gill nets might then attract either marine mammals or other predacious fish seems probable. The exact effect of lost gear on biota would seem to be dependent on a large number of variables including location of loss, depth, currents and time of year. Fishing gear lost in relatively shallow waters late in the year might be brought to shore by ice in the following spring and fall storms, more or less no longer fishing by the time whales returned to the area the following year. However, monofilament gill nets in areas of deeper water might fish almost indefinitely until the loss of float lines allowed them to sink.

Marine Transportation (Tourism, Oil and Gas, other industry, Northwest Passage)
Shipping provides several threats to the environment and animals of the North Slope. While the transportation of supplies and equipment to northern communities and oil and gas facilities is necessary, the noise they produced may disrupt normal activities, interfere with communication or even permanently damage hearing (Richardson *et al.*, 1995). The physical movement of ships may result in whale strikes causing injury or death, especially among young or old individuals when they are concentrated. With a supposed increase in the number of slow moving grey whales into Arctic waters, it is possible that these recent arrivals could be potential candidates for ship strikes.

Accidental discharge of pollutants or a large scale accident involving a ship sinking could release thousands of litres of fuel oil and other substances into the Arctic environment. Depending on the season, shipping activities may break ice thereby restricting movement desired by local residents for hunting. Ice that has been broken could conceivably move into areas which are typically ice free (polynyas) with unknown results, but possibly decreasing productivity. The breaking of ice creates noise that may interfere with normal communication by whales and may create “false” leads which whales may travel in and then become trapped.

Regardless of the type or reason for the shipping activity, all shipping traffic has to pass by the North Slope at some point. Whether this passage is near or far from shore is in part determined by the time of year and ice conditions. Typically, early in the year passage would be far off shore due to the creation of flaw leads. Later in the year as freeze up is occurring passage may be much closer to shore. Note that tourist ships probably more often than not travel closer to shore than other types of marine transportation expressly for the purpose of allowing passengers a better view of the shoreline. This may result in more risky travel than those ships which stay offshore away from any potential shipping hazard such as an uncharted sandbar or rocky outcrops.

APPENDIX 4: Risk categories for assessing the potential impact from anthropogenic activities.

Hazard Level	Criteria
Intensity	
High	The activity is characterized as intense within the area it occurs; where the degree of the activity is considered high in regards to: the number of people involved, the volume, density or concentration of the activity, etc.
Medium	The activity is characterized as moderately intense within the area it occurs; where the degree of the activity is considered moderate in regards to: the number of people involved, the volume, density or concentration of the activity, etc.
Low	The activity is characterized at a low intensity within the area it occurs; where the degree of the activity is considered low in regards to: the number of people involved, the volume, density or concentration of the activity, etc
Duration	
High	The activities associated to the activity operate continuously within the ecological unit. Impacts are considered chronic as they extend beyond a year.
Medium	The activities associated to the activity operate over a specified period only within the ecological unit. Impacts are considered to occur over one year or less.
Low	The activities associated to the activity operate only on a punctual basis within the ecological unit. Impacts are considered to occur within one season or less.
Geographic Extent	
High	The activity occurs over an extensive area within the ecological unit. The activity is considered to have an area of influence extending over a large geographic scale of the ecological unit or perhaps beyond the ecological unit.
Medium	The activity occurs over a portion of the area within the ecological unit. The activity is considered to have an area of influence which is limited to only a portion of the geographic scale of the ecological unit.
Low	The activity occurs over in a localized area within the ecological unit. The activity is considered to have an area of influence which is limited to only the footprint of the activity or its immediate vicinity.
Trend	
High	Increasing. The activity is expected to increase over the next decade (*i.e.*, change of the activity in terms of development, immigration, industry expansion, new emphasis, etc.).
Medium	Stable. The activity is expected to be relatively stable over the next decade (*i.e.*, no significant change of the activity in terms of development, immigration, expansion, new emphasis, etc.).
Low	Declining. The activity is expected to be decline over the next decade (*i.e.*, negative changes of the activity in terms of development, out-migration, industry closures, etc.).
Regulatory Response	
High	Negligible regulations - The activity is not subject to any specific regulatory measures or it may have voluntary guidelines and practices with collaborative agreements.
Medium	Partially regulated - The activity is guided by defined standards, best-management practices, policies although they may or may not be audited or enforced.
Low	Highly regulated -The activity is highly controlled through policies, regulations, or legislation. This can include specific zoning requirements (*e.g.*, Marine Protected Areas, exclusion areas) or other restrictions which require regular inspections, enforcement or audits under provincial or federal laws.

APPENDIX 5: Risk categories for assessing the potential impact from anthropogenic pressures.

Hazard Level	Criteria
Magnitude	
High	Impacts caused by the pressure have the potential to impact a whole stock(s), population(s), habitat(s) or ecosystem(s) which represents a major change in ecosystem structure and function or a total collapse of processes. Outside the range of natural variability.
Medium	Impacts caused by the pressure have the potential to impact a portion of a population or habitat, or ecosystem which represents a detectable change to structure and ecological function. Temporarily outside the range of natural variability
Low	Impacts caused by the pressure have the potential to cause localized impacts on specific sub-population, habitat, or ecosystem which represents minor alterations to some ecosystem components. Impacts are within natural variation.
Ecosystem Sensitivity	
High	The ecosystem is highly sensitive to change and perturbations caused by the pressure (*e.g.*, rare or unique species and habitat assemblages that require stable constant conditions)
Medium	The ecosystem is moderately sensitive to change and perturbations caused by the pressure (*e.g.*, species and habitat assemblages are common and typical within the ecological unit and they tolerate most changes to a degree)
Low	The ecosystem is resilient to changes and perturbations caused by the pressure (*e.g.*, species and habitat assemblages are acclimated to frequent disruptions such as tides, storm events, mobile sediments, etc.)
Reversibility	
High	Impacts caused by the pressure are irreversible or are only reversible over an extended period with active management efforts (*i.e.*, ecological restoration).
Medium	Impacts caused by the pressure are reversible over short term with active management or over a longer term without active management.
Low	Impacts caused by the pressure are reversible over short term without active management. The ecosystem will return to its previous state without any interventions.
Observed impacts in the past	
Certain	Occurred regularly in this ecological unit and is considered a chronic concern.
Likely	Occurred in this ecological unit more than once and is considered a concern.
Moderate	Has occurred before in this ecological unit, but infrequently
Unlikely	Has occurred only in exceptional circumstances.
Rare	Never observed under any circumstances.
Expected impacts in the future	
Certain	The impacts are expected to occur regularly in this ecological unit.
Likely	The impacts are expected to occur here more than once in this ecological unit.
Moderate	Uncommon, but evidence suggests that impacts could occur infrequently in this ecological unit.
Unlikely	The impact could potentially occur in this ecological unit under exceptional circumstances.
Rare	Impacts are not expected, but not completely impossible.

APPENDIX 6: Assigning likelihood and impact.

Likelihood: The likelihood of the risk occurring.

1. Rare <5% probability
2. Unlikely 5 – 24% probability
3. Moderate 25 – 75% probability
4. Likely 76 – 95% probability
5. Almost certain >95% probability

Impact: The actual effect on the environment if the event were to occur.

1. Negligible – an event, the consequences of which can be absorbed through normal activity
2. Low – an event, the consequences of which can be absorbed but management effort is required to minimize the impact
3. Medium – a significant event that can be managed under normal circumstances
4. High – a critical event that with proper management can be addressed
5. Extreme – A major event that will require the managing organization to make a large scale, long term realignment of its operations, objectives or finances