Commentary on the Management of Fish Habitat in Northern Canada: Information Requirements and Policy Considerations Regarding Diamond, Oil Sands and Placer Mining – Summary Report

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Canadian Technical Report of

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COMMENTARY ON THE MANAGEMENT OF FISH HABITAT IN NORTHERN CANADA: INFORMATION REQUIREMENTS AND POLICY CONSIDERATIONS REGARDING DIAMOND, OIL SANDS AND PLACER MINING – SUMMARY REPORT

by

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PREFACE

This report has been prepared in response to the need for information that will assist the management of fish and their habitat in northern Canada, and especially that relating to exploration and mining for diamonds. Increased exploration and mining activity is occurring across Canada and potential diamond mines have been identified in Nunavut, Alberta, Saskatchewan, Ontario and Quebec. Diamond mining is currently occurring in the Northwest Territories.

Fisheries and Oceans Canada (DFO) has authorized the elimination or partial destruction of 26 lakes for diamond mining since 1997, and an additional 5 for the metal mining sector. The elimination of lakes is escalating in relation to the needs of the mining sector in Canada.

The application of appropriate compensatory and restorative techniques is a fundamental requirement of developments that impact fish and their habitat. This poses an especially significant and unique challenge in northern Canada because of the prevalent climatic conditions and the paucity of applicable knowledge.

Although the focus of this report is related to diamond mining in the Arctic, attention is also given to oil sands and placer gold mining; other major industrial activities in northern Canada that impact upon fish and their habitat. The elimination and degradation of lakes across Canada for metal mine tailings disposal and access to ore exemplify decisions that have facilitated industrial developments.

One of the main objectives of this report was to identify deficiencies in our knowledge with respect to fish and their habitat in northern Canada, and the implications of habitat alteration and destruction to aquatic systems. Comments are also provided on related habitat compensatory and restorative measures and the consistency of application of the *Fisheries Act* and use of the “Policy for the Management of Fish Habitat” (Department of Fisheries and Oceans 1986).

Fifty-one representatives of the diamond, placer gold, and oil sands mining industries, scientific and operational colleagues in governments and academia, and certain independent people collaborated in the production of this report by providing valuable information and insight.

It is apparent that there is still much to know about the biology of Canada’s north, the implications of climate and habitat change to aquatic organisms, and the appropriateness and adequacy of compensation, restoration, and development activities. It is hoped that the information within this report will draw attention to these deficiencies in our understanding of the ecology of certain aquatic organisms and thereby help guide scientific research and assist habitat management.

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ABSTRACT

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This summary is derived from a detailed technical report (Birtwell et al. 2005) which identifies scientific and management information needs that are necessary in order to make consistent and defensible decisions which conform with the intent of the "Policy for the Management of Fish Habitat" ("Habitat Policy", Department of Fisheries and Oceans 1986), and that assist with the facilitation of responsible mining activities compliant with the *Fisheries Act* (Government of Canada 1985). The project was stimulated by increasing mining activities in northern Canada, and especially the requirement to eliminate and degrade lakes and watercourses. Since the 1950s, 50 lakes, in whole or in part, have been eliminated or approved for elimination. Of these lakes, 62% (31) were in the last decade, and an additional 20 are to be considered for approval within the next 4 years.

Compensation and restoration for the destruction of lake and stream habitats pose significant scientific and management challenges, especially so in northern Canada where ecological knowledge and understanding are rudimentary.

The detailed technical report and a literature search (Khan et al. 2005) provide reference information and an audit trail regarding the statements contained in this summary document. Assessments of published literature were combined with opinions from diamond, placer gold and oil sands mining representatives, government scientists and habitat practitioners, and other knowledgeable people in private and public sectors (unabridged comments are contained in Samis et al. 2005). These comments provide an insight into current habitat management practices and policies, industrial development, and related scientific research and needs.

The amalgamation of opinions and published information provide the basis for conclusions and recommendations regarding the management of fish habitat, and the scientific information and procedural requirements to effectively fulfill Departmental responsibilities in this regard. Among the numerous conclusions drawn and recommendations made in this review, the following are considered to be of paramount importance:

- **Damage to fish habitat in pristine regions of the Canadian Arctic is occurring and escalating and there is currently no assurance that habitat compensatory and restorative measures will be effective in meeting the Habitat Policy requirements regarding fish habitat productive capacity, which are linked to the *Fisheries Act* in order to sustain fish productivity.**

- **The inadequacy of even basic ecological knowledge, the absence of validations of habitat compensatory and restorative measures regarding habitat linkages to fish productivity, and no examples of whole lake restoration and compensation to guide developments forecast irreparable harm.**

- **Significantly more knowledge and understanding of the basic biology and habitat requirements of Arctic species are required, especially in view of the increasing human development in northern Canada, global environmental changes, and the need to determine and assess their cumulative effects. Provision of this knowledge and understanding will assist decision making, reduce risk and uncertainty, and facilitate mitigation, compensatory and restorative measures designed to sustain aquatic resources in this and other remote regions in Canada.**

- **Co-operative and collaborative ventures with industries, governments, academia and Aboriginal communities should provide for the acquisition of new information. Opportunities currently exist for this to occur. Multi-stakeholder consortia should be the mechanisms for fund acquisition and disbursement.**

- **The successful application of the Habitat Policy to developments in regions of Canada where there is a paucity or absence of basic information for making sound decisions is jeopardized in view of the potential uncertainty of success of habitat mitigation, compensatory and restorative measures. In this context consideration must be given to learning from, and adapting to, experimental decision making. This will be accomplished through committed research and monitoring which is appropriately scaled over time and in space to meet stated Departmental objectives.**

- **Compensatory, restorative, and related techniques, measurements and evaluation, are priority research topics that meet with approval from all industry sectors, the scientific community and habitat practitioners.**

RÉSUMÉ

Birtwell, I.K., Samis, S.C., and Khan, N.Y. 2005. Commentary on the management of fish habitat in northern Canada: information requirements and policy considerations regarding diamond, oil sands and placer mining – Summary Report. Can. Tech. Rep. Fish. Aquat. Sci. 2607: xii + 65 p.

Le présent sommaire a été préparé à partir d'un rapport technique détaillé (Birtwell et al. 2005) qui présente les renseignements scientifiques et l'information de gestion requis pour permettre la prise de décisions cohérentes et défendables, conformes à l'esprit de la Politique de gestion de l'habitat du poisson (Ministère des Pêches et des Océans 1986), et qui contribuent à faciliter des activités minières responsable conformes à la *Loi sur les pêches* (Gouvernement du Canada 1985). Les activités minières à la hausse dans le Nord du pays et, particulièrement, le besoin résultant de détruire et de dégrader des lacs et des cours d'eau sont à l'origine de la présente évaluation. Depuis les années 1950, 50 lacs, en entier ou en partie, ont été détruits ou leur destruction a été approuvée. De ceux-ci, 62 % (31) l'ont été au cours de la dernière décennie, et l'approbation de la destruction de 20 autres sera considérée au cours des quatre prochaines années.

La compensation de la destruction et la restauration de parcelles d'habitat lacustres et lotiques posent d'importants défis sur le plan scientifique et gestionnel, en particulier dans le nord du Canada, car les connaissances et la compréhension de l'écologie de cette région sont plutôt rudimentaires.

Le rapport technique détaillé et les résultats d'une recherche documentaire (Khan et al. 2005) constituent une source de référence et une piste de vérification des énoncés présentés dans le présent document sommaire. Les analyses de publications ont été combinées aux opinions de représentants de mines de diamants, d'or placérien et de sable pétrolière, de scientifiques de l'État et d'agents responsables de l'habitat, ainsi que d'autres personnes bien informées des secteurs public et privé (les versions non abrégées des commentaires sont présentées dans Samis et al. 2005). Ces commentaires donnent un aperçu des pratiques et politiques actuelles en matière de gestion de l'habitat du poisson, du développement industriel et des recherches et besoins connexes sur le plan scientifique.

La fusion des opinions et des renseignements publiés a permis d'établir le fondement des conclusions et des recommandations concernant la gestion de l'habitat du poisson, ainsi que les renseignements scientifiques et les modalités d'application pour s'acquitter efficacement des responsabilités du Ministère dans ce sens. Parmi les nombreuses conclusions tirées et les recommandations formulées dans le cadre du présent examen, nous considérons les suivantes comme les plus importantes:

- **Des dommages à l'habitat du poisson dans les régions sauvages de l'Arctique canadien se produisent et s'intensifient, et rien ne permet d'assurer à l'heure actuelle que les mesures de compensation et de restauration de l'habitat seront efficaces pour ce qui est de satisfaire aux exigences de la *Politique de gestion de***

l'habitat du poisson **découlent de la** ***Loi sur les pêches*** **relatives à la productivité soutenue du poisson.**

- **Le manque de connaissances écologiques même les plus fondamentales, le fait que les mesures de compensation et de restauration de l'habitat n'aient pas été validées en regard des liens entre l'habitat et la productivité du poisson et l'absence d'exemples de restauration et de compensation d'un lac entier pour orienter les activités de développement laissent prévoir des dommages irréparables.**

- **Des connaissances et une compréhension nettement plus poussées de la biologie fondamentale et des besoins au plan de l'habitat des espèces de l'Arctique sont requises, en particulier à la lumière des activités de développement à la hausse dans le nord du Canada, le changement de l'environnement planétaire et le besoin de déterminer et d'évaluer leurs effets cumulatifs. Ces connaissances et cette compréhension permettront de prendre des décisions, de réduire les risques et les incertitudes et de faciliter la mise en oeuvre de mesures d'atténuation, de compensation et de restauration visant à assurer la subsistance des ressources aquatiques dans cette région et dans d'autres régions éloignées du Canada.**

- **Des projets de collaboration réunissant des intervenants d'industries, de gouvernements, d'universités et de collectivités autochtones devraient permettre d'acquérir cette nouvelle information. Il existe actuellement des opportunités de le faire. Les fonds nécessaires devraient provenir de consortiums.**

- **L'application fructueuse de la Politique de gestion de l'habitat du poisson aux activités de développement dans les régions du Canada pour lesquelles on ne dispose que peu ou pas de données de base pour prendre des décisions judicieuses est compromise en raison de l'incertitude du succès des mesures d'atténuation, de compensation et de restauration. Dans ce contexte, il faut considérer que l'apprentissage se fera par le biais de la prise de décision expérimentale et qu'il faudra s'y adapter. Cela se fera pas le truchement de recherches et d'une surveillance ciblées, échelonnées adéquatement dans l'espace et le temps, de sorte à satisfaire aux objectifs énoncés par le Ministère.**

- **Les techniques de compensation et de restauration et les techniques connexes, les mesures et l'évaluation constituent des sujets de recherche prioritaires qui reçoivent l'agrément des secteurs de l'industrie, du monde scientifique et des spécialistes de l'habitat.**

INTRODUCTION

The initiation of diamond mining in Canada's north prompted concern over the management of fish habitat during the exploration, development and mining phases. Fish habitat has been, and will be, adversely affected through *Fisheries Act* authorizations that enable mining development. These effects range from those that are subtle, to the elimination of lakes and watercourses. Accordingly, and depending upon the extent and duration of these changes, there will be implications to the well being of aquatic resources that utilize these habitats, and the success of compensatory measures.

The challenge for those who must manage the habitat of fish is to understand the effects of changes in habitat, or its elimination, in relation to the protection and perpetuation of fish. Implicit in this approach is the requirement to provide a healthy environment that in turn produces healthy individuals thereby sustaining populations, stocks and species in the rigorous climatic conditions of Canada's north. Thus knowledge is required, not only to assist decisions that address the initial impacts of mining activities, but also to understand and utilize mitigation and compensatory and restorative measures to maintain the productivity of fish habitat.

The objectives of this report were to identify scientific and management information needs so that consistent and defensible decisions may be made that conform with the intent of the "Policy for the Management of Fish Habitat" ("Habitat Policy", Department of Fisheries and Oceans 1986), and that assist with the facilitation of responsible mining activities compliant with the *Fisheries Act* (Government of Canada 1985). Accordingly, comments are provided on placer gold, oil sands, and diamond mining, which are significant industrial activities that affect fish habitat in northern Canada, and pose similar questions and challenges. However, unlike the diamond mining industry, placer gold and oil sands mining have been in existence for many decades. The destruction of lakes is a common requirement to the diamond and metal mining sectors in Canada. Descriptions of lakes that have been eliminated, and comments on regulatory issues and associated compensation are provided in relation to these industries.

The "Speech from the Throne" in October 2004 (Government of Canada 2004*a*) emphasized a comprehensive strategy for the north. DFO will have a key role in the facilitation of economic development through observations of climate change and impacts on northern aquatic ecosystems, and co-operation with the international circumpolar community to promote "northern science and technology and Arctic development in a global context." The recommendations presented in this report are supportive of statements contained within that speech.

APPROACHES TO TASKS

To meet the objectives of the project, this report gathers assessed information into sections dealing with the biology and ecology of selected species of fish, watershed ecology, cumulative effects, historical and current details on mining industries their regulation and impact, habitat science, habitat management and policies (including aspects of mitigation, compensation, and restoration). A primary focus of the study was to identify critical gaps in knowledge relating to the biology and ecology of fish species in waters in the Canadian Arctic. Decisions have been made to permit changes to the productivity of Arctic waters to accommodate industry, and concerns exist over the potential short- and long-term impacts at the local and watershed level. Furthermore, the projected expansion of the diamond mining industry and other industries in northern Canada reveals the potential for more site-specific and cumulative impacts on aquatic productivity. While there are obvious incentives for the progression of industrial development, there is nevertheless a requirement that these activities occur in a responsible manner. Such initiatives would be within the authority of existing legislation, and with due regard and sensitivity for affected communities.

REQUIREMENT FOR KNOWLEDGE AND UNDERSTANDING

This report examines and reveals deficiencies in our knowledge of northern aquatic ecology within the context of industrial development, and habitat management requirements under the *Fisheries Act*. It is based on information obtained from the scientific literature, and the comments of people who are knowledgeable about certain industrial operations and their potential impact on fish and their habitat in northern Canada including comments from “habitat practitioners” within DFO. The report includes, therefore, a blend of quantitative information and of opinion that is intended to be current at the time of writing. It was our intention to minimize any potential bias by seeking the opinions of individuals who were recommended to us by industry, in addition to seeking the opinions of others who were also experts in their fields of research and northern Canadian issues.

The diversity of the tasks and the enormity of the information base necessitated the focusing of the activities and inevitably not all information will have been assessed.

The co-operation of the diamond mining industry was required during the process of gathering and assessing information, and of seeking opinion regarding priority research activities. Co-operation was also received from representatives of the placer gold and oil sands mining industries.

REPORTING

The activities undertaken, people interviewed and the opinions obtained from them, the findings and deductions from reviews of published information, and the conclusions and recommendations from these activities regarding research and management needs are provided in a detailed technical report and appendix (Birtwell et al. 2005; Samis et al. 2005, respectively). For clarity and brevity, only selected references are provided in this summary document.

The results of the literature search, which was focused on the primary literature, are contained within a separate report (Khan et al. 2005). The initial search resulted in the retrieval of approximately 3,000 documents, the majority of which were not specifically focused on the Arctic environment. However, more than 800 were used in the writing of the technical report upon which this summary document is based. Provision has been made to provide access to the information base through the use of electronic data-sorting techniques.

To simplify the task and place a priority on important factors, attention was focused upon information on habitat that is considered to be critical to the survival of fish, and how they use that habitat. The reports (Birtwell et al. 2005; Samis et al. 2005; and Khan et al. 2005) provide an audit trail of activities so that others may assess the value of the procedures and the information contained therein. By adopting this approach we hoped to reveal the risks associated with the degradation or removal of fish habitat due to mining. But also of importance was the identification of habitat structure and function for accommodation in mitigation, compensatory and restorative measures as outlined in the Habitat Policy (Department of Fisheries and Oceans 1986) developed under the auspices of the *Fisheries Act*.

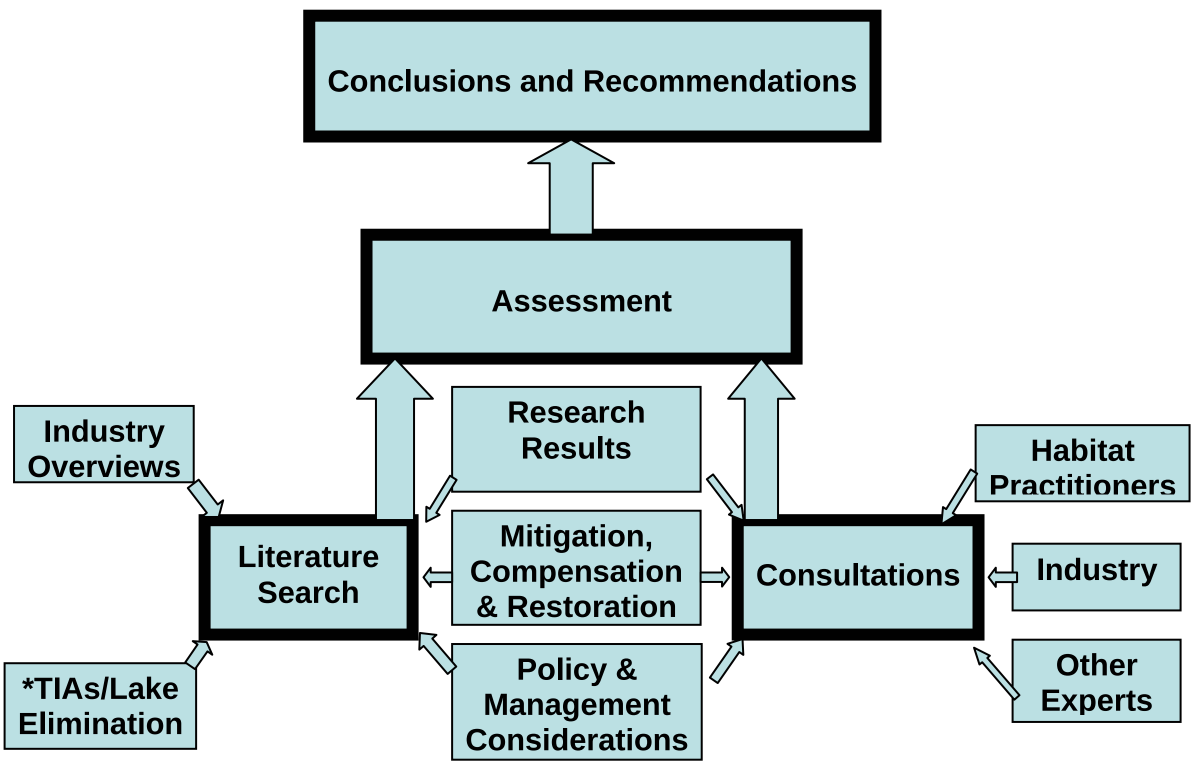

Figure 1. Main components of the tasks that were carried out in this review, their interrelationships, and the processes leading to the conclusions and recommendations (*TIAs – tailings impoundment areas).

Our intention was to reveal deficiencies in our knowledge at different levels of biological organization from the life stages of species to population levels, and habitat changes in watercourses and lakes, watersheds and larger drainage basins. This approach was guided by the premise that in order to understand more complex systems a suitable starting point is the simplest one that is available that contains all the parameters of interest (Platt 1964, cited by Johnson 2002). While pristine habitat in northern locations may well be in "stable" equilibrium from an ecological perspective (Johnson 2002), human interventions (e.g. global warming) are changing this and the challenge will be to determine in what manner it is changing and to predict the consequences (Schindler 2001). By providing and protecting the function of optimal habitat, one would expect benefits to accrue, in turn, to maintaining the health of individuals, to stocks and to populations (Hayes et al. 1996).

Recommendations to address the deficiencies in knowledge and understanding and approaches to decision making over developments that affect fish and their habitat were deduced from the reviews and consultations. Figure 1 is a diagram of the components of the tasks undertaken and the linkages among them.

LITERATURE REVIEW

FISH AND WATERSHED ECOLOGY

This aspect of the report focused on gaps in knowledge relating to the biology and ecology of fish species in the Canadian Arctic (the area north of 60^{o}N). This knowledge is considered to be critical to a determination of impacts of lake and stream destruction on the fisheries resources at local and watershed levels. This information would also be of value in the associated determination of mitigation, compensatory and restorative activities.

Seven species (lake trout, *Salvelinus namaycush;* round whitefish, *Prosopium cylindraceum;* lake whitefish, *Coregonus clupeaformis;* Arctic grayling, *Thymallus arcticus;* longnose sucker, *Catostomus catostomus;* burbot, *Lota lota;* slimy sculpin, *Cottus cognatus*) were selected for the review. They are commonly found in lakes and streams in the Lac de Gras area of the Canadian Barrenlands where the first two diamond mines are located. These species are of economic and ecological importance in the Canadian Arctic. Literature was searched to obtain information on various aspects of their biology, including distribution, habitat preferences, diet, seasonal changes, behavior, physiology, life cycle stages, residency and migratory behavior, species associations, limiting factors, tolerance and resistance to stressors, and critical habitat requirements.

Information in the reviewed literature revealed that the Canadian Arctic presents somewhat unique habitat for fish because of its extreme biogeochemical and climatic conditions (e.g. extreme cold and extensive ice cover of lakes and rivers, extreme variations in daylight, short growing season, low nutrient supply and primary productivity, and low biodiversity). Many Arctic lakes typically have a high degree of autonomy and freedom from human influence (Johnson 2002). They are relatively simple ecosystems, and despite extremely low primary productivity, the abundance of fish is generally high and comparable to that in lakes further south with much higher productivity (Johnson 2002).

Biodiversity of freshwater fish is low in the Arctic and less than 1% of the known species of fish in the world have been reported (Power 1997). In undisturbed and unexploited lakes, the fish biomass is usually represented by small numbers of larger and older fish; a reflection of the efficient conversion and storage of many years of primary production. In general, lake trout and lake whitefish are the dominant species in Arctic lakes and in many lakes account for nearly 95% of the fish biomass (Johnson 1976).

Arctic freshwater ecosystems are vulnerable to environmental changes that may affect food and energy transfer relationships and nutrient regimes; factors that are critical to the survival of fish and other aquatic organisms. Information necessary to determine these critical factors and relationships in this environment is scarce or absent. Furthermore, scientific evidence is mounting to suggest that the Arctic freshwater systems are particularly vulnerable to global issues such as climate warming and the transport of atmospheric pollutants (Schindler 2001). Long-term studies are required to examine these issues.

It was concluded from the review of literature that there is a general paucity of information with respect to environmental aspects of the Canadian Arctic, especially concerning habitats necessary for the survival of fish. Little work has been done on the biology and ecology of fish, especially with respect to the habitats used by their various life stages (for example, it has been stated that survival over winter is a critical and limiting phase for fish production). Habitat assessments and knowledge of watershed processes are particularly important considerations in habitat remediation and restoration plans. For a very few species (such as lake trout and Arctic grayling) the biological understanding is relatively better, but for most little is known. It has been widely accepted that the dearth of scientific information is perhaps the single most obvious impediment to the effective management of fisheries and fish habitat in the Canadian Arctic (Power 1997; Reist 1997; MacDonald 1999; MacDonald et al. 1999).

It has been suggested that there is a need for a more integrated, whole-ecosystem perspective of lakes that considers the quantification of energy flows as a precursor to an understanding of food web dynamics and lake ecosystem functioning (Keith 1994; Khan 1997; Jones and Taylor 1999; Minns 1999; Schindler 2001; Vorosmarty et al. 2001; Schlosser et al. 2003). The ecosystem approach represents a strategy for the management of all aspects and components of the environment (land, water, atmosphere and living resources) in an integrated way to promote conservation and sustainable use of natural resources equitably. The approach by its very nature and definition is integrative and collaborative and offers the opportunity to foster a common understanding of issues among scientists and stakeholders. The implementation of the ecosystem approach would, therefore, require integrated actions at the management, science and social levels.

INDUSTRIES

Brief details of the history and operation of the diamond, oil sands and placer gold mining industries are provided to give a perspective on these activities. The main regions in Canada where these activities are occurring are identified in Figure 2.

DIAMOND MINING

Diamonds are found in kimberlite in Precambrian Shields around the world. Within the Canadian Shield, in the Lac de Gras area of the Northwest Territories, over 250 kimberlite pipes and other intrusions have been located. Eighty percent of these pipes are under small lakes. Apart from the existing and proposed mines in the Northwest Territories, Nunavut and Ontario, there is widespread diamond exploration activity in Nunavut, Quebec, Ontario, Saskatchewan, and Alberta (refer to Figures 2 and 3).

Between 1997 and 2004, 26 fish-bearing lakes and numerous fishery streams have been authorized by DFO under section 35(2) of the *Fisheries Act* for use by the diamond mining industry as waste water, tailings, and waste rock storage basins, or have been drained for diamond mine site development, and for access to ore and deposits of construction material (refer to Figures 4 and 5). Such activities, together with those for other mine operations (changes to land drainage and impacts on streams and lakes), potentially impact fish and their habitat. The most obvious impacts relate to the elimination of lakes and streams.

Diamond mining in Canada is a relatively recent occurrence and exploration and mining activity has been increasing since the early 1990s. Exploration is currently at record levels and prospecting companies have laid claim to millions of hectares in the Northwest Territories and Nunavut. The significance of these developments is emphasized by 2003 production data (Santarossa 2004) that suggest that “Canada will have produced almost 15% of the world’s supply of diamonds….” In 2004, Canada was confirmed as the world’s third largest producer of diamonds (by value) behind Botswana and Russia (Bruna Santarossa, Statistical Economist, Minerals and Mining Statistics Division, Natural Resources Canada, Ottawa, Ontario; pers. comm.). Furthermore, in recognition of the growing importance of the diamond mining industry in Canada, the participants at the annual Premiers’ conference (Government of Canada 2003) “directed their Ministers to develop an action plan for a national diamond strategy that maximizes the benefits to Canadians from all stages of the emerging diamond industry and to report back to Premiers. Premiers invited the federal government and other stakeholders to join the provinces and territories in the development of this important national initiative.” (Government of Canada 2003). In August 2004, this action plan for the national diamond strategy was published (Council of the Federation 2004).

The revenues to governments during the life of just 3 diamond mines (approximately 20 years or less) is projected to be approximately $10 billion (Santarossa 2004).

Management of waste rock, tailings and pit water in permafrost regions presents challenges that are not generally encountered in the more temperate southern climatic regions. Due to the risk in permafrost areas posed by melting and erosion, excavation of lagoons for wastewater management and tailings disposal is not practical. Damming of valleys in northern Canada to impound mine wastes could also be expected to involve the destruction of lakes and streams.

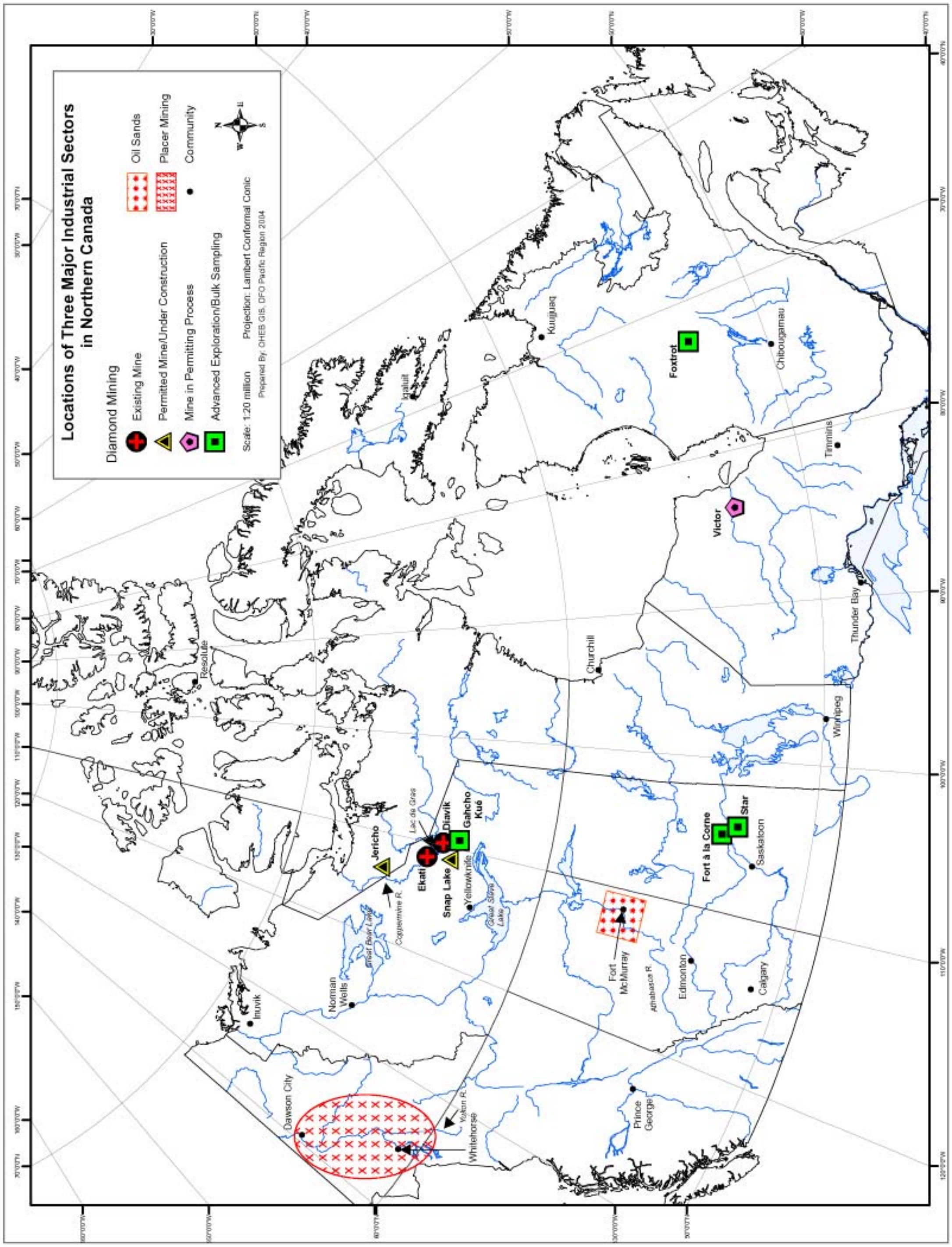

Figure 2. Map showing the main locations of current and proposed diamond, oil sands and placer gold mining operations in Canada.

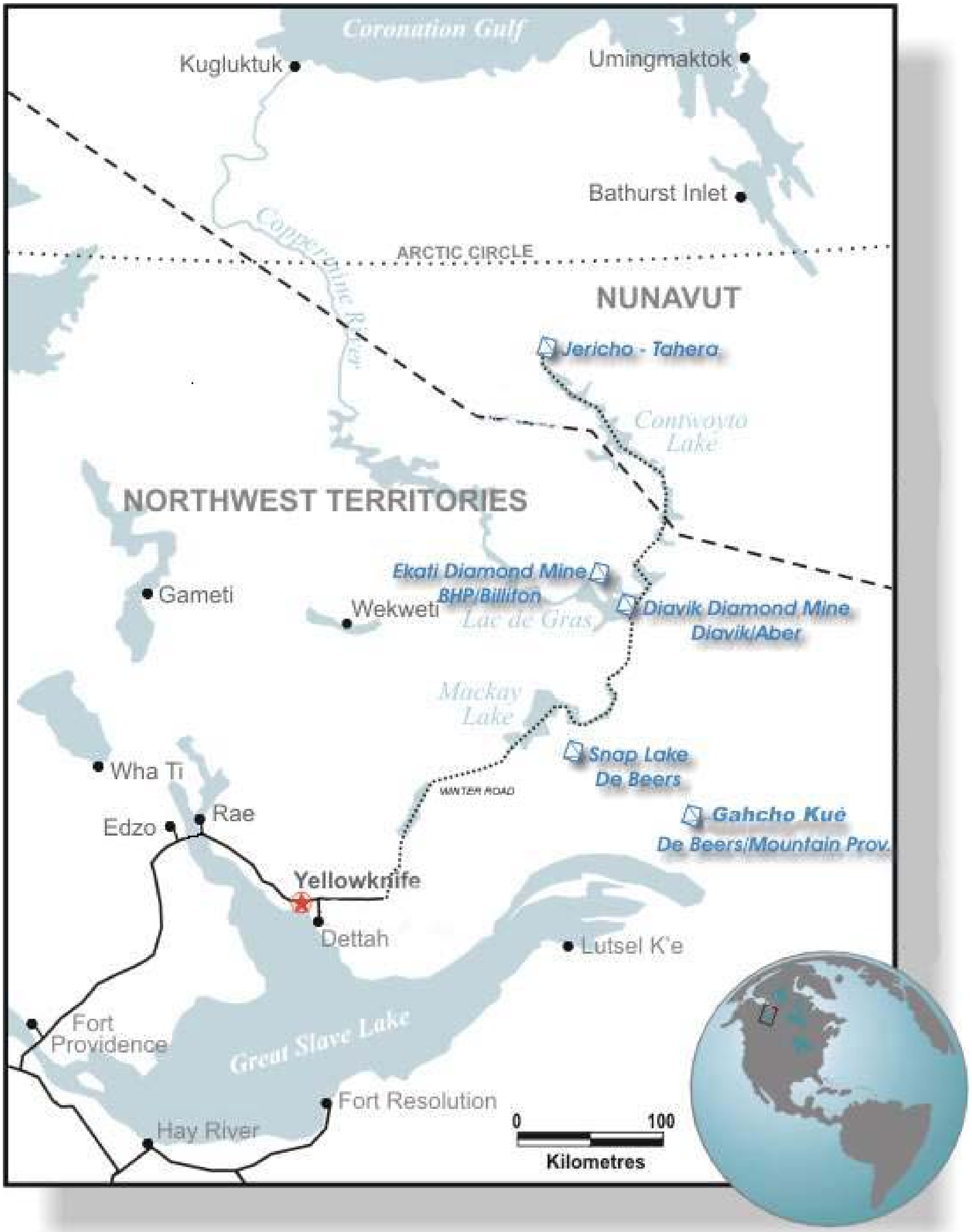

Figure 3. Location of existing (Ekati and Diavik) and planned (Snap Lake, Jericho and Gahcho Kué) diamond mines in the Northwest Territories and Nunavut (adapted from Diavik Diamond Mines Inc.).

Figure 4. Lake being de-watered for access to diamond ore in the Arctic.

Figure 5. An open diamond mine pit in the Arctic with the mill in the background: a lake was eliminated to permit the extraction of kimberlite.

OIL SANDS MINING

There are four major reserves of oil sands in Alberta – Peace River, Wabasca, Cold Lake and Athabasca (refer to Figures 2 and 6). It is estimated that the oil sands contain 174 billion barrels of remaining established crude bitumen (the estimated recoverable volume), but also contain in-place reserves of 1.6 trillion barrels (McCrank 2003).

The oil sands were first described in the 1700s and although there was some drilling and extraction schemes in the early 1900s mining did not begin to flourish until the mid part of that century. This industry has grown substantially within the last 60 years and existing mines are currently expanding and new mines are being proposed.

Oil sands currently represent about 52.7% of Alberta's total production of oil, and about 34.8% of all oil produced in Canada. Oil sands production is expected to represent 50% of Canada's crude oil output, and 10% of North American production (Alberta Department of Energy 2004); the oil sands deposits are large enough to supply total world needs for up to 15 years (Alberta Community Development 2004). Figure 7 is an aerial photograph of an oil sands plant.

It is projected that over the period of industrial expansion (1997-2025) new revenues to governments will have increased to $200 billion (Suncor Energy 2004). Impacts from these large-scale oil sands mining activities relate not only to changes in the physical landscape and watercourses but also to the potential chemical contamination of waters.

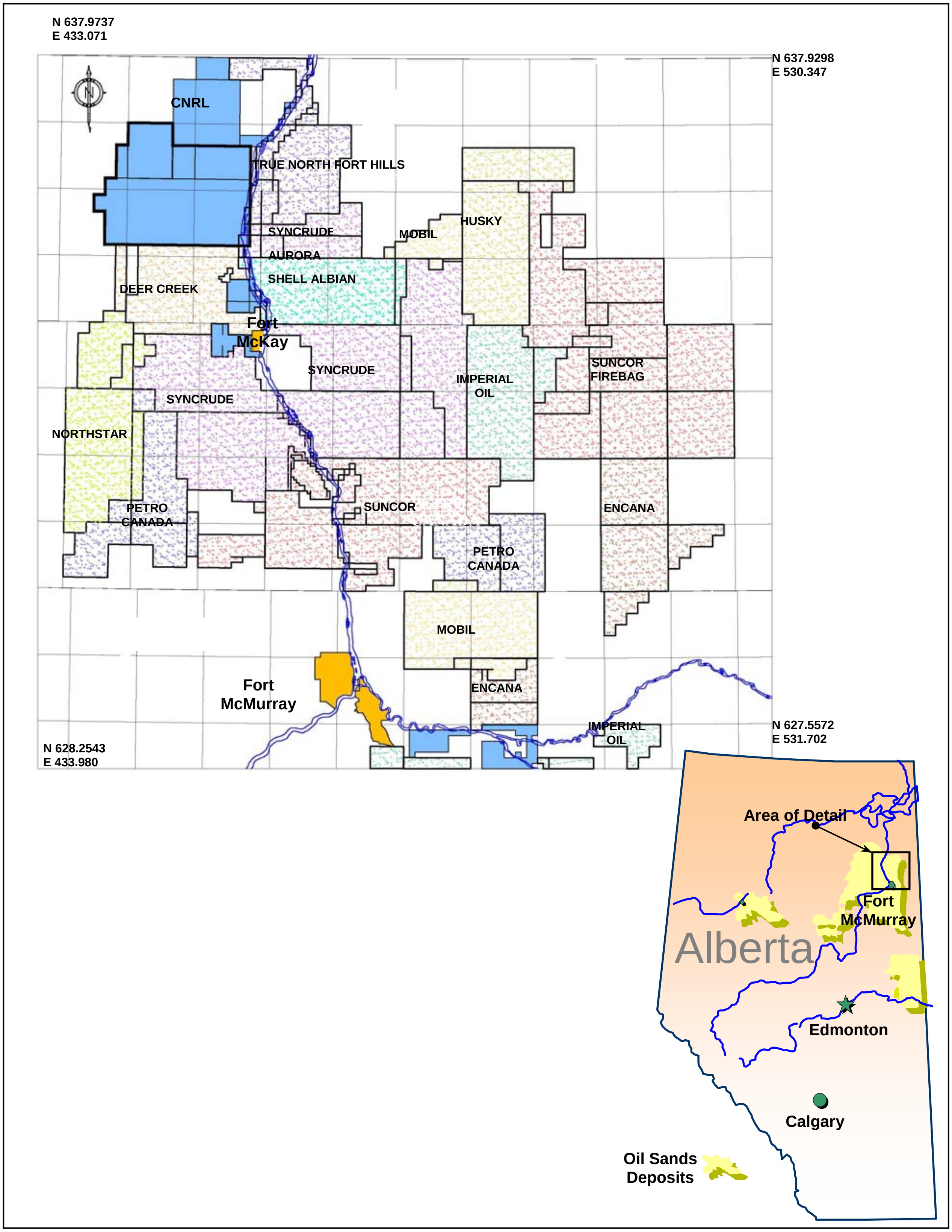

Figure 6. Location of Alberta oil sands developments (courtesy of CNRL).

Figure 7. Aerial photograph of an oil sands process plant (courtesy of J. Shamess).

PLACER GOLD MINING

Placer gold mining occurs in many locations throughout the Yukon Territory, and to a much lesser extent in British Columbia. It is primarily focused in regions within the extensive Yukon River basin (refer to Figures 2 and 8).

The earliest finds of gold in the Yukon occurred in the mid-1800s but it was not until the major discovery on Bonanza Creek in 1896 that placer gold mining became a significant activity that generated over one million ounces per year in the early 1900s. At present, the annual production is approximately 100,000 ounces (approximately $40 million). The total recorded fine gold production from 1885 to date is estimated to be about 12.5 million ounces, valued at US$4.4 billion at today's prices (Implementation Steering Committee (ISC) 2004).

Placer gold is typically extracted from its surrounding substrates by processes that include washing or sluicing large volumes of earth and capturing the heavier gold that is retained in the washing process. Because placer mining occurs within and adjacent to watercourses, the activities typically impact upon fish habitat. It has been estimated that placer mining has affected between 8% and 17% (area and lineal distance respectively) of the watercourses in the Yukon. These impacts are from the physical disturbance and destabilization of the watercourses themselves and the surrounding landscape, and also from the discharge of sediments from sluicing and other operations (Seakem Group Ltd. 1992) (Figures 9 and 10).

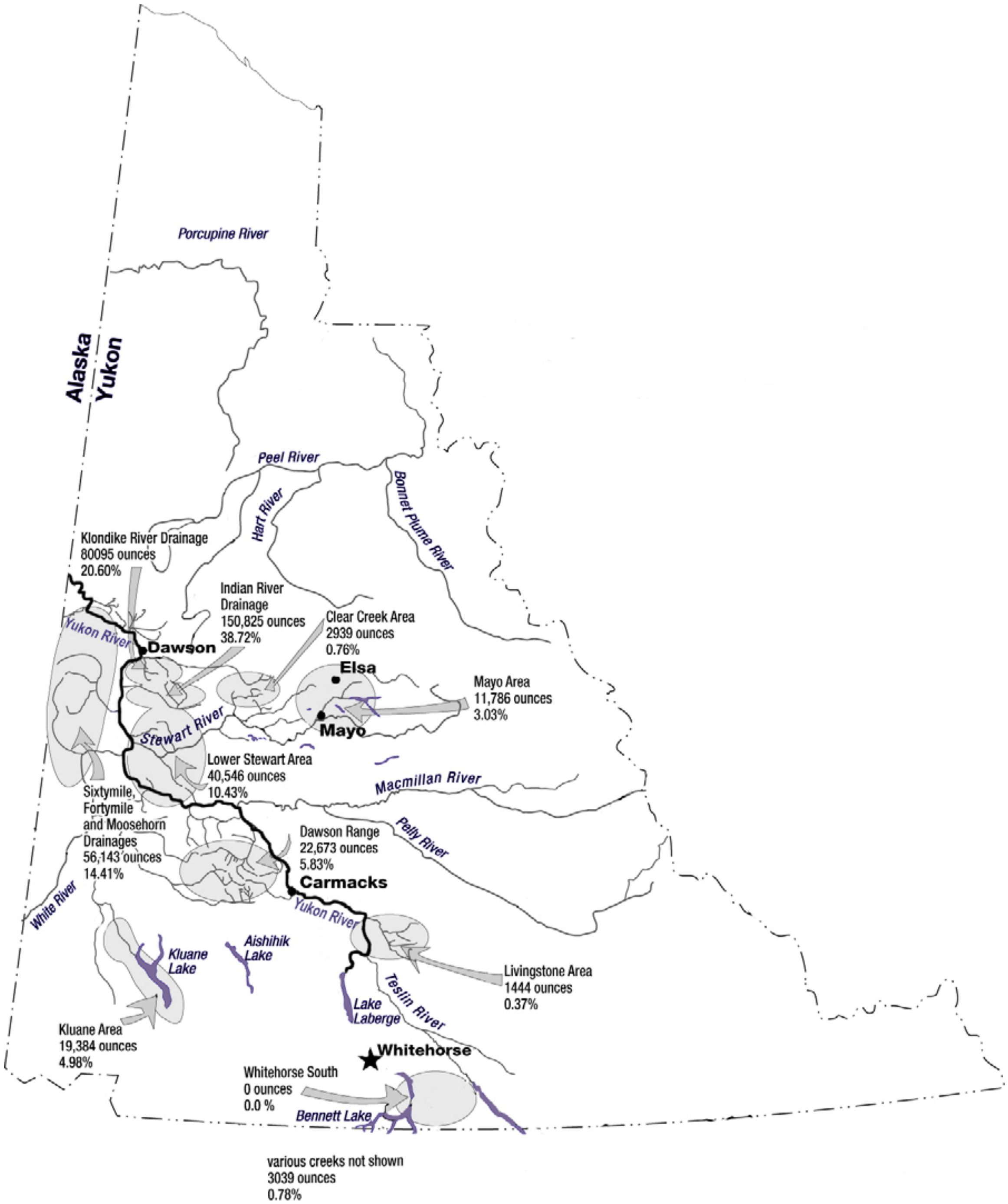

Figure 8. Placer gold mining in regions of the Yukon (adapted from Indian and Northern Affairs Canada 2003).

It was estimated that in 1988 that 6-8 million m^3 of earth were sluiced and 2 to 3 times that volume removed to expose the gold-bearing deposits, for a total of about 20-30 million m^3 of material moved (Norecol Environmental Consultants Ltd. 1989).

The decision to permit placer gold mining to occur in and around watercourses is dependent upon many factors, including historical mining activities, “fisheries” values and socio-economic needs. To facilitate decision making it was deemed appropriate to assess the importance of watercourses. With respect to fish, objective and subjective assessments of their value by species and their use, and their presence or absence have been used to classify streams. The stream classification is then used to guide the application of sediment discharge criteria in the expectation that the habitat of these species will or will not be affected by sediments discharged (Government of Canada 1993). Implicit in this approach is the use of current knowledge and the application of assumptions regarding the impact of sediment on fish, the potential impact of activities, mitigation and compensatory measures, and the recovery (including restoration measures) of the productive capacity of habitats upon cessation of mining.

Thus activities are regulated in relation to sediment discharge, and they have not previously included other aspects of habitat change such as stream integrity and destabilization, and compensation for the loss of the productive capacity of fish habitat.

Figure 9 Disturbance to fish habitat and landscape due to placer mining activities (courtesy of M. Miles).

Figure 10 Extensive modification of the Indian River due to placer mining, Yukon Territory (courtesy of M. Miles).

ASPECTS OF FISH HABITAT MANAGEMENT (INCLUDING MITIGATION, COMPENSATION AND RESTORATION)

Aside from the ecological importance and challenges to compensate for, and restore degraded fish habitat, the importance in achieving "no net loss" of the productive capacity of fish habitat was emphasized through the Auditor General's Report to the House of Commons in 1997 (Government of Canada 1997). Within this report it is stated that "Fisheries and Oceans should devote more time and effort to compliance monitoring and follow-up in order to assess the effects of its habitat management decisions and its performance toward the achievement of "no net loss" of habitat." Evaluations have been carried out within the last 5 years and the results have indicated a need to address many facets of these activities if the objectives of the Habitat Policy are to be met regarding the no net loss of fish habitat productive capacity

In the prevailing cold northern environment it is expected that fish habitat compensatory and restorative measures would occur over protracted periods of time relative to those in more temperate locations. Accordingly it will be necessary to choose appropriate strategies and to evaluate them in a manner that is commensurate with this understanding.

DIAMOND MINING

Compensation for the alteration or destruction of fish habitat has included the application of different techniques and the provision of money. It has been difficult to identify suitable habitat compensation projects, where gains in productivity can be achieved, that are also supported by Aboriginal communities. At two mines valuable research has been carried out to assess the efficacy of a water diversion channel (Jones et al. 2003*a*, 2003*b*, 2003*c*; Jones and Tonn 2004), and of a lake spawning reef as compensatory measures. At another location the effects of blasting on developing eggs in Lac de Gras are being investigated. These efforts are in addition to the extensive monitoring programs that are being carried out to provide time-series data.

According to the authorization issued to this diamond mining company, “To compensate for the loss of fish habitat associated with the Project, BHP Minerals shall implement the Fish Habitat Compensation Agreement negotiated between the Department of Fisheries and Oceans (DFO) and BHP Minerals.” In accordance with this authorization which recognized that “The Project will impact directly on 12 lakes within the claims block,” BHP placed $1.5 million into a Habitat Compensation Fund established and administered by DFO. Through this fund habitat compensatory projects are supported. The remainder of the Habitat Compensation Fund ($500-$700 K) is directed at community-based habitat restoration projects. A water-diversion channel (refer to Figures 11 and 12) was also constructed that diverts drainage water around active pits and also provides stream habitat as part of compensatory measures for development impacts on streams. Fish have occupied and migrated through the channel, but research and monitoring have yet to prove its success as a compensatory stream in terms of its productive capacity.

An artificial reef has been constructed to offset a small lake that was affected during development of a mine. Stream enhancement is also to occur at a mine site, and impacts on lakes are to be compensated for at another location.

No whole lake replacement has occurred as compensation for that which was lost. At the conclusion of mining pits are to be “restored,” and some streams and a lake are to be enhanced. Authorizations specify the requirement for compensatory and restorative measures.

OIL SANDS MINING

The initial removal of oil sands did not impact fish habitat or it occurred before the requirement for an authorization under the *Fisheries Act*. However, the current expansion of the industry will impact fish habitat and accordingly mitigation, and compensatory and restorative measures are required.

One company has proposed to create a 77-ha lake as a compensatory measure. This is to offset the damage and elimination of multiple stream diversions and part of a lake (372 ha) to facilitate an oil sands open pit mine. Future additional compensatory works include the construction of spillways, permanent diversion channels (46.7 ha) and channel reconstruction, all designed to provide stable fish habitat. The company is required to conduct monitoring to determine the effectiveness of the compensatory measures. These include the verification of fish habitat losses, participation in ongoing research into the ecological value of “end pit” lakes, and support for regional multi-stakeholder initiatives designed to address water quality issues, Athabasca River flows, fish health and tainting. These obligatory monitoring programs are to continue until DFO has been satisfied that the objectives of "no net loss" of the productive capacity of fish habitat have been met.

Significant monitoring and research initiatives have been, and are being, undertaken in relation to the mining of the oil sands. DFO participates in the Canadian Oil Sands Network for Research and Development (CONRAD) which is a consortium comprising industry, government and universities with a focus on priority environmental research topics.

PLACER GOLD MINING

Primary concerns for the management of fish habitat associated with placer gold mining relate to the effects of elevated levels of sediment deposited in, and suspended in aquatic habitat, and the need for habitat compensatory and restorative measures. The sediment affects aquatic organisms, and the disturbance to land and water changes the stability and nature of watercourses (e.g. Norecol Environmental Consultants Ltd. 1989; Seakem Group Ltd. 1992; Waters 1995).

The restoration of mined sites, which typically applies to the physical structure of channels, and land, is based on specified guidelines and the "mining site must be stabilised to allow physical and biological processes to be restored" (Fisheries and Oceans Canada 2000). While there has been an award (Robert E. Leckie) presented to mining operators for "outstanding mining reclamation practices" in recent years, there have yet to be evaluations of the success of the restorative activities regarding fish habitat. It is expected that there will be recovery of the previously-mined areas and improvements in water quality that will benefit biological resources. It is likely, however, that decades will be needed before the riparian zone of a previously-mined stream will be fully functional from an ecological perspective. Studies of mines abandoned under earlier regulatory regimes suggest that natural recovery is a very long process, and may not occur at all. Elevated sediment loads may continue for many decades following cessation of placer mining. Lack of channel stability and elimination of habitat, including pools, undercut banks and backwater areas, have been considered to be the greatest limitations to fish habitat recovery in placer-mined streams (Hardy and Associates Ltd. 1981; Alaska Department of Fish and Game 1987; Mossop and Bradford 2004).

The effects of sediment on aquatic systems have received world-wide attention for many years (e.g. European Inland Fisheries Advisory Commission (EIFAC) 1964; Waters 1995; Birtwell 1999). It is a ubiquitous issue particularly because of the potential to impact negatively on aquatic organisms. Sediments are transported into watercourses through many human developments. Placer miners have contributed to research to understand the effects of their activities in the Yukon, and opportunities exist to monitor restorative and compensatory measures.

Figure 11. Artificial stream-diversion channel in the Arctic.

Figure 12. An Arctic tundra stream.

At the time of writing this report, the regulatory and administrative framework regarding placer mining is undergoing change. Within this new regime is a recognition of the need to improve protection of fish habitat for "Yukon fisheries" and that compensation and restoration are the primary means through which the Habitat Policy goals (*Fisheries Act*) will be achieved. However, because this new regime will not be in place until at least 2007, the comments in this section are current (2005), and provide a status report on habitat management for this industrial sector.

According to the ISC (2004), scientific information is to be used in the construction of the new regime and as such it will include "approaches to assessing habitat "health"; relation between habitat "health" and fish populations; identification of critical, important and marginal habitat; impacts of sediments on fish and fish habitats; and sediment measuring techniques."

LAKE ELIMINATION, TAILINGS IMPOUNDMENT AREAS (TIAs) AND THEIR REGULATION

There are regulatory and operational differences in how mine tailings are managed in diamond mining versus metal mining even though in both industries lakes are used for the impoundment of tailings. However, in each recent circumstance there have been requirements for fish habitat compensatory and restorative measures. For example, concerning the 5 water bodies that are named as TIAs in the Metal Mining Effluent Regulations (MMER) (Government of Canada 2002), pursuant to the *Fisheries Act,* two lakes that were eliminated prior to the initiation of the Habitat Policy, and two fish-less lakes that receive mine tailings were not offset with fish habitat compensation.

Seventy lakes or parts of lakes, plus numerous streams, mostly in northern Canada, have been, or are proposed to be, eliminated for use as TIAs, pit water management basins, or to enable access to ore (see Table 1 and Figure 13).

There has been no "like-for-like" fish habitat compensation for those lakes that have been destroyed.

Table 1. The number of lakes approved for elimination/partial destruction in mining operations in Canada, lakes historically used, and those that are under review for elimination before 2009.

Date	Approved by DFO	Historic	*Proposed	Cumulative Number	Cumulative Percent
		15		15	21
1978	1			16	23
1981	1			17	24
1992	1			18	26
1994	1			19	27
1997	12			31	44
2000	10			41	59
2002	2			43	61
2003	7			50	71
Subtotal	35	15	20	70	100
Percentage	50	21	29	100	

* Lakes under review for elimination before 2009

METAL MINES

Under the former Metal Mining Liquid Effluent Regulations (MMLER) (Government of Canada 1977), TIAs were designated by the Minister. The MMLER were repealed in 2002 and replaced with the MMER, (also made under section 36 of the *Fisheries Act*) which preclude unconfined tailings deposits, and make the inclusion on Schedule 2 of MMER of new TIAs in natural, fish-frequented waters impossible without a Governor in Council (GIC) amendment of the regulations.

Environment Canada (EC) is proposing amendments to the MMER. One proposed amendment could result in the requirement for mines to provide fish habitat compensation plans as a condition of deposit for future TIAs in natural, fish-frequented water bodies.

DIAMOND MINES

The MMER do not apply to tailings and other discharges from diamond mines, which are subject to the *Fisheries Act* general prohibition against deleterious deposits into fish-frequented waters (section 36(3)). DFO has authorized the elimination and degradation of lakes due to tailings and pit water deposits under section 35(2) of the *Fisheries Act* and has used section 52 of the Fishery (General) Regulations to issue scientific fishing licences for fish removal prior to industrial use of a lake.

A database is being developed by DFO, in collaboration with the University of Alberta, to improve the ability to predict fish populations and assess the productivity of lakes using limnological and other data from the lakes that had been, and that are to be, eliminated.

MANAGEMENT AND POLICY

NEW MANAGEMENT STRATEGIES

DFO, through its Habitat Management Program, has embarked upon operational and organizational changes designed to enable the Department to more effectively carry out its mandate for the conservation and protection of fish habitat in the context of sustainable development. This approach is part of an "Environmental Process Modernization Plan" (EPMP) that contributes to the Government's "Smart Regulation" agenda (Government of Canada 2004*b*; Fisheries and Oceans Canada 2004*a*). The 6 elements of the EPMP include a risk management framework, streamlining tools, improving coherence, predictability and renewed emphasis on partnerships, a new management approach to environmental assessment and major projects, and habitat compliance modernization.

Figure 13. Aerial view of a tailings impoundment for processed kimberlite at a diamond mine in the Arctic. This portion of the 590-ha lake is receiving, and being filled with, mine tailings; the previous shoreline is visible at the upper parts of the photograph, whereas the extensive deposition of mine tailings has occluded much of the lake in the foreground.

Within the EPMP is the requirement for a "Risk Management Framework" (RMF) which has its base within science (i.e. the provision of peer-reviewed information) and an "examination of the public environment and citizens' risk tolerance." The potential effects of a wide range of industrial activities on fish and fish habitat are mapped and presented within Pathways of Effects (POE) models to facilitate this process. Applying approved guidelines and best management practices within the model improves the effectiveness and efficiency of the referral review process for applications for authorizations under section 35(2) of the *Fisheries Act*.

The RMF incorporates assessments of the severity of impact of activities on fish habitat in relation to the sensitivity of fish habitat as a means to categorize risk. Thus, the POE approach attempts to standardize the determination of the potential effects of activities on fish habitat, and to provide this to user groups. Consequently, DFO habitat practitioners, partner agencies and proponents can use POE models to identify potential impacts and concerns and to develop measures to mitigate or avoid effects on fish habitat. Residual effects that cannot be mitigated are then evaluated with respect to the need for compensatory and restorative actions. A risk management framework, or risk matrix, is then used to relate the severity of impact and the sensitivity of the receiving environment (habitat) to assign a category to the risks to fish habitat associated with these residual effect(s). The accuracy with which sensitivity is assigned is a function of knowledge. When the sensitivity is known the appropriate entry may be made, however, for those areas where this is not known (e.g. northern Canada and ecology of species), caution is required in the use of this scheme. Value judgments play a role within risk management but should be used cautiously. Above all, institutional learning can occur if the outcomes of decisions are monitored, thus leading to refinement of decision-making criteria through increased knowledge (McDaniels and Gregory 2004).

The Pathways of Effects model is an approach that relies upon sound, quantitative scientific research information to identify potential impacts of activities on fish and their habitat and the sensitivity of that habitat and fish to the impacts. Therefore, through its use, and evaluation, information requirements and actions will be identified.

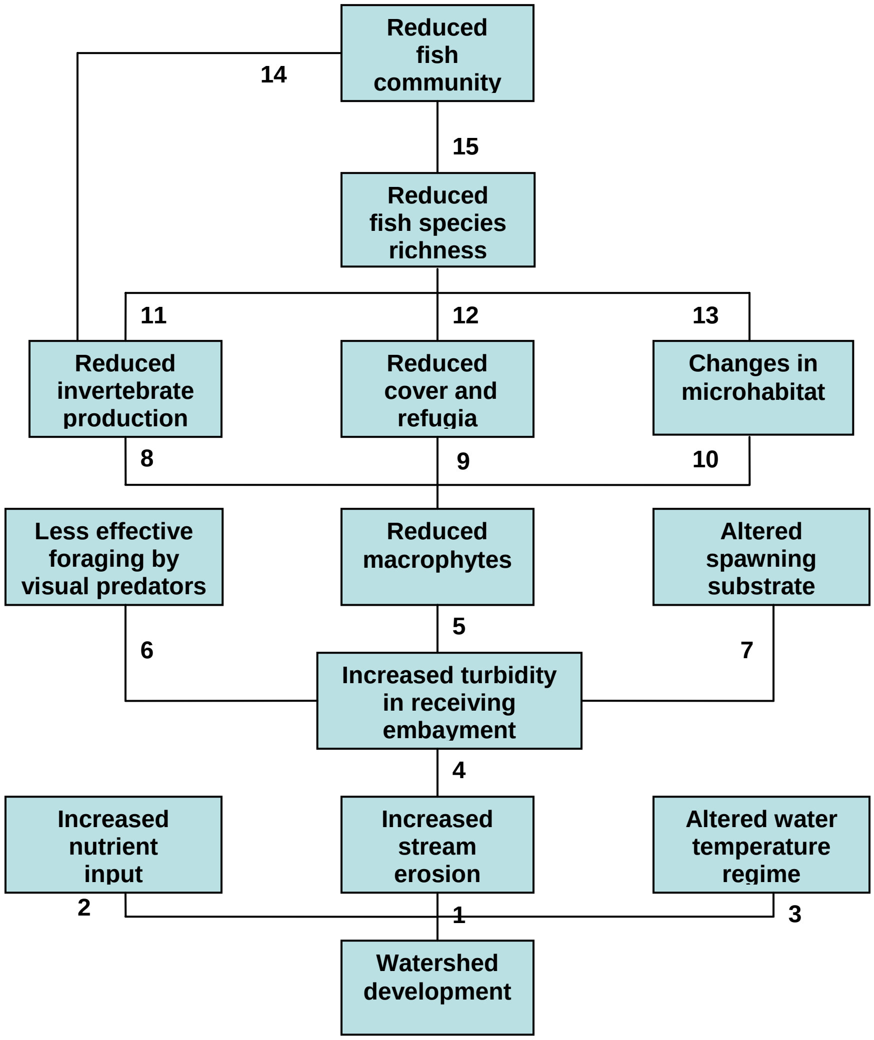

Figure 14. An example of cause-effect pathways from watershed development to fish production (adapted from Jones et al. 1996.)

A similar approach to that identified in the POE model was provided by Jones et al. (1996). They showed how watershed development was linked along certain pathways to effects on communities. In particular the approach showed how changes in habitat may affect functional linkages (refer to Figure 14). Consequently, Jones et al. (1996) provide an example of the linkages between habitat change and ecological effects, and a pathway to determine a rigorous assessment of possible effects. In this example, which was derived from a "littoral centrarchid-urbanization" situation, one of three probable hypotheses of effects is presented. Here, species richness is considered to be the fish community indicator of interest and is the "accepted measure of productive capacity" (Jones et al. 1996). Knowledge existed on the linkage between macrophyte abundance and species richness but in order to understand the cause and effect between them at least three linkages must be considered (numbered 11, 12, and 13 in Figure 14). Similarly, mitigation must consider all factors associated with macrophytes for "focussing on only one aspect (say using artificial habitat structure to replace lost cover) would not result in compensation."

Pathways of effects related to diamond, oil sands and placer gold mining

The POE approach was applied as an initial step to the three industrial operations of diamond, oil sands and placer gold mining. The POE diagram that was generated for these three industries is presented in Figure 15. It was considered that there were a number of common issues that could be identified in the exploration, operational and decommissioning phases of these industrial operations that would impact upon fish habitat. By constructing the POE diagram, the potential effects of activities are revealed, thus providing an explicit understanding of effects that need to be addressed. That is, effects that can be mitigated if possible, and if not, compensated for together with opportunities for habitat restoration.

The POE provides the opportunity to identify areas where the outcome of habitat change is uncertain and where information is lacking for sound decision making. From this follows the opportunity for research to provide the necessary information to support decisions that incorporate risk scenarios and the use of adaptive strategies regarding monitoring and assessment and overall management flexibility.

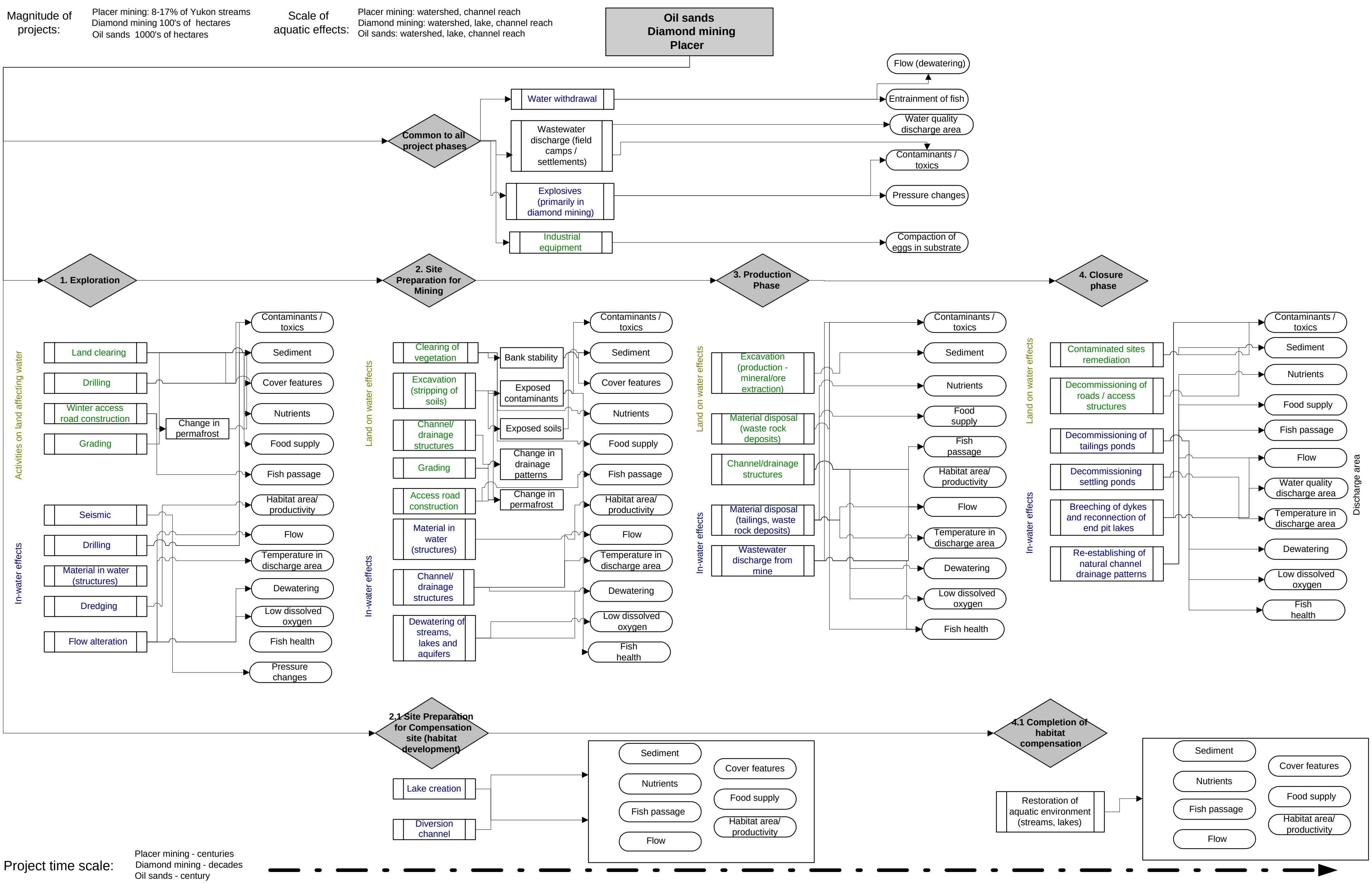

Figure 15. Pathways of effects diagram relating to the activities of the diamond, oil sands and placer gold mining industries.

CONSULTATIONS

Fifty-one people voluntarily contributed to this report through the direct submission of comments and via interviews. These people are identified in the appendix in this report. Their unabridged and accepted interview comments are contained within the report by Samis et al. (2005); the Appendix to the technical report by Birtwell et al. (2005) from which this summary document was derived.

DIAMOND, PLACER GOLD, AND OIL SANDS MINING INDUSTRIES

Four questions were posed to industrial representatives:

- What are the priority research/information needs regarding diamond mining/placer mining/oil sands development (as appropriate to the specific industry) and aquatic systems?
- What are your opinions regarding collaboration with DFO/universities/other industries?
- Regarding compensation/restoration actions, who decided upon that which was appropriate, who assesses the success/failure of them and what are the measures of success?
- What are the limitations to the growth of the industry, and what is the forecast for the future?

Respondents to these questions were identified by mining sector affiliation as follows: Allison Armstrong, Jane M. Howe, Jayda Robillard, Gord Macdonald, and Robin Johnstone (diamonds); Calvin Duane, Chris Fordham, and Darrell Martindale (oil sands); Mike McDougal and Tara Christie (placer gold).

HABITAT PRACTITIONERS AND MANAGERS

Consultation with this group was considered necessary because of its interface with industry and the need for information to assist with the decisions that must be made regarding fish habitat and developments.

Nine questions were asked in relation to oil sands, placer, and diamond mining, and other industrial operations that have the potential to affect fish habitat (e.g. use of lakes as tailings impoundment areas for metal mining). Representatives from all DFO Regions across Canada were canvassed for their input.

- Is there a formal or informal decision making process whereby habitat managers are able to assess impacts on fish and their habitat?
- Depending on the answer…what is it or how is it done?
- How are fish and fish habitat loss dealt with in quantitative terms? What are the species/habitats of concern?
- How are cumulative impacts addressed? Is there concern at the fish population level, the lake and/or watershed level?

- What knowledge gaps exist and how is this dealt with in decision making?
- How is uncertainty incorporated into the decision-making process regarding compensation?
- How is habitat restored in northern locations such as the Yukon, Alberta, Northwest Territories, and Nunavut – as appropriate re industry? What are the pros and cons? Are there case studies (successes and failures)?
- What initiatives (and who is doing them) are underway to fill gaps in knowledge and improve decision making over damage to fish and their habitat?
- What initiatives (and who is doing them) are underway to examine fish habitat compensation and restoration activities?
- Is collaboration with industry on monitoring/research ventures mutually profitable, and are there opportunities to further such co-operation?

Respondents to these questions are identified by DFO Region, as follows: Jeff Johansen and Al von Finster (Pacific Region); Julie Dahl, Jennifer Shamess, Dorthy Majewski, Alan Merkowsky, Derrick Moggy, Tania Gordanier, Ed DeBruyn, and Rich Rudolph (Central and Arctic Region); Sophie Bérubé (Quebec Region); Carole C.J. Grant and Mary B. Dawe (Newfoundland Region).

HABITAT SCIENCE AND NORTHERN ECOLOGY

Discussion with other people focused on selected topics about which they are particularly knowledgeable (Lionel Johnson, Terry Dick, Gordon Hartman, Peter McCart, David Fernet, John Gulley, and François Landry regarding Arctic ecology, Karsten Liber regarding toxicology, Mike Miles regarding geomorphology, Don Toews regarding fish ecology, and DFO scientists and engineers (Colin Levings, Mike Bradford, Martin Bergmann, Susan Doka, Rick Gervais, Chris Katopodis, Marten Koops, Ken Mills, Ken Minns, Michael Papst, Bob Randall, Terence Shortt, Michael A. Turner, and Mike Whittle) regarding fisheries management, ecology, habitat linkages, measurement and validation, and André Isabelle (Natural Sciences and Engineering Research Council of Canada, NSERC) regarding research funds, David Harper and Jason Quigley regarding habitat compensation and assessment, and Paula Pacholek regarding the coordination of northern environmental assessment.

Evaluation and presentation of comments and scientific findings

The extensive and valuable comments received through these consultations (Samis et al. 2005) were condensed and placed into the categories of a) Research, b) Mitigation, Compensation and Restoration, and c) Policy and Management. The significant main points were separated within each category as “Selected Points” and “Recommendations.” The same approach was used to abstract information from the scientific literature that we had gathered. Thus there were two sets of information bases – scientific and consultative.

The comments from the consultations were used as the starting point from which the next phase of the assessment occurred. Common topics from the consultations were searched for within the scientific information base and then combined with those from other consultations to provide un-ranked key topics. As an audit function the origin of the information used in this step was identified and linked to its source (scientific literature or consultations). Thus the final key topics are those that were identified through the consultations and that were also present in the scientific literature we abstracted for this task. Through this amalgamation it was expected that more value and importance would accrue to the final deduction of key issues. This process included inherent biases as, for example, some of the literature that was assessed was authored by some of the people that were consulted. Similarly, there was the expectation and likelihood that those with whom we consulted also knew some of the relevant scientific literature.

The final key topic areas deduced via the above-mentioned process are:

1. Biology and ecology of northern and remote aquatic ecosystems.
2. Linkages between fish and their habitats.
3. Measurements of productive capacity.
4. Program research.
5. Predictive models and their applicability to northern Canada.
6. Databases and archiving.
7. Impacts on fish and fish habitat.
8. Funding and partnerships.
9. Collaborative studies.
10. Fish habitat compensation and restoration.
11. Temporal and spatial considerations regarding decision making and monitoring.
12. Monitoring, assessment and evaluation.
13. Habitat policies and management.
14. Communication, guidelines and information transfer.

These key topic areas and brief supporting comments upon which they are based are presented in the Appendix.

GENERAL COMMENTS

INDUSTRIAL DEVELOPMENT

Industrial developments are escalating in northern Canada and impacting upon fish and their habitat. It is apparent that these developments are being encouraged and accommodated, but with an expectation that some environmental impacts may be mitigated and if not they can be compensated for and habitat eventually restored to permit the sustaining of Canada's natural resources. This expectation falls within our control and "as the dominant species in many ecosystems we are charged with the cardinal responsibility for order and good government within the Laws of Nature" (Johnson 1995). It follows therefore, that consideration must be given to sustaining the productivity of the environment and that "although humans may wish to place their use preferences first, sustained ecological integrity must take precedence if any human use options are to be retained" (Minns et al. 1996). Within this context, the relatively simple and often autonomous Arctic ecosystems (Vanriel and Johnson 1995) provide opportunities for research and understanding that will permit a better understanding of increasingly more complex systems (Johnson 2002). Such knowledge and understanding are of critical importance in accurate assessments and predictions of the effects of industrial developments, their potential mitigation, and compensatory and restorative measures.

To facilitate the needs of industrial developments and at the same time adhere to the intent of the habitat protection and pollution prevention provisions of the *Fisheries Act*, development must be responsible. Ideally it should be with an increased level of certainty regarding the sustaining of the productive habitat base that maintains ecosystems, and their components. Accordingly, decisions that permit development to proceed in regions where the outcome is less certain or more tenuous must be viewed as experimental and evaluated accordingly (Minns et al. 1996). By doing so others may learn and apply the knowledge gained in future decision making (McDaniels and Gregory 2004). This will only be possible through changes to the current knowledge base that is used to assess the implications of habitat alteration and destruction, and through adaptive management. Such a flexible approach would be applied to rigorous, defensible quantitative evaluations and audits of well-planned compensatory and restorative measures that are designed to meet objectives over relevant scales of time and space (Minns et al. 2001). Inevitably this will require significant scientific rigor and input.

From a review of the literature, and the opinion of the scientific and technical communities, and industries, there remains much to do to ensure that the policy provisions for the implementation of the *Fisheries Act* are followed and that the productive capacity of fish habitat in Canada is sustained.

There have been significant efforts by industries and regulators to mitigate the effects of development at a variety of scales of potential impact, to compensate for effects that cannot be fully mitigated and to restore fish habitat upon termination of the development (refer to Birtwell et al. 2005; Samis et al. 2005). However, in almost all circumstances there is implicit belief that there is sufficient knowledge and understanding of the links between habitat change and consequences to biota, or that there is a minimal or acceptable risk that permits development to proceed (notwithstanding the socio-economic aspects). This seemingly-widespread belief perhaps has some foundation in areas where proven compensatory and restorative measures have been applied to circumstances where the knowledge of fish-habitat linkages is better understood, and, therefore, the success of such measures is high (refer to Consultations, Samis et al. 2005). However, according to reviews of habitat compensatory measures required through *Fisheries Act* authorizations, the measures have generally not met the “no net loss” requirements, and uncertainty of success remains (e.g. Cudmore-Vokey et al. 2000; Lange et al. 2001; Harper and Quigley 2005; Quigley and Harper in Consultations, Samis et al. 2005). Success is, of course, related to the nature of the compensatory measures and the complexity of the problem (refer to Figure 16, below).

The problems associated with the practical application of the habitat provisions of the *Fisheries Act* have been openly reported over many years (e.g. Levings et al. 1997*a*, 1997*b*; Randall et al. 2003; DFO 2004). There has been a progressive but limited response within science to the deductions of the numerous workshops that have identified the need for more quantitative measures and evaluations of habitat change to facilitate management decisions and improve knowledge: effects that need to be placed in perspective from the site-specific to their role in cumulative impacts over time.

Given the growing prominence of diamond mining and other industrial activities in northern Canada, it is incumbent upon regulatory agencies to ensure the availability of appropriate information in order to make sound and consistent decisions, and at the same time minimize environmentally-detrimental activities, and make provision for appropriate compensation and restoration.

It is expected that the recent decision by government to employ administrative procedures to make assessments of developments more efficient, such as the use of risk management strategies, and the Pathways of Effects model, will assist decisions regarding the impacts of development of fish habitat (Fisheries and Oceans Canada 2004*a*). However, from a purely practical viewpoint the success of these activities is intimately linked to the information base that provides for the evaluative process (hence the recognition and incorporation of risk in decision making).

INFORMATION AND ECOSYSTEM COMPLEXITY

The review of scientific literature related to species of fish in the Canadian Arctic in the region of diamond mining was carried out to assess its adequacy to support decisions that must be made over the acceptability of habitat change and the consequences of those decisions. Research into fish-habitat linkages and direct and indirect (surrogate) measurement of habitat productive capacity have been progressing in more temperate regions because of the better knowledge base that exists there, and a focus of research effort (e.g. Randall and Minns 2000; Pratt and Smokorowski 2003). The applicability of the methods employed in more temperate regions has yet to be tested and validated under Arctic conditions, notwithstanding the recent research of Jones et al. (2003*a*, 2003*b*, 2003*c*) and Jones and Tonn (2004). There continues, therefore, to be a need for the validation of "tools" for indices and surrogates of habitat productive capacity and to link them with population and community fish production (Randall 2003). Thus sound decision making is jeopardized in such information-deficient regions because of the lack of basic biological and ecological information. Accordingly, risk increases with respect to predicted outcomes of the decisions that are made. Under such circumstances, it is considered that decisions must be viewed as experimental, monitored for their success, and openly reported to aid learning and understanding (Minns et al. 1996; Hartman 2004).

Various compensatory mechanisms are considered to function within fish populations that mask or otherwise obscure the determination of sublethal effects of environmental change (Kelso et al. 2001). While there are obvious adaptive capabilities of organisms that allow them to accommodate a wide variety of environmental stresses, the exceeding of thresholds and cumulative stress can both be detrimental to their well being (Wedemeyer et al. 1991). Thus cumulative stress within populations may go undetected because of compensatory or other mechanisms functioning within the population. For example, organisms have the abilities to adapt, resist or tolerate changing circumstances (habitat) until some threshold is achieved beyond which they show symptoms of debilitation (e.g. Birtwell and Korstrom 2002, regarding effects of the cumulative degradation of Alberni Inlet, BC, on adult sockeye salmon).

As our tools to determine cumulative effects of habitat change on systems (small and large) and populations are imprecise, the additional complication of “natural variability” leads to great uncertainty in predicting and quantifying cause-effect relationships (e.g. Hayes et al. 1996; Bilby et al. 2003; Randall 2003). So it is possible that a system under stress due to habitat change could be perceived as accommodating that change depending on the metric used to derive that conclusion. Frequently the presence of fish is viewed as an indicator of habitat health (refer to e.g. Quigley and Harper in Consultations, Samis et al. 2005). It is a very crude indicator for it is well known that fish will occupy “sub-optimal” habitats and by doing so potentially jeopardize performance, health and survival (Birtwell and Korstrom 2002; Jones and Tonn 2004). Conversely, they may derive an advantage through increased feeding opportunities and protection from predators (Gregory and Levings 1996). Thus, depending on the metrics used the perceptions of thresholds with respect to populations of fish can lead to erroneous conclusions. The determination of sublethal thresholds with a high degree of resolution to predict population-level responses to habitat change represents a significant scientific challenge.

Recovery of fish and fish habitat from environmental change is likely to be a protracted process because of the characteristically-harsh environmental conditions of the Canadian Arctic. The typically-low availability of food and cold temperature act together to slow growth rates and influence survival through simple energy pathways (Vanriel and Johnson 1995; Johnson 2002). Furthermore, risk and uncertainty increase depending upon the scale of examination. That is, detecting quantitative changes in large ecosystems is fraught with significantly more inaccuracies in measurement and quantification, than determinations at lower levels of ecological complexity and aspects of basic biology. The success of investigating the biology and ecology of fish is likely a simpler proposition than quantifying and understanding the implications of habitat change within watersheds (refer to Figure 16).

Fish populations are viewed as integrative metrics of habitat change (Lewis et al. 1996; Minns et al. 1996; Randall 2003), but resolution of reasons for changes relative to the environment also suffer from inaccuracies inherent in measurement techniques, aside from complicating influences of other variables. Thus detection of change is problematic irrespective of the level of complexity of the biological or ecological entity that is assessed. But, it is apparent that increasing ecological complexity compounds the difficulties in quantifying change. Irrespective of these obvious limitations, the basis for sound decision making regarding environmental change lies in understanding fundamental biology and ecology for they are inexorably linked.

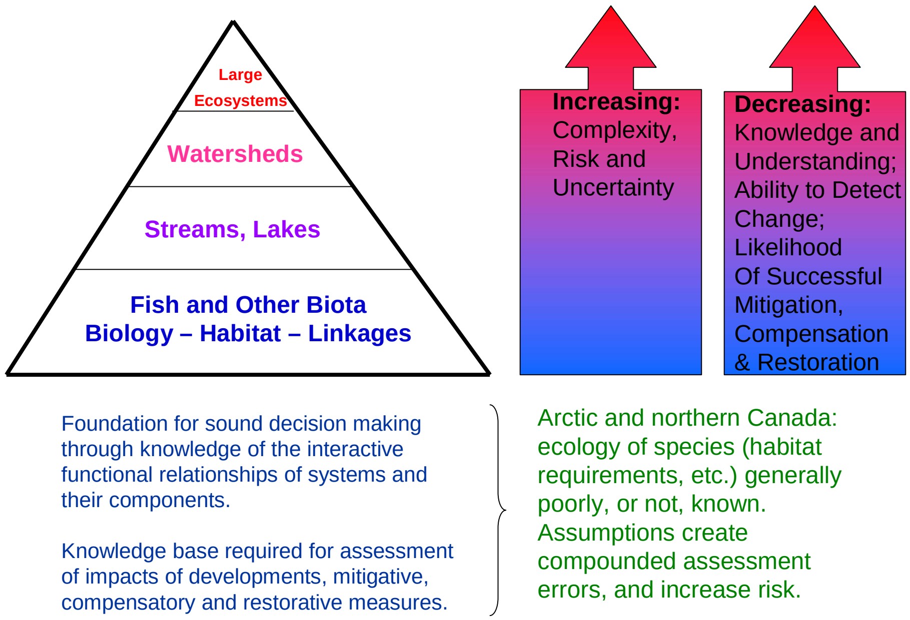

Figure 16. The basic foundation of knowledge required for sound decision making in relation to ecological complexity, risk and uncertainty.

ASPECTS OF FISH HABITAT MANAGEMENT (INCLUDING MITIGATION, COMPENSATION AND RESTORATION)

To promote sustainable aquatic ecosystems policy makers can let uncertainty guide the use of the "precautionary principle" in setting limits in human developments and in selecting from a range of restoration strategies, each of which has different levels of risk. (Wissmar and Bisson 2003). However, it may not be possible to repair the damage caused by decades of irresponsible land use, for typically we are able to destroy things more readily than we can repair them, thus restoration of it becomes a poor substitute for habitat protection (Hartman et al. 1996). Although there is a legacy of past developments that affected fish habitat, current administrative policies (e.g. Habitat Policy) and practices allied to better management of developments are being sought to ameliorate such negative effects. That said, habitat damage is still occurring and will continue to be the case until it is possible to mitigate damage, compensate for residual habitat disruption, and restore that which is degraded. But, there might be some regions in Canada where particular developments are likely to cause irreparable damage to fish habitat. The variables that influence the success of habitat compensatory and restorative measures are not only ecological, yet they are of overall importance (Wissmar and Bisson 2003). Without high social commitment, and sound judgment, and the associated economic considerations the likelihood of success of such measures is diminished (refer to Figure 17).

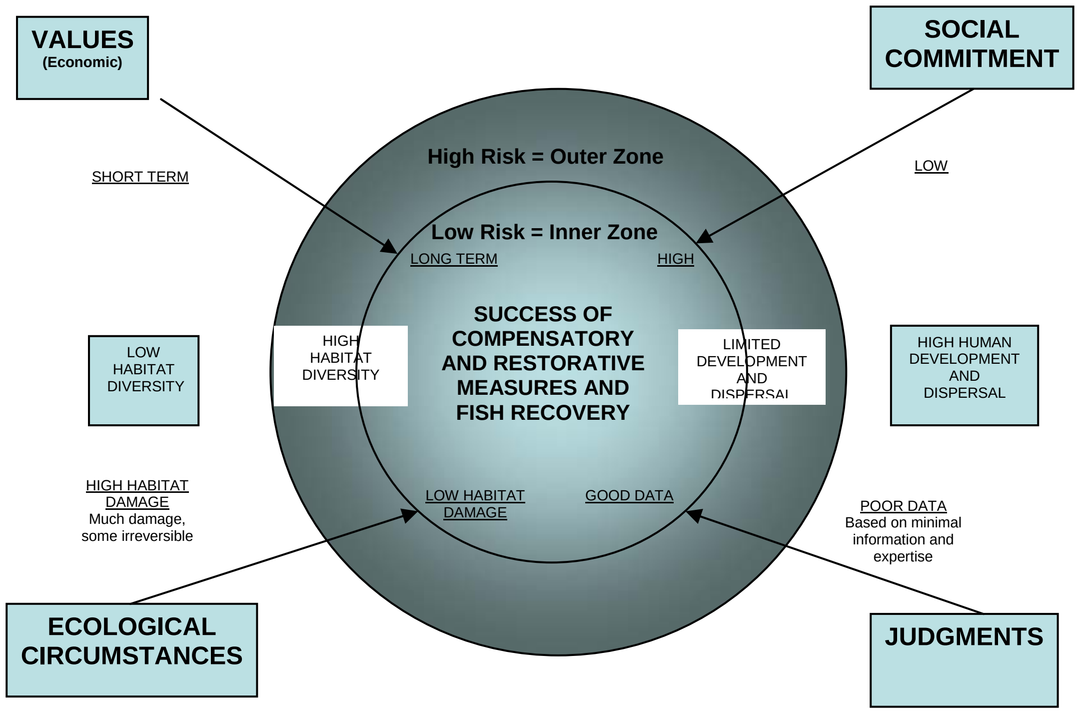

Figure 17. Diagram showing how the variables of ecological circumstances, social commitment, judgment, and values may influence the success of habitat compensatory and restorative measures (adapted from Wissmar and Bisson 2003).

Knowledge of the simple base of biological and ecological units permits a better understanding of the consequences of environmental change to more complex systems. However, it is of paramount importance that the assessment of habitat change is made over different scales of ecological complexity and that research and monitoring investigations are carried out over sufficient time frames to permit conclusions to be drawn (Lewis et al. 1996). This is particularly important in addressing the acceptability of habitat change in relation to developments. How mitigation takes place and what compensatory and restorative measures occur are a direct function of knowledge about that which is to be changed or lost and then predicting the consequences.

The successful restoration of fish habitat is as dependent on the requirement for knowledge as is the effective compensation for changes and losses to fish habitat. The successful restoration of habitat is closely linked to our understanding of ecological processes to the extent that if we do not understand the processes we are unlikely to be successful in efforts to make the restoration work (Bradshaw 1996). The criteria for successful restoration require such an understanding. In this regard, according to Bradshaw (1996), restoration applies to a return to an original state, and that it should be thought of as applying to whole ecosystems. That is, it includes water and its quality. Pastorek et al. (1997) provide a similar understanding and consider that restoration returns an ecosystem to a close approximation of its condition before it was disturbed (an issue not to be confused with rehabilitation which improves a system to a “good working order” (Pastorek et al. 1997)).

The results of evaluations of the success in the application of the *Fisheries Act* to prevent habitat loss in the face of development reveal a relatively low level of achievement (refer to Cudmore-Vokey et al. 2000; Lange et al. 2001; Quigley and Harper in Consultations, Samis et al. 2005). The reasons for this are numerous, but creating a positive change will require significant effort. This is especially important in the setting of clear objectives for compensatory and restorative measures and the requirement for adaptive monitoring over time and space that will permit a full evaluation to occur. Such an approach will inevitably lead to better understanding, albeit over time frames that will be related to the rate of habitat change and fish response. Scientific rigor is required in such a scenario, and its importance is greater in those areas where basic and relevant information is lacking. Such an approach could be stipulated within an authorization under the *Fisheries Act.*

More information is required to decide upon habitat compensation options in the Canadian Arctic and other remote regions. While there will be community-based considerations that require incorporation into such plans, success will likely be better if the function of habitat can be retained and enhanced. In that the lakes and streams of the Arctic are typically low in nutrients and are ultra-oligotrophic, fish growth and survival is intimately linked to the provision of food and controlled by relatively cold waters (refer to Deegan et al. 1997; Buzby and Deegan 2000; Jones et al. 2003*b*, 2003*c*). Thus, as an example, stimulation of productivity through the controlled provision of nutrients leads to enhanced food (Milbrink and Holmgren 1988; Peterson et al. 1993; Slaney and Martin 1997). However, such fertilization requires management to avoid eutrophic conditions (e.g. Rescan Environmental Services 2000) that can lead to ecologically-adverse hypoxic and anoxic conditions in lakes, and especially those that are ice covered for most of the year thereby preventing gas exchange with the atmosphere. Another option would be to improve fish access to unconnected lakes that will provide increased feeding opportunities and other resources, and at the same time retain ecological function within a watershed with direct benefits to fish. Such a hypothetical situation is presented within Figure 18.

Focused research and monitoring play important roles in decision making and the progression of policies and regulations and their implementation. Such interactions are presented in Figure 19 that serves to encapsulate the prior comments.

POLICY AND MANAGEMENT

Fish habitat management and guidance

Logically, negative changes to fish habitat would have adverse consequences to aquatic organisms, and fish habitat management practices typically involve strategies to avoid such harm. Avoidance of impacts, followed by mitigation of residual adverse effects to fish habitat are the first considerations to be taken when habitat loss is likely to be

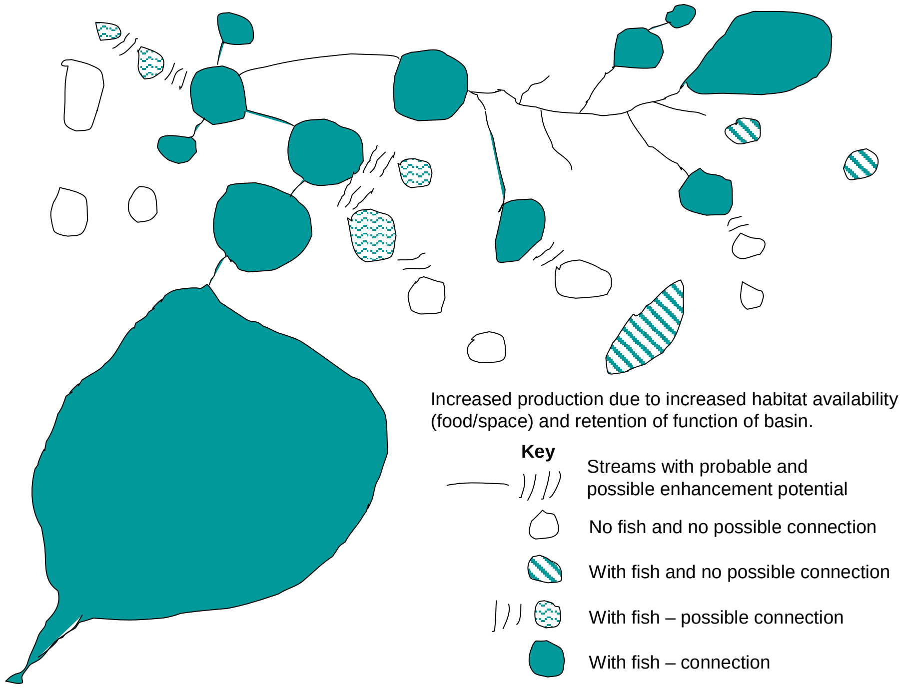

Figure 18. Hypothetical drainage basin and some connectivity-compensatory options.

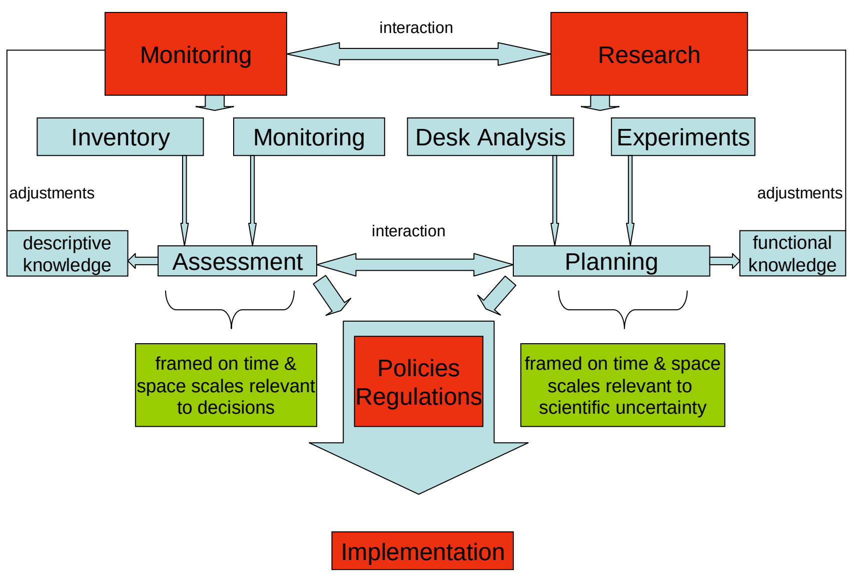

Figure 19. Simple integration of research, monitoring and management functions (adapted from Cudmore-Vokey et al. 2000).

encountered. In order to guide habitat practitioners who must make decisions regarding the management of fish habitat and ensure that there is compliance with the intent of the *Fisheries Act*, DFO prepared a policy document (Department of Fisheries and Oceans 1986). The guiding principle of the Policy is to ensure that there is “no net loss of productive capacity of fish habitats” (refer to Minns 1997*b*). Thus, a key analytical step of habitat management is to determine whether and how a habitat manipulation, either inadvertently or deliberately, will affect productive capacity (Jones et al. 1996).

Productive capacity is defined in the Habitat Policy (Department of Fisheries and Oceans 1986) as “the maximum natural capability of habitats to produce healthy fish, safe for human consumption, or to support or produce aquatic organisms upon which fish depend.” As Minns (1997*b*) points out, “the productive capacity is a potential, vested in the habitat and independent of the extant stocks of fish or associated organisms.”

Measurement and quantification of productive capacity is required in order to meet the NNL principle of the Habitat Policy which is to maintain the long-term productive capacity. Accordingly, when more fish are available or able to exploit habitat the productive capacity must be sufficient to support them (Fisheries and Oceans Canada 1998).

According to guidance documents (e.g. Fisheries and Oceans Canada 1998) productive capacity is the measure of the capability of a habitat to produce fish and/or food organisms in natural or restored conditions. Within this document productive capacity is considered to be analogous to carrying capacity, (defined as the maximum biomass of organisms that can be sustained on a long-term basis by a given habitat).

The determination of productive capacity inevitably involves more than an assessment of the number of fish utilizing a given habitat at one specific time or the current level of fisheries production from the habitat (Fisheries and Oceans Canada 1998). The concept of productive capacity encompasses cyclical variations in habitat utilization as well as cycles in fish production.

Typically, habitat lost through project development or created through compensation is assessed and described according to physical parameters (e.g. area or volume of habitat; littoral zone; mudflat; salt marsh; gravel bed) combined with a biological classification (e.g. spawning grounds and nursery, rearing, food supply and migration areas).

Fisheries and Oceans Canada (2004*b*) stated that physical and biological descriptors may have to be used as surrogate measures of productive capacity until ongoing research provides more precise “tools.” The development and provision of such techniques and their validation have been considered over numerous years, and at the present time there still remains the need for such research (e.g. DFO 2004). These aspects are addressed below in relation to technical considerations.

Fish management (exploited and unexploited resources) and habitat area plans

Fish management and fish habitat area plans are fundamental to the successful management of fishery resources and the attainment of the productivity and conservation goals identified within the Habitat Policy. They represent the starting point for sound management that is stated in the Policy and recognize the need for this integration to guide its implementation. The identification of fish and habitat management goals (such as those for conservation and fisheries) are viewed as requirements that are linked to decisions regarding the acceptability of developments and their impact on fish and their habitat. Minns (1997) describes such needs more fully. Intuitively, one expects that changes in the productivity of habitat upon which fish rely will in some way result in consequences to those organisms. Minns (1997) stated that "in North American freshwaters, most extinction of fish has been due to habitat destruction or alteration," and cited Pearse (1988) who showed that Canadian freshwater fisheries resources were in decline because of habitat loss and over exploitation.

Fish habitat area plans provide the means whereby the goals of the Habitat Policy may be realized. They provide the basis for conserving the productivity of an area. "Effective integration of resource sector objectives, including fisheries, will therefore involve co-operation and consultation with other government agencies and natural resource users" (Department of Fisheries and Oceans 1986). Thus there is an explicit understanding that integrated management will occur. There is also an understanding that this requires an ecosystem approach when one considers that fish productivity is dependent upon the productivity of the system as a whole (Minns 1997). However, rigorous scientific studies are necessary to provide the information that will permit such an understanding to occur.

Application of habitat policy and legislation

Differences exist in the application of the pollution prevention and habitat protection provisions of the *Fisheries Act* among the mining sectors identified in this document. However, there is recognition in government of the need to address this issue.

DFO has been inconsistent in implementing its policy and regulatory responsibilities in the context of mining in Canada's north. In addition, it appears there has been an overall net loss of fish habitat productive capacity due to human developments. In this regard, we have chosen to avoid commenting on the responsibility for past events and decisions that have been made regarding habitat management and related scientific research. Instead, we have endeavored to use this historical base, consultations, and information from pertinent literature, from which to move forward by recommending measures to facilitate habitat management and related science. By doing so there should be a benefit to aquatic resources, and also mutual benefits to industry and regulators.

The discharge of sediment into waters frequented by fish often occurs due to mining. Minimizing or avoiding its input into such waters has been recognized as an important step in the maintenance of most fish habitat (Waters 1995). Placer mining, by its very nature, has the potential to add large quantities of sediment into watercourses, and attention has been given in this document to industry and habitat management to reveal some of these issues around human developments that have occurred over many years in northern Canada.

Placer mining has been ongoing in the Yukon for over a century, typically by small operators on very limited budgets. Sediment discharges are regulated under the *Fisheries Act* using a section 35 "class authorization" (Government of Canada 1993) which allows the harmful alteration, disruption or destruction (HADD) of fish habitat based on stream classification, which is a function of fish use. For example for those streams considered more valuable, proposed habitat disruptions must be compensated for before mining commences. For other streams considered less valuable, habitat must be restored, or the channel stabilized, when mining is complete. Placer operators reportedly complete a worksheet on gradient and width, but it appears the work is inadequately monitored, and it is subject to disturbance from the effects of mining upstream.

To date restorative actions related to placer mining have been few, but in compliance with a new regulatory regime (as noted elsewhere in this report), "compensation and restoration are the primary means through which the policy goals (*Fisheries Act*) will be achieved where there are short-term disruptions of habitat" (ISC 2004). The net damage to fish habitat from placer mining may be reversible in some areas, but over a long time frame (Hardy and Associates Ltd. 1981; Alaska Department of Fish and Game 1987).

Diamond and oil sands mining, in contrast to placer mining, are conducted by comparatively well-capitalized interests, and the discharges are managed under fairly stringent territorial or provincial water licences. Fish habitat authorizations have been used to allow HADDs caused by lake draining, stream diversions, and the use of lakes to manage pit water and as dumps for waste rock or tailings. DFO has required fish habitat compensation or cash to offset damage from whole lake destruction in diamond mining, however, successful compensation has not yet been documented. This is in part due to the lack of proven compensatory measures for northern habitats, and because of the paucity of research that has been conducted on fish habitat requirements in the north. Furthermore, there is community resistance to enhancement or modification of pristine fish habitats thus presenting a limitation to compensatory measures that could be employed (J. Dahl, Area Chief, Habitat Management, DFO, Yellowknife, NWT; pers. comm.). Notwithstanding these comments there is, however, community support for the economic benefits that diamond mining provides, despite the fact that it often has resulted in whole lake destruction.

Diamond mining companies excavate multiple open pits concurrently, without being required to progressively restore mined-out pits in succession. As a result, achievement of no net loss of the productive capacity of fish habitat is being deferred, and consequently the development of end-pit restoration technology hindered.

The DFO Practitioners Guide to Compensation has a hierarchy of compensation options which requires assessment of like-for-like compensation first before consideration of creating or increasing the productive capacity of unlike habitat in the same ecological unit. Thirdly, consideration may be given to moving offsite with the replacement habitat (Fisheries and Oceans Canada 2004*b*). There have been many lakes eliminated for diamond mining developments, however, there has been no new lakes constructed as replacement habitat at these mines. It appears that damage to fish habitat in the tundra due to diamond mining is likely to be largely irreparable, in that end pit lakes or tailings impoundment areas are unlikely to be fully restored. A few compensatory measures that offset fish habitat damage at diamond mining operations in the tundra are being evaluated scientifically, and also being monitored for success – this will take many years.

In the oil sands industry, large-scale surface disruption occurs, and this can include whole stream destruction authorized by DFO using a section 35 authorization. Compensation has involved the replacement of streams with constructed channels, and lakes are proposed (the conversion of exhausted pits into lakes is not considered compensation (J. Shamess, Impact Assessment Biologist, DFO, Edmonton, AB; pers. comm.)). The effectiveness of replacing streams with diversion channels and artificial lakes to offset the loss of the productive capacity of fish habitat is untested. Residual hydrocarbon contamination can occur in surface waters in oil sands development areas.

Research is underway through the Canadian Oil Sands Network for Research and Development (CONRAD), a consortium of companies, universities and government agencies organized to facilitate collaborative research in oil sands, including environmental research.

Differences exist on a mining-sector-wide regulatory basis between metal mining and diamond mining in the context of tailings impoundment area designation. Regarding the former, natural, fish-frequented water bodies are scheduled as tailings impoundment areas (TIAs) through a Governor in Council amendment to MMER. Whereas, TIAs in diamond mining are authorized by DFO officials using the section 35 HADD provisions of the *Fisheries Act.*

The acceptance of money as partial compensation for lost and degraded habitat has occurred in relation to the development of a diamond mine in the Arctic. The money was placed into a federally-managed Habitat Compensation Fund. The acceptance of compensatory funds is a variation to standard practices that seek options to employ compensatory and restorative measures to combat such loss and degradation. The unique Arctic circumstances together with a general lack of ecological information and non-validated habitat assessment, compensatory and restorative measures, and limited options no doubt contributed to the acceptability of this contribution.

The application of the Habitat Policy differs among the Department's regions and in relation to many understandable factors. However, for consistency in decision making that will fit with the new initiatives being taken by government (Fisheries and Oceans Canada 2004*a*) it will be necessary for better guidance and supporting information. The choice and use of appropriate measures to assess the consequences of habitat change and thereby help to mitigate and compensate, and restore habitat will be dictated by site-specific circumstances. However, through the provision of appropriate guidance at the national level a more consistent approach will occur and learning will be facilitated.

These comments are not to be misconstrued, for significant and valuable effort has already gone into the provision of such approaches (e.g. with respect to the application of the Habitat Policy, and use of scientific methods). However, there are constraints that can only be offset through the provision of new information if greater consistency and less risk in decisions are required. This is particularly true for remote and northern parts of Canada where our understanding of ecology is very limited, and where validation of the existing assessment and evaluation methodologies has yet to occur.

Hypothetical management plan

A simple plan is provided based on the foregoing comments. It is presented in Figure 20. It is not all inclusive but serves to illustrate the components of the assessment of development that will impact fish habitat and the link to meet the overall goals of the Department. In this hypothetical situation it is assumed that a productive lake will be destroyed and that there will be compliance with habitat and pollution provisions of the *Fisheries Act.*

Regional fish production, harvesting and conservation objectives (including genetic considerations) are the fundamental starting points that should guide decisions on the acceptability of habitat change (e.g. Jones et al. 1996; Lester et al. 1997; Minns et al. 2001).

It is accepted that the setting of management objectives in some regions may be difficult, but they are fundamentally important. Thus, by setting such objectives the risk of loss of a productive lake may be assessed in an appropriate reference framework linked to fish management objectives (refer to Figure 21). At this assessment stage the initial steps could include the identification of potential and predicted lake productivity by employing standard measures, then assessing the loss of this lake in relation to the ranked importance of lakes within the watershed and larger ecological unit.

The use of risk management and "Pathways of Effects" models (Fisheries and Oceans Canada 2004*a*) would assist in the identification of activities that would impact upon fish habitat that may be mitigated and those which cannot. Progressive compensatory and restorative measures should be used so that environmental benefits may accrue during development activities rather than delaying them until completion of the project. Thus the value of habitat would be progressively restored rather than deferred for protracted periods or indefinitely.

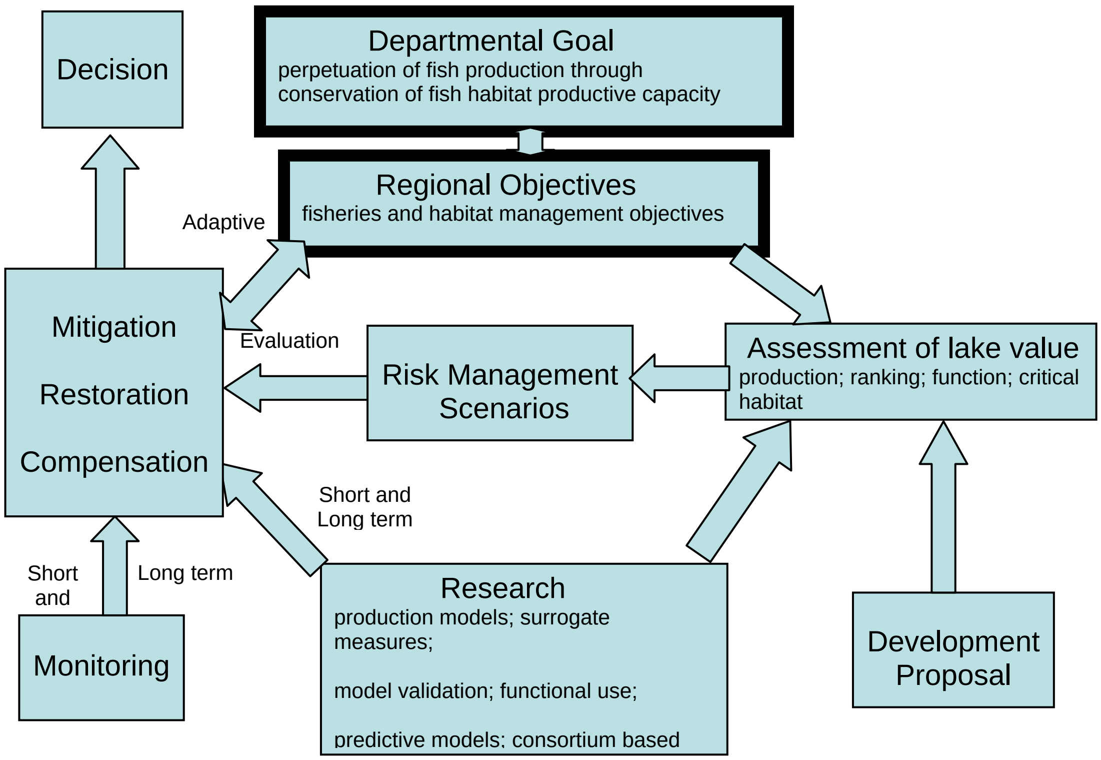

Figure 20. Processes and linkages regarding the assessment of a hypothetical development proposal that will eliminate a productive lake, and the relationship to Fisheries and Oceans' regional and Departmental objectives and goals.

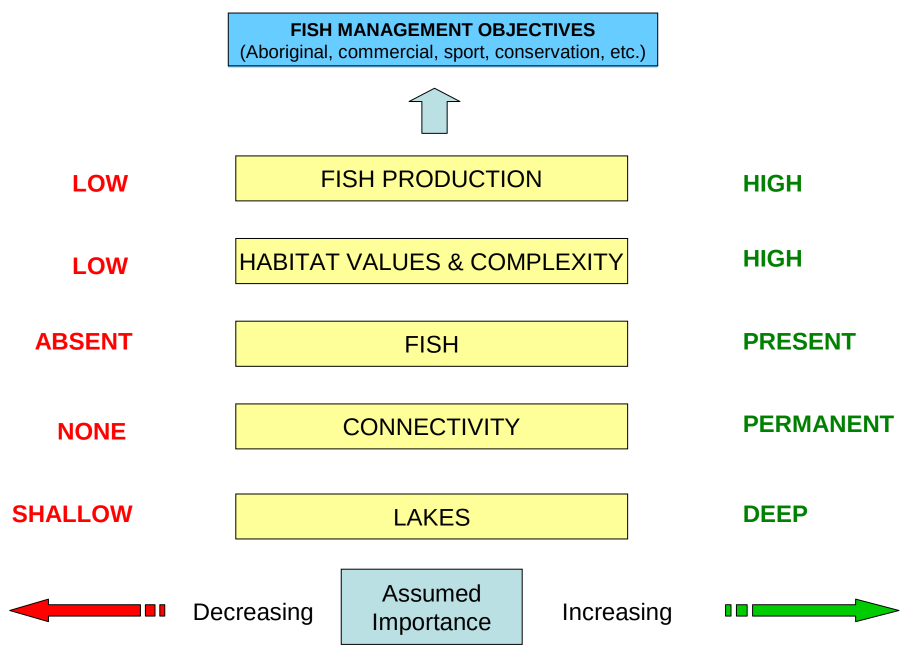

Figure 21. Initial considerations of lake importance in relation to fish management objectives (to be assessed in relation to compensatory options).

In relation to the Arctic and other regions where ecological information is scarce or lacking, the risk in accepting loss is compounded by this paucity of knowledge. Thus the decision is one including much uncertainty and of high risk and, as such, has inherent experimental value. Under these circumstances new information must be obtained. It is suggested that this should be over the short and the long term. It should be a joint responsibility of the industry and stakeholders, and the generation of knowledge through research should occur via a consortium of these parties and possibly others.

Funding for this research and monitoring should be the primary responsibility of the proponent of the development but collaborative studies would be for the mutual benefit of those within the consortium and the public. In this context if habitat compensation cannot be accomplished in the area of the development, and options are seriously limited, accepting funds as partial compensation could be considered. Such funds would be administered under the auspices of a consortium of stakeholders and could be directed towards the generation of new knowledge. While the acceptance of funds as partial compensation for damage to fish habitat is a departure from recognized choices its value lies in the opportunity to fund the obtaining of new knowledge that will benefit future decision making (McDaniels and Gregory 2004), and therefore reduce the risks that were present in the initial "experimental" decision (Minns et al. 1996).

Research will be required together with monitoring to assess the success of compensatory and restorative activities. This should be a component of authorizations where large-scale developments will impact fish habitat and/or where information is inadequate to predict the outcome of habitat change. Options to consider would include increasing the accessibility of habitats to fish, opportunities to access fish-less lakes, and changing physical features of lakes to add structural complexity and refuges while striving to maintain the function of habitat (refer to Figure 22).

The availability of relevant knowledge should drive the need for research and monitoring to reduce risks in decision making. As such, if decisions are made that incorporate the elimination of a lake, the provision of scientifically-defensible knowledge should be required within the context of assessing the effects of this environmental change and the success of compensatory measures. In addition, if restorative actions are required research and monitoring should be undertaken in order that a flexible plan may be assessed through the meeting of objectives over the course of industrial activity. In both the restorative and compensatory aspects it is essential that evaluations of success (and failures) be reported along the path towards meeting regional and Departmental objectives.

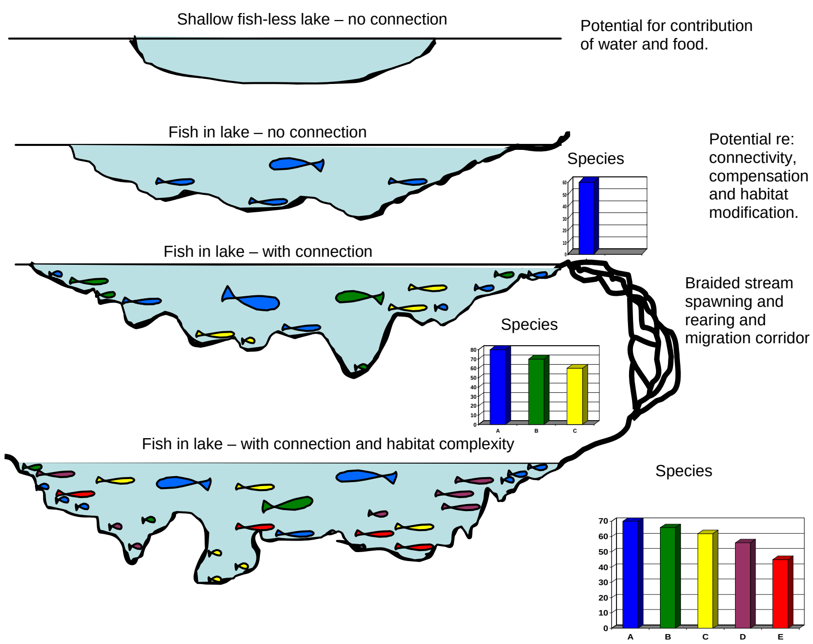

Figure 22. Species diversity, habitat complexity and linkages, for consideration of compensatory and restorative options.

CONCLUSIONS AND RECOMMENDATIONS

This section contains statements and recommendations deduced from the assessment of literature and from consultations. They are organized into the same broad categories used in the report, i.e. habitat science; industries; aspects of fish habitat management (including mitigation, compensation, and restoration); and policy and management. The categories are not necessarily independent of each other, for example the need for scientific research is a fundamental component of each.

CONCLUSIONS AND RECOMMENDATIONS OF PARAMOUNT IMPORTANCE

- **Damage to fish habitat in pristine regions of the Canadian Arctic is occurring and escalating and there is currently no assurance that habitat compensatory and restorative measures will be effective in meeting the Habitat Policy requirements regarding fish habitat productive capacity, which are linked to the *Fisheries Act* in order to sustain fish productivity.**

- **The inadequacy of even basic ecological knowledge, the absence of validations of habitat compensatory and restorative measures regarding habitat linkages to fish productivity, and no examples of whole lake restoration and compensation to guide developments forecast irreparable harm.**

- **Significantly more knowledge and understanding of the basic biology and habitat requirements of Arctic species are required, especially in view of the**

increasing human development in northern Canada, global environmental changes and the need to determine and assess their cumulative effects. Provision of this knowledge and understanding will assist decision making, reduce risk and uncertainty and facilitate mitigation, compensatory and restorative measures designed to sustain aquatic resources in this and other remote regions in Canada.

- **Co-operative and collaborative ventures with industries, governments, academia and Aboriginal communities should provide for the acquisition of new information. Opportunities currently exist for this to occur. Multi-stakeholder consortia should be the mechanisms for fund acquisition and disbursement.**

- **The successful application of the Habitat Policy to developments in regions of Canada where there is a paucity or absence of basic information for making sound decisions is jeopardized in view of the potential uncertainty of success of habitat mitigation, compensatory and restorative measures. In this context consideration must be given to learning from, and adapting to, experimental decision making. This will be accomplished through committed research and monitoring which is appropriately scaled over time and in space to meet stated Departmental objectives.**

- **Compensatory, restorative, and related techniques, measurements and evaluation, are priority research topics that meet with approval from all industry sectors, the scientific community and habitat practitioners.**

SCIENCE

Key conclusions

- **The Arctic represents unique habitat for fish because of its extreme biogeochemical and climatic conditions (extreme cold and ice cover of lakes and rivers, extreme variations in daylight, low nutrient supply and productivity, and low biodiversity).**

- **Arctic freshwater research has not received enough emphasis over the last 3 decades and as a result current development impacts on aquatic organisms cannot be easily, readily or accurately assessed.**

- **Information on the basic biology of Arctic fish, their dependence on, and interaction with, habitat is deficient, and as such, generally inadequate to meet the needs of habitat management.**

- **A number of human activities and human-influenced events (e.g. infrastructure development, mining, hydroelectric generation, oil and gas exploration and exploitation of renewable natural resources, seepage of toxic materials from abandoned sites, long-range transport of and deposition of atmospheric**

pollutants, and global change such as climate warming and ozone thinning) are affecting the Canadian Arctic environment.

<u>Key recommendations</u>

- **Increase and commit to long-term, core, freshwater Arctic research programs related to fisheries-habitat science by:**

    - **Undertaking interdisciplinary studies to address the deficiencies in knowledge of fish-habitat interactions in the Arctic and other remote areas where habitat is being destroyed and altered through human development (use the pristine lakes to obtain basic ecological information as reference sites);**

    - **Undertaking ecosystem and sub-component research. Specific topics requiring attention include seasonal habitat refuges, critical habitat needs, habitat-fish interactions, fish-habitat modeling, habitat productivity surrogates, lake "fish-out" protocols and data manipulation for predictive purposes regarding yield and assemblages, controlling factors concerning survival and recruitment, specific habitat requirements of fish at different life stages, behavioral and physiological aspects linked to habitat use and optimal conditions, survival and function, population research in relation to habitat manipulation, experimental compensatory and restorative techniques and their validation, genetic diversity and adaptability of populations to habitat change such as ionic increases under oligotrophic circumstances;**

    - **Initiating large-scale, long-term experiments using mining developments and pristine areas to determine fundamental fish-habitat interactions and improve predictive and decision-making capabilities for fish and habitat management (e.g. model approach on the Experimental Lakes initiative);**

    - **Seeking modification to funding strategies by e.g. NSERC to provide more flexibility in funding all sources of scientific endeavors and include government agencies; and**

    - **Establishing a consortium of stakeholders that would provide funds, evaluate, allocate and oversee priority research projects (e.g. industry, Aboriginals, Indian and Northern Affairs Canada (INAC), Natural Resources Canada (NRCan), Environment Canada (EC), DFO, territorial governments).**

INDUSTRIES

Key conclusions

- **The three industrial mining sectors examined and metal mining have impacts on fish habitat which include the alteration and degradation of lake and stream habitat.**

- **Alteration and degradation of habitat will continue. Quantifiable portions of fish habitat are impacted by the respective sectors.**

- **All the mining sectors examined are viable, and exploration and expansion of operations is continuing.**

- **There is every expectation that placer gold, oil sands, and diamond mining will continue to operate into the foreseeable future (>20 years). Placer, oil sands, and diamond mining have been in existence for over 100, 60, and 10 years, respectively.**

- **Differences of opinion exist among some industry sectors and regulators regarding their impact on fish habitat (issues that could be alleviated through unbiased independent reviews).**

- **All three industrial sectors expressed a positive interest in, and would welcome participation in, mutually-beneficial research projects, especially those designed around the issues of compensation and restoration.**

ASPECTS OF FISH HABITAT MANAGEMENT (INCLUDING MITIGATION, COMPENSATION, AND RESTORATION)

Key conclusions

- **The success of mitigation, compensatory and restorative measures is intimately linked to knowledge of the basic needs and uses of habitats by fish. Aside from the need for rigorous evaluations of the efficacy of compensatory measures, the absence or paucity of this information in the Arctic, and in other remote locations, is one of the fundamental problems facing successful mitigation, compensatory, and restorative efforts.**

- **Recent examinations of the efficacy of fish habitat compensatory measures and their evaluations on a national level revealed inadequate assessments and compliance resulting in an overall loss of fish habitat. Lack of scientific rigor, inadequacy of knowledge, and inadequate assessments were constraints to realizing Departmental objectives.**

- **There has been no aquatic habitat "restoration" of a diamond mine pit, and very limited and rudimentary restoration of placer gold mining areas.**

- **Compensatory and restorative measures and monitoring regarding fish habitat are required from diamond, oil sands, and placer mining sectors in relation to their activities. These activities should occur throughout the duration of mining and, wherever possible, not be deferred until it ceases.**

- **There have been no complete evaluations of habitat compensatory initiatives at diamond mining sites. They have yet to be proved effective and successful.**

- **Money (i.e. $1.5 million) has been received as compensation for some of the impacts due to diamond mining operations. In addition, compensatory measures have been implemented and are being monitored.**

- **The Habitat Policy's "hierarchy of preferences" to compensate for lost habitat on a "like-for-like" basis is seriously limited in areas where information deficiencies exist and there is uncertainty of success. "Like-for-like" habitat compensation is not considered to be a viable option when the likelihood of success is low.**

- **Significant money and effort is being expended by certain industries (i.e. diamond and oil sands mining) to monitor the changes to aquatic conditions creating large databases. Their value will be apparent through time and therefore analysis should be an ongoing and adaptive requirement.**

- **There has been no field evaluation and development of methods used to quantify fish habitat in the Arctic in relation to diamond mining.**

- **The use of an array of surrogates for habitat productive capacity and models used to link habitat and fish use and production require validation in the Arctic.**

- **Compensatory options are often limited by knowledge and constrained by physical features of the land. There has been no recreation of a lake as compensation for one that has been eliminated, but creation of a lake as compensation for the elimination of streams is proposed for oil sands developments.**

- **Successful compensation for lost and degraded habitat in the mining sectors examined is considered to have occurred in a few circumstances.**

<u>Key recommendations</u>

- **Scientific rigor is required in the design, and the evaluation of habitat compensatory and restoration projects.**

- **Scientific standard methodologies should be used in assessing fish yield and communities in lakes to be eliminated to build a database that will permit better predictions and understanding.**

- **Evaluation of projects that will significantly impact aquatic habitats must combine monitoring and research components in a defensible and flexible (adaptive) manner, over time frames sufficient to meet management and scientific needs. A combination of short- and long-term evaluations is required.**

- **Rehabilitation (which improves a system to a good working order) should be considered as a more practical, initial objective than the restoration of fish habitat (which returns an ecosystem to a close approximation of its condition before it was disturbed), both of which require scientific knowledge and understanding.**

- **Objectives that are linked to meet fish and habitat management plans must be described so that success may be evaluated along a path(s) towards them, and adapted as required.**

- **Evaluation of habitat compensatory and restorative measures should encompass different levels of biological organization and trophic status, while recognizing the importance of population variability, threshold responses, and the accuracy of the metrics employed. A national data management system with easy access for data retrieval and assessment is required for such activities and research information. At the very least this should be for the boreal-Arctic regions.**

- **Climate change issues must be recognized and addressed in the design of monitoring and research programs for areas that are especially vulnerable to such change (e.g. Arctic systems).**

- **Restorative activities should, wherever feasible, be undertaken during the operation of mining and not await its termination (e.g. the sequencing and decommissioning of open pits and their restoration).**

POLICY AND MANAGEMENT

Key conclusions

- **There has been inconsistent application of the *Fisheries Act* among the mining sectors.**

- **Placer mining has been permitted to affect fish habitat under a section 35 "class authorization," oil sands and diamond mining are permitted to operate under site-specific authorizations, lakes used in metal mining as tailings impoundment areas (TIAs) are regulated through the section 36 Metal Mining Effluent Regulations.**

- **Decisions to use lakes in metal mining for TIAs must be authorized by the Governor in Council (cabinet), whereas similar decisions regarding diamond mining are made by the Fisheries Minister or designate.**

- **There tends to be an absence or scarcity of fish management and habitat plans for areas where mining development is occurring in northern Canada.**

- **Information on, for example, freshwater Arctic research and management programs, appears fragmented and requires coordination at regional and national levels.**

- **There has been a lack of standardized approaches used by habitat practitioners to evaluate and audit alteration and degradation of habitat, and compensatory and restorative measures in Canada.**

- **Guidelines have been produced that assist habitat practitioners in making decisions regarding developments that will impact habitat.**

<u>Key recommendations</u>

- **Management decisions, and especially those relating to major developments that will significantly impact fish habitat, and that include much inherent uncertainty and therefore a high level of risk, must be viewed as experimental. They should be amenable to evaluation and be adaptable to derive better knowledge and thereby help to guide future decisions.**

- **Fundamental habitat area and fish management plans and objectives are required that will guide decisions regarding the destruction of fish habitat, compensatory and restorative measures.**

- **Clear objectives are required that will permit both management decisions and operational activities to be evaluated over time frames sufficient for their full assessment. The goals of the Habitat Policy and the needs to meet the mandate of the Department lie within this context. Conservation of fish habitat and fish is one such goal.**

- **A number of new and revised "guidance documents" is required regarding the use of selected metrics of habitat productivity, compensatory and restorative measures and evaluation criteria.**

- **The guide relating to the application of the Habitat Policy and the issues around NNL should be updated to incorporate new development circumstances (e.g. in northern and other remote areas in Canada where knowledge and understanding of fish and aquatic habitat is limited).**

- **Authorizations for major industrial developments in regions where knowledge of impacts, their mitigation, compensation and restoration is low, must include as part of the proposal the provision for long-term monitoring, research and assessment that may include experimental fish habitat manipulations to generate new knowledge of importance to future decision making.**

- **If a development is agreed upon by affected parties and allowed to proceed it is important that this acceptance includes all aspects of mitigation, compensatory and restorative actions.**

- **Financial compensation that is linked to fish and habitat area plans should be an option for consideration only in those circumstances where the requisite information base is low and habitat compensation is likely to be uncertain or impossible. Risk evaluations must be part of this scenario. Funding, in part, could be independently managed and directed for research and monitoring of the development, and habitat compensatory and restorative projects.**

- **The transfer of scientific information regarding techniques and methods to assist habitat practitioners must continue through meetings and information transfer to promote consistency of approaches to habitat management at national and regional scales.**

- **Habitat practitioners' workshops are required to assist in the application of scientific methodologies on a regular basis and, similarly, to evaluate performance in relation to decisions to achieve the goals of the Habitat Policy.**

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APPENDIX

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KEY TOPIC AREAS FROM CONSULTATIONS AND SCIENTIFIC LITERATURE

1. Biology and ecology of northern and remote aquatic ecosystems

The basic biology and ecology of northern fish species is poorly understood because so little research has been carried out. Specific habitat requirements of certain fish species have not been well documented, and the fundamental ecology of un-impacted lakes and streams in northern Canada is poorly understood. Scientific research that is required to assess ecological effects must be based on understanding the life history of fish, and how they use lakes and streams. Energy flow in nutrient-poor Arctic tundra lakes is not well understood. The factors that control populations of fish in Arctic lakes, and the effects of habitat change, need to be assessed. The paucity of information on certain species will require the incorporation of uncertainty into decision making regarding fish habitat management, and the adoption of a precautionary approach. Government must lead this type of work. Great Bear Lake (the world’s most pristine lake) and Great Slave Lake are among the most unstudied lakes in the world.

2. Linkages between fish and their habitats

Although an assessment of the significance of impacts to fish habitat is closely allied to fishery objectives, it has been recognized that fish-habitat linkages are not well known. Habitat assessments should be linked to fish populations so that the impact of habitat alteration is explicitly evaluated at the appropriate geographical scale. This will be possible by provision of long-term data sets on fish productivity and demonstrated linkages with their habitats, an acute issue in northern Canada and especially in the Arctic. The dynamics of fish populations are the ultimate measures of the quality and the quantity of habitat because growth, survival and reproduction are directly related to the requirements for specific abiotic and biotic resources. There is a need for more research on the functional relationships between habitat and the different life stages of fish (habitat-dependent process rates) and productive capacity at the population level. Knowledge of life-stage-specific rates and functional linkages with habitat will permit the use of population models to determine critical habitat. The successful restoration of habitat is closely linked to our understanding of ecological processes; if we do not understand the processes, restoration efforts are likely to be unsuccessful.

3. Measurements of productive capacity

Measurements of the productive capacity of rivers and lakes for the purposes of compensation and no net loss assessment are inadequate. There is a paucity of methods to assess habitat loss applicable to fish species in northern Canada. Science-based, simple methods to quantify net change in habitat productivity are needed and a goal should be reliance upon habitat indicators that can be mapped and subsequently validated. Notwithstanding the prior comment, measuring or predicting fish productivity may occur by direct measurement of production rates of all species, or measurement of biological indices such as biomass and surrogates for habitat variables. However, measurement of productive capacity using biological indices or habitat surrogates is based “on the sometimes untested assumption that these static indices are indicators of the dynamic population processes of recruitment, survival, and growth that together determine production.” Validation of the habitat surrogates is needed at the population level, as are methods for quantifying habitat.

4. Program research

The lack of program research is a limiting factor for DFO Science and managers trying to implement policies in northern Canada. This is particularly important because of likely “decades-scale” ecological responses to environmental perturbations. Long-term studies (i.e. 20-30 years) with spatial and temporal controls are necessary and should be commensurate with the longevity of the species. There is a fundamental need for limnological studies and a commitment to long-term research plus shorter-term, related studies that could produce products which have progressive value over time. It is considered that the link between DFO Habitat Management and Science in the north may be lacking, and Arctic Science is deficient in DFO. Management and science groups would be assisted by the interaction of monitoring and scientific evaluation of compensation initiatives. New programs in environmental science are needed urgently if the destruction of Canada's freshwater ecosystems is to be prevented. There is a requirement for a long-term commitment to core, freshwater Arctic research. A Network of Centres of Excellence [linked with industry] that deals with people and natural resources and the environment is needed to build "capacity" in the north for decision making. DFO should attempt to set up an LTER tundra network (U.S. Long Term Ecological Research network) which would include other agencies such as Environment Canada (EC) and Natural Resources Canada (NRCan), and universities. The Experimental Lakes Area in Ontario is a model to use in the Arctic to assess the effects of habitat changes.

5. Predictive models and their applicability to northern Canada

Predictive littoral fish-habitat biomass models have been constructed for the Great Lakes, but similar methods have not been developed for northern lakes because empirical data are unavailable. The development of fish-habitat models is lacking for many species, especially those considered to be of "lower value such as forage fish." Most of the development of methodologies has occurred in the more temperate regions and consequently applicability to colder areas such as the Canadian Arctic is, in general, yet to be validated. Some biological information may be anecdotal, and hence DFO needs to address this deficiency and integrate data into models. Quantitative, whole-ecosystem studies of fish and habitat, especially in the development of models and experimental manipulations requires emphasis. The incorporation of habitat into structured ecosystem models is needed. Predictions of fish (species, numbers, biomass, etc.) and their validation within lakes will facilitate decisions regarding the elimination or alteration of those lakes due to industrial development.

6. Databases and archiving

There is no substantive mechanism by which to collect, archive and make available data that have been collected for specific projects and which may be useful to others regionally and nationally. A national archival and retrieval system is required for the management of fish habitat data. Archiving of samples must occur to permit analysis of the collections in the future. Inventories in support of management and research are required. The increased use of inventories can be enhanced (e.g. through use of GIS). A nationally-accessible database which includes background material on specific fish habitat compensation activities and measures of success is required (plus a commitment to maintain it). This will promote consistency and adaptability.

7. Impacts on fish and fish habitat

Little research has been carried out on the loss of habitat and impacts to fish at the lake and watershed level. Cumulative impacts of development and climate change could result in additional stress in the north, but these have not been adequately examined in this region. Clearly-focused research is needed for the development of standardized, transparent, defensible methods to address impacts, to identify best measures of habitat, and the features that are important to fish communities. The evaluation of progress towards quantifying critical habitat and other facets of species recovery programs is an important adaptive management and research strategy. Methods for tracking cumulative change and the interaction of multiple stresses have not emerged. Many Canadian lakes are jeopardized by human intrusion without proper documentation of their baseline state and how humans have altered their communities and biogeochemical cycles. If current trends of fish habitat loss continue, declines in the quality and diversity of freshwater fish resources are certain. Although humans may wish to place their use preferences first, sustained ecological integrity must take precedence if any human-use options are to be retained.

8. Funding and partnerships

A fund needs to be created for research in relation to industrial development in northern Canada. The Natural Sciences and Engineering Research Council of Canada enables academia to obtain NSERC money if there are funding partnerships with industry. Consideration should be given to NSERC grants, which would allow for in-kind support from government. These would provide funds for research in the public interest. The needs for research funding and staffing must be assessed in relation to the revenues and/or income from industry such that strong, long-term, ecosystem-based process research should be possible in this fragile, vulnerable and changing part of Canada.

9. Collaborative studies

Projects should be focused and conducted jointly with government agencies and universities. "There are amazing possibilities for joint research" but studies need to benefit companies for this collaboration to occur. Collaboration is an essential part of research and should incorporate traditional knowledge where appropriate. It is the most effective method of achieving results. Opportunities exist for collaborative research on habitat compensation. A consortium that facilitates data sharing is one approach to obtain information that is needed, such as that about fish life history.

10. Fish habitat compensation and restoration

There is a paucity of knowledge regarding lake restoration in northern Canada. Watershed management and restoration requires that scientists, managers and policy makers view watersheds at much longer temporal and larger spatial scales than is currently the case. Successful watershed and habitat restoration requires clear and specific goals, objectives and decision criteria that will allow for accountability and project evaluation. "Appropriate" compensation needs to be defined. Compensatory habitat should be constructed prior to or concurrent with HADD occurrence. Improved access to fish-less lakes and increasing the depth of shallow lakes should be considered as compensation options. A series of experiments could be carried out to assess fertilization effects on dissolved oxygen in lakes over winter. Compensation has typically involved only physical habitat modification, yet there needs to be more assessments of the ability of habitats to augment fish populations by improving their carrying capacity (there is a need to know to what extent fish populations can be increased by habitat manipulation). Holistic studies on stream health and restoration are needed. Effective restoration of river systems has focused on reconnecting key habitats, especially those that function as refuges. Another priority research area is that concerning end pit lakes. Options should be considered to compensate for disturbed habitat with money directed at third party monitoring and research. In addition, compensation should be considered in locations that are more productive than at mines where there is mineralization and low aquatic productivity. Watershed restoration plans need to recognize the role of variability and disturbance in maintaining productivity and diversity of stream biota. Restoration is a poor substitute for habitat protection.

11. Temporal and spatial considerations regarding decision making and monitoring

Temporal losses of habitat productivity are inevitable when compensatory habitats are developed after the HADD occurrence. The losses can be exacerbated during the time for compensatory habitats to become functional. Acceptable time frames are needed for the assessment of productive capacity, time-series monitoring and assessment, and guidelines for compensation monitoring, including the identification of the appropriate scale for measuring compensation and determining its effectiveness. Also necessary is information on habitat dynamics (spatial and temporal variation in habitat use by fishes). A national review (USA) revealed that many restoration projects failed because they did not consider the broader scales necessary to understand the complexity and multidimensional nature of aquatic ecosystems.

12. Monitoring, assessment and evaluation

There has been little quantitative evaluation of habitat compensation; scientific methods are needed to assess the achievement of no net loss (NNL). Recent evaluation of authorizations revealed that NNL was achieved in 10% of the cases examined. In relation to an assessment of compensation ratios, in 12% of situations examined there was a net gain in the productivity of the habitat when the average compensation ratio ranged between 4 and 8:1, no net loss in 25% of cases (1:1 ratio), and a net loss in the remaining 63% of cases (0.74:1 ratio). Projects that succeeded in achieving a net gain in habitat productive capacity had compensation ratios of approximately 5:1. A simple, science-based approach to assessing the effectiveness of compensatory habitat is required. Projects should be implemented in a tiered fashion that allows information from the results of early tiers to be factored into the implementation of successive tiers. Monitoring the effectiveness of compensation activities should be given a higher priority. Adaptive management requires flexible goals and designs, and a long-term commitment to detailed monitoring and fine tuning after initial implementation. Development of standard methodologies for the monitoring of compensation programs (including criteria, duration and success) is required. Analysis of data is often missing and government agencies should be prepared to take data analysis to another level, and assess it against hypotheses and conclusions. While environmental effects monitoring is mainly focused on chemistry studies of fish, typically assessments are of adults, meanwhile juveniles could be compromised by, for example, food shortages. The provision of data could be a condition of a HADD authorization. Current monitoring requirements in authorizations and licenses are of limited value. Therefore, DFO requires a mechanism and the appropriate expertise to ensure the correctness of experimental design (and replication) so that the results will withstand rigorous scrutiny. It is far easier to protect existing high quality habitat than it is to recreate and restore degraded habitat.

13. Habitat policies and management

Uncertainty is incorporated into a decision-making process regarding HADDs by applying a precautionary approach and professional judgment, but the lack of a fishery is not grounds for devaluing habitat. Direction and a protocol are required from DFO on how to achieve the Habitat Policy’s objectives of achieving a net gain in fish habitat productive capacity in pristine areas; a stronger emphasis should be placed on habitat planning. Canada should take a firmer position with diamond mines to ensure progressive restoration as they develop their sites, and fill a previous open pit with waste material from the next pit being mined. If mining for diamonds and the inevitable changes to land and water are accepted (by Aboriginal communities), then perhaps enhancement measures should also be accepted in those areas to offset losses to fish habitat and fish caused by mining developments. Area-based habitat plans were recognized as important in the context of site-specific development activities. A habitat management plan is a plan to conserve, and to meet fisheries management objectives. The analysis of all habitat management issues should begin with a careful articulation of ecological objectives or targets. A risk assessment process for habitat referrals is required.

14. Communication, guidelines and information transfer

A “no net loss procedures manual,” “monitoring for success guide” and “standard habitat assessment and protocols guides” are required, together with guidelines to mitigate the effects of exploratory drilling in lakes. There is a need to establish consistent, operational guidelines for determining habitat alteration, disruption and destruction and no net loss of the productive capacity of fish habitat to facilitate consistent decision making.